OPEN EDUCATIONAL RESOURCES 4 OPEN SCHOOLS

Taking Education to the People

C·O·L

FINIS CORONAT OPUS

Open Educational Resources (OER) for Open Schooling

The Commonwealth of Learning (COL) Open Schools Initiative launched an Open Educational Resources (OER) Project to provide materials under the Creative Commons license agreement to support independent study in 17 specially selected secondary school subjects. Funded by the William and Flora Hewlett Foundation its aim is to broaden access to secondary education through the development of high quality Open Distance Learning (ODL) or self-study materials.

These specially selected OER subjects include:

1. Commerce 11
2. Coordinated Science 10 (Biology, Chemistry and Physics)
3. English 12
4. English Second Language 10
5. Entrepreneurship 10
6. Food & Nutrition
7. Geography 10
8. Geography 12
9. Human Social Biology 12
10. Life Science 10
11. Life Skills
12. Mathematics 11
13. Mathematics 12
14. Physical Science 10
15. Physical Science 12
16. Principles of Business
17. Spanish

Open Educational Resources are free to use and increase accessibility to education. These materials are accessible for use in six countries: Botswana, India, Lesotho, Namibia, Seychelles and Trinidad & Tobago. Other interested parties are invited to use the materials, but some contextual adaptation might be needed to maximise their benefits in different countries.

The *OER for Open Schooling Teachers' Guide* has been developed to guide teachers/instructors on how to use the Open Educational Resources (OER) in five of these courses.

1. English
2. Entrepreneurship
3. Geography
4. Life Science
5. Physical Science

The aim of this teachers' guide is to help all teachers/instructors make best use of the OER materials. This guide is generic, but focuses on Namibian examples.

Print-based versions are available on CD-ROM and can be downloaded from www.col.org/CourseMaterials. The CD-ROM contains the module and folders with additional resources, multimedia resources and/or teacher resources. Note that not all subjects have multimedia resources.

Acknowledgements:

The William and Flora Hewlett Foundation
Namibian College of Open Learning (NAMCOL): www.namcol.com.na
National Institute of Educational Development (NIED): www.nied.edu.na
Ministry of Education of the Republic of Namibian (MoE): www.moe.gov.na
Ministry of Education, Seychelles: www.education.gov.sc
Ministry of Education and Training, Lesotho: www.gov.ls/education
Ministry of Education Trinidad& Tobago: www.moe.gov.tt
National Open School of Trinidad & Tobago (NOSTT): www.moe.gov.tt/NOSTT
Ministry of Education and Skills Development, Botswana: www.moe.gov.bw
Botswana College of Distance and Open Learning (BOCODOL): www.bocodol.ac.bw
Ministry of Education Zambia: www.moe.gov.zm

Published by:
Commonwealth of Learning
1055 West Hastings, Suite 1200
Vancouver, British Columbia
Canada V6E 2E9
Telephone: +1 604 775 8200
Fax: +1 604 775 8210
Web: www.col.org
Email: info@col.org

The Commonwealth of Learning (COL) is an intergovernmental organisation created by Commonwealth Heads of Government to encourage the development and sharing of open learning and distance education knowledge, resources and technologies.

COURSE MANUAL

Coordinated Science

Biology, Chemistry and Physics for S4 & S5 levels (Grade 10)

COL Open School Initiative
The Seychelles

Copyright

COL Open School Initiative
The Seychelles

1055 West Hastings St
Suite 1200
Vancouver, V6E 2E9
Canada
Fax: +1 604 775 8210
E-mail: info@col.org
Website: www.col.org

Acknowledgements

The COL Open School Initiative, The Seychelles wishes to thank those below for their contribution to this course manual:

Rosianna Jules	Team Leader/Developer
Lionel Goonetilleke	Developer
Carole Jacques	Developer
Mariette Lucas	Developer
Alex Souffe	Developer/Steering Committee member
Micheal Antoine	Developer/Steering Committee member

Contents

About this course manual

Coordinated Science Biology, Chemistry and Physics for S4 & S5 levels (Grade 10) has been produced by COL Open School Initiative. All course manuals produced by COL Open School Initiative are structured in the same way, as outlined below.

How this course manual is structured

The course overview

The course overview gives you a general introduction to the course. Information contained in the course overview will help you determine:

- If the course is suitable for you.
- What you will already need to know.
- What you can expect from the course.
- How much time you will need to invest to complete the course.

The overview also provides guidance on:

- Study skills.
- Where to get help.
- Course assignments and assessments.
- Activity icons.
- Units.

We strongly recommend that you read the overview *carefully* before starting your study.

The course content

The course is broken down into units. Each unit comprises:

- An introduction to the unit content.

- Unit outcomes.
- New terminology.
- Core content of the unit with a variety of learning activities.
- A unit summary.
- Assignments and/or assessments, as applicable.

Resources

For those interested in learning more on this subject, we provide you with a list of additional resources at the end of this course manual. These may be books, articles or web sites.

Your comments

After completing the Coordinated Science course we would appreciate it if you would take a few moments to give us your feedback on any aspect of this course. Your feedback might include comments on:

- Course content and structure.
- Course reading materials and resources.
- Course assignments.
- Course assessments.
- Course duration.
- Course support (assigned tutors, technical help, etc.)

Your constructive feedback will help us to improve and enhance this course.

Course overview

Welcome to Coordinated Science Biology, Chemistry and Physics for S4 & S5 levels (Grade 10)

The coordinated science is a course which coordinates the contents of biology, chemistry, and physics so that ‘ideas developed in one science are taken up in another,’ to avoid ‘the duplication of teaching’ (University of Cambridge, 2010, p.6). As such you will study biology, chemistry and physics in an alternating manner as per the Course Overview below.

Coordinated Science Biology, Chemistry and Physics for S4 & S5 levels (Grade 10)—is this course for you?

This course is equivalent to the IGCSE coordinated science and is intended for people who wish to:

- study biology, chemistry and physics at Secondary 4 and 5 levels (age 15+/Grade 10), equivalent to IGCSE;
- re-sit their IGCSE examination;
- complete their IGCSE science course
- upgrade their science academic knowledge to advance their career

This course can also be used as a supplementary document for Secondary 4 and 5 science teachers and students in the conventional school setting. To be more specific, this course is designed for three categories of students:

- full-time students outside the conventional school setting;
- full-time students within the conventional school setting; and

- part-time students outside the conventional school setting.

To follow the course, you need to:

- have completed Science in the National Curriculum (Seychelles) course at Secondary 3 level (which is equivalent to Grade 9 science;
- have some mathematical skills, like solving equations and plotting and interpreting graphical information;
- have good and safe laboratory skills;
- be an independent learner and be ready to seek help from others;
- able to work in collaboration with other learners as necessary;
- be able to work on your own (without immediate supervision) and organize your own study time;
- have good note-taking and self-assessment skills;
- have basic ICT skills, such as word processing, excel, use of internet and emails;
- know your personal limitations and factors that can inhibit/slow the progress of your studies;
- have access to study centres, science laboratory, library, computer and internet when and as necessary.

Course outcomes

Upon completion of coordinated science, biology, chemistry and physics course you will be able to:

Outcomes

- *state* scientific phenomena, facts, laws, definitions, concepts and theories;
- *use* scientific vocabulary, terminology and conventions (including symbols, quantities and units);
- *manipulate* scientific instruments and apparatus, including techniques of operation and aspects of safety;
- *identify* scientific quantities and their determination;
- *outline* scientific and technological applications with their social,

economic and environmental implications;

- *translate* information from one form to another;
- *manipulate* numerical and other data;
- *use* information, experimental observations and data to identify patterns, report trends and draw inferences;
- *present* reasoned explanations for phenomena, patterns and relationships;
- *make* predictions and hypotheses;
- *solve* problems;
- *make* observations, measurements, estimates
- *record* observations, measurements, estimates
- *evaluate* experimental observations and data;
- *plan* scientific investigations;
- *criticise* methods of investigations and suggest possible improvements (including the selection of techniques, apparatus and materials);
- *report* trends and draw inferences.

Timeframe

How long?

This coordinated science course consists of 54 units, however, only the first 12 units of the course will be accessible in 2012. The other units will become available (be developed) at a later stage.

If you are accessing the first 12 units of this coordinated science course, your timeframe is as follows:

If you are a full-time student outside the conventional school setting, you are expected to complete the 12 units in 12 weeks. Your formal study time is 8 hours per week. You are encouraged to devote at least 4 hours extra each week for self-study (such as review and practice exercises).

If you are a full-time student within the conventional school setting, you are expected to complete the course in 24 weeks. Your formal study time is 4 hours per week. You are encouraged to devote at least 3 hours extra each week for self-study (such as review and practice exercises).

If you are a part-time student, you are expected to complete the course in 24 weeks. Your formal study time is 4 hours per week. You are encouraged to devote at least 2 hours extra each week for self-study (such as review and practice exercises).

Your total amount of study time for the first 12 units of the coordinated science course is 96 hours. Refer to Table 1 for a summary of the time frame.

Table 1: A summary of the timeframe for the first 2 units of the coordinate science course.

Student category	Duration		Recommended formal study time per week	Recommended Self-study time per week
	Weeks	Hours		
Full-time student outside the conventional school setting	12	96	8	4
Full-time student within the conventional school setting	24	96	4	2
Part-time student	24	96	4	2

If you are accessing all the 54 units of this coordinating science course, your total amount of formal study time is as follows:

If you are a full-time student outside the conventional school setting, you are expected to complete the course in 52 weeks (one year). Your formal study time is 8 hours per week. You are encouraged to devote at least 4 hours extra each week for self-study (such as review and practice exercises).

If you are a full-time student within the conventional school setting, you are expected to complete the course in 104 weeks (two years). Your formal study time is 4 hours per week. You are encouraged to devote at least 2 hours extra each week for self-study (such as review and practice exercises).

If you are a part-time student, you are expected to complete the course in 104 weeks (two years). Your formal study time is 4 hours per week. You are encouraged to devote at least 2 hours extra each week for self-study (such as review and practice exercises).

Your total amount of study time for the 54 units of the coordinated science course is 416 hours. Refer to Table 2 for a summary of the time frame.

Table 2: Summary of the timeframe for the 54 units of the coordinate science course

Student category	Duration		Recommended formal study time per week	Recommended Self-study time per week
	Weeks	Hours		
Full-time student outside the conventional school setting	52	416	8	4
Full-time student within the conventional school setting	104	416	4	2
Part-time student	104	416	4	2

Study skills

As an adult learner your approach to learning will be different to that from your school days as you will be choosing what you want to study, you will have professional and/or personal motivation for doing so and you will most likely be fitting your study activities around other professional or domestic responsibilities.

Essentially you will be taking control of your learning environment. As a consequence, you will need to consider performance issues related to time management, goal setting, stress management, etc. Perhaps you will also need to reacquaint yourself in areas such as essay planning, coping with exams and using the web as a learning resource.

Your most significant considerations will be time and space i.e. the time you dedicate to your learning and the environment in which you engage in that learning.

The materials in this course have been designed to get you actively involved in the construction of your learning. The content in the various topics will be organized in a meaningful sequence, starting from known to unknown in the form of a dialogue between you and your teacher. The material will provide opportunities for you to use the knowledge and practice the skills learnt in order to further enhance your learning.

Your personal experience and knowledge is a vital contribution to your learning. Hence the material will draw considerably on Grade 9 Science, your past experience, and real life examples. A variety of learning activities and resources will be used to support and enrich your learning experience.

Through the various activities you will have the opportunity to demonstrate and apply your understanding of the content learnt. There will be numerous occasions for you to experiment, simulate, carry out case studies, design models and solve problems.

The concepts that you learn will be revisited and built on as needed, throughout the unit. While you study the materials you will also be asked to refer to related content, concepts and ideas in Physics, Chemistry and Biology throughout the course. This will help you to understand the linkage between related content, concepts and ideas.

You will be provided with feedback for each activity and assessment. This will help you evaluate your understanding of the content and revisit the topics as necessary or proceed to the next step. During the course you will sit two examinations to test your progress in the course.

We recommend that you take time now—before starting your self-study—to familiarize yourself with these issues. There are a number of excellent resources on the web. A few suggested links are:

- http://www.how-to-study.com/

  The "How to study" web site is dedicated to study skills resources. You will find links to study preparation (a list of nine essentials for a good study place), taking notes, strategies for reading text books, using reference sources, test anxiety.

- http://www.ucc.vt.edu/stdysk/stdyhlp.html

  This is the web site of the Virginia Tech, Division of Student Affairs. You will find links to time scheduling (including a "where does time go?" link), a study skill checklist, basic concentration techniques, control of the study environment, note taking, how to read essays for analysis, memory skills ("remembering").

- http://www.howtostudy.org/resources.php

  Another "How to study" web site with useful links to time management, efficient reading, questioning/listening/observing skills, getting the most out of doing ("hands-on" learning), memory building, tips for staying motivated, developing a learning plan.

The above links are our suggestions to start you on your way. At the time of writing, these web links were active. If you want to look for more go to www.google.com and type "self-study basics", "self-study tips", "self-study skills" or similar.

Need help?

Help

Support for Students within the Conventional Schools

For students within the conventional schools, the course materials will be available at their respective secondary school. Teachers and learners will be free to use those self-contained course materials to support the teaching and learning process. The materials will also be used by students in classes with no regular science teacher. A Student Guide and a Teacher Classroom Guide will guide the learners and the teachers on how to use the course OERs for maximum benefit.

Support for Distance Education Learners

In addition to the Student Guide, tutorial support will be provided to students studying outside the conventional school setting. Tutorials will be provided through periodical face-to-face contact between learners and identified tutors at the Study Centres. The different Study/Regional Centres will be at regional Secondary Schools. Tutorials can be either group or individual. The Open School Teacher Guide will guide the tutors on how to make the optimal use of the OERs.

Group tutorials will be mainly for:

- carrying out certain experiments to give students first-hand experiences;
- discussions;
- gaining better comprehension of the printed materials; and
- getting help in working on assignments.

Individual tutorial will be mainly for:

- providing feedback on assignments and assessments
- giving specific and additional study skills support

You are strongly advised to attend tutorial sessions organized at your respective centre, as they could prove very useful in helping you to: comprehend some of the more complex concepts/ideas or difficult issues in the materials, share views with the tutor and fellow learners, clarify doubts, get help in working on assignments and be reminded of deadlines and other important dates. It is very important for you to come to tutorials thoroughly prepared.

Should you be encountering any problems affecting their studies, including technical issues (e.g. computer problems), do not hesitate to contact your course coordinator.

Assignments

Assignments

You are expected to complete three assignments: each assignment will have a component of biology, chemistry, and physics. Each assignment is worth 10% (a total of 30%) of the total marks for the course. The assignments will be posted to you by the Course Coordinator three weeks prior to the due date.

You can submit your assignments electronically to the Course coordinator at (email address will be communicated later) or by post on the address provided by your Course coordinator.

As a full-time student outside the conventional system you are expected to submit the first assignment at the end of week 19 by which time you should have completed units 1 to 18. You should submit the second assignment at the end of week 39 by which time you should have completed units 19 to 38. Your third assignment is due at the end of week 55 by which time you should have completed units 39 to 54.

As a full-time student within the conventional system or as a part-time student, you are expected to submit the first assignment at the end of week 38 by which time you should have completed units 1 to 18. You should submit the second assignment at the end of week 78 by which time you should have completed units 19 to 38. Your third assignment is due at the end of week 104 by which time you should have completed units 39 to 54.

Please ensure that you submit your assignments on the dates specified. Should you need an extension, you should contact the Course Coordinator at least three (3) working days before the due date.

Please refer to Table 1 for a breakdown of the assignments.

Table 1: A breakdown of the assignments

Assignment	Full time students outside conventional system		Full time students within conventional system and part-time students	
	Due date	Units to be assessed	Due date	Units to be assessed
1	Week 19	1-18	Week 38	1-18
2	Week 39	19-38	Week 78	19-38
3	Week 51	39-54	Week 104	39-54

Assessments

Assessments

This course contains both formative and summative assessments

1. Formative assessments

Formative assessment throughout the course will be used to help you monitor and evaluate your progress as you work through the course material. Formative assessment will be in the form of a series of activities and self-assessment tasks throughout each unit. Each unit will contain one or more self-assessment. The self-assessment tasks may be at the end of the topics and /or at the end of the unit. The answers for the self-assessments tasks will be given at the end of the unit while those for the activities may be given immediately after the activity or at the end of the topic/unit depending on the type of activity.

2. Summative assessments

Summative assessment will be given to assess your mastery and ability to integrate and apply the course content. Summative assessments will take the form of assignment and examinations. All summative assessment tasks are teacher-marked.

There will be two examinations. Each examination will contain three papers: paper 1 will contain 40 multiple choice questions; paper 2 will contain 12 structured questions (4 from each biology, chemistry, and physics); paper 3 is an alternative to the practical paper and will contain 6 questions (2 from each biology, chemistry and physics). Each assessment will be worth 35 % of the course. Paper 1 is worth 10 %, paper 2 is worth

15 % and paper 3 is worth 10 %.

You will sit for paper 1 and paper 2 on the same day and for paper 3 one week after papers 1 and 2. You will sit for the first examination half way through the course and the second examination within the next three weeks after completion of the course.

Papers 1 will be 45 minutes long, Paper 2 will be 2 hours long and Paper 3 will be 1 hour long. You are expected to complete each paper in the allocated time. You will sit for all examinations under supervision at designated centres. Refer to Table 2 for a summary of the examination papers, duration and due dates.

The teacher is expected to complete the marking of the examination papers within two weeks after the examination.

Table 2: Summary of examination papers, duration and due dates.

Paper	Duration	Full time students outside conventional system		Full time students within conventional system and part-time students	
		Due date		Due date	
		Examination 1	Examination 2	Examination 1	Examination 2
Paper 1: Multiple choice question	45 minutes	week 29	week 54	week 58	week 107
Paper 2: Structured question paper	2 hours	week 29	week 54	week 58	week 107
Paper 3: Alternative to practical	1 hour	week 30	week 55	week 59	week 108

Examination 1 will cover unit 1 to unit 28 and Examination 2 will cover unit 29 to unit 54. Please refer to Table 3 for clarification.

Table 3: Units to be covered for Examinations 1 and 2.

Examination	Units to be assessed
1	1-28
2	29-54

Getting around this course manual

Margin icons

While working through this course manual you will notice the frequent use of margin icons. These icons serve to “signpost” a particular piece of text, a new task or change in activity. They have been included to help you to find your way around this course manual.

A complete icon set is shown below. We suggest that you familiarize yourself with the icons and their meaning before starting your study.

Activity	Assessment	Assignment	Case study
Discussion	Group activity	Help	Note it!/Important!
Outcomes	Reading	Reflection	Study skills
Summary	Terminology	Time	Tip
Computer-Based Learning	Audio	Video	

Course Syllabus

Units of the Coordinated Science Course

The coordinated science course consists of 54 units. The first 12 units of the coordinated science course – Grade 10 are as listed below.

UNIT 1: BIOLOGICAL CLASSIFICATION

UNIT 2: THE ELEMENTS OF CHEMISTRY

UNIT 3: THE STRENGTHS OF SOLIDS

UNIT 4: ATOMS, BONDING AND THE PERIODIC TABLE

UNIT 5: PARTICLES IN MOTION

UNIT 6: CELLULAR ORGANISATION

UNIT 7: CLASSIFYING ELEMENTS

UNIT 8: MOTION

UNIT 9: FORCE AND MOTION

UNIT 10: DIET AND HEALTH

UNIT 11: SUPPORT AND MOVEMENT

UNIT 12: GRAVITY

NOTE: The other units that will make up the coordinated science course are listed below.

UNIT 13: DIGESTION

UNIT 14: PETROCHEMICALS

UNIT 15: DYES AND DRUGS

UNIT 16: PHOTOSYNTHESIS

UNIT 17: FUELS

UNIT 44: INHERITANCE

UNIT 45: ELECTRONS

UNIT 46: RADIOACTIVITY

UNIT 47: ORGANISMS IN THEIR ENVIRONMENT

UNIT 48: ENERGY RESOURCES

UNIT 49: ENERGY DISTRIBUTION

UNIT 50: BATTERIES

UNIT 51: CYCLES AND THEIR EFFECTS

UNIT 52: EVOLUTION

UNIT 53: METALS AND ALLOYS

UNIT 54: ELECTRONICS

COURSE MANUAL

Coordinated Science

Biology, Chemistry and Physics for Secondary 4 & Secondary 5 levels
(Grade 10)

COL Open School Initiative
The Seychelles

Copyright

COL Open School Initiative
The Seychelles

Fax: +1050 West Hastings St
Suite 1200
Vancouver, V6G 3E9
Canada

Fax: +1 604 775 8210
E-mail: : info@col.org
Website: www. www.col.org

Acknowledgements

The COL Open School Initiative wishes to thank those below for their contribution to this course manual:

Rosianna Jules	Team Leader/Master Teacher
Michael Antoine	Member of Country Management Committee/Master Teacher
Elva Gedeon	Member of Country Management Committee/Country Coordinator
Lionel Goonetilleke	Master Teacher
Carole Jacques	Master Teacher
Agathe Lewin	Consultant
Mariette Lucas	Master Teacher
Alex Souffe	Member of Country Management Committee/Master Teacher

Contents

Unit 1

Biological classification

Introduction

Welcome to your first unit in the Coordinated Science course! The unit is entitled **Biological classification**. *Classifying* is a fundamental skill in biology. Through the activities in this unit, you will understand the principle and importance of classification in biology and learn to appreciate the wide variety of organisms around you.

Classification requires good observation. Hence, the activities that you will do in this unit will require that you exercise your observational skills to the greatest extent. This will enable you to identify common characteristics in sets of organisms that allow for them to be grouped together. You will also get the opportunity to develop and use **dichotomous keys** to identify plant and animal species with particular focus on locally occurring ones.

Since the units in the Coordinated Science course have been developed in such a way to allow you to continuously see the relationships between Biology, Chemistry and Physics, we shall be referring you to other units in the course where the concept of classification is also dealt with. Hence, in the biology units **Evolution** (Unit 52) and **Organisms and their Environment** (Unit 47) you will be able to use your knowledge of biological classification to further develop ideas of differences and similarities between organisms.

Your knowledge of classification will equally be useful when you work on the chemistry unit **Classifying the Elements** (Unit 7) and **the unit Atoms, Bonding and the Periodic Table** (Unit 4).

.

In this unit you will learn about:

- why it is important to classify organisms in groups;
- the principles of biological classification;
- how to construct and use dichotomous keys;
- the binomial nomenclature and its use in naming living organisms;
- the hierarchical structure of the classification system;
- similarities and differences between various groups of vertebrates and invertebrates and the diagnostic characteristics that are used to sort them into groups;

Note it! / Important!

The outcomes for the unit are listed below. The outcomes written in **bold** are the extended outcomes and they are intended for students who are aiming for Grade B or higher in the examinations.

You are also required to keep a **portfolio** for some of the work that you will do in this unit. All you need is a file or a pocket to put your work in. On the cover page of the portfolio write your name and the title of the unit and the start and completion dates.

You will be required to submit the portfolio to your teacher/tutor on completion of the unit as part of the assessment.

Outcomes

Upon completion of this unit you will be able to:

- *explain* why organisms are classified into groups;
- *use* a simple dichotomous identification key;
- *use* the binomial system of naming organisms.
- *name* at least two different organisms using their binomial names;
- *state* that organisms belong to different species, which are discrete breeding groups;
- *list* the main features of the five main classes of vertebrates (fish, amphibians, reptiles, birds, mammals);
- *construct* a simple dichotomous key to enable identification of organisms;
- *describe* the main features of three classes of arthropods (insects, crustaceans and arachnids);

Terminology

Arthropods::	The group of invertebrates that have an exoskeleton, segmented bodies and jointed limbs.
Binomial nomenclature:	A two-part naming system of individual organisms comprising of a genus name and a species name.
Chordates:	Animals with a dorsal nerve cord and a skeletal notochord, present at some point in their development.

Classification: The categorisation of organisms and other items into defined groups on the basis of defined characteristics.

Dichotomous key: Branching keys with pairs of contrasting descriptions.

Kingdom: The first and largest category in the biological hierarchical classification system.

Species: The smallest category in the biological hierarchical classification system.

How long?

Students, Table 1.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	12 hours 30 minutes	6 hours 15 minutes
Full-time student within the conventional school setting OR Part-time student	12 hours 30 minutes	6 hours 15 minutes

Table 1.0: The proposed study time for full time and part-time students

Topic 1.1: Why classify organisms?

How long?

You will need 1 hour and 10 minutes at the most to complete this topic. It is advisable that you spend another 35 minutes of your own time to further practice the classification processes learnt.

There are so many different types of living organisms (living things) around us and new organisms are still being discovered every day. What if tomorrow you discovered a creature that you have not seen before in your home garden? Would you be able to figure out what known animal this creature might be related to? What would you look for about this creature for comparison with the known animal?

It would be natural for you to start studying the creature by looking for common characteristics and finding relationships with known animals. This is exactly what scientists who study living organisms do. They look for the differences and similarities between the living organisms and organize them into categories based on their relationships.

1.1.1 Using similarities and differences to classify organisms

If you observe living organisms closely, you will see a number of similarities and differences between them. These similarities and differences allow us to classify the living organisms around us. Classifying provides us with an ordered way of describing the organisms, and helps us to make sense of the information around us.

Let us see how this works in Activity 1.1.1 below. You are expected to complete the activity in 30 minutes.

Activity

Activity 1.1.1

You need 30 minutes to do the activities below.

In this investigation you will learn how similarities and differences help us to classify living organisms.

Problem

How do similarities and differences allow us to classify living organisms?

Procedure

a. Go outside. Take a look around you and pay attention to the sounds of animals and the plants around you. Make a list of five of the different living organisms that you observe.

b. Study the list carefully and look for one main difference between the organisms. Use the difference that you have noted to divide the living organisms into two groups (Group A and Group B) on Table 1.1.1 below.

You should also make use of the difference that you have observed to write suitable headings for Group A and Group B.

Group A:	Group B:

Table 1.1.1: Difference between five living organisms

Analysis

Look at the organisms in either Group A or Group B in Table 1.1.1 above.

i). In what way/s are the organisms similar?

ii). In what way/s are the organisms different?

iii). What information do you need in order to classify the organisms further?

Conclusion

How useful are similarities and differences in the classification of organisms?

Going further: Using similarities and differences to identify a living organism

Study the five types of bananas below.

Five types of bananas

Figure 1.1.1

Source of pictures: www.ocati.com/images/bananitosfruitR.jpg

i. Choose one type of banana. Write it down below.

ii. Starting from the large group of five types of bananas, find one main difference between the types of bananas. Use this difference to put the five types of bananas into two groups in the space below.

iii. Continue the exercise above, but use only the group containing your chosen type of banana each time. Do this exercise until you are left with only your chosen type of banana.

iv. Use the information in the groups above to describe the specific characteristics of your chosen type of banana.

Feedback

Feedback to Activity 1.1.1

I am sure that through Activity 1.1.1 above, you have realized that there are lots of similarities and differences between the living organisms around us. Noting these similarities and differences allow us to find specific characteristics of each living organism which in return allows us to pinpoint to and isolate specific organisms.

Here is one suggestion how you could have organized the different types of bananas to describe a chosen type of banana. I have chosen the lady's finger banana.

Looking at the five different types of bananas below:

Five types of bananas				
 Lady's finger	 Plantain	 Blue banana	 Red banana	 Wine banana

Source of pictures: www.ocati.com/images/bananitosfruitR.jpg

We immediately notice that their color is different. Three types of bananas are green; two types are reddish in colour. Hence:

Three of the five types of bananas are green in colour.				***Two of the five types of bananas are reddish in colour.***	
 Lady's finger	 Plantain	 Blue banana		 Red banana	 Wine banana

As lady's finger is a green type of banana, we shall continue by considering only the group of green bananas. One difference between these green bananas is that two types are short and one type is long. Hence:

Two of the green types of bananas are short.			***One of the green types of bananas is long.***	
 Lady's finger	 Blue banana		 Plantain	

We continue by looking at the group of bananas with lady's fingers. One difference that we notice is that the lady's finger bananas are bigger than the blue bananas. Hence:

The lady's finger bananas are bigger.			***The blue bananas are smaller.***
 Lady's finger			 Blue banana

Hence, my chosen type of banana (lady's finger) is green and short and the bananas are bigger than the blue bananas.

Note it! / Important!

In the above exercise we have focused on the sense of sight since we made use of pictures. Note that in real life, we could also have used our sense of smell, taste and touch to classify the five types of bananas.

Summary

To sum up we realize that classifying allows us to identify, describe and comprehend the numerous living organisms in the world. It helps us organize our world and allows us to develop and refine concepts about the wide variety of living organisms around us.

By now you might have realized that we need to create a classification system to help compare and identify specific organisms, and discover how they might be related. Classification systems include big groups that are subdivided into smaller groups.

Do you happen to know the classification system used by scientists who study living organisms?

In Topic 1.2 you will learn how scientists who study living organisms, organize them into categories based on their relationships. However, before proceeding to Topic 1.2, let us see how much you have learnt in Topic 1.1, by doing the self-assessment exercise below.

Assessment

Self-assessment 1.1

You need 20 minutes to do this self-assessment. This self-assessment is based on Topic 1.1. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 1.1. This will help you learn and reflect better on areas for improvement.

a. What are the main ideas that we need to consider when classifying living organisms?

b. What are the advantages of classifying living organisms?

c. Using the example given in the classification of types of bananas in Activity 1.1.1 above, compare the following leaves by finding similarities and differences between them to help you identify the wild passion fruit leaf.


Wild passion fruit


Hibiscus


Breadfruit

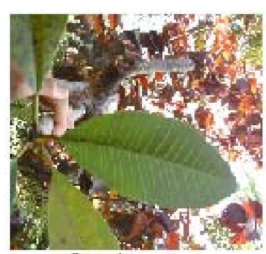

Frangipagne

Figure 1.1.2

Photos taken by: Mariette Lucas (2010)

i. Now that you have identified the characteristics of the wild passion fruit leaf, describe it as fully as you can.

ii. Is there another way how you could have compared and classified the leaves to identify the wild passion fruit leaf?

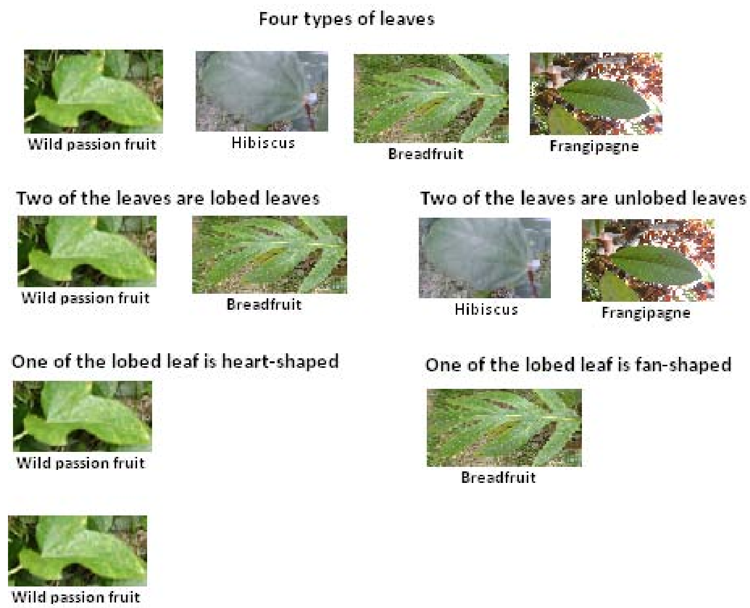
Well done! I have provided you with the Answers to Self-assessment 1.1 below.

Answers to Assessment

Answers to Self-assessment 1.1

a. When we classify living organisms, we reflect on the similarities and differences between the organisms. This helps us to see patterns in the different categories of living organisms and enables us to identify and describe the different organisms.

b. Classifying living organisms help us make sense of the vast number of living organisms around us. Classifying helps us to comprehend the numerous living organisms in the world. It allows us to develop and refine concepts about the organisms. It also helps us organize our world and allows us to identify organisms around us.



c. A possible classification to help identify the wild passion fruit leaf:

i. The wild passion fruit leaf is therefore a heart-shaped lobed leaf.

ii. Yes, objects and organisms can be grouped into many different ways. I am sure that you have grouped the leaves in a different way. Share your work with other students and note the different ways how the leaves have been grouped. You should realize that the way of classifying/grouping depends on the purpose of the grouping, and also the individual's preference.

This brings us to the end of topic 1.1. Reflect back on what you have learned about classifying organisms. What are some ways you can classify organisms? Why is classification important? I hope you know the answers to these questions. If you do not, make sure you review this topic before moving on.

The next topic will deal with classification keys. We will keep build on knowledge gained in topic 1.1.

Topic 1.2: Classification Keys

How long?

Students doing the extended syllabus will need 2 hours 30 minutes to do this topic and 1 hour and 15 minutes of your own time to further practice using dichotomous keys. Those of you who are doing the core syllabus will only need 1 hour 40 minutes at the most to do this topic. It is advisable that you spend another 50 minutes of your own time to further practice using dichotomous keys.

In Topic 1.1, you created your own classification system to help you identify individual organisms from a larger group of organisms. What did you consider to help you identify individual organisms?

Good! You drew on the similarities and differences between the organisms and used these to help you identify specific characteristics of particular organisms. Special characteristics of organisms allow us to group them together. We can use these characteristics to develop classification keys.

1.2.1 Characteristics of a classification key

Group Activity 1.2.1

Group activity

You need 10 minutes for this activity.

Some of you might have an idea of what a classification key is. Those of you who are not sure and who have access to the internet, type the question “What is a classification key?” and do some Google search for definitions. If you do not have access to the internet, look for book definitions of the term. Once you have found a good definition, share your ideas with colleagues before continuing to the next section. Also, try to explain this using pictures and diagrams that you may have seen on the internet or in a book.

Feedback

Feedback to Group Activity 1.2.1

I am not going to give you a textbook definition of what a *classification key is,* but you would have realized from your discussions that it involves the diagnosis of the characteristics that an object or organism has and grouping objects or organisms according to these observed characteristics.

In a classification key we start with the more general characteristics and progressively move to the more specific characteristics of the object or organism. The key leads to a series of questions or choices about the characteristic of the object or organism. By the time you have answered all the questions about the diagnosed characteristic, the object or organism should be identified.

It is important for us to note that early classification systems were based simply on characteristics that were observable to the eye. Present day scientists now focus on genetics, cellular make-up and other internal characteristics when they classify organisms.

It is now time for you to learn how classification keys are constructed. You will learn about dichotomous keys below. We shall start by looking at *what* are dichotomous keys and the *types* that are used.

1.2.2 What are dichotomous keys?

A dichotomous key is a tool designed to assist people with the identification of items in the natural world. "Dichotomous" means "divided into two parts", with contrasting or opposite ideas or descriptions. Therefore, dichotomous keys always give us two choices in each step. These are initially very general and become more specific as you proceed through the steps.

By analyzing the characteristics of the object/organism in question and using the steps and choices given in the key, you can identify an object/organism based upon established features.

When you construct a dichotomous key, it is important to note that each pair of contrasting descriptions must deal with the same characteristic.

Reflection

Reflection 1.2.1

You need 10 minutes for this activity.

In the classification of the leaves in the Self-assessment 1.1 above,

a. What was the first characteristic that you used to differentiate between the four leaves?

b. Give a couple of examples of incorrect pair of statements. In other words, what kind of statement will NOT have helped you differentiate between the four leaves?

You will have realized by now that you used principles of a dichotomous key to help you identify the wild passion fruit leaf and your chosen type of banana in Activity 1.1.1 above. Equally, if you use ideas that are NOT contrasting or different, you cannot move on to identify the species of choice.

Let us now look at different types of dichotomous keys.

1.2.3 Types of dichotomous keys

Dichotomous keys can be written as a branching or spider key, or as a list key.

We will now look at each type of key in Activity 1.2.1 below.

Activity

Activity 1.2.1

You need 20 minutes to complete the activities below.

We shall first make a list key, and use the same information to construct a branching or spider key.

Suppose you have the following five fruits:

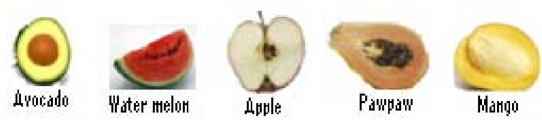


Figure1.2.1
Source of pictures: http://www.google.com/images

After studying the fruits, you might consider the following characteristics as the main characteristics in the different steps of the key: number of seeds, shape of seed, colour of flesh and shape of fruit. To begin the key, let us consider the characteristic number of seeds, hence the question

1. *Does the fruit have many seeds?*

This question will allow us to have two groups of fruits:

- Fruits with one seed (avocado and mango) and
- Fruits with more than one seed (water melon, apple and pawpaw)

We shall now start the list key from the above question, using the two groups of fruits. To do that we need to look at each group separately to find a characteristic that will help us differentiate further between the fruits in each group. Hence step 1 of the key is as follows:

1. (a) Fruits with one seed ……………………… go to step 2
   (b) Fruits with more than one seed……………..go to step 3

Step 2 needs to consist of a pair of statements that will lead to the identification of the avocado and the mango. We shall consider shape of seed as the diagnostic characteristic, hence the question:

2 *Is the seed round?*

In step 2 we therefore have:

2 (a) Fruits with round seed ……………………… avocado
  (b) Fruits with oval seed...…………………….. mango

As we have identified the avocado and the mango, we now move to step 3 to lead us to the identification of the three fruits with more than one seed.

Step 3 needs to consist of a pair of statements that will lead to the identification of the water melon, apple and pawpaw. We shall consider the colour of flesh as the diagnostic characteristic, hence the question:

3 Is the flesh varied in colour?

In step 3 we therefore have:

3 (a) Fruits with flesh of two distinct colours………… water melon
(b) Fruits with flesh in one colour……….................. go to step 4

Step 4 needs to consist of a pair of statements that will lead to the identification of the pawpaw and the apple. We shall consider shape of the fruit as the diagnostic characteristic, hence the question:

4 Is the fruit oval?

In step 4 we therefore have:

4 (a) Fruit with oval shape ……………….. pawpaw
(b) Fruit with heart shape..….……………....apple

Using only the questions in the list key above, I have also represented the list key in diagram form below.

1.2.3.1 A list key

1.	**Does the fruit have many seeds?**	**No**	**Go to 2**
		Yes	**Go to 3**
2.	**Does the fruit have round seed?**	**No**	**It is a mango**
		Yes	**It is an avocado**
3.	**Is the flesh varied in colour?**	**No**	**Go to 4**
		Yes	**It is a water melon**
4.	**Is the flesh oval shaped?**	**No**	**It is an apple**
		Yes	**It is a pawpaw**

Figure 1.2.2: A list key

Drawn by Mariette Lucas (2010)

The two options which we begin within a list key are the essential characteristics which will lead us through the key to identify the fruits. Starting with the first question, follow through the list key until you have identified each individual fruit.

Notice how each time we have used one characteristic which clearly allows us to differentiate between the fruits.

To test your understanding of the list key, I would now like you to tell us about the pawpaw by writing its characteristics below.

If you have said that the pawpaw is a fruit with many seeds, its flesh is of one colour and it is oval shaped, then you have no difficulty understanding a list key.

Now that you have understood a list key, you have learnt the essential aspects of dichotomous keys. You are therefore ready to learn about a branching/spider key. Let us now see how a branching/spider key can help us identify the fruits.

1.2.3.2 A branching/spider key

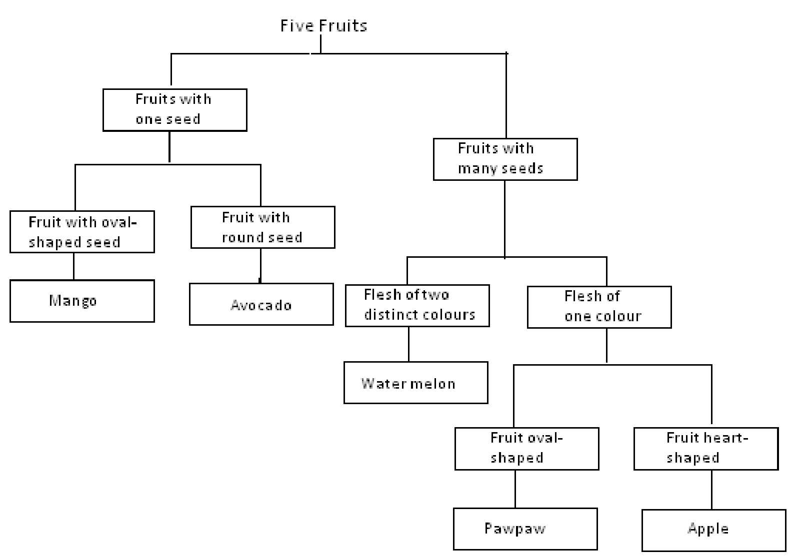


Figure 1.2.3: A branching key

Drawn by: Mariette Lucas (2010)

To see if you have understood the key, answer the following questions:

a. Which of the fruits has one seed which is oval-shaped?

b. Differentiate between the water melon and the avocado.

I am sure that you did not have any difficulty answering the two questions using the dichotomous branching/spider key.

Surely you could tell that the mango is a fruit with one seed, which is oval-shaped. In the case of the water melon and the avocado we can tell that the water melon is a fruit with many seeds and flesh which has two distinct colours, whereas the avocado is a fruit with one round seed.

Now look back at the branching/spider key and the list key. In each case you had to identify five different fruits.

Compare the number of characteristics or steps that were used in each type of key and the number of fruits that were classified. What relationship do you notice?

You have probably noticed that there were five fruits to be identified and we used only four characteristics or four steps to identify each individual fruit. This is always the case with dichotomous keys; there should be one step less than the total number of organisms to be identified in the key.

Let us now get your impressions about the two types of keys.

Which one of the two types of keys do you find easier to understand?

You are right! Branching/spider keys are easy to use, but they take up a lot of space when fully drawn out. It is for this reason that the listed form is usually used more often by scientists.

1.2.4 Using dichotomous keys

Tip

You have used dichotomous keys in Activity 1.2.1 above. You should have realized that using a dichotomous key is like following the branches of a tree, where each additional branch gets smaller and smaller until you reach a single branch tip. Each branch tip represents a single species or object.

In **using a dichotomous key**, you should keep the following in mind:

Begin with the first pair of statements and follow the descriptions of each successive pair of statements until you reach the name of the organism / object that you are trying to identify.

Always read both statements in each branch carefully, even if the first seems to be the most obvious at first.

Always ensure that you understand the meaning of the words involved. Do not guess.

Do not guess measurements. Always use a measuring instrument if required.

Activity

Activity 1.2.2

You need 15 minutes to complete this activity.

1. Pictures of four birds of Seychelles are shown below.

Figure ~~1.2.4~~

Source: Birds of Seychelles (1990)

This list key describes each of the four birds.

1a. Bird with long thin curved beak………………….Seychelles sunbird

1b. Bird with short pointed beak…………………….go to 2

2a. Bird with black and white tail features…………..go to 3

2b. Bird with brown tail feathers…………………….Madagascar fody

3a. Yellow patch around the eyes……………………Indian mynah

3b. Blueish patch around the eyes……………………Barred ground dove a). Use the list key to identify the birds. As you identify each bird write its name in the space provided underneath the pictures above.

b). Describe the Indian mynah.

Feedback

Well done! I have provided you with the Feedback to Activity 1.2.2 at the end of this topic. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

You will get plenty of other opportunities to use dichotomous keys in this unit as well as other units in the course.

Feedback to Activity 1.2.2

a). The names of the birds are as follows:

Figure 1.2.4

Source: Birds of Seychelles (1990)

b.) The Indian mynah has a short pointed beak, black and white tail and yellow patch around the eyes.

1.2.5 Constructing Dichotomous Keys

Note it! / Important!

This section is for students who are doing the extended objectives only. If you are a student doing the core objectives, you may also attempt this section, if you wish to do so. If you choose not to do this section, you would have an extra 50 minutes to review the unit.

It is easy for you to make your own dichotomous key for any group of living organisms or non-living things that you want to organize, using physically observable characteristics.

If you follow the guidelines below, you will be able to construct dichotomous keys for many different organisms. Please note that the more similarities the group of organisms has, the more difficult it is to develop a key.

Note it! / Important!

REMEMBER – There are usually several different ways in which you can construct a key, but at each stage, you need to focus on the special characteristics of a particular organism, and this would enable a person to name the organism you are referring to.

In constructing keys, keep the following in mind:

Use constant characteristics (e.g. colour, shape,...) rather than changing ones (e.g. temperature, speed,...)

Use measurement rather than terms like “large” and “small”.

Use characteristics that are available to the user of the key rather than varying or recurrent ones.

Make the choice a positive one – an object “is” instead of “is not”.

If possible, start both choices of a pair with the same word.

If possible, start different pairs of choices with different words.

Begin the descriptions with the name of the part to which they apply.

Now it is your turn to construct a dichotomous key. You will need to ask for the assistance of the laboratory technician or your Science teacher to advice you about the safety precautions when working with living organisms on the activities below.

Group activity

Group Activity 1.2.2

For this activity you need 15 minutes.

Find 4 different organisms, for example 4 different types of insects/fish or dogs or 4 different types of leaves/plants or flowers or any other living organisms that have some similarities. With a partner, design either a list key or a branching key for the 4 organisms that you have chosen.

Remember to follow the guidelines discussed above in “constructing a dichotomous key”. The branching/spider key and the list key above should help you construct your key.

Draw your key in the space below.

Review the guidelines on how to use a dichotomous key above. Then, test your key to ensure that there are no errors and that the statements are clear. Ensure that you are quite satisfied with your key before letting others use it.

Group Activity 1.2.3

Group activity

You need to give your friends at least 20 minutes to complete the key and use another 10 minutes to reflect and modify it.

Now test your key with a group of students in the class or any other group of people.

Give a clean copy of the key to the group of people/students that you have identified. You also need to give them the four organisms that you used (for example the 4 different types of insects) and a fifth organism, belonging to any of the groups. This would allow for further verification of the reliability of the key.

You need to clearly explain to the students how they should use the key to identify the given organisms. Then ask the students to follow through the key to identify the 5 organisms.

You need to stay beside the students while they are working. Take note of any questions that they ask and give them any assistance that they require.

Once the activity is over, answer the questions below.

a). How easy was it for the students to identify the organisms from your key?

b). What were some of the difficulties that your colleagues experienced while using the key?

Now use the observations and comments made to improve your key.

I hope that you found the exercise interesting. As you go through the unit, you will have opportunities to further practice using and constructing keys.

It is now time to see how much you have learnt in this topic. You will do this by doing the self-assessment below.

Assessment

Self-assessment 1.2

You should be able to do this self-assessment in about 15 minutes. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 1.2. This will help you learn and reflect better on areas for improvement.

This key is about domestic cats. Study the key; then answer the questions which follow.

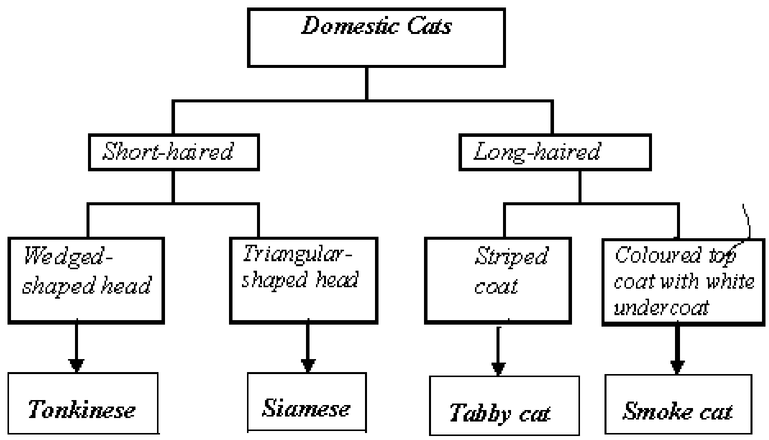


Figure 1.2.5: Classifying domestic cats

Designed by Mariette Lucas (2010)

a. Describe the Tabby cat.

b. Which domestic cat is short-haired and has a triangular head?

c. What similarity exists between all four cats?

d. Using the information on the key, write the names of the cats under their pictures.

……………………….. ………………………….

…………………………. ……………………….

Source of photos: Siamese cat (www.pictures-of-kittens-and-cats.com/pictures) and tonkinese cat (www.catsofaustralia.com/tonkinese.htm).

Photos of tabby cat and smoke cat taken by Mariette Lucas (2010).

I am sure that you understand classification keys very well by now. I have provided you with the Answers to Self-assessment 1.2 below.

Answers to Self-assessment 1.2

Answers to Assessment

a. The Tabby cat is a long-haired domestic cat with striped coat.

b. The Siamese is short-haired domestic cat with a triangular head.

c. All four cats are domestic cats.

d.

Smoke cat

Tonkinese cat

Tabby cat

Siamese cat

Source of photos: Siamese cat (www.pictures-of-kittens-and-cats.com/pictures) and tonkinese cat (www.catsofaustralia.com/tonkinese.htm).

Photos of tabby cat and smoke cat taken by Mariette Lucas (2010).

Well done! This brings us to the end of topic 1.2. Are you comfortable with classification keys now? If you have access to the internet, try the following classification activity by clicking on "launch interactive" http://www.pbs.org/wgbh/nova/nature/classifying-life.html

Please note that this site is provided for information only and we do not support or endorse any links from this site.

If you are ready, let's move onto topic 1.3 which deals with binomial nomenclature. From the title, you should be able to tell that the topic will be dealing with naming something.

Topic 1.3: Binomial Nomenclature

How long?

To do this topic you will need 1 hour of formal study time. It is advisable that you spend another 30 minutes of your own time to find the binomial names of some other organisms that you know.

Almost every one of us has a pet.

> *Which animal is your pet? Suppose you were to tell students in ten different countries which animal your pet is, would they all know which animal you are talking about? How can you be sure?*

You are right! Even if there are billions and billions of living organisms on earth, it is easy for the same organism to be recognized across the world. This is thanks to biologists who have classified them into meaningful groups according to how closely they are linked to each other.

Biologists have also found it important for the different groups of organisms to be named in an organized way, giving each organism its uniqueness. What do you think would happen if the yellow fin tuna, which is found in the Seychelles waters as well as in many different parts of the world, had different scientific names? Write your ideas below.

As you must have realized, this would have caused a lot of confusion and disorder in the world wide data banks about this species of tuna. It is therefore very important for scientists to use exactly the same names for particular kinds of living organisms.

Early naturalists used long complicated phrases to name the different types of animals and plants. This naming system was known as the "polynomial system." In this system, a plant might be described by a phrase of ten or more words. Polynomial names could become very complex and were often misinterpreted when translated from one language to another.

A more reliable and efficient naming system was developed in the mid 18th century. This system is known as the "**binomial nomenclature**". It is a universal system that is used in all countries irrespective of language barriers.

1.3.1 Scientific names of organisms

The **binomial nomenclature** is a system developed for the naming of organisms. Binomial means "two names". Hence the binomial nomenclature is a two-part naming system used by scientists to name each of the different species of organisms. The first part of the name gives the **genus** (first letter capitalized) and the second part gives the **species** (lowercase), with both genus and species written in Latin and in italics. The genus refers to a group of closely related species, and the species refers to the smallest group of organisms. You will learn more about genus, species and other larger groupings of organisms in the topic '**Hierarchical classification**' in this unit.

The binomial nomenclature was developed by a Swedish naturalist called Carolus von Linnaeus in 1735.

Let us find out how the binomial nomenclature works by using the example of the tea rose.

A **rose** is a perennial flower shrub or vine. Rose plants form a group of erect shrubs, and climbing or trailing plants, with stems that are often armed with sharp prickles. There are over 100 species of roses ranging from various species of wild roses, modern and old garden roses, landscape roses and carpet roses. All the different species of roses belong to the genus *"Rosa".* The tea rose is one of the species of old garden rose named for their fragrance (*odorata.)* The binomial name or scientific name for the tea rose is therefore *Rosa odorata*.

Source: http://en.wikipedia.org/wiki/Rose

Activity

Activity 1.3.1

You should be able to complete this activity within 30 minutes.

a. Let us practice writing the binomial (scientific) names of some organisms using their genus name and species name.

In Table 1.3.1 (a) below, I have given you either the genus name or the species name of six living organisms that you are familiar with or their scientific name. Refer to the example of the tea rose that I have done for you and write the missing information on the table.

.

Living organisms			
Common name	Genus	Species	Scientific name
E.g. Tea rose	Rosa	Odorata	Rosa odorata
Domestic cattle (cow)	*Bos*	*Primigenius*	
Killer whale	*Orcinus*	*Orca*	
Malaria mosquito			*Anopheles quadrimaculatus*
Mauritius blue pigeon	*Alectroenas*	*Nitidissima*	
Breadfruit			*Artocarpus altilis*
Pawpaw	*Asimina*	*Triloba*	

Table 1.3.1(a): Binomial naming system of organisms

b. Those of you who can access the internet go to Wikipedia, the free encyclopedia, and look for the scientific names of the following organisms: guinea pig, coconut, black parrot, human beings and domestic dog. If you find the names of organisms other than the ones given here, you may use them instead. Note that Wikipedia is a collaborative encyclopedia and information on that site may not always be correct. It is therefore important that you refer to other sources or websites to verify your information.

Those of you, who do not have access to the internet, do your research in biology books and under the topic “classification.” If you do not find information on the given organisms use any five organisms for which you can find the scientific names.

In Table 1.3.2 below, write the common name of each organism, their scientific name, the genus name and species name.

Living organisms			
Common name	Scientific name	Genus	Species

Table 1.3.2: Binomial naming system of organisms

Well done! I have provided you with the feedback for the exercises (a) and (b) of Activity 1.3.1 at the end of this topic. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

It is now time for us to see how much you have learnt in Topic 1.3. Do the self-assessment below to test your understanding.

Self-assessment 1.3

Assessment

You should be able to complete this self-assessment in 15 minutes. This self-assessment is based on Topic 1.3. The answers are given at the end of the topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 1.3. This will help you learn and reflect better on areas for improvement.

a. Using your own words complete this cloze passage.

The------------------------------is a two-part naming system used by scientists to name the different species of organisms. The first part of the name gives the ------------------------ (first letter capitalized) and the second part gives the ------------------------- (lowercase). The genus and species names are written in-------------------------and in ---------------------------. The binomial nomenclature was developed by a Swedish naturalist called --------------------------------in 1735.

b. Write the scientific name for the following organisms;

Common name	Scientific name
Human beings	
Malarial mosquito	
Seychelles black parrot	

Table 1.3.1: Binomial naming system of organisms

c. The common name and the scientific name of five different organisms are given in Table 1.3.4 below. Use the information in the table to answer questions (a), (b), and (c) which follow.

Common Name	Scientific name

Common Name	Scientific name
Lion	*Panthera leo,*
Barn owl	*Tyto alba*
Leopard	*Panthera pardus*
Tiger	*Panthera tigris*
Gray wolf	*Canis lupus*

Table 1.3.4 Binomial naming system of organisms

Source: http://animals.about.com/od/cats/tp/tencats.htm; http://www.caninest.com/types-of-wolf/; http://en.wikipedia.org/wiki/Barn_Owl

i). Which organisms are related? How could you tell?

____

____

____

____

ii). The domestic dog is related to the gray wolf. What would be its genus name?

____

____

iii). How can you differentiate between the genus name and the species name of an organism?

____

I am sure that you have successfully managed to answer the self-assessment questions above. I have provided you with the Answers to Self-assessment 1.3 at the end of the topic.

Feedback

Feedback to Activity 1.3.1

a. We hope that you have been able to find some of the scientific names of the animals and plants given. These are given in Table 1.3.1(b) below

Living organisms			
Common name	Genus	Species	Scientific name
Domestic cattle (cow)	*Bos*	*primigenius*	*Bos primigenius*
Killer whale	*Orcinus*	*orca*	*Orcinus orca*
Malaria mosquito	*Anopheles*	*quadrimaculatus*	*Anopheles quadrimaculatus*
Mauritius blue pigeon	*Alectroenas*	*nitidissima*	*Alectroenas nitidissima*
Breadfruit	*Artocarpus*	*altilis*	*Artocarpus altilis*
Pawpaw	*Asimina*	*triloba*	*Asimina triloba*

Table 1.3.1 (b): Binomial naming system of organisms

b. In Table 1.3.2 we have also provided you with some of the English equivalents of the Latin words to help you make sense of the names that scientists have given to each organism.

Living organisms			
Common name	Scientific name	Genus	Species
Domestic Pig	*Sus domestica*	*Sus*	*domestica*
Coconut	*Cocos nucifera*	*Cocos*	*nucifera*
Seychelles Black Parrot	*Coracopsis nigra barklyi*	*Coracopsis*	*nigra barklyi*
Human beings	*Homo sapiens*	*Homo* (man)	*sapiens* (wise)
Domestic dog	*Canis familiaris*	*Canis* (descendant of the common wolf)	*familiaris* (domesticated)

Table 1.3.2: Binomial naming system of organisms

Answers to Self-assessment 1.3

Answers to Assessment

a. The binomial nomenclature is a two-part naming system used by scientists to name the different species of organisms. The first part of the name gives the genus (first letter capitalized) and the second part gives the species (lowercase). The genus and species are written in Latin and in italics. The binomial nomenclature was developed by a Swedish naturalist called Carolus von Linnaeus in 1735.

b.

Common name	Scientific name
Human beings	*Homo sapiens*
Malarial mosquito	*Anopheles quadrimaculatus*
Seychelles black parrot	*Coracopsis nigra barklyi*

Table 1.3.1(b): Binomial naming system of organisms

c (i). The lion, the leopard and the tiger are related. They belong to the same genus.

c (ii). The domestic dog's genus name would be *canis*. Its scientific name is *Canis familiaris.*

c (iii).The genus name begins with a capital letter whereas the species name is in small letters. Both are written in italics and in Latin.

Now that you are at the end of topic 1.3, how comfortable are you with naming organisms? Think of three organisms to name. Were you able to name them correctly? If you were, move onto topic 1.4. If you were not, make sure to review topic 1.3 one more time.

In the next topic, we will learn about the hierarchical classification system. Make sure to reflect back on what you learned about classification systems to help you understand this new form of naming organisms.

Topic 1.4: Hierarchical Classification

How long?

You are expected to complete this topic within 1 hour 50 minutes. It is advisable that you spend another 55 minutes of your own time to further practice using hierarchical classification.

In Topic 1.3 you learnt that Carolus von Linnaeus invented a very useful system for the naming of organisms.

a). What is the system called?

---

b). What does this naming system comprise of? Give one example of the scientific name of an organism to support your explanation.

As you realized the binomial nomenclature is a two-part naming system comprising of the genus and the species name of an organism. You will also recall that when classifying, we start with big groups and progressively subdivide the organisms into smaller groups until we can identify individual organisms.

Carolus von Linnaeus also created a hierarchical biological classification system using seven taxonomic categories. These seven categories are: Kingdom, Phylum (plural-phyla), Class, Order, Family, Genus (plural-genera), and Species. Beginning with Kingdom (the big group), each successive level of classification becomes more and more specific.

You may want to use a *mnemonic* tool to help you remember the hierarchical classification system. All you need to do is to make a sentence that is easy for you to remember using the first letter of the taxonomic group, beginning with kingdom and ending with species. Here is one example I have created for you: "**K**enneth **P**aul **C**an **O**wn **F**ive **G**igantic **S**tores."

Activity

Activity 1.4.1

You should be able to complete these activities in 10 minutes.

a. Using the above mnemonic tool, list the seven taxonomic categories in order.

b. In which of the following taxonomic categories would organisms have more common characteristics and resemble each other more; in a class or in a family? Explain your answer.

We hope that you found the mnemonic tool useful in helping you remember the taxonomic categories in order. With practice you should become very good in using it. You may also wish to create your own memory aid tool for these categories. Should you find an easier one, you are welcomed to share it with other colleagues and teachers.

Well done! I have provided you with the Feedback to Activity 1.4.1 at the end of the topic. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

.

Feedback

Feedback to Activity 1.4.1

a. The seven taxonomic categories are: Kingdom, Phylum, Class, Order, Family, Genus, and Species.

b. Members of a class have more varied characteristics than members of a family. Members of a class are grouped into different orders and members of each order are further grouped into more specific families.

Let us learn more about each of the different taxonomic categories below

1.4.1 Kingdoms

As highlighted above, the biological classification system consists of seven taxonomic categories. The first and largest category is called a kingdom.

Scientists have grouped organisms into a **six-kingdom system** according to the relationships among the different groups of organisms that exist on earth. The six-kingdom system is as follows:

Figure 1.4.1: The six kingdom system

Drawn by Mariette Lucas (2009)

Table 1.4.1 below briefly describes each of the six kingdoms agreed on by modern scientists.

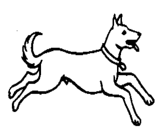
The six kingdoms	Main characteristics
Bacteria	Have only one cell, no nucleus. Too small to be seen with the naked eye.
Archaea	Have one cell, no nucleus. Similar in size to the bacteria but with different genetic makeup.
Protista	Most have one cell, with a nucleus and other cell structures. Examples: algae, amoeba
Plantae	 They have many cells and cannot move from one place to another. They use energy from the sun to make their own food. Examples: ferns, vegetables, flowers, trees.
Fungi	 Most have many cells. Fungi cannot move from one place to another. They absorb nutrients from other organisms. Examples: mushrooms, yeast, moulds
Animalia	 They have many cells. Most can move from one place to another. They get energy by feeding on other organisms. Examples: insects, crabs, birds, reptiles.

Table 1.4.1: Description of the six kingdoms

Drawn by: Mariette Lucas (2010).

The activity below will help you master the characteristics of kingdoms.

Activity 1.4.2

Activity

The activities below should not take you more than 10 minutes.

a. Think of as many organisms that you know that would belong to the kingdom animalia. What does this tell you about the types of organisms in a kingdom?

b. Examine the characteristics of organisms in each of the six kingdoms. What conclusion can you draw about the characteristics of organisms in specific kingdoms?

Feedback to Activity 1.4.2

Feedback

You must have realized from the above activity that each kingdom contains many organisms, each different from one other but sharing the same basic characteristics.

All organisms belonging to the animal (animalia) kingdom, for example, have many cells; most can move from one place to another and they get energy by feeding on other organisms. However, these are very general characteristics. To be able to identify individual organisms a kingdom has to be further divided into smaller groups.

Let us now look more closely at the animal (animalia) kingdom to understand further about the other five taxonomic groups.

1.4.2 Phylum

Organisms in each of the six kingdoms can be divided into different phyla (plural of phylum) based on their body plan, as well as their developmental and internal organisation. In the animal kingdom, those animals that have a backbone belong to the sub-phylum vertebrates of the phylum chordata. Animals in the phylum chordata, all have a dorsal nerve cord and a skeletal notochord (flexible, rod shaped body) at some point in their development, but it is only in the vertebrates that the notochord has been replaced by a number of interlocking bones (vertebrae) forming an internal bony skeleton.

The other animals are the non-chordates. They are all invertebrates (animals without a backbone) and they belong to many different phyla such as arthropoda, mollusca, and annelida. Animals of each phylum have very different characteristics. Arthropods for example have firm exoskeleton, and jointed appendages (body and limbs). Molluscs all have a head, a muscular foot and a dorsal hump containing internal organs. They also have soft skin and a calcareous shell. Annelids are wormlike invertebrates with well developed segmentation and a fluid-filled cavity

Which of the following animals would belong to the phylum chordata: shark, duck, dragonfly, snail, and frog? Give reasons for your answer. Also, if you have access to the internet, look up at least two other animals that belong to the phylum chordata.

between the body wall and the gut.

I am sure that you have said that the shark, the duck and the frog belong to the phylum chordata since they have a skeletal notochord. These animals also belong to the sub-phylum vertebrates since they have an internal bony skeleton (vertebrae), which has replaced the notochord. As for other examples, you should have come up with pretty much anything that has a dorsal nerve cord and a skeletal notochord.

Let us now consider the sub-phylum vertebrates, to learn about the various classes of vertebrates.

1.4.3 Class

Each phylum and sub-phylum is divided into a number of classes. Organisms in each class have very distinct features which separate them from organisms in the other classes of the same phylum. The sub-phylum, vertebrate, for example, is made up of five classes of animals: fish, reptiles, amphibians, birds and mammals. Animals in each of the five classes of vertebrates are very different from each other. Birds for example have skin covered with feathers, dry scales on their legs and they have wings; mammals on the other hand have hair or fur on the body; their young develop inside the mother's uterus attached to the mother through an umbilical cord and placenta.

Before we proceed further, let us review the first three levels of the biological classification system.

Activity

Activity 1.4.3

You should be able to complete the activities below in 10 minutes.

a. Write a short paragraph to explain to a friend the first three taxonomic categories in the biological classification system.

b. Complete the diagram below to show how *Homo sapiens* (human beings) are classified in the first three taxonomic groups.

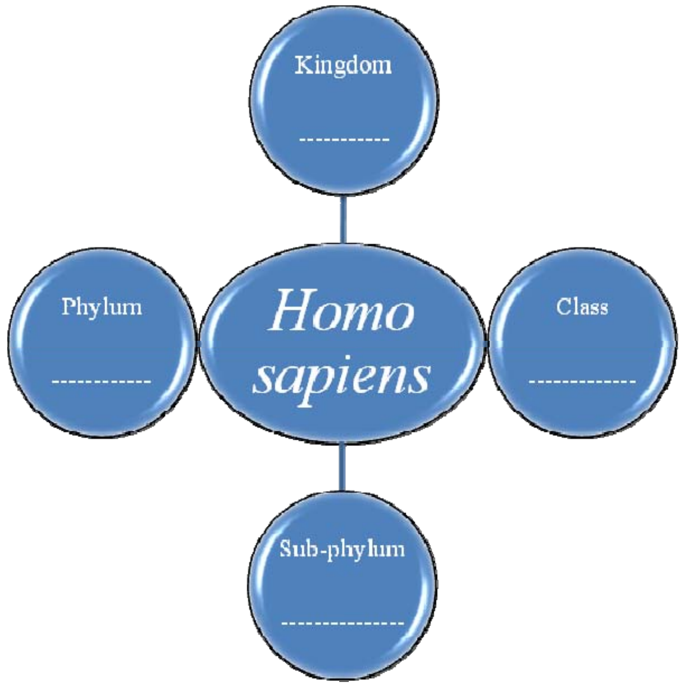


Figure 1.4.2: Classifying *Homo sapiens*
Figure created by author

Well done! I have provided you with the Feedback to Activity 1.4.3 at the end of the topic. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 1.4.3

That was good work. It shows that you have understood the first three taxonomic categories well. You may wish to compare your answers with mine below.

a. Indeed, you're right if you said that the first three taxonomic categories are kingdom, phylum and class. Kingdom is the largest category and comprises of six different kingdoms (bacteria, archaea, protista, plantae, fungi and animalia).

   Phylum is the next category and it includes sub phyla. In the kingdom animalia for example, animals are either chordates or non-chordates. The vertebrates are a sub-phylum of the phylum chordates. All invertebrates are non-chordates. Non-chordates belong to different phyla such as arthropoda, mollusca and annnelida.

   Organisms in a phylum or sub-phylum are further divided into classes. For example, animals in the sub-phylum vertebrates are divided into five classes. These are birds, fish, reptiles, amphibians and reptiles.

b. Figure 1.4.2 below shows how *homo sapiens* are classified

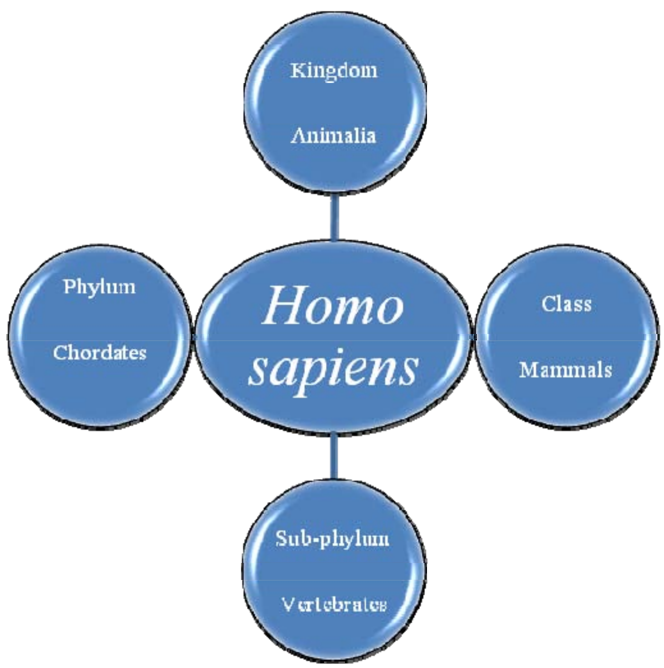


Figure 1.4.2: Classifying Homo sapiens

You can now read further about the last four taxonomic categories of the biological classification system.

1.4.4 Order

Each of the various classes of organisms is further divided into many orders. Let us consider the class Mammalia from the sub-phylum vertebrata, from the animal kingdom. One such order is called carnivora. Animals belonging to this order feed on the flesh of other animals. They usually have strong, sharp claws, well developed canines, and pre-molars and molars with cutting edges. Carnivorous mammals include animals such as dogs and foxes, weasels, seals and bears.

1.4.5 Family

Within each order there are a number of families. Mammals in the carnivora order for example belong to many different families. Carnivorous mammals such as otters, badgers and weasels belong to the mustelidae family. Mustelids have thick fur with a dense undercoat and a less dense outer coat. They have short ears and five toes on each foot. Some mustelids have an elongated body with a flexible backbone.

The domestic cat and other big / wild cats such as the tiger, lion, cheetah, leopard, jaguar, and cougar belong to the felidae family.

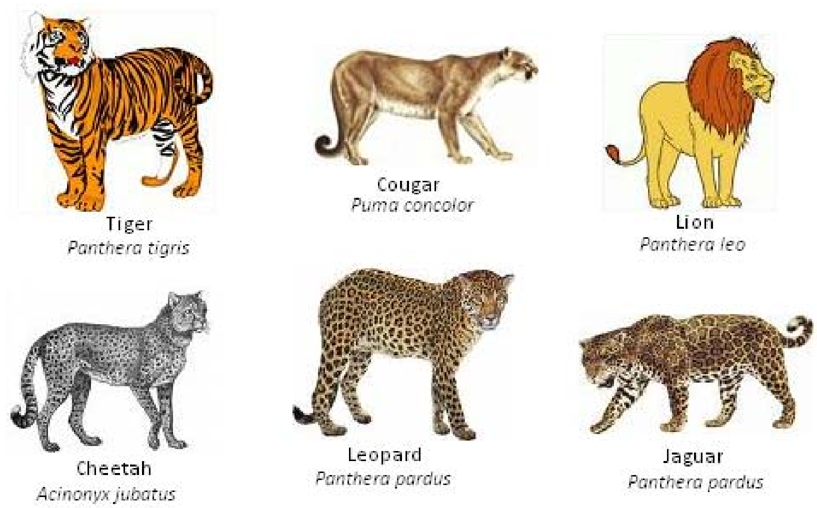
Let us do the short activity below to better understand orders and families.

Activity 1.4.4

Activity

I expect that you will not take more than 10 minutes to complete this activity.

Look carefully at some of the animals in the felidae family.



Source of pictures: http//www.google.com/ images: robertwinslowphoto.com

a. Give at least two ways how the animals in the felidae family look similar.

___

___

___

b. Animals such as dogs, wolves, foxes and jackals belong to the canidae family. What characteristic do they share with animals in the felidae family?

___

___

Well done! I have provided you with the Feedback to Activity 1.4.4 at the end of the topic below. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback to Activity 1.4.4

Feedback

a. I am sure that you have realized that these animals (usually called felids) are cat-like. They are generally agile climbers, most are secretive animals and they are often nocturnal. They have soft-furred bodies, acute vision and hearing, and claws and teeth that are well adapted for grasping and tearing.

b. Animals of the canidae family such as dogs, foxes and jackals, and animals of the felidae family both belong to the carnivore order.

Let us now look at the genus and species groups.

1.4.6 Genus

Each family consists of varying numbers of genera (plural for genus). The animals in the felidae family are grouped in many different genera such as the genus Felis which includes animals such as the domestic cat. The genus pantherae includes all big cats that can roar, such as lions, tigers, leopard and jaguar.

1.4.7 Species

Animals in the same species are very closely related. They can interbreed and produce fertile offspring. The genus *felis* consists of a number of different species of cats, one of which is the domestic cat. The species name of the domestic cat is *catus.* Species is the smallest group in the biological classification system.

Now that you have learnt about the seven taxonomic categories of the biological classification system, show us how you would classify one animal by doing Activity 1.4.5 below. You may wish to ask your science teacher to help you find some of the required information or you can do your own Google search for some websites.

Activity

Activity 1.4.5

This activity should not take you more than 15 minutes.

a. Choose an animal and draw a chart below to represent how the animal fits in all the seven taxonomic categories of the biological classification system.

b. Ask your teacher to verify the correctness of the information on your chart. Then share your chart with your friends. You should all be able to convince each other that you have understood the biological classification system.

c. Copy the information that you have obtained for your chosen animal as well as three other animals from your friends in Table 1.4.2 below. Look for the scientific names of each animal and write them alongside their common names below. I have completed the example of the lion for you.

Taxonomic categories	Animals Common names and scientific names				
	Lion *Panthera leo*				
Kingdom	Animalia				
Phylum	Chordata				
Sub-phylum	Vertebrates				
Class	Mammals				
Order	Carnivora				
Family	Felidae				
Genus	Panthera				
Species	Leo				

Table 1.4.2: Biological classification of animals

Well done! You have proved that you have really understood the biological taxonomic groups.

Assessment

Self-assessment 1.4

[Add assessment text here]

You should be able to complete this self-assessment in 20 minutes. This self-assessment is based on Topic 1.4. The answers are given at the end of the unit. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 1.4. This will help you learn and reflect better on areas for improvement.

The chart shows how the domestic cat is categorised in the biological classification system.

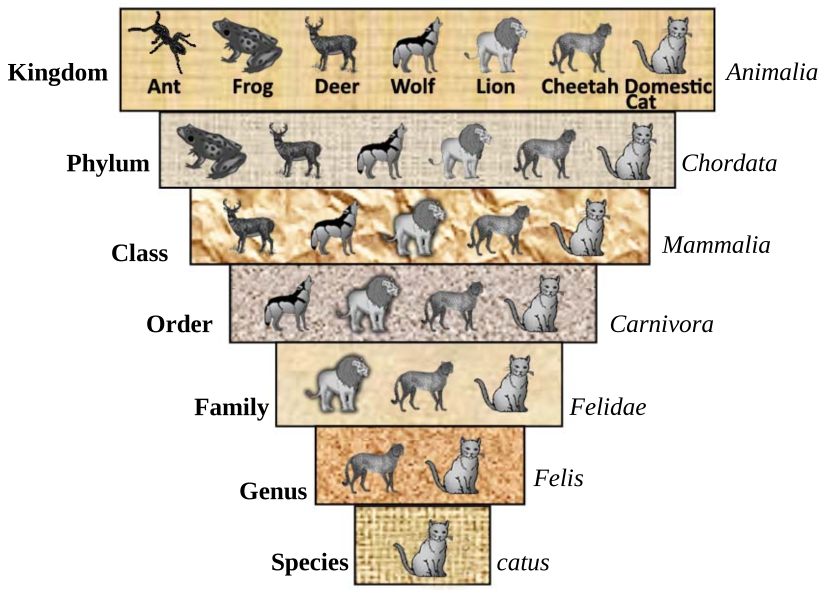


Figure 1.4.2: Classification of the domestic cat

Source: Drawn by Serge Mondon; original idea Mariette Lucas (2010).

Use Figure 1.4.2 above to help you answer questions (a) to (e) below.

a. Which animal does not belong to the phylum chordata? Give a reason why you think it does not belong.

b. As the groups get smaller, the animals are more alike. State at least one way how the animals in the order carnivora are alike.

c. Which is the smallest group of animals in Figure 1.4.2?

d. What common characteristic do animals of the same species share that cannot be shared by animals in other species?

e. What is the scientific name of the domestic cat?

f. Look at the animal below.

Figure 1.4.3: An animal for classification

Source of photo: wildlifemysteries.wordpress.com

Draw a diagram in the space below to show how the animal fits in the first three taxonomic categories of the biological classification system.

That was an interesting exercise, wasn't it? I have provided you with the Answers to Self-assessment 1.4 below.

Answers to Assessment

Answers to Self-assessment 1.4

a. The ant does not belong to the phylum chordate, because it does not have a dorsal nerve cord and a skeletal notochord at some point in its development. It is a non-chordate and belongs to the phylum arthropoda.

b. Animals belonging to the carnivora order feed on the flesh of other animals. They usually have strong, sharp claws, well developed canines, and pre-molars and molars with cutting edges. Carnivorous mammals include animals such as dogs and foxes, weasels, seals and bears.

c. Species is the smallest group in the hierarchical classification system.

d. Animals of the same species can interbreed to produce fertile offspring.

e. The scientific name of the domestic cat is *Felis catus*

f. The animal is the deer.

   i. It is related to animals such as cattle, goat, sheep, giraffe, camels, bison, antelope, llamas and wildebeest. They are all ruminants and digest plant-based food. They belong to the order artiodactyla.

   ii. Scientific Classification of the deer

Kingdom: → *Animalia*

Phylum: → *Chordata*

Class: → *Mammalia*

Order: → *Artiodactyla*

How did you find this topic? Quickly reflect back on what you have learned. Are you able to use the hierarchical classification system with ease now? If you are, let's move on.
In the next topic, we will be looking closely at vertebrates.

Topic 1.5: Vertebrates

How long?

You will need 3 hours at the most to do the activities in this topic. It is advisable that you spend another 1 hour and 30 minutes of your own time to research and consult people and / or documents to obtain the required information for some of the activities. You need to make prior arrangements with the persons that you need to consult to economize on your study time.

Think of an animal.

I am sure that you probably thought of a mammal such as a dog or a cow. This is because we are most familiar with mammals. Hence, many others would have come up with the same answer. You may wish to try asking the question to a few people around you.

As you are already aware, mammal is one class of vertebrates from the phylum chordata.

From what you have read in the previous section above,

a). What do you understand by the term "vertebrates"? Write what you currently understand below.

b). What are the five classes of vertebrates? List them below.

For sure, vertebrates have a hard, usually bony internal skeleton with a backbone. The backbone is made up of many small bones called vertebrae. The vertebrae are joined together making it possible for the vertebrates to move about easily.

There are five **classes** of vertebrates. They are *fish*, *amphibians*, *reptiles*, *birds* and *mammals*. Remember that animals in each of the five classes of vertebrates are very different from each other. We shall look at each of the five classes of vertebrate in the sections which follow. Let us start with *fish*.

1.5.1 Fish

Whenever we talk of fish, we suddenly think of a water environment. This is because all fish live and breathe in water. Some fish live in fresh water and some in sea water.

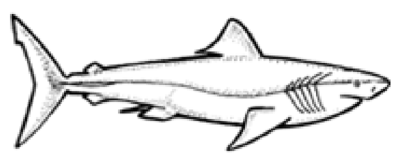
Fish are **ectotherms** (**cold-blooded animals**). They are unable to produce their own body heat. Their temperature depends on the temperature of their surroundings.

There are three main classes of fish. The two most common classes are the chondrichthyes (cartilaginous fish) and the osteichthyes (bony fish).

We shall start off by looking at the descriptions of cartilaginous fish.

Cartilaginous fish have placoid scales (flat and with sharp, tiny spines), a skeleton of cartilage and separate gill slits. Some examples of cartilaginous fish are:

Ray fish
Dasyatis centroura



White shark
Carcharodon carcharias

Bony fish have circular and thin scales with smooth edges, a bony skeleton and gills covered with an operculum. **Note that cartilaginous fish do not have an operculum, but have gill slits.** Some examples of bony fish are:

Figure 1.5.1

Fish drawn by Serge Mondon (2009).

Most fish have a streamlined body that helps them move swiftly through water. A fish has different types of fins which in different ways help the fish move through water.

The **caudal fin** (tail fin) helps to propel the fish forward in the water.

The **dorsal fin** (on the top side), the **anal fin** (behind the anus) and the paired **pelvic fins** or **ventral fins** (below the pectoral fins) help to stabilize the fish to stop it from rolling from side to side.

The paired **pectoral fins** (behind the operculum) help with fine movements; and also in moving the fish forward. Together with the pelvic fins the pectoral fins also serve as brakes.

Now use the information above to learn more about fish in Activity 1.5.1 below.

Activity

Activity 1.5.1

You should complete the activities below in about 50 minutes.

Study the cartilaginous and the bony fish above carefully.

a. Describe the main features of a fish.

b. Now compare your ideas with the main parts of a fish shown on the drawing below. Did you leave out any of the characteristics or did you include them all?

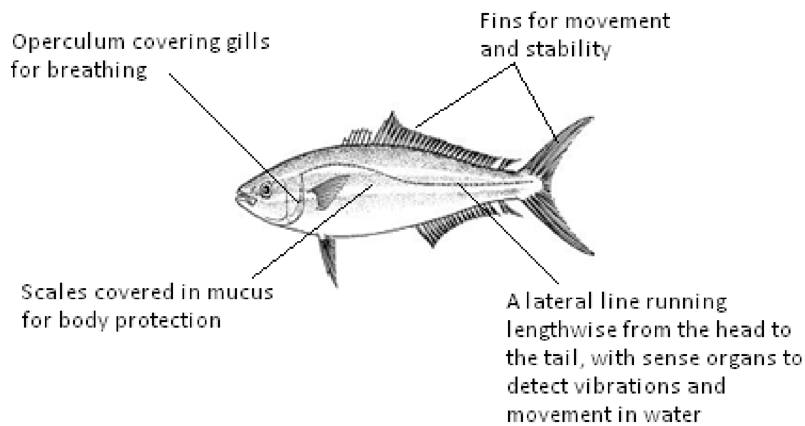


Figure 1.5.2: Main parts of a fish

Drawn by: Serge Mondon (2009).

You should also note that the operculum is found in bony fish only!

c. Using the information in the text above, label the pectoral fins, the pelvic fins, the caudal fin, the anal fin and the dorsal fin on the drawing of the fish below.

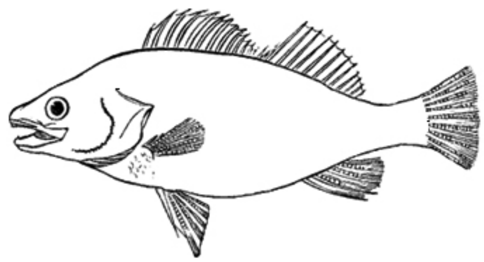


Figure 1.5.3 (a): An unlabelled diagram of a fish

Drawn by: Serge Mondon (2009)

d. Look for three different types of fish and find both their common name and the binomial name of each fish. Then, with the assistance of a fisherman or your parents/friends/relatives, compare the parts of the three fish and describe them as fully as you can.

   Make a leaflet of the three fish and show it to your teacher. You may also wish to give a copy of the leaflet to the fisherman or the person who assisted you. Keep your original leaflet in the portfolio.

e. Those of you, who have an aquarium at home or a stream close by, try to observe how a fish swims and how it breathes. You may wish to read further about this and include such information in your leaflet as well.

I am sure that you have made some interesting observations. I have provided you with the feedback to Activity 1.5.1 at the end of the topic below.

Feedback

Feedback to Activity 1.5.1

a. Fish are cold-blooded animals. They have fins, gills and their skin is covered with scales.

b. The fins of the fish are as follows:

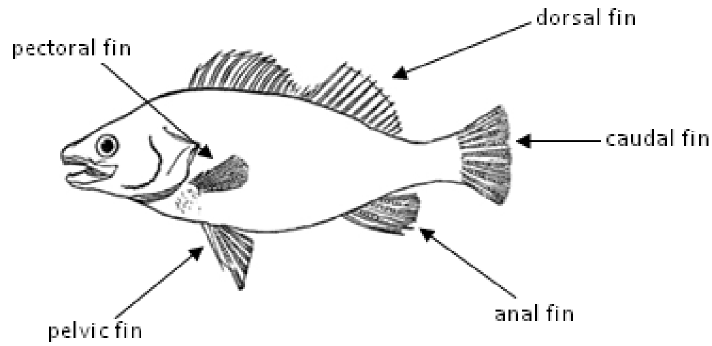


Figure 1.5.3 (b): Labelled diagram of the fins of the fish

Drawn by: Serge Mondon (2009).

We shall now look at the amphibians.

1.5.2 Amphibians

Amphibians comprise animals like the frog, toad and salamander. They have smooth, moist skin with no scales. Like the fish they are ectotherms (cold-blooded animals). Amphibians begin their life in water and most of them spend their adult life on land. They lay their eggs in water. Therefore the young amphibians have gills and breathe like fish. They also have tails which they use for swimming.

Amphibians undergo a process called metamorphosis (change in body form) as they grow. The changes take place both internally and externally. As the young amphibians grow older, they grow legs and they lose their gills. They breathe air through lungs and also through their moist skin. Many of the amphibians also lose their tail as they grow.

Figure 1.5.4 below shows how these changes take place in the frog.

Life cycle of the frog

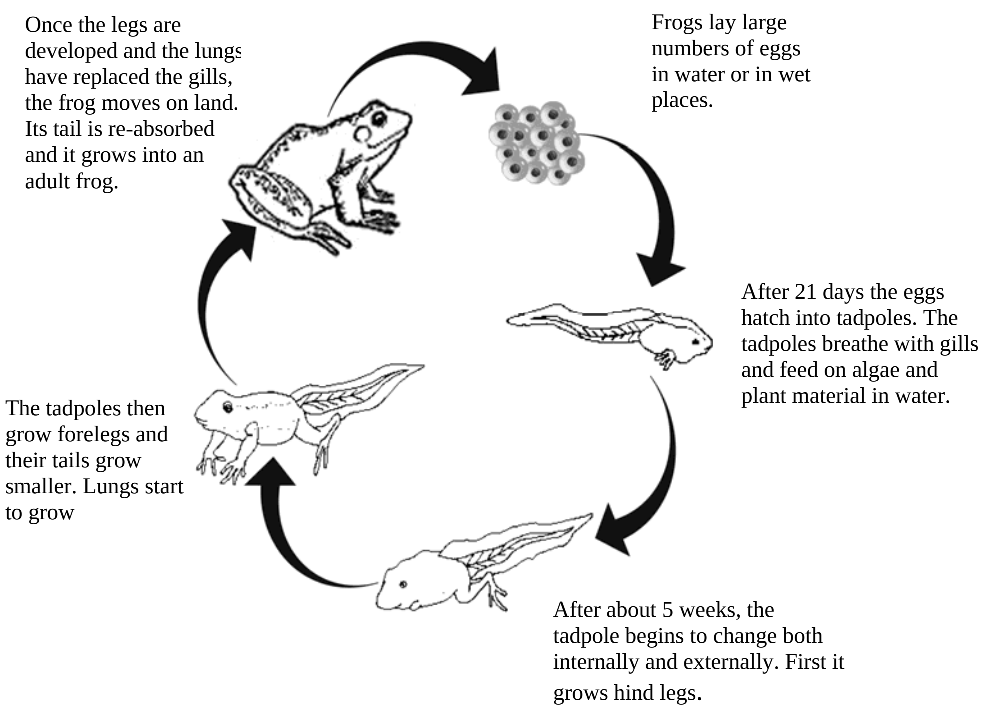


Figure 1.5.4: Life cycle of the frog

Drawn by: Serge Mondon (2009)

Now that we have learnt about amphibians, we shall learn about reptiles.

Reflection

1.5.3 Reptiles

Turtles, lizards, snakes, crocodiles and alligators are all reptiles. Look at the pictures of reptiles below; do you notice any common characteristics among them? Write a couple of your observations below.

Figure 1.5.5: Some reptiles

Source of pictures: Snake adapted from www.gpnc.org. Crocodile adapted from 3d4games.com. Turtle adapted from Seychelles Division of Environment; Conservation and National Parks Section (1994).

I am sure that it was not easy for you to come up with common characteristics of the reptiles, unless you have had firsthand experience with these animals. I have described the common of reptiles below.

All the reptiles have a dry and scaly skin. The scales tend to be horny with bony plates. Most have paired limbs with five toes on each limb. Most reptiles live on land, but some species have adapted special features to live in freshwater (e.g. crocodiles) and in marine environments (e.g. turtles). Reptiles lay rubbery-shelled eggs on land. They are also ectotherms (cold-blooded animals).

Let us now look more closely at one reptile, i.e. the turtle.

1.5.3.1 Turtles

Most turtles have a bony shell (or leathery skin for some species) on the top side of their body called the *carapace*, and a softer shell underneath the body called the *plastron*. Turtles live in water or near water. They have flatter or more streamlined shells which help in swimming. Many turtle species are endangered species.

Like all reptiles, turtles lay their eggs on land. Female turtles lay their eggs in holes which they dig in the sand. When the eggs hatch out, the young turtles rush down to the water. This journey is often very dangerous, and many of the young turtles are killed by predators.

The life cycle of the turtle is shown below.

Life cycle of the turtle

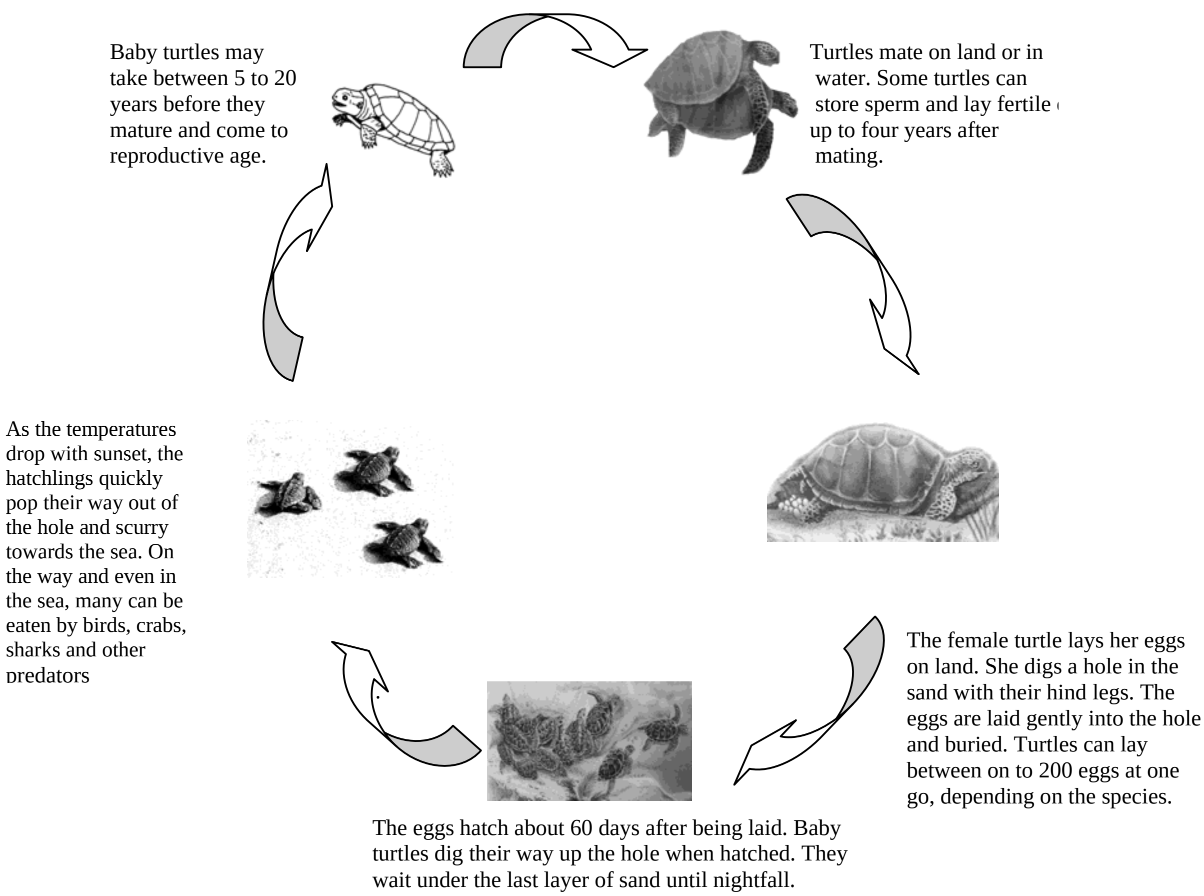


Figure 1.5.6: Life cycle of the turtle

Pictures adapted from: Seychelles Division of Environment; Conservation and National Parks Section (1994).

Turtles are species that are protected worldwide and there are penalties for people caught killing or interfering with turtles which come to nest on our beaches. You will find out more about this in Activity 1.5.2 below.

Activity

Activity 1.5.2

In 20 minutes you should complete the activities below.

Turtles’ nests and nesting sites are protected by law in most countries.

a. Find an article on the preservation of turtles in the national newspapers or any journals published by Environment Departments or related organizations in your country. Read the article and write an extract on the banner below. Remember to note the source of the information as well on the banner.

b. Keep a referenced copy of the article in your portfolio. You may also wish to look for and keep other related articles.

c. Use the new knowledge that you have gained about the preservation of turtles to write a letter to the Environment Department in your country to give your support for such initiatives. Keep a copy of your letter and any responses that you may get from the departments in your portfolio.

I am sure that you are now better aware of the efforts being made worldwide, and more specifically in your respective countries, to protect turtles. You should spread this awareness around and help in the preservation of turtles and other endangered organisms.

Now that you are familiar with fish, amphibians and reptiles, we shall look at the birds.

1.5.4 Birds

Suppose you are to find out whether an animal is a bird. What main question would you ask?

I'm sure it was not difficult for you to realize that birds have features like the hen shown below.

The hen is an example of a bird. Birds have the following parts.

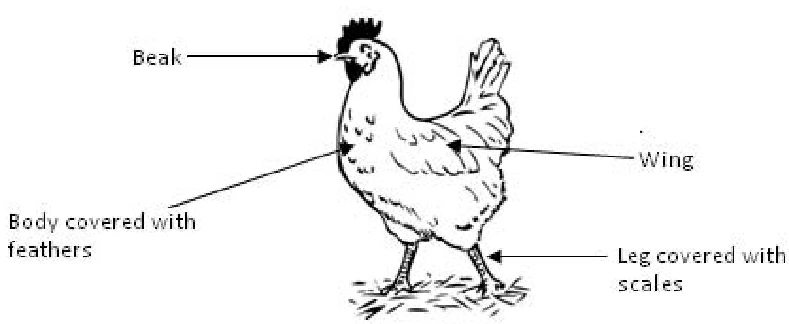


Figure 1.5.7: Main parts of a bird

Drawn by: Serge Mondon (2009).

Birds are endotherms (warm blooded animals) with feathers. Hence birds produce their own body heat and maintain a warm body temperature. The feathers are light to enable flight and help trap heat from the body. All birds have a pair of wings, although not all use their wings for flight. The shape of a bird's wings determines its style of flight; which could be gliding, soaring, or flapping. The lower parts of birds' legs are covered with scales. Birds lay eggs with hard shell. They have hollow bones which make their bodies light.

1.5.4.1 Flightless birds

Even if all birds have wings, not all can fly. Some of the flightless birds are shown below.

Drawn by: Serge Mondon (2009).

Activity

Activity 1.5.3

You should complete these activities in 40 minutes.

a. Each of the four flightless birds shown above is described below. Read each description and try to identify and name the birds. Write the correct description next to the picture of the correct bird.

The ostrich is the largest living species of birds. It is native to Africa. Although ostriches do not fly they can run at great speeds.

Penguins spend most of their lives in water. They are good swimmers and have flipper-like wings and webbed feet. The back and heads of all penguins are black and their breasts are white. Male and female penguins are similar in appearance.

Now extinct, the dodo which was found in Mauritius has a large hooked bill and short thick yellow legs. It had undeveloped wings and tail, and was a sluggish bird which fast became extinct.

Emus have underdeveloped wings that are hidden under thick hair like feathers. The top part of the neck is naked. Emus are quite fast runners and are found in places such as Australia.

b. Find out whether there are flightless birds in your country from the Department of Environment.

For example, in Seychelles information could be sought from the following address:

Division of Environment

Conservation Section

Fond Boffay

Praslin/Seychelles

Tel: 232984

Website address: http://www.env.gov.sc/

Make a mini poster about the bird. Use pictures of the bird and its main characteristics to embellish your poster. Remember to write both its common and scientific names. How about writing its local name as well…! When your mini poster is ready, discuss it with your teacher, and then file it in your portfolio.

I hope that you have learnt some valuable information about flightless birds. I am sure that you have started to develop an interest in the protection of flightless birds, so that they do not become extinct like the dodo of Mauritius. Should you have an opportunity, it would be worthwhile to participate in the protection of birds and other animals.

It should not have been that difficult for you to identify the birds in (a) above. I have provided you with the Feedback to Activity 1.5.3 at the end of the topic below. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback to Activity 1.5.3

Feedback

The following are the features of the different flightless birds.

Now extinct, the dodo (*Raphus cucullatus*), which was found in Mauritius, had a large hooked bill and short thick yellow legs. It had undeveloped wings and tail, and was a sluggish bird which fast became extinct.

Emus (*Dromaius novaehollandice*) have underdeveloped wings that are hidden under thick hair like feathers. The top part of the neck is naked. Emus are quite fast runners and are found in places such as Australia.

Penguins spend most of their lives in water. They are good swimmers and have flipper-like wings and webbed feet. The back and heads of all penguins are black and their breasts are white. Male and female penguins are similar in appearance. N.B Different species of penguins have different names. The Galapagos species is named *Speniscus mendiculus*.

The ostrich (*Struthio camelus*) is the largest living species of birds. It is native to Africa. Although ostriches cannot fly, they can run at great speeds.

We shall now have a look at the mammals.

1.5.5 Mammals

Mammals are the most familiar group of animals to us, human beings. After all, we are also mammals! The main characteristics of mammals are that they have hair or fur on the body; their young develop inside the mother's uterus attached to the mother through an umbilical cord and placenta, but there are a few exceptional mammals that lay eggs. Young mammals feed on their mother's milk from the mother's mammary glands. Most mammals live on land and have four legs. Mammals are endotherms (warm blooded animals).

Activity

Activity 1.5.4

You should complete the reading and the activity below in no less than 10 minutes.

Find a picture of a mammal and stick it in the space below. Alongside your picture, make a list of ten other mammals.

I am sure that your list included mammals such as cows, lions and rats. These mammals belong to one of the subclasses of mammals, i.e. the **placental** mammals. This is normal as this subclass contains a much larger and more widespread species

There are three main subclasses of mammals; the **monotremes,** the **marsupials** and the **placental** mammals. We shall start by looking at the monotremes, which is the smallest subclass of mammals.

Monotremes include only two species of mammals which lay eggs. These are the duck billed platypus, and the echidna. Both species are found in Australia, Tasmania and Papua New Guinea. They have fur and their young feed on the mother's milk. The special features of each species are given in Table 1.5.1 below

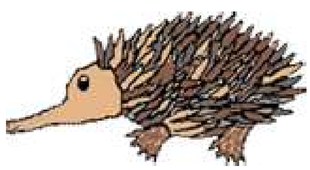
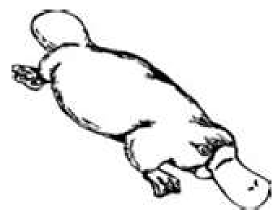
Echidna	**Duckbilled platypus**
	
• Broad body with short legs and body covered with stiff spines mixed with long coarse hairs. • Small head with slender snout and body between 35 to 53cm long • Long sticky tongue used to feed on termites, ants and other small insects.	• Semi aquatic, excellent swimmers and divers, with flat snout resembling a duck's bill and webbed feet. • The body length is between 30 to 40cm with a flattened tail of length 10 to 15cm. • Small eyes, no external ears, but a good sense of sight and hearing. • Feeds on insects, worms, and shellfish found in mud in rivers.

Table 1.5.1: Comparison of the echidna and the platypus

Source of pictures: Duck-billed platypus, drawn by Serge Mondon (2009).
Echidna: http://www.wikiforkids.com/wiki/echidna

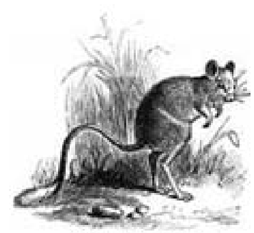
The **marsupials** include animals such as the kangaroo, the koala bear the opossum and the wombat. Marsupials give birth to underdeveloped young which continue their full development in the mother's pouch, feeding on milk from the mother's breast. Most marsupials are found in Australia and Tasmania, but some are also found in America.

We will further look at three of the marsupials below.

The **kangaroo** is found in Australia and neighboring islands. It has a small head and large ears. The front legs are short compared to the long, strong hind legs which are used for hopping. The kangaroo's tail is also very useful in hopping.

There are two main families of kangaroos; a family of large kangaroos (e.g. the red kangaroo up to 2 m in height) and one of smaller kangaroos (e.g. the rat kangaroo, up to 30 cm tall).

Red kangaroo



Rat kangaroo

Source of pictures for red kangaroo (www.cdli.ca) and for rat kangaroo (etc.usf.edu)

Opossums can be found in Australia and America. They have an unusually long tail, with long pointed face, and body length ranging from 17 to 104 cm including the tail. They are nocturnal animals (animals that are active at night) and most species are arboreal (animals that live mostly in trees) and omnivorous.

Koalas are native to Australia and have a specialized diet of eucalyptus leaves. They live in trees. They look like miniature bears with a round face and a large projecting nose. They are between 69cm to 79 cm long and the males are larger than the females. They have thick wooly fur and paws that are well adapted for gripping and climbing trees.

The **placental mammals** are the largest group of mammals on earth. The young develop inside the mother's uterus and when born they are fully developed.

Placental mammals are grouped into over 19 orders, depending on their specific characteristics. Some of these orders include **rodenta** (e.g. beavers, porcupines, and mice), **carnivora** (e.g. cheetahs. wolves, dogs, and lions), **primates** (e.g. monkeys, apes, human beings) and **marine mammals** such as whales, seals and dolphins.

Source of pictures: Koala: http://en.wikipedia.org/wiki/koala

Opossum: http://en.wikipedia.org/wiki/opossum

We have learnt about the five classes of vertebrates above. To help you review the topic, do the self-assessment below.

Assessment

Self-assessment 1.5

You should be able to complete the self-assessment in 25 minutes. This self-assessment is based on Topic 1.5. The answers are given at the end of the topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 1.5. This will help you learn and reflect better on areas for improvement.

1. Six animals are shown in Figure 1.5.8 below.

   Answer the questions (a), (b), and (c) below by studying the animals and the list key below.

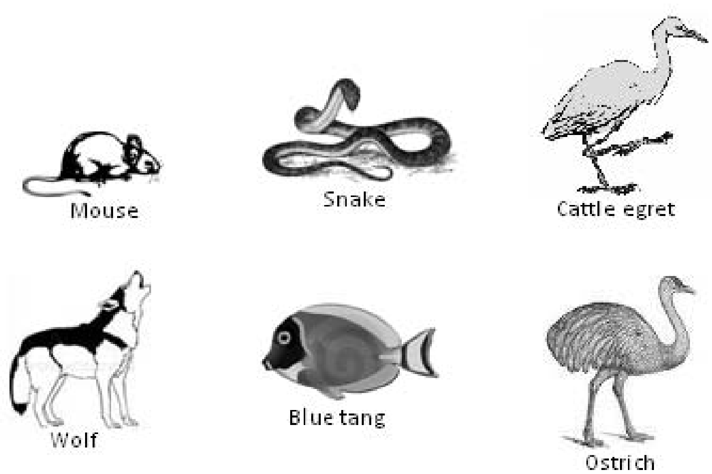


Figure 1.5.8: A group of vertebrates

Pictures drawn by Serge Mondon (2009).

1	a. The animal is an endotherm	Go to 2
	b. The animal is an ectotherm	Go to 3
2	a. Body covered with feathers	Go to 4
	b. Body covered with hair or fur.	Go to 5
3	a. Breathe with gills	Blue tang
	b. Breathe with lungs	Snake
4	a. Can fly	Cattle egret
	b. Cannot fly	Ostrich
5	a. Belongs to the carnivora order	Wolf
	b. Belongs to the rodenta order	Mouse

Table 1.5.2: A list key of vertebrates

a. Describe the snake.

____

____

b. Birds have legs and their body is covered with feathers.

i. Name the vertebrates in Figure 1.5.8 that are birds.

____

____

ii. Name one difference between the two birds in the key?

c. To which vertebrate group does the wolf belong? Explain why you classified the wolf in this group.

2. In what ways is an amphibian different from a fish?

3. To which vertebrate group do you belong? Explain your answer.

4. Complete Table 1.5.3 (a) below. You should:

a. Write the correct class of vertebrate next to its characteristics.

b. Give two examples of animals that belong to each class of vertebrate, and

c. Indicate whether the class of animals is warm blooded or cold blooded by writing the correct term in the temperature regulation column.

Characteristics	Class of vertebrate	Examples of animals	Temperature regulation
They have hair on the body; their young develop inside the mother's uterus and feed on the mother's milk.			
Most have a streamlined body that helps them move swiftly through water. They have scales, fins and gills.			
They have smooth, moist skin with no scales. They begin their life in water and most spend their adult life on land. They lay their eggs in water.			
They have a dry and scaly skin. The scales tend to be horny with bony plates. Most have paired limbs with five toes on each limb. Most live on land, but some species live in water. They lay rubbery-shelled eggs on land.			

Characteristics	Class of vertebrate	Examples of animals	Temperature regulation
They have feathers, a pair of wings and a beak. The lower parts of their legs are covered with scales. They lay eggs with a hard shell.			

Table 1.5.3(a): The five classes of vertebrates

I am sure that you have done very well. I have provided you with the Answers to Self-assessment 1.5 at the end of the topic below.

Answers to Self-assessment 1.5

Answers to Assessment

1. Answers to questions based on the list key:

   a. The snake is an ectotherm and it breathes with lungs.

   b. The two birds

      i. The two birds are the ostrich and the cattle egret
      ii. The ostrich cannot fly but the carrel egret can fly.

   d. The wolf is a mammal it gives birth to live young and feeds its young with milk. Mammals have hair or fur and are endotherms.

2. Fishes have the following characteristics: Most have a streamlined body that helps them move swiftly through water. They have scales, fins and gills. Amphibians have the following characteristics: They have smooth, moist skin with no scales. They begin their life in water and most spend their adult life on land. They lay their eggs in water.

3. We belong in the mammal group. We have hairs on our body and we develop inside our mother's womb and feed of our mother's milk.

4. Characteristics of the different classes of vertebrates

Class of vertebrate	Characteristics	Example	Temperature regulation
Mammal	They have hair on the body; their young develop inside the mother's	Humans, whales, etc	Warm blooded

	womb and feed on their mother's milk.		
Fish	Most have a streamlined body that helps them move swiftly through water. They have scales, fins and gills.	Hagfish, salmon, etc	Cold blooded
Amphibian	They have smooth, moist skin with no scales. They begin their life in water and most spend their adult life on land. They lay their eggs in water.	Frogs, salamanders ,etc	Cold blooded
Reptile	They have dry and scaly skin. The scales tend to be horny with bony plates. Most have paired limbs with five toes on each limb. Most live on land, but some species live in water. They lay rubbery-shelled eggs on land.	Crocodiles, lizards, etc	Cold blooded
Bird	They have feathers, a pair of wings and a beak. The lower parts of their legs are covered with scales. They lay eggs with a hard shell.	Seagulls, parrots, etc	Warm blooded

Table 1.5.3(b): The five classes of vertebrates

What did you learn about vertebrates? Can you guess what invertebrates are based on what you learned about vertebrates? Let us now proceed to learn about the invertebrates.

Topic 1.6: Invertebrates

Note it! / Important!

Please note that this topic is for students who are doing the extended objectives only. If you are a student doing the core objectives, you may also attempt this topic if you like. If you decide not to follow this topic, you are encouraged to use the 3 additional hours to read further on the 5 topics covered above.

How long?

You will need 3 hours at the most to do the activities in this topic. It is advisable that you spend another 1 hour 30 minutes of your own time to research and consult people and / or documents to obtain the required information for some of the activities. You need to make prior arrangements with the persons that you need to consult to economize on your study time.

Now that you have a good idea about the types of animals in the vertebrate group, you should be thinking about the other, usually smaller, animals around you! These animals are without a backbone.

Do you have any idea how we call this group of animals?

Can you name some animals belonging to this group?

Recall that when we were working on the phylum category of the biological classification system, we learnt that these animals are **non-chordates.** They are animals without a backbone and are known as **invertebrates**. Invertebrates are the most abundant animal groups on earth. The phylum arthropoda is one of the invertebrate phyla with the most species.

Arthropods have a body with jointed parts, a number of pairs of jointed limbs and a hard exoskeleton. Ninety percent of all arthropods belong to the class of insects. Apart from insects, the arthropod phylum includes other classes such as crustaceans (e.g. crabs) and arachnids (e.g. spiders).

We are now going to look closely at **insects**, **arachnids**, and **crustaceans.** We shall start with the insects in Activity 1.6.1 below.

Activity

1.6.1 Insects

Activity 1.6.1

In 40 minutes you should complete the reading and the activity below.

a. Some examples of insects are shown below.

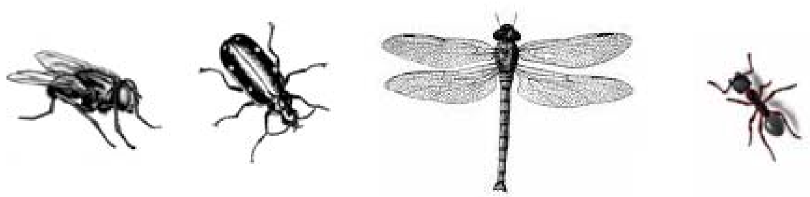


Figure 1.6.1: Some insects

Drawn by Serge Mondon (2009)

All the insects have the following characteristics in common:

Insects have three body parts; a head, thorax and an abdomen.

They have a pair of antennae and a pair of compound eyes made up of hundreds of separate lenses and sensory cells, as well as simple eyes on their heads.

Their thorax is made up of three segments and on each segment; one pair of legs is attached. Hence an insect has three pairs of legs. Some insects also have one or two pairs of wings attached to the second and third segments of the thorax.

Insects have 11 segments on their abdomen and they also have an exoskeleton.

Use the information above to label the body parts of the insect shown below.

Figure 1.6.2 (a): An unlabelled diagram of insect

Drawn by Serge Mondon (2009)

b. With a colleague, plan a visit to the Natural History Museum in your country or look for insects in your environment. Take photographs or look for pictures of some of the insects that you see there.

   Find information about the insects that you have observed from books, the internet or resource persons. Make a photo album or a sketch album of the insects. Include any information that you have gathered about them. Show your album to your teacher and keep it in your portfolio.

I'm sure that you enjoyed the above activity. It should not have been too difficult for you to label the insect. I have provided you with the Feedback to Activity 1.6.1 at the end of the topic below. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 1.6.1

The body parts of an insect are:

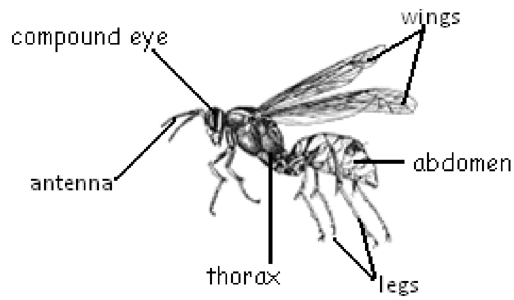


Figure 1.6.2: Labelled diagram of an insect

Drawn by Serge Mondon (2009)

The labelled picture above is that of an adult insect. Baby insects are usually very different from the adult. You may have seen baby insects around you, such as the caterpillar. Let us learn more about the life cycle of insects.

1.6.1.1 Life cycle of insects

Insects develop in special ways. They undergo metamorphosis as they develop. Metamorphosis means *change of form.* In some insects such as cockroaches and locusts, the change in form is less abrupt and the development to adult form is more direct. Such insects are said to undergo incomplete metamorphosis. Other insects such as butterflies and mosquitoes undergo complete metamorphosis. This means that each stage of development is quite distinct from the other.

I have presented an example of an insect that undergoes incomplete metamorphosis and one that undergoes complete metamorphosis on Table 1.6.1 below.

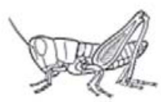
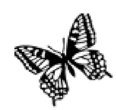
Incomplete metamorphosis (e.g. grasshopper)	Complete metamorphosis (e.g. butterfly)
• Eggs are laid in the ground. 	• Eggs are laid on the underside of leaves. 
• Egg develops into larva, known as instar or nymph which resembles the adult. The first nymph possesses simple eyes and legs, but no wings. 	• Eggs develop into larva (caterpillar) [1 to 2 weeks] which differs in body structure from the adult. The larva has no antennae or compound eye. It eats a lot and grows fast. The larva molts several times. 
• Each successive instar resembles the adult more and more. Frequent shedding of exoskeleton (molting) takes place. Wings gradually develop and are fully formed at the last stage (fifth instar). 	• The larva develops into pupa [1 to 2 months], which rests for complete development of the body structure, including the process for the wings to dry and exoskeleton to harden. 
• The fifth instar develops into a fully fledged adult [25 to 30 days]. 	• A fully developed adult hatches out of the pupa [2 weeks]. 

Table 1.6.1: Insect development

Drawn by: Serge Mondon (2009).

Keeping a caterpillar and watching how it develops into a butterfly or a moth is an interesting activity. In the first activity of Activity 1.6.2 below, I have given you the steps to follow if you would want to see how a caterpillar grows into a moth or a butterfly.

The activity is optional. Those of you who can try it are welcomed to do so.

Activity

Activity 1.6.2

You should all be able to complete the second activity below in 10 minutes.

a. Follow the steps below to know how to care for caterpillars (optional)

Step 1: With the help of a farmer or the owner of a flower or a vegetable garden, look for some caterpillars or their eggs. If you find the eggs, gently break off the leaf with the eggs and place it in a clear plastic container with air holes in the lid.

Step 2: Using a paint brush, transfer a newly-hatched caterpillar or a caterpillar found on a leaf in a transparent container. Give the caterpillar plenty of fresh food (leaves of the plant from which you took the caterpillar) everyday.

Step 3: Keep a record of the activities of and the changes that the caterpillar goes through. Here are some ideas of the types of observations and records that you could make:

i. Use a hand lens to help you make a labelled drawing of the caterpillar. With your hand lens try to look for the breathing holes, the true legs on the front segments and prolegs on the rear (back) segments, the mouth parts and the head.

ii. How much does the caterpillar eat each day?

iii. Measure the caterpillar each day and use your measurements to keep a caterpillar growth record.

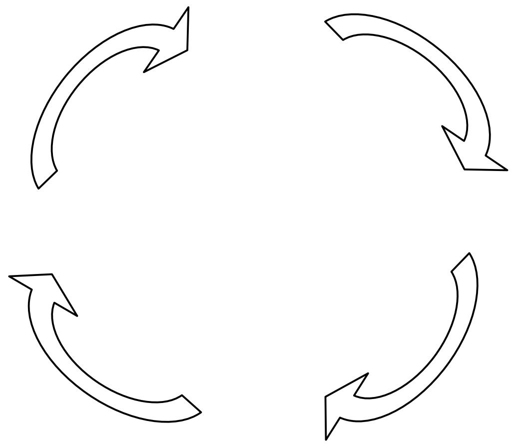
Step 4: Keep a record of your caterpillar study in your portfolio.

Those of you who are interested could further their studies by comparing caterpillars of butterflies and those of moths, or make a collection of the different species of butterflies or moths in Seychelles or worldwide.

b. Use the information in Table 1.6.1 above as well as your own observations to draw the life cycle of a grasshopper and that of a butterfly in the spaces provided below.

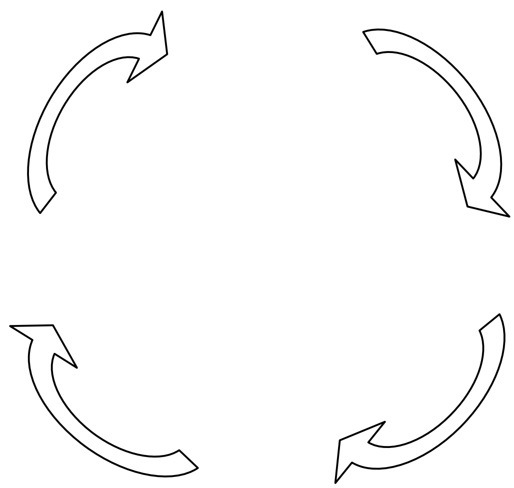
You may also wish to use general biology books such as Jones and Jones (1987) and D.G. Mackean (2002) to get more information on the life cycles of the butterfly and the moth.

i. Complete the life cycle of the grasshopper



ii. Give an example of two other insects with life cycles similar to that of the grasshopper.

iii. Complete the life cycle of the butterfly



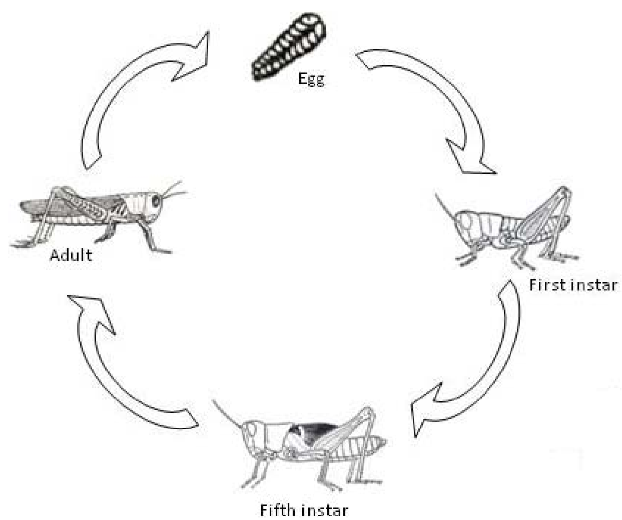
iv. Give an example of two other insects with life cycles similar to that of the butterfly.

I am sure that you have been able to clearly differentiate between the two groups of insects. I have provided you with the Feedback to Activity 1.6.2 at the end of the topic below. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 1.6.2

i. Life cycle of the grasshopper (incomplete metamorphosis)

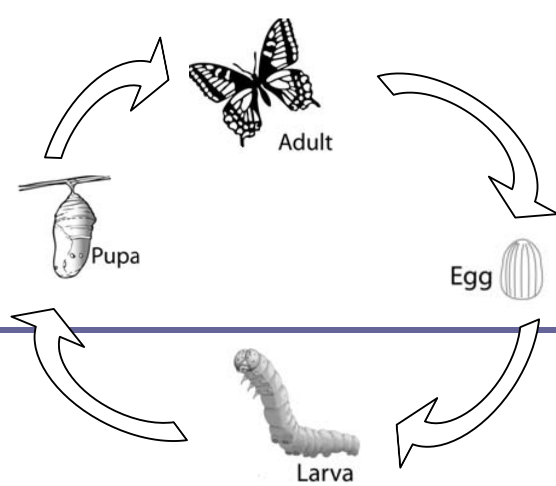


Life cycle of the grasshopper

Designed by Mariette Lucas (2009)

ii. Insects with similar life cycles include the dragonfly, cockroach, mayfly, and cicada.

iii. Life cycle of the butterfly (Complete metamorphosis)



Life cycle of the butterfly

Designed by Mariette Lucas (2009)

iv. Insects with similar life cycles include bees, wasps, ants, beetles, the housefly, fruit flies and mosquitoes.

I am sure that you now have a good understanding of insects. You will have the opportunity to compare insects with arachnids after you have studied the specific characteristics of arachnids below.

1.6.2 Arachnids

Arachnids are different from insects. They have two body parts. The head is fused with the thorax, forming one part known as the cephalothorax. Arachnids have simple eyes but no antennas, nor wings. Four pairs of legs are attached to the cephalothorax. The second part of the body is the abdomen.

Activity

Activity 1.6.3

You should be able to complete this activity in 20 minutes.

A spider is an arachnid.

Using the information in the text above, label the body parts of the spider, on the diagram.

Figure 1.6.3 (a): An unlabelled diagram of a spider

Drawn by Serge Mondon (2009)

From the above exercise, can you think of other examples of arachnids? Find pictures or draw two arachnids that you know in the space below.

I have provided you with a labelled diagram of a spider in the Feedback to Activity 1.6.3 at the end of the topic below. Some examples of arachnids are also given. You are, however, strongly advised to first complete the activities on your own before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 1.6.3

The body parts of a spider are as shown below.

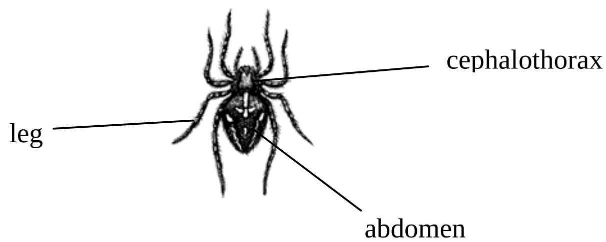


Figure 1.6.3 (b): Labelled diagram of a spider

Scorpions, ticks and mites are all arachnids.

Let us now learn about another group of arthropods.

1.6.3 Crustaceans

Another group of common arthropods is the crustacean. This includes animals such as crabs, lobsters, crayfish and shrimps.

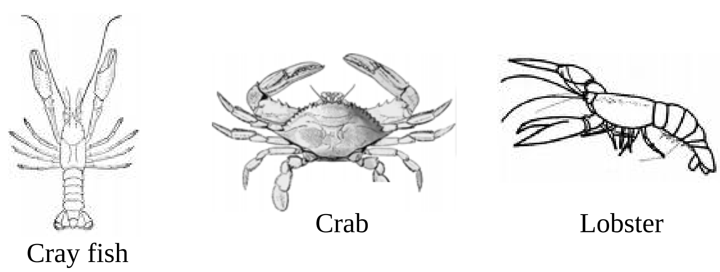


Figure 1.6.4: Some examples of crustaceans

Drawn by Serge Mondon (2009)

The body of crustaceans is composed of segments which are grouped into three regions: a head, a thorax and an abdomen. Sometimes the head and the thorax may be fused to form a cephalothorax. On the head there are two pairs of antennae and a pair of compound eyes raised on stalks. The abdomen has around 11 segments. Most crustaceans live in water and have gills for breathing.

Activity

Activity 1.6.4

You need 45 minutes to do this activity.

Conduct a research on 5 different crustaceans either from biology books or from the internet, and make a book of crustaceans. Your book should have the following content:

- The first page of your book should contain a general description of crustaceans, including how they are classified scientifically using the taxonomic categories.
- A page for each crustacean including a picture or diagram of the crustacean, its common name and scientific name, a brief description of its habitat and special characteristics.
- A page of references used to get the information included in the book.

Keep your crustaceans' book in your portfolio. You have to submit the portfolio to your teacher/tutor once you have completed the unit.

Assessment

Self-assessment 1.6

You need 30 minutes to do the self-assessment below. This self-assessment is based on Topic 1.6. The answers are given at the end of the topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 1.6. This will help you learn and reflect better on areas for improvement.

a. Using your own words complete this cloze passage**:**

Invertebrates are animals that do not have ----------------------------

The largest phylum of invertebrates is the ---------------------------

This includes classes of animals such as -------------------, arachnids,

and --------------------------- Arthropods are animals with --------------

----

b. Insect is the largest class of arthropods.

i. Name five insects

____

____

____

ii. List three features of insects.

____

____

____

iii. Complete the table below to show the main differences between insects and arachnids.

	Insects	Arachnids
Legs		

Body parts		
Wings		
Eyes		

Table 1.6.2 (a): Comparing insects and arachnids

c. Insects undergo a process called metamorphosis in their development.

i. What does this term *metamorphosis* mean?

____

____

ii. With the help of a diagram give an example of an insect that undergoes incomplete metamorphosis in the space below.

d. Draw a table in the space below, then classify the following animals as either insects, arachnids or crustaceans:

scorpion, prawn, palm spider, beetle, honey bee, hermit crab, housefly, mite, and lobster.

I have provided you with the Answers to Self-assessment 1.6 at the end of the topic below.

Answers to Self-assessment 1.6

Answers to Assessment

a. Invertebrates are animals that do not have an internal skeleton. The largest phylum of invertebrates is the arthropoda. This includes classes of animals such as insects, arachnids, and crustaceans. Arthropods are animals with segmented bodies and limbs.

b. Insects:

i. Some insects are mosquitoes, houseflies, butterflies, grasshopper, cockroach, bees, wasps, ants.

ii. Insects have the following features:

- Three body parts; head, thorax, abdomen
- Six legs attached to the thorax
- Compound eyes and simple eyes
- One pair of antennae
- Some have wings

iii. The main differences between insects and arachnids are:

	Insects	Arachnids
Legs	6 legs	8 legs
Body parts	Three parts; head, thorax and abdomen	Two body parts; cephalothorax, and abdomen
Wings	Two pairs	Absent

Eyes	Compound and simple eyes	Simple eyes

Table 1.6.2 (b): Comparing insects and arachnids

c. Metamorphosis:

i. Metamorphosis means change of form.

ii. A cockroach undergoes incomplete metamorphosis. Its life cycle is shown below:

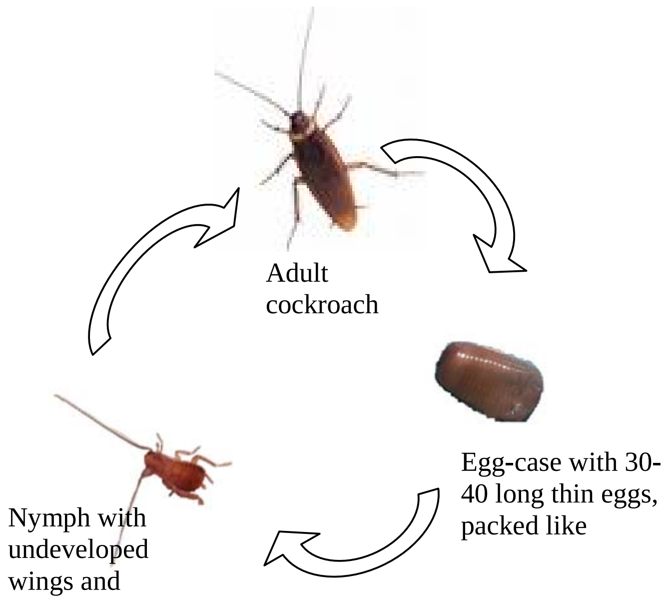


Figure 1.6.6: Cockroach life cycle

Source: http://en.wikipedia.org/wiki/Cockroach

d. Classifying invertebrates

Arachnids	Insects	Crustaceans
• scorpion • palm spider • mite	• beetle • honey bee • housefly	• prawn • hermit crab • lobster

You have now completed the study on Biological Classification. I am sure that you have gained a lot of new knowledge and that you are now much more observant and conscious of your surroundings.

I hope that you have enjoyed the activities that I have devised in this unit to help you learn about Biological Classification. I do hope that you are now ready and very keen to continue the course.

I wish you the best in your studies. I know that you will make it!!

Below I have provided you with a summary of what you have learnt in the unit.

Unit summary

Summary

In this unit you learned that it is important to classify organisms and that scientists have developed systems to help with the classification and naming of the billions of organisms on earth.

You have learnt that dichotomous keys are keys that use a system of comparing two groups of organisms at a time, moving from more general characteristics of the different groups to the more specific characteristics of individual species. We can differentiate between two types of dichotomous keys. They are *list* keys and *branching* or *spider* keys.

We also looked at the importance of the binomial nomenclature in the naming of individual organisms. It is due to this system that individual animals can be differentiated from each other. The system uses a *genus* and *species* name for all organisms. The genus name always starts with a capital letter and both the genus part and the species part of the name are always written in italics.

We also learnt about the instrumental contribution of the Swedish scientist, Carolus von Linnaeus in the development of the hierarchical classification system, in which organisms are classified from large to more specific groups. As such all organisms belong to a kingdom, a phylum, a class, an order, a family, a genus, and their specific species.

Finally, we have provided you with examples of how plants and animals are grouped. We discussed animals from the *phylum* chordate, more specifically the *vertebrates* under their specific classes; mammals, fish, reptiles, birds and fish. We have looked in detail at the specific characteristics of animals in each of these classes. We also looked at the phylum arthropoda, with specific focus on animals from the class insects, arachnids, and crustaceans.

Contents

Unit 2

The elements of chemistry

Introduction

Think of the last sandwich you ate. What was it made of? Maybe you had a tuna sandwich, so it contained tuna, mayonnaise, bread and some carrots. Take the mayonnaise, for instance made of other ingredients such as oil, egg yolks and vinegar. Similarly, everything around us is made of something, which scientists call matter.

In this unit you are going to learn about matter, the states of matter, the arrangement of particles in the states of matter, and what causes the change of state in solids, liquids and gases. You will learn about physical and chemical changes that occur to matter around you. You will learn about atoms, elements, molecules, compounds and mixtures. You will also learn that matter can be pure substances and mixtures, and that mixtures can be separated using different techniques.

Note it! / Important!

The outcomes for the unit are listed below. The outcomes written in **bold** are the extended outcomes and they are intended for students who are aiming for a Grade of B or higher in the examinations.

Upon completion of this unit you will be able to:

Outcomes

- *distinguish* between physical and chemical changes;
- *distinguish* between the three states of matter;
- *explain* how the three states of matter can be inter-converted in terms of the kinetic theory;
- *define* the terms *atom, element, molecule, compound,* and *mixture*;
- *use* appropriate separation techniques (magnet, sublimation, evaporation, filtration, distillation, crystallisation, separating funnel, chromatography, or fractional distillation) to separate different mixtures;
- *discuss* the application of each of those separation techniques;
- *state* that each element has a particular chemical symbol;
- *state* the relative charge and the approximate relative mass of a proton, a neutron and an electron;
- *explain* the meaning of *nucleon number* and *proton number;*
- ***explain*** that 'amount of substance' is measured in moles and that one mole of any substance contains the same number of particles;
- ***calculate*** the number of moles present in a given mass of substances (in grams), or to the number of atoms or molecules;
- ***calculate*** the mass (in grams) in given moles of different substances;
- ***derive the empirical*** formulae of substances from percentages and percentage composition from molecular formulae.

Terminology

Avogadro's constant — The Avogadro constant (N_A) is the number of particles (atoms, or molecules) in 1 mole which is equal to 6.02×10^{23}.

Boiling point: — The temperature at which a liquid boils. Each liquid has its own boiling point.

Chemical change: — A chemical change is a change which is not easily reversed. A chemical change always results in the formation of a new substance.

Compound: — A compound is a pure substance which contains two or more elements chemically bonded together.

Element: — An element is a substance that cannot be split up into other simpler substances by any known chemical processes.

Matter: — Matter is anything that has a mass and occupies space.

Melting point: The temperature at which a solid changes into a liquid. Each solid has its own melting point.

Mixture: A mixture contains two or more substances which can easily be separated by physical methods.

Mole The mole (mol) is the SI (Système International) unit of the ‘amount of substance’ (or the number of particles (atoms or molecules) of a substance). The mole is a unit which allows us to count the number of atoms by weighing them.

Physical change: A physical change is a change which is easily reversible by a simple change in the condition(s). A physical change does not result in the formation of new substances.

Saturated solution A saturated solution is formed when excess solute (solid to be dissolved) is added to a solvent (a liquid that dissolves the solute). The solution is said to be saturated when the solute added can dissolve no more.

How long?

Table 2.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	7 hours and 10 minutes	3 hours and 35 minutes
Full-time student within the conventional school setting OR Part-time student	7 hours and 10 minutes	3 hours and 35 minutes

Table 2.0: The time needed for you to work on this unit

Topic 2.1: Types of changes

How long?

You will need 50 minutes to complete this Topic. It is advisable that you spend another 25 minutes of your own time to further review the characteristics of physical and chemical changes.

In your everyday life, you may have observed that changes are always taking place. Sometimes the changes that take place can be reversed. For example, if you take some ice from a freezer, the ice melts and changes to water. If you want the ice back, you just have to put the water back into the freezer. On other occasions the changes that take place cannot be reversed. For instance, if you burn wood, you get charcoal. You could try as hard as you want, but you will never be able to change the charcoal back to wood. Changes also take place inside your body. In Unit 11 – Digestion, you will learn how the food that you eat undergoes changes as it passes through your digestive system. There are special names given to those two types of changes.

In this topic you are going to learn about the types of changes that take place in the world around us. Let us start off with a simple activity.

Activity

Activity 2.1.1

You should spend 5 minutes to carry out this simple experiment at home to show a reversible change.

For this experiment you will need a candle and some matches or a lighter.

Procedure: You are required to:

- Light a candle and let it burn for about three minutes or so.
- After the three minutes, blow out the flame and let it cool.
- Observe what happens to the candle wax when heated and when cooled.

Observation: write your observations in the spaces below.

When heated:

When cooled:

Feedback

Feedback to Activity 2.1.1

I hope you didn't burn yourself and was not uncomfortable with the smell of the smoke when you put the candle out! Well, you should have seen that when the candle burns, the candle wax melts and becomes a liquid, but upon cooling, the liquid wax becomes a solid again, although it did not return to its original shape. I'm sure you have seen those changes before, but you may have never thought about it in this way. These types of changes are known as physical changes.

There are two types of changes that occur in the world around us. They are physical changes and chemical changes.

A physical change is a change which is easily reversible by a simple change in the condition(s). A physical change does not result in the formation of new substances. In the experiment above, the candle wax remained as candle wax when it melted; it was only the state that the wax was in that changed. It changed from solid to liquid when it melted and back to solid when it cooled.

A chemical change is a change which is not easily reversed. A chemical change always results in the formation of a new substance. For example, earlier we saw that when we burn wood, we get a new substance called charcoal.

Now carry out the following experiments at home to further illustrate chemical changes.

Activity

Activity 2.1.2

You should spend approximately 10 minutes on this activity.

As you have seen earlier, new substance(s) are formed during chemical changes. You are now required to carry out these experiments at home to become familiar with more examples of chemical changes.

Experiment 1

For this experiment you will need a box of matches.

You are required to crush an egg shell, or snail shell or a small piece of coral. Be careful not to crush your finger in the process. Use ¼ of a teaspoon and add some vinegar until the shell is fully immersed (vinegar which is also known as acetic acid is a very weak acid) to it. Now observe what happens.

Observation:

Write down the changes that you observed in the space below.

____

____

Experiment 2

Equipment: For this experiment, you will need:

- an empty 500 ml clear plastic bottle (a small coca cola PET will do);
- some hot water;
- 2 tablespoons of sodium bicarbonate (also known as bicarbonate of soda or baking soda. Be careful not to confuse baking soda with baking powder as they are two different substances);
- some concentrated vinegar (vinegar which is also known as acetic acid is a very weak acid); and
- a few drops of detergent (optional)
- a few drops of food colouring (optional)

Procedure: You are required to carry out this experiment over a sink:

- Fill the empty bottle 3/4 full with warm water. (Do NOT use hot water)
- Add 2 tablespoons of sodium bicarbonate to the hot water. (You can add a few drops of detergent and a few drops of food colouring to make your experiment more spectacular).
- Add about 20 ml of concentrated vinegar to the mixture.
- Watch what happens.

Observation: Write down your observation in the space below.

Feedback

Feedback to Activity 2.1.2

I hope that you have enjoyed these simple experiments, especially experiment 2. Experiment 2 is a reaction that is used to illustrate a volcanic eruption. If you want to learn about making a model volcano during your spare time to amuse your relatives and friends refer to http://chemistry.about.com/od/chemicalvolcanoes/ss/volcano_2.htm for the details. Please note that this link is an external link for information only. We are not endorsing or recommending that you visit any other links that are made from that site.

From experiment 1 in Activity 2.1.2, you should have observed that bubbles were formed and eventually all the crushed shell reacted with the vinegar and was no longer visible.

From experiment 2, if you did not use the detergent and food colouring, you should have observed some bubbles coming from the bottle as the vinegar reacted with the baking soda. If you have used the detergent and food colouring, you should have observed a reddish coloured foam evolving from the bottle.

All of the changes that you have seen in experiments 1 and 2 in Activity 2.1.2 are not reversible, so they are all chemical changes.

Apart from physical changes being easily reversible and chemical changes not being easily reversible, there are other differences between chemical and physical changes. Table 2.1.1 provides a summary of the characteristics of physical and chemical changes.

Physical change	Chemical change
These changes are easily reversed.	These changes are not easily reversed.
These changes do not produce any new substances.	These changes always produce new substances.
There is no change in the masses of substances involved.	The total mass is unaltered but the mass of each product formed usually differs from that of each of the starting substances.
The physical properties of the substance change, but the chemical properties do not change.	The physical and chemical properties of the substance change.
These changes involve very little heat absorption or evolution, except for latent heat changes which occur during a change of state.	These changes may involve a considerable amount of heat being absorbed or evolved.

Table 2.1.1: The characteristics of physical and chemical changes

Now that you have learnt about physical and chemical changes around you, in the next two topics, we are going to take a closer look at what enable these substances to undergo such changes. To start off with, we are going to focus on the states of matter.

Topic 2.2: The three states of matter

How long?

You will need 60 minutes to complete Topic 2.2. You are advised to spend another 30 minutes of your own time to review the topic.

As you have seen at the beginning of this unit, everything in the world we live in is made up of matter. The air you breathe in, the water and the tea you drink, the curry you eat, and the chair you sit on, are all made up of matter. You are also made up of matter.

The question that you are probably eager to ask is "what is matter?" Well, let me throw the question back at you – 'What do you think matter is?' Jot down your ideas in the space below.

Well, now let me tell you what matter is. In science, matter is anything that has a mass and occupies space (has a volume).

Before we move on to learn more about matter let us see if you really know what matter is through this discussion.

Discussion

Discussion 2.2.1

You should not spend more than 10 minutes on this discussion.

You are required to meet up with three or four colleagues to discuss whether the following are matter or non-matter.

a. Categorise the following as matter or non-matter: air, wind, flame, smoke, sound, magnets, magnetism, electricity, electrons, soil, dissolved salt, apple, oxygen.
b. Discuss the properties which **all** the things you have classified as matter have in common.Record the result of your discussion in the space provided.

I hope you had a good discussion and did not find much difficulty with the classification. I think you would agree that some were quite tricky. For example, flame and smoke: while smoke is matter, flame is not matter. Please refer to the Feedback to Discussion 2.2.1 at the end of this Topic for the other expected answers.

As you have seen, matter is anything that has a mass and occupies space. **Matter can exist in three states.** The three states of matter are: **solid**, **liquid** and **gas**. In other words all the things around you can be classified as solids, liquids and gases.

Take water, for example: water, is the most common matter which can easily exist in all three states. In the solid state, we refer to water as *ice*, in the liquid state we call it *water* and in the gaseous state, we call it *water* *vapour* or *steam*.

In the next activity you will be expected to provide some examples of solids, liquids and gases.

Activity

Activity 2.2.1

You should be able to do this activity within 5 minutes.

You are now going to categorise the following matter as solids, liquids and gases in the Table below: carbon dioxide, lemonade, hydrogen, rock, sugar, juice, seawater, oxygen, pencil. An example is done for you.

Solid	Liquid	Gas
Coal	Petrol	air

Well, I hope that this task was easy for you. Please, refer to the Feedback to Activity 2.2.1 at the end of the topic for the correct answers.

Now that we have learnt that solids, liquids and gases are the three states of matter, we are going to study the differences between them.

As you may have already noticed, there are certain differences between ice, water and water vapour/steam. For instance, ice which is a solid, has a definite shape. As a liquid, water will take the shape of the container it is in. As a gas, the water vapour which escapes from boiling water can take different shapes.

Apart from the difference in their shape, there are other differences between solids, liquids and gases. Table 2.2.1 below gives a summary of the main differences between the three states of matter.

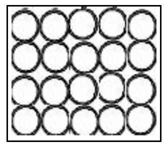
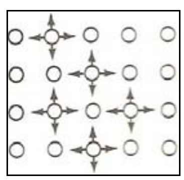
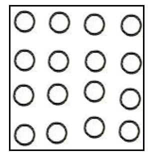
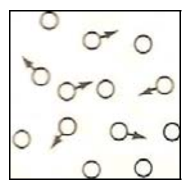
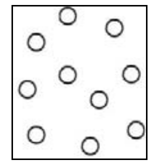
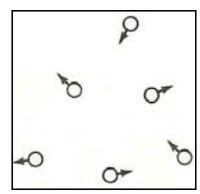
Solid	Liquid	Gas
The particles (which can be atoms, molecules or ions) are closely packed together (see Diagram A below).  Diagram A The forces of cohesion (forces of attraction) are so strong that the particles can only vibrate (move) about a fixed point (see Diagram B below).  Diagram B	The particles are not so closely packed as in a solid (see Diagram C).  Diagram C The forces of cohesion are weak, (see Diagram C) so the particles (atoms, molecules or ions) are relatively free to move (see Diagram D).  Diagram D	The particles do not occupy fixed positions (see Diagram E).  Diagram E The forces of cohesion are insignificant, so the particles are completely free to move (see Diagram F).  Diagram F
Has definite shape.	Has no fixed shape: it takes up the shape of its container	Has no fixed shape; it can change shape
Has definite size.	Its volume is fairly constant because the distances between the particles are relatively fixed. The volume is hardly affected by changes in temperature and pressure.	Has no fixed volume, and its volume is greatly affected by small changes in temperature and pressure.

Table 2.2.1: The main differences between solid, liquid and gas

Diagrams A to F were drawn by: Rosianna Jules, September, 2009

You now know about the differences in the states of matter. Next, you are going to learn about what causes the change in the states of matter. You will start by reflecting on simple everyday life experiences in the reflection below.

Reflection

Reflection 2.2.1

You should spend about 5 minutes on this reflection.

Think about water which can exist as solid, liquid and gas. Based on your personal experiences, what do you think causes water to change from one state of matter to another?

____

____

____

Feedback

I hope that the task was easy for you. You may have thought about the time you made some ice and when you boiled some water to make a cup of tea. In making ice you changed the liquid (water) to solid (ice) by freezing. By boiling the water to make tea, you changed some of the liquid (water) to gas (water vapour).

We will now take a closer look at the factors that cause the states of matter to change.

The change of state, which is also called the inter-conversion of state, is caused mainly by the addition or the removal of heat. In other words, the change of states of matter depends mainly on change in temperature.

Pressure is also a condition that causes the inter-conversion of state. You will learn about the effects of pressure on matter in Unit 5 – Particles in Motion. In this unit, however, we are only going to focus on the effects of temperature on the states of matter.

The question that we need to answer now is 'why does a change in temperature cause the states of matter to change?'

In Table 2.2.1 we saw the differences between solid, liquid and gas. From Table 2.2.1 we can also deduce that all states of matter are made up of particles which are in constant motion.

This deduction about matter forms the basis of the **kinetic theory** of matter. You will learn more about the kinetic theory in Unit 5 –Particles in Motion. But for now what you need to know is that according to the kinetic theory,

- matter consist of particles;
- there are spaces and forces of cohesion between the particles; and
- the particles in matter are in constant random motion.

The kinetic theory allows us to explain how a change in temperature causes the inter-conversion of state of matter.

As you have seen in Table 2.2.1 above, in the solid state, the particles (atoms, molecules or ions) are closely packed together and the forces of cohesion between the particles are so strong that the particles can only vibrate about a fixed point (see Diagram A in Figure 2.2.1 below).

Therefore when a solid is heated, it expands by a small amount. If the heating continues, the particles gain heat energy and vibrate more. As the kinetic energy increases, the conversion of state becomes possible. At a certain temperature, known as the **melting point**, the particles gain enough energy to overcome the forces of cohesion (forces of attraction) and the solid changes into the liquid state (see Diagram C in Figure 2.2.1 below). Figure 2.2.1 represents the change of solid to liquid on heating.

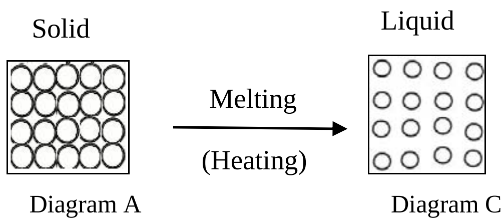


Figure 2.2.1: The change of solid to liquid on heating

Graphics by: Rosianna Jules, February 2010

In the liquid state, the forces of cohesion are weaker than in the solid state, hence, the particles are relatively free to move. On heating, a liquid expands more than a solid. The particles in the liquid gain kinetic energy and when the energy gained is large enough to overcome the forces of cohesion, these particles will escape from the surface of the liquid in the form of a gas (see Diagram E in Figure 2.2.2). This process is known as **evaporation**. Evaporation takes place at any temperature. On continued heating, at a certain temperature known as the **boiling point**, the liquid boils and vaporises at the fastest rate. Figure 2.2.2 represents the change of liquid to gas on continued heating.

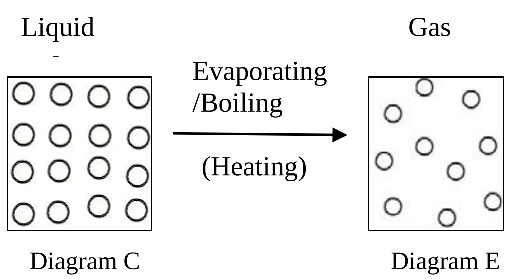


Figure 2.2.2: The change of liquid to gas on continued heating

Graphics by: Rosianna Jules, February 2010

Note it! / Important!

It is important for you to note that each liquid has its own boiling point. The boiling point of a liquid increases in the presence of impurities and/or with an increase in pressure. The boiling point of a liquid decreases with a decrease in pressure.

We can also show the effects of an increase of temperature on a substance being heated graphically. The resulting graph is referred to as the heating curve. The heating curve is a graph which shows the temperature changes as a substance is heated. Figure 2.2.3 below shows the effect of an increase of temperature on a substance being heated.

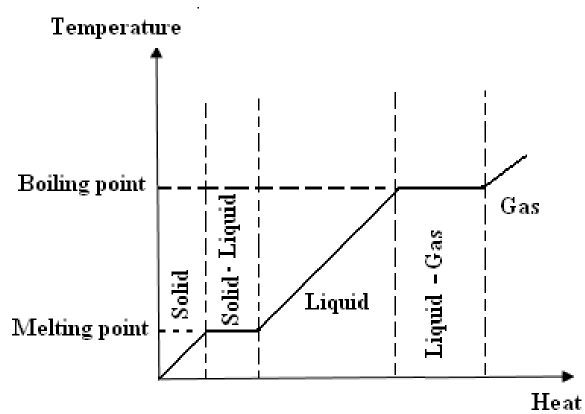


Figure 2.2.3: Graph showing the effect of an increase of temperature on a substance being heated

Graphics by: Rosianna Jules, September, 2009

Figure 2.2.3 shows that the temperature increases on continued heating. The two horizontal parts of the graph, also known as the plateaus or phase changes, occur when there is a change of state.

The first change of state is at the melting point of the solid. At the melting point the temperature remains constant while the solid melts.

The second change of state occurs at the boiling point of the liquid. At the boiling point the temperature remains the same while the liquid boils.

The reverse is true when a gas is cooled to become a liquid or when a liquid is cooled to become a solid. Figure 2.2.4 shows the effect of a decrease of temperature on a substance left to cool over time.

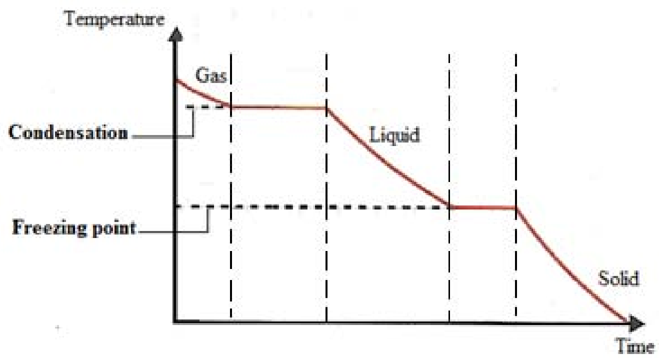


Figure 2.2.4: Graph showing the effect of a decrease of temperature on a substance left to cool over time

Graphics by: Rosianna Jules, September, 2009

As the gas is cooled, the particles loose kinetic energy causing the gas to change into a liquid. This process is known as **condensation**. If the liquid is cooled, the particles loose more kinetic energy. At a temperature known as the **freezing point**, the liquid changes into a solid. Figure 2.2.4 above shows the effect of a decrease of temperature on a substance left to cool over time. This graph is known as the **cooling curve.**

Note it! / Important!

The melting point of a solid is the same as the freezing point of its liquid. For example: the melting point of ice is 0°C and the freezing point of water is 0°C.

The change of state is best presented as follows:

	Melting		**Evaporation**	
	heating		**heating**	
Solid	⇌	**Liquid**	⇌	**Gas**
	cooling		**cooling**	
	Freezing		**Condensation**	

There are also substances that do not change into the liquid state when the solid is heated, or when the gas is cooled. For example, when solid iodine is heated, it changes straight into the gaseous state. When iodine gas is cooled, it changes straight into the solid state. This process is known as *sublimation*. Some other substances that sublime include: ammonium chloride, sulphur, carbon dioxide, naphthalene and benzoic acid.

We have come to the end of Topic 2.2. I hope that you now understand what matter is and also the three states of matter very well. If there is anything that you are not sure about, do not hesitate to go back and review this section. If you are confident, proceed to the next topic.

Feedback for Topic 2.2

Feedback

Feedback to Discussion 2.2.1

From your discussion, you may have realized the following:

a. From the list:

   i. the following are matter: air, smoke, magnets, electrons, soil, dissolved salt, apple and oxygen.

   ii. the following are not matter: wind, flame, sound, magnetism and electricity.

b. All the things that are matter have a mass and occupy space (has a volume)

   A flame is not matter; the heat and light it produces are energy but not matter. The smoke that rises from the flame contains matter (small particles and gases), so smoke is matter.

   Wind itself is not matter; it is the movement of air. Similarly, sound is also not matter; it is the movement of air against your eardrum. Air, however, is matter.

   Electricity is not matter; it is the movement of electrons. Electrons on the other hand is matter.

Feedback

Feedback to Activity 2.2.1

Solid	Liquid	Gas
Coal	Petrol	air
sugar	juice	carbon dioxide
rock	lemonade	hydrogen
pencil	sea water	oxygen

I hope that you got all of the answers correct. Well done! If you did not, do not worry; just go through Topic 2.2 again.

In the topic above we studied the three states of matter. Can you recall what they were? How can we go from one state to another? What are some examples of matter in these phases?

In the next topic, we will examine atoms, elements, molecules, compounds and mixture. Any guesses on what these are? Let's move on to find out.

Topic 2.3: Elements, atoms, molecules, compounds and mixtures

How long?

You will need 1 hour 30 minutes to complete Topic 2.3. You are advised to spend another 45 minutes of your own time to review the topic.

In Topic 2.2 you learned that everything around us is made of matter which can be in the solid, liquid and gaseous state. You might be anxious to know what you are going to learn in this topic. Well, I will not tell you yet. Let us wait and find out after this discussion.

Discussion

Discussion 2.3.1

You should spend not more than 10 minutes on this discussion.

Now think about some of the things around you, such as sugar, seawater, water, juice, salt, oxygen and air. These substances can be classified into two groups. In the first group we have sugar, water, salt and oxygen and in the second group we have seawater, juice and air.

Meet with one or two colleagues and discuss why these things can be classified as such.

Feedback

Well, you might have come up with different ideas. What you should have realised is that those things in the first group, e.g. sugar and water are made of only one type of substance, while those in the second group, e.g. juice and seawater are made of two or more substances. For example, sugar is made only of sugar crystals while juice contains water, sugar, flavouring, etc.

Matter which is made of only one type of substance is said to be a **pure substance**, like water and sugar. Matter which is made of more than one substance mixed together is said to be a **mixture**, like juice and seawater.

A **pure substance** has a fixed composition and can be a chemical **element**, a **molecule** or a chemical **compound**. By contrast, a **mixture** is made of two or more substances not chemically joined together. So if we take juice, we can separate the sugar, the water, and the other ingredients from each other.

In this topic we are going to look at elements, atoms, molecules, compounds and mixtures. We will start off by learning about elements.

2.3.1 Elements

An **element** is a substance which cannot be split into simpler substances by a chemical reaction.

Some examples of elements that you might be familiar with, are: oxygen, carbon, nitrogen, silver, gold, copper, mercury, and iron. Most of the elements exist as solids or gases at room temperature. For example: silver and gold are solids while oxygen and nitrogen are gases.

Scientists have discovered just over 100 elements and have classified them in a table known as the Periodic Table (see Figure 2.3.1 below for a copy of the Periodic Table). You will learn more about the Periodic Table in the unit entitled *Classifying Elements.* Also, visit the following link if you have access to the internet to see pictures of each element.
http://www.nrc-cnrc.gc.ca/eng/education/elements/index.html

Each element has a particular chemical symbol made of 1 letter (e.g. N for nitrogen) or 2 letters (e.g. Ca for calcium) derived from the name of the element as shown on the Periodic Table in Figure 2.3.1 below. The chemical symbol also represents 1 atom of the element. (You will learn about atoms in the next sub-topic.) If you look closely at the Periodic Table you will notice that the chemical symbol of some of the elements is not derived from the conventional name given on the Periodic Table. This is because for those elements, their symbol is derived from their Latin name. Some examples are given in Table 2.3.1 below.

Conventional name of element	Latin name of the element	Symbol
Sodium	Natrium	Na
Lead	Plumbum	Pb
Gold	Aurum	Au
Silver	Argentum	Ag

Table 2.3.1: Conventional name, Latin name and symbol of some elements

Note it! / Important!

When 1 letter is used for the symbol of an element, it is always a capital letter, for example: H for hydrogen, O for oxygen, and K for potassium. By contrast when two letters are used, only the first letter is a capital letter, the second letter is always a small letter, for example: He for helium, Li for lithium and Na for sodium.

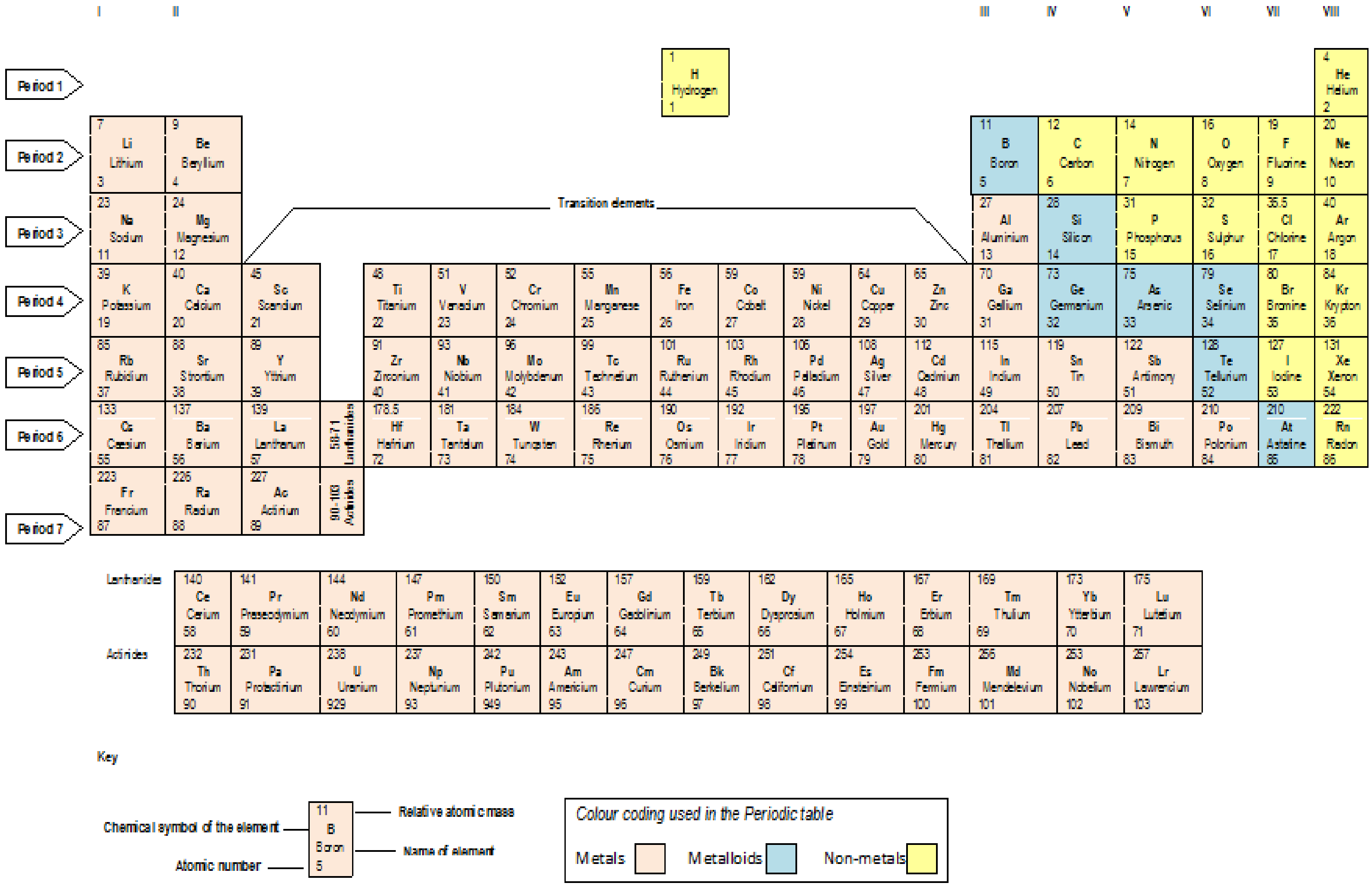


Figure 2.3.1: The Periodic Table

Adapted from: http://en.wikipedia.org/wiki/Periodic_table by: Rosianna Jules, July, 2009

Activity

Activity 2.3.1

You should spend no more than 10 minutes on this activity.

Study the Periodic Table in Figure 2.3.1. Complete the table below with the appropriate name or symbol of the elements. Please note that the elements are not listed in order. The first one has been done for you.

Elements	Symbol
Sodium	Na
	K
	N
Lithium	
	Ne
	S
Hydrogen	
	P
Boron	
	O

Elements	Symbol
Carbon	
	Ar
Calcium	
Chlorine	
	Be
	F
Helium	
Aluminium	
	Mg
Silicon	

Feedback

I hope that the task was easy for you. All you had to do was refer to the Periodic Table. However, you need to know the first 20 elements and their symbol in the correct order. Please, refer to the Feedback to Activity 2.3.1 at the end of the topic for the correct answers.

You will learn more about the Periodic Table as you proceed through the course. Now we are going to look at what an element is made of.

2.3.2 Atoms

We can define an **atom** as the smallest part of an element that can take part in a chemical change or chemical reaction. An atom cannot be split up into simpler particles.

An atom is extremely small and is measured in nanometers (10^{-9}). An atom is said to consist of 3 sub-atomic particles.

2.3.2.1 Sub-atomic particles

The sub-atomic particles of an atom are: p – proton

e – electron

n – neutron

Tip

If you read the symbol vertically, it reads as ‘pen’. You can use this acronym to help you remember the names of the sub-atomic particles. This technique is often used in science, especially in chemistry. You can make up your own acronyms as you go along to help you remember other important information.

The **proton** is a positively charged particle and has a mass of 1, equal to the mass of hydrogen.

The **electron** is a negatively charged particle and has a negligible mass of $\frac{1}{1840}$.

The **neutron** is not charged (it is neutral) and has a mass of 1 similar to that of a proton.

The protons and neutrons are found in the nucleus of the atom and together they are known as **nucleons**. The electrons on the other hand, revolve around (orbit) the nucleus along imaginary paths referred to as **shells**. Table 2.3.1 gives a comparison of the three sub-atomic particles.

Sub-atomic particle	Symbol	Charge	Relative mass
Proton	p	+1	1
Electron	e	-1	$\frac{1}{1840}$ often considered as 0
Neutron	n	0	1

Table 2.3.1: A comparison of the sub-atomic particles

2.3.2.2 Atomic notation

If you refer to the Periodic Table (Figure 2.3.1) you will notice that there are two numbers, a superscript (number at the top) and subscript (number at the bottom), attached to each element. These numbers have special meanings and they are used when writing the atomic **notation** (also known as nuclear notation) of an element.

The atomic notation of an element shows the chemical symbol of the element, its nucleon number (mass number) and its proton number (atomic number).

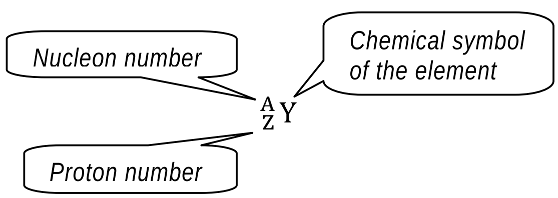


Figure 2.3.1: How to write the atomic notation of any element

Now let us see what the nucleon number and the proton number are all about.

2.3.2.2.1 Nucleon number / mass number

The nucleon number (A) or the mass number of an element is the sum of the number of protons and neutrons in the nucleus of the atom. This is best represented as:

$$\text{nucleon (mass) number (A)} = \text{number of proton(s)} + \text{number of neutron(s)}$$

The nucleon number is denoted by a superscript (number at the top) next to the symbol for the element as shown below.

Nucleon number (A)
Proton number (Z) $^{12}_{6}C$ (Carbon atom)

The nucleon number or mass number of an element is a whole number closest to the *atomic mass* of the element. The nucleon number is important in identifying *isotopes*. Isotopes are atoms of the same elements with the same proton (atomic) number but different mass (nucleon) number. You will learn more about isotopes later in the unit entitled *Atoms, Bonding and the Periodic Table*.

Note it! / Important!

Please make note of the following:

- The **mass number** (**nucleon number**) and the **atomic mass** (also called the **relative atomic mass**, A_r) are NOT the same thing. The relative atomic mass (A_r) of an element tells us the number of times one atom of that element is heavier than one-twelfth, ($\frac{1}{12}$), of an atom of the carbon- 12 isotope.
- The relative atomic mass of an element takes into account the mass of the isotopes of that element and the ratio of the isotopes.

2.3.2.2.2 Proton number / atomic number

The **proton number** (Z) or the **atomic number** of an element is the number of protons in the nucleus of the atom. In an atom, the number of protons is equal to the number of electrons in the shells. The proton number is denoted by a subscript (number at the bottom) next to the symbol for the element as shown in Figure 2.3.1 above.

The proton number indicates:

a. the number of protons in an atom;

b. the number of electrons in an atom;

c. where the element is ranked on the Periodic Table. For example, sodium has a proton number of 11. Hence, it is the eleventh (11^{th})

element on the Periodic Table.

Tip

The nucleon number (mass number) is the biggest number next to the symbol of the element whereas the proton number (atomic number) is the smallest number.

By knowing the nucleon number and proton number of an atom, you can calculate the number of neutrons in that atom.

To get the number of neutrons in an atom, you need to subtract the proton number from the nucleon number of the element.

$$\text{number of neutrons } = \text{nucleon number (A)} - \text{proton number (Z)}$$

For example, the number of neutrons in:

a. Sulphur $^{32}_{16}S$ is:

I am sure that you can give me the answer straight away as this subtraction can be done in your head. However, to ensure that you understand the process, I will show the calculation step by step.

Firstly, we write down the formula:

$$\text{number of neutrons } = \text{nucleon number (A)} - \text{proton number (Z)}$$

Secondly, we substitute the known values:

$$\text{number of neutrons } = 32 - 16$$

Finally, we calculate the difference

$$\text{number of neutrons } = 16$$

So, there are 16 neutrons in sulphur.

Let us try another example; this time let us find the number of neutrons in sodium.

b. Sodium $^{23}_{11}Na$ is:

$$\text{number of neutrons } = \text{nucleon number (A)} - \text{proton number (Z)}$$

number of neutrons $= 23 - 11$

number of neutrons $= 12$

Therefore, there are 12 neutrons in sodium.

Those were easy, were they not? I bet you want to try some more. But please wait a bit; you will have the opportunity to practise those in the Self-Assessment 2.1 at the end of this topic.

Now we are going to talk about molecules.

2.3.3 Molecules

A **molecule** is the smallest particle of an element or a **covalent compound** that normally exists on its own and still retains its properties. A molecule normally consists of two or more atoms chemically bonded together.

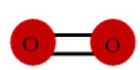
Note it! / Important!

Please note that you will learn about covalent compounds in Unit 4: *Atoms, Bonding and the Periodic Table.* But for now you may know, just to satisfy your curiosity, that a covalent compound is formed when the elements are chemically joined together by the sharing of their outer electrons.

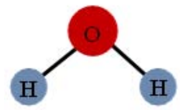
All the molecules of the same pure substance contain the same atoms in the same proportion and arrangement. For example:

a. all molecules of neon are always made up of 1 neon atom.

b. all molecules of oxygen always consist of 2 oxygen atoms;



c. all molecules of water always consist of 2 hydrogen atoms and 1 oxygen atom;



The number of atoms in a molecule gives the atomicity of the molecule. You can calculate the atomicity of a molecule (that is, the number of atoms in a molecule) from its molecular formula. The names given to molecules with the different atomicity are as follow:

- A molecule with **1 atom** (atomicity of 1) is described as a **monatomic molecule**, e.g. a neon molecule (N), or a helium molecule (He).
- A molecule with **2 atoms** (atomicity of 2) is described as a **diatomic molecule**, e.g. oxygen (O_2) and chlorine (Cl_2).
- A molecule with **3 atoms** (atomicity of 3) is described as a **triatomic molecule**, e.g. water (H_2O) and carbon dioxide (CO_2).
- A molecule with **more than 3 atoms** (atomicity of more than 3) is described as a **polyatomic molecule**, e.g. ammonia (NH_3) and ethane (C_2H_6). Ammonia contains 4 atoms–1 nitrogen atom and 3 hydrogen atoms; and ethane contains 8 atoms–2 carbon atoms and 6 hydrogen atoms.

What elements or molecules do you think your body contains? Think about what we breathe in and out on a daily basis as well as what we drink. 99% of the body's mass is made up of these 6 elements: oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus. If you have access to the internet, take a look at the following website for more information: http://chemistry.about.com/cs/howthingswork/f/blbodyelements.htm Please note again that we are providing this for information only and we do not endorse or recommend any links from this site.

You will learn more about the formation of molecules in Unit 4: *Atoms, Bonding and the Periodic Table*. You are now going to learn about compounds.

2.3.4 Compounds

A **compound** is a pure substance which contains two or more elements chemically bonded (joined) together.

Note it! / Important!

I believe that you are now thinking that you have just read the same thing regarding molecules. Yes, molecules and compounds are both made of two or more elements chemically bonded together. As you have seen above, a molecule can be a smaller part of a covalent compound. So, apart from the monatomic molecules, all molecules are formed by covalent bonding (sharing of electrons). By contrast, a compound is formed either by covalent bonding or by electrovalent bonding, also known as ionic bonding. In electrovalent/ionic bonding, the elements are joined together by losing or gaining electrons.

Do not worry; everything will become clearer when you learn about chemical bonding in Unit 4.

The chemical and physical properties of a compound are different from the elements it is made of. A compound can be split into simpler substances by a chemical reaction, although it is very difficult.

Some compounds that you might be familiar with include: sodium chloride (table salt), sodium bicarbonate (baking soda), sucrose (sugar), water, acetic acid (vinegar) and ethanol (alcohol).

As mentioned above, you will learn more about compounds in Unit 4.

Now, what will you get if you add a pinch of salt, some diluted vinegar, and some oil together?

Yes, you will get a mixture which we call a vinaigrette or salad dressing. You are now going to learn about mixtures.

2.3.5 Mixtures

As you have learnt earlier, a **mixture** is made up of two or more substances not chemically joined together. A mixture can easily be separated by physical methods to obtain pure substances from it.

By knowing the composition of the mixture, you could use appropriate techniques of separation to separate the mixture into its original constituents. In the next topic you will learn about the different separation techniques that can be used to obtain pure substances from:

a. solid-liquid mixtures, such as salt dissolved in water, and rice and water;

b. liquid-liquid mixtures, such as oil and water; alcohol and water; and crude oil.

c. solid-solid mixtures, such as salt and pepper, and iron filings and copper tunings.

Now let us briefly compare the differences between a compound and a mixture. A summary of the differences between a compound and a mixture is given in Table 2.3.2.

Compound	Mixture
It always has a chemical formula since its composition by mass is fixed.	It does not have a chemical formula as its composition may vary.
It is always homogeneous (fixed composition).	It may be homogeneous or heterogeneous (varying composition).
Its properties are different from those of its constituents.	Each constituent retains its own properties.
The constituents cannot be easily separated by simple physical methods.	Its constituents can easily be separated by simple physical methods.

Table 2.3.2: Summary of the differences between a compound and a mixture

I hope that you have understood what elements, atoms, molecules, compounds and mixtures are. Before we move on to the different separation techniques, you should now check how much you have understood so far by completing the self-assessment below.

Assessment

Self-assessment 2.1

You should spend 15 minutes on this self-assessment. This self-assessment is based on Topics 2.1 - 2.3. The answers are given at the end of topic 2.3. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 2.1. This will help you learn and reflect better on areas for improvement.

Please answer the following question in the space provided.

1.

a. State 2 differences between a physical change and a chemical change.

Physical change	Chemical change

b. Write true or false next to each statement.

	Statement	True OR False
i.	A physical change is reversible.	
ii.	Burning or combustion is a physical change.	
iii.	Condensation is a chemical change.	
iv.	Evaporation takes place at a fixed temperature.	
v.	The three states of matter are solids, liquids and gases.	
vi.	Water freezes at 0 °C and melts at 0 °C.	

2. The following table gives the boiling points and melting point of some substances. (Take the room temperature as 30° C).

Substance	Boiling point in ° C	Melting point in ° C
Iron	3000	1535
Magnesium	1110	650
Mercury	357	-39
Oxygen	-183	-218
Sodium	890	98
Sulphur	445	115

a) Which substance is a liquid at room temperature?

---

b) Which substance is a gas at room temperature?

---

c) Which substances are solid at room temperature?

---

d) Which substance stays a liquid over the widest range of temperature?

---

3. Complete the following table:

Sub-atomic particle	Relative mass	Charge

		0
	0	-1
Proton		

4. Complete the table below with the missing name or symbol of the element.

Elements	Symbol
Lithium	
	Ne
Helium	
	K

Elements	Symbol
Chlorine	
	B
	Al
Silicon	

5. Below is the atomic notation of an element.

$${}^{31}_{15}P$$

a) What is the name of the element?

____

b) Describe what the number 31 stands for?

____

c) What does the number 11 stand for?

____

d) What is the number of

i. Electrons

ii. Protons

iii. Neutrons in that element

I hope that you have found this self-assessment as easy as ABC. Please refer to the Answers to Self-assessment 2.1 at the end of this topic to verify your answers.

Feedback to Topic 2.3

Feedback

Feedback to Activity 2.3.1

Elements	Symbol	Elements	Symbol
Sodium	Na	Carbon	C
Potassium	K	Argon	Ar
Nitrogen	N	Calcium	Ca
Lithium	Li	Chlorine	Cl
Neon	Ne	Beryllium	Be
Sulphur	S	Fluorine	F
Hydrogen	H	Helium	He
Phosphorus	P	Aluminium	Al
Boron	B	Magnesium	Mg
Oxygen	O	Silicon	Si

Answers to Assessment

Answers to Self-assessment 2.1

1.

a) You could have given any 2 of these answers.

Physical change	Chemical change
Easily reversed.	Not easily reversed.
Does not produce any new substances.	Always produce new substances.
No change in the masses of substances involved.	Total mass is unaltered but the mass of each product usually differs from that of each reactant.
Physical properties change, chemical properties do not change.	Physical and chemical properties change.
Involves very little heat absorption or evolution.	May involve a considerable amount of heat being absorbed or evolved.

b)

i.	True
iii.	False
v.	False

ii.	False
iv.	True
vi.	True

2.

a) Mercury

b) Oxygen

c) Iron, magnesium, sodium, & sulphur

d) Iron

3.

Particle	Mass	Charge
Neutron	1	0
Electron	$\frac{1}{1840}$	-1
Proton	1	+1

4.

Elements	Symbol
Lithium	Li
Neon	Ne
Helium	He
Potassium	K

Elements	Symbol
Chlorine	Cl
Boron	B
Aluminium	Al
Silicon	Si

5.

a) Phosphorus

b) The nucleon number. It is the sum of neutron and protons in the nucleus of the atom.

c) Proton nucleon

d)

i. 15 electrons

ii. 15 protons

iii. 16 neutrons

This brings us to the end of this unit. How did you find it? Are you clear on what an atom, element, molecule, compound, and mixtures are? What is the smallest unit of matter? What do combinations of elements represent?

Quite often in chemistry, we want to deal with one phase or one part of a mixture at a time. Hence, it is important to know how to separate various mixtures. Let's find out how in the next topic!

Topic 2.4: Separation techniques

How long?

You will need 2 hours and 20 minutes to complete Topic 2.4. You are advised to spend another 1 hour and 10 minutes of your own time to review the topic.

In topic 2.3 you learned that there are different types of mixtures and that there are different types of separation techniques that can be used to separate those mixtures. In this topic you are going to learn about and practice some separation techniques that can be carried out at home or in a school science laboratory.

If you have access to the internet, go to www.youtube.com and search for “separation techniques in chemistry” and take a look at some **relevant** videos. Note that when doing any search on the internet, it is important to note that not everything that comes up from the search is relevant or correct, so you need to gain the skill of “filtering” through the irrelevant or incorrect materials.

There are several techniques that people from all walks of life use to separate mixtures. For instance, after infusing your tea if you are using tea leaves (not tea bags), you will use a strainer to remove the leaves from the infused tea. This simple and everyday technique is called filtration.

Before you learn more about filtration and other separation techniques, I would like you to find out more about some traditional ways of separating mixtures.

Activity

Activity 2.4.1

You should spend around 10 minutes on this activity.

Your task here is to ask around for more information about the types of separation techniques that your ancestors used to separate different types of mixtures. Record your information in the space provided below.

I’m sure that you have found some surprising information. For instance, you might have learnt that some people may have used a clean piece of cloth to strain their tea. The fibrous mesh from the coconut tree ('tanmi koko' in Creole) was also used as strainer.

Now we are going to learn about some techniques to separate different types of mixtures. As we have seen earlier, mixtures can be of different composition. We will start off with the separation of solid-liquid mixtures.

2.4.1 Separation of solid-liquid mixtures

There are different methods to separate solid-liquid mixtures. These are filtration, evaporation, decanting, crystallization, and simple distillation. However, you need to choose appropriate techniques depending on what you want to obtain. We will now discuss each of these methods.

2.4.1.1 Filtration

Filtration is a technique used to separate an insoluble solid (like the tea leaves) from a liquid (the infused tea). In the laboratory we use a **filter funnel** and a special paper known as **filter paper** for filtering mixtures.

Let's take a closer look at filtration. First, I am going to teach you how to prepare the filter paper to make a cone to filter your mixture.

Activity

Activity 2.4.2

You should spend less than five minutes on this activity.

Making a cone out of paper may be quite tricky for some people. So please carefully follow the simple instructions below to make yours.

Step 1

Fold the round filter paper provided in half to form a semi-circle.

Step 2

Fold the paper in half again to form a quarter of a circle.

Step 3

Open the folded filter paper by holding 3 parts of the quarter circle together on one side to form a cone.

Step 4

Put the cone into a filter funnel and wet it with a little bit of distilled water to hold it in place.

Figure 2.4.1: Procedures for folding the filter paper

Procedures demonstrated by: Carole Jacques

All photos for Activity 2.4.2 by: Rosianna Jules, July 2009

You are now ready to start filtering your mixture!

You are now going to carry out an activity in pairs or in a small group in the science laboratory.

Group activity

Group activity 2.4.1

You should spend about 10 minutes on this activity.

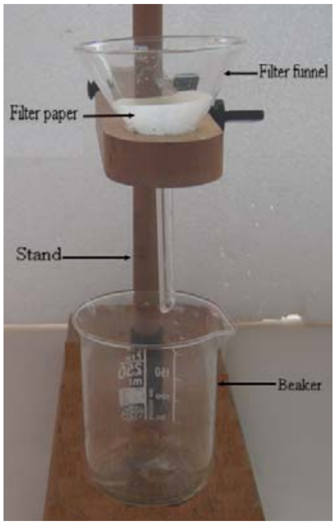
Equipment:

In your group, you will need: a filter funnel, a filter paper, some soil water (muddy or marshy water will also work) and 2 beakers.

Instruction:

1. Add a small amount of soil to a beaker half filled with water, and stir using a stirrer. Alternatively you can use muddy or marshy water.

2. Set up your apparatus as shown below. (You may ask for help from the tutor or laboratory technician if necessary.)



3. Carefully pour some of the mixture into the filter paper. Make sure that it does not spill over the rim of the filter paper. (If it spills over, you will have to start over as it might spoil your result.)

Figure 2.4.2: Setting up for filtration

Procedures demonstrated by: Carole Jacques

All photos for Group activity 2.4.1 by: Rosianna Jules, July 2009

4. Observe what happens and write down your observations in the space below. You may illustrate your observations with a labelled diagram.

Magic! Did you notice the difference in the appearance of the substance which was to be filtered and the substance which was collected in the beaker? If not, have another look at your result before moving on.

Feedback

Feedback to Group Activity 2.4.1

I hope that was interesting for you. You should have noticed that, just like when you strain your tea, the solid particles remain in the filter paper and the liquid part goes through the filter paper. In addition, you should have noticed that the liquid which passed through the filter paper and was collected in the beaker was clearer than the one which was poured into the filter paper.

The solid which remained in the filter paper is called the **residue**. The liquid that passed through the filter paper and collected in the beaker is known as the **filtrate**.

Applications of filtration

Filtration is used in the treatment of water. A filter or sand bed is used to remove the solid impurities before the water is treated with chlorine to make it safe for drinking.

Filtration is also used in industries in the manufacture of:

- sugar, and
- beer

You can use filtration to obtain the solid (residue) or the liquid (filtrate) from the mixture. However, the filtrate will not be pure as there are different substances dissolved in it.

The next method we are going to look at, allows us to obtain the pure liquid from the mixture. This method is known as **simple distillation**.

2.4.1.2 Simple distillation

Before we talk about simple distillation, I would like you to carry out this simple activity in your kitchen.

Activity

Activity 2.4.3

You should spend about 10 minutes on this activity.

<u>Equipment:</u>

You will need two clean glasses, some drinking water, two teaspoons of salt, a saucepan with a lid (a transparent glass lid is preferable if you have one) and a stove (or any fire source you use when cooking).

<u>Instruction:</u>

1. Dissolve two teaspoons of salt in a glass of water. (You can dip your finger into the salt solution and taste it; do not drink the salt solution).
2. Pour the salt solution into the saucepan, cover it with the lid.
3. Heat the salt solution to boil. Be careful when using fire.
4. Observe what happens as the salt solution boils.
5. After two minutes of boiling, remove the lid and tilt it to one side so that you can collect some of the liquid droplets formed under the lid into a clean glass. Be careful of the steam when uncovering the saucepan.
6. Taste the liquid that you have just poured into the glass.
7. Write your observation in the space provided.

I hope that you have found this activity simple to perform. Please refer to the feedback for the expected observation.

Feedback

Feedback to Activity 2.4.3

You should have observed that the salt solution, as expected, tastes salty. However, liquid that was collected under the lid was not salty as it was pure water. You should have also observed that, as we have seen in Topic 2.1, as the water boils, it vaporises, forming water vapour or steam. As the water vapour or steam cannot all escape (because of the lid), it condenses (turns back to water (a liquid)) under the lid.

From Activity 2.4.3 we can conclude that if we evaporate a salt solution (a solid-liquid mixture) and allow the vapour to condense, we can obtain pure water (the pure liquid). Evaporation and condensation are the two processes involved in simple distillation. We are now going to learn more about simple distillation.

Simple distillation is used to recover (obtain) a liquid from a solid-liquid mixture or from a liquid-liquid mixture. As mentioned above, simple distillation involves evaporation followed by condensation.

The liquid with the lowest boiling point distils (evaporates and condenses) first. So the thermometer is used to measure the temperature so that it can be maintained to ensure the complete distillation of the liquid for each successive boiling point. By monitoring the temperature, each liquid can be collected separately.

As the liquid with the lowest boiling point in the distillation flask boils, its vapour rises and moves into the Liebig condenser in order to escape. As the vapour passes through the inner tube in the condenser, the vapour is cooled by the water flowing around that tube causing it to condense into a liquid. The liquid which is collected in the beaker or flask is called the **distillate**.

Figure 2.4.3 below shows a green coloured mixture being distilled to obtain pure liquid.

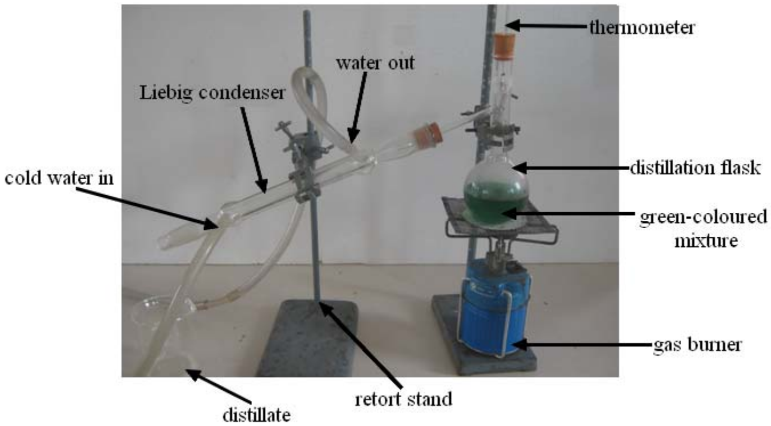
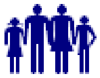


Figure 2.4.3: Simple distillation of a green coloured solution

Set up by: Louisette Bonte

Photo by: Rosianna Jules, July 2009

You are now going to illustrate the process of simple distillation by distilling some seawater or a coloured solution.



Group activity

Group activity 2.4.2

You should spend around 15 minutes on this activity.

You will need to carry out this group activity in the school science laboratory.

1. The laboratory technician will help you to set-up your apparatus as shown in Figure 2.4.3 above.
2. Light up the burner to heat the mixture and observe what happens.
3. Write your findings in the space below.

I hope that you have found this group activity interesting. Please read on for the feedback.

Feedback

Feedback to Group activity 2.4.2

You should have noticed that when the seawater or the coloured liquid was heated, it vaporized. When the thermometer read 100° C, it showed that the vapour being formed is water vapour or steam. As steam passed through the Liebig condenser, it condensed on the cold surface inside the Liebig condenser and water (the distillate) is collected in the beaker.

Applications of simple distillation

Simple distillation is used to:

- purify seawater to obtain fresh drinking water in many countries;
- obtain alcohol in the production of brandy or whisky.

2.4.1.3 Decanting

Decanting is normally used to separate a liquid from an insoluble solid that has settled in the bottom of the container. The solid that has settled is known as the precipitate or sediment. The liquid to be separated is carefully poured out of the container without disturbing the precipitate or sediment as illustrated by Figure 2.4.4 below.

For example, decanting is used when separating rice grains from water when rinsing the rice before cooking.

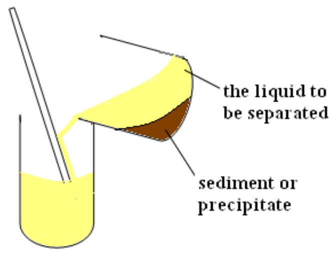


Figure 2.4.4: Illustration of decanting process

Graphics by: Rosianna Jules, June 2010

Applications of decanting

Decanting is used in the production of:

- wine, and
- olive oil

2.4.1.4 Evaporation

As you have seen in Topic 2.2, evaporation is a process whereby particles escape from the surface of a liquid. We can use evaporation to obtain any solid that is not heat-sensitive from a solution, by heating the solution directly to allow evaporation to dryness. For example, a sodium chloride solution can be evaporated to give sodium chloride (table salt).

However, if the solid is heat-sensitive, the evaporation should be done over a water bath as shown below.

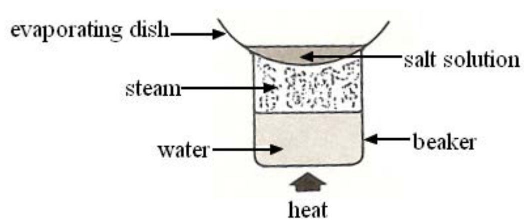


Figure 2.4.5: Evaporation of a heat sensitive solid over a water bath

Graphics by: Rosianna Jules, June 2010

Note it! / Important!

A solution is a mixture of solutes (solids which dissolved in the solvent to form the solution).

A solvent is the liquid that dissolves the solute to form a solution.

2.4.1.5 Crystallisation

Crystallisation is used to obtain pure crystals (solids) which are sensitive to heat by cooling a hot, saturated solution of the substance. The solution is said to be saturated when the solute added can dissolve no more.

You can make your own crystals at home.

Activity

Activity 2.4.4: Making crystals

You should spend around 10 minutes to set up the crystallisation process and about 3 minutes on the following day to separate the crystals from the solution.

For this activity you will need some sugar, a small saucepan and a gentle heating system.

<u>Procedure</u>

1. You need to make a saturated sugar solution by dissolving excess sugar (the solute) in a heat proof container (a small saucepan) of water (the solvent) over gentle heat. If you wish, you can add two drops of food colouring to the solution to make it a little bit more interesting.
2. Allow the saturated solution to cool overnight.
3. Filter the contents of the container to separate the crystals from the solution. (You can use a tea strainer to do that).

Feedback

I hope that you have enjoyed this activity. Did you get the sugar crystals? If you did not get the crystals, it may be because you did not have a saturated sugar solution. You could try again, this time make sure that you add excess sugar.

Applications of crystallisation

Crystallisation can be used to obtain:

- zinc nitrate crystals by cooling a hot saturated solution of zinc nitrate; and
- copper (II) sulphate by cooling a hot saturated solution of copper (II) sulphate.

So far we have seen the different separation techniques that can be used to separate solid-liquid mixtures. We are now going to talk about the separation of liquid-liquid mixtures.

2.4.2 Separation of liquid-liquid mixtures

Mixtures of liquids can be separated by using **a separating funnel**, **simple distillation** or **fractional distillation** depending of the physical properties of the liquids in the mixture, such as their boiling points and their miscibility (ability to mix together). For example, mixtures of **immiscible liquids** (liquids that do not mix together), like water and oil, can easily be separated using a separating funnel while mixtures of **miscible liquids** (liquids that mix together), like water and vinegar, cannot be separated using that same technique.

We are now going to see how we can separate mixtures of immiscible liquids using a separating funnel.

2.4.2.1 Separating funnel

A separating funnel can be used to separate immiscible liquids like a mixture of oil and water shown in Figure 2.4.6 below.

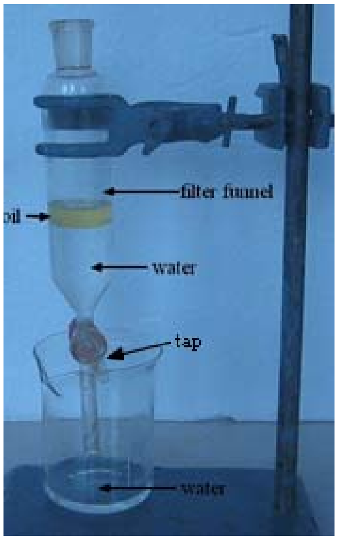


Figure 2.4.6: The separation of water from a mixture of oil and water

Set up by: Louisette Bonte

Photo by: Rosianna Jules, July 2009

You are now going to learn how to use the separating funnel.

1. Set up the equipment as shown in Figure 2.4.6 above.
2. Ensure that the tap at the neck of the separating funnel is closed.
3. Pour the mixture of immiscible liquids into the separating funnel.
4. Allow the mixture to settle so that the denser liquid (liquid with the higher density) sinks to the bottom of the filter funnel.
5. When the liquids have settled into separate layers (as shown above) you can open the tap and *carefully* allow the densest liquid to flow into the container.
6. Close the tap as soon as all of the densest liquid has flowed out.
7. You can run out the next denser liquid in a separate container.

Now let us look at simple distillation and fractional distillation as the two other techniques for separating liquid-liquid mixtures. Simple distillation and fractional distillation are appropriate for separating miscible liquids.

2.4.2.2 Simple distillation

You have seen earlier that simple distillation can be used to obtain a pure liquid from a solid-liquid mixture. We can also make use of simple distillation to separate mixtures of liquids. The greater the difference in the boiling points of the liquids in the mixture, the easier it is to separate the mixture by simple distillation.

If the difference in boiling points of the liquids in the mixture is 25° C or less, it is best to separate the mixture by a more complex distillation process known as fractional distillation.

2.4.2.3 Fractional distillation

As mentioned above, fractional distillation is used to separate mixtures consisting of liquids with close boiling points. For example, alcohol can be separated from water by fractional distillation because the boiling point of alcohol is 78° C and that of water, as you know, is 100° C. The mixture separates into different parts known as **fractions**.

In the school laboratory, a fractionating column with perforated plates (Figure 2,4,7 below) or filled with glass beads is fitted to a distilling flask as shown in the diagram below.

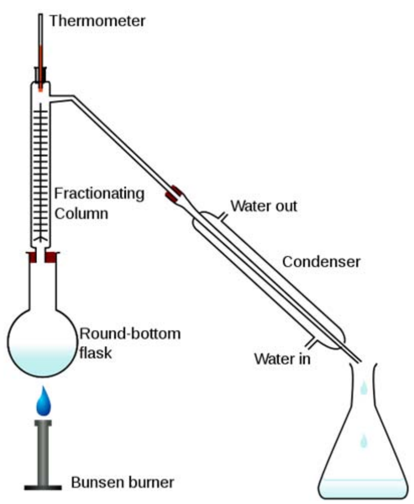


Figure 2.4.7: Diagram showing the set-up of fractional distillation for a school laboratory

Source: http://en.wikipedia.org/wiki/Fractional_distillation Retrieved August 29, 2009.

On heating, the liquid with the lowest boiling points evaporates and condenses on the cold glass beads. As the column warms up on continuous heating, the vapour rises further before condensing.

This process of evaporation and condensation is repeated over and over again. Eventually, the liquid with the lowest boiling points comes out of the top of the fractionating column into the Liebig condenser where it condenses into a liquid. Once all the liquid with the lowest boiling point has been separated, the temperature rises to match the boiling point of the next liquid. The process repeats until all the liquids in the mixture have been separated.

Application of fractional distillation

Fractional distillation has many industrial applications. For example it is used:

1. to distil crude oil to obtain several useful components, such as petrol, benzene and diesel;

2. in the liquefaction of air to obtain liquefied nitrogen and oxygen. Nitrogen is distilled off first at -196° C and oxygen at -183° C.

So far you have seen how to separate solid-liquid mixtures and liquid-liquid mixtures. We are now going to learn about the different techniques used to separate solid-solid mixtures.

2.4.3 Separation of solid-solid mixtures

Solid-solid mixtures can be separated using different separating techniques based on the properties of the solids. Before we go any further, let us see if you can think of a way to separate the following solid-solid mixtures.

Activity

Activity 2.4.5

You should spend around 10 minutes on this activity.

1. You are provided with two mixtures of solids:
    a. Mixture A is a mixture of salt and rice.
    b. Mixture B is a mixture of small needles and sawdust.
2. Think of an appropriate technique to separate each mixture to obtain the solids separately.
3. Write your answers in the space provided.

Mixture A can be separated by:

____

____

____

Mixture B can be separated by:

____

____

____

Feedback

I hope that you have come up with a way to separate each of the two mixtures.

The best way to separate Mixture A is by adding water to the mixture to dissolve the salt and then filter the mixture so that the rice will remain on the filter. The salt solution will go through the filter and can then be evaporated to obtain the salt.

The best way to separate Mixture B is by using a magnet to attract all the needles in order to separate them from the sawdust.

Now let us take a closer look at the techniques for separating solid-solid mixtures. Mixtures of solids can be separated using (a) dissolution followed by filtration; (b) magnets; and (c) sublimation.

2.4.3.1 Dissolution and filtration

Dissolution and filtration is used when one solid is soluble, while the other is not. Because the solubility varies with the solvent used, , it is very important to choose the appropriate solvent to dissolve the soluble solid.

For example, if we want to separate rice from a mixture of rice and salt, we need to add water to the mixture to dissolve the salt. This process is known as dissolution. The mixture is then filtered to separate the insoluble solid. Evaporation, as seen in 2.4.1.4, can then be used to obtain the salt (soluble solid) if necessary. (Feel free to go back to review evaporation if you need to.)

Activity

Activity 2.4.6

You should spend around 5 minutes on this activity.

Based on what you have learnt above about filtration, when filtering the mixture of rice and salt solution above, what will be:

(a) the residue?

The residue will be ____

(b) the filtrate?

The filtrate will be ____

You are correct! The residue will be the rice and the filtrate will be the salt solution. The salt solution is then evaporated to obtain the salt.

2.4.3.2 Using magnets

If one of the solids in the mixture exhibit magnetic properties, then that solid can be extracted using a magnet.

For example in a mixture of iron filings and sulphur, a magnet can be used to separate the iron filings from the mixture.

2.4.3.3 Sublimation

Sublimation is used to separate mixtures containing a solid which can sublime. As mentioned earlier in Topic 2.2, the substances which can sublime include: ammonium chloride, iodine, benzoic acid and naphthalene. Figure 2.4.8a and Figure 2.4.8b show the diagrams to illustrate the sublimation set up.

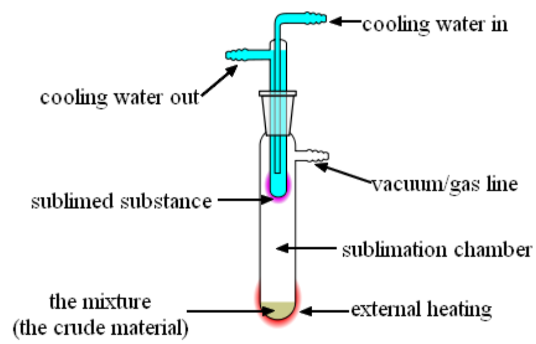


Figure 2.4.8a: Diagram to illustrate sublimation set up

Retrieved from: http://en.wikipedia.org/wiki/File:Sublimation_apparatus.svg
August 20, 2009

Adapted by: Rosianna Jules

Alternatively, you can place an inverted funnel on an evaporating dish containing the mixture consisting of a substance which sublimes. The sublimate collects on the cool parts of the funnel as shown in Picture B below.

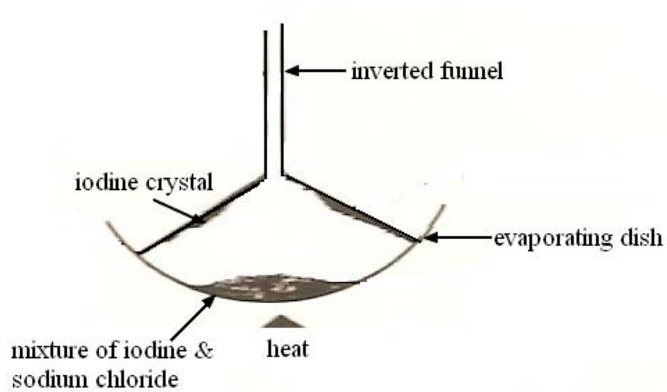


Figure 2.4.8b: Diagram to illustrate sublimation set up

Graphics by: Rosianna Jules, July 2009

2.4.3.4 Paper chromatography

Paper chromatography is a technique used for the separation and identification of mixtures. Chromatography is based on the:

1. solubility of the different solids in the mixture dissolved in the same solvent; and
2. selective absorption of the components by the filter paper.

When separating colourless substances, we can make the substances more visible by using ultraviolet light and by spraying them with **locating agents**. Locating agents are chemicals that react with and colour the separated substances.

Now you are going to do a simple paper chromatography.

Activity

Activity 2.4.5

Equipment:

You will need: a strip of filter paper about 1cm wide, a water soluble pen, and a boiling tube with rubber bung.

Instructions:

1. Cut a strip of filter paper about 1 cm wide.
2. Put a spot of water soluble ink (the mixtures) about 1 cm from the bottom of one end of the strip of filter paper. The filter paper is known as the **stationary medium**.
3. Allow the ink to dry.
4. Put a little water (solvent) in the boiling tube. Water or any other solvent used is known as the **moving medium**.
5. Hang the strip of filter paper so that the end with the dot of ink just touches the water. You have to ensure that the dot of ink is above the level of the water.
6. Leave the set up undisturbed for a while and observe what happens.
7. Stick your chromatogram and write down your observations in the space provided.

Stick your chromatogram made from black ink here:

Write your observations here:

Feedback

You may have noticed that black ink contains different colours of dyes. As the water (solvent) moves or flows along the filter paper, the dye which is more soluble in the water (solvent) and less absorbed by the filter paper, travels further up the filter paper. The dye which is less soluble and more absorbable travels the least.

Application of chromatography:

Chromatography is used in

1. the manufacture of medicine;
2. the analysis of protein and carbohydrates;
3. food industries
4. crime scene investigations

Now let us see how much you have understood about this section.

Assessment

Self-assessment 2.2

You should spend less than 10 minutes on this self-assessment. This self-assessment is based on Topic 4. The answers are given at the end of the topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 2.2. This will help you learn and reflect better on areas for improvement.

Answer the following questions in the space provided.

1. Which separation technique is most suitable for obtaining:

a) Ammonium chloride from a white powder consisting of ammonium chloride and sodium chloride?

b) Small pieces of iron from a mixture of iron and copper tunings?

c) The different pigments from an extract of flower petals?

d) Benzene from a liquid mixture of benzene and petrol?

e) Sugar from a sugar solution.

f) Oil from a mixture of oil and water.

2. Describe what the following terms mean.

a) Filtrate

b) Residue

c) Distillate

Answers to Assessment

Answers to Self-assessment 2.2

1.

a) sublimation	b) a magnet
c) chromatography	d) fractional distillation
e) crystallisation	f) separating funnel

2.

a. The filtrate is the substance (liquid) that goes through the filter paper during filtration.

b. Residue is the solid particles that remain in the filter paper during filtration.

c. Distillate is the pure substance that is collected during distillation.

I hope that you have enjoyed learning about separation techniques. I am sure that you have now realised that you are using some of those techniques in your everyday life. If you, however, feel that you need to go over certain techniques again, feel free to do so.

Now in the last topic in this unit, we are going to learn how to quantify the number of particles in an atom. The topic entitled '*The mole concept*' is especially for those of you who are ready to go that extra mile, or those who are aiming for Grades A or B in the examination. In other words, those of you who are not studying the extended objectives, you are not obliged to follow this topic. However, this does not prevent you from trying it. It involves a lot of calculations and if you love mathematics, you might enjoy doing it. If you choose not to do it, you can use the time to review the previous topics as necessary or make a head start on Unit 3.

Topic 2.5: The Mole Concept

Note it! / Important!

As mentioned above, this topic is for those of you who are studying the extended objectives. If you are a student doing the core objectives, you may also attempt this topic, if you like. If you choose not to follow this topic, you are encouraged to use the additional 90 minutes to further review the topics covered.

How long?

You will need 1 hour 30 minutes to complete Topic 2.5. You are advised to spend another 45 minutes of your own time to review the topic.

In this topic, you will learn how to quantify the number of particles in an atom.

In everyday life, we measure pieces of matter either by counting or weighing them, depending on what is most convenient for us. For instance, when baking a cake, it is more convenient to count the eggs and weigh the sugar rather than the other way round. Because the sugar crystals are so small, counting individual sugar crystals is simply ridiculous. Hence, for convenience, we weigh sugar using the mass units, kilograms (kg) or grams (g).

Similarly, because of the very large numbers of atoms that are involved in any chemical reaction are much too small to count individually, to quantify the large numbers of atoms, we use Avogadro's constant (often referred to as Avogadro's number) and the mole. The mole is a unit which allows us to count the number of atoms by weighing them.

Now let us learn more about Avogadro's constant and the mole.

2.5.1 Avogadro's constant

The Avogadro constant (N_A) is the number of particles (atoms, or molecules) in 1 mole which is equal to 6.02×10^{23}.

This means that:

- 1 mole of hydrogen atom (H) contains 6.02×10^{23} atoms of hydrogen.
- 1 mole of carbon-12 contains 6.02×10^{23} atoms of carbon-12.
- 1 mole of Hydrogen molecules (H_2) has $((6.02 \times 10^{23}) \times 2)$ molecules of Hydrogen

  We multiply by 2 because H_2 is made of 2 moles of H atoms

- 1 mole of water (H_2O) contains $((6.02 \times 10^{23}) \times 3)$ molecules of water

  We multiply by 3 because H_2O contains 2 moles of H atoms and 1 mole of O atoms

- 1 mole of methane gas (CH_4) contains $((6.02 \times 10^{23}) \times 5)$ of molecules of methane

  We multiply by 5 because CH_4 contains 1 mole of C atoms and 4 moles of H_2 is made of 2 H atoms

I hope that you have understood these examples. Now you are going to learn what the term mole means.

2.5.2 The Mole

The mole (mol) is the SI (Système International) unit of the 'amount of substance' (or the number of particles (atoms or molecules) of a substance). One mole contains the same number of particles, that is, 6.02×10^{23} (Avogadro's number) of particles as there are atoms in exactly 12 grams of carbon-12 isotope.

One mole has a mass exactly equal to the substance's relative atomic mass (A_r) or relative molecular mass (M_r). Very often, especially in calculations, these masses are expressed as molar mass. This is because the molar mass gives you the quantitative value of a substance. Hence, contrary to the relative atomic mass (A_r) and relative molecular mass

(M_r), the molar mass has a unit which is **grams per mol** (the unit symbol is: $g\ mol^{-1}$ which can also be written as: $\frac{g}{mol}$ or g/mol).

The relative molecular mass of a substance (compound or a molecule) is the sum of the relative atomic masses of the elements in the formula of the substance. Similarly, the molar mass of a substance is the sum of the atomic masses of the elements in the formula of the substance but has the unit $g\ mol^{-1}$ attached to it.

So to calculate the relative molecular mass and the molar mass of 1 mole of a substance you need to know the following:

- the relative atomic mass of the substance (which is usually given.If not you can get that value from the Periodic Table); and
- the formula of the substance to get:
    - the elements present; and
    - the number of moles of each element present;

Now let us see how to calculate the relative molecular mass (M_r) or the molar mass of some substances.

First of all, here are the A_r (relative atomic mass) for the elements we will be using in the examples: A_r (H) = 1; A_r (C) = 12; A_r (O) = 16; A_r (Al) = 27; A_r (Ca) = 40.

So, for example, for:

1. 1 mole of carbon dioxide (CO_2) which contains one mole of carbon atoms and two moles of oxygen atoms, the M_r (relative molecular mass) is 44 and the molar mass is 44 $g\ mol^{-1}$. See Table 2.5.1 below for the calculation.
2. 1 mole of aluminium oxide (Al_2O_3) which contains 2 moles of aluminium and 3 moles of oxygen, the M_r is 102 and the molar mass is 102 $g\ mol^{-1}$. See Table 2.5.1 below for the calculation.

More examples are given in Table 2.5.1 below.

1 mole of the substance	Calculations using relative atomic masses (A_r) and number of mole	Relative Molecular mass (M_r)	Molar mass ($g\ mol^{-1}$)

Carbon dioxide (CO_2)	$C + 2O = (1 \times 12) + (2 \times 16)$ $= 12 + 32$ $= 44$ No. of mole of C atoms; A_r (C)	44	44 $g\ mol^{-1}$
Aluminium oxide (Al_2O_3)	$2Al + 3O = (2 \times 27) + (3 \times 16)$ $= 54 + 48$ $= 102$	94	94 $g\ mol^{-1}$
Carbon-12 (C)	$C = (1 \times 12)$ $= 12$	12	12 $g\ mol^{-1}$
Oxygen (O)	$O = (1 \times 16)$ $= 16$	16	16 $g\ mol^{-1}$
Water (H_2O)	$2H + O = (2 \times 1) + (1 \times 16)$ $= 2 + 16$ $= 18$ No. of mole of H atoms; A_r (O)	18	18 $g\ mol^{-1}$

Table 2.5.1: Examples of how to calculate the M_r (relative molecular mass) and molar mass of 1 mole of some substances using the A_r (relative atomic mass)

Note it! / Important!

Please note that the calculations for relative molecular mass and molar mass are the same. The only difference is that the molar mass has the unit **g** attached to the value.

I hope that you have clearly understood these calculations as you will need them to proceed in this topic. If you are having any doubts, please go through it again and if necessary ask for further help from your colleagues and your tutor.

As you work through this topic, you will learn about calculations involving the use of the molar mass, the mole and Avogadro's constant.

2.5.3 Conversions involving Avogadro's' number and the mole

You can convert moles to mass of substances (in grams), or moles to number of atoms or molecules, and vice versa using different formulae.

Let us look at how to do these conversions. Later on in Self-assessment 2.3, you will have the chance to practise some of the conversions on your own.

2.5.3.1 Converting moles to masses

If you are given the number of moles of a substance, you can calculate its mass using formula 1 below.

Formula 1:

$$\text{mass} = \text{number of moles x molar mass}$$

Now let us look at two examples that involve the use of Formula 1. Let us go through this calculation together.

Example 2.5.3.1.1: What is the mass of 0.1 mole of calcium (Ca)? A_r (Ca) = 40.

First, write down the formula:

$$\text{Mass} = \text{number of moles} \times \text{molar mass}$$

Second, calculate the molar mass of calcium:

$$\text{Molar mass of calcium} = (1 \times \underbrace{40}_{A_r\,(Ca)}) = 40\ \text{g mol}^{-1}$$

Note it! / Important!

Please remember that the molar mass:

- is the sum of the relative atomic mass of the elements present in the formula of the substance; and
- is measured in g mol^{-1} (grams per mole) which can also be written as g/mol or $\frac{g}{mol}$.

Third, substitute the values in the formula

$\text{Mass of } 01. \text{ mole of calcium } = \text{ number of moles } \times \text{ molar mass}$

$$= 0.1 \cancel{\text{mol}} \times \frac{40\text{ g}}{\cancel{\text{mol}}}$$

40 g/mol is the molar mass of calcium

0.1 is the number of moles of calcium

$$= 4.0 \text{ g}$$

The 2 mol cancel out each other leaving the unit for mass (g)

So, the mass of 0.1 mole of calcium is 4 g

Let us try another example.

Example 2.5.3.1 2: What is the mass of 0.5 mole of sodium carbonate (Na_2CO_3)? A_r (Na) = 23, A_r (C) = 12, and A_r (O) = 16.

First, write down the formula:

$\text{Mass} = \text{ number of moles } \times \text{ molar mass}$

Second, calculate the molar mass of sodium carbonate:

Molar mass of sodium carbonate is:

Number of moles of O atoms

$$Na_2CO_3 = 2Na + C + 3O$$

$$= (2 \times 23) + 12 + (3 \times 16)$$

A_r (O)

$$= 46 + 12 + 48$$

$$= 106 \text{ g mol}^{-1}$$

So, the molar mass of sodium carbonate $= 106 \text{ g mol}^{-1}$

Third, substitute the values in the formula

Mass of 0.5 mole of sodium carbonate

$$= \text{number of moles} \times \text{molar mass}$$

$$= 0.5\ \cancel{\text{mol}} \times \frac{106\ \text{g}}{\cancel{\text{mol}}}$$

molar mass of Na_2CO_3

0.5 is the number of moles Na_2CO_3

$$= 53\ \text{g}$$

The unit mol cancels out each other leaving the unit for mass (g)

Hence, 0.5 mole of sodium carbonate has a mass of 53 g.

I hope that you have understood the conversion of moles to mass. Now we are going to look at the conversion of mass to moles.

2.5.3.2 Converting masses to moles

If you are given the mass of a substance, you can calculate the number of moles using the formula 2 below.

Formula 2:

$$\text{Number of moles} = \frac{\text{mass (g)}}{\text{molar mass } (g\ mol^{-1})}$$

Note it! / Important!

Please note that:

for ease of calculation $\frac{1}{(\text{g mol}^{-1})}$ is expressed as $\frac{1}{\text{g}} \times 1\ \text{mol}$

Example 2.5.3.2.1: What is the number of moles present in 9 g of water?
A_r (H) = 1 and A_r (O) = 16

First, write down the formula:

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{molar mass } (g\ mol^{-1})}$$

Second, calculate the molar mass of water

Molar mass of water is:

$$H_2O = (2 \times 1) + 16 = 18$$

Number of moles of H atoms

A_r (H)

$$\text{Molar mass of water} = 18\text{ g mol}^{-1}$$

Third, substitute the values in the formula

$$\text{number of moles in 9 g of water} = \frac{\text{mass (g)}}{\text{molar mass (g)}} \times 1\text{ mol}$$

$$= \left(\frac{9\text{ g}}{18\text{ g}}\right) x\ 1\text{ mol}$$

The unit for mass (g) cancels out each other leaving the number of mole (mol)

$$= 0.5\text{ mol}$$

$$\text{So 9 g of water} = 0.5\text{ mole of water or } \frac{1}{2}\text{ mole of water}$$

Now let us try another example.

Example 2.5.3.2.2: What is the number of moles of Ca^{2+} present in 15 g of Ca^{2+} ions? A_r (Ca) = 40.

First, write down the formula:

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{molar mass } (g\ mol^{-1})}$$

Second, calculate the molecular mass of calcium

Molar mass of Ca^{2+} $= 1 \times 40 \text{ g mol}^{-1}$

$= 40 \text{ g mol}^{-1}$

Third, substitute the values in the formula

number of moles in 15 g of $Ca^{2+} = \frac{\text{mass } (g)}{\text{molar mass (g)}} \times 1 \text{ mol}$

$$= \left(\frac{15 \text{ g}}{40 \text{ g}}\right) \times 1 \text{ mol}$$

$$= 0.375 \text{ mol}$$

The unit for mass (g) cancels out each other leaving the number of moles (mol)

So 15 g of $Ca^{2+} = 0.375$ moles of Ca^{2+}

Now that you have learnt how to convert mole to mass and mass to moles, you are going to learn how to convert mole to the number of particles. If you may recall in topic 2.5.1 you learnt that the number of particles (atoms, or molecules) in 1 mole equals to Avogadro's constant which is (6.02×10^{23}).

2.5.3.3 Converting moles to number of particles

If you are given the number of moles of a substance, you can calculate the number of particles using Formula 3 or Formula 4 below.

Formula 3:

$$\text{Number of particles} = \text{number of moles of the substance} \times \text{Avogadro's number } (6.02 \times 10^{23})$$

OR

Formula 4:

$$\text{Number of particles} = \text{number of moles of the substance} \times \text{Avogadro's number} \times \text{number of moles of atoms in that substance}$$

Note it! / Important!

Please note that:

- Formula 3 is used when finding the number of particles in an element.
- Formula 4 is used when calculating the number of particles in a molecule or a compound. In this case, you need to consider the number of moles of atoms present in the formula of the molecule or compound.

Let us try two examples together.

Example 2.5.3.3.1: How many atoms are there in ¼ mole of carbon?

First, write down the formula:

Since C is an element, we use Formula 3

$$\text{Number of particles} = \text{number of moles} \times \text{Avogadro's number}$$

This implies that:

$$\text{Number of atoms of carbon} = \text{number of moles of carbon} \times \text{Avogadro's number}$$

Second, substitute the values in the formula

$$\text{Number of atoms of carbon} = \underbrace{\frac{1}{4}}_{\text{Number of moles of C}} \times (\underbrace{6.02 \times 10^{23}}_{\text{Avogadro's number}})$$

$$= 1.505 \times 10^{23}$$

So ¼ mole of carbon contains 1.505×10^{23} particles

Let us try another example.

Example 2.5.3.3.2: How many atoms are there in ½ mole of methane (CH_4) molecule?

First, write down the formula:

Since CH_4 is a molecule, we use Formula 4

$$\text{Number of particles} = \text{number of moles of the substance} \times \text{Avogadro's number} \times \text{number of moles of atoms in the substance}$$

Since 1 molecule of methane is made up of 5 moles of atoms (that is, 1 mole of carbon atoms and 4 moles of hydrogen atoms), to find the number of atoms we need to multiply Avogadro's number by 5.

Second, substitute the values in the formula

$$\text{Number of particles} = \frac{1}{2} \times (6.02 \times 10^{23}) \times 5$$

Number of moles of CH_4

Number of moles of atoms in 1 molecule of CH_4

$$= 15.05 \times 10^{23}$$

$$= 1.505 \times 10^{24}$$

So the number of atoms in ½ mol of methane is 1.505×10^{24}.

Now let us learn how to convert the number of particles to moles.

2.5.3.4 Converting number of particles to moles

If you are given the number of particles, you can calculate the number of moles using the formula below.

Formula 5:

$$\text{Number of moles} = \frac{\text{number of particles}}{\text{Avogadro's constant } (6.02 \times 10^{23})}$$

Example 2.5.3.4.1: What is the number of moles of sodium ions (Na^+) present in 2.3×10^{23} of sodium ions?

First, write down the formula:

$$\text{Number of moles} = \frac{\text{number of particles}}{\text{Avogadro's constant}}$$

Second, substitute the values in the formula

The number of moles of Na^+ $= \frac{\text{number of particles}}{\text{Avogadro's constant}}$

Number of Na^+

$= \frac{2.3 \times 10^{23}}{6.02 \times 10^{23}}$

Avogadro's number

$= 0.382$

So the number of moles of sodium ions (Na^+) present in 2.3×10^{23} of sodium ions is 0.382 moles.

Let us try another example.

Example 2.5.3.4.2: What is the number of moles of carbon present in 3×10^{23} of carbon atoms?

First, write down the formula:

Number of moles $= \frac{\text{number of particles}}{\text{Avogadro's constant}}$

Second, substitute the values in the formula

The number of moles of C $= \frac{3 \times 10^{23}}{6.02 \times 10^{23}}$

Number of C atoms

Avogadro's number

$= 0.498$

So, the number of moles of carbon present in 3×10^{23} of carbon atoms is 0.498 moles.

I hope that the examples were easy to follow. Please feel free to revise this section if you have to. You are now going to learn how to convert the number of particles to mass.

2.5.3.5 Converting number of particles to masses

If you are given the number of particles, you can calculate the mass using the formula below.

Formula 6

$$\text{mass} = \frac{\text{number of particles}}{\text{Avogadro's constant } (6.02\ x\ 10^{23})} \times \text{molar mass}$$

Now let us try two examples together.

Example 2.5.3.4.1: What is the mass of sodium atoms present in 4.5×10^{23} atoms of sodium? A_r (Na) = 23

First, write down the formula:

$$\text{mass} = \frac{\text{number of particles}}{\text{Avogadro's constant } (6.02\ x\ 10^{23})} \times \text{molar mass}$$

Second, calculate the molar mass of sodium

Molar mass of sodium is:

$$\text{Na} = 1 \times 23$$

A_r (Na)

$$= 23\ \text{g mol}^{-1}$$

Remember, g mol^{-1} is read as grams per mol

Third, substitute the value in the formula

$$\text{Mass of sodium atoms} = \frac{\text{number of particles}}{\text{Avogadro's constant}} \times \text{molar mass}$$

$$= \frac{4.5 \times 10^{23}}{6.02 \times 10^{23}} \times 23\ \text{g}$$

$$= 17.19\ \text{g}$$

So, in 4.5×10^{23} atoms of sodium there are 17.19 g of sodium atoms.

Now let us try a second example.

Example 2.5.3.4.2: What is the mass of Ca^{2+} present in 3.01×10^{23} Ca^{2+} ions? A_r (Ca) = 40

First, write down the formula:

$$\text{mass} = \frac{\text{number of particles}}{\text{Avogadro's constant } (6.02\ x\ 10^{23})} \times \text{molar mass}$$

Second, calculate the molar mass of calcium ions

Molar mass of Ca^{2+} is:

$$\text{Ca}^{2+} = 1 \times 40$$

$$= 40 \text{ g mol}^{-1}$$

Third, substitute the value in the formula

$$\text{Mass of sodium atoms} = \frac{\text{number of particles}}{\text{Avogadro's constant}} \times \text{ molar mass}$$

$$= \frac{3.01 \times 10^{23}}{6.02 \times 10^{23}} \times 40 \text{ g}$$

$$= 20 \text{ g}$$

So, in 3.01×10^{23} atoms of Ca^{2+} ions there are 20 g of Ca^{2+} ions.

Now that you know how to convert number of particles to mass, you are going to learn how to convert mass to the number of particles.

2.5.3.6 Converting masses to number of particles

If you are given the mass of a substance, you can calculate the number of particles in the given mass using the formula below.

Formula 7:

$$\text{number of particles} = \frac{\text{mass}}{\text{molar mass}} \times \text{Avogadro's constant}$$

Example 2.5.3.5.1: How many molecules of water are there in 4.5 g of water?

First, write down the formula:

$$\text{number of particles} = \frac{\text{mass}}{\text{molar mass}} \times \text{Avogadro's constant}$$

Second, calculate the molar mass of water

Molar mass of water is:

$$H_2O = 2 \times 1 + 16$$

$$= 18 \text{ g mol}^{-1}$$

Third, substitute the value in the formula

$$\text{number of particles of water} = \frac{\text{mass}}{\text{molar mass}} \times \text{Avogadro's constant}$$

$$= \frac{4.5 \text{ g}}{18 \text{ g}} \times 1 \text{ mol} \times (6.02 \times 10^{23})$$

$$= 1.505 \times 10^{23}$$

Let us try another example.

Example 2.5.3.5.2: How many atoms of lithium are there in 0.7 g of lithium? A_r (Li) = 7

First, write down the formula:

$$\text{number of particles } = \frac{\text{mass}}{\text{molar mass}} \times \text{ Avogadro's constant}$$

Second, calculate the molar mass of water

Molar mass of lithium is:

$$\text{Li} = 1 \times 7$$

$$= 7 \text{ g mol}^{-1}$$

Third, substitute the value in the formula

$$\text{number of particles of water} = \frac{\text{mass}}{\text{molar mass}} \times \text{ Avogadro's constant}$$

$$= \frac{0.7 \text{ g}}{7 \text{ g}} \times 1 \text{ mol } \times (6.02 \times 10^{23})$$

$$= 0.602 \times 10^{23}$$

$$= 6.02 \times 10^{22} \text{ atoms}$$

I hope that you have understood the various conversions presented in this topic.

Now it is your turn to practice some of these conversions.

Assessment

Self-assessment 2.3

You should spend less than 15 minutes on this self-assessment. This self-assessment is based on Topic 5. The answers are given at the end of the topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 2.3. This will help you learn and reflect better on areas for improvement.

Use the relative atomic mass (A_r) given to answer the questions below. The A_r for:

Hydrogen (H) = 1	Carbon (C) = 12	Oxygen (O)= 16
Sulphur (S) = 32	Iron (Fe) = 56	Magnesium (Mg) = 24
Sodium (Na)= 23		

Show all your work in the space provided.

1. What is the mass of 0.66 mole of sulphur dioxide?

Show work here.

2. What is the number of moles of Fe^{2+} present in 2.8 g of Fe^{2+} ions?

Show work here.

3. How many atoms are there in ½ mole of water (H_2O)?

Show work here.

4. What is the number of moles of H^+ present in 3.01×10^{23} of hydrogen ions?

Show work here.

I hope that by following the steps in the examples above, you have found this exercise easy. Check the Answers to Self-assessment 2.3 below for the correct answers.

Answers to Assessment

Answers to Self-assessment 2.3

1.

A_r (S) = 32, A_r and A_r (O) = 16.

First, write down the formula:

$$\text{Mass} = \text{number of moles} \times \text{molar mass}$$

Second, calculate the molar mass of sulphur dioxide:

Molar mass of sulphur dioxide is:

Number of moles of O atoms

$$SO_2 = S + 2O$$

$$= 32 + (2 \times 16)$$

$$= 32 + 32$$

A_r (O)

$$= 64 \text{ g mol}^{-1}$$

So, the molar mass of sulphur dioxide $= 64 \text{ g mol}^{-1}$

Third, substitute the values in the formula

Mass of 0.66 mole of sulphur dioxide $=$ number of moles $\times$ molar mass

$$= 0.66\ \cancel{\text{mol}} \times \frac{64\ \text{g}}{\cancel{\text{mol}}}$$

molar mass of SO_2

0.64 is the number of moles SO_2

$$= 42.24 \text{ g}$$

The unit mol cancels out each other leaving the unit for mass (g)

Hence, 0.66 mole of sulphur dioxide has a mass of 42.24 g.

2. A_r (Fe) = 56

First, write down the formula:

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{molar mass } (g\ mol^{-1})}$$

Second, calculate the molar mass of Fe^{2+}

Molar mass of Fe^{2+} is:

$$Fe^{2+} = (1 \times 56)$$

$$= 56 \text{ g mol}^{-1}$$

Molar mass of $Fe^{2+} = 56 \text{ g mol}^{-1}$

Third, substitute the values in the formula

$$\text{number of moles in 2.8 g of } Fe^{2+} = \frac{\text{mass (g)}}{\text{molar mass (g)}} \times 1 \text{ mol}$$

$$= \left(\frac{2.8 \text{ g}}{56 \text{ g}}\right) \times 1 \text{ mol}$$

$$= 0.05 \text{ mol}$$

So 2.8 g of $Fe^{2+} = 0.05$ mole of Fe^{2+}

3.

First, write down the formula:

Since water (H_2O) is a molecule, we use the formula below

Number of particles = number of moles of the substance $\times$ Avogadro's number $\times$ number of moles of atoms in the substance

Since 1 molecule of water is made up of 3 moles of atoms (i.e. 2 moles of hydrogen atoms and 1 mole of oxygen atoms), to find the number of atoms we need to multiply Avogadro's number by 3.

Second, substitute the values in the formula

$$\text{Number of particles} = \frac{1}{2} \times (6.02 \times 10^{23}) \times 3$$

Number of moles of H_2O

$$= 9.03 \times 10^{23}$$

Number of moles of atoms in 1 molecule of H_2O

So the number of atoms in ½ mol of water is 9.03×10^{23}.

4.

First, write down the formula:

$$\text{Number of moles} = \frac{\text{number of particles}}{\text{Avogadro's constant}}$$

Second, substitute the values in the formula

$$\text{The number of moles of } H^{+} = \frac{\text{number of particles}}{\text{Avogadro's constant}}$$

Number of H^+

$$= \frac{3.01 \times 10^{23}}{6.02 \times 10^{23}}$$

Avogadro's number

$$= 0.5$$

So the number of moles of hydrogen ions (H^+) present in 3.01×10^{23} of hydrogen ions is 0.5 moles.

Do not be disappointed if you did not get all of them correct! Keep on practicing, and you will improve.

Now let us review what we have done in this unit.

Unit summary

Summary

In this unit you learned about the characteristics of physical and chemical changes that occur in the world around us. You should now be in a better position to classify the changes around you as physical changes or chemical changes. You have also learned that solids, liquids and gases are the three states of matter, and that matter is anything that has a mass and occupies space. With knowledge about the characteristics of the three states of matter, you should now be able to explain the inter-conversion of the states of matter in terms of the kinetic theory. With the knowledge you have gained about the different separation techniques and their application, you should be able to use appropriate separation techniques to separate solid-solid mixtures; solid-liquid mixtures; and liquid-liquid mixtures.

In this unit you also learned about atoms, elements, molecules, compounds and mixtures, and their characteristics. You have also learned about the charge and relative mass of the sub-atomic particles (protons, electrons and neutrons). With knowledge of the atomic notation (which involves the symbol of the element, the proton number and nucleon number) you should be able to deduce the numbers of protons, neutrons and electrons in an atom. For those of you who are aiming for a higher mark, you should know how chemists measure the amount of substance using the mole concept as well. With the understanding of the mole and Avogadro's constant, you can now convert moles to mass of a substance, or mole to number of atoms or molecules, and vice versa using the appropriate formula.

We have now come to the end of Unit 2. I hope that you have enjoyed learning about *the elements of chemistry* and have clearly understood all the contents of this unit. Should you feel the need to review certain contents, please do so before you tackle Unit 3, entitled *The strengths of solids*. I hope that you will enjoy learning the contents of Unit 3.

Contents

Unit 3

The strengths of solids

Introduction

In this unit you will learn about how forces can alter the shape and size of an object. The unit is divided into the following topics; elasticity, uses and choice of materials, moments, scalar and vector quantities.

Outcomes

Upon completion of this unit you will be able to:

- *investigate* the relationship between the extension of a spring and the force applied to it.
- *state* Hooke's law.
- *explain* that the strength of solids is derived from the forces between their constituent atoms and molecules.
- *illustrate* the spring-like nature of forces by comparing the behaviour of materials under tension and compression with the behaviour of springs.
- *justify* why materials selected for a particular use has to depend upon the materials' properties.
- *prove experimentally* that equal and opposite forces acting on the same body may have a turning effect.
- *calculate* the turning effects (moment) of a force.
- *prove* experimentally that for a body to be in equilibrium both the forces and their turning effects (moments) must balance.
- *differentiate* between vector and scalar quantities.
- *represent* graphically two vector quantities and their resultant.

Terminology

Compression: The reduction of the volume or size of matter by applying pressure.

Effort: Force applied to a simple machine that produces an effect on a load.

Elasticity:	The ability of an object or substance to return quickly to its original size after being bent, stretched or compressed.
Equilibrium:	A static or dynamic state in which all forces or processes are in balance and there is no resultant change.
Extension:	Increase in size, due to application of a force
Force:	A physical influence that tends to change the position of an object with mass, equal to the rate of change in momentum of the object.
Lever:	A rigid bar that pivots about a point (fulcrum) and is used to move or lift a load at one end by applying force at the other end.
Moment or torque:	The turning effect of a force
Pivot/fulcrum:	The point or support about which a lever turns.
Scalar:	A physical quantity which has a magnitude (size) but has no direction
Tension:	A force that pulls or stretches a substance.
Vector:	A physical quantity which has both magnitude and direction.

How long?

Table 3.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	5 hours	2 hours and 30 minutes
Full-time student within the conventional school setting OR Part-time student	5 hours	2 hours and 30 minutes

Table 3.0: The time needed for you to work on this unit

Topic 3.1: Elasticity

How long?

You will need 1 hour and 20 minutes to complete this topic. It is advisable that you spend another 40 minutes of your own time to further review the topic.

A vital property of matter is their elasticity. This is the ability of matter to regain their original size and shape after being stretched or compressed. Materials vary in their degree of elasticity; hence some materials are more elastic than others.

In this topic you will learn more about the elasticity of matter. After studying the topic, and having completed the tasks and activities which follow, you should have a greater appreciation of the vast implications of elasticity in everyday life.

Activity

Activity 3.1.1

You should do this activity within 10 minutes.

- Take a rubber band and measure its length. Then, gently stretch the rubber band and release it as shown in the photographs below.

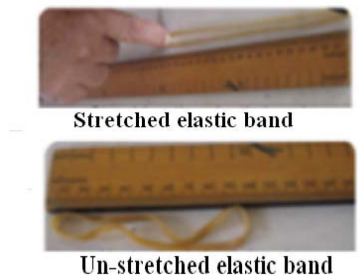


Figure 3.1.1: Measuring the length of a stretched and an un-stretched rubber band

Photo by: Mariette Lucas, March 2009

- Observe what happens to the elastic band. What do you notice?

____

____

- Repeat the activity, but this time use a spring instead. Compare your observations with what you observed when you stretched the elastic band

____

____

Feedback

Feedback to Activity 3.1.1

You should have noticed that the length of the elastic band and the spring increases (extends) when pulled and regains its original length when released.

The tasks you did above were about elasticity. **Elasticity** is the property of a material which causes it to extend (stretch) or compress when a force acts on it and to regain its original size and shape after the force is removed.

The catapult is an instrument which functions using elasticity.

Figure 3.1.2: A catapult

Photo by: Mariette Lucas, March 2009

Look carefully at the picture of the catapult above. What is the function of the elastic band in the catapult?

We are sure that you have figured out that the purpose of the elastic band is to provide energy to the catapult. When stretched, the elastic band stores energy which is then transferred to the catapult when the elastic band is released.

As you have seen the catapult is an example of where elasticity becomes useful. Bungee jumping is also an activity where elasticity is used. It involves jumping from a tall structure while being connected to a large elastic cord. The bungee jumper relies a lot on the elasticity of the rope. It is especially important that the elasticity of the rope is well calculated to avoid the jumper from hitting the ground or slowing down too quickly.

You have surely encountered several other instances where elasticity is applied in everyday life; give two examples of these.

We are sure that you might have thought of more than two examples. Some common day-to-day examples where we can observe the application of elasticity are: spring balances, chest expanders, trampoline, car suspensions, springs, car seats and others.

Activity

Activity 3.1.2

You should complete this activity within 30 minutes. You will now perform the following experiment to further understand the concept of elasticity.

- You need a ruler, a spring, a pointer, a mass hook or a plastic bag and five 100 g masses or five 1 N (newton) weights.
- Set up the equipment as shown in the diagram below.

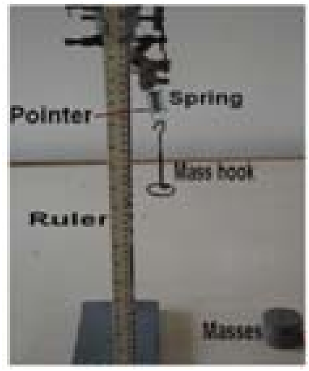


Figure 3.1.3: Set-up of experiment

Photo by: Mariette Lucas, March 2009

Note it! / Important!

You may use appropriate masses depending on the strength of your spring.

A load is a force. Force is measured in newton (N), mass is measured in kilogram (kg). A mass of 1kg will exert a force of 10 N.

- First, record the length of the spring indicated by the pointer in Table 3.1.1 below.
- Next, add the load of 1 N (or a mass of 100 g) to the spring and record the length of the spring shown by the pointer.
- Keep on adding 100 g masses and record the respective length each time.

Load (N)	Mass (g)	Length of spring (cm)	Extension of spring (cm)
0	0		
1	100		
2	200		
3	300		
4	400		

Load (N)	Mass (g)	Length of spring (cm)	Extension of spring (cm)
5	500		

Table 3.1.1: Length variation with load

To calculate the extension of the spring, you need to use the following relationship:

$$\boldsymbol{Extension\ = Length\ with\ load - Length\ without\ load}$$

Using the above relationship, three examples are given in the table below.

Load (N)	Mass (g)	Length of spring (cm)	Extension of spring (cm)
0	0	2	2 – 2 = 0
1	100	5.7	5.7 – 2 = 3.7
2	200	9.4	9.4 – 2 = 7.4

Table 3.1.2: Examples of how to calculate extension of the spring

Original length of spring

Note it! / Important!

Please note that in the calculations in the table above, the original length of the spring is 2 because when there is no load (weight/mass) on the spring the length of the spring is 2 cm. The original length of your spring may vary.

- Using your results, calculate the extension of the spring each time and record them in Table 3.1.1 above.
- Now that you have all the results, draw a line graph on the graph paper (Figure 3.3.1) below to show the **extension** against the **load**. The axes have been labelled for you but you need to decide on your own scale.

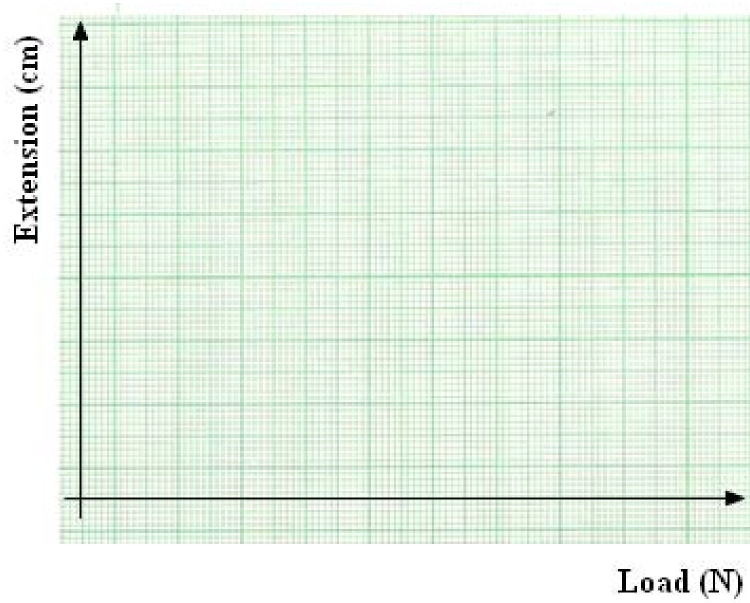


Figure 3.1.4: Graph to show the extension of spring against load

Scanned by: Rosianna Jules, June 2009

What conclusion can you draw from this experiment?

Feedback to Activity 3.1.2

You should have noticed that each time you added a load of one newton (or mass 100 g), the spring extended by the same amount. The way the spring behaves is governed by Hooke's law.

Now let us explain what Hooke's law is.

Hooke's law states that the *extension is directly proportional to the load* (force applied).

Extension $\propto$ load (force applied)

is the symbol for directly proportional

Certain solid materials follow a similar pattern when they are stretched or compressed. Normally when a material is gently stretched or compressed and then released, it will return to its original size and shape.

If you have access to the internet, take a look at this website of an animation of Hooke's law. http://www.learnerstv.com/animation/animation.php?ani=38&cat=physics

Please note again that we are providing this link only for information purposes and we do not endorse or recommend any links from the site.

What do we call this property of solids?

You are right! The property of a solid material that allows it to be gently stretched or compressed and return to its original size and shape when released is called elasticity.

You may have noticed that sometimes when you stretch an elastic material it does not return to its original shape or size. If you have not experienced this, get the small spring from an old pen and stretch it. You will notice that the spring does not return to its original shape. In other words, the spring is deformed.

Now let us explain what happens if you keep adding loads to the spring. If you continue to stretch or add loads to the spring, beyond a certain point, the spring will not obey Hooke's law. The spring will be damaged or deformed. The point at which the deformation starts is known as the elastic limit. This is shown by point X, on the graph below.

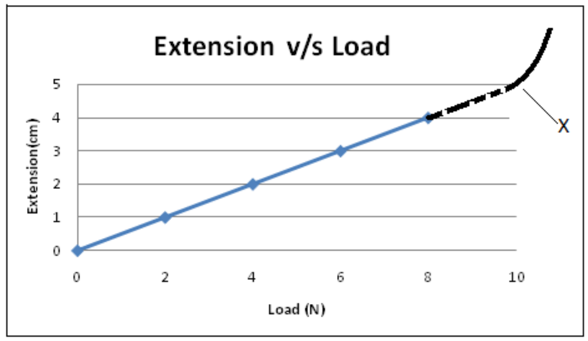


Figure 3.1.5: Graph showing elastic limit of a spring

Graph by: Ajith Bandara, March 2009

Now let us see how much you have understood about elasticity.

Assessment

Self-assessment 3.1

You should complete this self-assessment in less than 15 minutes. This self-assessment is based on Topic 3.1. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 3.1. This will help you learn and reflect better on areas for improvement.

1. Put in the missing words in the definition of elasticity:

Elasticity is the property of a material which causes it to _____________ (stretch) or compress when a _____________ acts on it and to regain its original size and _____________ after the force is _____________.

2. Tick the situation which is an example of an application of elasticity?

   A. Sitting on a wooden chair ☐

   B. Crushing marble chips ☐

   C. Using a bow and arrow ☐

   D. Chopping firewood ☐

3. State Hook's Law.

____

____

4. Use the graph below to answer the questions that follow.

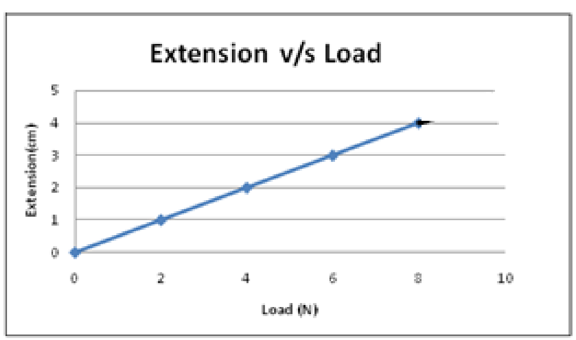


Figure 3.1.6: Graph showing extension of spring against load

Graph by: Ajith Bandara, March 2009

a. What is the extension of the spring for a load of 5 N?

b. What load would have caused the spring to extend by 3.5 cm?

c. The spring would reach elastic limit with a load of 10 N. Complete the graph to show the elastic limit of the spring. Use the letter X to indicate this.

Please refer to the Answers to Self-assessment 3.1 at the end of the topic below to verify your answers.

Answers to Assessment

Answers to Self-assessment 3.1

1. Elasticity is the property of a material which causes it to extend (stretch) or compress when a force acts on it and to regain its original size and shape after the force is removed.

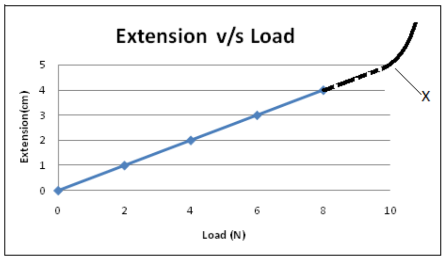
2. C

3. Hooke's Law states that: the extension is directly proportional to the load.

4. a) 2.5 cm

   b) 7 N

   c) The graph showing the extension of spring against load and elastic limit is given below



If you have access to the internet, take a look at the following video that explains Hookes' law. http://www.khanacademy.org/video/intro-to-springs-and-hooke-s-law?playlist=Physics

Again, please note that this link is provided for information only and we do not endorse any of the links that are associated from the site.

So far you have seen that elasticity is an important property of certain solid materials, but the materials can become deformed if too much force is applied to it. In the next topic you are going to learn how materials are chosen for different uses.

Topic 3.2: Uses and choices of materials

How long?

You will need 1 hour to complete this Topic. It is advisable that you spend another 30 minutes of your own time to further revision.

Materials have different properties and serve different purposes. Hence, we need to choose specific materials for certain jobs.

Now let us start by checking if you could make the right choice of material.

Between the following materials, which would be most suitable to make a knife: plastic, aluminium, soft iron or steel? Give reasons for your choice.

Now let us discuss the answer to the question above. As you know, a knife has to be strong, sharp and with a cutting edge that does not wear out fast. You must therefore have realized that steel is the best material for making knives.

So, suitable materials that we need to use for a particular job must possess advantageous properties in their elasticity, strength, thermal conductivity or electrical conductivity.

The strength of a solid is a factor which is of paramount importance for the making of tools. There are two main factors that affect the strength of a solid. These are the:

- **Molecular structure** as in diamond (natural) and in alloys (artificial); and
- **Design features** as in L-shaped iron girders or H-shaped iron girders.

In this unit we will focus on design features. You will have the opportunity to learn more about molecular structure in Unit 21: Materials and structures.

Activity

Activity 3.2.1

You should complete this activity in no more than 20 minutes.

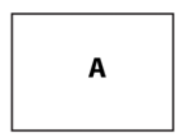
Through this activity you will learn the relationship between design features and the strength of structures.

You will need: two small identical empty cardboard boxes, such as empty juice boxes; one side of a shoe box, two 10 N weights; one pair of scissors; a ruler, and a pencil.

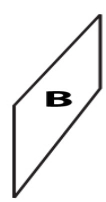
Procedure:

Step 1: Construction of the structure

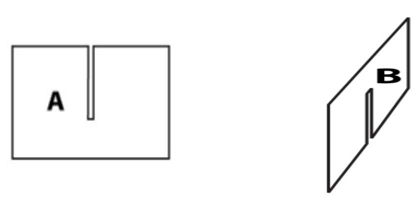
- First label your juice boxes as Box One and Box Two.
- Cut off one of the largest sides of Box One and Box Two.
- Measure the breadth and the height of side 1 of Box Two.
- Cut a piece of equal dimensions from the shoe box. Label it as A.



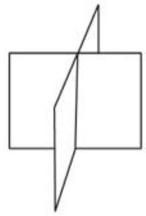
- Measure the length and the height of side 2 of Box Two.
- Cut a piece of equal dimensions from the shoe box. Label it as B.



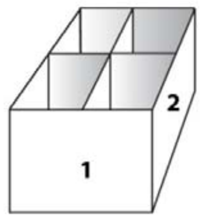
- Make a slit halfway along the length of A, from the edge to the centre. Repeat the same with B.



- Assemble A and B as shown below.



- Insert the assembled parts in Box Two as shown below.



All graphics for Step 1 by: Serge Mondon, June 2009

Designed by: Lionel Goonetilleke, June 2009

Step 2: The experiment

- Turn the open side of Box One and Box Two face down on a table.
- Place the 10 N weights one at a time on top of Box One and observe.
- Now remove the weights and place them one at a time on Box Two and observe what happens.

1. Write down your observations.

____

____

2. Using your observations, explain the relationship between design features and the strength of structures.

____

____

____

Well, we hope that you have enjoyed this task. Now check for the Feedback to Activity 3.2.1 for the expected observations. If your observations did not match up to those in the feedback, feel free to try the task again.

Feedback

Feedback to Activity 3.2.1

1. The box which had special support structures did not collapse while the box without the support structure collapsed.

2. The box which had special support structures did not collapse because the support structures gave additional strength to the box. This shows that we can strengthen structures by incorporating special design features.

In construction and packaging, special design features are used to give additional strength to structures such as buildings and packaging boxes. Some of these examples and types of special design features are shown below:

Figure 3.2.1: Structures with special design features

Photo by: Mariette Lucas, March 2009

Activity

Activity 3.2.2

You should be able to complete this activity in less than 15 minutes.

1. Look around you and make a list of five other structures with special design features. Draw or take pictures of any new design features that you find.

a. ______________________________

b. ______________________________

c. ______________________________

d.

e.

Insert your drawings or pictures here.

2. Look carefully at the different structures in Figure 3.2.1 above and those that you have found. What is each structure used for? List two intended purposes/jobs for which structures are made and the materials that are used to make these special structures on Table 3.2.1 below.

Intended Job	Material

Table 3.2.1: Materials used to make the special features for intended purposes

3. Draw lines to match each job with the most suitable material. Please note that one of the materials will not be used.

	Intended jobs/purposes	Material
A	Making a cutting tool such as a pair of scissors	Plastic
B	Packaging	Steel
C	Manufacturing nails	Copper
D	Manufacturing of lenses	Soft iron
E	Making the handle of a saucepan	Glass
F	Connecting wires in electric circuits	Paper

We hope you did not find the activity too hard to complete. Now refer to the feedback to verify your answers.

Feedback

Feedback to Activity 3.2.2

1. Some structures with special design features are bicycles, roofs, bridges, chairs, kites, and cars.
2. The answers will vary based on your answers to question number 1.
3. The answers are as follows:

A	Steel	D	Glass
B	Paper	E	Plastic
C	Soft iron	F	copper

Note it! / Important

Please note that you will learn further about what causes a material to be strong when you study the topic on molecular structures and alloys in a later unit in this course.

Topic 3.3: Moments

How long?

You will need 2 hours to complete Topic 3.3. It is advisable that you spend another 1 hour of your own time to further practice calculating moments.

Now you are going to learn about moments. The term **moment** may sound new to you, but it is a principle that you have been using in many of your day to day activities.

Activity

Activity 3.3.1

You should spend about 5 minutes on this activity.

Try to close a door by pushing near the hinge and further away from the hinge. (You may repeat the activity two or three times.) When was it easier to close the door? Why do you think so?

Feedback

Feedback to Activity 3.3.1

You should have realised that it was easier to close the door by applying the force further away from the hinge. When closing the door further away from the hinge you should have noticed that you used less force than when closing the door closer to the hinge.

We use **moment** when we close and open a door. The moment of a force depends both on the size of the force and how far it is applied from the **fulcrum** or **pivot**. The fulcrum or pivot is the point about which the lever turns. In other words, the fulcrum is the point about which the turning takes place. In the case of the door, the hinge is the fulcrum or pivot. You will learn about **lever** later in the Topic.

There are many other situations where moment is used. Using a key to lock or unlock a door, turning a door handle, using spanners to tighten or loosen a nut, turning the knob of a tap, turning a bicycle handle, turning the steering wheel of a car and the seesaw are examples where moment is in use.

Now consider the examples given above where moment is in use. What is common among these examples?

You are correct! What is common among all these examples mentioned is that they all involve turning. So, moment has a turning effect. You are now going to learn about the **turning effect** or the **moment of a force**.

The term **moment of a force** or the **turning effect** is measured by multiplying the force by the perpendicular distance of the line of action of the force from the fulcrum or pivot.

Moment is measured in newton metre (N m) and calculated as follows:

$$\textbf{Moment (Nm)} = \textbf{Force (N) x perpendicular distance (m)}$$

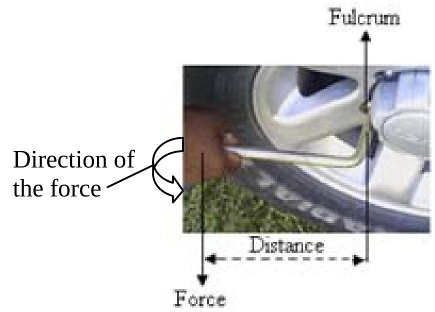


Figure 3.3.1: Loosening a nut on a wheel

Photo by: Michael Antoine, March 2009

Now let us calculate the moment of the force for the situation in Figure 3.3.1, if Joe is applying a force of 300 N to loosen the nut and at a distance of 0.3 m from the fulcrum.

The moment of the force is calculated as follows:

First, state the formula:

$$\text{Moment }\ (\text{N m}) = \ \text{Force (N) x perpendicular distance (m)}$$

Second, substitute the values:

$$\text{Moment }\ (\text{N m}) = \ 300\text{ N x }0.3\text{ m}$$
$$= 90\text{ N m } turning\ anti - clockwise$$

It is important to note that the moment also has a direction: it can be clockwise or anti-clockwise. For example, the tightening of a nut usually has a clockwise moment while the loosening of a nut is normally anti-clockwise.

For some more practice, let us consider a common example, such as the seesaw.

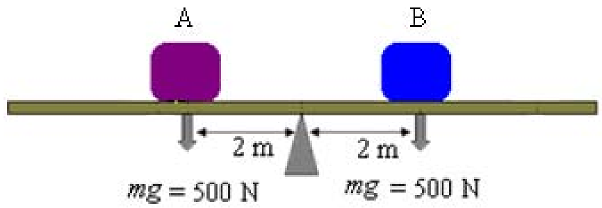


Figure 3.3.2: A seesaw

Graphics by: Rosianna Jules, June 2009

Note that *mg* represents weight which is the product of the mass (*m*) and the acceleration due to gravity (*g*) on the object. The value of *g* is 10 m/s^2 (read as 10 metres per second squared). You will learn more about these concepts in the unit 'Force and motion'.

Let us calculate the moment due to object B in Figure 3.3.2 above.

Remember: Formula first:

$$\text{Moment (N m)} = \text{Force (N) x perpendicular distance (m)}$$

Then substitute the values:

$$\text{Moment (N m)} = 500 \text{ N x } 2 \text{ m}$$
$$= 1000 \text{ N m } \textit{turning clockwise}$$

You will agree that calculating moment is not difficult as long as you remember the formula. Now it is your turn to practise calculating moments.

Activity

Activity 3.3.2

You should spend about five minutes on this activity.

Calculate the moment due to object A in the space provided.

Feedback

Feedback to Activity 3.3.2

From your working you should have noticed that the moment of object A is the same as that of object B. In other words, the magnitude (size) of the clockwise moment of object B is equal to the magnitude of the anti-clockwise moment of object A.

So when two objects of the same weight are placed at equal distance from the pivot (*provided the beam is uniform*—that is the beam balances at its centre) like in the example of the seesaw above, we say that it is balanced. This means that it is in equilibrium.

Note it! / Important!

Always remember that weight is a force.

Activity

Activity 3.3.3

You should spend no more than 20 minutes on this activity.

You will now try out an experiment to help you understand the **principle of moments** better.

Follow the steps to set up the apparatus as shown in the diagram below.

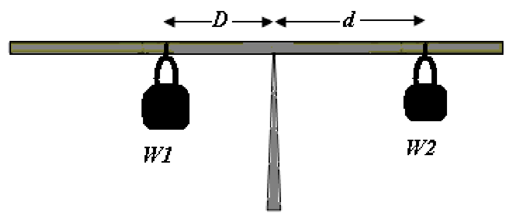


Figure 3.3.3: Set up to show the principle of moments

Graphics by: Rosianna Jules, March 2010

Steps:

1. Balance a meter ruler or better still a moment ruler at its centre.

Tip

If it doesn't balance, the ruler is not uniform. To correct that, add some plasticine on the lighter side. You may need to adjust the position of the plasticine.

2. Get two objects of different known masses, **W1** and **W2**.
3. Work out the weight of **W1** and that of **W2** using the equation:

$$weight = mass\ x\ acceleration\ due\ to\ gravity$$

$$W = mg$$

4. Draw a table as the one shown in Table 3.3.1 below and use it to record the weight of **W1** and **W2**.
5. Suspend **W1** on the left side of the ruler and **W2** on the right side.
6. Keeping **W1** stationary, move **W2** to bring the system to equilibrium.
7. Measure the distance from **W1** to the pivot and **W2** to the pivot and record your results on the table.

8. Now move **W1** closer to the pivot, and adjust **W2** to bring the system to equilibrium

9. Again, measure the distance from **W1** to the pivot and **W2** to the pivot and record your results on the table

10. You may repeat the experiment a few more times if you wish.

11. Calculate the clockwise and the anti-clockwise moment for each trial.

	Anti-clockwise			**Clockwise**		
Trial	**W1 (N)**	**Distance of W1 from pivot (m)**	**Moment (*W1* x *d*) (N m)**	**W2 (N)**	**Distance of W2 from pivot (m)**	**Moment (*W2* x *D*) (N m)**
1						
2						

Table 3.3.1: Record of experimental results to illustrate the principle of moments

Feedback

Feedback to Activity 3.3.3

From your experiment you should have noticed that when the system is in equilibrium the clockwise and the anti-clockwise moments are equal.

Now we are going to consider what happens when we have more than two forces in equilibrium.

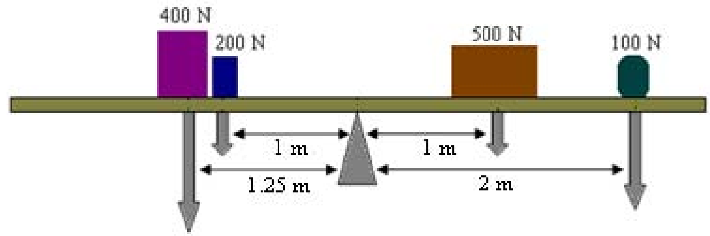


Figure 3.3.4: Diagram showing more than two forces in equilibrium.

Graphics by: Rosianna Jules, June 2009

According to the principle of moments, when an object is in equilibrium, the total clockwise moment is equal to the total anti-clockwise moment.

Total anti-clockwise moment = total clockwise moment

Now let us calculate the total clockwise and anti-clockwise moments for the situation in Figure 3.3.4.

At equilibrium,

the *total anti-clockwise moment = total clockwise moment*

Remember that, in order to calculate individual moment we need to use the formula:

$$\text{Moment (N m)} = \text{Force (N) x perpendicular distance (m)}$$

So by substituting the values, the total clockwise and anti-clockwise moments are calculated as follows:

$$(400\text{ N } x \text{ } 1.25\text{ m}) + (200\text{ N } x \text{ } 1\text{ m}) = (100\text{ N } x \text{ } 2\text{ m}) + (500\text{ N } x \text{ } 1\text{ m})$$

$$500\text{ N m} + 200\text{ N m} = 200\text{ N m} + 500\text{ N m}$$

$$700\text{ N m} = 700\text{ N m}$$

That was easy, wasn’t it? You can use the same principle of moments to calculate the unknown force or unknown distance of any system in equilibrium.

Now we will use the principle of moments to calculate an unknown force (weight). Consider the equilibrium system in Figure 3.3.5 below. Calculate the value of the force **A** acting on the system when the system is in equilibrium.

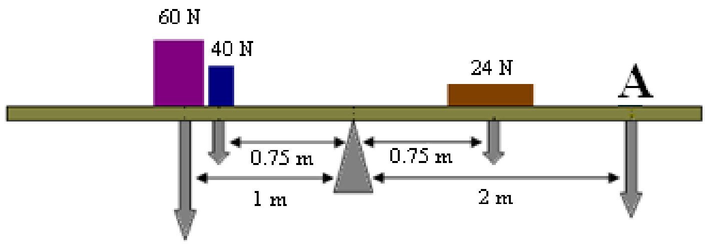


Figure 3.3.5: Diagram showing more than two forces in equilibrium.

Graphics by: Rosianna Jules, June 2009

Remember: at equilibrium,

total anti-clockwise moment = total clockwise moment

Step 1: work out the total clockwise and anti-clockwise moment using the formula:

$$\text{Moment } (\text{N m}) = \text{Force (N) x perpendicular distance (m)}$$

Step 2: By substituting the values we get:

$$(60\text{ N } x \text{ 1 m}) + (40\text{ N } x \text{ 0.75 m}) = (24\text{ N } x \text{ 0.75 m}) + (\text{A } x \text{ 2 m})$$

$$60\text{ N m} + 30\text{ N m} = 18\text{ N m} + (\text{A } x \text{ 2 m})$$

Step 3: Subtract 18 N m from both sides of the equation

$$90\text{ N m} - 18\text{ N m} = 30\text{ N m} - 18\text{ N m} + (\text{A } x \text{ 2 m})$$

$$72\text{ N m} = (\text{A } x \text{ 2 m})$$

Step 4: Divide both sides by 2 m. Note that the unit of distance (m) cancels out leaving the unit for force (N).

$$\frac{72\text{ N m}}{2\text{ m}} = \frac{(\text{A } x \text{ 2 m})}{2\text{ m}}$$

$$36\text{ N} = \text{A}$$

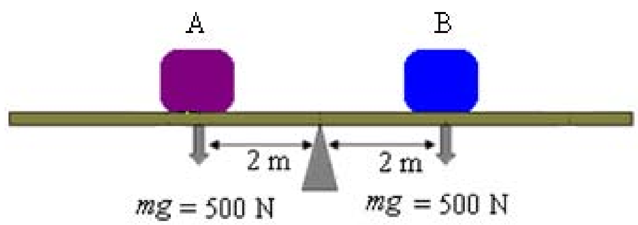
So the force exerted by **A** is 36N.

As we have mentioned earlier, you can use the same principle to calculate the perpendicular distance from the pivot to a force.

There are numerous applications of the principle of moments in our everyday life. The lever is one example of such applications. Let us now see how the principle of moments is applied in levers.

A lever is any device which can turn about a **pivot (fulcrum).** In a working lever, a force called the **effort** is used to overcome the resisting force, which we call the **load**.

The example of the seesaw given in Figure 3.3.2 earlier is one type of lever.



Copy of Figure 3.3.2 showing a seesaw

Graphics by: Rosianna Jules, June 2009

Activity

Activity 3.3.4

You should spend about 5 minutes on this activity.

- Consider that object **A** is exerting a downward force to bring about movement.
- Draw your own diagram to show this.
- Label the pivot, the load and the effort on your diagram.

Well, we hope that this small task was easy for you. Please refer to the Feedback to Activity 3.3.4 below for the expected answer.

Feedback

Feedback to Activity 3.3.4

Use the crowbar example below to evaluate your work.

The crowbar functions as a lever when we use it to move objects, as shown in the diagram below.

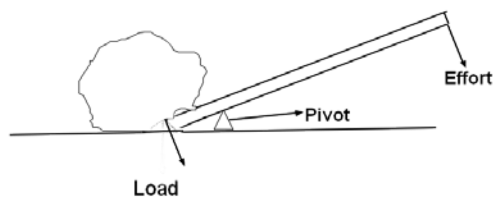


Figure 3.3.6: A crowbar functioning as a lever

Graphics by: Mariette Lucas, June 2009

It is possible to calculate the magnitude of any one of the quantities (effort, load, distance from pivot to load, and distance from pivot to effort), provided three of the quantities are given.

For example, to calculate the magnitude of the effort needed to move a rock (load) which weighs 600N, assuming that the distance from the pivot to the load is 0.5m and the distance from the pivot to the effort is 2m, as illustrated by Figure 3.3.6 below, the work would be as follows:

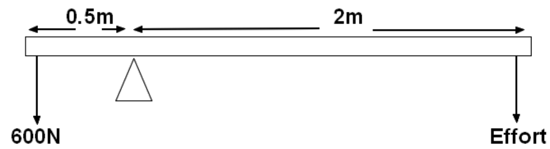


Figure 3.3.6: A lever

Graphics by: Rosianna Jules, June 2009

At equilibrium:

$$\text{Total clockwise moments} = \text{Total anti} - \text{clockwise moments}$$

$$Effort\ x\ distance\ 1 = load\ x\ distance\ 2$$

$$\text{Effort}\ x\ \ 2\ \text{m} = 600\ \text{N}\ x\ 0.5\ \text{m}$$

$$\frac{\text{Effort}\ x\ 2\ \text{m}}{2\ \text{m}} = \frac{300\ \text{N m}}{2\ \text{m}}$$

$$\text{Effort} = 150\ \text{N}$$

Now that you have learned about moments, it is time for you to test your understanding.

Assessment

Self-assessment 3.2

You should be able to complete this self-assessment in less than 25 minutes. This self-assessment is based on Topic 3.3. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 3.2. This will help you learn and reflect better on areas for improvement.

1. Give three examples where moment is used.

____

____

2. State the principle of moment.

3. What is a lever?

4. Use the principle of moments to calculate the missing values in the table below.

Anti-clockwise			*Clockwise*		
Weight *W1* (N)	Distance *d* (m)	Moment *(W1 x d)*	Weight *W2* (N)	Distance *D* (m)	Moment *(W2 x D)*
2	0.2	0.4	1	0.4	0.4
2	0.15		1		
2	0.1		1		

5. Figure 3.3.7 shows a rock that Jill is moving using a crowbar.

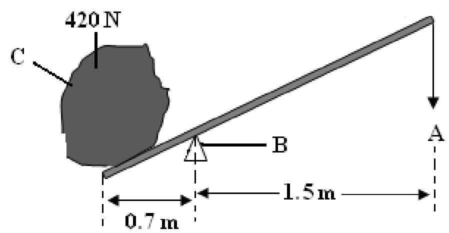


Figure 3.3.7: The rock Jill is moving with a crowbar

Graphics by: Rosianna Jules, October 2010

i. What device is the crowbar functioning as?

ii. What do the letters A, B and C stand for on the diagram?

A represents the

B represents the

C represents the

iii. What force should Jill apply at A to move the rock? Show the work in the space provided.

iv. If Jill is applying a force of 245 N, at what distance from the pivot should she apply the effort? Show the work in the space provided.

Well, we hope that this assessment was not too difficult for you. Please refer to the Answers to Self-assessment 3.2 at the end of the topic below to verify your answers. Don't be too disappointed if you did not manage to get all the correct answers. Just go back and review the topic again.

Answers to Assessment

Answers to Self-assessment 3.2

1. Some examples where moment is used include locking or unlocking a door lock, tightening or loosening a nut using spanners, turning a door handle, turning the knob of a tap, turning a bicycle handle, turning the steering wheel of a car and the seesaw.

2. The principle of moments states that when an object is in equilibrium, the total clockwise moment is equal to the total anti-clockwise moment.

3. A lever is any device which can turn about a pivot /fulcrum.

4. The underlined values are the missing values for the anti-clockwise and clockwise moments.

Anti-clockwise			***Clockwise***		
Weight *W1* (N)	Distance *d* (m)	Moment *(W1* x *d)*	Weight *W2* (N)	Distance *D* (m)	Moment *(W2 x D)*
2	0.2	0.4	1	0.4	0.4
2	0.15	0.3	1	0.3	0.3
2	0.1	0.2	1	0.2	0.2

5.

i. The crowbar functions as a lever.

ii. A represents the effort; B represents the fulcrum or pivot; C represents the load

iii. Jill should apply force of 196 N at A to move the rock. The work is shown below.

We use the principle of moment to find the unknown force, which is in this case the effort.

First, write down the principle of moment

At equilibrium:

$$\text{Total clockwise moments} = \text{Total anti} - \text{clockwise moments}$$

Second, write down the formula

$$Effort\ x\ distance\ 1 = load\ x\ distance\ 2$$

Third, substitute the known values

$$\text{Effort}\ x\ \ 1.5\ \text{m} = 420\ \text{N}\ x\ 0.7\ \text{m}$$

Fourth, divide both sides by 1.5 m (the perpendicular distance of the effort from the pivot to get the effort)

$$\frac{\text{Effort}\ x\ 1.5\ \text{m}}{1.5\ \text{m}} = \frac{294\ \text{N m}}{1.5\ \text{m}}$$

$$\text{Effort} = 196\ \text{N}$$

iv. Jill should apply the force at <u>1.2 m</u> from the pivot to move the rock. The work is shown below.

As mentioned in Topic 3.3.3, we can use the same principle of moment to find an unknown distance.

First, write down the principle of moment

At equilibrium:

$$\text{Total clockwise moments} = \text{Total anti} - \text{clockwise moments}$$

Second, write down the formula

$$Effort\ x\ distance\ 1 = load\ x\ distance\ 2$$

Third, substitute the known values

$$245\ \text{N}\ x\ \ \text{distance}\ 1 = 420\ \text{N}\ x\ 0.7\ \text{m}$$

Fourth, divide both sides by 245 N (the effort Jill is applying to move the rock)

$$\frac{245\ \text{N}\ x\ \ \text{distance}\ 1}{245\ \text{N}} = \frac{294\ \text{N m}}{245\ \text{N}}$$

$$\text{distance}\ 1 = 1.2\ \text{m}$$

We have now come to the end of topic 3.2. Can you recall what you learned about moments? If you are trying to use a stick as a lever to lift something, where should you be pushing? When working to understand all of these concepts, it helps to relate it to everyday occurrences.

What do you know about quantities in relation to physics? Can you think of any that you know? Let's take a look at scalar and vector quantities in the next section.

Topic 3.4: Scalar and vector quantities

How long?

You will need 40 minutes to complete Topic 4. It is advisable that you spend another 20 minutes of your own time to further review this topic.

The physical quantities used in science are divided into two classes: **scalar** and **vector** quantities.

3.4.1 Scalar quantities

A **scalar** quantity is a physical quantity which has a size (magnitude) but it has no direction. Here we are concerned only about how small or large the quantity is, and not about the direction.

One example of a scalar quantity is time.

Distance is another scalar. Suppose you walk a distance of 80m from your house to your neighbour's house, the direction is irrelevant. You can reach your neighbour's house along any route.

Speed is also a scalar. If you walked at a speed of 2m/s to reach your neighbour's house, it took you 40s for you to reach your neighbour's house.

$$\textbf{Speed} = \frac{distance}{time}$$

Speed is dependent on distance and time as shown above. Both distance and time are scalars which makes speed a scalar.

Some other examples of scalar quantities are mass, temperature, and volume.

3.4.2 Vector quantities

A vector is a quantity that has both magnitude and direction.

Displacement is a vector quantity. Displacement refers to a distance travelled in a particular direction. It has a magnitude (the distance travelled/moved) and a direction for the movement. Therefore, displacement has a magnitude as well as a specific direction and hence is a vector quantity.

Velocity is also a vector quantity. Velocity is the distance travelled per unit time, or the rate of change of position, or the rate of displacement. You will learn more about velocity in the unit 'Motion'.

A vector can be represented by a straight arrow drawn to scale. The straight line represents the magnitude and the arrowhead gives the direction.

Say for example a force of 10 N is applied towards the East. This can be represented by a straight arrow drawn to scale, where 1cm represents 2 N. Hence, the length of the arrow is 5 cm pointing in the easterly direction.

10 N

3.4.3 Adding forces

Sometimes we need to add two or more forces to find their effect or resultant force. Scalar quantities are added by ordinary mathematics as shown by the example below:

For example, a mass of 100 g and a mass of 50 g when added will result in 150 g as shown below.

$$100\ \mathrm{g} + 50\ \mathrm{g} = 150\ \mathrm{g}$$

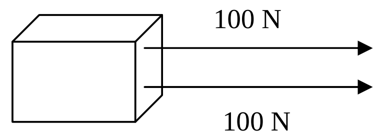
Vector quantities are added geometrically, taking account of their directions as well as their magnitude or size.

3.4.4 Adding vectors

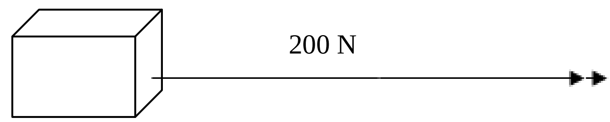
Normally in real life situations, more than one force acts on an object. Sometime the forces act in the same direction, sometimes in the opposite directions or even in different directions. Vectors can be added algebraically to determine the overall effect, which is known as the resultant vector.

3.4.4.1 Forces acting in the same direction

Consider a girl and a boy pulling a box with equal force of 100 N each as shown below.



The resultant vector is $100\ \text{N} + 100\ \text{N} = 200\ \text{N}$



Please note that the resultant vector is represented by a straight line with two arrowheads as shown above.

Note it! / Important!

3.4.4.2 Forces acting in the opposite direction

For example, when you sit on a chair, your weight acts downwards and the chair pushes upwards with a force equal to your weight. Since you remain at rest, the two forces must be equal in magnitude but opposite in direction as shown in the diagram below.

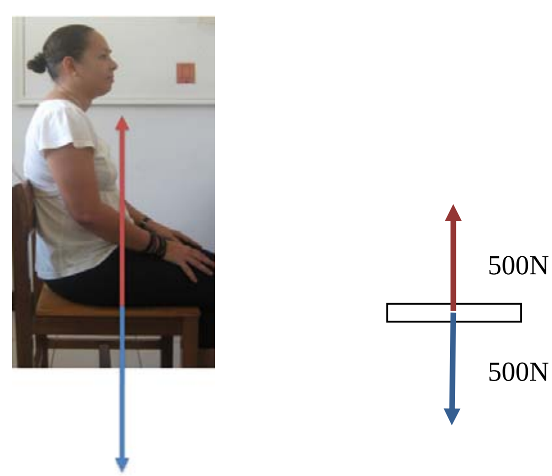


Figure 3.4.1: Illustrating forces acting in opposite direction

Photo of Carole Jacques sitting by: Rosianna Jules, June 2009

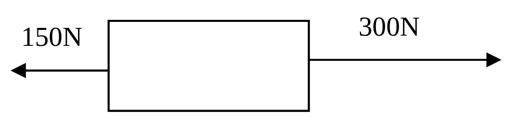
Calculating the resultant force is calculating the difference between the forces, so we use subtraction.

The resultant vector is $500 \text{ N} - 500 \text{ N} = 0 \text{ N}$

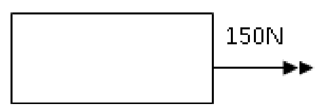
Note it! / Important!

Please note that for equal forces acting in opposite direction, the resultant force is always 0 N.

Now, let us try an example for unequal forces acting in opposite direction.



The resultant vector is $300 \text{ N} - 150 \text{ N} = 150 \text{ N}$ due East. This is illustrated as:



We think that you will agree that these calculations are very simple. Now it is you turn to practise calculating the resultant vectors and to test your understanding of Topic 3.4.

Assessment

Self-assessment 3.3

You should complete this self-assessment which is based on Topic 3.4 within 15 minutes. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 3.3. This will help you learn and reflect better on areas for improvement.

1. What is a scalar quantity?

2. List two scalar quantities.

3. Some quantities are listed here: volume, time, displacement, temperature, velocity, force. Underline the vector quantities.

4. State the difference between a scalar quantity and a vector quantity.

5. Figure 3.4.2 represents three friends playing tug of war. Please note that the vectors are not drawn to scale. Jim and Sarah are pulling towards the East while Sam is pulling towards the West.

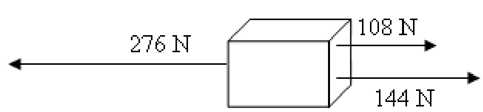


Figure 3.4.2: Diagram representing a tug of war

Graphics by : Rosianna Jules, October, 2010

a. Who won the tug of war?

b. Why do you say so?

c. Draw a diagram, using the scale of 1cm: 12 cm, to represent the resultant force.

Answers to Self-assessment 3.3

1. A scalar quantity is a quantity which has magnitude but it has no direction.

2. Some examples of scalar quantities are length, mass, temperature, time, volume, speed.

3. Volume, time, displacement, temperature, velocity, and force.

4. A scalar quantity has magnitude, whereas a vector quantity has both magnitude and direction.

5.

a. Sam won the tug of war.

b. Because the resultant vector is 24 N due West (Sam's side).

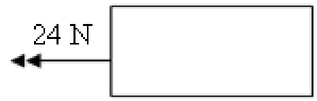
The resultant vector for Jim and Sarah (pulling in the same direction) is:

$$144 \text{ N} - 108\text{N} = 152 \text{ N}$$

The resultant vector for the tug of war is

$$276 \text{ N} - 152 \text{ N} = 24 \text{ N due West}$$

c. You diagram should look similar to that below.



You should have drawn a straight line that is 2 cm long (ratio of 1cm: 12 cm) with two arrowheads due West.

Unit summary

Summary

In this unit you learned that elasticity is the property of a material which causes it to extend (stretch) or compress when a force acts on it and to regain its original size and shape after the force is removed. You have also learnt that Hooke's law for extension states that the extension is proportional to the load. You will now have realized that elasticity has various useful applications in our day to day life and that if the material is stretched beyond its elastic limit, it will be deformed. You should also be able to choose appropriate materials for specific purposes and explain the importance of special design features in strengthening materials.

You have also learned about moment, the moment of a force and the application of moments in our everyday life. You should now be able to use the principle of moment which state that at equilibrium, the total anti-clockwise moment = total clockwise moment, to calculate unknown forces or distances in an equilibrium system.

Furthermore, you have also learned that quantities can be scalar, like time and speed, or vector like displacement. Vector quantities have both a magnitude and a direction while scalar quantities have only magnitude. You should now be able to calculate the resultant vector for forces acting in the same or opposite directions.

If you think that you have not grasped all these concepts, please go back and review as necessary. We hope that you have enjoyed this unit. All the best with the remaining units.

Contents

Unit 4

Atoms, Bonding and the Periodic Table

Introduction

In Unit 2 you learned that elements are arranged in the Periodic table and that atoms are made of sub-atomic particles: protons, neutrons and electrons. In this unit you are going to learn how electrons are arranged in shells around the nucleus of the atoms. You will also learn how elements can achieve stability by forming ionic or covalent bonds with other elements and illustrate these bond formations by using the 'dot and cross' diagrams. Finally, you will have the opportunity to determine the formula of compounds or molecules using either the valency of the atoms or ions involved, or the compound's composition by mass.

Upon completion of this unit you will be able to:

Outcomes

- *explain* that, in the Periodic Table, the elements are arranged in order of proton number;
- *define* the terms groups and periods;
- *explain* how the electrons in an atom are arranged;
- *draw* the diagrammatic representation of the first 20 elements of the Periodic table;
- *explain* how the arrangement of elements in the Periodic Table are done in terms of atomic structure;
- *explain* the relationship between the group number and the number of outer electrons;
- *discuss* the significance of the noble gas electronic structure;
- *use* symbols of elements to write formulae of simple compounds when given a list of symbols and combining powers;
- *work out* chemical formulae using the composition by mass;
- *describe* the term covalent bond;

- *explain* how molecules are formed;
- *explain* the relationship between the number of bonds formed by an atom in a molecule and its atomic structure;
- *describe* how ions are formed;
- *describe*, with reference to simple examples, how atoms turn into ions.

Terminology

Anions:	Anions are negatively charged ions formed by the gain of electrons.
Bond:	The strong electrical force of attraction between the atoms or ions in the structure.
Cations:	Cations are positively charged ions formed by the loss of electrons.
Covalent bond:	The bond formed between non-metals by the sharing of electron pair(s).
Duplet configuration:	The first shell is completely-filled with its 2 electrons.
Ionic bond:	The bond formed by the complete transfer of electrons from a metal atom to non-metal atom.
Ions:	Ions are positively and negatively charged particles formed by the loss and gain of electrons respectively.
Isotopes:	Isotopes are atoms of the same element with the same proton (atomic) number but different mass (nucleon) number.
Octet configuration:	An electronic configuration where the outermost shell is complete with 8 electrons.
Periodic Table:	The Periodic Table is an arrangement of elements in order of their atomic number.
Stable electronic configuration:	An electronic configuration where the outermost shell has a duplet or octet configuration.

How long?

Table 4.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	6 hours	3 hours
Full-time student within the conventional school setting OR Part-time student	6 hours	3 hours

Table 4.0: The time needed for you to work on this unit

Topic 4.1: The Periodic Table

How long?

You will need 30 minutes to complete this Topic. It is advisable that you spend another 15 minutes of your own time to further review the topic.

In Unit 2, *The Elements of Chemistry*, Topic 2.3, you learnt that each element has a particular chemical symbol and that these elements are arranged in the Periodic Table. During the 19^{th} century, many chemists have tried to arrange the elements according to different criteria. The most successful attempt was from the Russian, Dimitri Mendeleev, who published a Periodic Table in 1869 which now forms the basis of the modern Periodic Table.

In this topic, you are going to learn about:

- how the elements are arranged in the Periodic Table;

- **groups** and **periods** and;
- the alternative names given to the different groups of elements.

If you have access to the internet, try taking a look at the following link that gives you information on individual elements as well as the various trends of the periodic table.

http://www.teachersdomain.org/asset/lsps07_int_graphperiodic/

Please note again that we are providing this link for information only. We do not endorse or recommend any links from this page.

4.1.1 The arrangement of elements in the Periodic Table

The Periodic Table is an arrangement of elements in terms of the increasing order of their proton number, which as you will recall, is also known as the 'atomic number'. This arrangement relates to both the physical properties and the chemical properties of the elements. Because of this relationship, the Periodic Table is divided into **periods** and **groups** (see Figure 4.1 below).

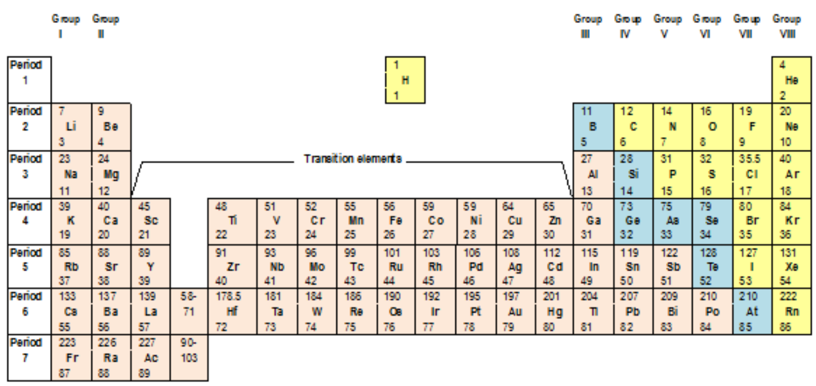


Figure 4.1.1: The Periodic Table of elements

Now let us see what **periods** and **groups** are.

4.1.1.1 Periods

A **period** is the horizontal row of elements in the Periodic Table. There are 7 periods in the Periodic Table.

- Period 1 contains only two elements: hydrogen and helium.
- Periods 2 and 3 contain eight elements and are known as the short periods.
- Periods 4, 5, 6 and 7 contain between 18 and 32 elements and are known as the long periods.

All elements in the same period have the same number of shells. As you move from one element to the next, from left to right across the period:

- the atomic number of the successive element increases by one. For example, in period 2 starting from the left, Lithium has an atomic number of 3, its successive element, Beryllium has an atomic number of 4, and Boron which follows has an atomic number of 5.
- the number of electrons in the outer shell of each successive element also increases by one.

This regular increase in the number of electrons from one element to the next leads to a rather regular pattern of change in the chemical properties of the elements across a period. For example:

i. the metallic properties of the elements decrease as we move from left to right across the Periodic Table; and

ii. the ability of elements to reduce other elements and compounds decreases while their oxidizing ability increases as we move from left to right across the Periodic Table. (You will learn about reduction and oxidation later on in the course.)

4.1.1.2 Groups

A group is the vertical column of elements in the Periodic Table. All the groups are numbered, except the groups of transition metals. The groups are numbered using Roman numerals (I, II, III, IV, V, VI, VII, and VIII). Group VIII is also known as group zero (0). Some groups also have alternative names given to them as listed in the Table 4.1.1 below.

Group number	Alternative names
I	The Alkali metals
II	The Alkali earth metals

Group number	Alternative names
VII	The Halogens
VIII or 0	The Noble gas or Inert gases

Table 4.1.1: The groups and their alternative names

Elements in the same group have the same number of electrons in their outer shells and similar chemical properties.

You will learn about group properties later in Unit 7 but as you go on, it is important to understand the trends you observe in the periodic table. Always think about the reason behind a particular element being located at that place in a periodic table. If you do this, it will help you understand the periodic table better.

In Topic 4.2 which follows, you are going to learn about the arrangement of electrons in an atom.

Topic 4.2: The Electronic Structure of Atoms

How long?

You will need 1 hour and 20 minutes to complete this Topic. It is advisable that you spend another 40 minutes of your own time to further review the electronic structure of atoms.

As you have seen in Unit 2, Topic 2.3, atoms are made of three sub-atomic particles: protons, electrons and neutrons. You also learned that the electrons in an atom are arranged in a series of shells or energy levels. In this topic you will learn:

- how the electrons are distributed in the shells of an atom;
- how to represent the structure of atoms diagrammatically;
- how to write the electronic configuration of atoms, and
- the relationship between the position of the element in the Periodic Table and the electronic configuration.

4.2.1 Diagrammatic representation of atoms

By convention or as a standard rule, the shells of electrons are shown as concentric circles. These circles correspond to the region where an electron would most likely be situated.

The shells are designated by the letters K, L, M, N, O, P and Q. Each shell can take a maximum number of electrons. The maximum number of electrons in the first four shells is shown as shown in Table 4.2.1 below.

Shell number	Shell name	Maximum number of electrons
1	K	2
2	L	8
3	M	18
4	N	32

Table 4.2.1: Maximum number of electrons per shell for the first four shells

Generally one shell must be filled with its maximum number of electrons before electrons can occupy the next shell. The first shell, shell K, is filled first. When a shell is filled with its maximum number of electrons, it is called a complete shell.

The distribution of electrons in the shells of an atom is referred to as the electronic structure or electronic configuration or electronic arrangement. The distribution of electrons can also be represented diagrammatically or numerically.

In order to draw the electronic structure of an atom, you need to know the proton number of the atom so that you can get the number of electrons in the atom. Figure 4.2.1 below illustrates the electronic structure of hydrogen and fluorine atoms diagrammatically and numerically.

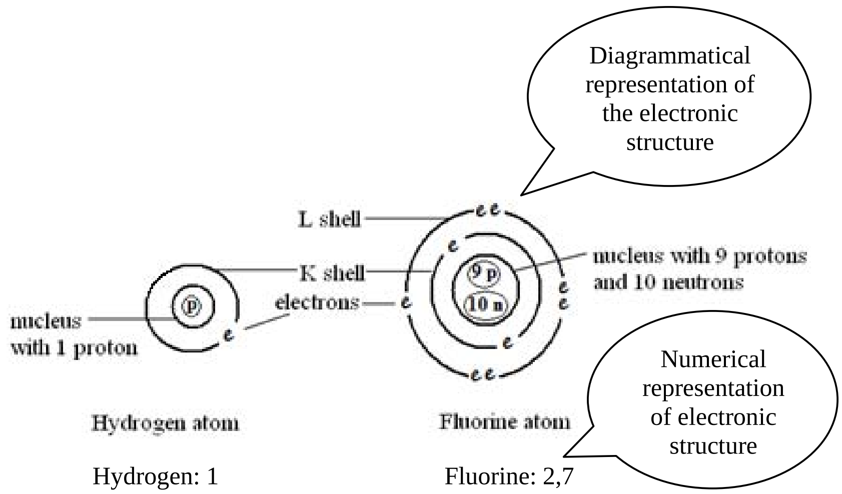


Figure 4.2.1: The atomic arrangement of hydrogen and fluorine atoms

Graphics by: Rosianna Jules, July 2010

Note it! / Important!

Please note that:

1. usually, when drawing the atomic structure of an element, an electron is represented by a dot (●) or cross (×) instead of the (ē);

2. the electronic configuration shows the distribution of electrons in the shells of an atom. Hence, when drawing the electronic structure of an atom it is often not required to show the composition of the nucleus (number of protons and number of neutrons); and

3. in the numerical representation of the electronic structure:

   a. the first number denotes the number of electron(s) in the first shell, the second number denotes the number of electron(s) in the second shell and so on; and

   b. each shell is separated by a comma.

Now it is your turn to practise drawing and writing the electronic configuration of the first 20 elements. Activity 4.2.1 will also help you to recapitulate the names and symbols of the first 20 elements.

Activity

Activity 4.2.1

You should spend about 15 minutes on this activity.

Figure 4.2.2a below shows the first 20 elements of the Periodic Table. *(Please note that Figure 4.2.2a is not an actual drawing of the full Periodic Table. It is drawn this way for convenience).*

Follow the pattern for hydrogen and helium to complete Figure 4.2.2a below with:

- a the missing name of the elements;
- b the missing symbol;
- c the missing electronic diagram to show the distribution of electrons; and
- d the missing electronic configuration.

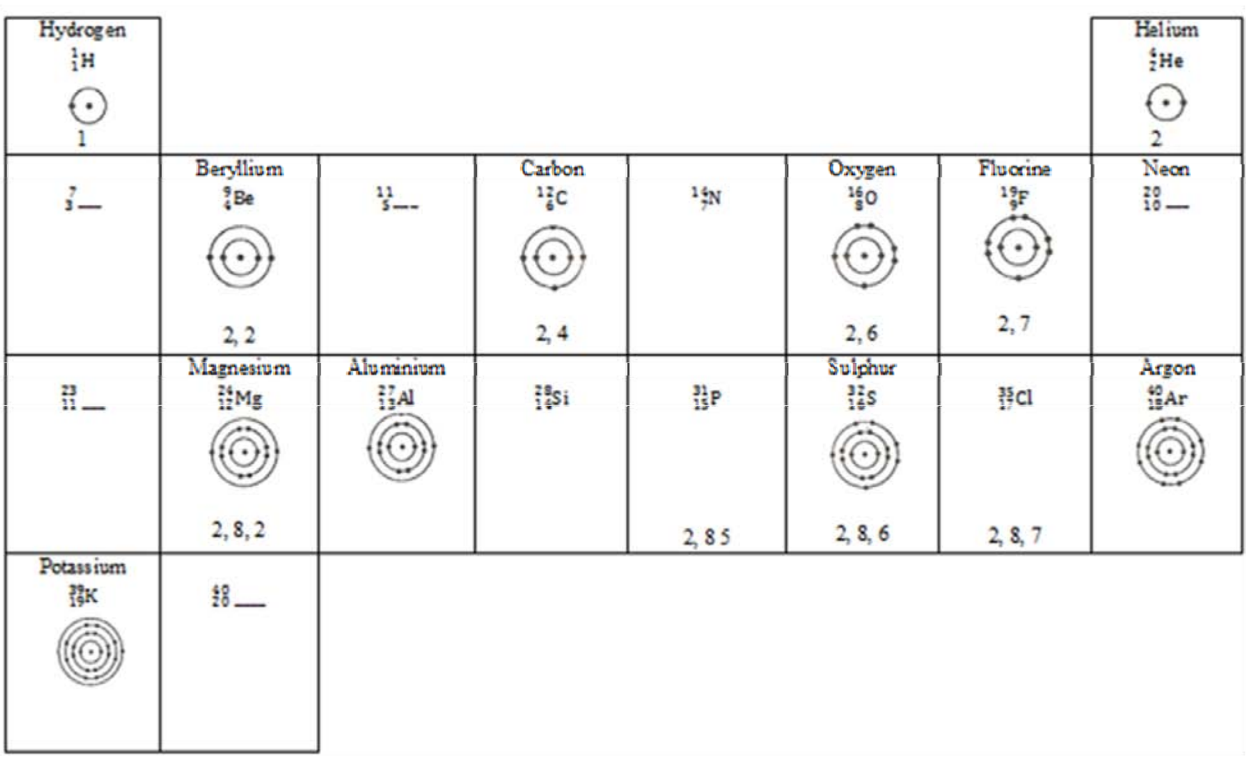


Figure 4.2.2a Periodic Table for you to complete the electronic configuration of the first 20 elements.

Graphics by: Rosianna Jules, July 2010

I hope this was straight forward for you. Please use Feedback to Activity 4.2.1 at the end of the topic to verify your answers.

4.2.2 The relationship between the position of the element in the Periodic Table and its electronic configuration

By knowing the proton (atomic) number of an element and the maximum number of electrons that each shell can hold, you can easily deduce the electronic configuration (electronic arrangement or electron distribution) of the element.

From the electronic configuration of an element you can easily deduce the position of the element in the Periodic Table. The group is indicated by the number of electrons in the **outer shell** or the **valence shell** (often referred to as the **outermost shell**) of the element. The period is indicated by the number of shells in which the electrons are distributed.

Now let us consider hydrogen, fluorine and calcium with the proton number 1, 9 and 20 respectively. Here are their electronic configurations: hydrogen 1, fluorine 2, 7 and calcium 2, 8, 2.

Now let us explain what each of these electronic configuration means. Let us start with hydrogen, followed by fluorine and calcium.

Hydrogen: 1

This means that hydrogen has only 1 electron in its first shell. Hence, hydrogen is in Group I (because of the single electron in the outermost shell) and in Period 1 (because the electron occupies only 1 shell).

Fluorine: 2, 7

This means that fluorine has 2 electrons in the first shell, and 7 electrons in the second shell (the valence shell). This implies that fluorine is in Group VII (because of the 7 electrons in the outermost shell) and in Period 2 (because the electrons occupy 2 shells).

Calcium: 2, 8, 2

This means calcium has 2 electrons in the first shell, 8 in the second and 2 in the third shell (the valence shell). So Calcium is in Group II (because of the 2 electrons in the outermost shell) and in Period 3 (because the electrons occupy 3 shells).

Now let us summarise this information in Table 4.2.2.

Element	Atomic number	Electronic configuration	Group	Period
Hydrogen	1	1	1	1
Fluorine	9	2, 7	7	2
Calcium	20	2, 8, 2	2	3

Table 4.2.2: The relationship between the electronic configuration and the position of the element in the Periodic Table

Feedback to Topic 4.2

Feedback

Feedback to Activity 4.2.1

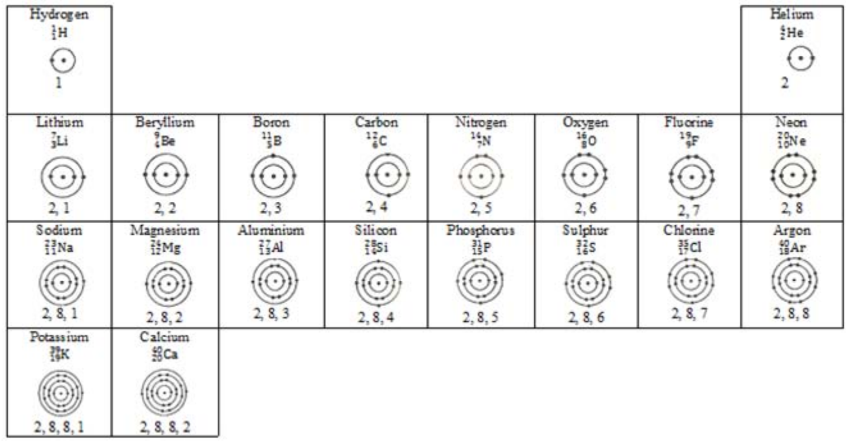


Figure 4.2.2b: The electronic arrangement and configuration of the first 20 elements

Graphics by: Rosianna Jules, July 2010

Now that you know about electronic configuration, in the next topic you are going to learn what happens to the electrons in the valence shell during chemical combination, i.e., when elements react together.

Topic 4.3: Chemical Bonding

How long?

You will need 2 hours and 20 minutes to complete this Topic. It is advisable that you spend another 1 hour and 10 minutes of your own time to further review chemical bonding.

The number of electrons in the outer shell (or the number of valence electrons) allows us to deduce the stability of the element and the type of reaction that the element will undergo to obtain a stable (full) outer shell of electrons. In this topic you are going to learn about:

- the stability of Group VIII (8) elements;
- ionic bonding;
- covalent bonding; and
- metallic bonding

We will start off with the stability of the rare gases.

4.3.1 Stability of rare gases

Elements in group VIII are known as the **rare gases**, the **noble gases** or the **inert gases**. Group VIII elements are known as the inert gases because they are **stable**.

Activity

Activity 4.3.1

You should spend about 5 minutes on this activity.

Based on your knowledge of electron distribution, why do you think the elements in group VIII are said to be stable?

You are right! The elements in group VIII are stable because they have completely-filled outermost shells. In other words, the valence shell of noble gases is complete with its maximum number of electrons. Table 4.3.1 shows how electrons are distributed in the shells or energy levels of the rare gases.

Group VIII (Rare gases)	Proton number	Electron distribution					
		K	L	M	N	O	P
Helium	2	2					
Neon	10	2	8				
Argon	18	2	8	8			
Krypton	36	2	8	18	8		
Xenon	54	2	8	18	18	8	
Radon	86	2	8	18	32	18	8

Table 4.3.1: The distribution of electrons in the energy levels of the rare gases

Apart from the rare gases, all other elements are unstable because they have an incompletely-filled valence shell. Unstable elements usually bond with each other to obtain stability. By contrast, because of their complete outermost (valence) shell, group VIII elements do not take part in chemical reactions.

We are now going to learn about bonding.

4.3.2 Bonding

Unstable elements or elements that do not possess a duplet or an octet configuration can acquire stability (a complete outer shell) either by:

1. the transfer of electrons (gaining or losing electrons) or
2. the sharing of electrons.

During the process of obtaining stability, the reacting atoms develop some kind of attraction between them. This attraction is referred to as bonding. So, the term **bond** refers to the strong electrical force of attraction between the atoms or ions in the structure.

There are **3 main types** of bonding. These are:

1. ionic bonding;
2. covalent bonding; and
3. metallic bonding.

If you have access to the internet, take a look at this site to get a visual idea of what an ionic bond and a covalent bond is.

http://www.mhhe.com/physsci/chemistry/animations/chang_7e_esp/bom1s2_11.swf

Please note again that we are providing the link for information only and we do not recommend or endorse any of the links from the site.

Now let us look at each type of bonding. We will start off with ionic bonding.

4.3.2.1 Ionic bonding

An **ionic bond** or **electrovalent bond** is formed when one or more electrons are completely transferred from the outer shell of a metal atom to the outer shell of a non-metal atom.

Normally, metals with 1, 2 or 3 electrons in their outer shells donate (give away) their electrons to become stable. On the other hand, non-metals with 5, 6 or 7 electrons in their outer shell, gain (accept) 3, 2 or 1 electrons respectively to become stable.

It is easier for metals to donate their electrons because less energy is required to lose 1, 2, or 3 electrons rather than to gain 7, 6 or 5 electrons. Similarly, less energy is needed to gain 3, 2 or 1 electron(s) rather than to lose 5, 6 and 7 electrons.

Atoms which donate their electrons become positively charged. Atoms which gain (accept) the electrons become negatively charged. The positively and negatively charged particles are called **ions**. A positively charged particle is called a **cation** and a negatively charged particle is called an **anion**. Table 4.3.2 shows the ions formed by elements in groups I, II, III, VI, V and VII.

<table>
<tr><th>Elements</th><th>Number of valence electrons</th><th>Electron transfer (loss (-); gain (+))</th><th>Charge acquired</th><th>Ions formed</th><th>Type of ions</th></tr>
<tr><td>Lithium (2, 1)
Sodium (2, 8, 1)
Potassium (2, 8, 8, 1)</td><td>1</td><td>-1 ē</td><td>+1</td><td>Li^+
Na^+
K^+</td><td rowspan="3">CATIONS</td></tr>
<tr><td>Beryllium (2, 2)
Magnesium (2, 8, 2)
Calcium (2, 8, 8, 2)</td><td>2</td><td>-2 ē</td><td>+2</td><td>Be^{2+}
Mg^{2+}
Ca^{2+}</td></tr>
<tr><td>Aluminium (2, 8, 3)</td><td>3</td><td>-3 ē</td><td>+3</td><td>Al^{3+}</td></tr>
<tr><td>Nitrogen (2, 5)
Phosphorous (2, 8, 5)</td><td>5</td><td>+3 ē</td><td>-3</td><td>N^{3-}
P^{3-}</td><td rowspan="3">ANIONS</td></tr>
<tr><td>Oxygen (2, 6)
Sulphur (2, 8, 6)</td><td>6</td><td>+2 ē</td><td>-2</td><td>O^{2-}
S^{2-}</td></tr>
<tr><td>Fluorine (2, 7)
Chlorine (2, 8, 7)</td><td>7</td><td>+1 ē</td><td>-1</td><td>F^-
Cl^-</td></tr>
</table>

Table 4.3.2: Ions formed by elements in groups I, II, III, VI, V and VII

Later in the course you will also learn how ions are formed during electrolysis.

Now you are going to carry out an activity to check your understanding.

Activity

Activity 4.3.2

You should spend approximately 10 minutes on this activity.

Based on your knowledge about an atom:

1. Briefly describe why:

   a. an atom which loses electrons becomes a positively charged ion.

___

___

___

   b. an atom which gain electrons becomes a negatively charge ion.

___

___

___

2. What are cations and anions?

Cations are: ___

Anions are: ___

That must have been quite easy for you. Use Feedback to Activity 4.3.2 below to verify your answers.

Feedback

Feedback to Activity 4.3.2

1. As you have seen in Unit 2, protons are positively charged and electrons are negatively charged. Therefore:

   a. atoms which donate their electrons become positively charged because their ions have more protons than electrons.

   b. atoms which gain (accept) the electrons become negatively charged because their ions have more electrons than protons.

2. Cations are positively charged ions, and anions are negatively charged ions.

Now, let us consider the ionic bonds formed during the formation of sodium chloride and calcium chloride.

Example 4.3.2.1.1: Formation of sodium chloride

Each sodium atom has an unstable electronic configuration of 2, 8, and 1. To become stable with an electron arrangement of 2 and 8, a sodium atom loses 1 electron to a chorine atom to form a positively charged sodium ion, Na^+.

On the other hand, each chlorine atom also has an unstable electronic configuration of 2, 8, and 7. To obtain the stable electron arrangement of 2, 8, and 8, a chlorine atom gains 1 electron from a sodium atom to become a negatively charged chloride ion, Cl^-.

The oppositely charged particles are attracted to each other by strong electrostatic forces (attraction) to form an ionic bond. The compound formed is called sodium chloride and has the formula NaCl.

Dot and cross diagrams showing only the outer electrons are used to illustrate the formation of ionic and covalent bonds. Figure 4.3.1 below illustrates the bond formation in sodium chloride

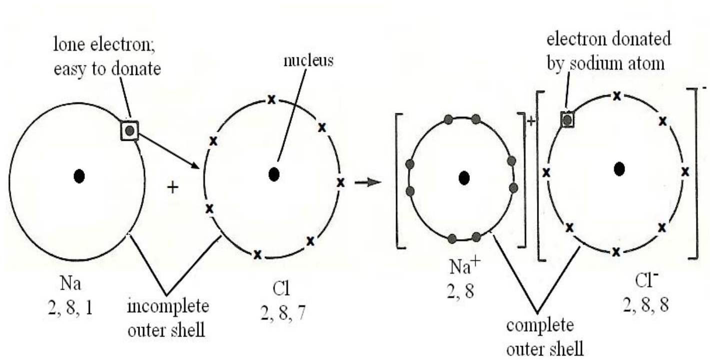


Figure 4.3.1: Bond formation in sodium chloride

Graphics by: Rosianna Jules, September 2010

The equation for this reaction is as follows:

$$\mathrm{Na} - \bar{e} \rightarrow \mathrm{Na}^{+}$$

$$\mathrm{Cl} + \bar{e} \rightarrow \mathrm{Cl}^{-}$$

$$\therefore \mathrm{Na} + \mathrm{Cl} \rightarrow \mathrm{Na}^{+}\mathrm{Cl}^{-}$$

Because equal numbers of positive and negative charges cancels out each other, you can write the formula as NaCl.

Sodium chloride is a giant structure of ions. Sodium chloride has a regular pattern which is called a crystal. A sodium chloride crystal consists of a regular arrangement of equal numbers of sodium ions and chloride ions. This arrangement is called a lattice. Each sodium ion (Na^{+}) is surrounded at equidistant by 6 chloride ions (Cl^{-}). The same is true for the chloride ions: each chloride ion is surrounded at equidistant by 6 sodium ions. Figure 4.3.2 shows the sodium chloride lattice.

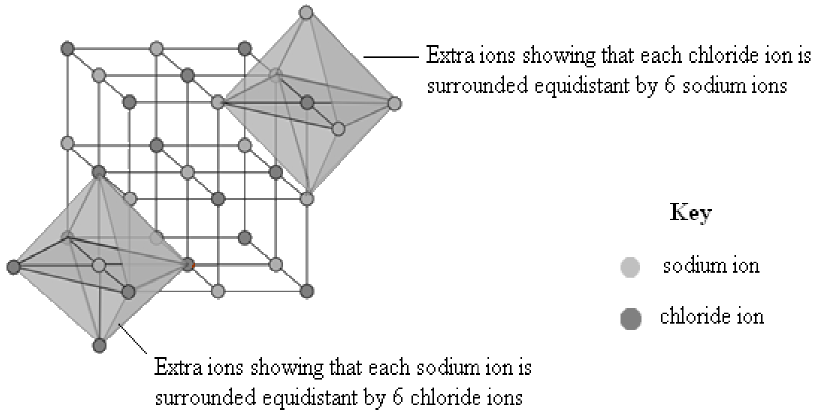


Figure 4.3.2: Sodium chloride lattice

Source: Adapted from **http://en.wikipedia.org/wiki/Nacl**

Adapted by: Rosianna Jules, July 2010

Note it! / Important!

Please note that:

1. boron does not form ions.
2. an ionic bond is formed by the complete transfer of electrons. It is completely wrong to say that the atoms swap electrons.
3. dot and cross diagrams are used to illustrate bond formation. Both dots and crosses represent electrons.
4. when drawing dot and cross diagrams, the electrons from the same type of atom are represented by the same symbol: either by dots or by crosses. For example, you should represent the electrons from two chlorine atoms either by dots or by crosses, not both.
5. to make the dot and cross diagrams simpler, only the outer electrons are drawn. However, you should always remember that the electrons in the inner shells are still there.

Now let us consider our second example: the formation of calcium chloride.

Example 4.3.2.1.2: Formation of calcium chloride

Calcium atom has an unstable electronic configuration of 2, 8, 8,and 2. So each calcium atom loses the 2 outer electrons to 2 chlorine atoms to form a positively charged calcium ion, Ca^{2+}, with a stable arrangement of 2, 8, and 8.

For each calcium atom, 2 chlorine atoms are needed because chlorine has an unstable electron arrangement of 2, 8, and 7 (a chlorine atom can accept only 1 electron). By gaining 1 electron, the chlorine atoms become negatively charged chloride ions, Cl^-, with a stable electron arrangement of 2, 8, and 8. Figure 4.3.3 illustrates the formation of calcium chloride by dot and cross diagrams.

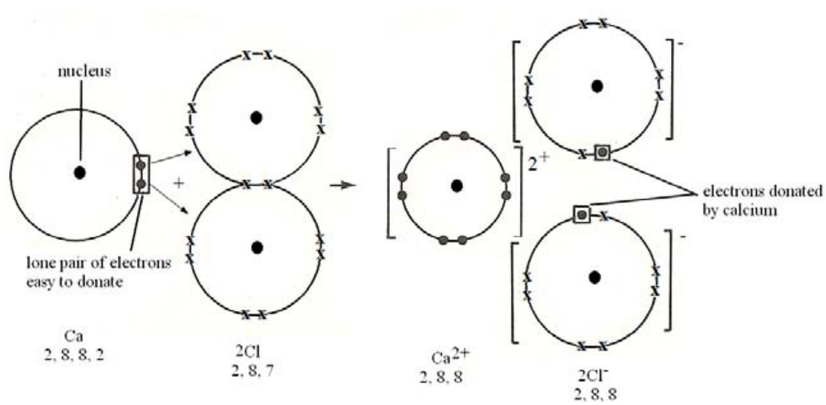


Figure 4.3.3: The formation of calcium chloride

Graphics by: Rosianna Jules, September 2010

The equation for this reaction is as follows:

$$Ca - 2\bar{e} \rightarrow Ca^{2+}$$

$$2Cl + 2\bar{e} \rightarrow 2Cl^-$$

$$\therefore Ca + 2Cl \rightarrow Ca^{2+}2Cl^-$$

As you have seen, equal numbers of positive and negative charges cancels out each other, therefore the formula is written as $CaCl_2$.

Now it is your turn to practice some dot and cross diagrams.

Activity

Activity 4.3.3

You should spend approximately 15 minutes on this activity.

In the space below draw dot and cross diagrams to illustrate the formation of the following ionic compounds. Write the equation for each reaction.

a. Magnesium oxide

b. Sodium oxide

c. Aluminium chloride

I hope that you have found the task easy to complete. Now use Feedback to Activity 4.3.3 at the end of the topic to verify your answers.

Do not be disappointed if you got any of the questions wrong. Just go through the material again and keep on practising.

In this sub-topic we have seen that ionic bonds are formed by the complete transfer of valence electrons between metals and non-metals. We are now going to learn about covalent bonding and the formation of covalent bonds.

4.3.2.2 Covalent bonding

Covalent bonds are formed between non-metals. Non-metals are elements in groups IV, V, VI and VII. Covalent bonding occurs when non-metals share the electrons in their outer shell to achieve stability. So, atoms which have 4, 5, 6 or 7 electrons in their outer shells, share 4, 3, 2, or 1 electrons, respectively.

Note it! / Important!

Please note the following:

Each pair of electrons shared between two atoms results in the formation of a covalent bond between the atoms.

1. If two atoms share 1 pair of electrons, then a single covalent bond is formed between them, like in a hydrogen, H_2, molecule. The single bond in the H_2 (read as H two) molecule is shown as $H - H$.

2. If two atoms share 4 electrons (2 pairs), then a double covalent bond is formed between the atoms, like in the case of an oxygen molecule. The double bond in O_2 molecule is shown as $O = O$.

3. If two atoms achieve a stable octet configuration by sharing 3 pairs of electrons, then a triple covalent bond is formed between them, as in the case of a nitrogen molecule. The triple bond in N_2 is shown as $N \equiv N$.

Now let us illustrate the formation of covalent bonds by using dot and cross diagrams. For our examples, we shall consider the formation of a hydrogen molecule, a carbon dioxide molecule, and a water molecule.

Example 4.3.2.2.1: Formation of hydrogen molecule

Hydrogen is a very unstable element with only 1 electron in its shell. Two hydrogen atoms can achieve stability (obtain a full shell) by sharing a pair of electrons, bringing in one electron from each hydrogen atom. The pair of electrons shared between the two hydrogen atoms results in a single covalent bond between the two atoms.

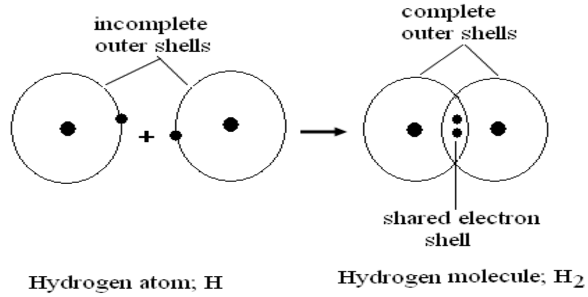


Figure 4.3.4: Formation of hydrogen molecule, H_2

Graphics by: Rosianna Jules, September 2010

Example 4.3.2.2.2: Formation of water molecule

Each water (H_2O, read as: H - two - O) molecule is formed by the sharing of electrons between hydrogen and oxygen. 2 atoms of hydrogen share 2 electrons (1 electron each) with 1 oxygen atom to form a water molecule. Two single covalent bonds are formed in each water molecule.

Because hydrogen and oxygen exist as gas molecules, 2 hydrogen molecules are needed to react with 1 oxygen molecule to form 2 molecules of water as shown in Figure 4.3.5 below.

Note it! / Important!

Please note that all common gases, such as oxygen, hydrogen, chlorine, and nitrogen, exist as molecules formed by covalent bonding (or the sharing of electrons). So during chemical combination or chemical reaction, these common gases will participate as molecules.

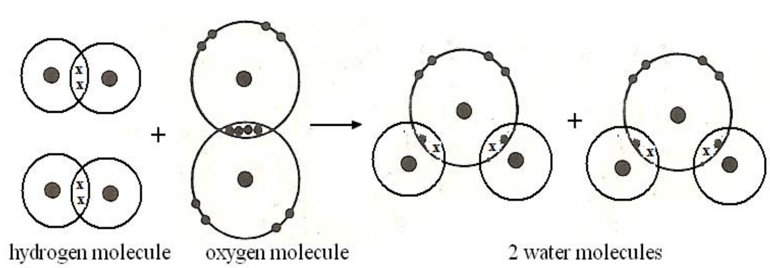


Figure 4.3.5: Formation of water molecules

Graphics by: Rosianna Jules, September 2010

Example 4.3.2.2.3: Formation of a carbon dioxide molecule

Carbon atoms and oxygen atoms have an unstable electronic configuration of 2, 4 and 2, 6 respectively. To achieve stability, 1 carbon atom shares its 4 valence electrons with 2 oxygen atoms (1 oxygen molecule). So each oxygen atom shares 2 electrons with 2 electrons from the carbon atom as shown in Figure 4.3.6. Two double covalent bonds are formed in each carbon dioxide molecule.

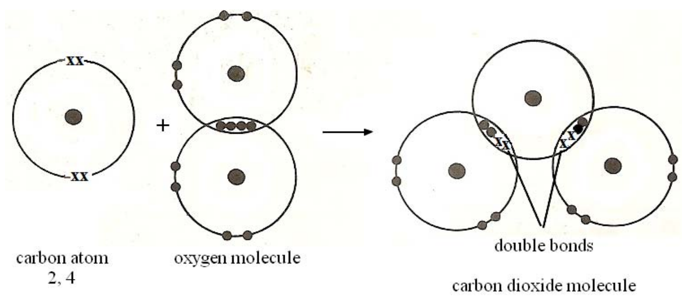


Figure 4.3.6: Formation of carbon dioxide molecule

Graphics by: Rosianna Jules, September 2010

Now as you may expect, it is your turn to practice.

Activity

Activity 4.3.4

You should spend about 15 minutes on this activity.

In the space provided:

1. draw dot and cross diagrams to show the covalent bond formation for the following molecules;
2. briefly describe how the bond(s) is formed and state the number of bond(s) formed in each molecule.

a. Nitrogen molecule (N_2)

b. Chlorine molecule (Cl_2)

c. Methane molecule (CH_4)

I hope that this exercise was very easy for you. Refer to the Feedback to Activity 4.3.4 at the end of the topic to verify your answers.

Remember, practice makes perfect!

Covalent bonds are also found in large molecules referred to as macromolecules such as sugars, proteins and plastics. You will learn about macromolecules later in this course.

So far you have seen that ionic bonds are formed between metals and non-metals and covalent bonds are formed between non-metals. Now you are going to learn about metallic bonding which is found in metals.

4.3.2.3 Metallic bonding

Metallic bonds are found only in metals. All metals consist of a closely-packed regular arrangement of positive ions, which are surrounded by a 'sea' of electrons. The regular arrangement of positive ions accounts for why metals are crystalline solids.

Positive ions repel each other. Metallic bonding is the force of attraction between two positive ions and the delocalised electrons (free electrons or 'sea' of electrons) between them. This explains why metallic solids:

1. are good conductor of electricity;
2. are good conductors of heat; and
3. are malleable and ductile (can easily be bent or hammered into shape)

Now let us look in more detail why metals conduct electricity and heat and why metals are malleable and ductile.

1. Electric current is the flow of electrons. Metals can conduct electricity because they possess free electrons which move through the lattice carrying negative charges as illustrated in Figure 4.3.7.

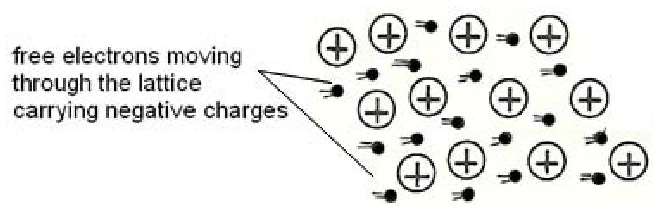


Figure 4.3.7: Free electrons carrying negative ions

Graphics by: Rosianna Jules, September 2010

2. Metals conduct heat because of the rapid random movement of the mobile electrons within the metal lattice as shown in Figure 4.3.8.

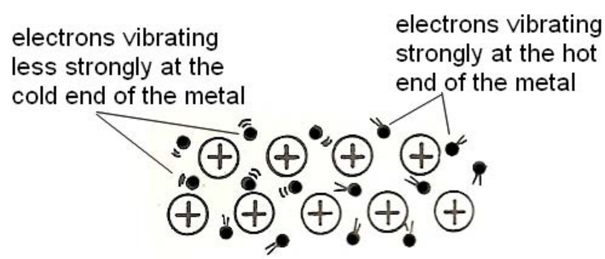


Figure 4.3.8: Illustration of the conduction of heat in metals

Graphics by: Rosianna Jules, September 2010

3. Metals are malleable and ductile because when force is applied on the metal, the layers in the lattice can slide past each other without breaking the metallic bonds which hold the metal together as shown in Figure 4.3.9.

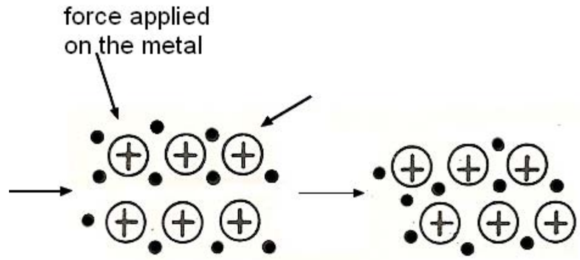


Figure 4.3.9: Malleability of metals

Graphics by: Rosianna Jules, September 2010

4.3.3 The properties of ionic, covalent and metallic bonds

The properties of ionic and covalent compounds differ considerably. Table 4.3.3 shows the differences in the properties of ionic, covalent and metallic bonding.

Ionic bonding	Covalent bonding	Metallic bonding
Ionic bonding results in the formation of giant structures. They consist of an aggregate (a collection) of ions arranged in a crystalline lattice. They may be in powdered form like calcium carbonate (CaCO3).	Covalent boding can form either: molecular structures, e.g. hydrogen molecule and methane which may exist as discrete molecules; macromolecules, e.g. proteins, starch, and plastics; or giant structures, e.g. silicon dioxide. Some solid covalent compounds like sugar	Metallic bonding form giant structures e.g. copper, lead

Ionic bonding	Covalent bonding	Metallic bonding
	exist as crystals.	
Ionic compounds are usually solids at room temperature.	Covalent compounds are usually gases or volatile liquids at room temperature. However, a few covalent compounds, such as sugar and naphthalene, are solids at room temperature	They form crystalline solids. This is because of the regular arrangement of particles in the structure.
Ionic compounds have high melting and boiling points.	Covalent compounds normally have low melting and boiling points.	They have high density. This is because their ions are closely packed.
Ionic compounds conduct electricity when molten or in an aqueous solution.	They do not conduct electricity with the exception of hydrochloric acid (HCl) and ammonia (NH3).	Metallic bonding results in good conductors of electricity. This is because the sea of electrons can move throughout the structure.
They are normally soluble in water and insoluble in organic solvents such as benzene and ether. For example, sodium chloride (table salt) is soluble in water but insoluble in oil. (You can try that at home for yourself). Some compounds such as copper oxide, and calcium carbonate are insoluble.	They are normally insoluble in water but soluble in organic solvents. Ethanol is an exception because it is soluble in water.	

Table 4.3.3: The differences in the properties of ionic, covalent and metallic

bonds

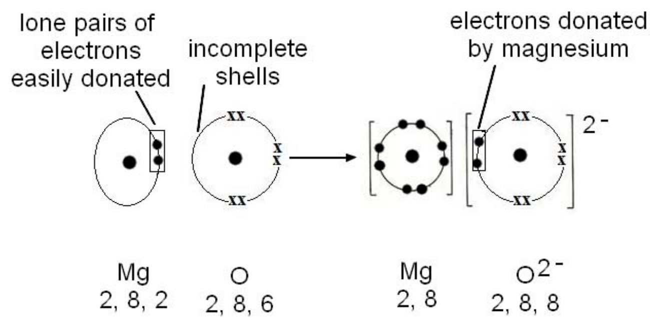
Now that you know about ionic, covalent and metallic bonding, let us learn how to work out the chemical formula using different chemical combinations.

Feedback to Activity 4.3.3 and Activity 4.3.4

Feedback

Feedback to Activity 4.3.3

a. Ionic formation of magnesium oxide



Graphics by: Rosianna Jules, September 2010

The equation for this reaction is as follows:

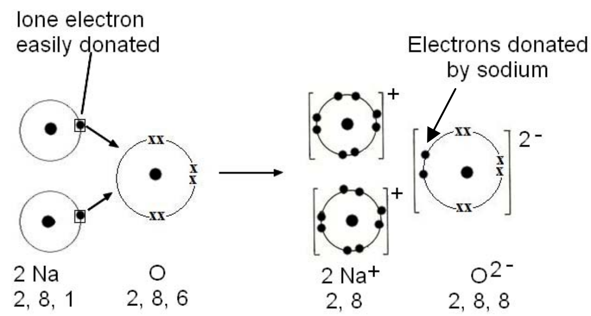
$$\mathrm{Mg} - 2\mathrm{e}^- \rightarrow \mathrm{Mg}^{2+}$$

$$\mathrm{O} + 2\mathrm{e}^- \rightarrow \mathrm{O}^{2-}$$

$$\therefore \mathrm{Mg} + \mathrm{O} \rightarrow \mathrm{Mg}^{2+}\mathrm{O}^{2-}$$

Because the numbers of positive and negative ions are equal, the formula can be written as MgO.

b. Ionic formation of sodium oxide



Graphics by: Rosianna Jules, September 2010

The equation for this reaction is as follows:

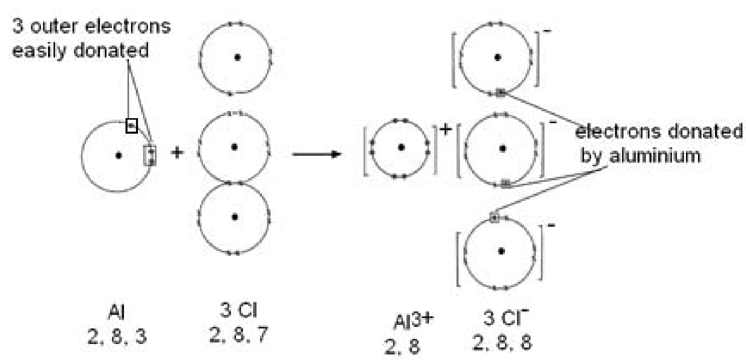
$$2\text{Na} - 2\text{e}^- \rightarrow 2\text{Na}^+$$

$$\text{O} + 2\text{e}^- \rightarrow \text{O}^{2-}$$

$$\therefore 2\text{Na} + \text{O} \rightarrow 2\text{Na}^+\text{O}^{2-}$$

Because the numbers of positive and negative ions are equal, the formula can be written as NaO.

c. Ionic formation of aluminium chloride



Graphics by: Rosianna Jules, September 2010

The equation for this reaction is as follows:

$$\text{Al} - 3\text{e}^- \rightarrow \text{Al}^{3+}$$

$$3\ \text{Cl} + 3\text{e}^- \rightarrow \text{Cl}^-$$

$$\therefore \text{Al} + 3\ \text{Cl} \rightarrow \text{Al}^{3+} 3\ \text{Cl}^{-}$$

Because the numbers of positive and negative ions are equal, the formula can be written as $AlCl_3$.

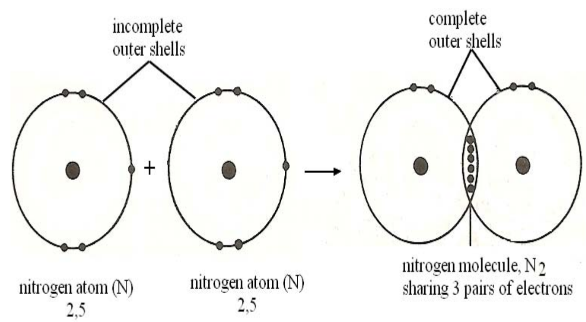
Feedback

Feedback to Activity 4.3.4

Use the dot and cross diagrams below to verify your answers.

a. Nitrogen molecule (N_2)

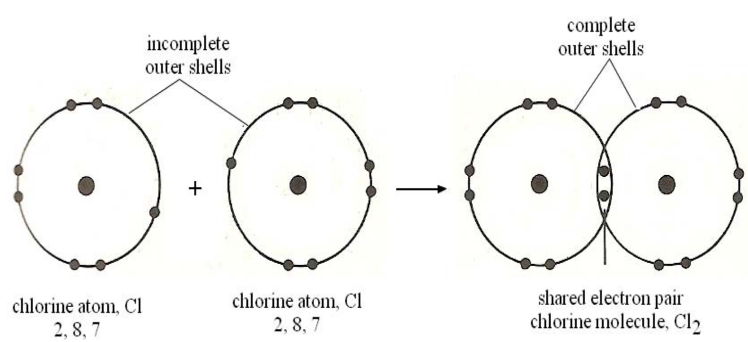
2 nitrogen atoms share 3 electrons each to obtain a stable octet configuration. The 3 pairs of electrons result in a triple bond between them.



Graphics by: Rosianna Jules, September 2010

b. Chlorine molecule (Cl_2)

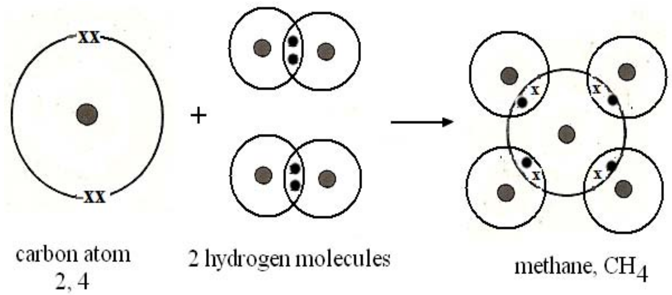
2 chlorine atoms share 1 electron each to achieve a complete outer shell. A single bond is formed between them.



Graphics by: Rosianna Jules, September 2010

c. Methane molecule (CH_4)

In the formation of methane, 1 carbon atom shares its four electrons with 4 hydrogen atoms (2 hydrogen molecules). Four single bonds are formed in each molecule of methane.



Graphics by: Rosianna Jules, September 2010

We are now at the end of topic 4.3. Reflect back on what ionic and covalent bonds are. Can you provide some examples of each? In your day to day life, where would you find ionic bonds? How about covalent bonds?

In the next topic we will learn how to represent these combinations of atoms through what is called a chemical formula.

Topic 4.4: Chemical Formulae

How long?

You will need 2 hours and 50 minutes to complete this Topic. It is advisable that you spend another 1 hour and 25 minutes of your own time to further review this section on chemical formulae.

In this topic you are going to learn about:

- the combining power of an atom or ion
- how to write chemical formulae; and
- how to work out the chemical formula of different chemical combinations.

4.4.1 The combining power of an atom or ion

By knowing the combining power of an atom, you can easily work out the chemical formula of any compound or molecule.

The combining power of an atom normally relates to the valency of the atom (before it is combined) or the valency of its ion (the charge on its ion). Table 4.4.1 shows the formula of some common ions.

Positive ions (cations)			Negative ions (anions)		
+1	+2	+3	-1	-2	-3
Hydrogen H^+	Magnesium Mg^{2+}	Aluminium Al^{3+}	Chloride Cl^-	Oxide O^{2-}	Nitride N^{3-}
Sodium Na^+	Calcium Ca^{2+}		Bromide Br^-	Sulphate SO_4^{2-}	Phosphate PO^{3-}
Potassium K^+	Copper Cu^{2+}		Nitrate NO_3^-	Carbonate CO_3^{2-}	
Ammonium NH_4^+	Lead Pb^{2+}		Hydroxide OH^-	Sulphide S^{2-}	
Silver Ag^+	Zinc Zn^{2+}		Permanganate MnO_4^-	Dichromate $Cr_2O_7^{2-}$	

Table 4.4.1: The formula of some common ions

As you already know, elements in group IV do not form ions. Hence, Carbon and Silicon, as atoms, have a combining power (valency) of 4.

Now let us look at how to write a chemical formula.

4.4.2 How to write a chemical formula

The chemical formula of a compound or a molecule consists of 2 or more elemental symbols written in close proximity to one another. The metal atoms or the positive ions are always written first, followed by the non-metal atoms or negative ions.

The combining power of the atoms or ions of each element in the formula of a compound or a molecule, is indicated by a subscript after the symbol of that particular atom or ion.

For compounds which contain complex ions like NH_4^+ (ammonium), SO_4^{2-} (sulphate), NO_3^- (nitrate) and CO_3^{2-} (carbonate), each complex ion is written as a single unit. When more than one unit of these ions are present in a compound, the unit is written in brackets and the number of units is written as a subscript.

Three chemical formulae and the particles present in each molecule or compound are given in Table 4 4.2 below:

Name of compound/molecule	Formula of compound/molecule	The particles present
Water	H_2O	2 hydrogen atoms + 1 oxygen atom
Sugar	$C_6H_{12}O_6$	6 carbon atoms +12 hydrogen atoms + 6 oxygen atoms
Calcium chloride	$CaCl_2$	1 calcium ion +2 chloride ions
Magnesium nitrate	$Mg(NO_3)_2$	1 magnesium ion + 2 nitrate ions

Table 4.4.2: Some chemicals, their formulae and the particles present

Now, before you learn how to work out the chemical formula of some compounds or molecules, let us check your understanding so far.

Activity

Activity 4.4.1

You should spend about 10 minutes on this activity.

Complete the table below with either the name, chemical formula, or the particles present in the compounds or molecules.

Name of compound/molecule	Formula	The particles present
Sodium oxide	Na_2O	
		1 calcium ion + 2 hydroxide ions
Carbon dioxide		
		1 sodium + 1 sulphate ion
Sulphur dioxide		1 sulphur atom + 2 oxygen atoms
	N_2	

This must have been very easy for you. Check the Feedback to Activity 4.4.1 for the answers.

Feedback

Feedback to Activity 4.4.1

Use the table below to verify your answer.

Name of compound/molecule	Formula	The particles present
Sodium oxide	Na_2O	2 sodium ions + 1 oxide ion
Calcium hydroxide	$Ca(OH)_2$	1 calcium ion + 2 hydroxide ions
Carbon dioxide	CO_2	1 carbon atom + 2 oxygen atoms
Sodium sulphate	Na_2SO_4	2 sodium ions + 1 sulphate ion
Sulphur dioxide	SO_2	1 sulphur atom + 2 oxygen atoms
Nitrogen	N_2	2 nitrogen atoms

Now that you know about the combining power of some atoms and ions and how to write chemical formulae, let us look at how to work out the formula of some compounds and molecules.

4.4.3 Working out chemical formulae

You can work out the chemical formula of a compound or molecule by using:

- the valency of the atoms or ions of the elements involved; or
- the composition by mass.

We will start off with determining the chemical formulae by using the valency of the atoms or ions involved.

4.4.3.1 Working out a chemical formulae using valency of atoms or ions involved

Let us consider the following as examples: silver nitrate, calcium carbonate, ammonium sulphate, and aluminium oxide.

When writing chemical formulae, you need to balance the positive and negative charges.

Example 4.4.3.1.1: Silver nitrate

The ions in silver nitrate are Ag^{+} and NO_3^{-}

As there are equal numbers of positive and negative charges (ratio $positive : negative$ is $1:1$), the formula is $AgNO_3$.

Example 4.4.3.1.2: Calcium carbonate

The ions in calcium carbonate are Ca^{2+} and CO_3^{2-}

With equal numbers of positive and negative charges (ratio $positive\ charges : negative\ charges$ is $1:1$), the formula for calcium carbonate is $CaCO_3$.

Example 4.4.3.1.3: Ammonium sulphate

The ions present in ammonium sulphate are NH_4^{+} and SO_4^{2-}

Here, the ratio of $positive\ charges : negative\ charges$ is $1:2$). In order to balance the charges (that is, to have equal numbers of positive and negative charges), there needs to be twice as many ammonium ions in the formula. In other words, for each sulphate ion we need 2 ammonium ions. Therefore the formula for ammonium sulphate is $(NH_4)_2SO_4$

Some of you may understand this better if we put the information in a table. By cross multiplying the valency, you get the number of particles (atoms/ions) of each element in the chemical formula.

	Ammonium sulphate	
Particles	NH_4^+	SO_4^{2-}
Valency	+1	-2
Multiplying factor	x 2	x 1
Formula	$(NH_4)_2SO_4$	

Table 4.4.3: Working out the formula of ammonium sulphate

Example 4.4.3.1.4: Aluminium oxide

The ions in aluminium oxide are Al^{3+} and O^{2-}

The ratio $positive\ charges : negative\ charges$ is $3:2$. So to balance the charges, for every 2 aluminium ions, we need 3 oxide ions. The formula for aluminium oxide is Al_2O_3.

Now let us see this in the table, if it is easier for you.

	Aluminium oxide	
Particles	Al^{3+}	O^{2-}
Valency	+3	-2
Multiplying factor	$x\ 2$	$x\ 3$
Formula	Al_2O_3	

Table 4.4.4: Working out the formula of aluminium oxide

Now it is your turn to practice. Don't panic, just follow the examples above.

Activity

Activity 4.4.2

You should spend approximately 20 minutes on this activity.

Refer to Table 4.4.1 above for the combining power of some ions. Use those combining power to complete the table below. An example has been done for you to give you guidance.

Name of compounds or molecules	Formula of combining ions/atoms	Formula of compounds or molecules
Copper nitrate	Cu^{2+} and NO_3^-	$Cu(NO_3)_2$
	Al^{3+} and Cl^-	
		$MgSO_4$
Zinc chloride		
Ammonium nitrate		
Sliver nitrate		
	K^+ and MnO_4^-	

How was this activity? I bet you did not expect it to be that easy. Please refer to Feedback to Activity 4.4.2 to verify your answers.

Feedback

Feedback to Activity 4.4.2

Use the table below to verify your answers to Activity 4.4.2.

Name of compounds or molecules	Formula of combining ions/atoms	Formula of compounds or molecules
Copper nitrate	Cu^{2+} and NO_3^-	$Cu(NO_3)_2$
Aluminium sulphate	Al^{3+} and SO_4^{2-}	$Al_{2(}SO_4)_3$
Magnesium sulphate	Mg^{2+} and SO_4^{2+}	$MgSO_4$
Zinc chloride	Zn^{2+} and Cl^-	$ZnCl_2$
Ammonium nitrate	NH_4^+ and NO_3^-	NH_4NO_3
Sliver nitrate	Ag^+ and NO_3^-	$AgNO_3$
Potassium permanganate	K^+ and MnO_4^-	$KMnO_4$

I suppose that was easy for you and you got the correct answers. Now let us look at how to determine the chemical formula of a compound given its composition by mass.

4.4.3.2 Working out chemical formulae using its composition by mass

It is also possible to work out the chemical formula of a compound or molecule from its composition by mass. The formula obtained is referred to as the **empirical formula** (i.e. the simplest formula). Let us consider some examples.

Example 4.4.3.2.1: Determining the formula of Copper oxide using the composition by mass

If 3.2 g of copper oxide is produced by 2.56 g of copper, what is the formula of the copper oxide formed? The relative atomic mass (A_r) of copper and oxygen are as follows: $A_r(Cu) = 64$, $A_r(O) = 16$.

First, write down the equation with the reacting masses

$$3.2 \text{ g Copper oxide} \rightarrow 2.56 \text{ g Copper } + x \text{ g Oxygen}$$

Next, subtract the mass of copper from copper oxide to get the unknown mass of oxygen

$$x \text{ g Oxygen} = 3.2 \text{ g Copper oxide} - 2.56 \text{ g Copper}$$

$$x \text{ g Oxygen} = 0.64 \text{ g}$$

$$\text{Mass of Oxygen } = 0.64 \text{ g}$$

So 3.2 g of copper oxides produces 2.56 g of copper and 0.64 g of oxygen.

Now divide the reacting masses of copper and oxygen by their relative atomic mass (A_r) to find the number of moles of copper and oxygen in copper oxide. (This calculation uses the formula learned in Topic 2.5.3.2: *Converting masses to moles*).

Reacting masses of Cu

Reacting masses of O

$$\text{Number of moles} \quad \text{Copper} \quad \frac{2.56}{64} = 0.04 \qquad \text{Oxygen} \quad \frac{0.64}{16} = 0.04$$

A_r (Cu)

A_r (O)

Now, divide by the smallest number of moles to get the ratio of the reacting masses.

$$\frac{0.04}{0.04} = 1 \qquad \frac{0.04}{0.04} = 1$$

So copper and oxygen reacts in the ratio 1: 1. So the simplest formula for copper oxide is CuO.

Example 4.4.3.2.2: Determining the formula of calcium carbonate using the percentage composition by mass

What is the formula of a compound which contains 40.4% calcium; 11.8% carbon; and 47.8% oxygen? (A_r (C) = 12; A_r(O) = 16; A_r(Ca) = 40).

The calculation involving percentage composition of different elements is best completed using a table as shown below.

	Elements		
First write down the elements involved	Ca	C	O
Second write down the % composition	40.4 %	11.8 %	47.8 %
Next, divide % composition by A_r to get ratio of number of atoms	$\frac{40.4}{40}$ = 1.01	$\frac{11.8}{12}$ 0.98	$\frac{47.8}{16}$ 2.99
Finally, divide number of atoms by smallest ratio to get the combining ratio of the elements in the compound	$\frac{1.01}{0.98}$ = 1	$\frac{0.98}{0.98}$ = 1	$\frac{2.99}{0.98}$ = 3
Formula	$CaCO_3$		

Table 4.4.5: Deriving the formula of a compound from the % composition by mass

Now, it is your turn to give it a go.

Activity

Activity 4.4.3

You should spend about 20 minutes on this activity.

1. Determining the formula of Magnesium oxide

Magnesium burns in oxygen to produce magnesium oxide. The relative atomic mass of magnesium and oxygen are $A_r(Mg) = 24$, $A_r(O) = 16$

The results of the experiment are as follows:

Mass of crucible + lid	= 27.18 g
Mass of crucible + lid + magnesium	= 27.54 g
Mass of crucible + lid + magnesium oxide	= 27.78 g
Mass of magnesium oxide	$27.78 - 27.18 = 0.6$

From these results, determine the formula of magnesium oxide.

2. Determining the formula of an iron oxide compound

A compound contains 25 % of iron and 75 % of oxygen. Work out the formula of the compound. A_r (Fe) = 56, A_r (O) = 16).

How was the exercise? I hope you have found it easy to do. Refer to Feedback to Activity 4.4.3 for the solution.

Feedback

Feedback to Activity 4.4.3: Determining chemical formula using composition by mass

1: Determining the formula of Magnesium oxide

The relative atomic mass of magnesium and oxygen are $A_r(Mg) = 24$, $A_r(O) = 16$.

First, write down the equation with the known masses

$$\text{y g magnesium} + x \text{ g Oxygen} = 0.60 \text{ g of magnesium oxide}$$

Second, calculate the reacting masses of magnesium and oxygen.

a. To obtain the reacting mass of magnesium subtract the *mass of crucible + lid* from the *mass of crucible + lid + magnesium*

So, the reacting mass of magnesium $= 27.54 - 27.18 = 0.36 \text{ g}$

Mass of crucible + lid + Mg

Mass of crucible + lid

b. To obtain the reacting mass of oxygen, subtract the *mass of magnesium* from the *mass of magnesium oxide*

So, the reacting mass of oxygen:

$$x \text{ g Oxygen} = 0.60 \text{ g magnesium oxide} - 0.36 \text{ g magnesium}$$

$$x \text{ g Oxygen} = 0.24$$

$$\text{mass of Oxygen} = 0.24 \text{ g}$$

So, 0.36 g of magnesium reacts with 0.24 g of oxygen to produce 0.60 g of magnesium oxide.

Now divide the reacting masses of magnesium and oxygen by their relative atomic mass (A_r) to find the number of moles of magnesium and oxygen in magnesium oxide.

Number of moles magnesium $\frac{0.36}{24}$ Oxygen $\frac{0.24}{16}$

$= 0.015$ $= 0.015$

Now divide by the smallest number of moles

$\frac{0.015}{0.015}$ $\frac{0.015}{0.015}$

$= 1$ $= 1$

So magnesium and oxygen reacts in the ratio 1: 1. So the simplest formula for magnesium oxide is MgO.

2. Determining the formula of iron oxide

A compound contains 70 % of iron and 30 % of oxygen. Work out the formula of the compound. (A_r(Fe) = 56; A_r(O) = 16).

The calculation is shown in the table below.

	Elements	
First write down the elements involved	Fe	O
Second write down the % composition	70	30
Next, divide % composition by A_r to get ratio of number of atoms	$\frac{70}{56}$ =1.25	$\frac{30}{16}$ = 1.875
Then, divide number of atoms by smallest ratio to get the combining ratio of the elements in the compound	$\frac{1.25}{1.25}$ = 1	$\frac{1.875}{1.25}$ = 1.5

Finally, as the ratio is a decimal, calculate to the smallest whole number (in this case, multiply the ratio by 2)	1 x 2 = 2	1.5 x 2 = 3
Formula	Fe_2O_3	

I hope that you have got both answers correct. If not, do not be disappointed, but have another go at it after reviewing the topic.

Now let us review what you have learned in this unit. Also, make sure not to forget about the self-assessment located after the unit summary.

Unit summary

Summary

In this unit you learned about atoms, bonding and the Periodic Table. You learned that the Periodic Table is an arrangement of elements in increasing order of their proton number. The Periodic Table is divided into 7 Periods (the horizontal rows) and 8 groups (the vertical columns). You should now know that the Period relates to the number of electron shells that the element possesses and that all elements in the same period have the same number of shells. You should also be aware that the groups relate to the number of electrons in the outermost shell of the atom. With the knowledge of the Periodic Table, you should be able to explain that the metallic properties of the elements decrease as we move from left to right across the Periodic Table. The elements on the left of the Periodic Table are metals, while the elements on the far right are non-metals.

In this unit you have also learned that the electrons are distributed in concentric circles called shells, and that one shell must be filled with its maximum number of electrons before electrons can occupy the next shell. With that knowledge, you should be able to draw the electronic structure and write the electronic configuration of the first 20 elements. Now that you know about the electronic configuration, you should be able to explain that elements in group VIII are stable because they have a completely-filled outer shell. Meanwhile, the elements in groups I to VIII can achieve stability by combining with other elements either by the transfer or the sharing of electrons. Elements in groups I to group III can achieve stability by the transfer (loss or gain) of electrons while those in group IV to group VII can become stable by the sharing of electrons.

You have learned about the three types of bonds: ionic bonds, covalent bonds and metallic bonds. Ionic bonds are formed by the complete transfer of electrons between metals and non-metals. Covalent bonds, on the other hand, are formed by the sharing of electrons between non-metals, while metallic bonds are found only in metals. You have also learned to draw dots and cross diagrams to show the formation of ionic bond and covalent bonds.

After studying this unit, you should be able to work out the chemical formulae of different compounds and molecules by using either the valency of the atoms or ions involved, or its composition by mass.

We have now come to the end of Unit 4. I hope that you have clearly understood all the contents of the unit. Should you feel the need to review certain contents, please do so before you tackle Unit 5. All the best with Unit 5!

Assessment

Assessment

Self-assessment 4.1

You are encouraged to spend no more than 45 minutes on this self-assessment.

This self-assessment covers the whole unit and requires that you use the knowledge you have acquired to answer the questions. The answers are given at the end of the unit. You are strongly advised to answer all questions in the space provided before you refer to the Answers to Self-assessment 4.1. This will help you learn and reflect better on areas for improvement.

1. Write **true** or **false** next to each of the following statements.

	Statements	True/False
1.	The vertical columns in the Periodic Table are called *Periods*.	
2.	Elements in the Periodic Table are arranged in order of increasing atomic mass	
3.	The electron shells are also referred to as the energy level.	
4.	An ionic bond is formed by the complete transfer of electrons.	
5.	Covalent bonds are formed between non-metals only.	
6.	Covalent compounds have high boiling and melting points.	

2. Use the outline of the Periodic Table below to answer the questions that follow.

								1									
																	2
3	4											5	6	7	8	9	10
11	12											13	14	15	16	17	18
19	20	21	22	23	24	25	26	27	28	29	30					35	36
37	38															53	54

a) Which element is represented by the following numbers?

Element N$^{o.}$	Name of element
1	
8	
9	
11	
18	
20	

b) In the table below write all the numbers which represent the following groups of elements:

Group of elements	Element N$^{o.}$
Alkali metals	
Alkali earth metals	
Halogens	
Inert gases	
With a valency of 4	
Elements which form +2 ions	
Elements which form +3 ions	

Elements which form -2 ions	
Elements which do not form ions	
The transition elements	

3. Use the following information about 10 elements to answer the questions that follow.

$^{1}_{1}H$ $^{12}_{6}C$ $^{16}_{8}O$ $^{14}_{7}N$ $^{23}_{11}Na$

$^{24}_{12}Mg$ $^{27}_{13}Al$ $^{37}_{17}Cl$ $^{39}_{19}K$ $^{40}_{20}Ca$

a) Draw and write the electronic configuration of oxygen and calcium.

Oxygen	Calcium

b) Write down the ions formed by the following elements.

Elements	Ions
Potassium	
Nitrogen	
Oxygen	
Magnesium	

Aluminium	

c) Sodium and chlorine react together to form a compound.

i. What is the name of the compound?

____

ii. What type of bond is formed between sodium and chlorine?

____

iii. Explain why this type of bond is formed between these two elements when they combine.

____

____

____

____

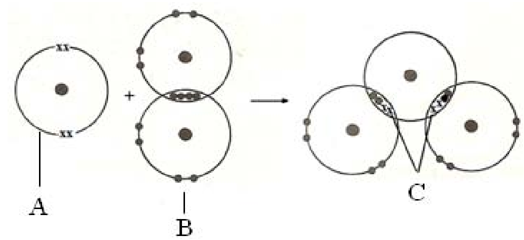
____

iv. Use a dot and cross diagram to show the formation of this compound.

v. Write the equation for the formation of this bond.

vi. Why is it wrong to call the compound formed between sodium and chlorine a molecule?

d) The diagram below shows the dot and cross diagram for the substance T.



i. Which elements are represented by the letter A and B?

A is

B is

ii. What is the name of compound T?

T is

iii. What is the name of the bond shown in compound T?

iv. Explain why this type of bond is formed between these two elements.

4. When 28.68 g of lead oxide was heated in dry hydrogen, 24.84 g of lead (Pb) was collected. A_r (Pb) = 207, A_r (O) = 16.

a) How many grams of oxygen were present in the oxide?

b) Calculate the number of moles of oxygen atoms.

c) Calculate the number of moles of lead in the oxide.

d) How many moles of oxygen were combined with 1 mole of lead?

e) Write down the formula for the lead oxide used.

Refer to the Answers to Self-assessment 4.1 for the solutions. Do not be disappointed if you did not succeed on all the questions. You can review the unit and try again. Remember, you also learn from your mistakes!

Answers to self-assessments

Answers to Assessment

Answers to Self-assessment 4.1

1. True or False

	Statements	True/False
1.	The vertical columns in the Periodic Table are called Periods.	False (vertical columns are called *Groups* and horizontal rows are called *Periods*)
2.	Elements in the Periodic Table are arranged in order of the increasing atomic mass	False (they are arranged in terms of increasing proton (atomic) number)
3.	The electron shells are also referred to as the energy level.	True
4.	An ionic bond is formed by the complete transfer of electrons.	True
5.	Covalent bonds are formed between non-metals only.	True
6.	Covalent compounds have high boiling and melting points.	False (this is true for ionic bonds)

2. The Periodic Table

a) Which element is represented by the following numbers?

Element No.	Name of element
1	Hydrogen
8	Oxygen
9	Chlorine

Element No.	Name of element
11	Sodium
18	Argon
20	Calcium

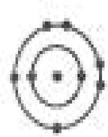
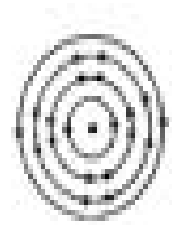
b) In the table below, write all the numbers which represent the following groups of elements:

Group of elements	Element No.
Alkali metals	3, 11, 19, 37
Alkali earth metals	4, 12, 20, 38
Halogens	9, 17, 35, 53
Inert gases	2, 10, 18, 36, 54
With a valency of 4	6, 14
Elements which form +2 ions	4, 12, 20, 38
Elements which form +3 ions	13
Elements which form -2 ions	8, 16
Elements which do not form ions	2, 5, 6, 10, 14, 18, 36, 54
The transition elements	21, 22, 23, 24, 25, 26, 27, 28, 29, 30

3.

a) Electronic structure and electronic configuration

Oxygen	Calcium

Oxygen	Calcium
$^{16}_{8}O$  2, 6	$^{40}_{20}Ca$  2, 8, 8, 2

b)

Elements	Ions
Potassium	K^{+}
Nitrogen	N^{3-}
Oxygen	O^{2-}
Magnesium	Mg^{2+}
Aluminium	Al^{3+}

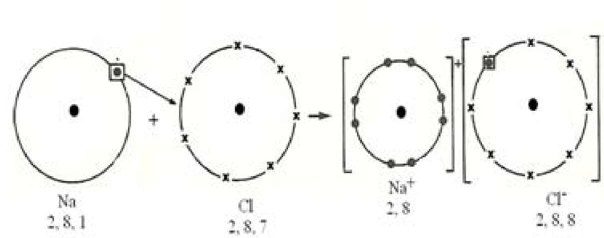
c) Reaction of sodium and chlorine

i. Sodium chloride

ii. Ionic bonds

iii. An ionic bond is formed between sodium and chlorine because there is a complete transfer of an electron from sodium to chlorine. Sodium has 1 electron and chlorine has 7 electrons in their outer shell. So to achieve a stable octet configuration it is easier for sodium to lose 1 electron and for chlorine to gain 1 electron than lose 7 electrons.

iv. Bond formation between sodium and chlorine



v. The equation for this reaction:

$$Na - e^{-} \rightarrow Na^{+}$$

$$Cl + e^{-} \rightarrow Cl^{-}$$

$$\therefore Na + Cl \rightarrow Na^{+}Cl^{-}$$

As there are equal numbers of positive and negative charges the formula is written as NaCl.

vi. It is wrong to refer to sodium chloride as a molecule because sodium chloride exists as ions within a giant lattice structure.

d) Compound T

i. A is carbon, B is oxygen

ii. Carbon dioxide

iii. Double covalent bond (covalent bond is also correct)

iv. Covalent bonds are formed when the sharing of electrons take place. Two double covalent bonds are formed in carbon dioxide. To achieve a stable octet configuration, carbon shares its 4 electrons with 2 oxygen atoms (an oxygen molecule). Each oxygen atom shares 2 electrons with the carbon atom.

4.

a) Mass of oxygen

$$\text{Mass of oxygen} = \text{mass of oxide} - \text{mass of lead}$$

$$\text{Mass of oxygen} = 28.68\ \text{g} - 24.84\ \text{g}$$

$$\text{Mass of oxygen} = 3.84\ \text{g}$$

b) Number of moles of oxygen atoms

$$\text{Number of moles of oxygen atoms} = \frac{3.84}{16}$$

$$\text{Number of moles of oxygen atoms} = 0.24$$

c) Number of moles of lead atoms

$$\text{Number of moles of lead atoms} = \frac{24.84}{207}$$

$$\text{Number of moles of lead atoms} = 0.12$$

d) Number of moles of oxygen reacting with 1 mole of lead

0.12 mole of lead atoms reacts with 0.24 mole of oxygen atoms

	Lead	Oxygen
Divide by 0.12 (the smallest number) to get the combining ratio	$\frac{0.12}{0.12}$ = 1	$\frac{0.24}{0.12}$ = 2

So 1 mole of lead atoms reacts with 2 moles of oxygen atoms

e) The formula is PbO_2

Contents

Unit 5

Particles in motion

Introduction

Welcome to this fifth unit of the "Coordinated Science Course." It is the second unit which focuses on the physical strand of the course and it consists of three main topics:

- Moving particles,
- The behaviour of gas molecules and
- Density.

Hence, in this unit we will discuss *kinetic theory, matter, evaporation, behaviour of gas molecules*, and *density* in general. We will, whenever possible provide opportunities for you to try out some basic experiments and to apply principles and formulae learnt within the unit.

Since the units in the Coordinated Science course have been developed in such a way to allow you to continuously see the relationships between Physics, Chemistry and Biology, we shall be referring you to other units in the course where the concept of *particles in motion* is also dealt with. Hence, in the physics **Motion** unit **(Unit 15)**, you will be able to use your knowledge of the particulate nature of matter to further advance your thought process in regards to matter. You may already know certain things about matter. Think back to what you have learned in unit 2. Remember that we learned about matter and the states of matter in that unit.

In this unit you will learn about:

- the particulate nature of matter;
- the connection between the temperature of an object and the movement of its particles;
- the process of evaporation in terms of the kinetic theory;
- the relationship between pressure, volume and temperature of a gas;
- how to determine the density of a liquid and of a regularly and an irregularly shaped solid.

We hope that this ‘Physics’ unit will be both interesting and enjoyable to you.

Note it! / Important!

The outcomes for the unit are listed below.

Outcomes

Upon completion of this unit you will be able to:

- *describe* the kinetic theory of matter as a model for matter in terms of particles (atoms and molecules) in motion.
- *investigate* the connection between the temperature of an object and the movement of its particles.
- *explain* that the three states of matter can be understood in terms of inter-molecular and inter-atomic forces and the motion of the atoms and molecules.
- *describe* the process of evaporation in terms of the kinetic theory.
- *explain* how the relationship between the pressure and volume of a gas may be predicted by the kinetic theory.
- *describe* qualitatively the effect of a change in temperature on the volume of a gas.
- *describe* how the relationship between pressure, volume and temperature for a gas leads to the Kelvin scale of temperature
- *carry out* an experiment to determine the density of a liquid and of a regularly shaped solid using the formula: *density = mass/volume*
- *use* the displacement method to find the density of an irregularly shaped solid

Terminology

Density: It is the mass in gramme (g) of 1 cm^3 of a substance or mass in kilogramme (kg) of 1 m^3 of a substance

Directly proportional: When one variable increases in value, the other variable also increases proportionately

Evaporation: A change of state from liquid to gas

Inversely proportional: When one variable increases in value, the other variable decreases proportionately

Mass: The amount of matter in an object measured in gramme or kilogramme

Perfectly elastic collision: When particles or objects bounce in a straight line upon collision and the total kinetic energy before and after the collision is the same.

Pressure: The result of a force (s) exerted over an area of 1 cm^2 or 1 m^2

Unit volume: Cubic centimetre (cm^3) or cubic metre (m^3)

Volume : The amount of space an object takes up

How long?

Table 5.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	6 hours	3 hours
Full-time student within the conventional school setting OR Part-time student	6 hours	3 hours

Table 5.0: The time needed for you to work on this unit

Topic 5.1: Moving Particles

How long?

You will need 2 hours and 10 minutes at the most to complete this topic. It is advisable that you spend another 1 hour and 5 minutes of your own time to further review the activities you have completed. Make sure you read and try to understand everything in order to achieve the specific objectives.

As you may recall, in Unit 2 - *The Elements of Chemistry,* you learnt about the particulate nature of matter. We are now going to build on what you have learnt there, so if you feel you have forgotten some of the concepts, please go back and do some review. We are going to start off this topic by looking at the *kinetic theory of matter*, then *physical states of matter, Brownian motion* and finally *evaporation*.

5.1.1 The Kinetic Theory of Matter

The **Kinetic Theory** explains the differences between the three states of matter – solid, liquid and gas. It states that all matter is made up of moving particles which are molecules, atoms or ions. Both solids and liquids are made up of particles that touch one another. In solids, the particles are so tightly bound to each other that they can only vibrate, and not move to another location.

In liquids, the particles have enough free space to move about, but they are still attracted slightly to one another.

In gases, the particles are far apart and can move about freely and faster than in liquids since there is much free space. However, as they move in straight lines they often collide with one another. The collisions between particles are perfectly elastic.

Solids change into liquids, and liquids into gasses, as the particles are heated and are able to move apart from each other, gaining **kinetic energy** in the process. . When the molecules vibrate more quickly upon heating, some of the molecules escape from the liquid state into the gaseous state. This explanation of particles in motion is what the **Kinetic Theory** is about.

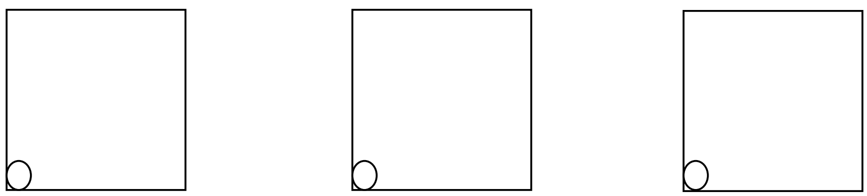
Activity

Activity 5.1.1

You should spend approximately 5 minutes on this activity.

Based on what you have read above, you are now invited to use the circle shown in each box to show how you think the particles in the solids, liquids and gases are arranged. (*Remember particles are so small that we cannot see them. We have used a circle as a representation of a particle simply as a matter of convenience*).

Solid Liquid Gas



We hope that you have found this activity very easy to do since you have already learned about the states of matter in Unit 2. However, just in case refer to the Feedback to Activity 5.1.1 to verify your answers.

Feedback

Feedback to Activity 5.1.1

Well done! We are sure that you will agree that it was not that challenging after all! You should have drawn the circles representing the particles in the solid very close together (see Figure 5.1.2), slightly further apart in the liquid (see figure 5.1.4), and far apart in the gas (see figure 5.1.6). We are going to provide more information on particles in the next section. Please note that you addressed some aspects of this topic in Unit 2, but with a slightly different focus, so go through this section carefully without assuming you know all of it already.

5.1.2 Physical states of matter: solid, liquid and gas

We can commonly define the physical states of matter by their physical characteristics. A **solid** has a definite **shape** and **volume** like the stone in Figure 5.1.2 A **liquid** has a definite **volume**, but **not a definite shape** as water and

"Fanta" in the bottles in Figure 5.2.1. A **gas** has **neither definite volume** nor **shape** like the air in the plastic bag in Figure 5.2.1**.** However, while these are true characteristics, they are not the best description of the physical state of each example. Hence, let's take a look at the kinetic theory (explanation of particles in motion) to describe the physical states of matter.

Figure 5.1.1: Different states of matter

Photographed by Alex Souffe, August 2010

5.1.2.1 Solids

Solids - are substances whose **particles have low kinetic energy**. The particles of solids are held close together by **intermolecular forces of attraction**. The attraction between the particles of solids is so strong that the particles are held rigidly together. It is this rigidity that gives solids a definite shape and volume. Because the particles are so close together, they appear to **vibrate around a fixed point**.

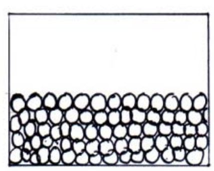


Figure 5.1.2: Arrangement of particles in solids

Drawn by: Lionel Goonetilleke, August 2010

Photographed by: Alex Souffe, August 2010

When solids absorb heat energy, their temperature is raised as long as no melting occurs. The increase in the energy of the particles causes an increase in the **kinetic energy of the particles** which leads to an increase in the temperature of the substance. The **collisions** between the particles **occur with greater force**, causing the particles **to move**

further apart. Continued heating (i.e. further increase in kinetic energy) may result in a change in the orderly arrangement of the particles in the solid leading to a change in the physical state. As a result, the solid changes to a liquid. The change of state of a particular solid to liquid always occurs at a fixed temperature, which is called its **melting point.** For example, pure ice melts at 0ºC as it absorbs heat energy (more details will be provided in later units).

Now you are going to carry out an activity to illustrate the arrangement of particles in a solid.

Activity

Activity 5.1.2

You should spend approximately 20 minutes on this activity.

For this activity you will need 27 beads or large spherical fruits or seeds and some plasticine or glue and small sticks and a board.

Procedure: You are required to make your own model of the arrangement of particles in a solid by following the steps below.

1. Collect a set of 27 large spherical fruits or seeds of about the same size (e.g. of the Takamaka) as shown in the picture below. You may use marbles or make some clay beads as alternatives to the fruits or beads. .

2. Use plasticine or glue to stick them together to form a cubic arrangement of 3x3x3 seeds (that is length x breadth x height).

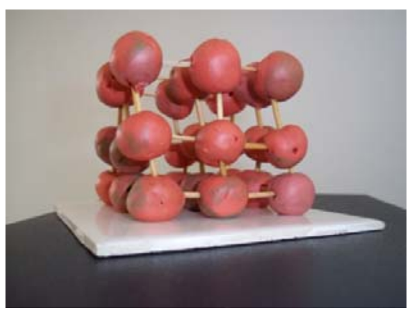


Figure 5.1.3: Model of the arrangement of particles in solids

Photographed by Louisette Bonte, August 2010

Observe your arrangement carefully. Then answer the questions below.

1. What do the seeds or beads represent in your model?

2. What does the glue or plasticine represent?

3. What is the maximum number of parts or points of contact of a seed in your regular arrangement that is stuck to other seeds?

4. Can the seeds move freely from one place to another?

5. Try to give a "gentle strike" to one of the seeds or shake the table. Is the vibration transmitted to the other seeds?

We hope that you have found this activity interesting. Refer to the Feedback to Activity 5.1.2 to verify your answers.

Feedback

Feedback to Activity 5.1.2

1. The seeds or beads represent the particles (atoms, molecules or ions).

2. The glue or plasticine represents the bonding (attraction) between the different particles.

3. The maximum touching points is 6 for the seeds found in the middle of the regular arrangement (i.e. where one seed is supported onto the other).

4. The seeds cannot move from one place to another as they are firmly held together by the glue.

5. Yes, the vibrations are transmitted to the other molecules.

Now let us focus on the arrangement of the particles in liquids.

5.1.2.2 Liquids

Liquids - are substances whose particles **have enough kinetic energy to overcome the intermolecular forces of attraction** and can move from place to place. The attraction between particles in any liquid is great enough to hold the particles near each other, but too weak to prevent the particles from sliding around. Liquids have a definite volume but take the shape of the container.

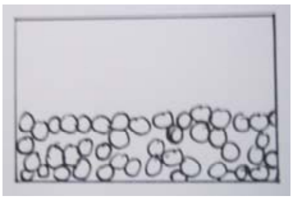


Figure 5.1.4: Arrangement of particles in liquids

Drawn by: Lionel Goonetilleke, August 2010

Photographed by: Alex Souffe, August 2010

As the temperature of a liquid is raised, the kinetic energy and velocity of the particles increase. The collisions eventually become so great that all the intermolecular forces between particles are overcome. The particles then begin moving independently between collisions, and a change in physical state occurs resulting in liquid changing into a gas. This process is called *evaporation*. We will look at evaporation in more detail in section 5.1.4 of this unit.

Activity

Activity 5.1.3

You should spend about 15 minutes on this activity.

For this activity you will need 27 beads or plasticine, glue or small sticks and a board. You may re-use the set of 27 large seeds used in activity 5.1.2.

Procedure: You are required to make your own model of the arrangement of particles in a liquid by following the steps below.

1. Use plasticine or glue to stick seeds together in groups of two only.
2. Allow the glue to dry.
3. Arrange them into a pile similar to the model of a solid.

Figure 5.1.5: Model of the arrangement of particles in liquids

Photographed by Louisette Bonte, August 2010

Observe your arrangement carefully before answering the questions below.

1. Gently strike one of the seeds or shake the table. What do you observe?

2. Compare the movement of the seeds in the two activities (Activity 5.1.2 and Activity 5.1.3). In which activity did they move more freely?

Feedback

Feedback to Activity 5.1.3

1. They move about in pairs.

2. They moved more freely in activity 5.1.3.

Finally, let us focus on the arrangement of the particles in gases.

5.1.2.3 Gases

A **gas** is a substance whose particles **have enough kinetic energy to break all intermolecular forces of attraction**. The particles of a gas move independently of each other. The particles move at random because they have overcome the intermolecular forces of attraction.

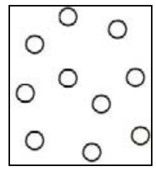


Figure 5.1.6: Arrangement of particles in gases

Source: Unit 2, Table 2.2, Diagram E by Rosianna Jules, September, 2009

The particles that make up a gas are completely separated from one another. Because gas particles are separated, the attractive forces between them are extremely small and are insufficient to hold gases in a definite shape or volume. Gases expand freely to fill their containers.

Gas particles are relatively far apart from each other, because they are free to move inside a container. In a closed container, pressure can be applied and you will see that the volume decreases. This means the particles move closer together with the distance between particles decreasing, while the number of particles present stays the same.

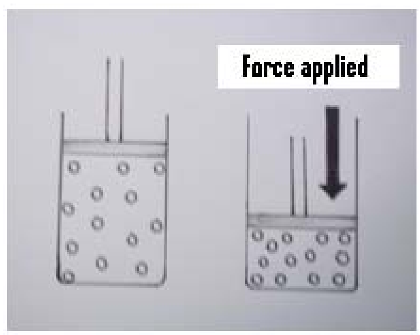


Figure 5.1.7: Diagram of air particles trapped in cylinders under normal pressure and with extra force applied

Drawn by: Lionel Goonetilleke, August 2010

Photographed by Alex Souffe, August 2010

If enough force is applied to the plunger, the particles get so close together that the gas turns into a liquid. But liquids and solids cannot be compressed because their particles are already close together.

Now try the following activity to show the arrangement of particles in gases.

Activity

Activity 5.1.4

You should spend about 15 minutes on this activity.

For this activity you will need 27 beads or plasticine, and a trough or cardboard. You may re-use the set of 27 large seeds that you have used in activity 5.1.3.

Procedure: You are required to make your own model of the arrangement of particles in a gas by following the steps below.

1. Use a strip of stiff paper to make a frame with a diameter of 15cm or a trough as shown in Figure 5.1.8.
2. Arrange two layers of seeds inside the frame.
3. Label two of the seeds with the letter “X”.

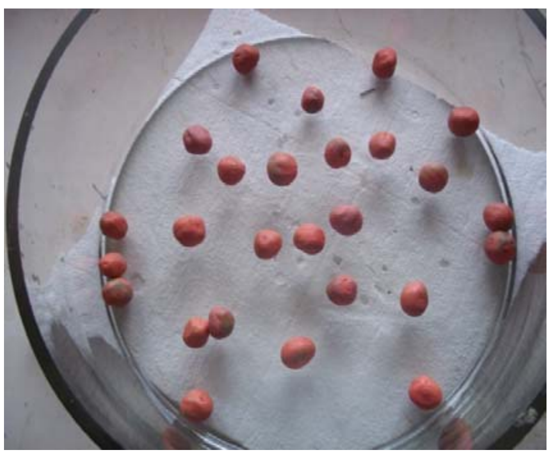


Figure 5.1.8: Model of particles arrangement in gases

Photographed by: Alex Souffe, August 2010

Observe your arrangement carefully, then answer the questions below after you have carried out the different steps.

1. Shake the table or the frame gently. What do you observe?

2. Do the two numbered seeds stay in the same place?

3. In which of the three arrangements do the seeds move more easily?

4. Based on the three activities (Activity 5.1.2, Activity 5.1.3 and Activity 5.1.4) what can you conclude (say) about the arrangement and level (amount) of movement of the particles in the three states of matter?

We hope that you have enjoyed the activity. Now refer to the Feedback to Activity 5.1.4 below to check your answers.

Feedback

Feedback to activity 5.1.4

1. All the seeds moved freely.

2. The two numbered (marked) seeds moved about, along with the other seeds.

3. In the last arrangement (Activity 5.1.4) the seeds moved more easily.

4. Particles in solids are closer together and cannot move from one place to another. In liquids the particles are close together, but are able to move from one place to another. In gases the particles are further apart and can move more easily than in liquids.

Now that we have described the physical properties of matter in terms of the kinetic theory, let us review what you have learnt so far by completing Activity 5.1.5.

Activity

Activity 5.1.5

You should spend about 5 minutes on this activity.

Procedure: You are required to use the information provided in sub-topics 5.1.2.1, 5.1.2.2 and 5.1.2.3 above to complete the table summarising the properties of the three states of matter.

Properties	Solids	Liquids	Gases
Space between particles	Virtually no spaces between particles		Very large spaces
Vibration of particles		Move fast from place to place	Move very fast from place to place
Force of attraction	Strong force		Very weak force
Shape	Has a definite shape	Take the shape of the container	
Volume		Has a definite volume	Fills any container
Ability to be compressed	Cannot be compressed		Can be compressed
Ability to flow	Cannot flow	Can flow	

Table 5.2.1a: Differences in the behaviour and arrangement of particles between solids, liquids and gases.

Source: Adapted from Namibia's Unit 2, 2009.

I'm sure you will agree that this activity provides a very good summary of the properties of solids, liquids and gases. We hope that you have managed to complete the table. Please refer to the Feedback to Activity 5.1.5 below to verify your answers.

Feedback

Feedback to Activity 5.1.5

Properties	Solids	Liquids	Gases
Space between particles	Virtually no spaces between particles	<u>Larger spaces</u>	Very large spaces
Vibration of particles	<u>Vibrate at one position</u>	Move fast from place to place	Move very fast from place to place
Force of attraction	Strong force	<u>Weaker force</u>	Very weak force
Shape	Has a definite shape	Take the shape of the container	<u>Take the shape of the container</u>
Volume	<u>Has a definite volume</u>	Has a definite volume	Fills any container
Ability to be compressed	Cannot be compressed	<u>Can only be compressed very slightly</u>	Can be compressed
Ability to flow	Cannot flow	Can flow	<u>Can flow</u>

Table 5.2.1b: Differences in the behaviour and arrangement of particles between solids, liquids and gases.

Source: Adapted from Namibia's Unit 2, 2009.

So far we have used the **kinetic theory** and our own model to describe the physical states of matter. Now we will turn our attention to the work done by Robert Brown to shed more light on the particulate nature of matter and the fact that they are always in constant motion.

5.1.3 Brownian Motion

About 200 years ago, a Scottish botanist, Robert Brown, was observing some pollen grains floating in a drop of water through a microscope. He noticed that the pollen grains were continuously moving about in all directions as shown in the diagram.

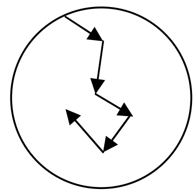


Figure 5.1.9: Diagram of the pathway of the motion of particles in gases.

Brown was unable to explain his observations, but it is now believed that his experiment is evidence for the existence of atoms and molecules. For example, molecules in a gas move constantly, freely, randomly, in all directions and at high speeds. They are able to do so because the intermolecular forces of attraction between the molecules is negligible when in a gaseous state. This constant motion of the molecules causes them to collide with anything in their path. For example, dust particles will be bombarded by the molecules moving at high speeds, causing them to have a zig-zag motion. This movement is named after Robert Brown and is called **Brownian motion**.

We can easily observe Brownian motion by looking at smoke particles under a microscope. Smoke is really small pieces of solid matter floating in the air. The air particles are too small to be visible.

(Source: http://wiki.answers.com/Q/What_is_the_cause_of_Brownian_motion)

Group activity

Group Activity 5.1.1

You should spend about 20 minutes on this activity.

For this activity you will need a smoke cell apparatus, matches and cotton wool or other material to produce some smoke.

Procedure:

If you can have access to a laboratory, you may try this activity by using a smoke cell apparatus. The photograph and the steps given below will help you to carry out this activity on Brownian motion.

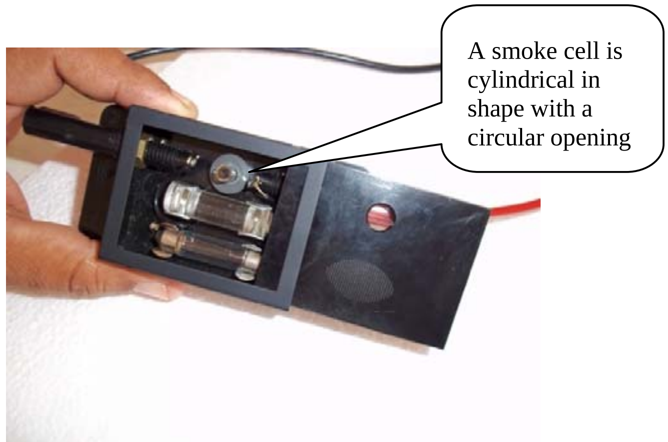


Figure 5.1.10: Smoke cell apparatus

Photographed by: Louisette Bonte, August 2010

1. Fill the smoke cell with some smoke and close it immediately.

2. Place the smoke cell on the stage of the microscope as shown in Figure 5.1.11.

3. Switch on the light bulb of the smoke apparatus.

4. Observe carefully through the microscope, the content of the smoke cells and then answer the questions below.

Figure 5.1.11: Set up for observing smoke particles

Photographed by: Louisette Bonte, August 2010

1. Describe what you observed.

2. Explain your observations.

We hope that the activity was at the right level for you. To verify your answers, please refer to the Feedback to Group Activity 5.1.1 below.

Feedback

Feedback to Group Activity 5.1.1

1. Bright, tiny white dots “jerking” in different directions.

2. The bright tiny white dots are in fact specks of smoke. The jerking movement was due to their collisions with the invisible air particles which were also moving randomly (in all directions).

Note it! / Important

Please note that Brownian motion also takes place in molecules in a liquid, but to a less obvious extent than in a gas. This is because the particles are closer together and experience greater intermolecular forces of attraction in liquids.

5.1.3 Evaporation

Evaporation is the process where some molecules of a liquid become a gas. It is a type of *vaporization* of a liquid that occurs only on the surface of a liquid. This is due to the fact that some particles (molecules) of the liquid have more energy than others. As a result they overcome the attraction forces between them and other molecules in the liquid, enabling them to escape from the surface of the liquid as shown in the diagram below.

As the high energy particles escape from the surface of the liquid, the remaining particles have on average less energy, so the liquid cools. This means that the temperature of the liquid is lowered. The cool liquid then cools the surface on which it is resting. This is called *evaporative cooling*.

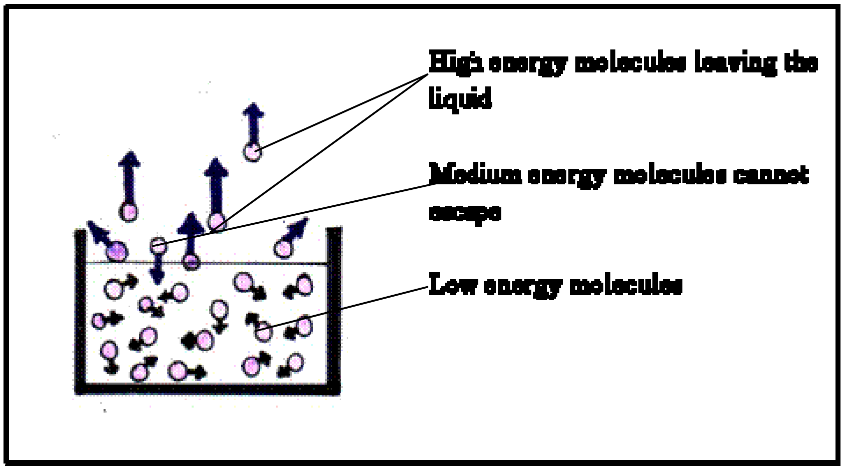


Figure 5.1.12: Sketch showing the behaviour of molecules of an evaporating liquid.

Photographed by: Lionel Goonetilleke, August 2010

Some common examples are when you apply perfume on your skin or when a wet towel is placed on your forehead when you have a fever. In both situations you feel cool due to the evaporation of the liquids. Your body heat is absorbed by the particles of the liquids causing the following effects:

1. an increase in the average kinetic energy of the liquids' particles and as a result overcoming the attraction forces between molecules and;
2. your body losing heat energy to the liquids particles and as a result you feel cooler.

Hence, a liquid does not have to boil in order to change into a gas (evaporate). However, the change of state of any liquid to a gas is affected by factors that affect the kinetic energy of the particles, namely:

a. the temperature of the liquid;
b. air flow over the liquid (wind);
c. surface area of the liquid;
d. pressure above the liquid;
e. attracting forces between the molecules of the liquid.

We will discuss the concept *evaporation* further in a later unit.

(Source: http://wiki.answers.com/Q/What_is_evaporation)

Well, you have come to the end of Topic 5.1. Before proceeding to the next topic, let us see how much you have learnt, so far. At this stage, you should be ready to try out the self assessment below.

Assessment

Self Assessment 5.1

You should spend approximately 10 minutes on this self-assessment. This self-assessment is organised into two sections. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 5.1. This will help you learn and reflect better on areas for improvement.

Section A:

Complete these phrases by using the most suitable words.

1. All matter is composed of small particles. Particles can be

   _______________, _________________, or ______________.

2. The particles of matter are in constant ____________________.

3. All collisions between the __________________ of matter are

   perfectly elastic. ____________________ means that the

   particles bounce upon collision.

4. Particles move in a straight line between ___________________.

Section B:

Answer all questions in the spaces provided.

1. What is evaporation?

____

2. State four factors that affect the rate of evaporation.

3. Explain how evaporation causes a cooling effect.

Please see our suggestions in the Answers to Self Assessment 5.1 provided at the end of the topic below to see if you were on the right track.

Answers to Assessment

Answers to self-assessment 5.1

Section A

1. Molecules, atoms or ions

2. Motion

3. Particles, elastic

4. Collisions.

Section B:

1. Evaporation is the process where some of a liquid becomes a gas.

2. Temperature, molecular attraction force, surface area and pressure.

3. Evaporation causes a cooling effect because it is the energy of the molecules in the system that is used by some of the molecules to cause them to overcome the attraction force of the liquid molecules. This leaves the remaining molecules within the system with less energy.

This brings us to the end of topic 5.1. Reflect back on what you learned in this topic. What is significant about moving particles? What happens to these particles as energy is added to them?

In topic 5.2, we will examine the behavior of gas molecules. Judging from what you learned in topic 5.1, I am sure you will be able to predict how gases will behave in some situations. Let's move on to learn more about gases.

Topic 5.2: The behaviour of gas molecules

How long?

You will need 4 hours and 10 minutes at the most to do the activities in this topic. It is advisable that you spend another 2 hour and 5 minutes of your own time to further practise the activities learnt. Make sure you read and understand everything in order to achieve the outcomes.

As you have seen in Topic 5.1, solids, liquids and gases behave differently when they gain heat energy. Now we are going to investigate the behaviour of particles (molecules) in a fixed mass of gas when subjected to variations in pressure, volume and temperature.

To find the laws linking pressure, volume and temperature experimentally, each factor has to be kept constant (the same) while the relation between the other two factors is tested. We will start off by looking at the relationship between pressure and volume of a fixed mass of a gas at constant temperature.

5.2.1 Relationship between gas pressure and gas volume

The relationship between the **pressure applied to a gas** and the **volume it occupies** will be demonstrated by conducting a simple experiment using a plastic syringe or a bicycle pump similar to the arrangement shown in the diagram below.

$$\text{Total Pressure} = \text{Pressure due to Weight} + \text{Pressure due to Atmosphere}$$

Materials Needed

- Large plastic syringe
- Large rubber stopper
- Retort stand
- 3 identical weights of 1.0 kg or books

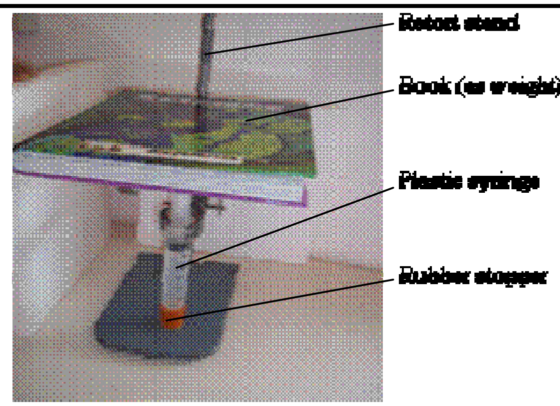


Figure 5.2.1: Apparatus for pressure and volume measurements

Set up ad photographed by Louisette Bonte, August 2009.

The pressure on the gas will be changed by applying different forces. The magnitude of the force could be controlled by using standard weights or different objects of the same mass (e.g. books) to be placed on top of the plunger of the syringe. The total pressure acting on the gas consists of the standard weights (or the books). (*We are going to ignore atmospheric pressure*).

You are now going to carry out an activity to illustrate the effect of pressure on a gas.

Activity

Activity 5.2.1

You should spend about 25 minutes on this activity.

Experimental Steps:

Refer to Figure 5.2.1 to help you to better comprehend the following steps.

1. Set the plunger at the 100 cm^3 mark of a dry syringe.
2. Plug the tip of the syringe inserting it into a tiny hole in the rubber stopper. (You may use an alternate method).
3. Clamp the syringe-stopper arrangement in an upright position, as shown in the diagram. Do not tighten the syringe too much, for the cylinder will be distorted and the plunger will not move freely. This will affect your results.
4. Carefully place one weight on top of the plunger. (If necessary steady and centre the weight, and take the reading of the volume of gas trapped in the syringe).
5. Record the reading in the table below.
6. Repeat by adding 2 weights and record the volume. Continue in this manner until a pressure of 4 weights is obtained and all readings are recorded in Table 5.2.1 below.

Note it! / Important!

Please note that if the syringe does not return to the original volume when the weights are removed, you should **NOT** attempt to correct it!

Pressure (weight)	Volume measurement			
	Result 1 (R1) (volume in cm^3)	Result 2 (R2) (volume in cm^3)	Result 3 (R3) (volume in cm^3)	Average volume in cm^3
1×1 kg				
2×1 kg				
3×1 kg				
4×1 kg				

Table 5.2.1: Pressure and volume measurements

7. Repeat the experiment at least 3 times and record your results in Table 5.2.1, then calculate the average volume for each of the different sets of values of volume.

Note it! / Important!

Please remember that the average volume is calculated by adding the three values of volume and dividing the sum by three as shown below.

$[(R1 + R2 + R3) \div 3]$

Now answer the questions that follow.

1. What happens to the volume of the air in the syringe as the pressure (number of books) is increased?

____

____

____

2. Do you think there is a change in the number of particles inside the syringe?

3. Do you think the mass of the air has changed with an increase in the external pressure?

We hope that the activity was interesting for you. To verify your answers, please refer to the Feedback to Activity 5.2.1 below.

Feedback

Feedback to Activity 5.2.1

1. The volume decreases as the pressure is increased.
2. No, there is no change in the number of particles.
3. No, there is no change in mass.

In the event that you could not do the above experiment, we believe that you may have fiddled with a bicycle pump (inflator) where you have blocked the exit while you applied a downward force on the handle. In so doing, you noticed that the volume of the trapped air decreased as the pressure on the handle was increased.

Activity

Activity 5.2.2

You should spend approximately 30 minutes on this activity.

To help you better understand the relationship between pressure and the volume of a fixed mass of gas at constant temperature, consider the data given in Table 5.2.2 below.

Pressure (p) (x 100 kPa)	**Volume (V) (dm^3)**	**P x V**	**1/V**
a) 0.5	2.0	0.5 x 2.0 = 1.0	0.5
b) 1.0	1.0	1.0 x 1.0 =	
c) 2.0	0.5	2.0 x 0.5 =	
d) 4.0	0.25	4.0 x 0.25 =	
e) 10.0	0.1	10.0 x 0.1 =	

Table 5.2.2: Data of pressure and volume

Source: Nick England, (1989, p.102). *Physics Matters*.

1. Complete Table 5.1.1 by calculating the reciprocal of volume (1/V) for each of the values of volume given in the table. (Check your answer by referring to the feedback section at the end of the topic).

2. Now, use the data to draw two graphs:

   i. Pressure against volume. Plot the pressure (in kilopascal) on the vertical (Y) axis and volume (in dm^3) on the horizontal (X) axis. Draw a best fit curved line through your points.

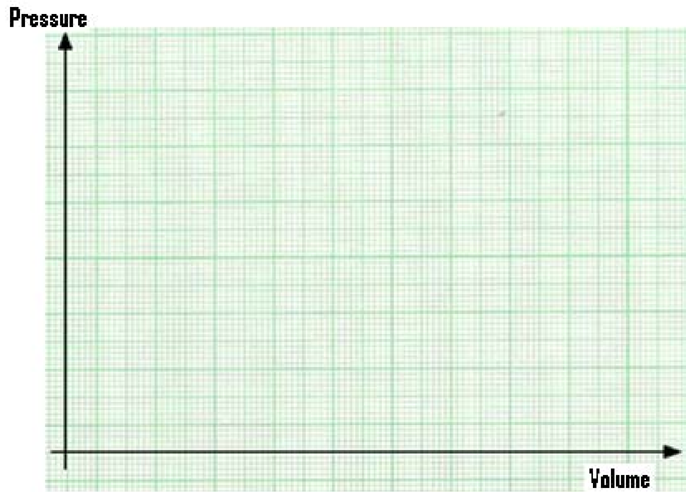


Figure 5.2.1: Grid for drawing the graph of pressure against volume.

ii. Pressure against reciprocal volume. Use the values for pressure and the reciprocal of volume to draw a second graph. Plot the reciprocal volume (i.e. one over **v** (1/v)) on the horizontal (X) axis and pressure on the vertical (Y) axis. Be sure to start with x = 0 at the origin. Draw a straight best fit line through your points, and extend your line to the (Y) axis.

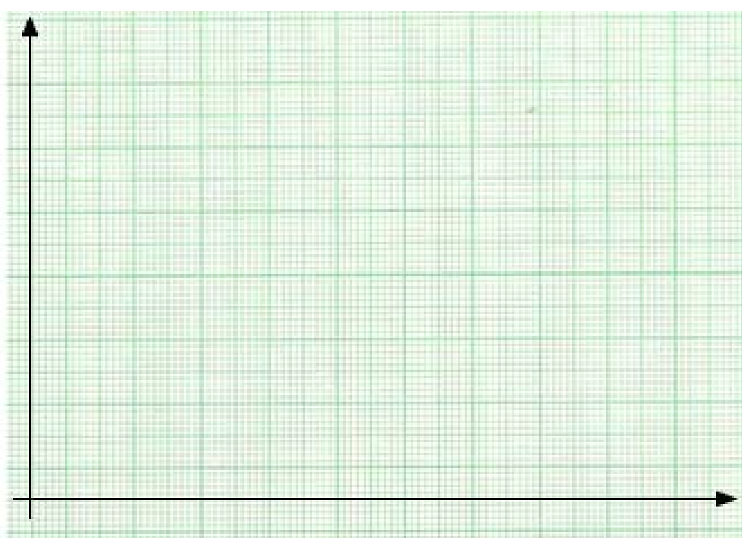


Figure 5.2.2: Grid for drawing the graph of pressure against reciprocal volume

3. Now answer the following questions.

   i. What is the shape of:

      a. the graph of pressure (p) against volume (V)

      b. pressure (p) against reciprocal volume (1/V)?

   ii. Extend the graph of pressure against reciprocal volume (1/V) with a dotted line. Where does it cut the x and y axes?

   iii. What is the relationship between pressure and the reciprocal volume? Explain your answer.

   iv. What is the relationship between pressure and the volume? Explain your answer.

v. Complete the fourth column in Table 5.2.2 by multiplying the corresponding values of P and V. (The first one has been done for you). What do you notice?

I hope that you have found the activity easy to complete. Please refer to the Feedback to Activity 5.2.2 below.

Feedback to Activity 5.2.2

Feedback

1.

	Pressure (p)	Volume (V)	P x V	1/V
a.	a. 0.5	2.0	0.5 x 2.0 = 1.0	0.5
b.	b. 1.0	1.0	1.0 x 1.0 = 1.0	1.0
c.	c. 2.0	0.5	2.0 x 0.5 = 1.0	2.0
d.	d. 4.0	0.25	4.0 x 0.25 = 1.0	4.0
e.	e. 10.0	0.1	10.0 x 0.1 = 1.0	10.0

Table 5.2.2: Data of pressure and volume

Source: Nick England. (1989, p.102). *Physics Matters*

2. The two graphs you have drawn should look similar to the ones shown

below.

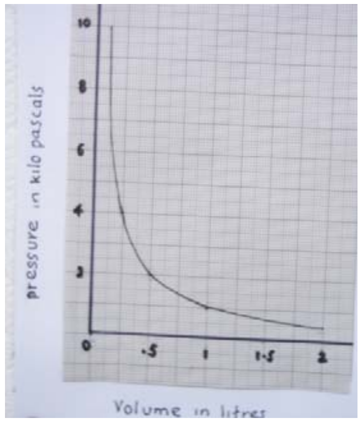


Figure 5.2.1: Graph of pressure against volume.

Sketched by Alex Souffe, August 2009

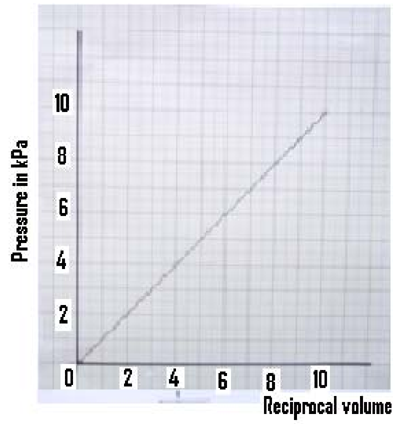


Figure 5.2.2: Graph of pressure against reciprocal volume.

Sketched by Alex Souffe, August 2009

3. i (a) A smooth curve. (b) A straight line.

   ii At the origin (i.e.0,0).

   iii They are directly proportional.

   iv They are inversely proportional. When one quantity is doubled the other one is halved.

   v All the answers are the same (1.0) or constant.

Good work! We are now going to move on to the last stage of this section; the Mathematical relationship between pressure and volume and how the relationship can be explained by the kinetic theory.

5.2.2 Mathematical expression of the relationship between pressure and volume

Your observations in the above activity are no different from those made by scientists many, many years ago. They proved that for a fixed mass of gas at constant temperature, its pressure and volume are inversely proportional. This can be recognized in two ways:

When the pressure of a fixed mass of a gas is reduced, the volume increases, but the value of pressure multiplied by the value of volume gives a constant value.

When the pressure of a fixed mass of a gas is halved, the volume is doubled, and so on.

In fact their findings can be expressed in the form of a law as follows:

The pressure of a fixed mass of gas is inversely proportional to its volume, provided the temperature remains the same (constant).

The above relationship was first proved by a scientist, named Robert Boyle in 1662. The relationship is known as **Boyle's Law**, in honour of its discoverer.

This relationship p α 1/*V* is read as *"pressure is inversely proportional to its volume"*.

In symbolic or Mathematical form it can be put as **p α 1/V**.

At this stage we will ask you to refer to Table 5.2.2. Choose any value of 1/V and multiply it by the corresponding value obtained by multiplying **P** and **V** (constant). For example: (a) $0.5 \times 1.0 = 0.5$, (b) $1.0 \times 1.0 = 1.0$, and so on. You should have noticed that all the answers correspond to the different values of **p** in Table 5.2.2.

Therefore, we can say that $p = \text{constant} \times 1/V$. Once again refer to Table 5.2.2. What do you notice about the product of each corresponding set of values $(p \times V)$?

Good observations! All the values are the same. Therefore, $p \times V = \text{constant}$ (normally denoted by **k**). Now let us focus on the first (a) and fourth (d) set of values given in Table 5.2.2. We will consider the first set of values where the pressure 0.5 could be called the *initial pressure* and is denoted by "**p1**", and the volume 2.0 could be called *initial volume* and is denoted by "**V1**", and the product of p_1 andV_1 is 1.0. This can be represented symbolically as:

$p_1V_1 = 1.0$ ……………………equation (1)

Similarly, let us consider the pressure in (d) as pressure in the second instance which is denoted by "$\mathbf{p_2}$" and the volume in the second instance which is denoted by "$\mathbf{V_2}$" and the product of p_2 and V_2 is 1.0 as well. This can also be represented symbolically as:

$p_2 V_2$ = 1.0…………………..equation (2)

Given that the products of the two sets of values (a) and (d) are equal, the two equations could be combined to give:

Both products have the same value of **1.0,** which is a constant **(k).**

$p_1V_1 = \mathbf{k} = p_2V_2$

This equation is based on Boyle's law, involving the relationship between pressure and volume of a fixed mass of a gas at constant temperature. Therefore, it is not surprising that this equation $p_1V_1 = p_2V_2$ is known as the **Boyle's Law equation**. You should have also noticed that the value p_2 (4) was made eight times greater than p_1 (0.5) and V_2 (0.25) was reduced to a volume eight times less compared to V_1 (2.0).

Now you should be ready to apply the **Boyle's Law** equation to solve problems. We shall start off by taking you through one example.

Example 5.2.1

A sample of gas collected in a 400 cm^3 container exerts a pressure of 100 kPa (kPa means kilopascal) on the wall of the container. What would be the volume of this gas if the pressure is increased to 200 kPa? (Assume that the temperature remains constant.)

Steps for solving the problem:

List what is given and what is unknown.

p_1 = 100 kPa

V_1= 400 cm^3

p_2 = 200 kPa

V_2 = ?

Think of the relationship, and then write the original formula:

$$p_1V_1 = p_2V_2$$

Next, see if you can predict what will happen. In this case the pressure has increased, so the volume should decrease.

Then, adjust the original formula to make the unknown the subject. In this case the subject is V_2.

$$p_1V_1 = p_2V_2$$

$$\frac{p_1V_1}{p_2} = \frac{\cancel{p_2}V_2}{\cancel{p_2}}$$

$$V_2 = \frac{p_1V_1}{p_2}$$

Substitute values:

$$V_2 = \frac{100\text{kPa} \times 400\text{cm}^3}{200\text{kPa}}$$

Answer: $V_2 = 200 \text{ cm}^3$

Note it! / Important!

Please note that from this example the pressure has doubled (from 100 to 200 kPa so, as we predicted, the volume of the gas has reduced by half (from 400 to 200cm^3).

Activity

Activity 5.2.3

You should spend approximately 15 minutes on this activity.

Now try these questions. Show your work in the box provided.

1. A student partially filled a syringe with 100 cm^3 of air at a pressure of 1 atmosphere. The nozzle of the syringe was sealed. The piston was pushed in slowly until the volume was 50 cm^3. What is the pressure being exerted on the gas now?

2. A mass of a gas occupies a volume of 1200 cm^3 at a fixed temperature and a pressure of 2 atmospheres. Calculate the volume of the gas when the pressure is increased to 3 atmospheres and the temperature is kept constant.

Feedback

Feedback to Activity 5.2.3

1. List what is given and what is unknown:

p_1 = 1 atm; V_1= 100 cm^3; V_2 = 50cm^3

p_2 = ?

$p_1V_1 = p_2V_2$

$$\frac{p_1V_1}{V_2} = \frac{p_2\cancel{V_2}}{\cancel{V_2}}$$

$$p_2 = \frac{1\text{ atm x }100\ \cancel{\text{cm}}^3}{50\cancel{\text{cm}}^3}$$

Pressure = 2 atm

2. List what is given and what is unknown:

p_1 = 2 atm; V_1= 1200 cm^3; p_2 = 3 atm;

V_2 = ?

$p_1V_1 = p_2V_2$

$$\frac{p_1V_1}{p_2} = \frac{\cancel{p_2}V_2}{\cancel{p_2}}$$

$$V_2 = \frac{p1V1}{p2}$$

$$V_2 = \frac{2\ \cancel{\text{atm}} \times 1200\text{cm}^3}{3\ \cancel{\text{atm}}}$$

$V_2 = 800\ cm^3$

Volume = 800 cm^3

Well done! I hope that you did not find these questions too challenging.

5.2.3 Boyle's Law and the Kinetic Theory

Now that you are familiar with both Boyle's law and the Kinetic theory you are ready to study the relationship between the two. In order to gain a better understanding of the relationship between Boyle's law and the kinetic theory, you should try the simple activity suggested below.

Note it! / Important!

Remember, the kinetic theory explains the behaviour of particles and Boyle's law is about the relationship between pressure and volume of a gas.

Activity

Activity 5.2.4

You should spend about 15 minutes on this activity.

Study the diagram carefully and then follow the experimental steps closely. You do not need to have access to a laboratory to do this activity.

Figure 5.2.3a: Photo of marked plastic bag.

Photographed by: Louisette Bonte, September 2010

Experimental steps

1. Use a new plastic bag that has no holes.
2. Remove all the air from the plastic bag by flattening it on a table.
3. Use a marker to draw three lines across the plastic bag so that it is divided into approximately four equal parts as shown in Figure 5.2.3a.
4. Use a straw to half fill the plastic bag with air by blowing gently. (Caution: *do not make it too hard as the plastic will burst*.)
5. Remove the straw and tie the bag firmly at the three quarter mark (*i.e. the upper line*) so that the air does not escape.
6. Hold the bag at the point it has been tied firmly and gently twist it until the twisted part reaches the half way mark. Feel the bag as you twist.

Figure 5.2.3b: Photo of marked and twisted plastic bag.

Photographed by: Alex Souffe, September 2010

Using your observations in the activity you have carried out about the air in the plastic bag after it was twisted, complete the table below by putting a tick in one of the boxes that best represents your observations or inferences for each quantity.

	Quantities	Remain the same	Increased	Decreased
a.	Volume of air			
b.	Temperature of the air			
c.	Pressure of the air			
d.	Distance between air particles			

Table 5.2.3: Table to record observations

Feedback to Activity 5.2.4

Feedback

Good observations!

Remained the same (b), Decreased (a) and (d), Increased (c).

We hope that you were not too nervous while twisting the bag. The air particles were subjected to an external pressure causing them to move closer together. By being closer together, the same number of moving molecules occupied less volume, but their rate of collision with the wall of the plastic bag increased. The decrease in volume has also resulted in a decrease in the surface area of the inside wall, and the increase in collision rate on the reduced area of wall of the bag led to the increase in pressure (bag felt harder).

In terms of the particle theory there is far more impact (i.e. as if more particles are exerting forces) on each square centimetre (cm^2) of the inner sides of the plastic bag, causing an increase in the pressure which is in accordance with Boyle's Law.

5.2.4 Relationship between volume and temperature of a gas

Now we are going to study the relationship between *volume* and *temperature* of a fixed mass of a gas at constant pressure. If you have access to a laboratory and the assistance of a science teacher you may try this experiment. Study the diagram carefully and then follow the experimental steps.

Activity

Activity 5.2.5

You should spend about 15 minutes on this activity.

Experimental Steps:

Refer to the Figure 5.2.4 to help you to better understand the whole process.

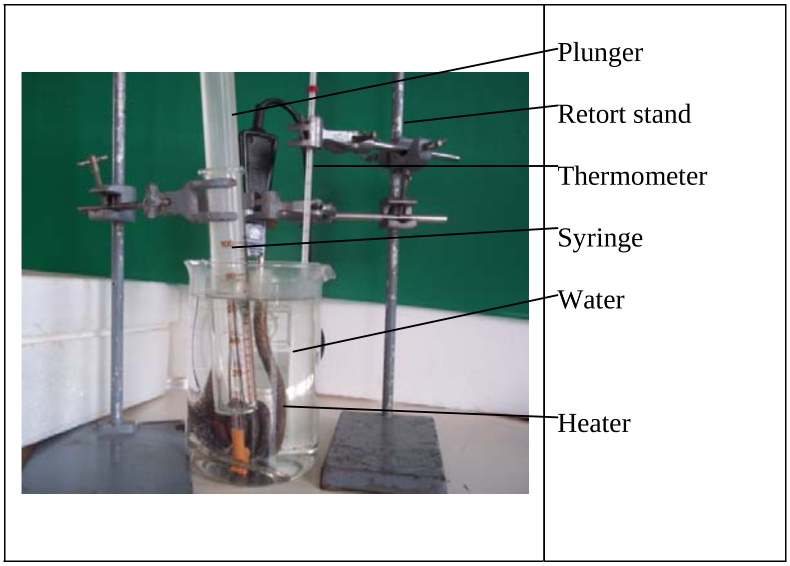


Figure 5.2.4: Diagram of set up to investigate the relationship between volume and temperature of a gas.

Photographed by Lionel Goonetilleke, August 2010

1. Use a plastic or glass syringe which measures in cm^3.
2. Remove the piston and lubricate it.
3. Insert the lubricated piston into the syringe and leave it at the half way mark.
4. Use a short piece of rubber tubing and a clip to seal the outlet of the syringe so that it is half filled with air.
5. Use a retort stand to submerge the syringe in a beaker of tap water in a vertical position.
6. Use a thermometer to measure the temperature of the water.

7. Leave it for 3 minutes so that the temperature of the trapped air becomes the same as that of the water.

8. Record the temperature and the volume of the trapped air.

9. Without adjusting the syringe, repeat step 5 but use boiling water instead of tap water and record the measurement after 1 minute.

Experiment	Temperature (^{o}C)	Gas volume (cm^3)
Tap water (30 ^{o}C)		
Hot water (90 ^{o}C)		

Questions

1. What did you notice?

____

____

____

2. If the syringe was placed in very cold water instead, what would have happened?

____

____

____

Feedback

Feedback for activity 5.2.5

1.When the syringe of air was placed in hot water (90 ^{o}C) the plunger moved outwards and the volume of the trapped air was increased.

2.In cold water the plunger would move inwards and the volume of air would decrease.

Good! What you have done has also been proven by scientists. They carried out even more controlled experiments to understand the relationship between the volume and the temperature of gases. Let us consider some of the measurements that they obtained. To help you better understand, let us consider the data given in Table 5.2.4 below.

Volume in mm^3	Temperature in ^{o}C
127	16
134	32
139	46
152	71
159	89

Table 5.2.4: Measurements of volume and temperature

Activity

Activity 5.2.6

You should spend about 15 minutes on this activity.

Use the information in the table to draw a graph of volume against temperature in ºC. Plot the volume (in mm^3) on the vertical (Y) axis and the temperature (in ºC) on the horizontal (X) axis. Through the points on your graph, draw the best fit straight line, and extend your line until it intersects both the (Y) and (X) axes. (Scale: 1 small square represents 5 mm^3 on the vertical axis and 5 ºC on the horizontal axis)

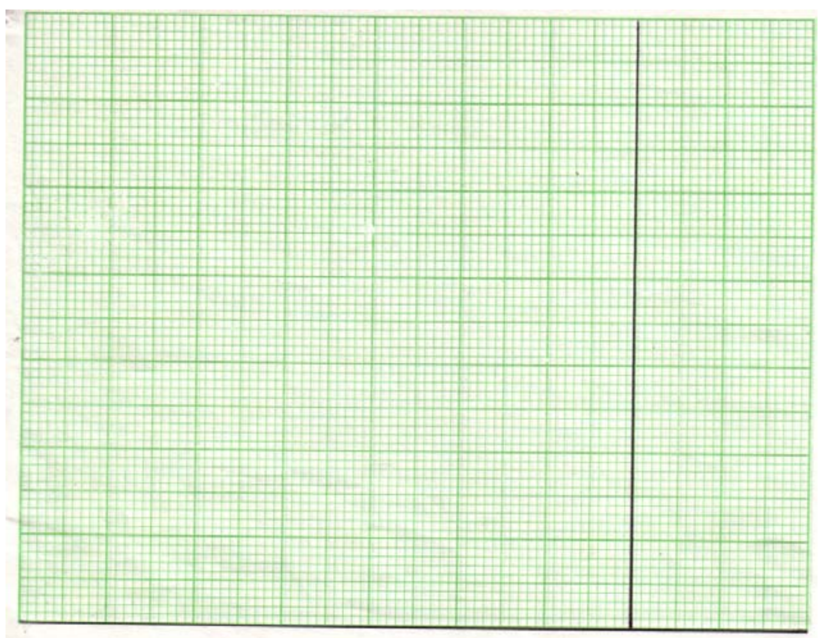


Figure 5.2.5: Grid for drawing the graph of *volume* against *temperature*

Sketched by Lionel Goonetilleke, September 2010

Questions

1. What does the graph indicate about the way the volume of the air

changes as the temperature increases?

2. What is the volume of the gas when the temperature is 0 ºC?

3. What is the temperature when the volume of gas is 0 mm^3?

Feedback

Feedback for activity 5.2.6

You should have obtained a graph similar to the one shown below in figure 5.2.6.

Graph showing volume against temperature

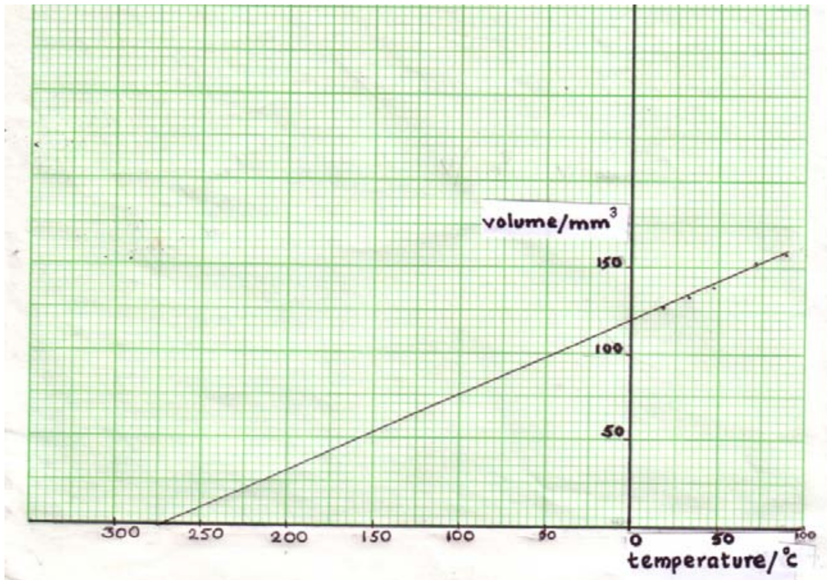


Figure 5.2.6: Graph of volume against temperature

Sketched by Lionel Goonetilleke, September 2010

1. The volume of the gas increases uniformly (indicated by the straight line graph) as the temperature of the gas increases and vice versa.

2. about 124 mm^3

3. about -273 ºC

Well done! So far you have learnt that matter is made up of particles. Particles in gases are further apart and are free to move at different speeds depending on their temperature. When the temperature of a gas is lowered the speed of the particles also lowers and they occupy less volume (space). If the cooling process is continued the gas changes state. Normally, this happens to all gases.

From the graph the limit of coldness is -273 ºC. This value (-273 ºC) is referred to by scientists as the **absolute zero**. Remember the scientists obtained this value through very careful experiments. The scale starting from absolute zero (-273 ºC) is called the **kelvin** or **the absolute temperature scale**.

One division on the Kelvin scale is equal to *one division* on the Celsius scale. Hence, -273 ºC is equal to 0K, 0 ºC is equal to 273K and 100 ºC is equal to 373K. To convert from a Celsius temperature (t) to Kelvin temperature (T) simply add 273 to the Celsius value; i.e. $T = t$ ºC + 273.

Activity

Activity 5.2.7

You should spend 15 minutes on this activity.

To help you apply this equation ($T = t$ ºC + 273) we are going to ask you to complete Table 5.2.5. The first one has been done for you.

	Volume (mm^3)	Temperature (^{0}C)	Temperature (K)
a)	127	16	289
b)	134	32	
c)	139	46	
d)	152	71	
e)	159	89	

Table 5.2.5: Measurements of volume and absolute temperature

Feedback

Feedback for activity 5.2.7

We hope you found this easy! Check your answer by referring to the feedback below.

	Volume (mm^3)	Temperature (^0C)	Temperature (K)
a)	127	16	289
b)	134	32	305
c)	139	46	319
d)	152	71	344
e)	159	89	362

Table 5.2.5: Measurements of volume and absolute temperature

We have used the calculated data for Table 5.2.5 found above to draw a graph of *volume* against *absolute temperature* (K).

Graph showing volume against absolute temperature.

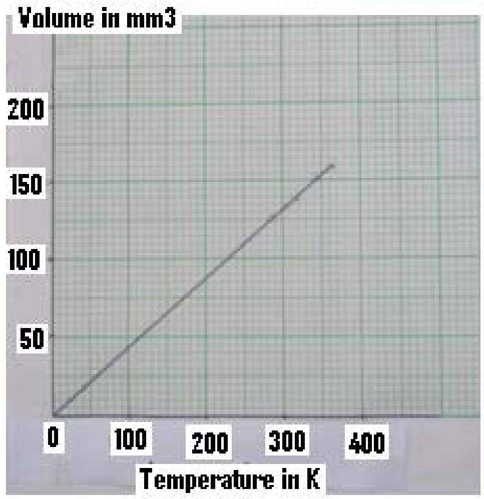


Figure 5.2.7: Graph of volume against absolute temperature

Sketched by Lionel Goonetilleke, September 2010

The graph of *volume* against *absolute temperature* in kelvin that we have drawn is also a straight line, like the graph of volume against temperature in degrees Celsius. However, the marked difference is that the line passes through the orgin (00), so there is a direct proportionality between the absolute temperature and the volume of a fixed mass of a gas. This means that as the temperature increases so too does the volume. Furthermore, the graph passing through the origin indicates that at 0 K, the volume of the gas is also zero but in reality the gas will turn to liquid before reaching 0 K.

The graph we have drawn in Figure 5.2.7, is similar to what scientists obtained a long time ago. In fact these findings can be expressed in the form of a law as follows:

> **The volume (V) of a fixed mass of gas is directly proportional to its absolute temperature (T) provided the pressure of the gas is kept constant.**

The above relationship was first proved by a scientist, named Jacques Charles in 1787. This is known as **Charles' Law**, in honour of its discoverer.

This relationship **V α T** is read as "volume is directly proportional to the absolute temperature"

In symbolic or mathematical form it can be stated as **V α T.**

At this stage we will ask you to refer to Table 5.2.4. Choose any value of volume and divide it by the corresponding value of absolute temperature. You should notice that all the answers are the same.

Therefore we can say that $V \div T = k$.

Now let us focus on the first (a) and the third (c) sets of values given in Table 5.2.4. We will consider the first set of values where the volume could be called the initial volume and is denoted by "V_1" and the corresponding initial absolute temperature could be called "T_1" and the quotient of $V_1 \div T_1$. This can be represented symbolically as:

$V_1 / T_1 = 0.439$ which to the nearest hundredth is **0.44** equation (1).

Similarly, let us consider the volume in (c) as volume in the second instance and is denoted by "V_2" and the temperature in the second instance and is denoted by "T_2" and the quotient of p_2 and V_2 is 1.0 as well. This can also be represented symbolically as:

$V_2/T_2 = 0.436$ which to the nearest hundredth is **0.44** equation (2)

Given that the quotient of the two sets of values (a) and (c) are equal, the two equations could be combined to give:

The answers to both questions are the same which is **0.44,** a constant **(k).**

$V_1/T_1 = \boldsymbol{k} = V_2/T_2$

This equation is based on the Charles' law, involving the relationship between volume and absolute temperature of a fixed mass of a gas at constant pressure. Therefore it is not surprising that this equation "$V_1/T_1 = V_2/T_2$" is known as the **Charles' Law equation**. Now you should be ready to apply **Charles' Law** equation to solve problems. We shall start off by taking you through one example.

Example:

A sample of gas collected in a 400 cm^3 container is at 27 ºC. What would be the volume of this gas if the temperature is increased to 57 ºC? (Assume that the pressure remains constant.)

Steps for solving the problem:

List what is given and what is **unknown.**

V_1= 400 cm^3

T_1 = (27 + 273) K = 300K

T_2 = (57 + 273) K = 330K

V_2 = ?

Think of the relationship, then write **the original formula:**

$$\boldsymbol{V_1/T_1 = V_2/T_2}$$

Next, see if you can predict what should happen. In this case the absolute temperature has increased, so the volume should increase because there is a direct proportionality between the two quantities.

Then, adjust the original formula **to make the unknown** the **subject.** In this case the subject is V_2.

$V_1/T_1 = V_2/T_2$

$$\frac{V1T2}{T1} = \frac{V2\cancel{T2}}{\cancel{T2}}$$

$$V2 = \frac{V1T2}{T1}$$

$$V2 = \frac{400\text{cm}^3 \times 330\cancel{\text{K}}}{300\cancel{\text{K}}}$$

$$\boldsymbol{V2 = 440\ cm^3}$$

(NB: From this example you should have noticed that as the temperature increased the volume increased as well.)

Activity

Activity 5.2.8

You should spend 10 minutes on this activity.

Now try these questions.

1. A student partially filled a syringe with 100 cm^3 of air at a temperature of 32 ºC. The nozzle of the syringe was sealed. The syringe was then placed in refrigerator at a temperature of 7 ºC for one hour. What was the volume of the gas? (NB: Through out the exercise the pressure of the air in the syringe remained constant and the friction of the plunger was negligible).

2. A fixed mass of a gas occupies a volume of 1200 cm^3 at a temperature of 17 ºC. The gas was heated and the volume increased to 1407 cm^3 and the pressure was kept constant throughout. Calculate the temperature to which the gas was heated?

Feedback

Feedback for activity 5.2.8

1. List what is given and what is **unknown.**

V_1= 100 cm^3; T_1 = (32+273) K; $T2$ = (7 + 273) K; V_2 = ?

$$V2 = \frac{V1T2}{T1}$$

$$V2 = \frac{100\text{cm}^3 \times 280\cancel{\text{K}}}{305\cancel{\text{K}}}$$

V2 = 91.80 cm^3

2. List what is given and what is **unknown.**

V_1= 1200 cm^3; T_1= (17+273) K; V_2 = 1407cm^3, T_2 = ?

$$T2 = \frac{T1V2}{V1}$$

$$T2 = \frac{290\text{K} \times 1407\cancel{\text{cm}}^3}{1200\ \cancel{\text{cm}}^3}$$

T_2 = 340 K or 67 °C

Well done! Now you are ready to handle any questions involving Charles' Law and ready to study the relationship between pressure and temperature of a gas.

5.2.5 Relationship between *pressure* and *temperature* of a gas

Now we are going to study the relationship between *pressure* and *temperature* of a fixed mass of a gas at constant volume. If you could have access to a laboratory and the assistance of a science teacher you may try this experiment. Study the diagram carefully and then follow the experimental steps.

Figure 5.2.8: Photograph of set up to investigate the relationship between pressure and temperature of a gas.

Photographed by Lionel Goonetilleke, August 2010

Activity

Activity 5.2.9

You should spend 10 minutes on this activity.

Experimental Steps:

1. Refer to Figure 5.2.8 to help you to better understand the whole process. Normally, students are asked to:

- Set up the apparatus as shown in figure 5.2.8.
- Seal the glass container to ensure that the air in it does not escape. This will ensure that the volume of air is kept constant throughout the experiment.
- Heat the water around the round-bottomed flask in stages (e.g 30, 40, 50, 60 and 70 ºC) to increase the temperature of the air.
- At each stage, the pressure of the air is measured on the Bourdon gauge (the flexible plastic tubing should be as short as possible to reduce the amount of air of different temperature).
- Record your *data for pressure* and *temperature* in the table below.

Pressure (N/m^2)	Temperature (°C)	Temperature (K)

(Remember that you have to convert all the temperature measurements in degrees Celsius to Kelvin by adding 273 to each value.)

In the event that you cannot do the experiment, study the data given in table 5.2.5 below.

Pressure (kPa)	Temperature (°C)	Temperature (K)
102	27	300
111	52	325
119	77	350
122	87	360

Table 5.2.6: Pressure and Temperature measurements

2 Use the data you have obtained from the experiment or the ones in Table 5.2.6 to draw a graph of pressure (y-axis) against temperature in ºC (x-axis).

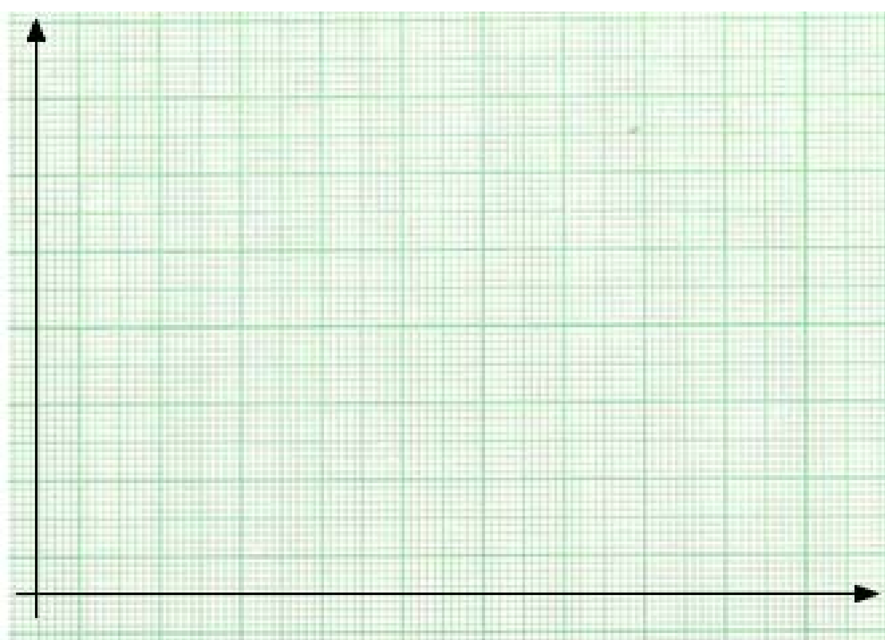


Figure 5.2.9: Grid for drawing the graph of *pressure* against reciprocal *temperature*

Questions

1 What is the shape of the graph?

2 Use the graph to work out the gas pressure when the temperature is 80 ºC

3 Extend the graph with dotted line. Where does it cut the x and y axes?

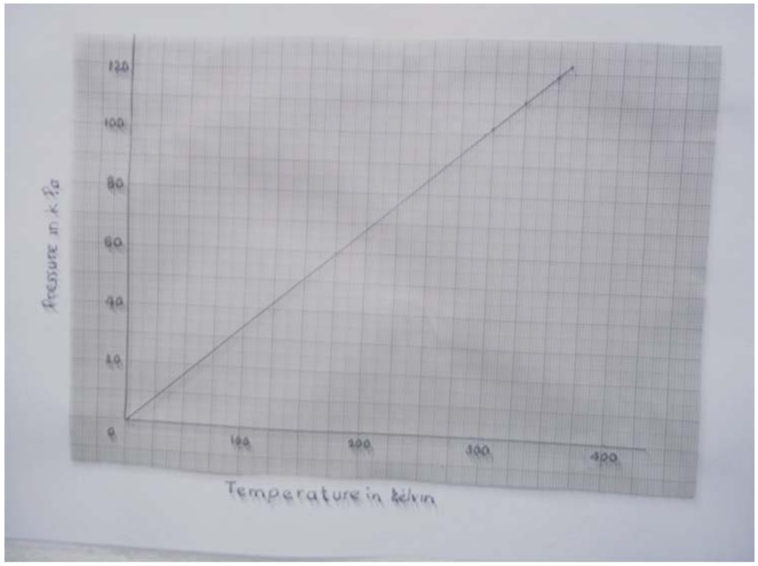
4 What is the relationship between the Kelvin temperature and the pressure of the fixed mass and constant volume of gas?

5 Explain in term of the behaviour of particles what causes the increase in pressure as the temperature increases?

Feedback

Feedback for activity 5.2.9

2. If you have used the data from Table 5.2.5, your graph should be similar to the one given below.



Answers to questions:

1. Straight line.

2. 237.5 ^{o}C

3. At the origin (at 0 K, 0 N/m^2).

4. For a fixed mass of gas, at constant volume, the pressure (p) is directly proportional to the absolute temperature (T).

5. As the temperature is increased the particles move faster and strike the wall of the container at a higher rate with greater force. This results in higher pressure.

From the graph you have drawn, you should have noticed all the usual signs of a simple proportion:

a. The graph is a straight line passing through the origin (0,0).

b. Doubling the absolute temperature (K) of the air doubles the pressure.

c. Dividing the pressure of the air by its absolute temperature always produces the same (constant) value.

Your observations are not too different from those made by scientists many years ago. In fact they used better equipment and they obtained more accurate results than you did. From their findings they were able to sum up their observations in a law which states that:

> **The pressure of a fixed mass of gas is directly proportional to its absolute temperature provided the volume of the gas is kept constant.**

This is known as the **Pressure Law**

> This relationship $\boldsymbol{p \alpha T}$ is read as "pressure is directly proportional to the absolute temperature"

In Mathematical form it can be stated as **p α T**.

At this stage we will ask you to refer to Table 5.2.5. Choose any value of pressure and divide it by the corresponding value of absolute temperature. You should notice that all the answers are the same.

Therefore we can say that $p \div T = \mathbf{k}$.

Now let us focus on the first (a) and third (b) set of values given in Table 5.2.5. We will consider the first set of values where the volume could be called the initial pressure and is denoted by "p_1" and the corresponding initial absolute temperature could be called "T_1" and the quotient of $p_1 \div T_1$ can be represented symbolically as:

$p_1 / T_1 = 0.34$ ………………..equation (1).

Similarly, let us consider the pressure in (b) as pressure in the second instance and is denoted by "p_2" and the temperature in the second instance and is denoted by "T_2" and the quotient of p_2 and T_2 is 0.34 as well. This can also be represented symbolically as:

$p_2/T_2 = 0.34$ which to the nearest hundredth is 0.34 ………..equation (2)

Given that the quotient of the two sets of values (a) and (b) are equal, the two equations could be combined to give:

> The answers to both questions are the same which is **0.34,** a constant **(*k*).**

$p_1/T_1 = \mathbf{k} = p_2/T_2$

This equation is based on the **Pressure law**, involving the relationship between pressure and absolute temperature of a fixed mass of a gas at constant volume. Hence, this equation "$p_1/T_1 = p_2/T_2$" is known as the Pressure Law equation. Now you should be ready to apply this Law to solve problems. We shall now invite you to go through one example.

Example:

A driver pumps each tyre of his car very early in the morning and sets out on a long journey. The temperature was 22 ºC and the pressure in each tyre was 230 kPa. At the end of his journey the temperature of the air in the tyres has increased to 42 ºC.

Calculate the pressure of the air in the tyres just at the end of his journey. Assume that the volume of the tyres does not change.

Steps for solving the problem:

1. List what is given and what is unknown.

$p_1 = 230$ kPa

$T_1 = (22 + 273)$ K $= 295$K

$T_2 = (42 + 273)$ K $= 315$K

$p_2 = ?$

2. Think of the relationship, then write the original formula:

$$p_1/T_1 = p_2/T_2$$

3. Next, see if you can predict what should happen. In this case the absolute temperature has increased, so the pressure should increase because there is a direct proportionality between the two quantities.

4. Then, adjust the original formula to make the unknown the subject. In this case the subject is p_2.

$$p_1/T_1 = p_2/T_2$$

$$\frac{p1T2}{T1} = \frac{p2\cancel{T2}}{\cancel{T2}}$$

$$p2 = \frac{p1T2}{T1}$$

$$p2 = \frac{230\text{kPa} \times 315\cancel{\text{K}}}{295\ \cancel{\text{K}}}$$

p_2 = 245.6 kPa

(NB: From this example you should have noticed that the temperature increased and the pressure increased as well.)

Well, you have come to the end of Topic 5.2. Before proceeding to the next topic, let us see how much you have learnt, so far. At this stage, you are ready to try out the self assessment exercise below.

Assessment

Self-assessment 5.2

You need approximately 30 minutes to do the self assessment which is organised into two sections. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 5.2. This will help you learn and reflect better on areas for improvement.

Part A:

Complete these sentences with the most suitable words:

1. The three states of matter are ________________, __________________ and ________________.

2. The particles of a solid have ________________ kinetic energy. This is because the particles in solids experience strong ________________ forces of attraction.

3. The intermolecular forces of attraction between particles in a liquid are great enough to hold the particles near each other, but ________________ to prevent the particles from sliding around.

4. ________________ have a definite volume, but take the shape of their container.

5. The velocity or kinetic energy of the particles of liquids or gases increases as the ________________ increases.

6. Based on Boyle's law, for a ________________ mass of a gas, at constant ________________ the product of________________ ×

_________________ is constant.

7. At the absolute temperature (-273ºC) particles have

_________________ energy than at zero degree Celsius.

Part B:

Complete the table and the questions below.

1. Complete the table by converting the different temperatures.

	Temperature in (ºC)	Temperature in (K)
a.	-273	0
b.	-100	
c.		273
d.	37	
e.		373

For question 2 to 4, select and circle the best response.

2. When the temperature of a gas rises at constant volume, its molecules

   A. move closer to one another.

   B. move with greater average speed.

   C. collide with one another less often.

   D. exert smaller forces on one another.

3. As part of the décor for parties, inflated balloons are used. During the day when it is much warmer, the balloon becomes larger and much smaller than during the night when it is much cooler.

How does the behaviour of the air molecules in the balloon explain this?

A. The molecules become larger and move slower.

B. The molecules evaporate at a faster rate.

C. The molecules move more quickly and collide with the balloon walls more often.

D. The molecules repel each other and collide with the wall.

4. A student places her thumb firmly on the outlet of a bicycle pump, to stop the air from coming out. What happens to the pressure and to the volume of the trapped air as the pump handle is pushed in?

	Pressure	**Volume**
A	increases	decreases
B	decreases	remains the same
C	decreases	decreases
D	increases	remains the same

5. A sealed syringe contains 90 cm^3 of air at a pressure of 1.0 atmosphere. A pressure of 1.5 atmospheres is applied to the piston and this causes a change in the volume of the gas. What is the volume of the gas?

Please see our suggestions in the Answers to Self Assessment for Topic 5.2 provided at the end of this topic to see if you were on the right track.

Answers to self-assessment 5.2

Part A

1. Solids, liquids and gases
2. Low , intermolecular
3. Insufficient
4. Liquids
5. Temperature
6. Fixed, temperature, pressure x volume
7. Less

Part B

1. b) 173K; c) 0 ^{o}C; d) 310; e) 100 ^{o}C,
2. B
3. C
4. A
5. 60cm^{3}

Now that we have come to the end of topic 5.2, what do you recall about the behavior of gas molecules? How do they react to increase or decrease in temperature or pressure?

Ever wondered why things sink and float? You may be able to find the answer in the next topic. Let's move on to find out!

Topic 5.3: Density

How long?

You will need 1 hour 40 minutes at the most to complete this topic. It is advisable that you spend another 50 minutes of your own time to further practise the activities learnt. Make sure you read and try to understand everything in order to achieve the specific objectives.

We will start off this topic by posing two simple trivial questions:

1. Which is heavier, a kilogram of lead or a kilogram of foam (polystyrene)?

____

2. Which is heavier: wood or iron?

____

It is not surprising that your answer to the first question is that they are the same in mass for they are both one kilogram. However, the one kilogram of lead occupies less space (volume) than the one kilogram of foam. Lead is more compact than foam.

Regarding the second question, most people tend to give iron as the answer but it could be either iron or wood. Can you guess why? Yes! It depends on the size of the pieces being compared: a large piece of wood being compared with a small piece of iron or a large piece of iron.

In science, whenever we want to compare things, we have to make a fair comparison by fixing (keeping constant) some parameters, for example volume, mass, length and so on. Let us for example consider equal volume of the two materials (wood and iron) and then the mass will be measured in kilogram (kg) or gram (g) using a beam balance.

Say for example, let us take the mass of a regular shaped piece of wood and a piece of iron of length 10cm, width 4cm and height 5cm each. The mass of the piece of wood is, let us say, 160g and that of the iron is 1560 g.

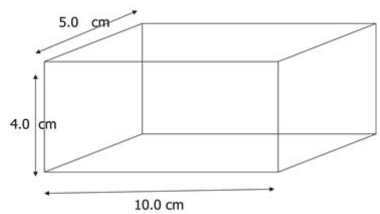
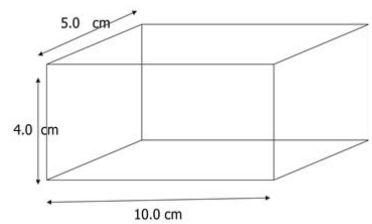
Wood	Iron
 Mass = 160g	 Mass = 1560g

Figure 5.3.1: Regular shaped pieces of wood and iron

The volume of the two blocks is calculated by using the equation:

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$

Now let us calculate the volume of the piece of wood and the piece of iron.

Volume of Wood	*Volume of Iron*

Volume of Wood	*Volume of Iron*
$V = l \times w \times h$ $= 10\text{ cm} \times 4\text{ cm} \times 5\text{ cm}$ $= 200\text{ cm}^3$	$V = l \times w \times h$ $= 10\text{ cm} \times 4\text{ cm} \times 5\text{ cm}$ $= 200\text{ cm}^3$

Figure 5.3.2: Calculating the volume of the piece of wood and the piece of iron

We know that the mass of the two objects are:

Mass of wood = 160g   Mass of Iron =1560g

The calculations show that the regularly shaped pieces of wood and iron of mass of 160g and 1560g, respectively both have the same volume of 200 cm^3. Now we can confidently say that, in this example, when equal volumes of iron and wood are compared, iron is heavier than wood.

In Physics, whenever we are comparing the mass of equal volumes of two substances to determine which one is heavier, the property we are in fact comparing is the **density** of the substances.

5.3.1 What is density?

Density is a measurement which is influenced by a number of factors namely - how tightly packed the particles are within a substance, how heavy each particle of that particular substance is and the space the substance occupies (i.e. how large or small it is). You can therefore understand that though a hockey ball and a cricket ball may be roughly of the same size, the cricket ball is denser as it has more matter packed in the same volume (space).

As a matter of fact for us to do a fair comparison of the two balls we need to measure the density of each one. In so doing, we have to compare the mass of equal volume of each ball. Density is defined as **mass per unit volume** (i.e. the mass of **1 cm^3 or 1 m^3**) of the substance. The commonly used formula to determine the density of an object is mass of the object divided by its volume

[$d = m/V$ or $\rho = m/V$, the letter (d) or ρ (Greek letter ‘rho’) is used to represent density, m to represent mass, and V to represent volume].

The SI unit used to indicate density is kilogram per cubic metre (**kg/m³**) or gram per cubic centimetre (**g/cm³**). The procedure for converting 1000 kg/m^3 to 1 g/cm^3 is given below.

To convert m^3 to cm^3 we multiply by 100x100x100 because 1 m is equal to 100cm and volume is calculated by multiplying length x width x height

To convert 1000kg to grams we multiply by 1000 because 1 kg is equal to 1000grams

$$\frac{1000\text{kg}}{1\ \text{m}^3} = \frac{1000kg}{1\ \text{m}^3} \times \frac{1000}{100 \times 100 \times 100} = \frac{1\ \cancel{0000000}\ g}{1\ \cancel{0000000}\ cm^3} = 1\ \text{g/cm}^3$$

The formula for calculating density is:

$\text{Density} = \frac{\text{mass}}{\text{volume}}$, which may be represented symbolically as

$$\text{d} = \frac{\text{m}}{\text{V}} \text{ or } \rho = \frac{\text{m}}{\text{V}}$$

Now we can work out the density of the wood and iron stated in the example above.

Wood	Iron
Mass = 160g, Volume = 200cm^3 density =? $\rho = \frac{m}{V}$ $\rho = 160g/200\ cm^3$ $\rho = 0.8\ g/cm^3$	Mass = 1560g, Volume = 200cm^3 density =? $\rho = \frac{m}{V}$ $\rho = 1560g/200cm^3$ $\rho = 7.8\ g/cm^3$

Figure 5.3.2: Calculating the density of a piece of wood and a piece of iron

Remember, density tells us the mass of unit volume of the substance, therefore, 1 cm^3 of the wood has a mass of 0.8g, and 1 cm^3 of the iron has a mass of 7.8g. Evidently, 1 cm^3 of iron is nearly 10 times heavier than 1 cm^3 of wood. Now, you will be given the opportunity to go through the steps for solving problems involving density, mass and volume.

Given certain known values, we can use the formula to calculate the density, the mass and the volume of any given object. We will start off with an example of how to use the formula to solve for the density.

Example 5.3.1: Solving for Density

Note it! / Important!

Remember, when solving for density, you must use the formula [density = mass ÷ volume] exactly as it is given. Here is an example where density is the unknown, and the steps for solving the problem.

Problem 5.3.1:

Mary finds that a piece of an unknown material has a mass of 54.0g and a volume of 20.0 cm3. What is the density of the material?

Step 1: List the “known values” and the “unknown values”.

d = ?

m = 54.0 g

V = 20.0 cm^3

Step 2: Write the correct formula.

$$d = \frac{m}{V}$$

Step 3: Substitute the **known values** in the equation.

$$d = \frac{m}{V}$$

$$= \frac{54.0 \text{ g}}{20 \text{ cm}^3}$$

Step 4: Calculate your answer, including units.

$$d = 2.7\text{g/cm}^3$$

Example 5.3.2: Solving for Mass

This time we are going to solve for mass. We must start with the original formula [density = mass ÷ volume], and isolate the unknown values like shown below, so that mass becomes the subject.

Step 1: Write the correct formula.

$$d = \frac{m}{V}$$

Step 2: Multiply both sides by V.

$$V \times d = \frac{m}{V} \times V$$

Notice that the Vs cancel out and ‘m’ the unknown is on the right hand side of the equation.

$$V \times d = \frac{m}{V} \times V$$

Step 3: By convention you have to rearrange the formula so that the unknown appears on the left hand side of the equation, as shown below.

$$mass = volume \times density$$

$$m = V \times d$$

Now that you have worked out the mathematical formula for solving mass as the unknown, you are ready to solve a problem.

Problem 5.3.2

Lead has a known density of 11.40 g/cm^3. What would be the mass of a 1.5 dm^3 piece of lead?

Step 1: List the **known values** and the **unknown values**.

m = ?

d = 11.40 g/cm^3

V = 1.5 dm^3

Note it! / Important!

Please, notice that the unit for density is given in g/cm^3, but the unit of volume is in dm^3. We have to change dm^3 to cm^3. Hence, this problem requires an additional step.

Remember 1dm^3 is equal to 1000 cm^3 because 1 dm = 10 cm, so
$1 \text{ dm}^3 = 10 \text{ cm} \times 10 \text{ cm} \times 10 \text{ cm} = 1000 \text{ cm}^3$.

Step 2: Change the unit of volume so that it is the same as the volume component in the unit for density.

Use the factor label method:

$$1.5\ \cancel{dm^3} \times \frac{1000\ cm^3}{1\ \cancel{dm^3}} = 1500\ cm^3$$

Please note that the dm^3 units appear above and below the line, so they cancel out, leaving cm^3

Note it! / Important!

Please note that not all questions will require this step. You will have to make this very important decision when solving questions of this kind.

Step 3: Write the correct **formula** (*adjusted formula*)

$$m = V \times d$$

Step 4: Substitute the known values in the adjusted formula

$$m = V \times d$$

$$m = 1500\ cm^3 \times 11.40\ g/cm^3$$

Step 5: Calculate the answer including units

$$m = 1500\ \cancel{cm^3}\ x\ 11.40\ g/\cancel{cm^3}$$

$$m = 17100\ g$$

$$\text{or } m = 17.10\ kg$$

Divide 17100 g by 1000 to convert the answer to kilogram for 1kg is equal to 1000g.

Note it! / Important!

You should note that we may even use the standard form or scientific notation to express the correct answer as follows:

$$m = 17100\ g$$

$$m = 1.71 \times 10^4\ g$$

Now you are ready to try one out on your own. You are invited to solve problems involving volume, mass and density in Activity 5.3.1.

Activity

Activity 5.3.1

You should spend approximately 10 minutes on this activity.

Solve the problem involving density in the space provided below, and show all your calculations.

Steel has a density of 7.8 g/cm^3. How much space (what volume) would 75.0 g of steel occupy?

We believe that you have found the problem rather easy to solve. Please refer to the Feedback to Activity 5.3.1 at the end of the topic to verify your answers.

Feedback

Feedback to Activity 5.3.1

1. When solving for volume, we must take the original formula, and isolate the unknown like shown below:

Step 1: List the known quantities and the unknown quantities.

$d = 7.8 g/cm^3$

$m = 75.0$ g

$V = ?\ cm^3$

Step 2: Rearrange the formula for density.

$$d = \frac{m}{V}$$

i) $$V \times d = \frac{m}{V} \times V$$

ii) $$\frac{V \times d}{d} = \frac{m}{d}$$

$$V = \frac{m}{d}$$

Steps to follow:

1. Multiply both sides of original formula by volume; making **m** the subject, but we want **v** as the subject, so go to step 2.
2. Divide both sides by ***d*,** giving **v** = **m** ÷ ***d***

Step 3: Substitute the known values in the equation.

$$V = \frac{m}{d}$$

$$V = \frac{75.0\ g}{7.8\ g/cm^3}$$

Step 4: Calculate your answer, including units

$V = 9.615\ cm^3$

According to us, you have completed the most difficult part, and you are now ready to carry out an experiment or use given data to determine the density of a regularly shaped solid using the formula: density $= \frac{\text{mass}}{\text{volume}}$.

5.3.2 Measuring the density of regular and irregular solids

Now that you know how to calculate the density of regular solids mathematically, we are going to provide you with the techniques of how you could take the necessary measurements experimentally for both regular and irregular solids. You need to have access to a science laboratory or the following materials: a ruler, a mass balance, measuring cylinder, a piece of string, water, regularly shaped and irregularly shaped solids. Then carry out the experiment by following the steps listed in Activity 5.3.2 for regular shaped solids and Activity 5.3.3 for irregular shaped solids.

5.3.2.1 Measuring the density of regularly shaped solids

Activity

Activity 5.3.2

You should spend about 10 minutes on this activity.

You are required to determine the density of a regularly shaped solid (e.g. cubes, cuboids, cylinders). The experimental steps to find the density of regularly shaped solids are as follows:

1. Find the mass of the regular shaped solid (e.g. rectangular glass block) by using a suitable balance.
2. Measure the length, width and height of the glass block and calculate its volume.
3. Draw a table and record your measurements.
4. Use the appropriate formula to calculate the density of the glass.

Measurement	Results
1. Mass of solid	g
2. Length of solid	cm
3. Width of block	cm

4. Height of block	cm
5. Volume of block (V = l x w x h)	cm^3
6. Density of glass	g/cm^3

Table 5.3.1: Table to record the results regarding the density of a regular solid

We know that you have found this to be a very simple task. Try to compare the value you have obtained with the one given in the table of densities of common substances in section 5.3.5. Don't be surprised if you do not get the same value, but it is important for you to try to understand what could have contributed to the difference. There are several possible reasons:

1. errors in measuring the length, width or height of the block;
2. errors in measuring the mass of the block;
3. errors in calculating the volume or the density of the glass; and
4. the glass might not be of the same type.

Note it! / Important!

Please note that the main sources of errors in scientific experiments are generally due to:

1. mistakes made by the person carrying out the experiments for example in taking measurements;
2. faulty equipment; and
3. errors in calculations.

Now you may be wondering how you can determine the density of irregular solids. We will help you by providing you with the steps that you should follow. Since the shape of an irregular solid does not have a definite length, width, or height, **it is impossible to use the formula involving length, width and height to calculate its volume**. Instead you must use the displacement method. The procedure is given in Activity 5.3.3.

5.3.2.2 Measuring the density of irregularly shaped solids

Activity

Activity 5.3.3

You should spend about 10 minutes on this activity.

You are required to determine the density of an irregularly shaped solid (e.g. a small stone). The experimental steps to find the density of irregularly shaped solids are as follows:

1. Find the mass of the irregularly shaped solid (e.g. stone) by using a suitable balance.
2. Put some water into a measuring cylinder and measure the volume of water.
3. Record the volume of water.
4. Tie the stone with a piece of thread and immerse the stone gently and completely in the water. (Ensure that there is enough water to cover the stone completely).
5. Record the reading of the water level in the measuring cylinder (while the stone is fully submerged).
6. Find the volume of the stone by subtracting the reading in step 3 from the reading in step 5.
7. Use the appropriate formula to calculate the density of the stone for you now have the measurements of both the volume and the mass of the stone.

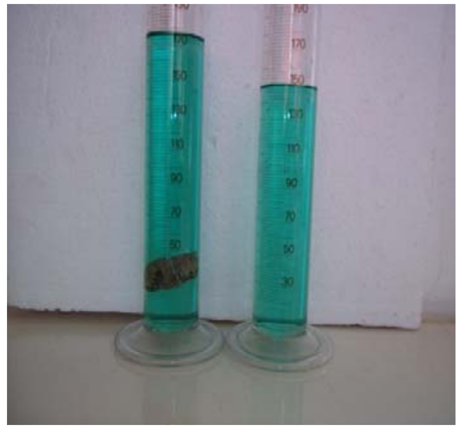


Figure 5.3.2: Apparatus for measuring the volume of an irregular solid

Photographed by: Louisette Bonte, August 2010

Measurement	Results
1. Mass of stone	g
2. Volume of stone	cm^3
3. Density of stone	g/cm^3

Table 5.3.2: Table to record the results regarding the density of an irregular solid

Now that you are in a position to calculate the density of solids, it is time for us to figure out how to calculate the density of liquids.

5.3.2.3 Measuring the density of liquids

Before turning your attention to the procedure for measuring the density of liquids, we are going to ask you to reflect on a common observation made by many people in Seychelles, given in the bubble.

Their observation is based on their experience in swimming in sea water and fresh water. They found that it is more difficult to swim in fresh water than in sea water. As a result of their swimming difficulties, they say that "fresh water is heavier than sea water".

Based on your scientific background, what would you consider to be incorrect with their assumption?

You should have noticed that they are correct in saying that it is more difficult to swim (float) in fresh water, but they are incorrect in saying that fresh water is heavier than sea water. Their observations are due to other factors in physics which we are going to address in later units.

Now that you are in a position to calculate the density of solids, we will provide you with the steps to determine the density of liquids.

Activity

Activity 5.3.4

You should spend approximately 10 minutes on this activity.

You are required to determine the density of a liquid (e.g. water, juice etc.). The experimental steps to find the density of a liquid are as follows:

1. Measure the mass of an empty container (e.g. measuring cylinder).
2. Measure the volume of some liquid (e.g. 50cm^3) by using the same measuring cylinder.
3. Measure the mass of the container and the liquid.
4. Record the results.
5. Find the mass of the liquid by subtracting the reading in step 1 from the reading in step 3.
6. Use the appropriate formula to calculate the density of the liquid for you now have the measurements of both the volume and the mass of the liquid.

Measurement	Results
1. Mass of empty container	g
2. Volume of liquid	cm^3

3. Mass of liquid and container	g
4. Mass of liquid	g
5. Density of liquid	g/cm^3

Table 5.3.3: Table to record the results regarding the density of a liquid

Try to confirm your answer through the internet or through your teacher or peers.

5.3.3 Density of some common substances

The table below shows the density of a few common substances. Try to familiarize yourself, but there is no need to learn them by heart.

Substance	**Density**	
	kg/m^3	**g/cm^3**
Air	1.3	0.0013
Foam polystyrene	100	0.10
Cork	250	0.25
Wood	700	0.70
Ethanol	800	0.80
Ice	920	0.92
Water	1000	1.00
Glass	2500	2.50
Aluminium	2700	2.70
Steel	7800	7.80

Lead	11400	11.40
Mercury	13600	13.60
Gold	19300	19.30

Table 5.3.4: Table showing the density of different substances

Source: http://www.marzinske.com/weeks/Density/DensityRead.htm

Activity

Activity 5.3.5

You will need about 5 minutes to complete this activity.

Use the information in the table to answer questions 1 to 7 in this activity:

1. The density of ethanol is __________________.

2. The substance which has a density of 2.70 g/cm^3 is ___________.

3. One cubic metre (m^3) of mercury has a mass of ______________.

4. The mass of 1 cm^3 of gold is ________________.

5. _______________ is a solid substance which is denser than ice, but

   less dense than Aluminium.

6. _____________ substances have densities greater than 1.00 g/cm$^{3.}$

7. The mass of 10 cm^3 of lead is ____________________.

We hope that you have found the activity quite easy to complete. Please refer to Feedback to Activity 5.3.5 below to verify your answers.

Feedback

Feedback for Activity 5.3.5

1. 0.80 g/cm^3
2. Aluminium
3. 13600 kg
4. 19.3 g
5. Glass
6. Six
7. 114.0 g

We are sure that you got them all right. Good attempt! You should now be ready to have a go at our final self assessment in this unit.

Assessment

Self assessment 5.3

You need about 15 minutes to complete this self assessment for Topic 5.3.

The feedback is given at the end of the topic. Once again you are strongly advised to answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Part A

Each question in Part A has four possible responses. Answer all the questions by selecting and circling the most suitable response.

1. In Physics SI units are used for different measurements. Which of the following is the SI unit used to measure density?

   A g/cm^2

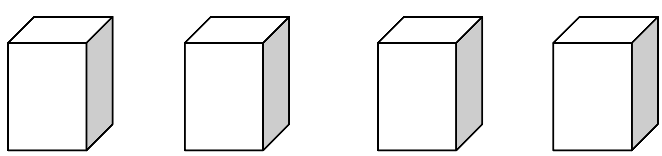
   B cm^3/ g

   C kg /m^3

   D kg/m^2

2. Each of the solids shown in the diagram has the same volume. Which solid has the lowest density?

   A 50 g   B 70 g   C 80 g   D 90 g



3. Which items does a student need to determine the density of a liquid?

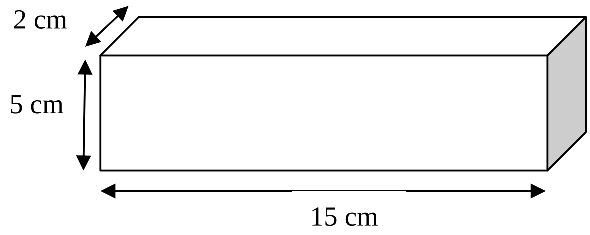
   A beam balance and force metre

   B beam balance and measuring cylinder

   C metre rule and measuring cylinder

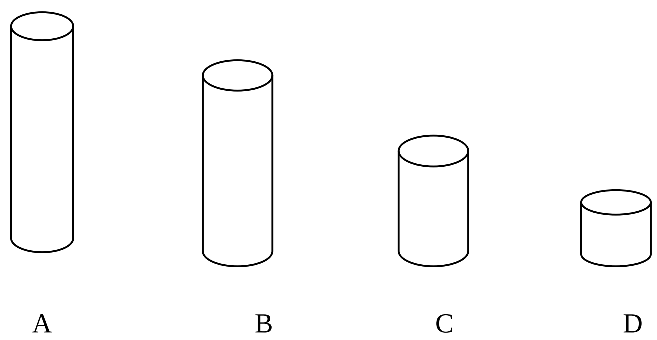
D metre rule and thermometer

4. A lady bought a rectangular piece of soap of a mass of 300 g as shown below. What is the density of the soap?



A 2.0 g / cm3 B 13.6 g / cm3 C 20.0 g / cm3 D 30.0 g / cm3

5. The four cylinders below are full of different liquids. They have the same mass. Which measuring cylinder contains the liquid with the greatest density?



6. Two students record the volume of a liquid from the scale on the measuring cylinder. They then put the measuring cylinder containing the liquid on a balance and record the mass.

Figure 5.3.3: Two girls measuring the mass of a cylinder containing a liquid

What else needs to be measured before the density of the liquid can be calculated?

A the depth of the liquid in the measuring cylinder

B the mass of the empty measuring cylinder

C the temperature of the liquid in the measuring cylinder

D the volume of the empty measuring cylinder

Part B

Answer the following question in the space provided below:

1. The mass of 60 identical glass beads is found to be 66 g and the total volume of the marbles is found to be 25.70 cm^3. Explain how you would find the density of the marbles experimentally.

   Please include the following in your answer:

   i. The apparatus you would use;

   ii. All the measurements that you would take;

   iii. State how you would use your measurements to obtain a value for the density of the glass beads.

Please refer to the Answers to self assessment 5.3 at the end of this topic below to verify your answers. Do not be disappointed if you did not get all the answers correct.

Answers to self-assessment 5.3

Part A:

1. C
2. A
3. B
4. A
5. D
6. B

Part B

1. i) measuring cylinder, beam balance, beaker

   ii) Measurements to be taken:

   - mass of dry empty beaker (M_1)
   - mass of dry beaker with glass beads (M_2)
   - initial volume of water in the cylinder (V_1)
   - Final volume of the water in the cylinder with the glass beads from the glass beaker (V_2)

   iii) $\text{Density of glass beads} = \dfrac{\text{Total mass of glass beads}}{\text{volume of water displaced by glass beads}}$

$$D = \frac{M2 - M1}{V2 - V1}$$

We have now completed the study on Particles in Motion. We are sure that you have gained a lot of new knowledge on the particulate nature of matter, their behaviour and the density of matter.

In the next unit you will be learning about “Cellular organisation”.

Unit summary

Summary

In this unit you learned that the three states of matter, i.e. - solids, liquids and gases, are made up of particles. The particles are always in motion, but the degree of their movement depends on the strength of the intermolecular forces of attraction they experience. Hence, particles in solids experience a large attraction force and the particles cannot move from one place to another like in liquids and gases which experience a much smaller force of attraction. Particles that are free to move always do so in straight lines.

When particles of matter gain energy, they move faster causing an increase in temperature and even a change of state. For example, when liquid particles absorb heat energy, some gain more heat than others. The ones with high enough energy escape the body of the liquid and move freely away, as a gas. This process is called **evaporation**. It is affected by a number of factors and it results in the liquid becoming cooler, as well as smaller in volume and mass over a period of time as the liquid has turned into a gas.

We then addressed the behaviour of particles (molecules) in a fixed mass of gas when subjected to variations in pressure, volume and temperature. From this we learned three relationships.

The first relationship is that for a fixed mass of gas at constant temperature, its pressure and volume have an inverse proportionality. That is, when the pressure of the gas is halved, the volume is doubled, and so on.

The second one is that the volume (V) of a fixed mass of gas is directly proportional to its absolute temperature (T) provided the pressure of the gas is kept constant. That is, when the temperature is doubled, the volume is also doubled and so on.

The third one is that the pressure of a fixed mass of gas is directly proportional to its absolute temperature provided the volume of the gas is kept constant. That is, when the absolute temperature is doubled, the pressure is also doubled and so on.

Finally, we learned that the density of a substance is a measure of how much mass is present in a given unit of volume (i.e. mass per cubic centimetre) of that substance.

Now you are ready to move onto Unit 6.

Contents

Unit 6

Cellular organisation

Introduction

"What are living organisms made of?" and "what makes them so different from each other?" are questions that have been of interest to scientists for a long time in history. In the mid-1600s, Robert Hooke discovered the presence of cells, but it was only two centuries later that three German biologists confirmed that cells are small building blocks of all living things.

In this unit you will learn about the microscope and how it is a useful instrument in the study of cells. You will get opportunities to learn how to use a simple light microscope and make slides of plant and animal cells. Drawings and photographs of plant and animal cells as seen under the electron microscope will be available for you to interpret and describe.

Correspondingly, you will learn about the structure of a typical plant cell and an animal cell, as well as the functions of the organelles therein. We will also look at osmosis and its consequences on plant cells and animal cells. We will also study a few specialized cells to see how their special structures relate directly to the specific functions which they perform. Finally, you will be able to differentiate between cells, tissues and organs and understand how these work together to perform related functions.

Hence, in this unit you will learn about the following:

- instruments used for magnification;
- how to use a microscope;
- animal and plant cells, tissues , organs and systems;
- osmosis and;
- some types of specialised animal cells and specialised plant cells.

The knowledge that you now have from the study of particles in motion in Unit 5 will be useful in helping you better understand osmosis in Topic 6.3. The contents of Topic 6.3: Osmosis, provide useful background knowledge for the understanding of certain concepts in other units. The knowledge of:

(i) turgor pressure will be used to show the importance of turgor in the support mechanism of plants in Unit 14;

(ii) osmosis in plant cells will help you comprehend the uptake of water by osmosis in plant roots when you study transport systems in plants in Unit 23;

(iii) the importance of water concentration to animal cells will be useful when you study homeostasis in Unit 38.

The contents of this unit will also be useful when learning about chemicals from plants in Unit 17.

Outcomes

Upon completion of this unit you will be able to:

- *define* a tissue.
- *define* an organ system.
- *define* the term osmosis.
- *draw* the structure of a typical animal cell and a typical plant cell to show the cell membrane, cytoplasm, nucleus, cell wall, vacuole and chloroplast.
- *explain* how different types of cells perform different functions and how their structure is related to their function.
- *investigate* the effects of solutions of different concentrations on animal cells and plant cells.
- *state* that all living organisms are made up of cells.
- *state* the functions of the following parts of plant and animal cells: cell membrane, cytoplasm, nucleus, cell wall, vacuole and chloroplast .
- interpret light micrographs and simple electron micrographs of plant and animal cells.

Terminology

Cell membrane: A cell membrane is a selectively permeable boundary which regulates what enters and leaves the cell.

Cell wall: The cell wall is the membrane that forms outside the cell membrane in plant cells and other organisms such as bacteria, archaea, fungi and algae. It provides support and protection to the cell. It also is a pathway for movement of water and mineral salts.

Chloroplast:	Chloroplasts are cells which contain the pigment chlorophyll which is necessary for a plant to photosynthesise. Chloroplast is the site of photosynthesis, where carbon dioxide, water and light energy are used to make sugars for the plant.
Cytoplasm:	Cytoplasm is the jelly-like substance in a cell that contains organelles. It provides shape to the cell and is the region where many metabolic reactions occur.
Endoplasmic reticulum:	This is a system of flattened membrane-bounded sacs of two kinds: rough endoplasmic reticulum and smooth endoplasmic reticulum. Rough endoplasmic reticulum (with ribosomes) is the transport system for proteins and smooth endoplasmic reticulum (without ribosomes) is the site of lipid synthesis.
Golgi apparatus:	These are membrane-bound sacs responsible for the secretion of waste products from the cell and the transportation of cell materials such as enzymes and lipids.
Hypotonic solution	A hypotonic solution is a solution with a high water potential. It is a weak solution or a solution of low concentration.
Hypertonic solution	A hypertonic solution is a solution with a low water potential. It is a concentrated solution.
Isotonic solution	Isotonic solutions are two solutions that have the same water potentials. They are solutions of the same concentration.
Lysosome:	Lysosome is an organelle containing a large range of digestive enzymes used for digestion and removal of excess or worn out organelles, food particles and engulfed viruses and bacteria.
Mitochondria:	Mitochondria are rod-shaped organelles. It is the site for the production of high-energy compounds such as ATP. It is referred to as the power house of the cell.
Nucleus:	The nucleus is a large membrane-bounded organelle that contains the genetic material in the form of DNA molecules.
Organ:	An organ is made up of different tissues which work together and contribute towards one particular function in the life of an organism.

Osmosis: Osmosis is the passage of water molecules from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration.

Plasmolysis: Plasmolysis is the shrinking of the cytoplasm away from the cell wall of a plant. The cell becomes flaccid. This is due to water loss from osmosis.

Semi-permeable membrane: A semi-permeable membrane is a partially permeable membrane that controls the entry and exit of nutrients and waste.

System: A system is a group of organs which work together to perform several related functions for the proper functioning of an organism.

Tissue: A tissue is a group of cells of the same type or different types working together to perform a particular function.

Turgidity: This is the state of a plant cell that has taken in water through osmosis, to a point where no more water can enter the cell. When the cell becomes swollen and hard, it is said to be turgid.

How long?

Student Category	Recommended formal study time per week.	Recommended self-study time per week.
Full time student outside the conventional school setting.	8 hours and 40 minutes	4 hours and 20 minutes
Full time student within the conventional school setting and Part-time student.	8 hours and 40 minutes	4 hours and 20 minutes

Table 6.0: Proposed study time for full time and part-time students

Topic 6.1: What are organisms made of?

How long?

You will need 2 hours and 30 minutes at the most to do the activities in this topic. It is advisable that you spend another 1 hour 15 minutes of your own time to further learn about plant and animal cells and their functions.

We have already seen in the unit on biological classification that there is a vast number of species of living organisms on earth. These living organisms are very different from each other and yet all the different species of organisms share one thing in common. This is that they are all made up of **cells**.

*What do you know about cells? Complete the Burr diagram below to show **four** ideas that you have about cells.*

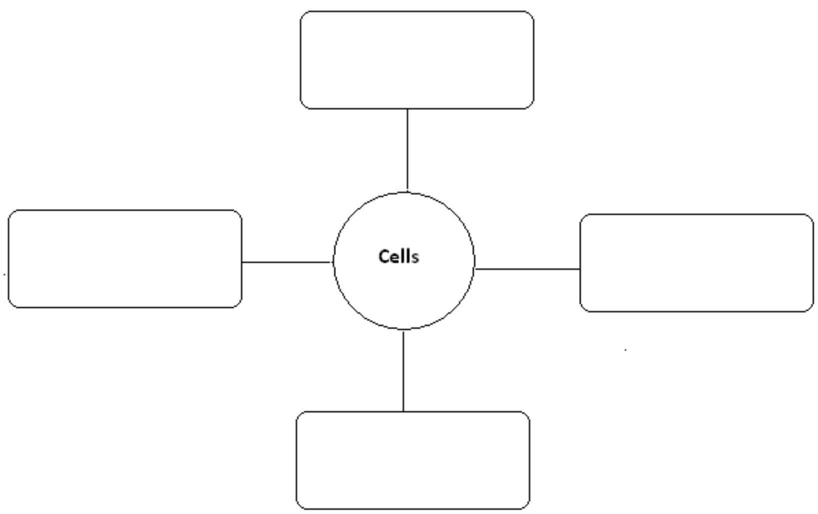


Figure 6.1.1: Burr diagram to note ideas on cells.

I have no doubt that you have mentioned some important ideas about cells. If you do not have many ideas about cells at the beginning of this unit, do not worry. You will learn a lot about cells in this unit; hence you can complete the Burr diagram as you work through the unit or even when you have completed the unit.

6.1.1 What are cells?

Cells are the smallest building blocks of life. Living things are made up of trillions of cells of different types. Nonetheless, some organisms like the amoeba have only one cell compared to organisms like ourselves that have many cells.

Reflection

Reflection 6.1.1

You should spend no more than 5 minutes on this activity.

Refer back to **Unit 1: Biological Classification**. Go to **Topic 1.4: Hierarchical Classification** and study **Table 1.4.1** again. Look for the kingdoms of organisms that have only one cell and those that have many cells.

Organisms that have only one cell, also referred to as unicellular organisms, are called **prokaryotes** and those organisms that have many cells, also known as multi-cellular organisms, are called **eukaryotes.**

Now complete Figure 6.1.2 below to show the kingdoms of organisms that have only one cell (the prokaryotes) and the kingdoms of organisms that have many cells (the eukaryotes).

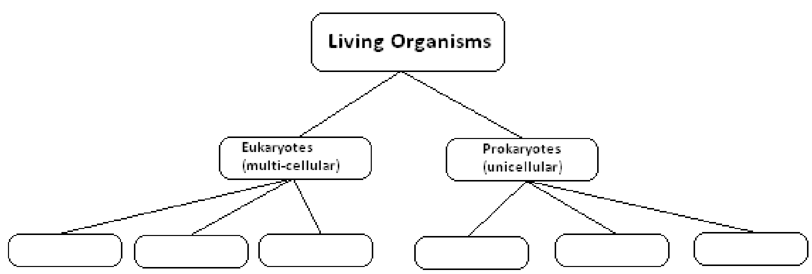


Figure 6.1.2: Classifying kingdoms of organisms as eukaryotes and prokaryotes

Feedback

Feedback to Reflection 6.1.1

Well done! As you have noticed bacteria, archaea and protists are prokaryotes, i.e. they have only one cell. They are unicellular organisms. On the contrary fungi, plants and animals are eukaryotes. They have many cells. They are multi-cellular organisms.

Most of the cells of eukaryotes have the same basic structure. We shall start by looking at a typical animal cell below to learn more about the main parts of a eukaryotic cell.

6.1.2 Parts of an animal cell and their function

Maybe some of you have written about the parts of a cell and possibly the functions of some parts of a cell in the Burr diagram at Figure 6.1.1 above. If you already have some knowledge of the parts and functions of a cell you have an advantage. If this topic is new to you, then here is your opportunity to learn about parts of an animal cell and the functions of each part.

Note it! / Important!

Students who are doing the core objectives are only required to know the following parts and functions of the animal cell: cytoplasm, nucleus and cell membrane.

Students who are doing the extended objectives should also know the following parts and functions of the animal cell: mitochondria, lysosome, rough endoplasmic reticulum, smooth endoplasmic reticulum, and Golgi apparatus, in addition to the cytoplasm, nucleus and cell membrane.

We saw above that cells are the smallest building blocks of living organisms. Cells are so small that they need to be magnified many, many times for us to see them in detail.

You should therefore realize that the parts of the cell would be even tinier!! These tiny structures that form part of the cell are called organelles.

The main organelles of an animal cell as seen by an electron microscope are shown in Figure 6.1.3 below.

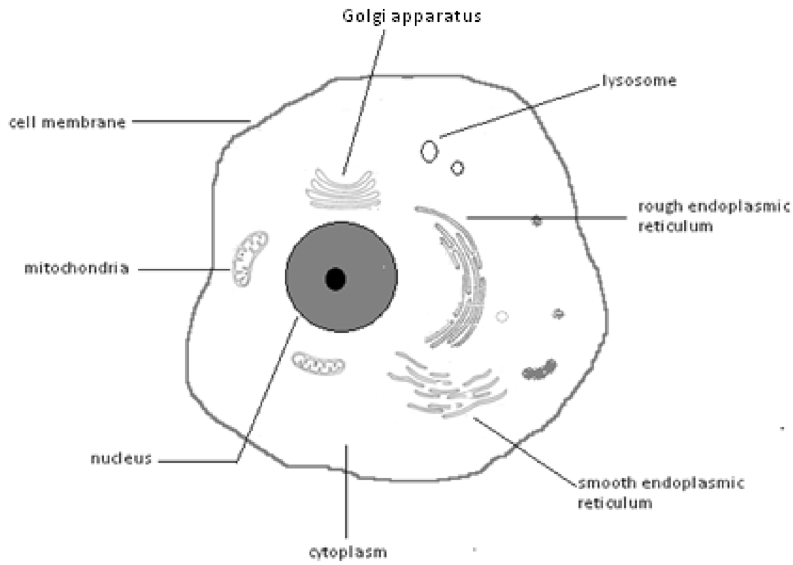


Figure 6.1.3: Parts of a typical animal cell
Drawn by: Serge Mondon (2009)

The activities below will help you learn and master the organelles of a typical animal cell. Have fun!

Computer-Based Learning

Computer-Based Learning 6.1.1

You should spend approximately 10 minutes on this task.

Those of you who have access to a computer go to the following website:

http://en.wikipedia.org/wiki/Cell_(biology)

You will find a 3-dimentional diagram of an animal (eukaryotic) cell. On the diagram try to identify the organelles shown in Figure 6.1.3 above. Write the name of each organelle and the number representing each organelle in Table 6.1.1 below.

All students should start with the three organelles that are common for both the students doing the core objectives and those doing the extended objectives.

Name of cell organelle	Corresponding number on the online diagram

Table 6.1.1 (a): Matching cell organelles with their number from an online diagram.

Those of you, who do not have access to a computer, work with a friend on the "Hang Man" game below.

The first 3 words are common to all students. The last 3 words are for students doing the extended objectives only; however, this does not prevent those doing the core objectives from trying.

i) _ _ _ _ _ _ _ s

ii) _ _ _ t _ _ _ _ _ _

iii) _ _ e _ _   _ e _ _ _ _ _ e

iv) _ _ _ _ _ _   a _ _ a _ a _ _ _

v) _ _ _ _ _ _ _ _ _ _ _ _ _

vi) _ _ _ _ _ _ _ _ _

Well done! I have provided you with the feedback for the matching exercise and the "Hang-the-man" game at the end of the topic.

Group Activity 6.1.1

You should spend around 10 minutes on this activity.

Get together with two or three friends and compose a word search game using the cell organelles that you have learnt above.

Start by writing a list of the cell organelles that you will include in your word search game in the space below.

List of cell organelles:

____

____

____

____

____

____

____

Group activity

A word search game is easy to devise. All you need is to draw a grid with enough squares for you to include all the words that you want a person to look for.

In a word search, one square is for one letter. What you need to do therefore, is to write the letters for each organelle in the squares either horizontally, vertically, or diagonally. Once you have written the names of the organelles, write any other letters in the blank squares to fill all the squares in the grid.

Note it! / Important!

I have started the word search for you by doing an example using the organelle lysosome.

							E		
						M			
					O				
				S					
			O						
		S							
	Y								
L									

Figure 6.1.4: Word Search Game on cell organelles to be completed.

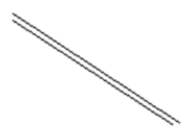
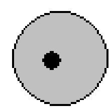
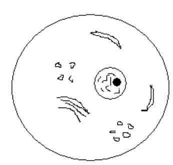
Once you have completed your word search game, exchange it with your classmates and have a class competition to see which group completes the word search faster. All your friends have to do is to highlight or circle the organelles listed once they have identified them.

I hope that the activities above have helped you to get to know the organelles of an animal cell better.

Now look back at the shape of the cell organelles in Figure 6.1.3 above. You should have noticed that the organelles have very different shapes. Each type of organelle is also different in the functions that they perform to ensure the proper functioning of the cell.

The functions of the organelles are given in Table 6.1.2 below.

Students doing the core objectives should concentrate on the first three organelles only.

Name of organelle	Diagram	Functions
Cell membrane		Partially permeable membrane controlling entry and exit of nutrients and waste.
Nucleus		Contains chromosomes with DNA which controls all the activities of the cell.
Cytoplasm		Aqueous substance containing a variety of organelles
Endoplasmic reticulum (ER)	Rough ER  Smooth ER 	**Rough ER** contains ribosomes and transports proteins made by the ribosomes, **Smooth ER** does not have ribosomes and is the site of lipid synthesis.
Mitochondria		Site of energy metabolism and synthesis of high-energy

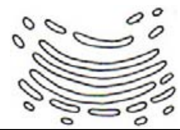
		ATP.
Golgi apparatus		Responsible for the secretion of waste products from the cell.
Lysosomes		Contains digestive enzymes. Concerned with breakdown of structures and molecules.

Table 6.1.2 Cell organelles and their functions

Activity 6.1.1 below will help you to learn and master the functions of the organelles in a typical animal cell.

Activity

Activity 6.1.1

You should spend no more than 10 minutes on this activity.

1. Come up with questions in the space below to test your colleagues' understanding of the functions of the cell organelles in Table 6.1.2 above.

   Students doing the core objectives should write three questions, and students doing the extended objectives should write four questions.

   Underneath each question write the correct answer to the question.

Question 1

Answer to Question 1

Question 2

Answer to Question 2

Question 3

Answer to Question 3

Question 4

Answer to Question 4

2. Now find two or three friends who are also doing this course and who would be willing to answer your questions. Ask the questions one by one. Listen to your friends' answers and together try to clarify any doubts that you or your friends might have by referring to the answers that you have written for each question as well as the notes in Table 6.1.2 above.

I am sure that this exercise was worthwhile and that it has helped you and your friends to master the functions of the cell organelles of a typical animal cell.

We shall now move on to study the parts and functions of a typical plant cell.

6.1.3 Parts of a plant cell and their function

Note it! / Important!

Students who are doing the core objectives are required to know the following parts and functions of the plant cell only: cytoplasm, nucleus, cell membrane, cell wall, vacuole and chloroplast.

Students who are doing the extended objectives should already know the following cell organelles and their functions: mitochondria, lysosome, rough endoplasmic reticulum, smooth endoplasmic reticulum, and Golgi apparatus. You should note that these organelles are common to both plant and animal cells.

Please note also that these organelles have not been labelled again on the diagram of the plant cell below. Nonetheless, I expect you to be able to recognise these organelles on the plant cell diagram.

A plant cell as seen under an electron microscope is shown in Figure 6.2.4 below.

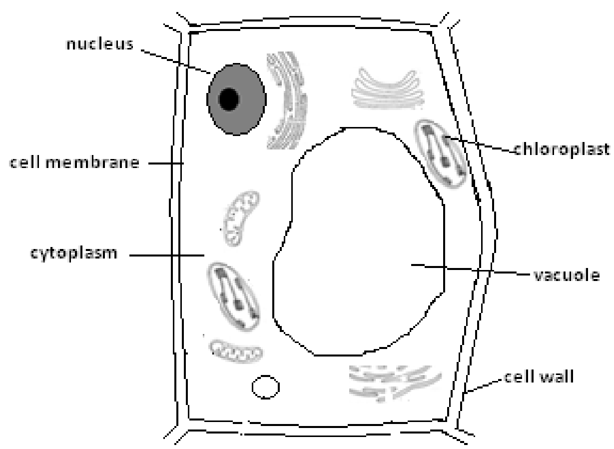


Figure 6.2.5: Parts of a plant cell

Drawn by: Mariette Lucas, (2010).

Activity

Activity 6.1.2

You should spend about 5 minutes on this activity.

Now that you have observed the picture of a plant cell, look for the similarities and the differences between the plant cell above and the animal cell shown in Figure 6.2.3, then answer the questions below.

a). Which organelles are common to both the plant cell and the animal cell?

b). What differences did you notice between the plant cell and the animal cell? Write down four of these differences below.

i.

ii.

iii.

iv.

Feedback

Feedback to Activity 6.1.2

You were right to realize that all the organelles in the animal cell are also present in the plant cell. That is, both animal and plant cells have the following parts: a nucleus, cytoplasm and cell membrane, (as well as rough endoplasmic reticulum, smooth endoplasmic reticulum, lysosomes, Golgi apparatus and mitochondria).

However, you may also have noticed that plant cells also contain chloroplasts, a cell wall and a large vacuole. Chloroplasts and cell walls are not present in the animal cells. Vacuoles, however, also exist in animal cells, but they are usually much smaller.

You might also have noted that the position of the nucleus in a plant cell is different from that in an animal cell. In the animal cell the nucleus is around the centre of the cell, whereas in the plant cell it is found at the edge of the cell. This is due to the fact that the plant cell has a large vacuole in its centre. This causes the cytoplasm to be pushed to the towards the outer walls of the cell. As such all the organelles found in the cytoplasm are found between the cell wall and the vacuole.

I am sure that you also have noticed that animal cells tend to be more circular in shape and that plant cells tend to be more rectangular in shape.

We shall now look at the functions of the three organelles that are specific to a plant cell.

What are these three organelles? List them below.

Good! I have written the functions of these three parts of the plant cell (the cell wall, chloroplast and vacuole) in Table 6.1.3 below. Study the functions of each organelle carefully.

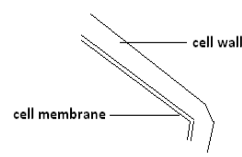
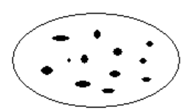
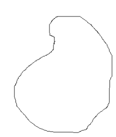
Name of organelle	Diagram	Function
Cell wall		Provides for support and protection and allows for the movement of water and mineral salts.
Chloroplast		Organelle in which photosynthesis takes place.
Vacuole		Usually in the centre of the cell. Mostly liquid with various substances including waste products, dissolved in it.

Table 6.1.3: Organelles specific to a plant cell and their function.

Drawn by: Mariette Lucas, (2010)

Activity

Activity 6.1.3

You should spend no more than 5minutes on this activity.

Now that you know the functions of the specific organelles of a plant cell, answer the questions below.

1. *Why is it important for a plant cell to have a cell wall?*

___

___

___

2. *Explain why chloroplasts are found in plant cells but not in animal cells.*

___

___

___

3. *What do vacuoles contain?*

___

___

___

Feedback

Feedback to Activity 6.1.3

I am sure that you could easily answer the three questions and that your answers were similar to the following:

1. The cell wall in a plant cell provides for support and protection of the cell and allows for the movement of water and mineral salts in and out of the cell.

2. The chloroplasts are organelles in which photosynthesis takes place. Animals do not photosynthesise and so do not need chloroplasts.

3. Vacuoles contain mostly liquid with various substances including waste products, dissolved in the liquid.

Let us now proceed to Activity 6.1.4 below. The tasks in the activity will help you to review what you have learnt about plant and animal cells above.

Activity

Activity 6.1.4

You should spend about 10 minutes on this activity.

1. Complete the Venn diagram to show the similarities and differences between animal cells and plant cells.

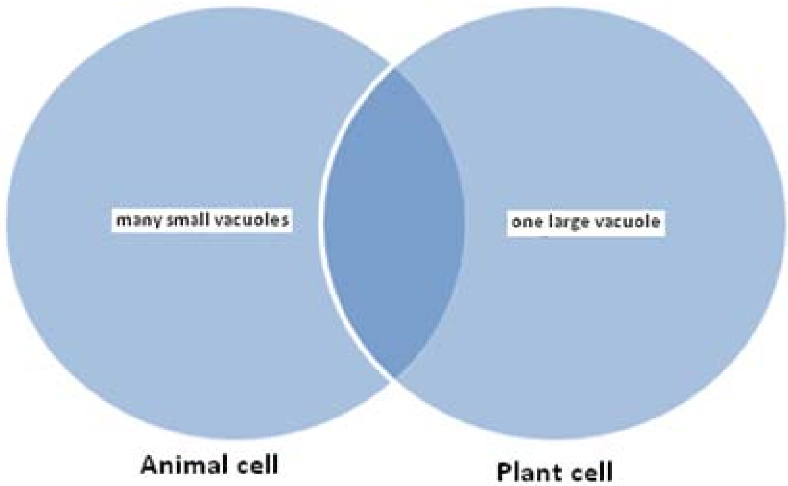


Figure 6.1.6: Venn Diagram on plant and animal cells

2. Draw a plant cell and an animal cell. Use the following colours in your drawing to help you identify the different organelles:

Cell organelles	Colour
Cytoplasm	grey
Mitochondria	red
Chloroplast	green
Nucleus	orange
Rough endoplasmic reticulum	dark blue
Lysosome	yellow

Cell organelles	Colour
Golgi apparatus	violet
Cell membrane	black
Cell wall	brown
Smooth endoplasmic reticulum	pale blue
Vacuole	white

Table 6.1.7: Colours for the identification of cell organelles

Note it! / Important!

Students doing the core objectives need to identify the following organelles only: cytoplasm, cell membrane, cell wall, nucleus, chloroplasts and vacuole.

A plant cell

An animal cell

I am sure that you have found the above activity easy and straight forward. I have provided feedback to this activity in Feedback to Activity 6.1.4 for you at the end of the topic. However, you are strongly advised to first complete the activity on your own before you refer to the feedback.

Note it! / Important!

The drawings of the plant and animal cells that you have seen above are what you would see if you observe those cells under an electron microscope. You would not see as much details if you observe the cells under a light microscope.

It is now your turn to view the plant and animal cells under a light microscope.

Activity

Activity 6.1.5

You should spend around 30 minutes on this activity.

From the above activities you now have an idea of how a plant cell and an animal cell look like. You also know the different organelles of a plant cell and an animal cell, as well as the functions of the organelles.

The knowledge that you have will make it easier for you to understand the structure of a real plant cell and an animal cell under a light microscope.

So now, go to the laboratory and ask the lab technician to help you get the following equipment. Tell the technician to assist you to observe a plant cell and an animal cell under the light microscope.

- A light microscope
- 2 blank slides and cover slips
- Tweezers
- An onion
- A dropper
- Some toothpicks
- Methylene blue or iodine
- A clear ruler
- Paper towel
- A permanent slide of animal cells
- A razor blade
- A clean tile

Now start your work! We shall first look at a plant cell.

❖ Place a drop of water in the middle of a clean slide. Cut an onion in half. Remove one of the slices. Using the tweezers, gently remove the skin from the inside layer of the onion slice. Place the onion skin onto the tile and flatten it taking care not to damage or tear it. Carefully use the razor blade to cut a small square of the skin and place it on the slide in the drop of water. Straighten out any wrinkled skin using toothpicks.

❖ Carefully lower a cover slip over the sample. Remember to place the cover slip at a 45 degree angle over the specimen, with one edge touching the water drop on the slide and gently drop it.

❖ Set the objective lens to the scanning power lens. Place your slide on the microscope stage. Ensure that the specimen is at the centre of the glass-hole so it can get light reflected from the light sources.

❖ Change the objective lens to low power and adjust the coarse focus knob and the light sources until you get a clear image of the plant cells. If you need to use higher power, use it, but ensure that you use only the fine focus knob.

- Make a clear diagram of the cells that you see in the space below. Try to see if you can recognize any of the organelles of a plant cell. Show these on your diagram with the appropriate labels.

- Now bring the objective lens back to the scanning power. Then carefully remove the slide from the stage and put some iodine stain on one edge of the cover slip and place a piece of paper towel at the opposite end. Leave the slide aside for about 3 to 4 minutes to allow the specimen to become properly stained.

- Place the stained slide back on the microscope stage. Set the slide, the objectives lens, and the light properly and focus as required.

- Do you see more details of the cell organelles? Try to improve the previous diagram you made. Use the labelled diagram of the plant cell in Figure 6.1.5 above, to help you refine your own diagram. It should be possible for you to see the cell wall, nucleus, vacuole and mitochondria as well as some of the other organelles.

- Under your drawing note the type of plant cell that you have looked at and the **magnification** of the cell. The magnification shows by how much the actual cell has been enlarged. You get this information from the lens power; e.g. 10x, 50x, etc.

Note it! / Important!

Now that you have observed plant cells, return the objective lens of the microscope to the scanning power, and then remove the slide from the stage. Wash the slide and cover slip, dry them and put them away. Wipe the stage clean if this is needed.

Let us now have a look at an animal cell.

- Place the permanent animal cell slide that the laboratory technician has given you on the stage of the microscope. Adjust the knob and light until you see the animal cells clearly.
- Try to identify as many of the parts shown on the animal cell that you have learnt in Figure 6.1.3 above. Then draw a diagram of the animal cell that you have seen under the light microscope in the space below. Label the organelles that you see.
- Under your drawing note the type of the animal cell that you have looked at and the magnification of the cell.

From the activities above, you now know how a plant cell and an animal cell look like, the cell organelles that the cells contain and their functions. You have seen how a plant cell and an animal cell looks like under the light microscope and you have seen diagrams of the same cells taken from an electron microscope.

Activity 6.1.6 below will help you summarize what you have learnt in this topic.

Activity

Activity 6.1.6

You have about 5 minutes to do this activity.

Write three "Did you know?" statements in the bubbles below to show what you have learnt in Topic 6.1.

Did you know?

An example

Did you know that plant cells have a cell wall and animal cells don't?

1.

2.

3.

That was interesting! Show your "Did you know" questions to students who have not done this course. Try to answer any comments and questions that they may have as best as you can.

Let us now see how much you have learnt in the topic.

Assessment

Self-assessment 6.1

You need 30 minutes to do the self-assessment. The feedback is given at the end of the unit. You are, however, strongly advised to answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

1. If you are shown the picture of a cell,

    a. explain how you would decide whether it is from a plant or an animal.

____

____

____

____

____

b. Suppose the cell was from a plant, draw and label the cell in the space below.

2. List the organelles found in both plant and animal cells.

3. Cell organelles and their functions have been mixed up in Table 6.1.5 below:

Cell organelles	Functions of cell organelles
1. Cytoplasm	A. Partially permeable membrane controlling entry and exit of nutrients and waste.
2. Nucleus	B. Organelle in which photosynthesis takes place.
3. Cell wall	C. Aqueous substance containing a variety of organelles
4. Chloroplast	D. Contains chromosomes with DNA which controls all the

Cell organelles	Functions of cell organelles
	activities of the cell.
5. Cell membrane	E. Provides for support and protection and allows for the movement of water and mineral salts.

Table 6.1.5a: Cell organelles and their functions for matching.

Match the numbers with the letters to show the correct functions of the five cell organelles.

Cell organelles	Functions of cell organelles
1.	
2.	
3.	
4.	
5.	

Table 6.1.5b: Matching cell organelles and their functions.

I am sure that you enjoyed the self-assessment and that you have proved that you have mastered the content of Topic 6.1. Please check your answer below at the end of this topic.

Feedback

Feedback to Computer-Based Learning 6.1.1

The cell organelles are matched according to the numbers below.

Cell organelle	Corresponding number in the online diagram
Nucleus	2
rough endoplasmic reticulum	5
Golgi apparatus	6
smooth endoplasmic reticulum	8
Mitochondria	9
Cytoplasm	11
Lysosome	12

Table 6.1.1 (b): Matching cell organelles with their number from an online diagram.

"Hang-the-man" activity

i. nucleus

ii. cytoplasm

iii. cell membrane

iv. rough endoplasmic reticulum

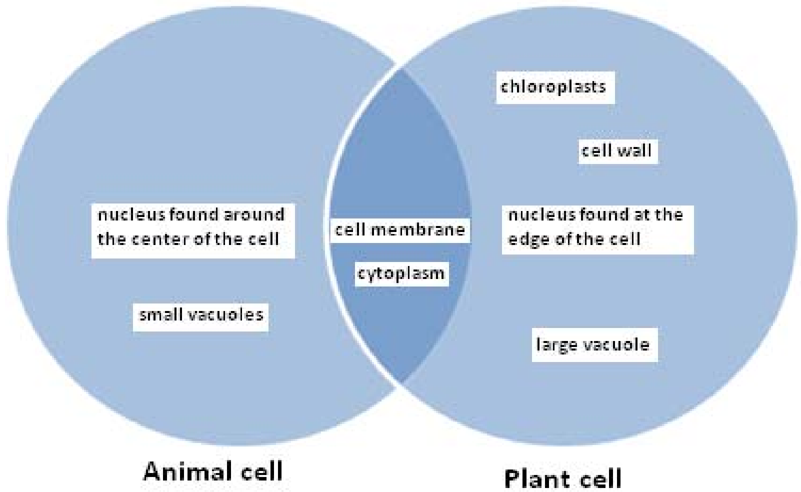
v. mitochondria

vi. lysosome

Feedback

Feedback to Activity 6.1.4

1 Venn diagram showing similarities between plant and animal cells.



2 Organelles of plant and animal cells identified by colour.

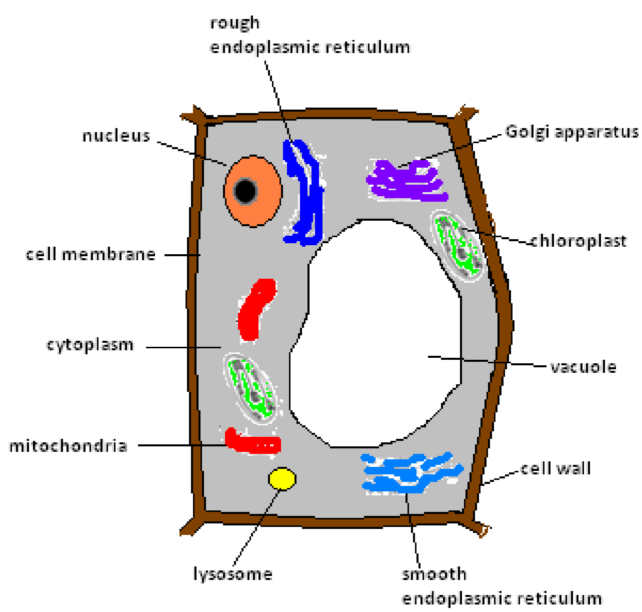


Figure 6.1.6 Organelles in a plant cell identified by colour

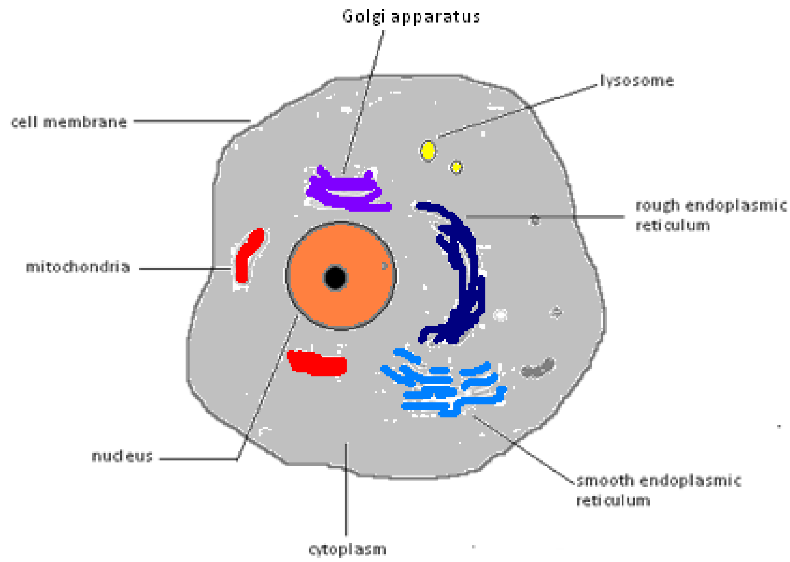


Figure 6.1.7: Organelles in an animal cell identified by colour

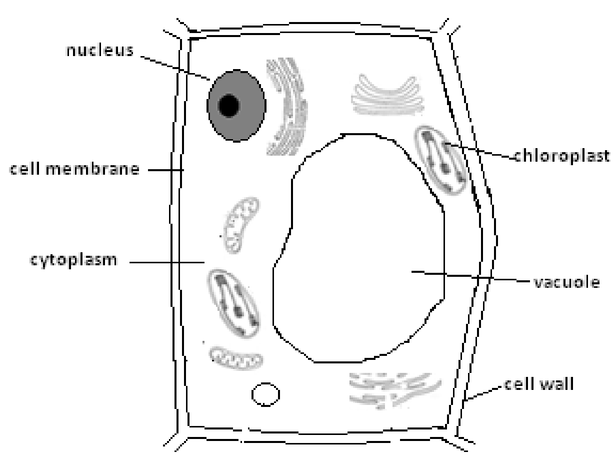
Answers to Assessment

Answers to Self-assessment 6.1

1.

a. To decide whether a cell comes from a plant or an animal, one has to look for the presence of a cell wall, chloroplast and a large vacuole in the centre of the cell. A cell with these organelles is a plant cell. Animal cells do not have these organelles.

b. A plant cell would look like this:



2. The organelles found in both plant and animal cells are nucleus, cytoplasm and cell membrane.

3. Cell organelles matched with their functions.

Cell organelles	Functions of cell organelles
1.	C
2.	D
3.	E
4.	B
5.	A

Table 6.1.5 (b): Matching cell organelles and their functions.

I hope now you are familiar with the components of an organism. Can you name 3 components of an organism and their function?

Let us now continue to learn further about cells in Topic 6.2 below.

Topic 6.2: Osmosis

How long?

You will need 2 hours and 50 minutes at the most to do the activities in this topic. It is advisable that you spend another 1 hour and 25 minutes of your own time to further practice osmosis experiments and read further about the topic.

We saw in Topic 6.1 above, that both plant and animal cells have a cell membrane.

What is the function of the cell membrane?

____

____

____

____

Good! I know that you could easily answer this question, even without referring back to Topic 6.1. Hence, we know that the cell membrane is semi-permeable. It allows useful substances such as oxygen, water and glucose, to pass into the cell and waste substances such as carbon dioxide, to pass out of the cell.

In this topic, we shall be looking at the passage of water through the cell membrane. The process by which water moves through a semi-permeable membrane is known as osmosis.

6.2.1 What is osmosis?

Read the text below to find out what osmosis is.

Osmosis is a form of diffusion. It is the movement of water from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration.

In order for you to have a better grasp of osmosis, it is important that you understand each of the key words that are highlighted above, so we will now discuss each of the these key words separately.

Semi-permeable membranes are very thin layers of material, which allow **some** things to pass through them but prevent others from passing through.

We saw in Topic 6.1 that cell membranes are semi-permeable. The cell membranes will allow small molecules such as oxygen, water, carbon dioxide, ammonia, glucose and amino acids to pass through, but will not allow larger molecules such as sucrose, starch and protein to pass through.

Please remember that: Osmosis is about the movement of water through the semi permeable membrane (cell membrane) and not about the movement of the other dissolved substances.

A region of *high concentration of water* is a very **dilute solution** of something such as dilute sucrose solution, dilute salt solution or pure water. In each case there is a lot **more water molecules** than molecules of the solute (sucrose or salt); i.e. there is a **high concentration of water**.

A region of *low concentration of water* is a very **concentrated solution** of something like sucrose or salt. In this case there is much **less water molecules** compared to molecules of sucrose or salt; i.e. there is a **low water concentration**.

The discussion below will help you think carefully about and understand osmosis. As you read and think about the statements in the discussion, refer to the texts above to remind you of the key terms associated with osmosis.

Discussion

Discussion 6.2.1

You should spend around 10 minutes on this discussion.

What is osmosis?

Three statements which attempt to define osmosis are given below. Only one of the statements is correct.

Find a group of students who are doing this course. In your group, read and discuss each of the three statements below one at a time. You need to decide which of the three statements is correct and explain why the other two statements are not correct.

Statement 1: Osmosis is the movement of water molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane.

Statement 2: Osmosis is the movement of sucrose molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane.

Statement 3: Osmosis is the movement of water molecules from a dilute solution to a more concentrated solution through a semi-permeable membrane.

1. *a)Which statement is correct about osmosis?*

____

____

b). Why is this statement correct?

____

2. *Why are the other two statements not correct?*

Feedback

Feedback to Discussion 6.2.1

I am sure that you have had some interesting discussions in your group and that you have realized that statement 3 is the only statement among the three which defines osmosis properly. Let us now consider each of the three statements and try to understand what each statement means.

Statement 1 states that *osmosis is the movement of water molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane.* First, we realize that a concentrated solution does not have much water. It has a low water concentration. As osmosis is the movement of water from a region of high water concentration to a region of low water concentration, through a semi-permeable membrane, this statement about osmosis is not true.

Statement 2 states that *osmosis is the movement of sucrose molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane.* This statement about osmosis is also not true. This is because osmosis is about the movement of water molecules, not the movement of other types of molecules such as sucrose.

Statement 3 tells us that osmosis is the movement of water molecules from a dilute solution to a more concentrated solution through a semi-permeable membrane. In a dilute solution, the water concentration is much higher than in a concentrated solution. Hence water will move from *the dilute solution, where water concentration is high*, to the *more concentrated one, with low water concentration,* through the semi-permeable membrane. This is the same definition as the one given above. Hence, *the movement of water from a dilute solution to a more concentrated solution through a semi-permeable membrane* is the same as *the movement of water from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration*.

To help you better understand osmosis, I have illustrated the idea in Figure 6.2.1 below.

In the diagram, I have showed that there is pure water outside a cell and some sugar solution inside the cell. The water molecules are shown by small blue circles and the sugar molecules are shown by larger red circles.

Use the knowledge that you have gained in the discussion activity at 6.2.1 above to help you make sense of how osmosis takes place in a cell.

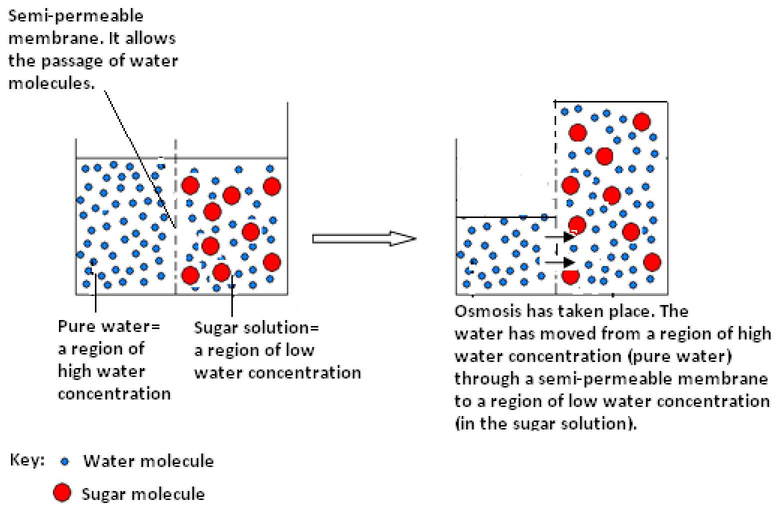


Figure 6.2.1: Diagram showing osmosis taking place in the case where a cell is surrounded by pure water or a very dilute solution.

Drawn by Mariette Lucas (2009)

If you have access to the internet, try visiting the following site to take a look at an animated description of osmosis.

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

Please note again that we are providing this for information only and we do not endorse or recommend any links from this site.

Activity

Activity 6.2.1

You should spend approximately 5 minutes on this activity.

1. Write a short paragraph, to explain how osmosis has taken place in the diagram above. I have started the paragraph for you.

   When a cell with low water concentration content (concentrated sugar solution) is placed in ……

____

____

____

____

2. What do you think will happen if a cell that contains a very dilute sugar solution (high water concentration) is placed in a very concentrated sugar solution (low water concentration)? Circle the correct answer.

   A. Water molecules will move from the dilute sugar solution inside the cell into the concentrated solution outside the cell.

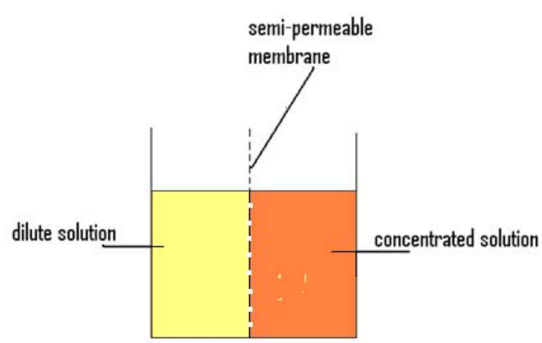
   B. Water molecules will move from the concentrated solution outside the cell into the dilute solution inside the cell.

   C. Sugar molecules will move from the dilute sugar solution inside the cell into the concentrated solution outside the cell.

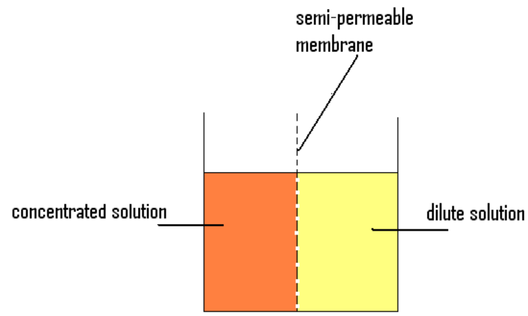
   D. Sugar molecules will move from the concentrated solution outside the cell into the dilute solution inside the cell.

3. In each case below, osmosis is likely to take place. On the respective diagrams, show how this will happen by drawing solid black arrows to show the direction in which the water will move.

   i) Diagram 1:



   ii) Diagram 2



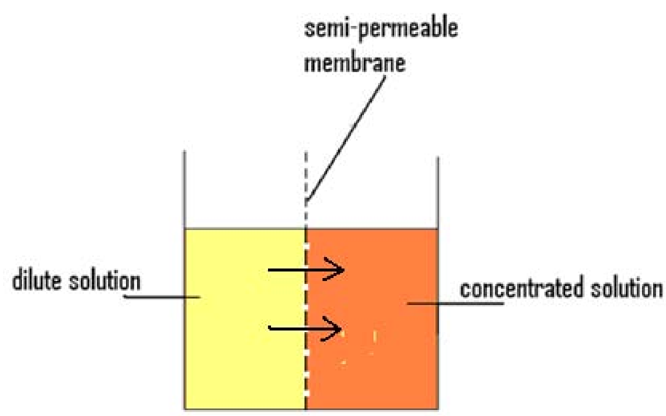
Feedback

Feedback to Activity 6.2.1

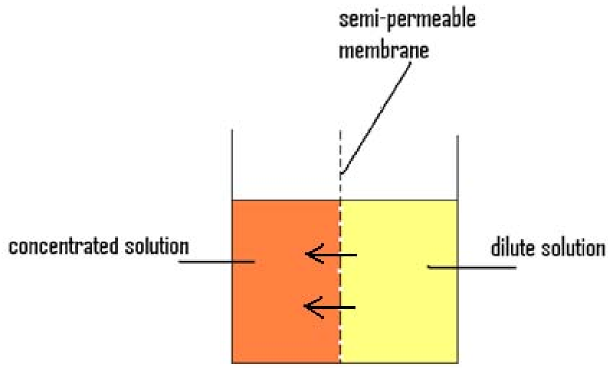
I hope that you have had no problems realizing that in each case above, **water molecules** will move through the **semi-permeable membrane** of the cell from a region of **high water concentration** (dilute solutions) to a region of **low water concentration** (weak solutions). This is what osmosis is all about.

As such you should have shown the movement of water for diagrams 1 and 2 of Question 3 as follows:

i) Diagram 1



ii) Diagram 2



Drawn by: Mariette Lucas (2009).

Well done!

It is now your turn to see for yourself how osmosis takes place. Get a few friends and work together on the group activity below.

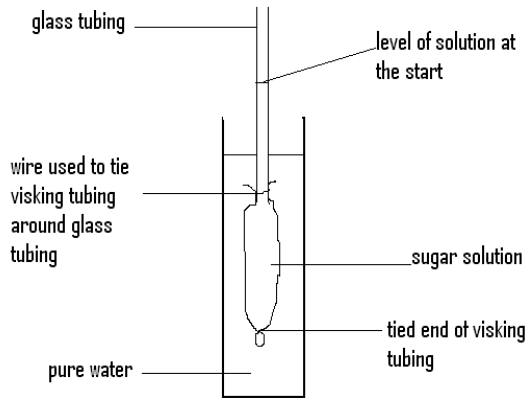
Group activity

Group Activity 6.2.1

You should spend around 20 minutes on this group activity.

With the help of a laboratory technician, set up the following experiment:

- Cut a piece of visking tubing and leave it to soak for a few minutes.



- Tie a knot in one end of the visking tubing and fill it with sugar solution.
- Fix the open end of the visking tubing over the end of a glass tube with some wire. The glass tube should be well inserted in the sugar solution.
- Mark the level of the liquid in the glass tube.
- Using a retort stand and clamp, completely immerse the visking tubing in a beaker of tap water.
- Over the next 10 to 15 minutes, watch the level of liquid in the glass tube.

Adapted from: http://en.wikipedia.org/wiki.Dialysis_tubing

Illustrated by Mariette Lucas (2009).

Reflection

Reflection 6.2.1

Spend 5 minutes to reflect on what happened in the experiment.

1. What did you notice about the level of liquid in the glass tube at the end of the time span (10 to 15 minutes)?

Your logo here

2. What do you think has caused the change in the liquid level in the glass tube?

Feedback

Feedback to Reflection 6.2.1

As you should have noticed the level of liquid in the glass tube went up. This is due to the movement of water molecules from the beaker (where the water concentration is high), through the semi-permeable membrane (the visking tubing), into the sugar solution (where the water concentration is low). The experiment is a demonstration of how osmosis takes place.

Reflection

Reflection 6.2.2

Spend 5 minutes to reflect further.

What do you predict will happen if you reverse the content of the visking tubing and that of the beaker (i.e. if you put pure water in the visking tubing and sugar solution in the beaker/outside the visking tubing)?

Write your prediction below.

Now try to reverse the liquids. You need to use a new set of materials (visking tubing, sugar solution, water, glass tube and beaker) to get the best results.

After 15 minutes, observe your set-up. Draw a diagram in the space below to show what happened. Clearly show all the observations that you made.

What evidence do you have that osmosis has taken place?

Feedback

Feedback to Reflection 6.2.2

As you might have expected, the liquid moved from the inside of the visking tubing out into the beaker. This caused the level of liquid in the glass tube to decrease and the visking tubing to become flabby.

We have seen that water will either move in or out of a cell depending on the concentration of the solution inside and outside of the cell. Below we shall now look at the special terms that are used to describe the solutions involved in osmosis.

6.2.2 Hypotonic, hypertonic and isotonic solutions

We have seen in Activity 6.2.1 and in Group Activity 6.2.1 above that in osmosis, water moves from an area of high water concentration to an area of low water concentration. This tendency for water molecules to move from one area to another is known as the water potential. Pure water or a dilute solution contains more water molecules per unit volume than a concentrated solution. Therefore pure water and weak solutions are said to have greater water potentials than concentrated solutions.

A solution that has a higher water potential (a dilute solution) than another solution is a hypotonic solution. If two solutions have the same water potentials, they are said to be isotonic. A solution with a low water potential (a concentrated solution) is called a hypertonic solution.

Discussion

Discussion 6.2.2

You need no more than 10 minutes for this discussion activity.

Join back together with the group of students with whom you worked on Group Activity 6.2.1 above. Refer back to the activity and study the content of the glass tube and the visking tubing for both the first and second experiment that you did.

In each case discuss and determine whether the solutions were hypotonic, hypertonic or isotonic. Then complete the table below to show the results of your discussions.

Experiment	Contents of:	Type of solution Hypotonic/hypertonic/isotonic
First experiment	Visking tubing	
	Glass tube	
Second experiment	Visking tubing	
	Glass tube	

Table 6.2.1: What happens in a visking tubing experiment

Feedback

Feedback to Discussion 6.2.2

Well done!! You have surely realized that in the first experiment the solution in the visking tubing was hypertonic (concentrated solution), whereas the solution in the glass tube was hypotonic (dilute solution).

In the second experiment the solution in the visking tubing was hypotonic (dilute solution) whereas the solution in the glass tube was hypertonic (concentrated solution).

Let us now represent hypertonic, hypotonic and isotonic solutions with diagrams.

Diagram 1

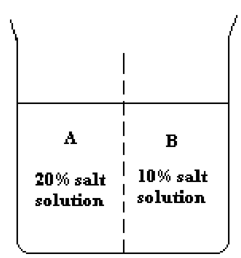


Diagram 1 shows that *solution A is hypertonic* (more concentrated) and *solution B is hypotonic* (less concentrated).

Diagram 2

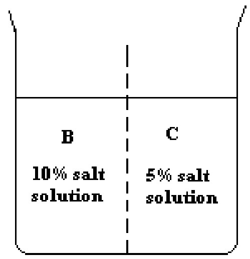


Diagram 2 shows that *solution B is hypertonic* (more concentrated) and *solution C is hypotonic* (less concentrated).

Diagram 3

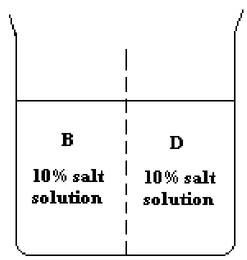


Diagram 3 shows that *solutions B and D are isotonic* (same concentration).

Reflection

Reflection 6.2.3

Take 5 minutes to reflect on this question.

In principle osmosis should happen in situations represented by diagrams 1 and 2, but not in the situation shown by diagram 3. Explain why.

Feedback

Feedback to Reflection 6.2.3

That was good thinking! I am sure you realized that in situations where solutions enclosed in a semi-permeable membrane are placed in a solution with a different water concentration, water will move in if the solution inside the semi-permeable membrane is hypertonic and the solution outside is hypotonic. The reverse will happen if the solution inside the semi-permeable membrane is hypotonic and the solution outside is hypertonic.

In situations where solutions inside and outside a semi-permeable membrane are isotonic, there is no net movement of water.

We shall now look at osmosis in real life situations.

We saw earlier that plant and animal cells have a cell membrane which is semi-permeable. We also learnt that the cytoplasm and vacuoles of the cells contain mainly water with substances such as salts, sugar and proteins dissolved in them. Plant and animal cells are immersed in solutions. Hence osmosis is always taking place in plant and animal cells.

Water moving in or out of plant and animal cells have various consequences on the cells and hence on the organism.

Note it! / Important!

In living cells, water is always moving in and out of the cell through the cell membrane, which is semi-permeable. Water molecules are free to pass in both directions through the cell membrane. However, the difference in the concentration of water inside and outside the cell causes water to move faster / more depending on the water potential of each solution. Water moves faster when the water potential either inside or outside the cell is high.

Remember that a hypotonic solution (a weak solution) has a greater water potential than a hypertonic solution (a concentrated solution).

Therefore, if an animal cell or a plant cell is placed in a liquid, one of the following three things will happen:

- If the liquid surrounding the cell is hypertonic (a concentrated solution; hence a solution with low water concentration), the cell will lose water by osmosis. That is, much more water will leave the cell compared to the amount entering the cell. As a result, the cell will shrink.
- If the liquid surrounding the cell is hypotonic (a weak solution; hence a solution with high water concentration), the cell will gain water by osmosis. That is much more water will enter the cell, compared to the amount of water leaving the cell. As a result, the cell will swell up.
- If the liquid surrounding the cell is isotonic (of the same concentration as the liquid in the cell), the cell will neither lose nor gain water. In other words osmosis will not take place. There will be the same amount of water entering the cell and leaving it. Therefore, there is no change in the size of the cell; the cell stays the same size.

6.2.3 Osmosis in plant cells

We saw earlier that one of the main differences between a plant cell and an animal cell is that plant cells have a cell wall. The cell wall is made of cellulose and is strong. It is freely permeable; that is it allows dissolved substances to move in and out of the cell freely.

Reflection

Reflection 6.2.4

You will require 5 minutes for this reflection exercise.

What do you think will happen if a plant cell is placed in a hypotonic solution? Draw and write about your idea in the space below.

Tip

In a situation such as the one stated in the question above, there is greater water potential outside the plant cell than inside the plant cell.

Feedback

Feedback to Reflection 6.2.4

As you realized, since there is greater water potential outside the cell, water will move from outside the cell to the inside. This will cause the cell to bulge.

Let us read the explanation below to understand better what really happens in such a situation.

When a plant cell is placed in a hypotonic solution, it takes up water and starts to swell. Because of the strong cell wall, the cell does not burst, it becomes swollen and hard. In this state the cell is said to have become **turgid**. As water continues to enter the cell, pressure builds up inside the cell until no more water can enter the cell.

I have represented this outcome in Figure 6.2.2 (a) below.

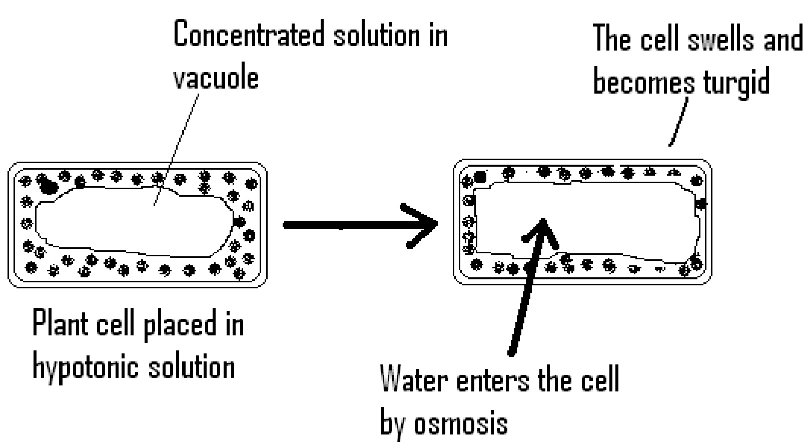


Figure 6.2.2: Plant cell in hypotonic solution

Drawn by Mariette Lucas (2009)

Note it! / Important!

The turgidity of plant cells help the plants that are not composed of wood to stay upright and it also keeps the leaves firm. You will learn about the importance of turgidity in plant cells in the unit on Support and Movement (Unit 14).

Activity

Activity 6.2.2

You should complete this activity in 5 minutes.

It should not be difficult now for you to tell what would happen when a plant cell is placed in a hypertonic solution. Complete Table 6.2.2 below to show your ideas. To help you in your thinking, I have noted on the table, what we said would happen if the cell is placed in a hypotonic solution.

What to observe?	Osmosis in a plant cell placed in a hypotonic solution	Osmosis in a plant cell placed in a hypertonic solution
In which direction does the water move?	Water moves into the cell.	
What happens to the cell?	The cell swells and becomes turgid.	
Is there any pressure that is exerted on the cell?	Pressure builds up inside the cell until no more water can come in.	

Table 6.2.2: Completing observations of a plant cell that is placed in a hypertonic solution.

Feedback

Feedback to Activity 6.2.2

You have surely realized that if a plant cell is placed in a hypertonic solution, water will move out of the cell. This will therefore cause the cell to shrink.

I have explained the situation below and have also drawn diagrams to show what will happen.

When a plant cell is placed in a hypertonic solution, water moves out of the cell. The vacuole decreases in size and the cytoplasm shrinks and pulls away from the cell wall. The cell becomes **flaccid** and is said to be **plasmolysed**. This is illustrated in Figure 6.3.3 below.

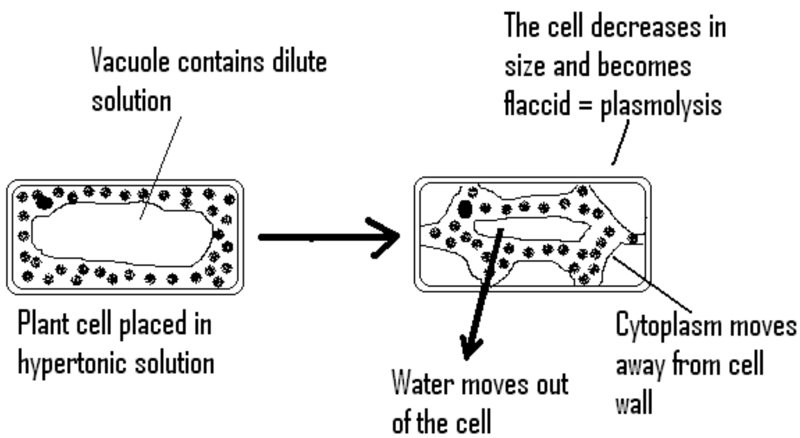


Figure 6.2.3: Plant cell in hypertonic solution

Drawn by Mariette Lucas (2009)

In real life situations this is when we see plants wilting.

In the activity below you will now work with pieces of potatoes in hypertonic and hypotonic solutions in order to experience turgidity and plasmolysis yourself.

Activity

Activity 6.2.3

You will need 15 minutes to set up the experiment and a further 10 minutes to record and interpret the results.

Follow through the steps below to do your experiment. You may wish to get the assistance of a laboratory technician to get a cork borer. If you do not have cork borers, instead of potato cylinders, you can prepare potato chips of a specific dimension (6cm in length x 0.5cm in width).

Step 1:

Get a large potato and a cork borer of size No. 5. Wash the potato and dry it with a paper towel. Then place it on a board.

Step 2:

Cut off the top and bottom parts, making a flat top and bottom surface. Push a cork borer of size No. 5 into the potato and remove the potato cylinder out of the cork borer using a pencil. Place the potato cylinder in a petri dish.

Step 3:

Prepare a few more potato cylinders in the same way as above. Then choose the best four cylinders.

Step 4:

Get four clear containers such as test tubes or petri dishes and label them A1 and A2 and B1 and B2. Then place a potato cylinder in each container.

Step 5:

Cover the potato cylinder in container A1 and A2 with water and the ones in containers B1 and B2 with a concentrated sugar solution. Leave the containers for 2 to 3 hours.

Step 6:

After the time has passed, remove the potato cylinders from containers A1 and A2, feel each potato cylinder and observe carefully how they now look, then measure their lengths. Record the new length, texture and appearance of the potato cylinder that has changed the most, in the table below.

Step 7:

Repeat step 6 for the potato cylinders in test-tubes B1 and B2, but rinse them in water before measuring them. Record your observations in Table 6.2.3 below.

Experiment set-up: Louisette Bonte (2009)

Photos taken by Mariette Lucas (2009).

	Length at start	Final length	Difference in length	Appearance and texture
Potato cylinder A (in water)				
Potato cylinder B (in sugar solution)				

Table 6.2.3: Results of osmosis in the potato

I am sure that you have made some very interesting observations!

Now use the observations that you have recorded above to answer the following questions.

Questions	Potato cylinder A	Potato cylinder B
In which type of solution was the potato placed in? (hypertonic/hypotonic/isotonic)		
In which direction did the water move?		
What happened to the potato?		
What happened to the cells of the potato? In your explanation you are required to make reference to the terms "turgidity" and "plasmolysis".		
How would the cells of the potato look like? Show this by drawing one of the cells. You should also label the cell as clearly as you can.		

Table 6.2.4: Interpreting results about osmosis in the potato.

I hope you enjoyed the activity. The feedback is given at the end of the topic. You are, however, strongly advised to answer all questions first before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

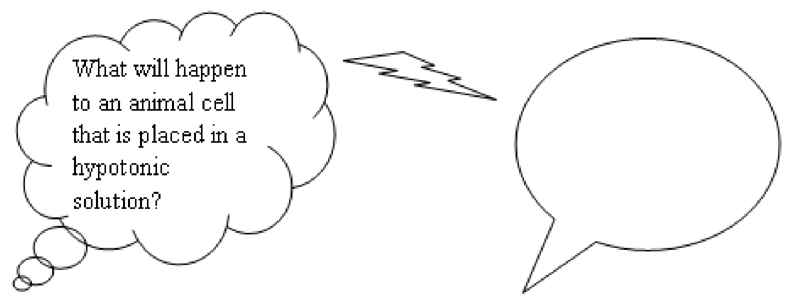
Reflection

Reflection 6.2.5

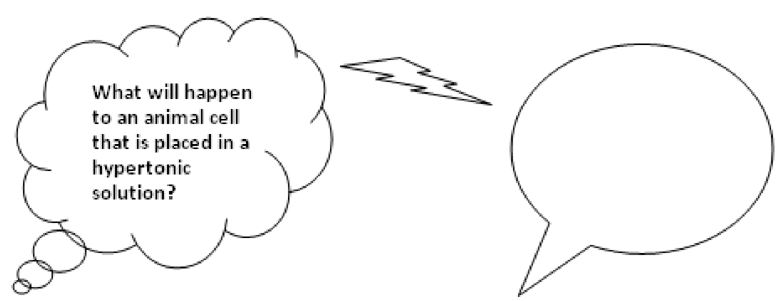
You should spend 5 minutes on this activity.

We shall now see how osmosis takes place in animal cells. But I am sure that you already have an idea of what to expect, so I want you to share your ideas for each situation, by writing them in the solid callout shape below.

Situation 1:



Situation 2:



Feedback

Feedback to Reflection 6.2.5

I am sure that you have expressed your ideas correctly. Did it occur to you that animal cells do not have a cell wall but that they only have a cell membrane? As a result of this animal cells would behave slightly differently when placed in hypertonic and hypotonic solutions.

Read the text below to learn more.

6.2.4 Osmosis in animal cells

You will recall that animal cells have a cell membrane, but no cell wall and that in living cells water is constantly moving in and out of the cell through the cell membrane.

We also know that if the liquid outside the cell is hypotonic, water will move in faster than it moves out and that this is due to osmosis.

Provided that there is a difference in the concentration of the liquid inside and outside the cell, osmosis will take place and this will affect the direction and speed of water in or out of the cell.

If animal cells are placed in hypertonic solutions (concentrated solutions), the water inside the cells will pass out of the cell membrane by osmosis and this will cause the cells to shrink.

Figure 6.2.4 below summarises what happens when an animal cell is put in a hypertonic solution.

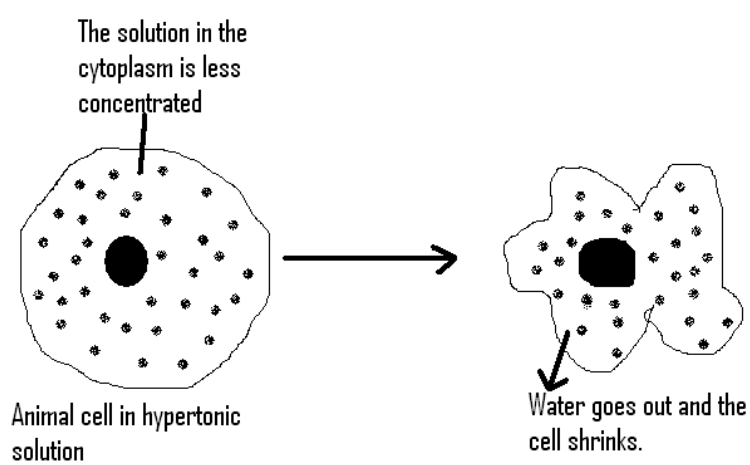


Figure 6.2.4: Animal cell in hypertonic solution

Drawn by Mariette Lucas (2009)

Reflection

Reflection 6.2.6

Spend 5 minutes reflecting on the question below.

From the reading that you have done above and after you have studied Figure 6.2.4, what do you think will happen if an animal cell is placed in a hypotonic solution?

Show your ideas in the space below. You are also encouraged to draw a diagram to make your ideas clearer.

Feedback

Feedback to Reflection 6.2.6

I am convinced that you are not very far from the expected observation. Compare your ideas with the text below and the drawing in Figure 6.2.5.

When an animal cell is placed in a hypotonic solution, water from outside the cell will move in fast. The cell will swell up and since animal cells do not have cell walls, the cell will burst.

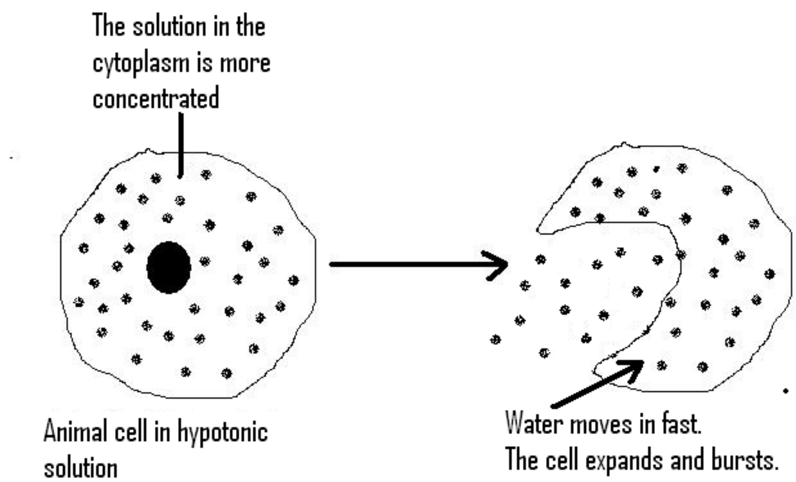


Figure 6.2.5 Animal cell in hypotonic solution

Drawn by Mariette Lucas (2009)

Were you surprised that the cell burst? Maybe you had not realised that the cell would burst, if you missed the part that an animal cell does not have a cell wall. Good try anyway!

You may have realised that in both cases above, whenever the animal cell takes in a lot of water or when it loses a lot of water, it is a problem for the animal. Hence, it is very important for animal cells to be always bathed in an isotonic solution, which is a liquid which has the same concentration as the liquid in the cytoplasm.

Note it! / Important!

Water and the solvents dissolved in the animal's body have to be regulated and kept constant. The process by which this is done is called osmoregulation. You will learn more about this in unit 21which is about Coordination and Response.

It is now time to test your understanding about osmosis. Try Self-assessment 6.2 below to see how well you have learnt and mastered the above content.

Assessment

Self-assessment 6.2

You need 30 minutes to do the self-assessment. The feedback is given at the end of the topic. You are, however, strongly advised to first answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

1. Define the term osmosis.

____

____

____

____

2. Why is the cell membrane said to be semi-permeable? Circle the best answer.

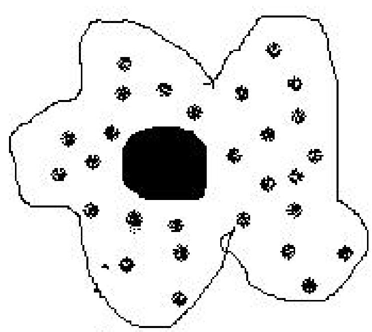
   A. It allows sugar molecules to pass through.

   B. It allows molecules to enter and leave the cell.

   C. It allows the free passage of all types of molecules.

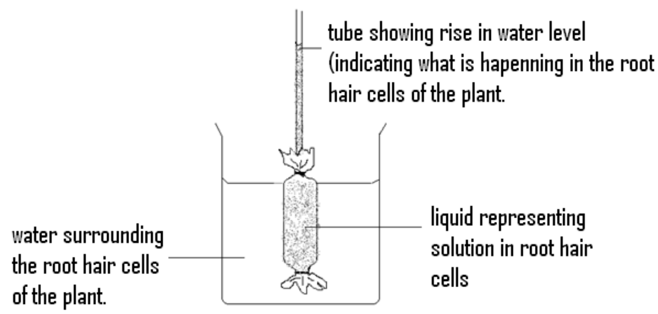
   D. It allows some molecules to pass through, but not others.

3. If an animal cell is placed in some concentrated sugar solution, it would look like this.



a. Explain why this happens.

b. Roots of plants are usually surrounded with water. This situation is represented in the diagram below.



i. The visking tubing represents the cell membrane. It separates two solutions of different concentrations. Which solution is more concentrated?

ii. What causes the water level in the tube to rise?

iii. Explain the effect of such a situation on the leaves of a plant in real life situations.

4. Draw lines to match each term with its correct meaning.

Term	Definition
Hypotonic	A solution with a low water potential (concentrated solutions) than another solution.
Isotonic	A solution that has a higher water potential (dilute solutions) than another solution.
Hypertonic	Two solutions that have the same water potentials

Table6.2.6 (a): Definition of hypotonic, hypertonic and isotonic

Feedback

Feedback to Activity 6.2.4

Table 6.2.5 below explains what happened in potato cylinder A and potato cylinder B.

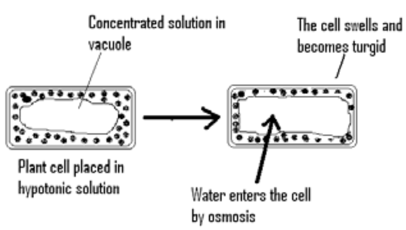
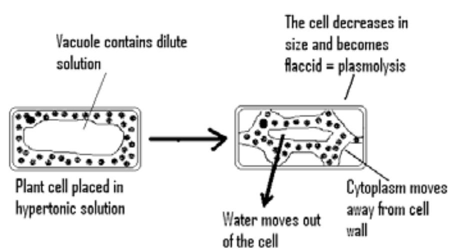
Questions	Potato cylinder A	Potato cylinder B
In which type of solution was the potato placed in? (hypertonic/hypotonic/isotonic)	It was placed in water. Water is a weak solution. It has a high water potential. It is a hypotonic solution.	It was placed in sugar solution. The sugar solution is a concentrated solution. It has a low water potential. It is a hypertonic solution.
In which direction did the water move?	The water moved from the outside of the potato into the potato.	The water moved from the inside of the potato into the sugar solution outside of the potato.
What happened to the potato?	The potato increased in length. It became bigger.	The potato decreased in length. It became smaller.
What happened to the cells of the potato? In your explanation you are required to make reference to the terms “turgidity” and “plasmolysis”.	When a plant cell is placed in a hypotonic solution, it takes up water and starts to swell. Because of the strong cell wall, the cell does not burst, it becomes swollen and hard. In this state the cell is said to have become turgid. As water continues to enter the cell, pressure builds up inside the cell until no more water can enter the cell.	When a plant cell is placed in a hypertonic solution, water moves out of the cell. The vacuole decreases in size and the cytoplasm shrinks and pulls away from the cell wall. The cell becomes flaccid and is said to be plasmolysed.
How would the cells of the potato look like? Show this by drawing one of the cells. You should also label the cell as clearly as you can.		

Table 6.2.5: Interpreting results of osmosis in the potato.

Answers to Assessment

Answers to Self-assessment 6.2

1. Osmosis is the passage of water molecules from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration.

2. The cell membrane allows some molecules to pass through, but not others. (D).

3. The following are answers to question 3

   a. If animal cells are placed in hypertonic solutions (concentrated solutions), the water inside the cells will pass out of the cell membrane by osmosis and this will cause the cells to shrink.

   b. The following are answers to part (b) of question 3:

      i. The solution inside the visking tubing is more concentrated.

      ii. The water level rises because water from outside moves in through the visking tubing, which is semi-permeable. Hence osmosis takes place.

      iii. The plant cells will become turgid and plant parts such as the stem will become firm and the leaves will be held upright.

4. Matching each term with its correct meaning.

Term	Definition
Hypotonic	A solution that has a higher water potential (dilute solutions) than another solution.
Isotonic	Two solutions that have the same water potentials
Hypertonic	A solution with a low water potential (concentrated solutions) than another solution.

Table 6.2.6 (b): Definition of hypotonic, hypertonic and isotonic

Quickly reflect back on what you learned in this topic. Now that you have understood cells and osmosis, let us have a look at specialized cells.

Topic 6.3: Specialized cells

How long?

You will need 3 hours and 20 minutes at the most to do the activities in this topic. It is advisable that you spend another 1 hours 40 minutes of your own time to further learn about specialized cells, tissues, organs and body systems.

You have seen the skin and the bones of many animals. Each animal's skin is very different from their bones. Do you have any idea of what causes this difference? Write down your idea below.

I am sure that you have realized that the skin is made up of cells that must be very different from the bones' cells. It is these different types of cells that make our body organs different. In this topic you will learn about some of the special cells of plants and animals.

Let us start by reading the text below:

The body of eukaryotic organisms is made up of different types of cells. Most of these different types of cells have a cytoplasm, a cell membrane and a nucleus. The number of organelles in the different types of cells in one organism varies according to the special functions that the specific cells have to do in the body of the organism. This also varies from species to species, giving each organism its uniqueness.

Look carefully at the little girl and her cat. They are very different!

Figure 6.3.1: A little girl and her cat.

Photo taken by Mariette Lucas (2009)

Cats are hunters and agile climbers. They need to move fast to catch their prey. The number of mitochondria in the cells of the cat would therefore not be the same as in the little girl. Who do you think would have more mitochondria, the cat or the girl?

For sure the cat would have more mitochondria in its cells than the girl. This is because it needs more energy to do its day to day hunting.

Cells in the body of the same organism differ according to their special functions. They become specialized for a specific job, they have a distinct shape and special chemical changes take place in their cytoplasm. Let us start by looking at some of the specialized cells in plants.

6.3.1 Specialized cells of plants

I have shown some of the specialized cells of a plant for you below:

Plant leaves contain many different types of cells such as the **epidermal cells** on the lower and upper surface of the leaf and the **guard cells**.

- The epidermal cells prevent the leaf from excessive loss of water and protect the plant against injury.
- The guard cells contain chloroplasts with the green pigment chlorophyll, which enables the leaves to photosynthesize.

The stem contains xylem and phloem tissues. **Xylem** consists of four types of specialised cells for the transportation of water and minerals in the plant. The **phloem** consists of five cell types for the conduction of food made by the plant for use and storage. Two of these cells are **sieve –tubes** and **companion cells.**

Roots consist of different types of cells, including special **root hair cells** which increase the surface area of the roots for absorption of water and nutrients.

Figure 6.3.2: Some specialized plant cells

Photo taken by Mariette Lucas (2009)

Activity

Activity 6.3.1

You should spend about 5 minutes to complete the activity.

Use the information in Figure 6.3.2 above and make a table in the space below to show the specialised cells of a plant and their functions.

Feedback

Feedback to Activity 6.3.1

Specialised cell	Functions
Epidermal cells	• Prevent the leaf from excessive loss of water. • Protect the plant from injury
Guard cells	• Contain chloroplasts which enable the plant to photosynthesize.
Xylem	• Allows for the transportation of water and minerals in the plant.
Phloem	• Allows for the conduction of food made in the plant for storage and use.
Root hair cells	• Increase the surface area of roots for the absorption of water and nutrients from the soil.

I am sure that you had included the appropriate headings on your table and that you now know some of the specialized cells of a plant and their functions.

In Activity 6.3.2 below, we shall be looking at two of these specialised cells. These are the root hair cells in the roots of plants and the guard cells in the leaves.

Activity

Activity 6.3.2

You should complete the activity in about 20 minutes.

The texts below are about the structure and function of guard cells and root hair cells. Read the texts carefully, and then do the activities that follow.

Guard cells:

The underside of leaves contain guard cells. Guard cells contain chloroplasts, which contain chlorophyll. Guard cells are pairs of bean shaped cells that surround the stomata.

Stomata (singular: stoma) are tiny pores between each pair of guard cells.

The guard cells control the opening and closing of the stomata in response to light and heat. Carbon dioxide and oxygen moves in and out of the cell through the stomata. Water also moves out of the stomata in the form of water vapour. At night the stomata closes to conserve water in the plant.

There are more stomata on the underside of the leaf. This stops water from evaporating too quickly from the upper surface of the leaf which is exposed to the sun.

Root hair cells

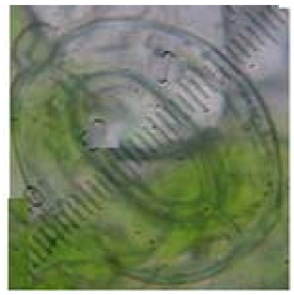
Certain cells of the outer layer of roots are modified for absorption purposes. These are the root hair cells, which are long tube-like projections which anchor the roots into the soil.

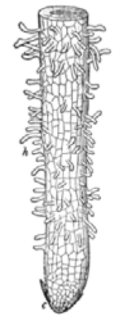
Root hair cells grow from the main root and increase the surface area of the root for water intake.

The water absorbed by the root hairs is transferred to the water storage area in the root to be taken up by the plant.

1. From the descriptions of guard cells and root hair cells in the text above, you should be able to tell how each type of cell looks like.

Pictures of the cells are shown below. Write the name of each cell under their drawing.





------------------- -------------------

Source of pictures: http://en.wikipedia.org/wiki/Stoma and http://en.wikipedia.org/wiki/Root_hair

2. Which of the sentences explain why there are more guard cells on the bottom surface of a leaf rather than on the top surface? Circle the correct answer.
   A. Guard cells become weak in too much light.
   B. It is easier for oxygen to get into the plant at the bottom of the leaf than on the top.
   C. The top surface of a leaf gets more sunlight and so the plant would lose too much water by evaporation.
   D. The stomata in the bottom surface of the leaf are smaller than the stomata in the top surface of the leaf.

3. Where are root hair cells found in a plant and what is their role in the plant?

____

____

____

____

Now that you know how guard cells and root hair cells look like, where they are located and what their functions are, you will be better able to identify those cells under the microscope.

You need to go to your Science teacher or a laboratory technician to get the following materials: **a light microscope** and **a permanent slide of root hair cells** and one of **leaf guard cells**.

Once you have got the equipment that you need:

- Observe each type of cell under the microscope.
- Make an enlarged drawing of the cells in the correct box below.
- Label any of the parts of the cell that you can see.

Root hair cells

Guard cells

I have provided labelled diagrams of the root hair cell and the guard cell in the feedback to Activity 6.3.2 at the end of the topic. Use the drawings given in the feedback to improve on the drawings that you have made above.

You are, however, strongly advised to make your own drawings before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

We hope that the above exercise triggered you to think of some of the specialized cells that an animal could also have. Let us now learn some of these cells.

6.3.2 Some specialized cells of animals

As you might have realized, the body of an animal also consists of many different types of specialized cells. These cells, which are located in specific places in the body, have very specific structures that enable them to perform their very specific functions. As a result different types of chemical reactions take place in the different cells. In this unit we shall be looking at two types of animal cells: the blood cells and the muscle cells.

6.3.2.1 Blood cells

Blood consists of different types of cells: red blood cells, white blood cells and platelets, suspended in liquid called plasma. Each type of cell has a specific structure to allow them to perform their different functions. These are shown in Table 6.3.1 below.

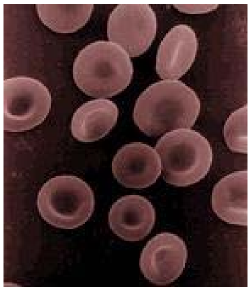
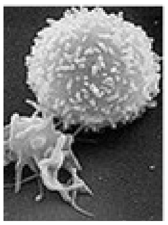
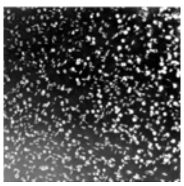
Blood cell	Drawing	Function
Red blood cell (erythrocyte)		• Contains haemoglobin, which takes oxygen from the lungs and carries them to all the other parts of the body. • The haemoglobin gives the blood its red colour. • Has no nucleus. • Has a flexible cell membrane to allow it to squeeze through narrow capillaries.
White blood cell (leukocyte)		• Identifies and destroys bacteria and other disease-causing-organisms which enter the body. • Has a nucleus and some have granules. • Regulates the immune system of the body
Platelets		• The smallest cells in the blood, which helps it to clot.

Table 6.3.1: Blood cells and their functions

Source: http://en.wikipedia.org/wiki/Red_blood_cell

Group activity

Group Activity 6.3.1

You will need 15 minutes to first find the answers to the quiz questions, and a further 10 minutes to do the quiz.

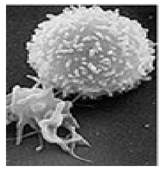
To help you learn the different types of blood cells and their functions, I have devised a set of questions for the quiz below. You should write the answers to each question in the space provided before you do the quiz.

Quiz : Blood cells and their functions

Instructions:

Group the participants in two groups. Ask each question for a maximum of **two** times. Award 2 marks for the correct answer when the question is first offered. Award 1 mark for the correct answer when the question is offered the second time.

	Question	Answer
1	What are erythrocytes?	
2	What are platelets?	
3	Which blood cell helps destroy bacteria and other disease causing organisms which enter the body?	
4	State two functions of haemoglobin.	
5	Which blood cell is shown in this diagram?	

		
6	Which blood cell is described here: • It has no nucleus. • It has a flexible cell membrane to allow it to squeeze through narrow capillaries.	

Once you have written the correct answers to the quiz questions above, find a group of about six students who are doing this course. Each time your friends have answered a question, tell them whether or not they got the correct answer. If they did not, let them know what the correct answer is.

Enjoy the game!!

Feedback

Feedback to Group Activity 6.3.1

1. Erythrocytes are red blood cells. They have no nucleus and contain haemoglobin which carries oxygen. Erythrocytes have flexible membranes that enable them to squeeze through narrow capillaries.

2. Platelets are the smallest cells in the blood which help the blood to clot.

3. The white blood cell (leukocyte) helps destroy bacteria and other disease causing organisms which enter the body.

4. Haemoglobin carries oxygen from the lungs to all parts of the body and gives the blood its red colour.

5. A white blood cell (leukocyte).

6. The red blood cell (erythrocyte).

I hope that you have really enjoyed the quiz and that it has helped you and your friends to better understand the different types of blood cells and their functions.

We shall now take a closer look at some of the blood cells under the light microscope.

Activity

Activity 6.3.3

You will need 15 minutes to do the activities below.

1. Go to the laboratory and ask the laboratory technician for a permanent blood slide and a microscope. Look at the slide under the microscope. Make a drawing of what you see in the space below.

   Use the knowledge that you have gained above about blood cells in Table 6.3.1 above to label your drawing.

2. Using two types of blood cells, write a short paragraph, to show how cells have special structures to match their functions.

Feedback

Feedback to Activity 6.3.3

1. You should have been able to see some red blood cells. Under the microscope, they look like pink discs, which are thinner in the middle and thicker on the outside, like donuts.

2. **Red blood cells** have flexible membranes and they contain haemoglobin. Their flexible membranes allow them to easily squeeze through the blood capillaries and their haemoglobin allow for the transportation of oxygen.

   White blood cells have a nucleus and some have granules (small grains on the surface). They destroy bacteria which enter the body and regulate the immune body system.

   Platelets are the smallest cells in the blood which help it to clot.

I'm sure that it was very easy for you to complete the activity. If, however, you had any problems, you should refer back to the information in Table 6.3.1 above.

We shall now look at muscle cells.

6.3.2.2 Muscle cells

Activity

Activity 6.3.4

Take 5 minutes to do the activity.

Move your lower arm up and down and feel your upper arm muscles.

Do you have any idea what these muscles look like?

Discuss with a friend and make a rough sketch of your ideas below.

I am sure that you are not far from reality. Once you have learnt about muscle cells, return to this drawing and assess how close your drawing is to the structure of muscle cells.

There are three main types of muscle cells in the body of vertebrates. These are the **skeletal muscle cells**, the **smooth muscle cells** and the **cardiac muscle cells**. We shall be looking more specifically at skeletal muscle cells in this unit as skeletal muscles are one type of muscle that we are more familiar with.

Reflection

Reflection 6.3.1

You need to spend 5 minutes on this reflection.

What does the word **muscle** remind you of?

____

____

____

Feedback

Feedback to Reflection 6.3.1

Of course you may have thought of the muscles in your upper arm and in your upper and lower leg or even muscles in the flesh of animals that we eat. Some of you may have thought of the muscles in the upper arms of body builders.

When you eat drumsticks, you are eating muscles in the lower half of the leg of the chicken.

Let us now learn about the cells that make up skeletal muscles and their functions

A skeletal muscle is linked to a bone by tendons. A skeletal muscle consists of multiple bundles of muscle fibres held together by connective tissue. Skeletal muscle fibres contain long sausage shaped cells, with many nuclei. The cells contain special proteins that are necessary for muscle contraction. Contraction of the skeletal muscles causes the bones of the body to move. The flesh of vertebrates underneath the skin is mostly skeletal muscle.

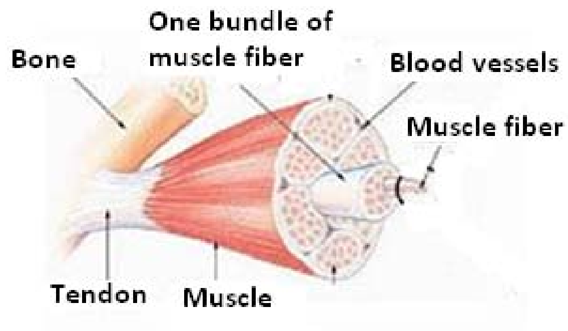


Figure 6.3.3:Skeletal Muscle

Adapted from: http://en.wikipedia.org/wiki/Skeletal_muscle

Reflection

Reflection 6.3.2

Spend 5 minutes on this reflection activity.

Let us now reflect on the above text.

1. Copy the sentence in the text above that tells us about the function of the skeletal muscle. Then underline the function of the skeletal muscle in the sentence.

___

___

___

2. Describe the cells of the skeletal muscle.

___

___

___

3. In which part of the body are skeletal muscles found?

Feedback

Feedback to Reflection 6.3.2

1. Contraction of the skeletal muscles causes the bones of the body to move.

2. Skeletal muscle fibres contain long sausage shaped cells, with many nuclei. The cells contain special proteins that are necessary for muscle contraction.

3. Skeletal muscles are found underneath the skin. The flesh underneath the skin is mostly skeletal muscle.

Well done! By now you must be conscious of the two major skeletal muscles in our upper arm. These muscles are the **biceps** and the **triceps.** To lift your lower arm, the biceps muscle contracts. When the triceps muscles contract the lower arm is lowered.

Try moving your lower arm up and down and you will feel the contraction of the biceps muscles.

You will learn more about these skeletal muscles in the topic **Support and Movement** in **Unit 14**.

We saw above in the example of the skeletal muscle, that it is made up of many muscle fibres. Each fibre contains long sausage shaped cells. This shows that cells group together to do specific jobs.

We shall see how cells work together below.

6.3.3 Tissues

Groups of cells working together to perform a particular function are known as *tissues*. A tissue may contain cells of only one type of cell, or a mixture of different types of cells. Muscle tissue, for example, contains only one type of cell, known as muscle fibre, whereas the xylem tissue contains four different types of cells. Below we shall be looking more closely at bone tissues and epithelial tissues in animals, and xylem, phloem and mesophyll tissues in plants.

6.3.3.1 Sample animal tissues

6.3.3.1.1 Bone tissues

We have all seen the bones of animals and have also probably eaten or crushed bones that have been cooked.

Activity

Activity 6.3.5

You should complete this activity in 10 minutes.

Find the bone of a chicken or that of an animal that we use as food. With a hand lens and a toothpick study the outside and the inside of the bone carefully. Then complete the table below to show the differences in the inside and outside of the bone. Include a drawing of the bone in the table.

Bone of................................		
Bone Properties	Inside of bone	Outside of bone
Texture		
Colour		
Other observations		

Table 6.3.2: The inside and outside of a bone

Below is a text on bone cells. Read the text and compare the information with what you have written in Table 6.3.2 above.

Bones consist of compact bone tissue in the outer layer and spongy bone tissue filling the interior of the bone. They are covered by a layer of dense connective tissue.

The different tissues are made of different types of cells. The compact bone tissue facilitates the passage of nutrients, metabolic waste and respiratory gases towards and away from the cells and produces a structure of great strength.

The spongy bone tissue is the site of production of the blood cells and fat cells. It enables the bone to withstand tension and compression forces effectively, whilst at the same time keeping the weight of the bone to a minimum.

Figure 6.3.4 below is part of the femur bone, showing the bone tissues.

Figure 6.3.4: Femur bone showing bone tissues

Source: http://simple.wikipedia.org/wiki/Bone_marrow

1. *In what ways was your drawing similar to the drawing of the femur bone drawing above?*

2. *What new information about bone tissues have you learnt from the text and the drawing above?*

Try discussing your results with your peers and your teacher.

Now that you have some good knowledge about bone tissues, let us learn about epithelial tissues.

6.3.3.1.2 Epithelial tissues

The epithelium is a thin layer of tissue which forms the lining of the mouth cavity and other organs such as the windpipe and food canals. Epithelial tissues protect the organs from physical and chemical damage.

Summary

Summary 6.3.1

You should take about 5 minutes to do this activity

In a short paragraph of no more than 100 words, write a summary of what you have learnt about animal tissues. Use the notes above to help you.

Show your summary to your teacher. I am sure that you will get some very positive feedback.

Now, let us proceed to learn about some plant tissues.

6.3.3.2 Sample plant tissues

6.3.3.2.1 Xylem and phloem

We saw earlier that plants have phloem and xylem tissues which help with the conduction of materials in the plant. The cells of the xylem tissue are different from those of the phloem tissue.

This is because they conduct different types of materials.

Figure 6.3.5: Xylem and phloem tissues

Source: http://en.wikipedia.org/wiki/Xylem

Activity

Activity 6.3.6

You have about 5 minutes to do this activity.

What do the xylem and the phloem tissues conduct?

If you are not sure, go back to our section on specialized cells to find the answer.

Feedback

Feedback to Activity 6.3.6

Good! You noticed that the xylem tissue conducts water and minerals from the soil to the leaves to allow the plant to photosynthesise. The phloem tissue is responsible for the transportation of food made in the leaves to the other parts of the plant.

We shall now look at some tissues found in the leaves of plants.

A leaf has three main groups of tissues. These are the **epidermal tissue**, which covers the upper and lower surfaces of the leaf, the **mesophyll tissue** which forms part of the interior of the leaf, and the **vascular bundle tissues** which consist of xylem and phloem.

The epidermal tissue and each of the mesophyll tissues consist of only one type of cell, whereas the xylem tissue and the phloem tissue consist of more than one type of cell.

We shall have a look at the mesophyll tissues in the next section.

6.3.3.2.2 Mesophyll tissues

The mesophyll tissues in the leaves of plants comprise of the **palisade mesophyll** and the **spongy mesophyll**.

The **palisade mesophyll** is directly below the upper epidermis of leaves. These are tightly packed, vertically elongated cells, regularly arranged in one to five rows.

The cells in the **spongy mesophyll** are more rounded and not so tightly packed, with large intercellular air spaces.

The cells in the palisade mesophyll contain a lot **more chloroplasts** than the cells in the spongy mesophyll, which is just beneath the palisade layer (see diagram below).

Most photosynthesis takes place in the palisade mesophyll, whereas the large air spaces in the spongy mesophyll allows for efficient gaseous exchange.

The main tissues in a leaf

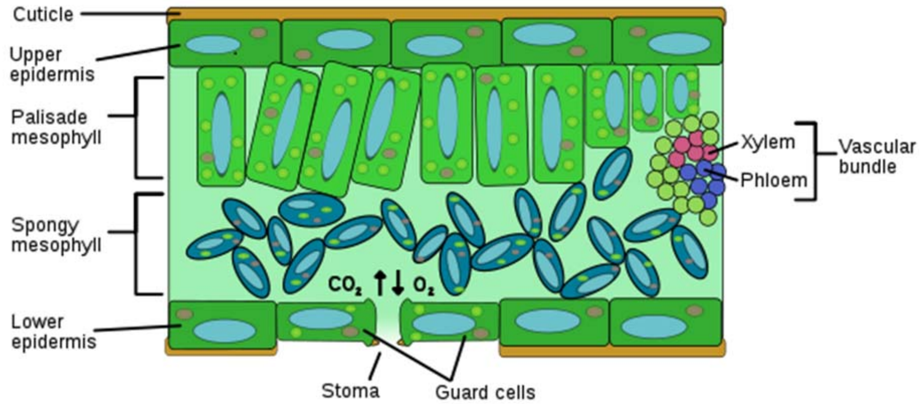


Figure 6.3.6: Mesophyll tissues in a leaf

Source: http://en.wikipedia.org/wiki/Epidermis_(botany)

Summary

Summary 6.3.2

You should spend about 5 minutes on this activity.

Draw a table in the space below. In the table list all the plant tissues and the animal tissues that you have learnt about in the sections above.

Make sure that you give a title to your table to show the type of information that it contains.

Feedback

Feedback to Summary 6.3.2

Plant tissues	Animal tissues
• Epidermal tissue	• Bone tissue
• Mesophyll tissues o Palisade mesophyll o Spongy mesophyll	• Epithelial tissue
• Vascular bundle tissues o Xylem tissue o Phloem tissue	

It is now your turn to view some of the tissues that you have learnt about under the microscope. You will do this by doing the activity below.

Activity

Activity 6.3.7

You should spend at least 15 minutes on this activity.

You will observe at least one plant tissue and one animal tissue.

Ask the laboratory technician for permanent slides of epithelial tissues of the skin or bone tissues, and the xylem or phloem tissues of plants or the epidermis of a leaf.

Observe the tissues under the light microscope. Draw and label what you see below.

Do not forget to write the type of tissue that you have observed next to the drawing.

An animal tissue

A plant tissue

Use the diagrams of the various tissues that you have learnt above to improve on your drawings.

Feedback

Feedback to Activity 6.3.7

I hope that you have been able to see first-hand some animal and plant tissues and that you have been able to represent what you saw under the light microscope clearly. Show your drawings to your teacher and ask for any comments or for ways you to improve on your work.

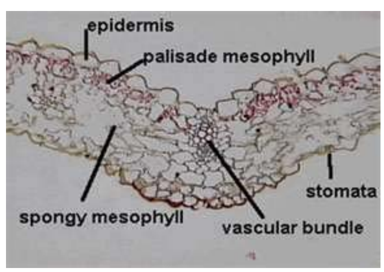
Below, I have provided you with sample microscopic views of an animal tissue and plant tissues.

- Animal epithelial tissue.

Human cheek cells (Nonkeratinized stratified squamous epithelium) 500x

Source: http://en.wikipedia.org/wiki/Epithelium

- Plant tissues (epidermal, mesophyll and vascular bundle tissues)



http://kentsimmons.uwinnipeg.ca/16cm05/16labman05/lb4pg5.htm

We saw above that cells group together to form tissues. Below we shall look at how the different tissues together, form organs in plants and animals.

6.3.4 Organs and systems

An organism's body is made up of various systems. These systems consist of different organs. We will now look at some organs and systems of plants and animals below.

6.3.4.1 Organs in plants

6.3.4.1.1 The leaf

You have seen above that each of the different tissues has a particular function for the organism (the plant or the animal). For example, we saw the specific functions of the mesophyll tissues and the xylem and phloem tissues of a plant.

Even though each of these tissues does a different job, they all contribute to help the leaf make food for the plant. Hence, the leaf is made up of many different tissues, and together it is called an **organ**. **An organ is made up of different tissues.**

Some other organs in the plant are the **roots**, and the **stem** (the vegetative organs) and the **flower**, **seeds** and **fruits** (the reproductive organs).

In this unit we shall focus on the leaf as an organ.

Activity

Activity 6.3.8

You need 5 minutes to do this activity.

Take some time to think of how the epidermal tissue, the mesophyll tissue and the xylem and the phloem tissues in the leaf could work together to make food for the plant. Then complete the passage below using your own words.

The leaf is an example of an ....

An organ is a group of different .... working together to perform a particular function.

The main function of the .... is to make food for the plant.

To make food, the plant needs to take .... from the air, water from the .... and use light energy to convert these into food.

The .... in the spongy mesophyll provide for air to reach the chloroplasts in the ...., and the xylem brings the water needed.

The .... conducts the food that is made in the leaf to the other parts of the plant.

The different tissues make up the......................., and by working together the tissues contribute to the specific job of the leaf.

Good! I am sure that you now understand how tissues work together to form organs.

The feedback to Activity 6.3.8 is given at the end of this topic. You are, however, strongly advised to first complete the activity above before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

6.3.4.2 Organs in animals

As we saw above, the various tissues in animals make up organs, which do specific jobs for the body. Think about some organs that are found in our bodies.

Activity

Activity 6.3.9

You should spend 5 minutes on this activity.

1. List three organs of the human body in the boxes below.

Three organs in the human body

Each of these organs comprise of different tissues working together for one common purpose.

2. *What is the purpose (function) of each of the organs that you have listed above? Write the function of each in their respective boxes.*

Feedback

Feedback to Activity 6.3.9

1. That was not difficult was it! I have no doubt that you have mentioned organs such as the stomach and the heart as an example! The eyes, lungs, heart and skin are some of the other organs in the human body.

2. You surely know the main functions of many of our body organs already. The stomach is one of the organs for *digestion*, the heart *pumps blood* to ensure that it is circulated around the body, the eyes *allows us to see*, the lungs allows us to *exchange the gases* that our body needs and the skin is the organ for *touch*.

   Each of these organs is made up of different types of tissues, each of which contributes in a very specific way to the proper functioning of the organ. The stomach for example, is an organ which is made up of muscle tissues, gland tissues, and epithelial tissues amongst others.

Below, we shall now look at how organs also work together to make it possible for the plant or the animal to work properly.

6.3.5 Systems

Organs in the body do not work independently. Groups of organs work together to perform several related functions in a system. I have described some of the body systems for you below.

6.3.5.1 The digestive system

The digestive system comprises of organs such as the oesophagus, the stomach, the small and large intestine, the pancreas. All these different organs contribute to the digestion of food in the body.

6.3.5.2 The circulatory system

The circulatory system comprises of organs such as the veins, arteries and the heart. These organs transport food, gases, hormones and waste products to and from the cells of the body. There are two types of fluids that move in the circulatory system; *blood* and a clear fluid called *lymph*. Lymph flows in separate lymph vessels as part of an independent lymphatic system, which eventually links up with the bloodstream. The lymphatic system has three interrelated functions: it is responsible for the removal of interstitial fluid from tissues, it absorbs and transports fatty acids to the circulatory system and transports immune cells to and from the lymph **nodes**.

6.3.5.3 The nervous system

The nervous system comprises of organs such as the brain, spinal cord, and the sense organs. The sense organs provide the nervous system with information of what goes on inside and outside the body. This information known as impulses travel to the brain and spinal cord, where the body activities are controlled and monitored.

6.3.4.5 The endocrine system

The endocrine system comprises of glands which are organs that produce and secrete hormones. The hormones regulate growth, metabolism, and sexual development and function.

Activity

Activity 6.3.10

You should spend approximately 5 minutes on this activity.

I have mentioned four of the main systems of the body above. Look for any Biology book and make a list of three other body systems in the space below.

Feedback

Feedback to Activity 6.3.10

I am sure that you have mentioned systems such as the skeletal system, respiratory system, immune system, excretory system, muscular system and reproductive system.

Note it! / Important!

You will learn about each of the different systems mentioned above in other related units as you go through course.

With the study on body systems, we have come to the end of this Topic. To test how much you have learnt, you should now do the Self-assessment 6.3 below.

Assessment

Self-assessment 6.3

You need 30 minutes to do the self-assessment. The answers to Self-assessment 6.3 are given at the end of this topic. You are, however, strongly advised to first answer the questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

1. Draw a table in the space below, and classify the following as cells, tissues or organs:

erythrocyte, xylem, root hair, phloem, leukocyte, bone, and muscle.

2. With the help of diagrams, differentiate between a specialized cell and a tissue.

3. In Table 6.3.3 (a) below, write the name of the cell next to its function.

Function	Cell
Controls the water loss in a plant and the exchange of oxygen and carbon dioxide in the leaf, by regulating the opening and closing of the stomata.	
Helps fight invading organisms that enter the body	
Absorbs water for the plant	

Table 6.3.3 (a): Completing a table to show cell types and function

4. Draw any two specialized animal cells in the space below and state their functions.

5. Name two plant tissues and describe their functions.

6. To which system would you associate the following groups of organs? Write the correct system next to its corresponding group of organs.

	Group of organs	System
a.	Heart, veins and arteries	
b.	Stomach, intestine, and oesophagus	
c.	Brain, neurons and spinal cord	
d.	Flower, seeds, and fruits	

7. Discuss the relationship between cells, tissues and organs in a system.

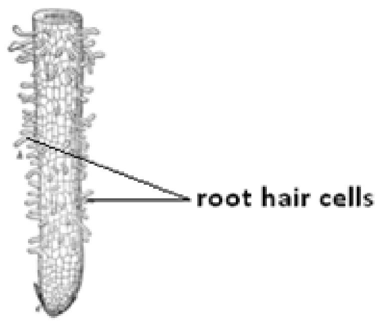
Feedback

Feedback to Activity 6.3.2

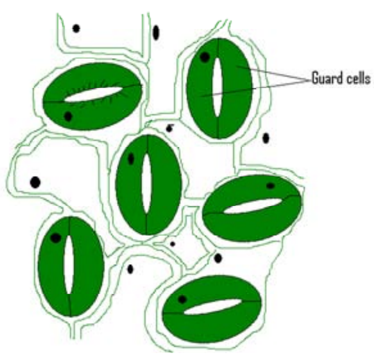
Please note that:

Answers (a) and (b) below serve as feedback to Question 1 as well as the observation of root hair cells and guard cells under the microscope.

1. Root hair cells growing from a root.



Guard cells



2. C. The top surface of a leaf gets more sunlight and so the plant would lose too much water by evaporation.

3. Root hairs are found on the main roots of plants. They help absorb water for the plant.

Feedback

Feedback to Activity 6.3.8

The leaf is an example of an **organ**.

An organ is a group of different **tissues** working together to perform a particular function.

The main function of the **leaf** is to make food for the plant.

To make food, the plant needs to take **carbon dioxide** from the air, water from the **soil** and use light energy to convert these into food.

The **air spaces** in the spongy mesophyll provide for air to reach the chloroplasts in the **palisade mesophyll**, and the xylem brings the water needed.

The **phloem** conducts the food that is made in the leaf to the other parts of the plant.

The different tissues make up the (**leaf**) **organ**, and by working together the tissues contribute to the specific job of the leaf.

Answers to Assessment

Answers to Self-assessment 6.3

1. Erythrocyte, leukocyte and root hair are **cells,** xylem, phloem and muscle are **tissues,** and bone is an **organ.**

2.

Specialized cells	Tissues
A **specialized cell** has a distinct shape, location and function.	A **tissue** is a group of similar cells working together to perform a particular function.
Any of the following specialised cells can be drawn: • a root hair cell, • a guard cell, • a muscle cell or	Any of the following tissues can be drawn: • Bone tissues (compact bone tissue and spongy bone tissue • Mesophyll tissues (palisade

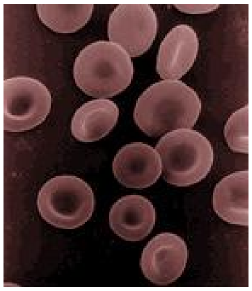
• any of the following blood cells: white blood cell, red blood cell, platelets	mesophyll tissue and spongy mesophyll tissue). • Xylem and phloem tissues.

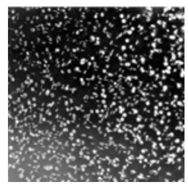
3. Cells and their functions

Function	Cell
Controls the water loss in a plant and the exchange of oxygen and carbon dioxide in the leaf, by regulating the opening and closing of the stomata.	Guard cell
Helps fight invading organisms that enter the body	White blood cell
Absorbs water for the plant	Root hair cell

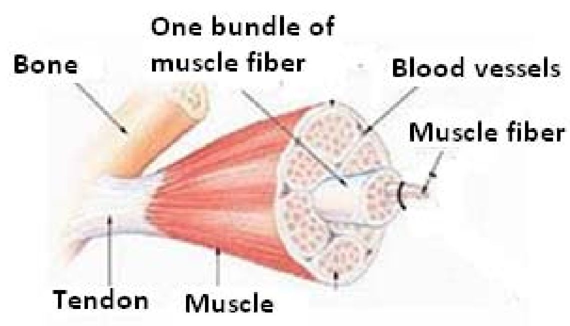
Table 6.3.3 (b): Cell types and function

4. Any two cells shown below is accepted:

Blood cell	Drawing	Function
Red blood cell (erythrocyte)		Contains haemoglobin, which takes oxygen from the lungs and carries them to all the other parts of the body. The haemoglobin gives the blood its red colour. Has no nucleus. Has a flexible cell membrane to allow it to squeeze through narrow capillaries.

White blood cell (leukocyte)		Identifies and destroys bacteria and other disease-causing-organisms which enter the body. Has a nucleus and some have granules. Regulates the immune system of the body
Platelets		The smallest cells in the blood, which helps it to clot.

Muscle cells. They help bones of the body to move.



5. Some plant tissues and their functions are as follows:

The mesophyll tissues consist of the palisade mesophyll which is directly below the upper epidermis and the spongy mesophyll.

The palisade mesophyll consists of tightly packed, vertically elongated cells, regularly arranged in one to five rows. The cells contain a lot more chloroplasts than the cells in the spongy mesophyll.

The spongy mesophyll, which is just beneath the palisade layer contain cells that are more rounded and not so tightly packed, with large intercellular air spaces.

The xylem and phloem tissues are both conducting tissues in the plant. The xylem tissue conducts water and minerals from the soil to all parts of the plant.

The **phloem tissue** conducts food from the leaves where food is made to all other parts of the plant for energy production and storage.

6. The table below shows organs and their related systems.

Organs	Systems
Heart, veins and arteries	Circulatory system
Stomach, intestine, and oesophagus	Digestive system
Brain, neurons and spinal cord	Nervous system
Flower, seeds, and fruits	Reproductive system

7. The relationship between cells, tissues and organs in a system is that cells make up tissues, tissues make up organs and organs form part of different systems.

We have come to the end of the unit. I hope that you have enjoyed doing the activities and that you have really mastered the concepts on cells, osmosis, specialised cells, tissues, organs and systems.

Good luck and Bon courage for the remaining units that you will study to complete the course. I know that you will persevere until you have completed the remaining units.

Unit summary

Summary

In this unit you learned about the structure of the cell and differentiated between plant cells and animal cells. You learnt about the functions of organelles found in plant and animal cells and had opportunities to view animal and plant cells under the microscope.

You learnt about osmosis and its importance for living organisms.

You also acquired information about special types of cells and how their shape and location relate to their functions. Added to that, you learnt how to differentiate between cells, tissues, organs and organ systems, and you saw the relationship between cells, tissues, organs and systems for the proper functioning of an organism.

Contents

Unit 7

Classifying elements

Introduction

Classification is an important activity in our everyday life. For instance, looking for a word in the dictionary is easy because the words are classified in alphabetical order. Classification is also very crucial in science. In Unit 1: *Biological classification*, you learned how to classify living organisms according to specific characteristics. Unit 2: *The elements of chemistry*, we classified matter (anything that has a mass and occupies space) as either solids, liquids or gases based on their properties. In Unit 4: *Atoms, Bonding and the Periodic Table*, Topic 4.1, we learned that the elements of the Periodic Table are arranged into: (i) Periods according to their number of shells; and (ii) Groups according to the number of electrons in their outermost shells and their chemical properties. As promised in Unit 4, Topic 4.1, in this unit we are going to learn more about the properties of elements.

To start of this unit, we will classify the elements of the Periodic Table as metals and non-metals and identify the differences between them in terms of their physical and chemical properties. In this unit you will also learn about the properties of the elements in Group I and Group VII of the Periodic Table. As a result you will also be able to predict the trends in the properties of elements in other Groups.

Upon completion of this unit you will be able to:

Outcomes

- *differentiate* between metals and non-metals on the basis of their physical properties, in particular, density, malleability, electrical and thermal conductivity.
- *state* that some metals form oxides through the reaction with oxygen.
- *state* that some metals form basic oxides and some non-metals form acidic oxides.
- *explain* that elements can be arranged in groups with similar chemical properties and may also form compounds with similar chemical properties.
- *describe* the trends in physical properties of the alkali metals, in particular, density, hardness and melting point.
- *state* that the reactivity of the alkali metals increases down Group I.
- *describe* the trends in physical properties of the halogens, in particular, colour, physical state, density and melting point.
- *state* that the reactivity of the halogens decreases down Group VII.
- *predict* the properties of elements from their position in the Periodic Table, given relevant information, and identify trends in other groups of elements.
- *describe* what is meant by a periodic pattern, exemplified by electronic structure of atoms and melting point of elements (qualitative treatment only required).

Terminology

Alkali metals:	Elements in Group I of the Periodic Table
Combustion:	Also known as burning, is a chemical reaction in which a substance reacts with oxygen to produce heat and light.
Halides:	A compound resulting from the reaction of a halogen with a positively charged ion.
Halogens:	Halogens are elements in group VII.
Oxides:	The main product formed during combustion or burning (reaction of metals or non-metals with oxygen).

How long?

Table 7.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	5 hours	2 hours and 30 minutes
Full-time student within the conventional school setting OR Part-time student	5 hours	2 hours and 30 minutes

Table 7.0: The time needed for you to work on this unit

Topic 7.1: Metals and non-metals

How long?

You will need 1 hour 40 minutes to complete this topic. It is advisable that you spend another 50 minutes of your own time to further review the topic.

As it was mentioned in Unit 4, Topic 4.1, the metallic properties of the elements gradually decrease as we move from left to right across the Periodic Table. In this unit, we are going to learn about the positions of metals and non-metals on the Periodic Table. You are also going to learn about the differences in physical and chemical properties between metals and non-metals.

7.1.1 The position of metals and non-metals on the Periodic Table

The elements of the Periodic Table exist as metals, metalloids, and non-metals. With reference to Figure 7.1.1 below, we are now going to describe the position of metals, metalloids and non-metals on the Periodic Table.

If you have access to the internet, try taking a look at this youtube video. It is called the "chemistry element song." http://youtu.be/DYW50F42ss8 Please note again that we are providing this only for reference and we do not recommend or endorse any links from this site.

The elements found on the left-hand side and the middle parts of the Periodic Table (the pink part) are the **metals** whereas those found on the right-hand side of the Periodic Table (the yellow part) are the **non-metals**. The small number of elements in between the metals and non-metals (the blue part) are called **metalloids**.

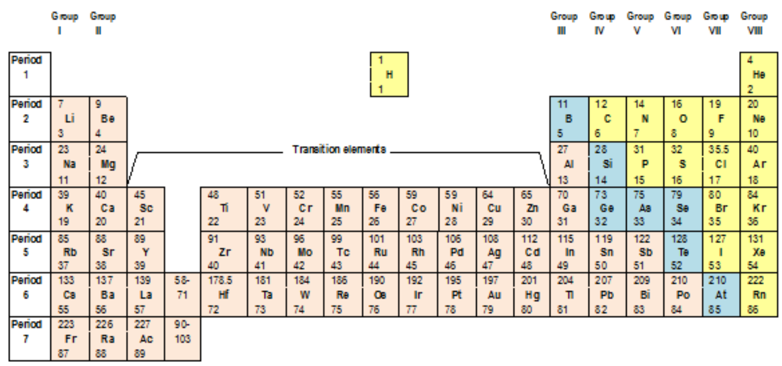


Figure 7.1.1: The Periodic Table of elements showing the positions of the metals (the pink part), the metalloids (the blue section) and the non-metals (the yellow section)

Source: Unit 2:The elements of chemistry, Topic 2.3, Figure 2.3.1

Take a look at the following link to get a visual idea of what each element looks like. http://www.rsc.org/periodic-table/

Please note again that we are providing this only for reference and we do not recommend or endorse any links from this site.

Now that you know the positions of metals and non-metals on the Periodic Table, we are going to look at the physical and chemical properties on metals and non-metals.

To start off, let us learn about the physical properties of metals and non-metals.

7.1.2 The physical properties of metals and non-metals

Metals and non-metals exhibit different physical properties. Metalloids exhibit some properties of metals and non-metals. Before we talk about the difference in physical properties between metals and non-metals, you are going to carry out a short activity in groups to try to identify some physical differences between metals and non-metals.

Group activity

Group Activity 7.1.1

You should spend about 25 minutes on this activity.

You are advised to carry this activity in the science laboratory in groups of 4 or 5.

Equipment:

In your group, you will be provided with a small sample of: iron nails, copper turnings, sulphur, carbon, zinc, bromine, magnesium and iodine crystals.

Instruction:

1. You are required to observe those substances and group them as metals and non-metals.

Metals	Non-metals

2. Briefly state why you have grouped the materials as metals and non-metals in terms of the differences in physical properties (physical state, appearance, ability to produce sound when hit, etc.). You may want to present these in a table.

I hope that you have found the task interesting. Please refer to the Feedback to Group Activity 7.1.1 for the possible observations.

Feedback

Feedback to Group Activity 7.1.1

1. From your observation, you should have classified those elements as shown in the table below.

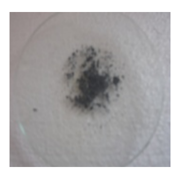
Metals	Non-metals
Iron  (iron nails)	Sulphur 
Copper turnings 	Carbon (graphite) 
Zinc 	Bromine 
Magnesium 	Iodine crystals 

Photo of sulphur and carbon adapted from: http://en.wikipedia.org

All other photos by: Rosianna Jules, January 2011

Prepared by: Louisette Bonte, January 2011

2. Some possible observations between the physical properties of metals and non-metals are listed below.

Metals	Non-metals
Are solids	Can be solids, liquids or gas (the brownish vapour in the bromine reagent bottle)
Are shiny	Are not shiny
Are hard	Are soft, not hard
Produce sounds when hit	Do not produce sounds when hit

I hope that you have managed to make those observations. If you did not, please go back and observe those elements again.

Apart from the physical difference mentioned above, there are more physical differences between metals and non-metals. We are now going to learn more about the difference in physical properties between metals and non-metals. The differences in physical properties of metals and non-metals are summarised in Table 7.1 below.

Physical Properties	Metals	Non-metals
Physical state at room temperature	Solid (except mercury which is semi solid)	Solid (e.g. sulphur, carbon, iodine & silicon); Liquid (bromine is the only liquid); or Gas (e.g. oxygen, nitrogen, & helium).
Appearance	Shiny / lustrous and can be polished	Non-shiny / have no lustre and cannot be polished

Physical Properties	Metals	Non-metals
Boiling point and melting point	High (except for mercury)	Low
Heat and electrical conductivity	Good	Poor
Density	Relatively high	Relatively low (except for solid non-metals)
Malleability and ductility (ability to be bent and to withstand stress and strain)	Good (metals are not brittle and have great tensile strength)	Poor (usually brittle and break easily under stress and strain, except for diamond, a carbon allotrope)
Sonority (ability to produce a sound / a note / resonance when hit)	Good (metals are sonorous)	Poor (non-metals are not sonorous)

Table 7.1.1: The differences in the physical properties of metals and non-metals

So far we have seen the physical differences between metals and non-metals. Next, we are going to learn about the chemical differences between metals and non-metals.

7.1.3 Chemical properties of metals and non-metals

In Unit 4: *Atoms, bonding and the Periodic Table*, we saw that when metals and non-metals react together, ionic (electrovalent) bonds are formed and the metals and non-metals acquire opposite charges. Before we continue, let us see how much you can recall regarding ionic bonds.

Activity

Activity 7.1.1

You should spend about 5 minutes on this activity.

Please answer the questions below in the space provided.

1. What happens during the formation of ionic bonds?

___

___

2. During ionic bond formation, what charge is acquired by:

   a. the metal

   ___

   b. the non-metals?

   ___

I hope that you still remember the answers to the questions above. Please refer to the Feedback to Activity 7.1.1 for the answers.

Feedback

Feedback to Activity 7.1.1

1. Yes, you are right! During ionic bond formation, there is the complete transfer of electrons. The metals lose (donate) their outer electrons to the non-metals while the non-metals gain (accept) the electrons.

2. a. During ionic bonds formation, the metals become positively charged

   b. During ionic bonds formation, the non-metals become negatively charged.

I bet that this activity has brought back some memories of Unit 4 and I hope that you have managed to get the correct answers. If you did not, please devote some more time to review Unit 4.

From the Feedback to Activity 7.1.1 above, we saw that there is a difference in the charge that metals and non-metals acquire during ionic bond formation. Metals and non-metals exhibit other differences in chemical properties. The main differences in chemical properties between metals and non-metals are summarised in Table 7.1.2.

Chemical Properties	Metals	Non-metals
Formation of ions	Metals react by losing electrons to become positively charged ions. E.g. $Ca - 2e \rightarrow Ca^{2+}$	Non-metals react by gaining electrons or sharing its electrons to become negatively charged ions. E.g. $Br + e \rightarrow Br^{-}$
Ability to displace hydrogen from dilute acids	Metals above hydrogen in the activity series displace (can release) hydrogen from dilute acids. E.g. $Mg^{2+} + H_2SO_4 \rightarrow H_2 + MgSO_4$	Non-metals cannot displace hydrogen from dilute acids.
Combustion (reaction with oxygen)	Metals burn in oxygen to form basic oxides. E.g. $Ca^{2+} + O_2 \rightarrow 2CaO$ Soluble basic oxides are	Non-metals burn in oxygen to form either acidic oxides or neutral oxides. E.g. $2C + O_2 \rightarrow 2CO$ (*neutral* oxide)

Chemical Properties	Metals	Non-metals
	called alkalis. E.g. $CaO + H_2O \rightarrow Ca(OH)_2$ (You will learn about the terms bases, alkali, acids and neutral later in the course.)	E.g. $C + O_2 \rightarrow CO_2$ (*acidic* oxide) Soluble acidic oxides form acids. E.g. $CO_2 + H_2O \rightarrow H_2CO_3$
Reaction with halogens (group VII elements)	Metals react with halogens to form electrovalent halides. E.g. $2Na^+ + Cl_2 \rightarrow 2Na^+Cl^-$	Non-metals react with halogens to form covalent halides. E.g. $P_4 + 6Cl_2 \rightarrow +2P_2Cl_6$
Reaction with hydrogen	Metals react with hydrogen to form electrovalent hydrides. $2Na^+ + H_2 \rightarrow 2Na^+H^-$	Non-metals react with hydrogen to form numerous covalent hydrides. E.g. $C + 2H_2 \rightarrow CH_4$ (methane) Other examples include: C_2H_2 – ethyne C_2H_4 – ethene NH_3 – ammonia HCl – hydrogen chloride
Ability to reduce or oxidise	Metals are reducing agents. E.g. $2Mg^{2+} + CO_2 \rightarrow 2MgO + C$	Non-metals may be either (i) reducing agents E.g. $2C + 2CuO \rightarrow 2Cu + 2CO_2$ OR (ii) oxidising agents E.g. $2NaI + Cl_2 \rightarrow 2NaCl + I_2$

Table 7.1.2: The differences in the chemical properties of metals and non-metals

Note it! / Important!

Please note that you will learn about alkalis, bases, acids, reduction and oxidation later in the course.

Now before we move on to the next topic, let us see how much you have learned through this self-assessment.

Assessment

Self-Assessment 7.1

You should spend no more than 20 minutes on this self-assessment. This self-assessment is based on Topic 7.1. The answers are given at the end of the topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 7.1. This will help you learn and reflect better on areas for improvement.

You are required to answer the questions below in the space provided.

1. Write TRUE or FALSE next to each statement regarding the physical properties of metals and non-metals.

	Statements	TRUE / FALSE
A	All metals form covalent bonds.	
B	Non-metals form negatively charged ions.	
C	Metals are shiny when cut while non-metals are not shiny.	
D	Metals have relatively high density just like non-metals.	
E	Metals and non-metals are good conductors of electricity and heat.	
F	Non-metals have low boiling points and melting points.	

G	Apart from mercury, all metals are solids at room temperature.	
H	Silicon is an example of a metal.	

2. Complete the statements with the most appropriate word or chemical symbol or chemical formula.

   a. Metals burn in ____________ to form ____________ oxides.

      $\_\_O + H_2O \rightarrow Mg(OH)_2$

   b. Non-metals burn in oxygen to form either ____________ oxides ($C + O_2 \rightarrow$ ____) or neutral oxides ($2C + O_2 \rightarrow$ ____).

   c. ____________ above hydrogen in the activity series can displace ____________ from dilute acids.

   d. ____________ cannot displace ____________ from dilute acids.

   e. Non-metals react by ____________ ____________ or ____________ ____________ to form ____________ charged ions.

   f. Metals react by losing electrons to become ____________ charged ions.

   g. Metals react with ____________ to form ____________ halides. $\_\_\_ + \_\_\_ \rightarrow 2K^+Br^-$

I hope that the assessment was easy for you. Once, you have completed the self-assessment, please refer to the Answers to Self-Assessment 7.1 at the end of this topic for the correct answers.

Answers to Assessment

Answers to Self-assessment 7.1

1. TRUE or FALSE

	Statements	TRUE / FALSE
A	All metals form covalent bonds.	FALSE: metals form electrovalent or ionic bonds.
B	Non-metals for negatively charged ions.	TRUE
C	Metals are shiny when cut while non-metals are not.	TRUE
D	Metals have relatively high density just like non-metals.	FALSE: true for metals but non-metals have relatively low density
E	Metals and non-metals are good conductors of electricity and heat.	FALSE: true for metals, non-metals are poor conductors of heat and electricity
F	Non-metals have low boiling points and melting points.	TRUE
G	Apart from mercury, all metals are solids at room temperature.	TRUE: mercury is semi-solid
H	Silicon is an example of metals	FALSE: silicon is a non-metal

2. Filling the blanks

   a. Metals burn in oxygen to form basic oxides.

   $\underline{Mg}O + H_2O \rightarrow Mg(OH)_2$

   b. Non-metals burn in oxygen to form either acidic oxides ($C + O_2 \rightarrow \underline{CO_2}$) or neutral oxides ($2C + O_2 \rightarrow \underline{2CO}$)

c. Metals above hydrogen in the activity series can displace hydrogen from dilute acids.

d. Non-metals cannot displace hydrogen from dilute acids.

e. Non-metals react by losing electrons or sharing electrons to form negatively charged ions.

f. Metals react by losing electrons to become positively charged ions.

g. Metals react with halogens to form electrovalent / ionic halides. $\underline{2K^{+}} + \underline{Br_2} \rightarrow 2K^{+}Br^{-}$

I hope that you have got all the answers correct. If you did not, please review Topic 7.1 before moving on.

So far we have seen that the difference in the properties of metals and non-metals. Take a moment now to reflect back on what you have learned.

In the next topic we are going to look at the properties of a group of metal and a group of non-metals.

Topic 7.2: Properties of Group I elements

How long?

You will need 1 hour 40 minutes to complete this topic. It is advisable that you spend another 50 minutes of your own time to further review the topic.

Note it! / Important!

Before you carry on with this topic, you are advised to contact the laboratory technician at your school or centre so that you can place a booking for group demonstration to illustrate the reaction of two alkali metals with water (sub-topic 7.2.3.1).

Please note that for economical purposes, a minimum of five students is required per demonstration.

You will remember that in Unit 4, Topic 4.1, we saw that a **group** is the vertical column of elements in the Periodic Table and that all groups (except the groups of transition metals) are numbered using Roman numerals (I, II, III, IV, V, VI, VII, and VIII). We also saw that the elements in Group VIII / Group 0 (zero) are stable gases and do not undergo chemical reactions. In other words, they are inert gases. Similarly, all groups of elements exhibit certain specific characteristics.

In this topic you are going to learn about the trends in the physical and chemical properties of elements in Group I (the alkali metals). We will start off with the physical properties of the elements in Group I.

7.2.1 Group I elements

As mentioned previously, Group I elements are also known as the **alkali metals**. The most common Group I elements are: lithium, sodium and potassium. Table 7.2.1 shows the common elements in Group I, their proton number, period and electronic configuration.

Group I Elements	Symbol	Proton number	Period	Electron configuration
Lithium	Li	3	2	2,1
Sodium	Na	11	3	2,8,1
Potassium	K	19	4	2,8,8,1

Table 7.2.1: Group I elements, their proton number, period and electronic configuration

With one electron in their outermost (valence) shell, Group I elements are a group of very reactive metals. We are now going to learn about the physical and chemical properties of Group I elements. We will start with the physical properties of the alkali metals.

7.2.2 Physical properties of Group I elements

We have seen earlier that metals exhibit certain physical properties. We are now going to look at the properties of Group 1 elements. Table 7.2.2 shows some of the physical properties of these elements.

Group I Elements	Appearance	Melting point in °C	Boiling point in °C	Density in g/cm^3
Lithium	Soft grey metal (has a shiny metallic surface when freshly cut)	181	1342	0.54
Sodium	Soft light grey metal (has a shiny metallic surface when freshly cut)	98	883	0.97
Potassium	Very soft blue/grey metal (shiny when cut)	63	759	0.86

Table 7.2.2: Some physical properties of Group I elements

The melting points and boiling points of the most common alkali metals (Group I elements) can also be displayed graphically as shown in Figure 7.2.1 below.

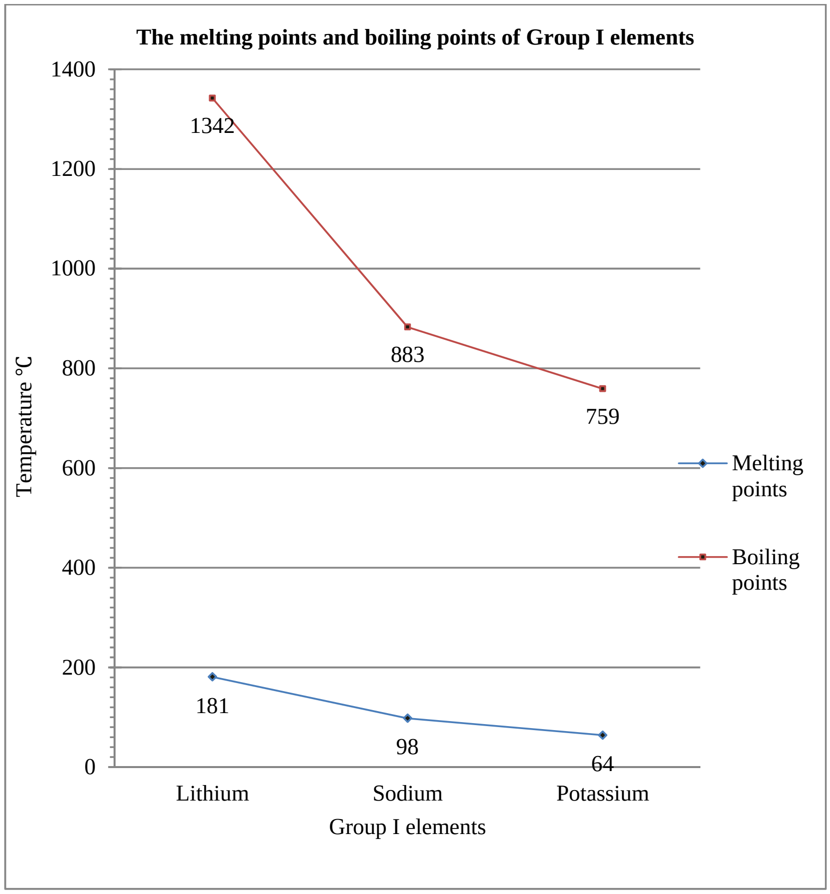


Figure 7.2.1: Graph showing the melting points and boiling points of Group I elements

Now that you know the physical properties of the Group I elements, let us look at the trend (pattern) in these physical properties. You will do this through a short group discussion.

Discussion

Group Discussion 7.2.1

You should spend about 10 minutes on this discussion.

With one or two colleagues, with reference to Figure 7.2.1 and Table 7.2.2, discuss the trend in the physical properties of the elements in Group I.

I hope that you have enjoyed this discussion. In the information that follows, you will find out the pattern or trend in the physical properties of the elements in Group I.

From Figure 7.2.1 and Table 7.2.2, we can conclude that as we go down the group, there is a progressive change in the physical properties of the elements in Group I. These progressive changes are as follows:

a. the hardness of the metals decreases (in other words, the metals become softer);

b. the melting point decreases;

c. the boiling point decreases; and

d. the density decreases.

Note it! / Important!

Please note that all the previous properties of metals discussed in Topic 7.1.2 also apply to the elements in Group I. This means that the elements in Group I are also:

a. solids;

b. good conductor of electricity;

c. malleable and ductile.

So far you have learned about the trend in the physical properties of Group I elements; now we are going to look at their chemical properties.

7.2.3 Chemical properties of Group I elements

Previously, we learned that metals lose their valence electron(s) to form positively charged ions. From Table 7.2.1, we saw that the elements in Group I have only one electron in their outermost (valence) shell. Since a small amount of energy is required to lose their single valence electron, Group I elements are a group of very reactive metals: they react immediately with water. Consequently, alkali metals are stored under paraffin oil to exclude humidity (moisture).

All the members of the alkali family exhibit similar chemical properties. You are now going to learn about the three common chemical properties of the alkali metals.

7.2.3.1 Reaction of alkali metals with water

To illustrate the reaction of alkali metals with water, you are required to follow the group demonstration which you should have booked with the laboratory technician at the start of Topic 7.2.

However, if you did not place a booking, please check with the laboratory technician for the next demonstration session. Alternatively, you could watch the video clips on CD ROM which can be borrowed from your school or centre.

Group activity

Group Activity 7.2.1

You should spend no more than 25 minutes to follow this demonstration performed by the laboratory technician and to answer the questions involved.

You are required to stand to watch this demonstration. Please take heed to the lab technician's advice as to the distance you should be from the set up. Make sure that you should read all the instructions before the demonstration starts.

Instructions:

1. The laboratory technician will cut a small piece of sodium and a small piece of potassium. Observe the cut surface of the metals. What do you notice?

____

____

____

2. The lab technician will now fill a trough half full with tap water. What is the temperature of the water?

____

3. When it is time for the live demonstration, you should back away. Respect the technician's advice.

4. The lab technician will now repeat steps 2 to 4 but this time using the small piece of potassium. Observe what happens. (You may want to take the temperature of the water in the trough after the reaction.)

____

____

5. Which of the two elements reacted faster or more vigorously?

6. You should have noticed that sodium and potassium floated on water. Why do you think this happens?

I hope that you have found this demonstration interesting. Please refer to the Feedback to Group activity 7.2.1 for the expected observations.

Feedback

Feedback to Group activity 7.2.1

Expected observations.

1. The cut surfaces of sodium and potassium were shiny (silvery in colour).

2. The temperature of the tap water in the trough (before adding the metal) was around room temperature (30°C).

3. When the small piece of sodium was placed in the trough of water, you should have observed that:

    a. the piece of sodium floated and skidded on the water surface as it reacted;

    b. the piece of sodium ignited and burned with an orange flame;

    c. after the metal has reacted, the water become warm: the temperature of water has increased (it was more than 30 °C);

    d. the piece of sodium melted.

4. When the small piece of potassium was placed in the trough of water, you should have observed that:

    a. the piece of potassium floated and skidded on the water surface as it reacted;

    b. the piece of potassium ignited and burned with a pink or lilac flame;

    c. after the metal has reacted, the water became warm: the temperature of water has increased (it was more than 30 °C).

    d. the piece of potassium melted.

5. Potassium acted faster and more vigorously than sodium.

6. The reason why sodium and potassium float on water is because they are less dense than water. The density of water is 1 g/cm^3 and the density of sodium and potassium are 0.97 g/cm^3 and 0.86 g/cm^3 respectively.

You are now going to talk more about the reaction of alkali metals with water.

When an alkali metal is added to cold water, it reacts immediately to produce an alkali (a hydroxide solution of the respective metal) and hydrogen gas. The heat produced when sodium and potassium react with water is enough to melt the metal.

The chemical equations for the reactions of lithium, sodium and potassium with water are given below.

Word equation

lithium + water → lithium hydroxide + hydrogen

$2Li^{+}\ (s) + 2H_2O\ (l) \rightarrow 2LiOH(aq) + \ H_2\ \ (g)$

Symbol equation

sodium + water → sodium hydroxide + hydrogen

$2Na^{2+}\ (s) + 2H_2O\ (l) \rightarrow 2NaOH(aq) + \ H_2\ \ (g)$

potassium + water → potassium hydroxide + hydrogen

$2K^{+}\ (s) + 2H_2O\ (l) \rightarrow 2KOH(aq) + \ H_2\ \ (g)$

You should have noticed from the equations, that the three metals react in the same ration and they all produce an alkali (base) and hydrogen gas. So, if the alkali metals were represented by the letters 'Am', then the general chemical equation would be:

Alkali metal + water → alkali metal hydroxide + hydrogen

$2Am\ (s) + 2H_2O\ (l) \rightarrow 2AmOH(aq) + \ H_2\ (g)$

Note it! /
Important!

Please note that there are two ways of writing chemical equations. We can write them as *word equations* or *symbol equations*.

- In a *word equation*, the chemicals are represented by their names.

  An example of word equation is:

  potassium + water → potassium hydroxide + hydrogen

- In a *symbol equation*, the chemicals are represented by their chemical symbols.

  An example of symbol equation is:

  $2K^{+}\ (s) + 2H_2O\ (l) \rightarrow 2KOH(aq) +\ H_2\ (g)$

When writing a symbol equation, the equation needs to be balanced. This means that, the number of atoms of each of the element in the reactants (chemical reacting on the left hand side) should be equal to the number of atoms of each of the element in the product (the chemical produced on the right hand side).

You will learn more about balancing equation later in the course.

Now let us move on to the reaction of Group I elements with oxygen.

7.2.3.2 Reaction of alkali metals with oxygen

When heated, the alkali metals burn in oxygen (air) to form a white solid oxide. Each alkali metal burns with distinct coloured flames. In Group activity 7.2.1, we saw that sodium burned with an orange flame and potassium burned with a pink/lilac flame. So when the alkali metals react with oxygen, the colour of the flames produced is as follows:

a. lithium burns with a red flame;

b. sodium burns with an orange flame; and

c. potassium burns with a pink/lilac flame.

The colour of the flame is a unique characteristic of each of the alkali elements.

The chemical equation for the reaction of lithium with oxygen is given below.

Lithium + oxygen → lithium oxide

$$4Li^{+}(s) + O_2(g) \rightarrow 2Li_2\,O(s)$$

The equation for the reaction of any Group I elements with oxygen is the same as that for lithium. So, the general equation for the reaction of any alkali metal (represented by the letters ‘Am’) with oxygen is as follows:

Alkali metal + oxygen → alkali metal oxide

$$4Am^{+}(s) + \ O_2(g) \rightarrow 2Am_2O(s)$$

We are now going to look at another characteristic reaction of Group I elements.

7.2.3.3 Reaction of alkali metals with chlorine

Alkali metals react readily with chlorine. When a piece of burning alkali metal is lowered into a gas jar of chlorine, the alkali metal continues to burn forming a white smoke of the alkali metal chloride.

The reaction of an alkali metal with chlorine is illustrated below.

Lithium + chlorine → Lithium chloride

$$2Li^{+}(s) + \ Cl_2(g) \rightarrow 2LiCl(s)$$

The reaction of any Group I elements with chlorine is similar to that of lithium. Hence, the general equation for the reaction of any alkali metal (represented by the letters ‘Am’) with chlorine is as follows:

Alkali metal + chlorine → alkali metal chloride

$$2Am^{+}(s) + \ Cl_2(g) \rightarrow 2AmCl(s)$$

We have seen three different reactions involving the three most common alkali metals. Now let us see if there is a trend in the reaction of the alkali metals with water.

From the Group activity 7.2.1, you learned that potassium react faster and more vigorously than sodium. This is a fact: **as you go down the group, the reactivity of the alkali metals increases.** This implies that sodium reacts faster than lithium and potassium reacts faster than sodium. So, among the three elements, lithium is the least reactive alkali metal and potassium is the most reactive.

There are three more members of the alkali metals family: rubidium (Rb) in Period 5, caesium (Cs) in Period 6 and francium (Fr) in Period 7. These three alkali metals are all more reactive than potassium.

Reflection

Reflection 7.2.1

Now take 10 minutes to reflect on what you have learned about the properties of the elements in Group I.

1. Among the seven alkali metals, which do you think:

    a. has the highest boiling and melting points? ___________

    b. has the lowest boiling and melting points? ___________

    c. is the most reactive metal? ________________

    d. is the least reactive metal? _________________

2. Put these elements in order of decreasing reactivity: caesium, lithium, potassium, francium, sodium and rubidium.

____

____

You are right!

1.

   a. The alkali metal with the highest boiling and melting points is lithium.

   b. The alkali metal with the lowest boiling and melting points is francium.

   c. The most reactive metal is francium.

   d. The least reactive metal is lithium.

2. In order of decreasing reactivity, the elements are: francium, caesium, rubidium, potassium, sodium and lithium.

To conclude this section regarding the properties of the alkali metals, Figure 7.2.2 below provides the relative reactivity of the alkali metals as we move down the group.

Lithium	least reactive
Sodium	
Potassium	
Rubidium	
Caesium	
Francium	most reactive

Figure 7.2.2: The relative reactivity of the alkali metals as we move down the group

This brings us to the end of topic 7.2 but what did you learn about the properties of Group I elements? How are these elements unique? What is it about them that give them these characteristics? Briefly think about their reactivity going down the table. Why don't they all have the same reactivity?

In the topic below, we are going to learn about the properties of the elements in Group VII. Judging from what you learned about Group I elements, can you make any predictions on the reactivity of Group VII elements? Let's move on to find out.

Topic 7.3 Properties of Group VII elements

How long?

You will need 1 hour 40 minutes to complete this topic. It is advisable that you spend another 50 minutes of your own time to further review the topic.

In this topic you are going to learn about the trends in the physical and chemical properties of elements in Group VII (the halogens). We will start off with the physical properties of the elements in Group VII.

7.3.1 Group VII elements

The elements in Group VII are also known as the **halogens**. The halogens are a family of reactive non-metals. The most common halogens are fluorine, chlorine, bromine and iodine. Table 7.3.1 shows the common elements in Group VII, their proton number, period and electronic configuration.

Group VII Elements	Proton number	Period	Electron configuration
Fluorine	9	2	2, 7
Chlorine	17	3	2,8,7
Bromine	35	4	2,8,18,7
Iodine	53	5	2,8,18,18,7

Table 7.3.1: Group VII elements, their proton number, period and electronic configuration

Like in the case of metals, non-metals display certain physical and chemical properties as we saw earlier. We are now going to look more closely at the properties of Group VII elements. We will start with their physical properties.

7.3.2 Physical properties of Group VII elements

Table 7.3.2 shows some of the appearances of these elements at room temperature.

Group I Elements	Appearance at room temperature	Melting point in ℃	Boiling point in ℃	Density in g/cm^3
Fluorine	Pale yellow gas	-220	-188	1.7
Chlorine	Yellow/green gas	-101	-35	3.2
Bromine	Red/brown volatile liquid	-7	58	3.1
Iodine	Dark grey crystalline solid	114	184	4.94

Table 7.3.2: Some of the physical properties of Group VII elements

Now to help us discuss the trend in the physical properties of the halogens (Group VII elements), you are required to carry out this short activity.

Activity

Activity 7.3.1

You are advised to spend about 15 minutes on this activity.

1. Use the information from Table 7.3.2 to draw a graph to show the melting points and boiling points on Group I elements on the graph paper (Figure 7.3.1a) provided.

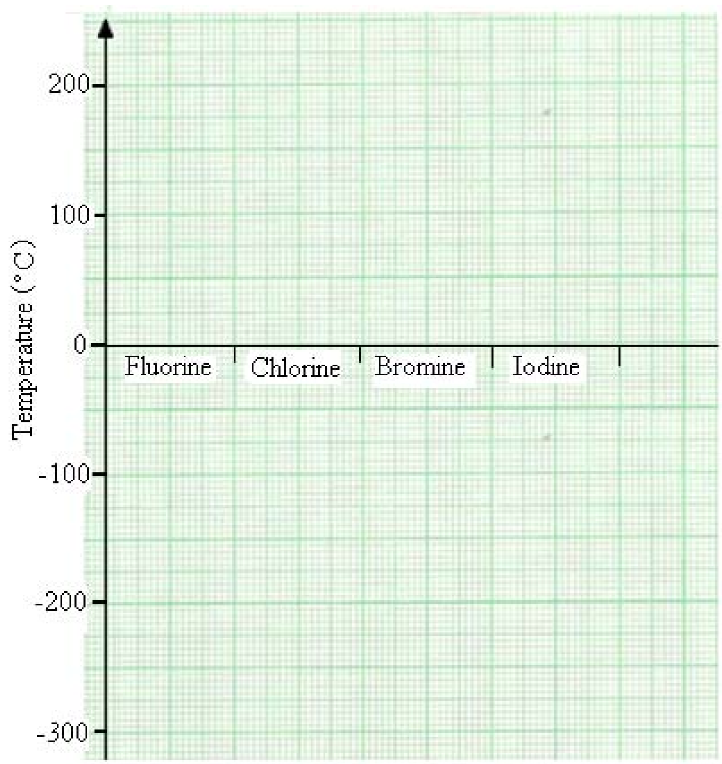


Figure 7.3.1a: Graph paper to show the melting points and boiling points of Group VII elements

2. From Table 7.3.2 and your graph (Figure 7.3.1a), what trend do you notice regarding the melting points and boiling points of Group VII elements?

3. What other conclusion can you draw from Table 7.3.2?

I hope that you have found the activity easy. Once you have completed the activity, please refer to the Feedback to Activity 7.3.1 below for the expected answers.

Feedback

Feedback to Activity 7.3.1

1. Figure 7.3.1b shows the melting points and boiling points of Group VII elements.

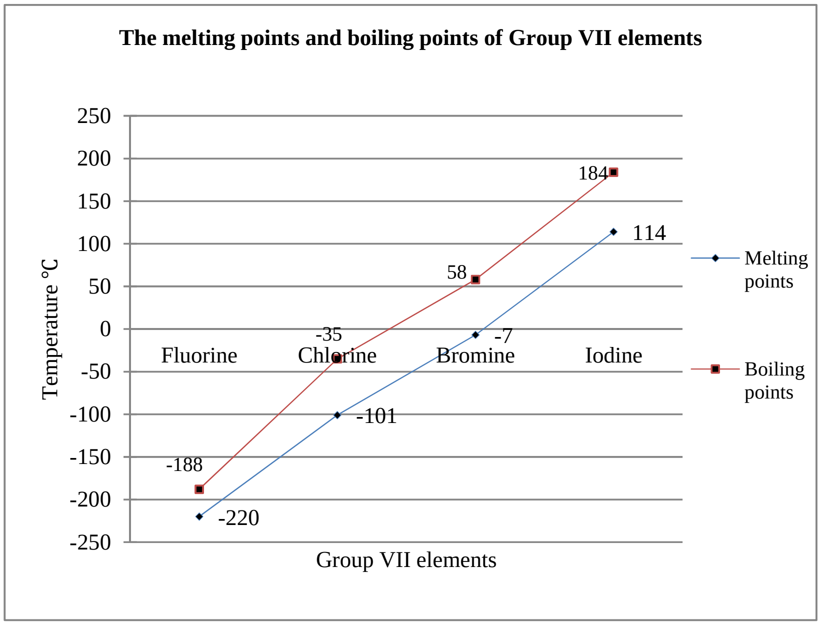


Figure 7.3.1b: The melting points and boiling points of Group VII elements

2. You should have noticed from your graph (Figure 7.3.1a, as illustrated by Figure 7.3.1b above) and Table 7.3.2 that:

   As we move down Group VII:

   a. the melting point of the elements increases; and

   b. the boiling point of the elements increases.

3. From Table 7.3.2 you can also conclude that as we move down the group:

   a. the particles in the halogens becomes more closely packed. Hence, the state of the halogens change from gas (fluorine and chlorine) to liquid (bromine) then to solid (iodine); and

   b. the density of the halogens increases.

I believe that you have found this activity interesting and easy, and that you have managed to get all the correct answers.

Note it! / Important!

Please note that all the previous properties of non-metals discussed in Topic 7.1.2 also apply to the elements in Group VII. This means that the elements in Group VII:

a. can be in the gaseous, liquid or solid state;

b. are bad conductor of electricity;

c. are not malleable and ductile.

Now we are going to learn about the trend in the chemical properties of the elements in Group VII.

7.3.3 Chemical properties of Group VII elements

Being in Group VII, the halogens have seven electrons in their outermost shells as shown in Table 7.3.1 above. Hence, the **halogens are very reactive non-metals** as they require a small amount of energy to acquire a full/stable octet. The halogens (like all non-metals, apart from the elements in Group VIII) can acquire a full octet either:

1. by forming ionic bonds with metals. During ionic bond formation, the halogen gains an electron from the metal to become a negatively charged ion; OR

2. by forming covalent bonds with non-metals. During covalent bond formation, the halogen shares an electron with another non-metal.

Note it! / Important!

Please note that although the elements in the halogen family have different physical appearances (different state of matter as shown in Table 7.3.2 above), they are in the same family because they exhibit similar chemical properties.

We are now going to look at some characteristic chemical properties of the elements in Group VII.

Note it! /
Important!

Please note that because fluorine is a very reactive gas and too reactive to handle in a normal laboratory, it will not be addressed in the reaction examples below. Hence, we will focus on chlorine, bromine and iodine.

7.3.3.1 Solubility of the halogens in water (a polar solvent)

None of the halogens are very soluble in water (a polar solvent) because halogens are made of molecules. The halogen which is the most soluble in cold water is chlorine. Iodine does not dissolve much in cold water and it only dissolves slightly in hot water.

Chlorine solution (also known as chlorine water) has a very pale green colour. Chlorine water is acidic, so it turns a universal indicator red. Chlorine solution also bleaches the indicator quickly.

Bromine solution (also called bromine water) is orange in colour. It is a very weak acid and it is also serves as bleach.

Iodine solution is also a very weak acid and it also slightly acts as bleach.

7.3.3.2 Reaction of the halogens with hexane (a non-polar solvent)

The halogens dissolve readily in hexane (a non-polar solvent) to give the following distinctive coloured solutions.

Chlorine dissolves in hexane to give a colourless solution.

Bromine dissolves in hexane to give an orange solution.

Iodine dissolves in hexane to give a purple solution.

Note it! / Important!

Please be aware that you will learn about polar and non-polar molecules later in the course. For now, you simply need to know that the distribution of electrons due to the arrangement or geometry of the atoms in a molecule can cause a molecule to be polar or non-polar

A polar molecule (like water, alcohol, ammonia and sulphur dioxide) has a positive electrical charge on one side and a negative electrical charge on the other side due to the unsymmetrical distribution of electrons.

A non-polar molecule (like hexane, carbon dioxide, nitrogen and oxygen gases) is one where the electrons are distributed more symmetrically and hence, there is no abundance of charges on either side.

7.3.3.3 Displacement reaction of the halogens

When chlorine is bubbled into a solution of potassium bromide, the colourless solution turns orange. This is because chlorine displaces the less reactive bromine. The orange colour results from the free bromine in the solution.

The equation for the displacement is shown below.

Potassium bromide + chlorine → potassium chloride + bromine

$$2\mathrm{KBr(aq)} + \mathrm{Cl_2(g)} \rightarrow 2\mathrm{KCl(aq)} + \mathrm{Br_2(aq)}$$

If iodine solution was added to potassium bromide, no reaction will take place because iodine is less reactive than bromine.

So, based on the information above, what can we conclude about the displacement of a halogen by another halogen? Jot down your conclusion in the space provided.

You're right! We can conclude that a more reactive halogen can displace a less reactive halogen from its compound.

Now, based on what you have learnt about the chemical properties of the halogens, what can we conclude about their reactivity as we move down the group? Write your thoughts in the space below.

____

____

____

Now let us see if your conclusion is correct. We can conclude that **as we move down the group, the reactivity of the halogen decreases.** Astatine which is radioactive and a very rare element, is the last member of the halogen family. Astatine is the least reactive halogen. Figure 7.2.4 below shows the relative reactivity of the halogens as we move down the group.

Fluorine (F)	most reactive
Chlorine (Cl)	↓
Bromine (Br)	↓
Iodine (I)	↓
Astatine (At)	least reactive

Figure 7.3.2: The relative reactivity of the halogens as we move down the group

We have now come to the end of Unit 7. I hope that you have found the content of this unit easy to master. If you feel that you need to review certain parts again, please do so before you attempt the self-assessment which follows.

Assessment

Self-Assessment 7.2

You should spend around 40 minutes on this self-assessment. This self-assessment is based on Topics 7.2 and 7.3. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 7.2. This will help you learn and reflect better on areas for improvement.

1. The table below provides a summary of the trend in the physical properties of Group I elements and Group VII elements. Complete the table with the word *increases* or *decreases*.

	As we move down	
	Group I elements	Group VII elements
Boiling points	________	________
Melting points	________	________
Density	________	________

2. The melting points and boiling points of some elements are given in the table below. Use the information to answer the following questions.

Group I Elements	State at 30°C	State at 100°C	Melting point in °C	Boiling point in °C
Lithium	Solid	Solid	181	1342
Bromine	________	________	-7	58
Chlorine	________	________	-101	-35
Fluorine	________	________	-220	-188
Iodine	________	________	114	184
Potassium	________	________	63	759

Group I Elements	State at 30℃	State at 100℃	Melting point in ℃	Boiling point in ℃
Sodium	________	________	98	883

Table 7.2.5a: Table to be completed to show the state of the elements based on their melting points and boiling points.

a. Complete Table 7.2.5a to show the state of the elements (as in the example of lithium) at:

   i. 30℃; and

   ii. 100℃

b. Separate the 7 elements in table 7.2.5a above into two groups in Table 7.2.6a and also do the following:

   i. Name the two groups of elements.

   ii. Classify the elements in order of their increasing reactivity.

Name of the two groups of elements	________	________
least reactive		
Increasing order of reactivity		
most reactive		

Table 7.2.6a: Table to classify the elements into their respective group in order of increasing reactivity

3. Use the table below to summarise the results of the reaction when chlorine, bromine and iodine are added to potassium halides.

	Solutions of		
Element added	Potassium chloride	Potassium bromide	Potassium iodide
Chlorine	☓	—	√
Bromine	—	—	—
Iodine	—	—	—

a. Complete the table using a cross (☓) to indicate when no reaction takes place and a tick (√) to indicate when a reaction occurs. Two examples have been done for you.

b. What type of reaction is taking place when potassium iodide reacts with chlorine?

---

c. For the reaction of potassium iodide with chlorine, write

i. the word equation;

---

ii. the symbol equations

---

4. One chemical property of the alkali metals is their reaction with oxygen.

a. What is the name given to the reaction of alkali metals with oxygen?

---

b. What type of oxide is formed by the reaction?

c. For the reaction of sodium with oxygen, write:

i. the word equation for the reaction

ii. the chemical equation for the reaction

iii. what colour of flame is produced during the reaction?

I am sure that you have found the self-assessment quite easy to tackle. Please refer to the Answers to Self-assessment 7.2 at the end of the topic below for the correct answers.

Answers to Assessment

Answers to Self-assessment 7.2

1.

	As we move down	
	Group I elements	Group VII elements
Boiling points	Increases	Increases
Melting points	Increases	Increases
Density	Increases	Increases

2. a. i & a. ii

Group I Elements	State at 30°C	State at 100°C	Melting point in °C	Boiling point in °C
Lithium	Solid	Solid	181	1342
Bromine	liquid	gas	-7	58
Chlorine	gas	gas	-101	-35
Fluorine	gas	gas	-220	-188
Iodine	solid	solid	114	184
Potassium	solid	solid	63	759
Sodium	solid	solid	98	883

Table 7.2.5b: The state of the elements based on their melting point and boiling points

b. i. & b. ii

Name of the two groups of elements	Group I / Alkali metals	Group VII / Halogens

Name of the two groups of elements	Group I / Alkali metals	Group VII / Halogens
least reactive	Lithium	Iodine
Increasing order of reactivity	Sodium	Bromine
	Potassium	Chlorine
most reactive		Fluorine

Table 7.2.6b: The elements classified into their respective group in order of increasing reactivity

3. a.

	Solutions of		
Element added	Potassium chloride	Potassium bromide	Potassium iodide
Chlorine	X	√	√
Bromine	X	X	√
Iodine	X	X	X

b. The type of reaction is: displacement reaction

c. For the reaction of potassium iodide with chlorine,

i. the word equation is:

Potassium iodide + chlorine → potassium chloride + iodine

ii. the symbol equation is:

$$2KI(aq) + Cl_2(g) \rightarrow 2KCl(aq) + I_2(aq)$$

4.

a. Combustion

b. Basic oxide

c.

i. sodium + oxygen → sodium oxide

ii. $4Na^{+}(s) + O_2(g) \rightarrow 2Na_2\,O(s)$

iii. Sodium burns in oxygen with an orange flame.

How well did you do? I hope that you are satisfied with your performance. If you are not, please review the topic before moving on to Unit 8.

All the best with the remaining units!

Unit summary

Summary

In this unit you learned that elements can be categorised as metals and non-metals. You learned that the metals are situated in Groups I, II, III (on the left hand side) and the lower part of the Periodic Table (known as the transition elements) while the non-metals are in Groups: IV, V, VI and VII (on the right hand) of the Periodic Table.

You also learned about the chemical and physical properties of metals and non-metals. You learned that, at room temperature, all metals (except for mercury) are solids while the non-metals can be solid, liquid or gas. You learned about the different types of chemical reactions that metals and non-metals undergo.

You also learned about the physical and chemical properties of the elements in Group I (also known as alkali metals) and the elements in Group VII (also known as the halogens). You saw that elements are put in a particular group because they exhibit similar properties. You established that as we go down Group I the melting point and the boiling point of the elements decreases. You also established that the melting point and boiling point of the elements in Group VII increases as we go down the group.

You learned about the trend in the reactivity of the alkali metals and that of the halogens. You learned that the reactivity of the alkali metals increases as we go down Group I. Hence, among lithium, sodium and potassium, potassium is the most reactive while lithium is the least reactive. By contrast, we saw that the reactivity of the halogens decreases as we move down the Group VII. So, among fluorine, chlorine, bromine and iodine, fluorine is the most reactive while iodine the least reactive.

Contents

Unit 8

Motion

Introduction

Welcome to your 8th unit of the "Coordinated Science Course." The unit is entitled Motion. It consists of two main topics – Distance and displacement, and velocity. Hence, in this unit we will discuss *distance, displacement, speed, velocity and acceleration* in general. We will whenever possible provide opportunities for you to try out some basic experiments and to apply principles and formulae learnt within the unit.

The concept of motion is also dealt with in Unit 9: Force and Motion. In Unit 9, you will be able to use your knowledge of motion to further develop your thinking by applying the concepts to everyday transport and travelling situations.

In this unit you will learn about:

- the difference between distance and displacement;
- the relationships between distance, speed, time and acceleration
- speed, velocity and acceleration;
- how to use a velocity time graph to calculate distance travelled;
- how to use the relationships $v = at$ and $s = \frac{1}{2}at^2$ to solve problems.

We hope that this unit will be both interesting and enjoyable to you.

Upon completion of this unit you will be able to:

Outcomes

- *define* displacement as the distance moved in a particular direction.
- *define* speed as the rate of a change of distance with time.
- *define* acceleration as the rate of change of velocity with time.
- *define* velocity as the rate of change of displacement with time.
- *use* a stopwatch to measure time of distance travelled (displacement) to determine velocity.
- *calculate* velocity in simple everyday examples.
- *state* that the existence of errors in measurements may be reduced by taking the average of a number of readings.
- *draw* graphs to show the relationships between distance, time, speed and acceleration.
- *explain* how the ideas of speed and acceleration can be applied to transport (e.g. road, rail etc.).
- *differentiate* between speed and velocity.
- *state* that a body may accelerate by change in velocity, but without a change in speed.
- *derive* the distances travelled from the area under a speed-time graph.
- *use* the relationships $v = at$ and $s = \frac{1}{2} at^2$ when applied to an object accelerating uniformly from rest.

Terminology

Acceleration:	The rate of change of velocity with time
Deceleration:	The rate of decrease of velocity with time.
Displacement:	The distance moved in a specified direction.
Distance:	The actual length of a journey.
Speed:	Rate of change of distance with time.
Velocity:	The rate of change of displacement with time

How long?

Table 8.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	3 hours	1 hours and 30 minutes
Full-time student within the conventional school setting OR Part-time student	3 hours	1 hours and 30 minutes

Table 8.0: The time needed for you to work on this unit

Topic 8.1: Distance and displacement

How long?

You will need 30 minutes at the most to complete this topic. It is advisable that you spend another 15 minutes of your own time to further review the contents. Make sure you read and try to understand everything in order to achieve the specified objectives.

As you may recall in Unit 5 (*Particles in Motion*) of this course, you addressed particles in motion. We are going to build on what you have learnt but this time we are going to focus on the motion of large objects. If you feel you have forgotten some of the concepts, feel free to go back to do some review. We are going to start off this topic by looking at 'distance and displacement', then speed, velocity, acceleration, how to work out distances using speed-time graphs and finally how to use simple formulae to solve problems involving velocity, acceleration ,time and distances.

The term *distance* is commonly used in our everyday language when we talk about the distance between places. However, *displacement* is not commonly used in everyday language. Hence, in this topic we are going to help you to establish the differences between *distance* and *displacement* and also on how to solve problems involving the two concepts.

Let us start this topic by drawing your attention to a real life situation. Consider for example the journey you make from home to the shop and then to school. In physics, this situation involves both displacement and distance.

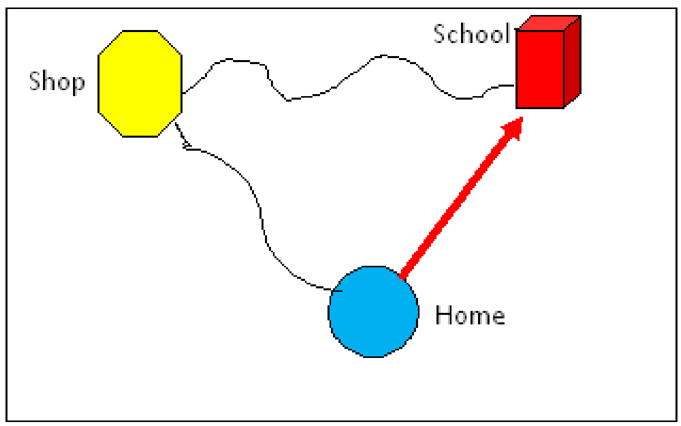


Figure 8.1.1: showing displacement and distance moved.

Sketched by Alex Souffe, October 2009

Say for example you walk from home to the shop and then to school as shown in Figure 8.1.1. So your actual journey gives the actual physical distance that you walked from home to the shop and then to school. If you were to walk directly from home to school then your actual distance would be shorter and in the direction from home to school. This *shortest distance from home to school (that is, the straight line distance)* is called *displacement.* So can you see the difference between distance and displacement? We can simply say that *distance is the length of the journey* while *displacement is the length of the straight line distance between the starting point and the end point*. The unit of both distance and displacement is kilometre (km), metre (m) or centimetre (cm) depending on what you measured. Take note that these are not the only units for distance and also that in some situations the actual distance can also be the displacement. Therefore, when we talk about distance, we mean the actual length of the journey undertaken while displacement is always the shortest distance moved in a specified direction.

Activity

Activity 8.1.1

You should spend about 10 minutes to do this activity.

You are required to fill in the blanks in statements 1 to 4 with the most suitable words. Then study Figure 8.1.2a to answer question 5:

1. __________________ is the actual length taken throughout the journey.

2. __________________ is the shortest distance between two points.

3. __________________ has both magnitude and direction.

4. Quantities that have both direction and magnitude (size) are called __________________.

5. Study the map in Figure 8.1.2a. A taxi driver is at the Old Port and would like to go to New Port.

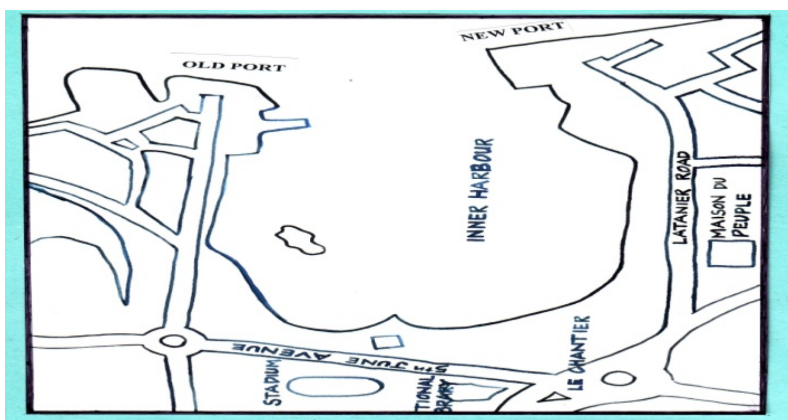


Figure 8.1. 2a: Map showing two ports in Victoria, Seychelles.

Sketched by: Gelage Dogley, October 2010

a) Draw a line on the map to indicate his most effective journey.

b) Use a dotted line to indicate his displacement.

Feedback

Feedback to Activity 8.1.1

1. Distance
2. Displacement
3. Displacement
4. Vectors.
5. The red continuous line on Figure 8.1.2b shows the actual journey (distance) the driver has to move from Old port to New port. The blue dotted line shows his displacement from Old port to New port.

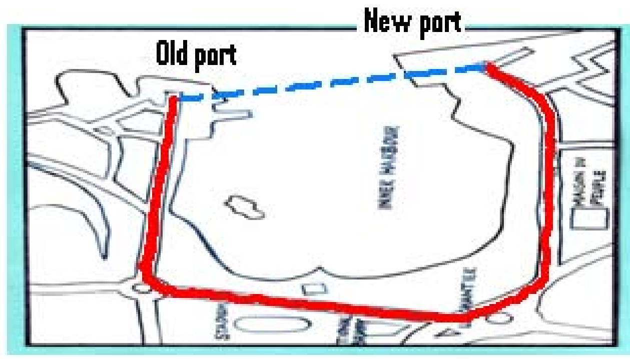


Figure 8.1. 2b: Map showing the distance and displacement from one port to the other in Victoria, Seychelles.

Solution by: Alex Souffe, October 2010

Well, it was not that difficult to distinguish between distance and displacement was it? Now you are ready to move onto two other concepts, speed and velocity. Make sure that when you go through the next topic, you keep a clear distinction between distance and displacement as it will affect your outcome in some cases.

Topic 8.2: Speed and velocity

How long?

You will need 2 hours and 30 minutes at the most to complete this topic. It is advisable that you spend another 1 hour and 15 minutes of your own time for revising the contents of this topic.

What do we mean when we talk about the speed or velocity of an object? In Topic 8.1 we have considered the distance a student has to travel from home to school, be it by bus or on foot. Now we are going to consider the time it takes for him/her to get there for we are interested in working out how fast (that is, the speed) the person gets to school.

8.2.1 Speed

Let us assume that the distance between his/her home and the school is 2 kilometres (km) and it takes him/her 1 hour to walk to school. Evidently, the student covers a distance of 2 km in 1 hour, so the student's walking speed is 2 kilometres per hour, which can be written as 2 km/h.

On the other hand if we were to consider another student who travels by bus along the same route.

Figure 8.2.1: Bus taking students to school

Photographed by Alex Souffe November 2010

Say for example the student looks at the speedometer of the bus and notices that the reading is 40 km/h. This means that at this instance (that is, at this point in time) the bus is travelling at a speed of 40 km/h. Such reading is also referred to as the *instantaneous speed* of the bus.

Figure 8.2.2: Speedometer

Photographed by Alex Souffe November 2010

If the student were to keep an eye on the speedometer of the bus throughout this particular journey he/she would notice that the reading (actual speed) keeps on changing (fluctuates) throughout the journey depending on the traffic and the state of the road. Hence, it is more practical to consider the *average* speed rather than the *instantaneous* speed.

The average speed can be easily calculated by measuring the total distance of the journey and dividing it by the total time taken. This may be represented by this formula:

$$\text{Average speed} = \frac{\text{Total distance in metres (m)}}{\text{Total time taken in second (s)}}$$

Symbolically average speed is written as;

$$\boxed{\text{average speed} = \frac{\mathbf{s}}{\mathbf{t}}}$$

's' represents distance or displacement and '***t***' the time interval

"-1" means metre divide by second

Hence, an average speed gives the distance covered in a unit time (that is, the number of metres per second written as m/s or ms^{-1}, or the number of kilometre per hour written as km/h or kmh^{-1}. The standard unit for speed is metres per second (m/s). Therefore, from the above explanation, speed is defined as the rate of change of distance with time.

Note it! / Important!

Please note that in the case of speed, the direction in which a body moves is not mentioned.

You might be wondering what would be the problem if direction was mentioned. In fact in the next section, we are going to consider both the speed and the direction a body moves, for example the school bus.

8.2.2 Velocity

As stated in the example mentioned above, the bus was travelling from the student's home to the school. In Physics, whenever we consider both the speed and the direction of a moving body, we are in fact referring to its velocity. The velocity of a body is defined as the rate of change of distance moved with time in a specified direction. [Please note that: (i) the specified direction implies that the motion is in a straight line; and (ii) motion in which the direction does **not** change is called rectilinear motion (that is, the object moves in a straight line)].

Therefore, when referring to the velocity of the bus, the direction in which it is moving must be mentioned. Since distance in a specified direction is called displacement, we can also say that velocity is the rate of change of displacement. For example, the bus travelled with an average velocity of 40 km/h from the student's home (point A) to the school (point B).

As shown in Figure 8.1.4, velocity takes into consideration the shortest distance (straight line, that is, 2000 m) in a specified direction between two places (from point A to point B) and *not* the actual journey of (path taken, that is 2500 m) the bus *unless* it is a straight line. This applies to all moving bodies.

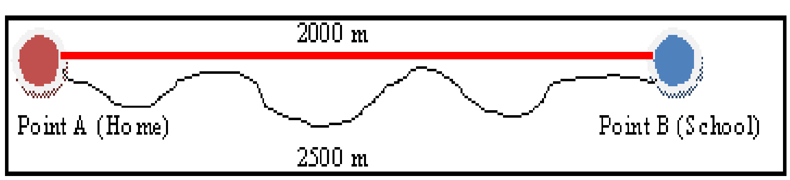


Figure 8.2.3: Diagram showing the actual path taken by the bus (black line) and the displacement from point A to point B

Reflection

Reflection 8.2.1

We are sure that now you can distinguish between speed and velocity, so we are going to invite you to take around 5 minutes to reflect over these two concepts – speed and velocity. Then in the space provided write one similarity and one difference between them.

Well, one similarity - is that both of them are measured in the same unit; km/h, m/s or cm/s and one difference - is that, in the case of speed, the direction in which a body moves is not mentioned but in the case of velocity the direction in which a body moves has to be mentioned.

If you have been consulting other Physics textbooks, you could have stated as a difference that *velocity is a vector quantity* and *speed is a scalar quantity*. A vector quantity has both magnitude (size) and direction while a scalar quantity has only magnitude.

Now, it is time for you to consolidate what you have learnt. We are going to invite you to carry out an activity with your friends.

Group activity

Group Activity 8.2.1

You should spend about 20 minutes on this activity

For this activity you will need two partners, a stopwatch, a whistle and a measuring tape.

Procedure: You are required to:

1. Measure and mark a distance of 100 metres in the park or playing field.
2. Ask your friend (runner) to stand at one end (starting line) of the marked 100m distance and you stand at the other end (finishing line).
3. Ask the other partner to act as the starter who will need to blow the whistle for the runner to start running the marked distance.
4. As the whistle is blown the time keeper starts the stopwatch and stops it as the runner completes the marked distance (i.e. as the person crosses the finishing line).
5. Record the reading.

Results:

Distance in (m)	Time in (s)
100	

Once you have measured the time it takes your partner to run the distance of 100 m, you can determine both the speed and the velocity of your partner who ran the distance of 100 m. We will start off by calculating the speed of the runner by dividing the total distance by the time taken as stated earlier.

This relationship can be written as:

$$\text{Speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

In symbolic form;

$$\text{Speed} = \frac{\mathbf{s}}{\mathbf{t}}$$

Note it! / Important!

Remember that the speed found in this way may mean that your partner was running at the same speed from the starting line to the finishing line. This as you have observed is not correct. Your partner started off from rest, his/her speed increased gradually until he/she was running as fast as he/she could and possibly slowed down a little towards the end of the race. So your partner did not run at the same speed throughout the race, and that is why the term average speed is normally used. Therefore the above equation could be re-written as :

$$average\ speed = \frac{\boldsymbol{distance\ travelled}}{\boldsymbol{time\ taken}}$$

and in symbolic form;

$$average\ speed = \frac{\boldsymbol{s}}{\boldsymbol{t}}$$

Now that you have applied through a practical activity the idea of *average speed* we will turn our attention to the velocity of your partner.

Reflection

Reflection 8.2.2

Can you at this stage work out the velocity of your friend from the data you have collected in activity 8.2.1?

Yes! This is due to the fact that your partner ran along a straight line path over a distance of 100 m, which is also his/her displacement in a given period of time. In addition to the distance and time, it is compulsory to specify the direction your partner was running. Since the chosen course (path) was in a straight line, it is easy for you to state the direction your friend was running - say from north to south, or from a named place to another. Therefore, to calculate your partner's velocity, you simply have to divide the distance in the stated direction or his/her displacement by the time he/she took to complete the race as shown:

$$\text{velocity} = \frac{\text{distance in a given direction}}{\text{time taken}}$$

or

$$\text{velocity} = \frac{\text{displacement}}{\text{time taken}}$$

In symbolic form;

$$\mathbf{v} = \frac{\mathbf{s}}{\mathbf{t}}$$

"-1" means metre divide by second

Therefore, the standard unit for velocity is also m/s also written as ms^{-1} or km/h also written as kmh^{-1}.

Note it! / Important!

Remember like speed that the velocity found in this way may mean that your partner was running at the same velocity from the starting line to the finishing line. This as you have observed is not correct. Your partner started off from rest, his/her velocity increased gradually until he/she was running as fast as he/she could and possibly slowed down a little towards the end of the race. So your partner did not run at the same velocity throughout the race that is why the *average velocity* is normally used. Furthermore, if your partner was not travelling along a straight line (as is the case in most real life situations) the direction as well as his/her displacement will be constantly changing. Therefore it is better to use his/ her *average velocity*.

Now, you will be given further opportunities to go through the steps for solving problems involving velocity.

Problem 1: A motorcycle covered a distance of 120 km in the westerly direction. If it covered the distance in 2 hours, calculate its velocity.

Step 1: List the "*known values*" and the "*unknown values*".

$s = 120 \text{ km west}$

$t = 2 \text{ h}$

$v = ?$

Step 2: Write the correct formula.

$$v = \frac{s}{t}$$

Step 3: Substitute the known values in the equation.

$$v = \frac{120\ \text{km}}{2\ \text{h}}$$

Step 4: Calculate your answer, including units.

$$v = \frac{120\ \text{km}}{2\ \text{h}}$$

$$v \ = \ 60\ \text{km/h in a westerly direction.}$$

Now you are ready to solve problems involving both speed and velocity.

Remember velocity is calculated in the same way as speed if the displacement is the same as the distance.

Activity

Activity 8.2.1

You should spend about 15 minutes on this activity

For this activity you will need your calculator. You are required to solve the given problems.

1. A fishing boat takes 3 hours to travel from Mahe island to Praslin island. The boat travelled a distance of 45 km. Calculate the average speed of the boat.

2. A car moved 150 km west and then 30 km east in 2 hours. What is its average velocity?

3. How far will a motor cycle travel in 30 minutes at 25 m/s?

We hope that you have found this activity easy. Please refer to the Feedback to Activity 8.2.1 for the solutions.

Feedback

Feedback to Activity 8.2.1

1. s = 45 km west, t = 3 h, speed (v) = ?

$$\text{speed} = \frac{s}{t}$$

$$\text{speed} = \frac{45\ \text{km}}{3\ \text{h}}$$

Speed = 15 km/h

2. s = 150 km west and 30 km east, t = 2 h, average velocity= ?

s = 150 km – 30 km

= 120 km towards west

$$\text{average velocity} = \frac{s}{t}$$

$$\text{average velocity} = \frac{120\ \text{km}}{2\ \text{h}}$$

v = 60 km/h

Please note that the car travelled **west** and then **east**, so its **displacement** is only **120 km** from its starting point. However, it has travelled a total **distance** of **180 km**.

3. s = ?, t = 30 minutes = (30 × 60) = 1800 s, v= 25 m/s

$$s = \text{speed} \times t$$

= 25 m/s × 1800 s

= 45000 m or 45 km

Minutes has been converted to ***seconds*** for the speed is given in ***metres per second*** (m/s).

Well done! The problems were not too challenging, after all we hope. We shall now focus our attention on the motion of objects whose *velocity changes* during the journey. This means that the objects are *accelerating*.

8.2.3 Acceleration

Once again we are going to draw your attention to the school bus travelling on a straight stretch of road. When students board the bus it is stationary and its velocity is zero metres per second (0 m/s). The bus starts off from rest, its velocity increases gradually until it reaches the speed limit of (say 16.66 m/s) and maintains that constant velocity until it reduces its velocity and stops at another bus stop in order to pick up other students. Clearly, there have been two changes to its velocity over that period of time.

Initially it started from rest and its velocity increased to a higher value. The rate of change (increase) in velocity is called acceleration. Therefore, acceleration is defined as the rate of change in velocity. In the second instance, its velocity decreased from a higher value to zero. This decrease is called deceleration or negative acceleration. The acceleration of a body can be calculated by using the formula:

$$\mathbf{acceleration} = \frac{\mathbf{change\ in\ velocity}\ (\frac{\mathbf{m}}{\mathbf{s}})}{\mathbf{time\ taken\ for\ the\ change}\ (\boldsymbol{s})}$$

The standard unit for acceleration is metres per second each second (m/s^2 or ms^{-2}) or it could be read as metres per second per second or metres per second squared.

Now we will compute the acceleration of the bus. Let us assume that the bus accelerates uniformly from rest and reaches a velocity of 10 m/s in five seconds. We are going to show you how we could calculate the acceleration of the bus in a series of steps similar to what you have used previously.

Step 1: List the “*known values*” and the “*unknown values*”.

Initial velocity represented by ‘u’ = 0 m/s

Final velocity represented by ‘v’ = 10 m/s

Time represented by ‘t’ = 5 s

Acceleration represented by ‘a’ = ?

Step 2: Write the correct formula.

$$\mathbf{acceleration} = \frac{\mathbf{change\ in\ velocity}\ (\frac{\mathbf{m}}{\mathbf{s}})}{\mathbf{time\ taken\ for\ the\ change}\ (\mathbf{s})}$$

Step 3: Substitute the known values in the equation.

$$\textbf{acceleration} = \frac{\textbf{final velocity} - \textbf{initial velocity}}{\textbf{time taken}}$$

$$\textbf{acceleration} = \frac{\mathbf{10\,\frac{m}{s} - 0\,\frac{m}{s}}}{\mathbf{5\ s}}$$

$$\textbf{acceleration} = \frac{\mathbf{10\,\frac{m}{s}}}{\mathbf{5\ s}}$$

Step 4: Calculate your answer, including units.

$\text{acceleration} \ = .2\text{m/s}^2$

Now that you are familiar with the three concepts speed, velocity and acceleration you are in a position to carry out several activities involving a simple equipment called the ticker-timer.

Figure 8.1.4 shows a ticker-timer also known as a ticker-tape timer. It is an electric device that can put marks on tape that represent distances moved by an object and help you to measure accurately the time taken for the tape to move a certain distance.

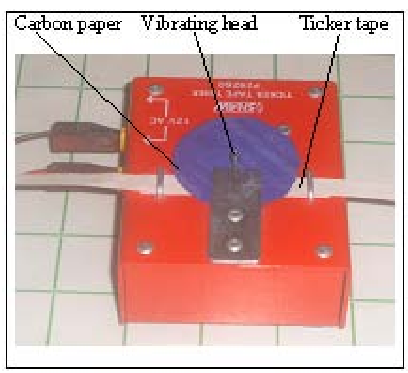


Figure 8.2.4: A 50 Hz Ticker timer

Photographed by: Marie-France Raccombo, September 2009

The most common types of ticker-timers are those designed to make fifty (50) and one hundred (100) strikes (dots) or vibrations per second. The number of strikes (vibrations) per second is called the frequency, represented by the symbol (f). The unit of frequency is hertz (Hz) (i.e. the number of vibrations per second), so the two types of ticker-timers are the ones having frequencies of 50 Hz and 100 Hz.

In science to help us better understand the relationship between speed, velocity and acceleration we use the ticker-timer. It allows us to take measurements of required quantities like time intervals and displacement. The diagram below shows a piece of a ticker tape with the marks made by the ticker hammer as it was pulled at a certain speed.

In school, physics students carry out experiments using the ticker-timer to study rectilinear motion of objects. Figure 8.2.5 shows a 50 Hz ticker-timer and a tape attached to a trolley.

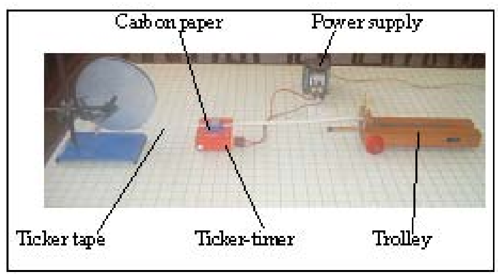


Figure 8.2.5: A 50 Hz ticker-timer and tape attached to a trolley

Photographed by Marie-France Raccombo, September 2009

As the trolley moves at a certain speed, it pulls the tape and marks are made by the ticker hammer striking on the carbon paper. Figure 8.2.5 shows a series of dots on the paper tape produced by the 50 Hz ticker-timer.

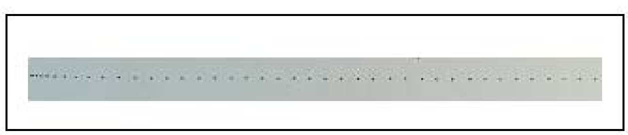


Figure 8.2.5: Shows a piece of ticker-tape that has passed through the ticker-timer

Photographed by Lionel Goonetilleke, November, 2010

As you can see, initially the distances between adjacent ticker marks (dots) are different (increasing) and after a certain point (7th dot) they are equal. Please note that the time taken for each strike or the time taken for the tape to move the distance between two adjacent marks is the same. Given that a 50 Hz ticker timer was used means that the time taken for the 50 dots shown in Figure 8.2.5 is 1 second. Therefore the time interval between two consecutive dots is one fiftieth of a second (i.e. $1s \times 1/50 = 0.02$ s). The time for each strike or cycle or vibration is known as the period, which is represented by (T).

Now we are going to show you how we could construct distance/time graphs or velocity /time graphs by using the ticker tape obtained in Figure 8.2.6. We are going to use the part of the tape showing the last 25 ticker gaps to construct the graph - velocity against time. In order to do that we have to count five ticker gaps and cut the strip through the centre of the ticker mark. Then we repeat this so that we end up with five strips of five ticker gaps. Then the five piece of tape are stuck vertically side by side on the 'x-axis'. Each strip of ticker tape shows five gaps and a time interval of (1/50 x 5) s = 1/10 s x 5= 0.5 s. The graph we have constructed shows that the distance moved by the strip over the same period of time (1/10 s) is the same. In fact the graph is distance (length of strip in cm) against time in seconds.

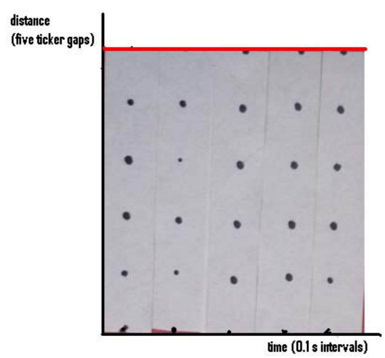


Figure 8.2.6: Distance /time graph using ticker tape

Photographed by: Lionel Goonetilleke, November, 2010

Figure 8.2.7: Distance /time graph using information from Fig. 8.2.6

Drawn by: Alex Souffe, December, 2010

Since the motion being considered is in a straight line, the distance moved is also its displacement and the rate of change of displacement is velocity. As such these graphs are also depicting velocity against time.

The height of the strips (i.e. the distance moved) is the same and the time taken for the motion of each is also the same. If a line were to be drawn connecting the tips of the pieces of ticker tape, a horizontal line is obtained, as shown in Figure 8.2.7. This means the object attached to the tape was moving with the same (constant) velocity.

Now we are going to consider the other half of the ticker tape (i.e. first 25 ticker gaps of the ticker tape) obtained in Figure 8.2.6. We are going to construct another distance against time graph. Once again, we are going to count five ticker gaps and cut the strip through the centre of the last ticker mark, so that we end up with five strips of five ticker gaps. The five pieces of tape are then stuck vertically side by side on the –'x-axis starting with the shortest to the longest. Each strip of ticker tape shows five gaps and a time interval of (1/50 x 5) s = 1/10 s x 5= 0.5 s. The graph we have constructed shows that the distance moved by the strip over the same period of time (1/10s) is increasing this time. In fact the graph is distance / displacement (length of strip in cm) against time in seconds.

If a line were to be drawn connecting the central tips of the pieces of ticker tape, an ascending straight line is obtained, as shown in Figure 8.2.9. This means the object attached to the tape was moving with uniformly increasing velocity.

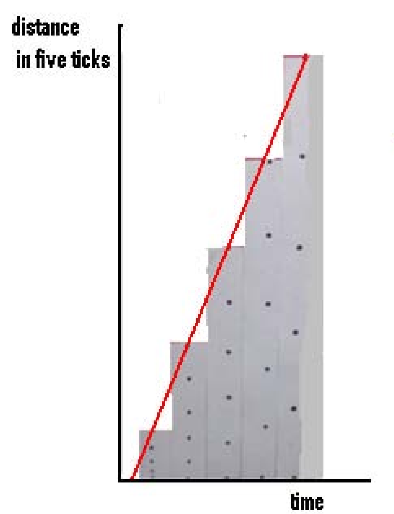


Figure 8.2.8: Distance time graph using ticker tape

Photographed by: Lionel Goonetilleke, November, 2010.

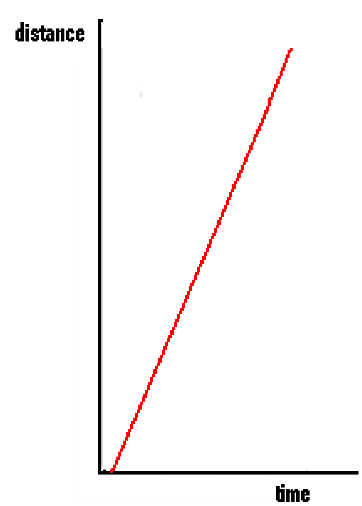


Figure 8.2.9: Distance time graph using information from Fig. 8.2.8

Drawn by :Alex Souffe ,December, 2010

After having studied the practical activities involving velocity, time, displacement and acceleration you are now ready to focus your attention to velocity time graphs.

If you have access to the internet, take a look at this site to get an idea of the relationship between the displacement vs time, velocity vs time, and acceleration vs time graphs.
http://www.learnerstv.com/animation/animation.php?ani=27&cat=physics
Please note again that we are providing this link for information only and we do not endorse or recommend any links from this site.

8.2.4 Velocity Time Graphs

Velocity time graphs are similar to other graphs for they show the relationship between two variable quantities. In this case the variable quantities are velocity and time. We are going to consider two graphs similar to those in Figures 8.2.7 and 8.2.9, respectively, by inviting you to do Activity 8.2.2.

Activity

Activity 8.2.2

You should spend 20 minutes on this activity

You are required to use the velocity time graphs to answer the questions.

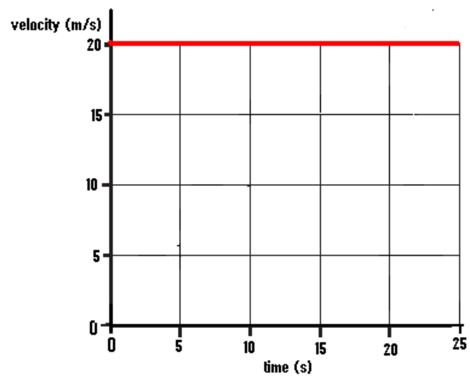


Figure 8.2.10: Constant Velocity

Drawn by Alex Souffe, December 2009

Gentle increase	Rapid increase

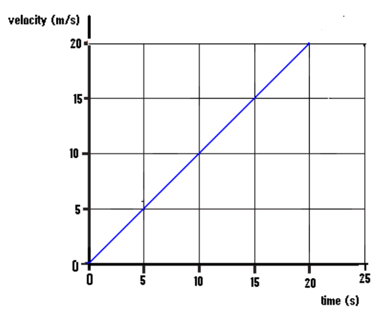
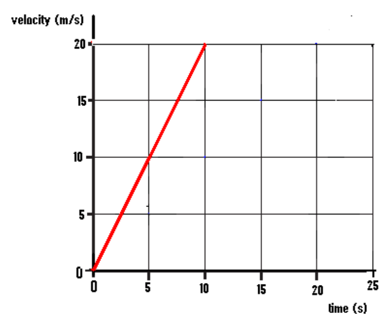

	

Figure 8.2.11a: Graphs showing increase in velocity	Figure 8.2.11b: Graphs showing increase in velocity

Drawn Alex Souffe, November 2010

1. What can you say about the velocity of the moving objects in Figure 8.2.10, Figure 8.2.11a and Figure 8.2.11b?

____

____

2. What can you say about the acceleration of the moving objects?

3. From the graph in Figure 8.2.10, what was the object's acceleration?

4. Calculate the acceleration of the object in Figure 8.2.11b?

We are sure that you have managed to tackle this activity without difficulties. Please refer to the Feedback to Activity 8.2.2 for the correct answers.

Feedback

Feedback to Activity 8.2.2

1. In Figure 8.2.10 the velocity is constant.

   In Figure 8.2.11a the velocity increases gradually and uniformly (straight line ascending graph).

   In Figure 8.2.11b the velocity increases rapidly and uniformly (straight line ascending graph).

2. In Figure 8.2.10 the acceleration is zero because the velocity is constant.

   In Figure 8.2.11a the acceleration is constant but is lower than in Figure 8.2.11b.

   In Figure 8.2.11b the acceleration is constant but is greater than in Figure 8.2.11a.

3. Since the velocity of the object is constant, there is no acceleration.

4. $\text{acceleration} = \dfrac{\text{change in velocity } (\frac{\text{m}}{\text{s}})}{\text{time taken for the change (s)}}$

   $$\text{acceleration} = \frac{20\,\frac{\text{m}}{\text{s}} - 0\,\frac{\text{m}}{\text{s}}}{10\text{ s}}$$

   acceleration = 2 m/s^2

Well done. We hope that the exercise was not too challenging. As you have noticed in Figure 8.2.10 the graph is parallel to the x-axis. This shows that the time changes but the velocity remains the same. The acceleration is zero for there is no change in velocity.

In Figures 8.2.11a and 8.2.11b velocity increases with time but at different rates. The acceleration is the rate of increase in velocity with time. The objects in both Figures 8.2.11a and 8.2.11b are accelerating. However, there is a marked difference in the slope (gradient) of the graphs which is a clear indication of the rate. As such the acceleration in Figure 8.2.11b is greater than the acceleration in Figure 8.2.11a. Remember in velocity/time graph the slope (gradient) gives the acceleration and the deceleration depending on whether the graph is ascending or descending.

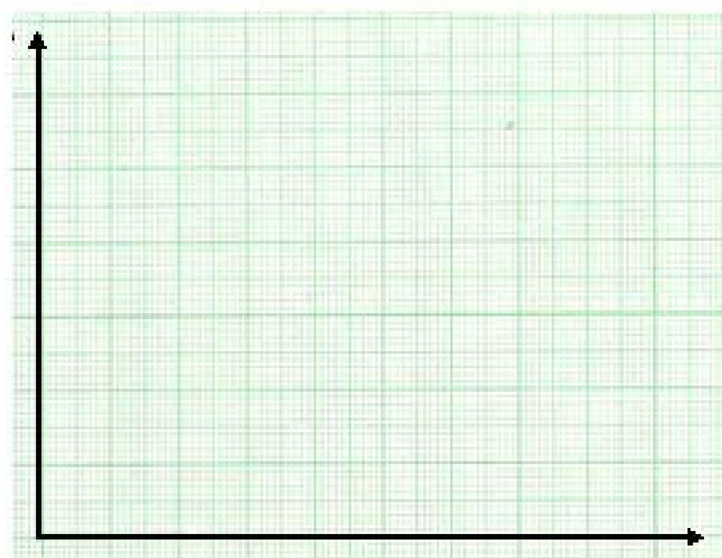
Now, we are going to consider a short journey of a vehicle requiring the calculation of its acceleration.

Activity

Activity 8.2.3

You should spend about 10 minutes on this activity

A bus starts from rest and accelerates uniformly and reaches a final velocity of 20m/s in 10 seconds. It travels at this velocity for another 20 seconds then the driver applies the brakes and the bus decelerates uniformly and comes to rest in another 5 seconds.



1. Use the graph paper provided and draw a velocity time graph for the complete journey.

2. Use the graph you have drawn to calculate the acceleration of the bus for:

    a. the first ten seconds of the journey.

b. the next 20 seconds of the journey.

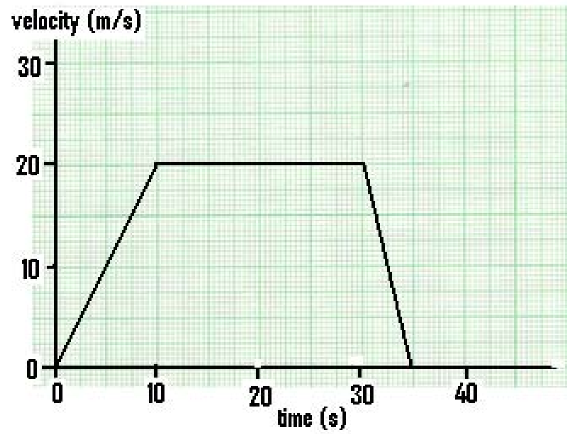
c. the last five seconds of the journey.

We hope that this activity was easy for you. Now, please refer to the Feedback to Activity 8.2.3 for the solutions.

Feedback

Feedback to Activity 8.2.3

1.



2a) $\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$

$$\text{acceleration} = \frac{20\frac{\text{m}}{\text{s}} - 0\frac{\text{m}}{\text{s}}}{10\ \text{s}}$$

$$\text{acceleration} = 2\ \text{m/s}^2$$

2b) $\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$

$$\text{acceleration} = \frac{20\frac{\text{m}}{\text{s}} - 20\frac{\text{m}}{\text{s}}}{30\text{s} - 10\ \text{s}}$$

$$\text{acceleration} = 0\ \text{m/s}^2$$

2c) $\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$

$$\text{acceleration} = \frac{0\frac{\text{m}}{\text{s}} - 20\frac{\text{m}}{\text{s}}}{35\text{s} - 30\ \text{s}}$$

$$\text{acceleration} = \frac{-20\frac{\text{m}}{\text{s}}}{5\text{s}}$$

$$\text{acceleration} = -4\ \text{m/s}^2$$

Well done! It was not that difficult after all was it? Now we are going to consider the velocity of a car undergoing changing acceleration.

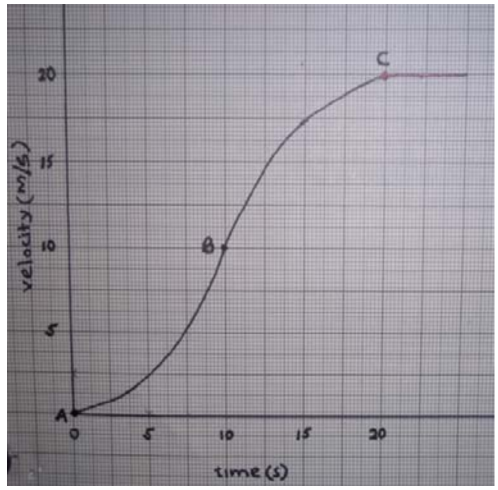


Figure 8.2.12: Velocity-time graph (changing velocity)

Drawn by: Lionel Goonetilleke, November 2010

As shown in Figure 8.2.12 the car starts from rest at point A and accelerates to point C. The graph is steepest at point B. Hence the acceleration of the car is greatest at point B. It must be noted that from point A to B the acceleration is increasing (the steepness of the graph is increasing), beyond point B the acceleration is decreasing (the steepness of the graph is decreasing). Beyond point C, there is no acceleration (graph is parallel to the x-axis).

After having studied various velocity-time graphs you are ready to use these types of graphs to calculate the distances travelled. However, for simplicity we are going to consider only straight line graphs. Figure 8.2.13, is a graph showing the velocity of a car at a point when it was travelling at a velocity of 40km/h which was maintained for 4 hours.

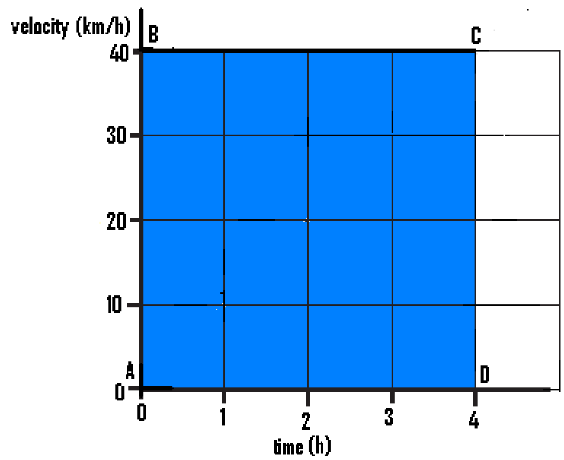


Figure 8.2 13 Velocity-time graph (Constant velocity)

Drawn by: Alex Souffe, November 2010

At the end of the period of 4 hours, the distance travelled by the car can be calculated by using the equation:

$$\text{average velocity} = \frac{\text{total distance travelled}}{\text{time taken}}$$

Since there was no change in velocity, the average is 40 km/h.

The total time for the journey is 4 hours.

From the above equation,

$$\text{the total distance travelled} \; = \; \text{average velocity} \; \times \; \text{time taken}$$

$$\text{the total distance travelled} = \; 40 \text{ km}/\cancel{\text{h}} \text{ x } 4 \; \cancel{\text{h}}$$

$$\text{the total distance travelled} = \; 60 \text{ km}$$

As you can see from Figure 8.2.13, the average velocity of 40 km/h is represented by the part AB and the time taken is represented by the side AD. The product of AB and AD (40 km/h x 4h) is 160 km, which is also the area under the line BC (the blue area) of the graph. This finding has been proven by scientists many years ago, so you can use the area under the line of the velocity-time graph as a convenient method to calculate distance travelled.

Now let us consider a velocity-time graph showing the motion of a car undergoing uniform acceleration starting from rest as shown in Figure 8.2.14.

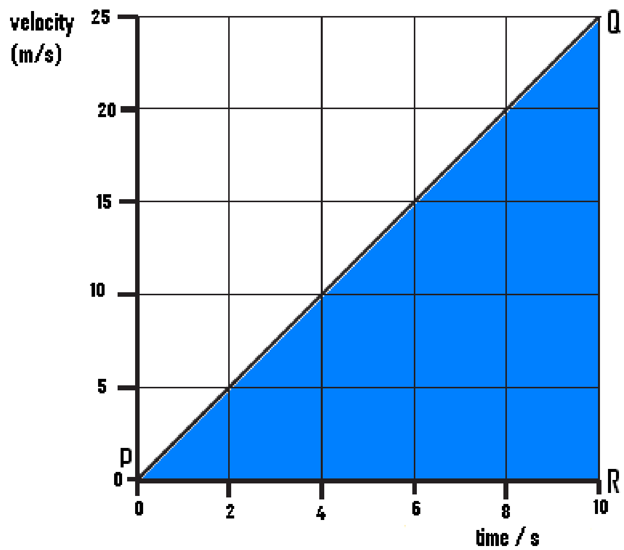


Figure 8.2.14: Velocity-time graph (uniformly increasing velocity)

Drawn by: Alex Souffe, November 2010

We are going to workout the distance travelled by calculating the area under the line of the graph. The area under the graph (the shaded area) is represented by a triangle PQR.

Area of a triangle $=$ ½ base x height

Area of a triangle $=$ ½ PR x QR

Area of a triangle $=$ ½ x 10 s x 25 m/s

So the distance travelled $=$ 125m

Now you are ready to use this strategy to solve problems involving distance travelled and velocity time graphs.

Activity 8.2.4

Activity

You should spend approximately 10 minutes on this activity

Use the velocity time graph of a car in Figure 8.2.15 to answer questions a) to d).

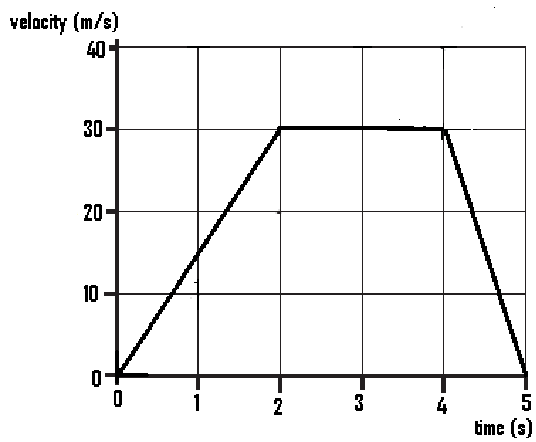


Figure 8.2.15: Velocity/ time graph

1. Calculate the distance travelled:

a. while the car was accelerating;

b. while it was moving at constant velocity;

c. while the car was decelerating; and

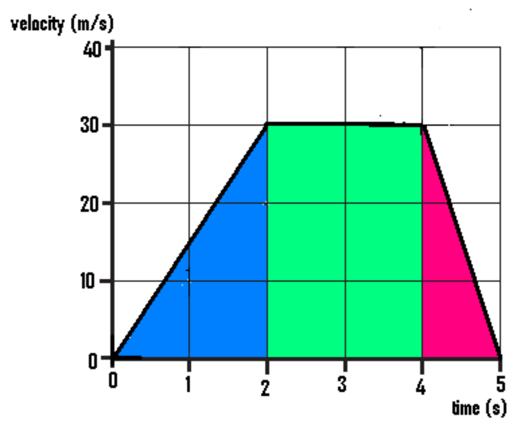
d. the total distance travelled by the car.

We bet that this activity easy to tackle. Please refer to the Feedback to Activity 8.2.4 for the correct answers.

Feedback

Feedback to Activity 8.2.4

For ease of comprehension the different stages of the car's journey (a to c) shown in Figure 8.2.15 has been shaded in a different colour. Remember: *distance travelled in a velocity-time graph is represented by the area under the line of the graph.*



a. Distance travelled while the car was accelerating is represented by the area of the first triangle (blue).

$$\text{Area of triangle (blue)} = ½ \text{ base} \times \text{height}$$

$$\text{Area of triangle (blue)} = 2 \text{ s} \times 30 \text{ m/s}$$

$$\text{Area of triangle (blue)} = 2 \text{ s} \times 30 \text{ m/s}$$

$$\text{So the distance travelled} = 30\text{m}$$

b. Distance travelled while the car was moving at constant velocity is represented by the area of the rectangle (green).

$$\text{Area of rectangle (green)} = \text{base} \times \text{height}$$

$$\text{Area of rectangle (green)} = ½\, 2 \text{ s} \times 30 \text{ m/s}$$

$$\text{Area of rectangle (green)} = ½ \text{ x } 2 \text{ s} \times 30 \text{ m/s}$$

$$\text{So the distance travelled} = 60\text{m}$$

c. Distance travelled while the car was decelerating is represented by the area of the second triangle (red).

Area of triangle (red) $=$ ½ base $\times$ height

Area of triangle (red) $=$ ½ $\times$ 1 s $\times$ 30 m/s

Area of triangle (red) $=$ ½ $\times$ 1 s $\times$ 30 m/s

So the distance travelled $=$ 15m

d. The total distance travelled by the car is given by the total area under the line graph. So,

total distance travelled by the car $= (a) + (b) + (c)$

total distance travelled by the car $=$ 30m $+$ 60m $+$ 15m

total distance travelled by the car = 105 m

Well done! Now we are going to consider distance-time graph of a car undergoing uniform acceleration.

8.2.5 Distance Time Graphs

A battery operated toy car travels with uniform velocity on flat surface covers equal distances in equal time intervals. Figure 8.2.16 shows the distances travelled by the car over a period of five seconds. The graph shows how the distances travelled in equal intervals of time.

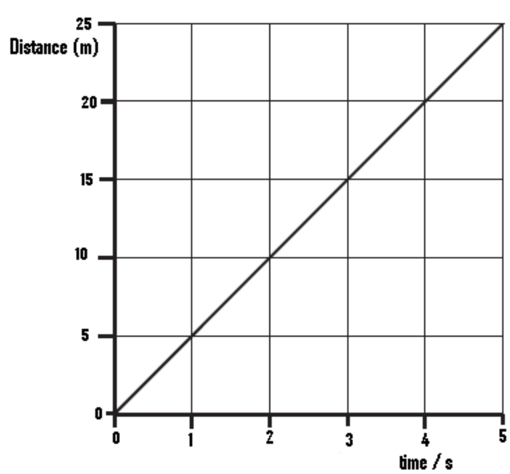


Figure 8.2.16:Distance-time graph showing constant velocity

Drawn Alex Souffe, November 2010

As equal distances are covered in equal time intervals, the velocity of the toy car is constant (uniform), hence zero acceleration. Remember the slope or gradient of a distance -time graph represents the magnitude of the velocity of the car.

On the other hand Figure 8.2.17 is a distance- time graph showing part of the journey of a toy car while its velocity kept on changing.

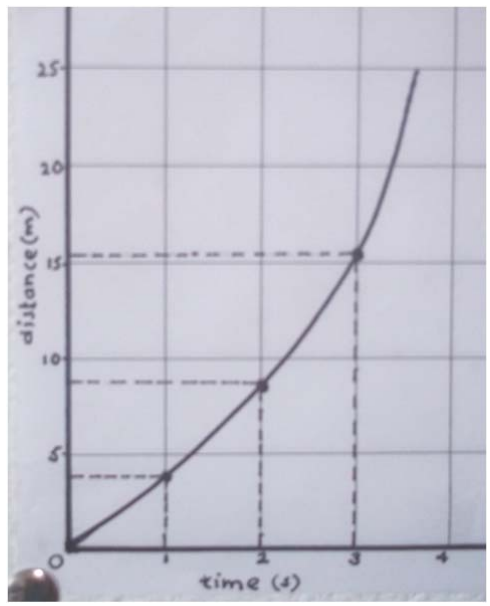


Figure 8.2.17 Distance-time graph showing increasing velocity

Drawn and photographed by Lionel Goonetilleke, November 2010

To gain better understanding of the change in velocity we have considered the distances travelled during two selected equal time intervals. It is evident that the distance travelled in the first second as shown by the dotted line is less than 5 m and the distance travelled during the third second is greater than 5 m. This indicates that the velocity of the car over the latter period (third second) was greater than in the first second. This increase in velocity also indicates that the car was accelerating.

As you may be aware it is time consuming to draw graphs each time when one has to workout the velocity and other related quantities of moving objects. Scientists have come up with mathematical equations involving quantities related to the motion of objects. However these equations, referred to as "equations of motion" can only be used with objects moving with uniform (constant) acceleration and in a straight line.

When considering the motions of objects in straight lines, the quantities normally involved are distance travelled, initial velocity, final velocity, acceleration and time. For convenience, they are represented by accepted symbols s, u, v, a, and t respectively. (Please note that all of the different quantities may not be involved in every situation).

First, we will consider acceleration. As stated above *acceleration is* defined as *the rate of increase in velocity with time*. It is represented by the equation:

acceleration = change in velocity / time taken.

In symbolic form: $a = v - \frac{u}{t}$

$$at = v - u$$

$$v = u + at \quad (1)$$

Note it! / Important!

Please note that:

i. the initial velocity u and the final velocity v refer to the start and finish of the timing and do not necessarily mean the start and the finish of the motion; and

ii. for all bodies starting from rest "u" is always zero, so the equation (1) becomes v = at for objects starting from rest and moving in a straight line.

$$\boxed{v = at}$$

Hence, we can use this equation to determine any one of the three quantities for any object starting from rest if the other two quantities are known.

Say for example a motorcyclist starts from rest and accelerates uniformly at 4 m/s for 5 seconds. Then its final velocity at the end of the five seconds can be calculated by using the equation: "$v = at$".

Can you see why?

Yes, this is due to the fact that the motorcyclist starts from rest, so its initial velocity (u) is zero and can be left out of the equation:

$$\text{“}v = u + at.$$

We will proceed to solve the problem by following the steps shown below.

Step 1: List the "*known values*" and the "*unknown values*".

$u = 0\ \mathrm{m/s},$

$t = 5\ \mathrm{s},$

$a = 4\ \mathrm{m/s^2},$

$v = ?$

Step 2: Write the correct formula.

$v = at$

Step 3: Substitute the known values in the equation.

$v = 4\ \mathrm{m/s^2} \times 5\ \mathrm{s}$

Step 4: Calculate your answer, including units.

$v = 20\ \mathrm{m/s}$

So far we have leant about the relationship between distance, velocity and time, and you have even used the equation $v = at$ to solve problems. Now we are going to focus our attention on another equation which involves distance, velocity, acceleration and time. We are going to once again consider the journey of the motorcyclist but we are interested in working out the distance he/she travelled in the stated time. The question indicates that the motorcyclist 'starts off from rest and accelerates uniformly at 4 m/s/s (ms^{-2}) for 5 seconds. We would like to know the distance he/she travelled at the end of the journey. So far we have learnt that the distance travelled could be calculated by finding the area under a velocity-time graph. Since no graph is given we are going to show you how to obtain an equation for calculating the distance travelled (s) in situations where time and acceleration are given.

From the example, the following information is provided – initial velocity (u); acceleration (a) and time (t). But so far we have addressed only one equation v = u +at, with a focus on situations where u = 0 only, giving v = at. Since we want an equation involving distance travelled (s), acceleration and time we are going to use these two relationships:

i. average velocity = $\frac{u+v}{2}$ (1)

ii. average velocity = $\frac{s}{t}$ (2) along with the equation

iii. v = u+at (3)

Now we are going to use the equation of motion (3) and the two relationships (1) and (2) to derive an equation for solving distance travelled.

Replace v in equation (ii) by $u + at$ gives $\frac{u+u+at}{2}$, which is simplified to average velocity = $u + \frac{at}{2}$

Equation of motion: v = u + at

Since average velocity = $\frac{u+v}{2}$

Using (i) and (ii) giving average velocity = $\frac{u+u+at}{2}$.

$\frac{u+u+at}{2}$ simplified gives $\frac{2u}{2} + \frac{at}{2}$, where 2/2 are cancelled leading to step (iii) below.

(iii) average velocity = $u + \frac{at}{2}$

If ‘s’ is the distance moved in time ‘t’, then

$$\text{average velocity} = \frac{\text{distance}}{\text{time}}$$

(iv) average velocity $= \frac{s}{t}$

Using (iii) and (iv), $\frac{s}{t} = u + \frac{at}{2}$

Multiply both sides by" t" $\frac{t \times s}{t} = \left(u + \frac{at}{2}\right) t$

$$s = ut + \frac{1}{2}at^2$$

For objects starting from rest u = 0, therefore, ut = 0.

Therefore the s =ut + ½ at^2 can be written as:

$$\boxed{s = \frac{1}{2} at^2}$$

Note it! / Important!

*You need to remember the formula "*s = ½ at^2*" and* **NOT** *the steps for obtaining it from the other formulae as illustrated above.*

Now we can use this equation to calculate the distance travelled by the motorcyclist as given in the example:

The motorcyclist starts from rest and accelerates uniformly at 4 m/s^2 for 5 seconds. Then its distance travelled at the end of the five seconds can be calculated by using the equation: "s = ½ at^2".

Step 1: List the "*known values*" and the "*unknown values*".

t = 5 s, a = 4m/s^2 , s = ?

Step 2: Write the correct formula.

s = ½ at^2

Step 3: Substitute the known values in the equation.

s = ½ × 4 m/s^2× 5 s ×5 s

Step 4: Calculate your answer, including units.

s =.50 m

Now you are ready to solve problems involving distance, velocity, time and acceleration.

Activity

Activity 8.2.5

You should spend about 20 minutes on this activity

You are required to use these two formulae '$v = at$ and $s = ½ at^2$' to answer the questions 1 to 2 below.

1. A car starts from rest and accelerates uniformly at $3m/s^2$ for 5 seconds. Calculates its velocity in the 5th second.

2. A car accelerates uniformly from rest and reaches a velocity of 30m/s in 6seconds. Calculate:

    a. the acceleration of the car.

    b. the distance it travelled at the end of the 6th second.

We hope that you have found this activity easy to tackle. Please refer to the Feedback to Activity 8.2.5 for the answers.

Feedback

Feedback to Activity 8.2.5

1. $u = 0$ m/s, $t = 5$ s, $a = 3 m/s^2$, $v = ?$

$v = at$

$v = 3\ m/s^2 \times 5s$

$v = 15\ m/s$

2

a. $u = 0$ m/s, $t = 6$ s, $v = 30 m/s$, $a = ?$,

$v = at$

$a = v/t$

$a = 30\ m/s/6s$

$a = 5\ m/s^2$

b. From (a) $t = 6$ s, $a = 5\ m/s^2$, $s = ?$

$s = ½ at^2$

$s = ½ \times 5\ m/s^2 \times 6\ s \times 6s$

$s = 90\ m$

Note it! / Important!

Remember! If you were given a velocity-time graph you could have used it to work out the distance travelled.

Well done! The questions were not too difficult after all was it? You have come to the end of Topic 8.2 and in fact the end of the unit. Before you have a go at the self assessment for the unit, let us review what you have learned.

Unit summary

Summary

In this unit you learned that distance is different from displacement although they are both measured in the same unit (metres, kilometres, etc.). Distance is the actual length of the journey and has magnitude only whilst displacement has both magnitude and direction and is the shortest distance between two points.

You studied about speed, velocity and acceleration. Speed is the rate of change of distance with time and it is measured in metre/second (m/s). Similarly, velocity is also measured in metres per second (m/s) but the direction of motion has to be included, unlike speed. Hence, velocity, like displacement is a vector quantity while speed is a scalar quantity.

You also learned that acceleration is the rate of increase in velocity with time and a rate decrease in velocity is called deceleration. Acceleration is measured in metres per second per second (m/s^2).

Finally, you learned how to use velocity /time graphs, distance/time graphs, some equations of motion to calculate acceleration, the distance travelled and related quantities of objects moving in straight lines.

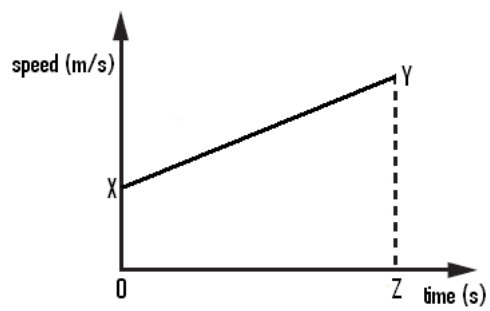
Assessment

Self-assessment 8.1.

You need 20 minutes to do the self-assessment for Topics 8.1 and 8.2. This self-assessment covers the whole unit and it will not be submitted but marked by you. Once again you are strongly advised to answer all questions before you refer to the Answers to Self-assessment 8.1 at the end of the unit. This will help you learn and reflect better on areas for improvement.

Answer the following questions:

1. The graph shows how the speed of a car changes with time



Which of the following gives the distance travelled in time interval OZ?

A The area OXYZ

B Length OX × length YZ

C Length OX + length YZ

D The length (YZ - OX)

2. Which of the following statements is true about distance and displacement?

A Displacement depends on the route taken.

B Displacement is the physical distance travelled.

C Distance depends on the route taken.

D Distance is the physical distance travelled in a given direction

3. Which of the following statements is true about speed and velocity?

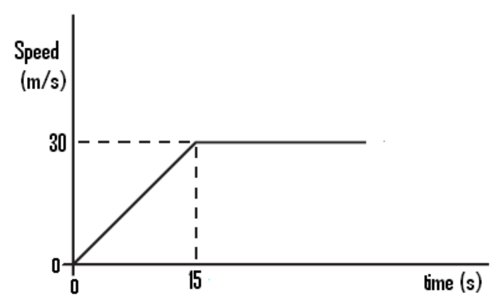
   A Speed has direction only.

   B Speed is a vector quantity.

   C Velocity has direction only.

   D Velocity has size and direction.

4. A motorcycle accelerates from traffic lights. The graph shows how the motorcycle's speed changes with time.



   How far does the motorcycle travel before it reaches a constant speed?

   A 15 m

   B 30 m

   C 225 m

   D 450 m.

5. A bus travels 200 km. During the journey the bus achieved a maximum speed of 90 km/h, and a lowest speed was 20 km/h. The journey takes *four* hours.

   What is the average speed for the journey?

   A 20 km/h

B 50 km/h

C 55 km/h

D 110 km/h.

6. The distance time graph in Figure 15.2.18 shows the journey of a bus which started at 6.00 a.m. The different stages of its journey is marked by the letters P, Q, R, S,T and U.

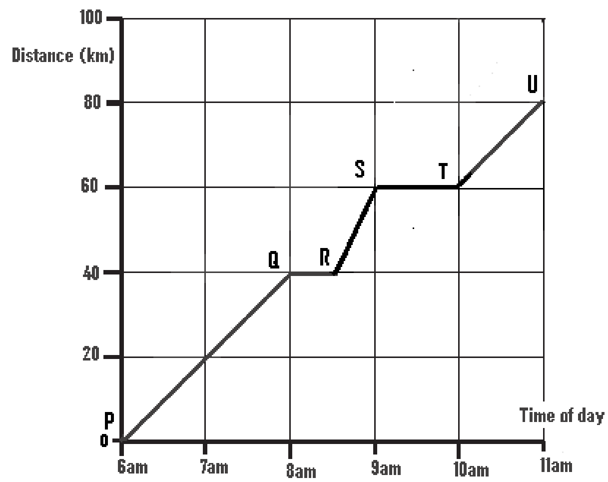


Figure 15.2.18:Distance-time graph

Sketched by Alex Souffe, November 2010

a. What is the total time taken for the journey including stops?

b. How many stops did the bus make during the journey?

c. What is the total time the bus stopped during the journey?

d. What is the total time that the bus was in motion?

e. What is the average speed of the bus, excluding stops?

f. At which *stage* of the journey did the bus travel the fastest? Give a reason for your answer.

7. A car covers a distance of 1920 m in 4 minutes due south. Calculate its velocity in:

a. m/s

b. km/h

We have now completed the study on Motion. We are sure that you have gained new knowledge on distance, displacement, speed, velocity and acceleration of bodies in motion.

Below you will find the Answers to Self-assessment 8.1.

Answers to self-assessments

Answers to Assessment

Answers to Self-assessment 8.1

1. A   2. C   3.D   4. C   5. B

6

a. 5 hours (from 6 am to 11 am)

b. 2 stops (between QR and ST)

c. 1½ hours (8 am to 8:30 am and 9:00 am to 10:00 am)

d. 3½ hours (from 6:00 am to 8:00am = 2 hours; 8:30 am to 9:00 am = ½hour and 10:00am to 11:00 am = 1 hour)

e. $\text{Average speed} = \text{total distance travelled}/\text{total time in motion}$

$$\text{Average speed} = 80\text{km}/3.5\text{ hours}$$

$$\text{Average speed} = 22.8\text{ km/h}$$

f. Between R and S. The line is steepest between R and S.

7

a. s = 1920m, t = 4 minutes = (4 × 60) = 240 s, v= ?

$$\text{average velocity} = \frac{s}{t}$$

$$\text{average velocity} = \frac{1920\text{ m}}{240\text{s}}$$

$$\text{average velocity} = 8\text{ m/s}$$

b. s = 1920m = (1920m/1000 km), t = 4 minutes = (4/ 60) = 0 v= ?

$$\text{average velocity} = \frac{s}{t}$$

$$\text{average velocity} = \frac{1920}{1000}\text{km} \div \frac{4}{60}$$

$$\text{average velocity} = \frac{1920}{1000}\,\text{km} \div \frac{4}{60}\,\text{h}$$

$$\text{average velocity} = \frac{1920}{1000} \times \frac{60}{4}$$

$$\text{average velocity} = 28.8\ \text{km/h}$$

Well done! Now you are ready to move onto Unit 9. Good luck!

Contents

Unit 9

Force and Motion

Introduction

Welcome to the 9th unit of the "Coordinated Science Course." The unit is entitled **Force and Motion.** It consists of three main topics – Balanced and unbalanced forces, friction and relationship between force, and mass and acceleration. Hence, in this unit we will discuss *forces, inertia, friction,* and the *effects of forces* in general. We will whenever possible provide opportunities for you to try out some basic experiments and to apply principles and formulae learnt within the unit.

In this unit you will learn about:

- SI unit of force.
- The effects of unbalanced and balanced forces on the motion of objects.
- Friction and its effects on motion.
- The relationship between force, mass and acceleration .
- How to use the equation $F=ma$ in simple problems.

We hope that this Physics unit will be both interesting and enjoyable to you.

Upon completion of this unit you will be able to:

Outcomes

- *state* that force is measured in newtons.
- *explain* that unbalanced forces change motion and that in the absence of an unbalanced force, an object will either remain at rest or travel with a constant velocity.
- *carry out* experiments to show that friction often provides an opposing force acting on moving bodies.
- *state* that the relationship between force, mass and acceleration is given by the equation $F=ma$.
- *use* the relationship $F=ma$ in simple problems.
- *describe* qualitatively that the acceleration of a body depends both on its mass and on the size of the unbalanced force acting on it.

Terminology

Contact forces:	Forces acting on objects that are touching each other.
Friction:	A force that opposes the movement of objects that is touching each other.
Inertia:	The property of mass which resists change in motion.
Non-contact forces:	Forces that act at a distance.

How long?

Table 9.1.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	4 hours	2 hours
Full-time student within the conventional school setting OR Part-time student	4 hours	2 hours

Table 9.1.0: The time needed for you to work on this unit

Topic 9.1: Effects of forces

How long?

You will need 1hour and 30 minutes at the most to complete this topic. It is advisable that you spend another 45 minutes of your own time to further practice the activities learnt. Make sure you read and understand everything in order to achieve the specific objectives

9.1.1 Balanced forces

Reflection

Reflection 9.1.1

You should spend about 5 minutes on this reflection

We will start off this topic by inviting you to reflect on the effects of forces by stating at least five instances or examples in your everyday activities where you think forces are used.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

Feedback

Feedback to Reflection 9.1.1

Well done! We are certain that based on what you have done so far, you managed to give examples such as when a push or a pull or objects have changed size or shape such as kicking a ball, stretching of an elastic band, crushing of garlic, riding or stopping your bicycle, etc.. At this stage, becoming familiar with what forces do, you should have started to develop better understanding of what a "force" is.

We must admit that it is difficult to define *force* but from our everyday experiences, we could in simple terms describe 'it as a "pull" or a "push" that one object applies on another object'. Furthermore, as you have started to notice in the other units, it can have several observable effects on things. For example, it can change the shape, size and motion of objects. The *SI unit* of force is the newton (N). Please note that in Unit

17 Gravity, you will have the opportunity to experience how large a force of one newton is.

Now we are ready to start considering forces in action in different situations. Figure 9.1.1 shows a man sitting on a chair. While he is sitting, he is exerting a force on the chair called his body weight or *action force.* The chair reacts by exerting an equal but opposite force to his weight called the *reaction force*.

Figure9.1.1: Picture of a man sitting on a chair

Photographed by Alex Souffe, October 2010

Since these forces are equal in magnitude and opposite in direction, he remains stationary (at rest). That is, he did not go down through the seat of the chair nor up. In such a situation, we say that the forces are balanced.

Activity

Activity 9.1.1

You should spend about 15 minutes on this activity.

For this activity you will need a friend, two spring balances and a flat surface.

Procedure:

Use the two spring balances to try this simple contest (activity) as shown in Figure 9.1.2

1. Label one A and the other **B.**
2. Hook the two spring balances and place them on a flat surface (eg. Table)
3. Ask your friend to hold one and pull in one direction while you pull in the opposite direction while they rest on the flat surface.
4. Note the reading on each balance. *(Please ensure that the two spring balances are in a straight line and that they are stationary while the readings are taken).*
5. Repeat with slightly different forces and change hands.

Figure9.1.2: Picture of 2 spring balances

Photographed by Lionel Goonetilleke, November 2010

1. Which of the two spring balances won the contest?

____

____

Feedback

Feedback to Activity 9.1.1

You are right; neither of the two spring balances won the contest. All the different pairs of readings were the same but they were in opposite directions.

Good observations! In fact such observations were made many years ago by a great scientist, Sir Isaac Newton. He noticed that forces **always** acted in pairs and that the two forces were **always** equal in size (magnitude) but opposite in direction. He called the pair of forces **action** and **reaction**. His observations gave rise to the fact that a single object cannot experience a force by itself. In everyday situations, forces exist because two objects exert a push or pull on each other. Therefore, forces always occur in pairs. This has been summarized by **Newton's third Law of Motion**, which states that:

> If **body A** exerts a force on **body B**, then **body B** will exert an equal and opposite force on **body A.**

Often this law is expressed in the form of: **To every action there is an equal but opposite reaction.** Now, we will consider two more examples in everyday situations where the **action-reaction** pair of forces occurs. The first example as shown in Figure 9.1.3 is a pile of books on a table.

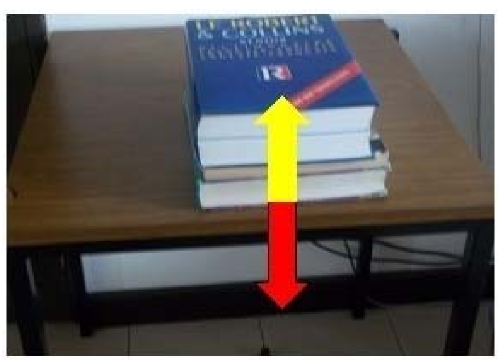


Figure 9.1.3: A pile of books on a table.

Photographed by Alex Souffe, November 2010

The books are at rest. This is because they are pushing downward, due to their weight (action force) on the surface of the table and the table is pushing upward on them with an equal and opposite force (reaction force).

Figure 9.1.4: Two teams contesting a tug-of-war

Photographed by Alex Souffe, November, 2010

The second example as shown in Figure 9.1.4 is about two teams contesting in a tug-of-war. Say that at the initial stage, the rope is stationary due to the fact that the two teams are pulling with equal forces in opposite directions. At this stage we say that the total force of each team is opposite and balanced. Obviously, after sometime one team is bound to get tired (say team A), so the other team's (say team B) total force will be greater than team A. As a result, team (A) is bound to be pulled (moved) in the direction of team B. At this stage we say that the opposite forces are unbalanced unlike in the first situation.

In the first example, it is obvious that only a balanced force was acting in the situation of the pile of books and the table. Consequently, the books which were at rest, remained at rest. This shows that the sum of the two forces (action and reaction) known as the resultant force was zero. *(If you feel that you have forgotten the idea of resultant forces please go back to Unit 3 to do some review.)*

In the second example (tug-of-war), initially the two teams did not move in any direction. This is because they were pulling with *equal* and *opposite forces* and their resultant force was zero. However, later on team A was pulled (i.e. moved) in the direction of team B. This shows that the sum of the two forces (**resultant force**) was NOT zero (i.e. unbalanced). In fact the pulling force of team B was larger than that of team A, so the opposite forces were **unbalanced.**

So far we have addressed two examples of the effects of forces acting on objects at rest. Now we will turn our attention to the effects of forces on moving objects. We are going to invite you to try Activity 9.1.2 with your friends.

Activity

Activity 9.1.2

You should spend approximately 20 minutes on this activity.

For this activity you will need a friend, a bicycle and a flat stretch of road.

Procedure:

1. Ask your friend to ride the bicycle as shown in Figure 9.1.5

Figure 9.1.5: Cyclist riding along a flat road

Photographed by Alex Souffe, October 2010

1. What action caused the bicycle to move?

2. What did your friend try to do in order to ensure that the bicycle moved at the same velocity along the flat road?

3. What happened to the motion of the bicycle when your friend stopped pedaling?

4. What caused the change in the motion of the bicycle?

5. Based on the idea that 'forces' always act in pairs, what can you say about the magnitude of the force that caused the bicycle to

move compared to the force that caused it to slow down at the time it was moving at the same speed?

Feedback

Feedback to Activity 9.1.2

1. The *pedalling force* applied by the cyclist caused the bicycle to move.

2. He tried to ensure that the pedaling force was kept the same.

3. When he/she stopped pedaling the bicycle slowed down until it stopped.

4. The change in the motion of the bicycle was caused by opposing forces mainly due to air pushing on the body of the cyclist (air resistance) and the surface of the road in contact with the tyres of the bicycle (friction).

5. At the time the bicycle was moving at the same speed, the two opposing forces (i.e. one causing forward motion and the other opposing the forward motion) were equal but acting in opposite directions.

Good work! We hope that you did not find this activity and the questions too challenging. More importantly you should have begun to appreciate the effects of forces on a moving body. We will draw your attention on two phases of the motion of the bicycle; (i) the stage it was moving at constant velocity and (ii) the stage when the cyclist stopped pedaling and the bicycle slowed down and eventually came to rest.

At the time it was moving at constant velocity, the pedaling force of the cyclist that caused the bicycle to move forward was equal and opposite to the force that caused the bicycle to come to rest when the cyclist stopped pedaling. Hence, at the time the bicycle was travelling at constant velocity the resultant force was zero (i.e. equal and opposite), so the forces were balanced.

During the stage when the cyclist stopped pedaling the magnitude of the two forces changed. The force that caused the moving bicycle to slow down and eventually come to rest became larger than the force that caused the bicycle to move forward (in fact pedaling force was zero). At this stage of the motion of the bicycle, the sum of the two forces (resultant force) was NOT zero, so the forces were unbalanced.

We won't be surprised if by now you are wondering what would happen to the motion of the bicycle at the time the cyclist stopped pedaling if there were no opposing forces. Well, you are not wrong if you were thinking that it will continue to move with the same velocity in a straight line. In fact, this is what happens to a spaceship when travelling deep in space where there are no opposing forces. It continues to travel in a straight line without changing velocity. It does not need its engine to continue moving with the same speed. However, it needs a force from its engine to change its speed or direction.

These ideas are summarized in Newton's first Law of Motion, which states:

If the forces acting on a mass (object) are balanced (no resultant force), then

- If the mass (object) is at rest, it stays at rest.
- If the mass (object) is moving, it keeps on moving at a constant speed in a straight line.

According to Newton's first Law, a *force* is needed *to make a body move, stop it from moving or change its velocity.* We are also aware that all objects resist a change in velocity, including zero velocity (at rest). Newton called this resistance to change in velocity inertia. Inertia is the property of mass that 'resists' change in motion. It is the 'laziness' of objects to start moving if they were at rest or to stop if they were moving.

Inertia can be shown by doing a simple experiment as shown in Figure 9.1.6. Have fun! But more importantly think of the physics involved.

Activity

Activity 9.1.3

You should spend about 10 minutes on this activity.

For this activity, to investigate one of the effects of inertia, you will need an empty glass bottle, a coin, a strip of paper and a ruler.

Procedure:

1. Rest a coin on a strip of paper over the mouth of a bottle as shown in Figure 9.1.6
2. Remove the paper quickly. This can be done by holding the free end of the paper in one hand and striking the paper with the fore finger or ruler with a downward force.
3. Repeat the activity.

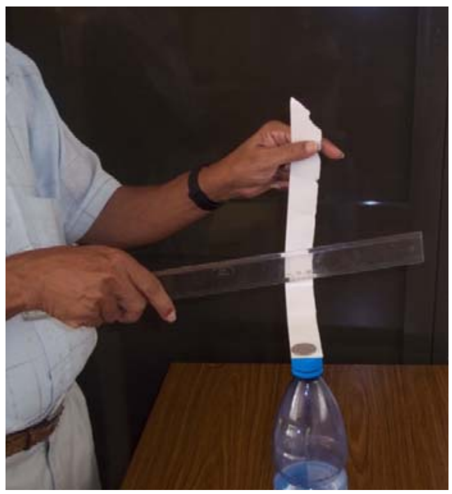


Figure 9.1.6: Set up to investigate one effect of inertia

Photographed by Alex Souffe, October 2010

1. What did you observe?

2. According to Newton, which property caused the coin to behave in this way?

Feedback

Feedback to Activity 9.1.3

1. The coin stayed on the mouth of the bottle.

2. Inertia is the property of the coin (mass) that caused it to ‘resist’ change in motion.

Well done! When you removed the paper quickly, the coin stayed on the mouth of the bottle. This is because the coin was in a state of rest and it was reluctant to move. Now try Activity9.1.4.

Activity

Activity 9.1.4

You should spend about 10 minutes on this activity.

For this activity you will need two identical containers with a capacity of about 4 to 5 litres, two pieces of rope and some sand or water.

Procedure:

Hang two similar containers as shown in the Figure 9.1.7. Leave one empty and fill the other with sand or gravel.

Try to push them forward through a distance of about 30 cm from their rest position and let go.

While the two cans are swinging try to stop them.

Repeat the experiment at least two times. Note your observations and then answer the questions below.

Figure 9.1.7: Two identical containers of different masses used to investigate inertia

Photographed by Alex Souffe, October 2010

1. Which container was more difficult to move?

2. Which container was more difficult to stop from moving?

3. Which container needed a larger force to move and to stop it from moving?

Feedback

Feedback to Activity 9.1.4

1. The full container.
2. The full container.
3. The full container.

Good observations! The full container was more difficult to move and to stop from moving than the empty one. So we can say the heavier container (having more mass) had a higher resistance to changes in its state of motion.

From your everyday experience you could have observed that it is more difficult to push a car than a bicycle from rest and likewise, it is more difficult to stop a car than a bicycle, travelling at the same speed.

When you are travelling in a car, your body is moving at the same speed as the car. If the driver quickly applies the brakes, your body continues moving forward. This can be very dangerous if you are in the front seat because you can hit the windscreen or windshield. To prevent this from happening people have to wear seatbelts. They prevent the passengers from being pushed forward quickly.

Figure 9.1.8: Seat belt stopping a person from going through the wind screen.

Photographed by Alex Souffe, October 2010

From the above example, when the brakes of the car were applied the braking force opposed the forward motion of the car and it eventually stopped. The force that opposed the forward motion of the car is called friction.

This brings us to the end of topic 9.1. What forces did we learn about in this topic? What are some things that Newton observe in regards to forces? Again, try to think how all of these forces play a role in your everyday life to help you understand the concepts better.

In Topic 9.2 we are going to address the frictional force in greater detail.

Topic 9.2: Friction

How long?

You will need 1hour and 10 minutes at the most to complete this topic. It is advisable that you spend another 35 minutes of your own time to further review the activities. Make sure you read and understand everything in order to achieve the specific objectives

Although we do not frequently talk about friction in our everyday experiences, it is a very important force to us. Hence, in this topic we are going to focus on the effects, advantages and disadvantages of friction. We will start off by inviting you to carry out a simple activity.

Simply move your hand through the air and then try to place it on a table and move it forward. You should have noticed that it was more difficult to move your hand when it was placed on the surface of the table. This is because your hand was in contact with the table top. The table top offered an opposing contact force which acted against the direction you moved your hand. The force that opposed the forward motion of your hand is friction.

9.2.1 What is friction?

Friction is a force that opposes the movement of objects that are touching each other.

Clearly, it is an example of a contact force as mentioned earlier and it exists while the force is being applied irrespective of whether the object is moving or stationary. The friction on stationary objects is called static friction and that on moving objects is called dynamic friction.

Activity

Activity 9.2.1

You should spend about 15 minutes on this activity.

For this activity you will need a spring balance, a rough flat surface, a well polished flat surface, a rectangular block of wood, a mass of 1kg and a piece of string or a hook.

Procedure

1. Set up the experiment with the string tied to the block of wood and the spring balance, as shown in Figure 9.2.1 below.

2. Place the block on its largest surface on the unpolished (rough) flat surface.

3. Pull gently until the block moves at roughly the same speed and note the force.

4. Repeat steps 2 and 3 on the polished (smooth) flat surface.

5. Repeat steps 1 to 3 but this time use an unpolished surface and place the block on its face with the smallest surface area.

6. Record your observations in the table below.

7. Repeat the experiment but this time place a mass of 1 kg on the block and record your observations in the table below.

Figure 9.2.1: Set up to investigate frictional force

Photographed by Alex Souffe, March 2011

Observations

	Varying factors (area and weight of block)	Force needed to cause the block to move on an unpolished surface. (N)	Force needed to cause the block to move on a polished surface (N)
1.	Large area and normal weight		
2.	Small area and normal weight		
3.	Large area plus weight of 10N (1kg)		
4.	Small area plus weight of 10N (1kg)		

Conclusion

In the space below write down what you noticed from the observations that you have made and recorded on the table above.

____

____

____

____

____

____

Feedback

Feedback to Activity 9.2.1

From the first experiments you should have noticed two things.

i. When the block of wood was pulled along the rough surface, a larger force was required to cause it to start moving compared to when it was pulled along the smooth surface; and

ii. The force needed to move the block when placed on its side with the smallest area required nearly the same force to make it start moving as when it was placed on its larger surface while in contact with a given surface.

In fact if the experiments were done in ideal conditions, like scientists do, the magnitude of the force needed would have been the same for the two different areas of contact on a particular surface.

Finally, you should have noticed that the force of friction which was opposing the movement of the block was due to the degree of roughness of the surface. It must be noted that all surfaces (even the smoothest) if in contact will offer some degree of friction. This is because all surfaces have 'humps' and 'hollows' which may only be visible under the microscope. These 'humps' and 'hollows' tend to fit together and offer resistance to movement. This explains why you had to initially apply a greater force to cause the object to start moving. However, when it starts moving a lesser force was needed to keep it moving with constant velocity. This is due to the fact that while it was in motion the humps and hollows from the two surfaces were not allowed to interlock.

Friction does not only occur between solid surfaces. It also exists when objects move through liquids and gases. This type of friction is called fluid friction. Fluid friction unlike solids depends on the surface area of the moving object. The greater the surface area of an object moving through the fluid, the greater the friction will be. This means that if the surface of an object moving through the fluid is large, the friction will also be large. When an aircraft flies in the sky, it experiences friction. Where do you think the friction comes from? Obviously, the plane flies through the air, so the resistance is caused by the air particles which oppose its motion. This kind of friction is also called air resistance or the drag.

Now that you know what friction is, it is time for you to consider some advantages and disadvantages of friction.

Now let us look at some **advantages** and **disadvantages** of friction.

9.2.2 Advantages of friction

Reflection

Reflection 9.2.1

You should spend about 5 minutes on this activity.

To help you appreciate the advantages of friction we are going to invite you to reflect on some everyday activities. Have you ever tried to hold a glass or a plate with wet 'soapy' hands? Well, it might have got you into trouble with your parents. The glass slipped between your fingers and broke for there was very little friction between your hand and the glass.

From this situation you should have realized that one of the advantages of friction is that it enables us to hold things firmly in our hands such as the pen or pencil you are using, your cup, comb, etc.... It also enables us to walk by pushing us forward without slipping and helps us to stop from moving. This also applies to vehicles.

For example a car moves due to friction between the surface of the road and the tyres. Once it is in motion, it requires friction to stop it from moving but this time it is the friction between the brake pads and the brake disc as shown in Figure 9.2.2 and the friction between the tyres and the road surface.

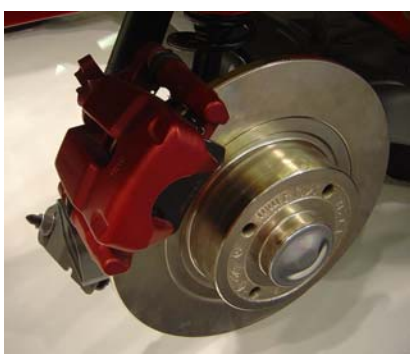


Figure 9.2.2: Hydraulic disc brake

Source: http://en.wikipedia.org/wiki/File:Disk_brake_dsc03682.jpg

Friction could be increased by making the contact surfaces very *rough* and by increasing the *normal force* being applied. On the other hand if friction is seen to be a nuisance, then it could be reduced by several means.

Reflection

Reflection 9.2.2

You are advised to spend about 5 minutes on this activity.

From your everyday experience, please think of at least two *situations* and *strategies* that you have used or familiar with to reduce friction.

Feedback

Feedback to Reflection 9.2.2

Well, there are two basic ways of reducing friction when solid surfaces are in contact. One is to prevent the solid surfaces from rubbing against each other and the other is to make the surfaces in contact smoother. Therefore, you might have stated the following strategies:

1. The sliding surfaces could be separated by applying a film of oil or grease in a process called **lubrication.** Oil and grease are called **lubricants.** The lubricants help to reduce friction by separating the surfaces that rub against each other resulting in a cushioning effect. In this way, the moving parts are **not** in contact with each other. This makes the surfaces in contact smoother like all the moving parts of engines such as the pistons and the surface of the cylinder, axle, etc.

2. **Rollers or Ball bearings** reduce friction by separating the surfaces. Instead of surfaces rubbing against each other, they roll over each other.

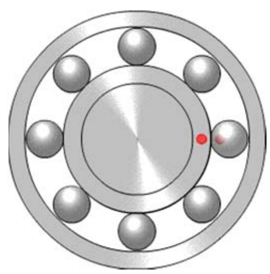


Figure 9.2.3: Ball bearings

Source: http://upload.wikimedia.org/wikipedia/commons/3/30/BallBearing.gif

Now we are going to invite you to investigate the above mentioned strategies by doing Activity 9.2.2

Activity

Activity 9.2 2

You should spend about 10 minutes on this activity.

For this activity you will need for part A - a smooth table top, some talcum powder or flour, 1 cm^3 of cooking/lubricating oil and for part B – a block of wood or a brick, and a set of 20 marbles.

Procedure:

Part A

1. Place the palm of your hand on a smooth table top and slide it forward.

2. Spread some talcum powder or flour on the table top (twice the area of your hand) and place your hand over the powder and slide it as in step 1.

3. Wipe the table top and clean your hands properly.

4. Then wet the palm of your hands with a few drops of cooking oil and repeat step 1.

5. Clean the table top. Wash and dry your hands.

6. Record your observations in terms of the ease of movement.

____

____

____

____

Part B

1. Place a block of wood or a brick on a cemented floor and try to push it along the floor over a distance of 30 cm.

2. Place the block of wood on a set of at least 20 marbles and try to move over a distance of 30 cm.

3. Record your observations in terms of the ease of movement.

Feedback

Feedback to Activity 9.2.2

Part A

You should have noticed that it was easier to move your hand on the table when it was wet with oil and when it was over the powder/flour. This is because oil and the powder prevented your hand from being in direct contact with the table surface. This reduces the amount of friction.

(Please note that oil and powder are two examples of lubricants.)

Part B

You should have noticed that it was easier to move the block of wood when placed on the marbles than on the floor. This is because the marbles allowed the block to roll on them.

(Please note that ball bearings as shown in figure 9.2.2 which are fitted to a wheel axle use the same principle).

You are now ready to turn your attention to the disadvantages of friction.

9.2.3 Disadvantages of friction

1. It can make surfaces that rub against each other to heat up, melt, and may even catch fire.

   You must have seen an automobile spin its wheels so much that the tyres start to smoke, or perhaps when the brakes of a vehicle are applied for a long time, they become red hot. These are examples of friction creating heat energy and even causing damage to machines.

2. It can cause wastage of energy.

   In any type of vehicles such as cars, boats or airplanes --excess friction means that extra fuel must be used to power the vehicles. In other words, fuel or energy is being wasted because of the friction.

3. It can make surfaces that rub against each other to wear out useful components (to be damaged).

   Any device that has moving parts or that are used over long period of time can wear out rapidly due to friction. Some other examples of materials wearing out due to friction include the soles of your shoes, the moving parts in a car, stairs, car tyres, clothes, etc.

4. It can make movement difficult.

   Any time you want to move an object, friction can make the job more difficult, so extra energy has to be spent in order to slide a heavy box across the floor, ride a bicycle or walk through soft sand.

We would not be surprised if you are now wondering if friction is a good or a bad thing. What do you think? Well it depends on the situation, if you are trying to stop a moving car then it is a good thing but if you are trying to move a car from rest and the bearing of the wheels are not moving freely, then friction is a nuisance.

Clearly a compromise has to be made between a high degree of friction and virtually no friction. For example, if you wanted to slide a heavy box across the floor, you would want to reduce the friction between the box and the floor, so that it would be easy to move. Rollers could be used to reduce friction so that less force is required to move the box.

Friction is necessary in many applications to prevent slipping or sliding. But also, it can be a nuisance because it can hinder motion. A good compromise is necessary to get just enough friction or a proper combination of frictions.

Source:
http://wiki.answers.com/Q/What_are_the_advantages_and_disadvantages_of_friction

Now that you have learnt that forces are used to maintain motion in everyday life because of the need to overcome friction, you are ready to study the relationship between force, mass and acceleration.

At this stage we are going to draw your attention to Unit 8, Topic 8.2, where we addressed acceleration. If you feel that there is a need for you to do some review, you may spend some time to go through Topic 8.2 once again.

Topic 9.3: Force, Mass and Acceleration

How long?

You will need 1 hour and 20 minutes at the most to complete this topic. It is advisable that you spend another 40 minutes of your own time to further practice the activities learnt. Make sure you read and understand everything in order to achieve the specific objectives

From what you have studied so far, you learned that when an unbalanced force acts on an object, the object will start to move in the direction of the larger force, provided the unbalanced force is greater than the frictional force. The size of the unbalanced force is the difference between the two opposite forces acting in the direction of the larger force and is called the **resultant force**. It has the same effect as a single force in the direction of motion of the object. The resultant force will make the object move faster (change in velocity). In fact, an increase in the velocity of a body is referred to as **acceleration**.

Activity

Activity 9.3.1

You should spend about 20 minutes on this activity.

For this activity, you will need for part A: a trolley of 1kg mass, a ticker timer, ticker tape and three identical elastic bands, and for part B, the same set of apparatus and two 1kg weights.

Procedure for Part A

1. Use a trolley of 1kg throughout the experiment.
2. Attach a ticker tape to the trolley. (You may refer to Figure 8.2.5 of Topic 8.2, Unit 8).
3. Attach one rubber band to the trolley and pull it to the edge of the trolley and try to maintain the same length while the trolley is moving.
4. Allow the trolley to move a distance of 1m.
5. Carry out three trials.
6. Repeat steps 3 to 5 by using two and then three elastic bands respectively.
7. Select a central part of 5 ticker gaps (i.e. 6 ticker marks) from one of the three trials in each experiment (i.e. 1, 2 and 3 elastic bands) and paste it in the table.

	Force	Ticker timer of 5 ticks
1.	 One elastic band	

	Force	Ticker timer of 5 ticks
2.	 Two elastic bands	
3.	 Three elastic bands	

Questions

1. Why were the elastic bands pulled the same distance each time?

____

____

____

2. Why was the same trolley used each time?

____

____

____

3. Why were ticker tape pieces with five ticker gaps used?

____

____

4. Which piece of ticker tape was the longest?

5. Which trolley experienced the greatest force?

6. Which trolley do you think experienced the highest acceleration?

Procedure for Part B

Repeat the experiment by using the same set up in part A, but this time make the following changes:

1. Use the same force (i.e. one rubber band) for all three stages.
2. Use a trolley of mass 1kg for the first stage.
3. Repeat step 2, but this time increase the total mass of the trolley to 2 kg and then to 3 kg.
4. Note your observations and then answer the questions.

Questions

1. Why were the elastic bands pulled the same distance each time?

2. Which variable in the experiment was changed?

3. Which piece of ticker tape was the longest and which one was the shortest?

4. Which trolley do you think experienced the lowest and highest acceleration?

Feedback

Feedback to Activity 9.3.1

Part A

1. The elastic bands were pulled the same distance each time to ensure that proportionate forces were exerted each time.

2. To ensure constant mass.

3. To ensure that the time intervals were constant and large enough for comparison.

4. The ticker tape was longest when the trolley was pulled with three rubber bands.

5. The trolley that was pulled with three rubber bands experienced the greatest force.

6. The trolley that was pulled with three rubber bands experienced the highest acceleration.

Feedback to Part B

1. The elastic band was pulled the same distance each time to ensure that the same force was applied during each stage.

2. The mass of the trolley.

3. The piece of ticker tape was the longest when the mass of the trolley was the lowest (1kg) and the shortest when the mass of the trolley was the highest (3kg).

4. The trolley experienced the greatest acceleration when the mass of the trolley was the least (1kg) and the least acceleration when the mass of the trolley was highest (3kg)

From the first set of results where the **mass** of the trolley was kept constant and the **force** was systematically increased, we observed that the greater the force, the greater the acceleration. In fact, the **acceleration** is directly proportional to the **force** applied. This means that when the force is doubled the acceleration is also doubled.

"acceleration ∝ force" is read as acceleration is directly proportional to the force applied.

This is normally written as: acceleration ∝ force

In Mathematical form the above relationship is written as: $a \propto F$ ....(1)

From the second set of results (part B) where the force was kept constant and the mass of the trolley was systematically increased by one kg each time, we observed that the greater the mass, the lesser the acceleration. In fact, the acceleration is inversely proportional to the mass of the trolley

"acceleration ∝ 1/mass" is read as acceleration is inversely proportional to the mass.

This is normally written as: acceleration ∝ 1/mass

In Mathematical form the above relationship is written as: $a \propto 1/m$ ....(2)

When these two relationships are combined, the following equation is obtained:

$$a \propto F \times 1/m \text{ ....(3)}$$

$$a \propto F/m$$

$$m \times a \propto F$$

(Rearrange the above to give) $F \propto m \times a$

Therefore $F = K \times m \times a$ *where K is a constant*

This formula can be made simple by choosing our units, so that K = 1

This gives the Formula: $F = 1 \times m \times a$

Force (N) = Mass (kg) x acceleration (m/s^2) or Simply, $F = ma$

Remember the unit of force is the *newton (*N*)*. One newton (1N) is defined as the unbalanced force which gives a mass of one kg an acceleration of 1 m/s^2. This relationship *(F =ma)* is based on Newton's second law of motion which will be addressed in detail in a later unit on Momentum.

Now it is time for us to show how the formula $F = ma$ can be used to solve problems involving force, mass and acceleration.

Example

An unknown force was applied to a body with a mass of 2 kg. The force caused the body to accelerate at a rate of by 5 m/s^2. Calculate the force applied on the body.

Steps to follow:

Step 1: List the "known values" and the "unknown values".

mass = 2kg; acceleration = 5 m/s^2; force =?

Step 2: Write the correct formula. We are going to use:

$$\text{Force (N)} = \text{mass (kg)} \times \text{acceleration } (\text{m/s}^2)$$

Step 3: Substitute the known values in the equation.

$$\text{Force (N)} = 2\text{ kg} \times 5\text{m/s}^2$$

Step 4: Calculate your answer, including units

Force =.10N

This means that when a net force of 10N is applied to a mass of 2kg, it accelerates at a rate of $5m/s^2$.

Now you should be ready to try out some questions.

Activity

Activity 9.3.2

You should spend about 5 minutes on this activity. You are required to solve the given questions. You may use your calculator.

1. A force of 20N was applied to a body with a mass of 5kg. The force caused the body to accelerate. Calculate the acceleration of the body.

2. A force of 50N was applied to a body of an unknown mass. The force caused the body to accelerate at a rate of $5m/s^2$. Calculate the mass of the body.

Feedback

Feedback to Activity 9.3.2

1. mass = 5kg; force =20N, acceleration = ?

   F = ma

   a = F/m

   = 20N/5kg

   = 4

   = 4 m/s^2

2. force =50N, acceleration = 5 m/s^2, mass = ?

   F = ma

   m= F/a

   = 50N/ 5 m/s^2

   = 10

   = 10 kg

Well done! The questions were not too difficult after all were they? You have come to the end of Topic 9.3 and in fact the end of the unit. I have provided you with a summary of what you have learnt in the unit below. Read the summary carefully, and then have a go at the self-assessment for the unit.

Unit summary

Summary

In this unit you studied some of the effects of forces in general before focusing on unbalanced forces. Unbalanced forces change motion and in the absence of an unbalanced force, an object will either remain at rest or travel with a constant velocity.

You also learned that friction is a contact force and it always results in an opposing force which acts on moving bodies. Friction has numerous advantages as well as disadvantages. We addressed how to alter friction depending on the situation.

Finally, you learned the relationship between force, mass and acceleration and the mathematical expression of the relationship between the three quantities. Opportunities were provided for you to apply the mathematical relationship to solve problems.

Now you are ready to attempt the self-assessment for this unit. Good luck!

Assessment

Assessment

Self-assessment 9.1

You need 20 minutes to do the self-assessment for Topics 9.1, 9.2 and 9.3. This self-assessment covers the whole unit and it will not be submitted but marked by yourself. The feedback is given at the end of the unit. Once again, you are strongly advised to answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Answer all the questions in parts A and B.

Part A:

Circle the letter next to the correct answer.

1. Which of the following statements is true about force?

    A. It is measured in kilogram (kg).

    B. It is measured in joule.

    C. It is measured in newton (N).

    D. It is measured in metres per second per second (m/s^2).

2. When a force is applied to a body, several effects are possible. Which of the following is NOT a possible effect of a force?

    A. It causes a moving body to stop from moving

    B. It causes a moving body to change direction.

    C. It causes a moving body to accelerate.

    D. It causes a moving body to change in mass.

3. When a car is being driven, frictional forces:

    A. act at the points of contacts between the tyres and the road.

    B. act on the body of the car and the air (air resistance).

    C. act between moving parts of the car which are in contact with each other.

    Which of the above statements are correct?

    A. (i) and (ii)

    B. (i) and (iii)

    C. C (ii) and (iii)

    D. (i), (ii) and (iii).

4. Friction is a force. It is

    A. always helpful.

    B. sometimes a nuisance.

C. always a nuisance.

D. never useful.

5. Friction can be increased by

A. lubricating.

B. making the surfaces in contact smoother.

C. increasing the roughness of the surfaces in contact.

Which of the above statements is/are incorrect?

A. (i)

B. (ii)

C. (iii)

D. (i), (ii) and (iii).

6. A hovercraft is made to move easily by

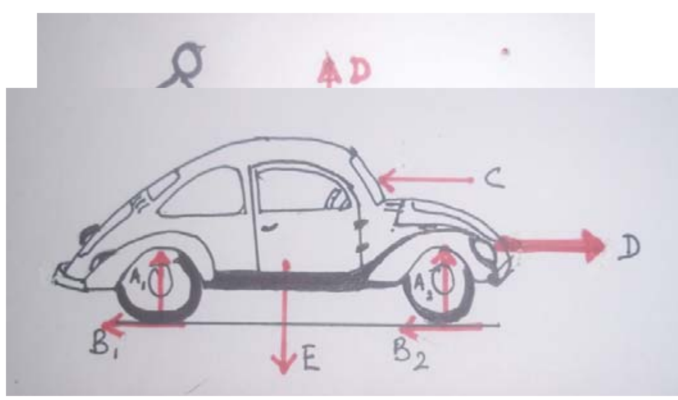
A. having an air cushion between its bottom and the water.

B. reducing the area of its bottom.

C. making it lighter.

D. increasing the area of its bottom.

7. A man is pushing a trolley forward as shown in the diagram?



We have now completed the study on Force and Motion. We are sure that you have gained new knowledge on balanced and unbalanced forces, inertia, friction, some effects of forces and the relationship between force, mass and acceleration in general.

Below you will find the Answers to Self-assessment 9.1.

Answers to Self-Assessment

Answers to Assessment

Assessment to Self-assessment 9.1

Part A

1. C
2. D
3. D
4. B
5. C
6. A
7. B
8. A

Part B

1. a. mass = 800 kg; acceleration = $2m/s^2$; Force =?

   $F=ma$

   $F=800kg \times 2m/s^2$

   = 1600N

   b. Total force = frictional force + **net force** necessary to cause the car to accelerate by $2m/s^2$

Total force = 400N + 1600N

= 2000N

c. The acceleration of the car will decrease.

2. a.

Forces	Corresponding letter
Weight	E
Reaction	A_1, A_2
Driving force	D
Air resistance	C
Friction	B_1, B_2, C

b. $D=C+B_1+B_2$

c. $E=A_1+A_2$

Now you are ready to move onto Unit 10. Good luck!

Contents

Unit 10

Diet and Health

Introduction

Food is considered as the source of energy for living organisms. When food is being burned energy is released and this energy is used to drive the metabolic reactions taking place in the body. Apart from providing energy, food is also the source of different nutrients. The different nutrients or classes of food have specific functions in the body. In this unit you will be able to learn about the importance of consuming the right proportion of those classes of food. Moreover, you will learn about the different deficiency diseases. You will also have the opportunity to carry out food tests on a variety of food samples.

Outcomes

Upon completion of this unit you will be able to:

- *define* the term diet.
- *define* the term balanced diet.
- *state* the importance of having carbohydrates, fat, vitamins, minerals water and roughage in our diet.
- *state* the uses of iron, calcium, iodine, vitamin A, B C and D in our body.
- *state* some examples of foods which are good sources of carbohydrate, fat, protein, vitamins, minerals, roughage and water.
- *state* the tests for starch (iodine solution), reducing sugar (Benedict's solution), protein (Biuret test) and fat (ethanol test).
- *perform* the tests for starch, reducing sugar, protein and fat.
- *identify* a few local dietary problems.
- *explain* how the dietary problems may affect peoples' health.

Terminology

Balanced diet:	A diet that contains all seven basic classes of food in sufficient quantities and in the correct proportion.
Cell nutrients:	They are components of the tissue fluid around the living cells.
Diet:	Diet is the food intake over a period of time.
Foods:	They are mixtures of chemical materials of different composition.
Malnutrition:	It is the name given to all body disorders due to dietary imbalance involving either over-nutrition or under-nutrition.
Nutrition:	The process of supplying body cells with cell nutrients from food materials.
Over-nutrition:	It is the dietary intake excess, of excess energy providing foods and certain nutrients.
Under nutrition:	It is dietary intake deficiency or insufficient energy providing foods and nutrients.

How long?

Table 10.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study. Self-study includes revision and practice exercises.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	5 hours	2 hours and 30 minutes
Full-time student within the conventional school setting OR Part-time student	5 hours	2 hours and 30 minutes

Table 10.0: The time needed for you to work on this unit

Topic 10.1: Diet

How long?

You will need 20 minutes to complete Topic 10.1. It is advisable that you spend another 10 minutes of your own time to further review the Topic.

A diet is very important to each and every one of us. In this topic you are going to learn what a diet is. We will start off will a small reflection.

Reflection

Reflection 10.1.1

You are required to spend around 5 minutes on this reflection.

Imagine you have gone for a walk on the mountain and you have planned to spend about five hours there. With you, you have brought only four sandwiches, two apples and two bottles of water.

Do you think that the type and amount of food that you have brought with you are sufficient for the walk? Explain your answer.

Well, I am sure that you have given some interesting answers. Some of you may have decided that it will be enough while some of you may have decided that it will not be enough. As you work through this unit you will learn how to decide on the type and quantity of food that you need to survive.

Now we are going to learn about diet. So, let us see what you already know about the term diet.

Activity

Activity 10.1.1

You are advised to spend about 5 minutes on this activity.

In the space below write down what you already know about the term diet.

I am sure that you have come up with a good explanation. Now refer to the Feedback to Activity 10.1.1 for the correct answer.

Feedback

Feedback to Activity 10.1.1

Let us see what the term diet means.

Diet is the food that you consume every day. In other words, we can say that, diet is the food intake over a period of time.

Reflection

Now take a moment and think about why we need to consume food throughout our lives.

Of course, everybody needs food to survive. There are different groups or classes of food that our body depends on in order to function healthily. Hence, each group or class of food has its own importance in the body.

Food is needed for different purposes and they are as shown in Figure 10.1.1 below.

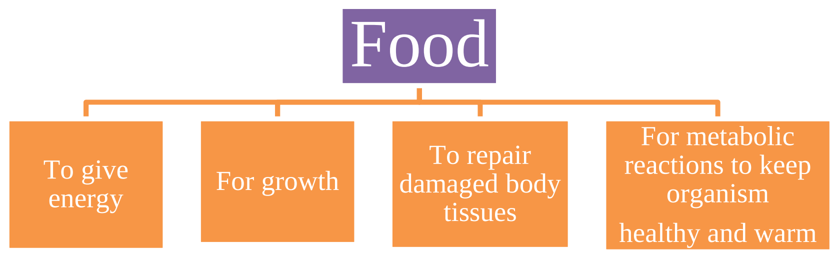


Figure 10.1.1: The importance of food

I hope you are now familiar with the term diet. However, is any kind of diet considered healthy? You first need to understand what your body needs in order to create a healthy diet. Let's find out how in the next topic!

Topic 10.2: Balanced diet

How long?

You will need 40 minutes to complete Topic 10.1. It is advisable that you spend another 20 minutes of your own time to further review the Topic.

In the previous topic you learnt about what a diet is and why we need food. So, now you are going to learn about what is meant by a balanced diet and why we need to have one.

Do you know what a balanced diet is? Don't worry if at this stage you are not too sure of what a balanced diet is. Try out this first activity to better understand what a balanced diet is.

Activity

Activity 10.2.1

You are advised to spend 5 minutes on this activity.

Please answer the questions in the space provided.

a. How many classes of food do you think there are?

____

b. Name the different classes of food

____

____

____

____

____

____

I am sure that you could name some of the classes of food, if not all of them. Please, refer to the Feedback to Activity 10.2.1 for the correct answer.

Feedback

Feedback to Activity 10.2.1

Well done! There are seven classes of food and they are:

1. Carbohydrates;
2. protein;
3. fat;
4. vitamins;
5. mineral;
6. water; and
7. roughage or fibre.

Now that you know the seven classes of food, let us move on to the next activity.

Activity

Activity 10.2.2

You are advised to spend about 10 minutes on this activity.

Write down a list of things that you normally eat for breakfast, lunch and dinner.

Breakfast:

____

____

____

Lunch:

Dinner:

I am sure that you have eaten some very nutritious and yummy food. We are now going to see what each food is rich in and classify it according to its respective class of food.

Activity

Activity 10.2.3

You should spend around 10 minutes on this activity.

Now take a careful look at what you are consuming for breakfast, lunch and dinner and write down the different classes of food that they are rich in.

Breakfast:

Lunch:

Dinner:

By looking back to Activity 10.2.3, do you think you are eating healthily?

If you are not really aware of your answer yet, let us move on to the next topic entitled *Classes of Food*. I am sure that by the end of this topic you will be able to say if you are having a balanced diet or not.

Topic 10.3: Classes of food

How long?

You will need 50 minutes to complete Topic 10.1. It is advisable that you spend another 25 minutes of your own time to further review the Topic.

Like previously stated in Topic 10.2 there are seven classes of food and they are carbohydrates, protein, fat, vitamins, minerals, roughage and water. In this topic now you are going to learn about the composition and importance of the different classes of food.

10.3.1 The seven classes of food

The table below concisely presents the differences between carbohydrates, proteins and fats.

	Carbohydrates	**Protein**	**Fat**
Elements	Carbon, hydrogen, oxygen	Carbon, hydrogen, oxygen, nitrogen and sulphur	Carbon, hydrogen, Oxygen
Basic unit	Monosaccharide Eg. Glucose	Amino acids (20 different)	3 fatty acids and 1 glycerol

Type	Monosaccharide E.g:glucose, fructose Disaccharide E.g:maltose, sucrose Polysaccharide E.g: starch, cellulose	Animal and plant proteins.	Saturated and unsaturated fats.

Table 10.3.1: The differences between carbohydrates, proteins and fats.

You are now going to learn more about each class of food and their importance in our diet.

10.3.1.1 Carbohydrate

Carbohydrate is the main source of energy.

Since cellulose cannot be digested, it adds bulk to the food and helps in peristaltic movement

10.3.1.2 Protein

Protein:

- is a good source of amino acids which are required for growth of new tissues and replacing cell components.
- builds up body structures such as hair, nails, cell membranes
- is used in the formation of muscles, tendons and ligaments.
- is used in the formation of enzymes, hormones and anti-bodies.

10.3.1.3 Fat

Fat:

- is one component of the cell membrane, hormones, myelin sheath of neurones.
- is stored in adipose tissues beneath skin and around body organs as insulator.
- protects delicate organs from physical damage.
- is an energy reserve.

10.3.1.4 Water

Water is needed:

- For transport. It is the main constituent of blood and body fluids and acts as a medium of transport. Nutrients, waste substances, hormones are transported in solution.
- For chemical reactions. Water serves as a solvent for many chemical reactions of the body.
- For temperature regulation. Evaporation of water in sweating causes the removal of heat from the body. This cooling effect is very important in preventing overheating of the body.
- For lubrication. Main constituent of the synovial fluid found in the synovial joints and mucus in the alimentary canal.

10.3.1.5 Roughage

Roughage (also known as dietary fibre):

- Adds bulk to the food and assist in peristaltic movement in the alimentary canal.
- Helps to retain water, absorb poisonous substance from the gut and soften the faeces.
- Prevents constipation and reduce the risks of getting colon cancer.

10.3.1.6 Vitamins

- Vitamin A: Needed for healthy growth and maintenance of the skin tissues, and formation of visual pigment in the retina.

- Vitamin B: Promote cell respiration and normal growth.
- Vitamin C: For normal growth and development of healthy teeth and gums. For formation and maintenance of healthy connective tissues.
- Vitamin D: to maintain calcium and phosphorous in the body and to help in the absorption of calcium in the intestine.

10.3.1.7 Minerals

In order to lead a healthy life, our body also needs different types of minerals. Some of the most important minerals in our diet are:

- Calcium: Combines with phosphorous to form healthy bones and teeth. It is needed for muscular contraction, nerve function and blood clotting.
- Iron: Used in the formation of haemoglobin in red blood cells and is an enzyme activator.
- Iodine: Used in the formation of the hormone thyroxine which prevents goitre.

10.3.2 Foods rich in the seven classes of food

The food that you eat everyday contains a percentage of the different classes of food. Some will contain a higher percentage of one particular class of food and therefore we say that it is rich in that particular group of food.

Activity

Activity 10.3.1

You are advised to spend about 10 minutes on this activity.

Complete the table below by writing in the names of some local foods rich in carbohydrates, protein, fat, vitamins, minerals, water and roughage.

Class of food	Examples of foods rich in each class of food		
Carbohydrate			
Protein			
Fat			
Vitamins			
Minerals			
Roughage			
Water			

Well done. I know that you have written the names of some interesting foods. Let us move on to the feedback to see if you are on the right track.

Feedback

Feedback to Activity 10.3.1

Table10.3.2 shows some main food sources for the seven classes of food. Use the table to check if you have recorded your answers correctly.

Class of food	Main sources
Carbohydrates	Rice, potatoes, bread, fruits, cereals, cassava and other plant storage organs.
Protein	Lean meat, fish, milk, cheese, egg white, soya beans and legumes.
Fat	Butter, cream, fatty meat, oil, egg yolk, lard.
Vitamin A	Green vegetables, liver, egg, coloured fruits.
Vitamin B	Meat, vegetables, wholemeal bread.
Vitamin C	Fruits particularly citrus fruits such as oranges and lemons, green vegetables and potatoes.
Vitamin D	Fish, dairy products, liver, eggs and from sunbathing.
Calcium	Milk, cheese, bread and green vegetables.
Iron	Liver, raw egg, meat, green vegetables such as cabbage and spinach.
Iodine	Sea foods, seaweed and iodised table salt.

Table 10.3.2: Sources of the seven classes of food

The diagram below shows some common foods. You can refer to the table to try and find for yourself in which classes of food they are rich in.

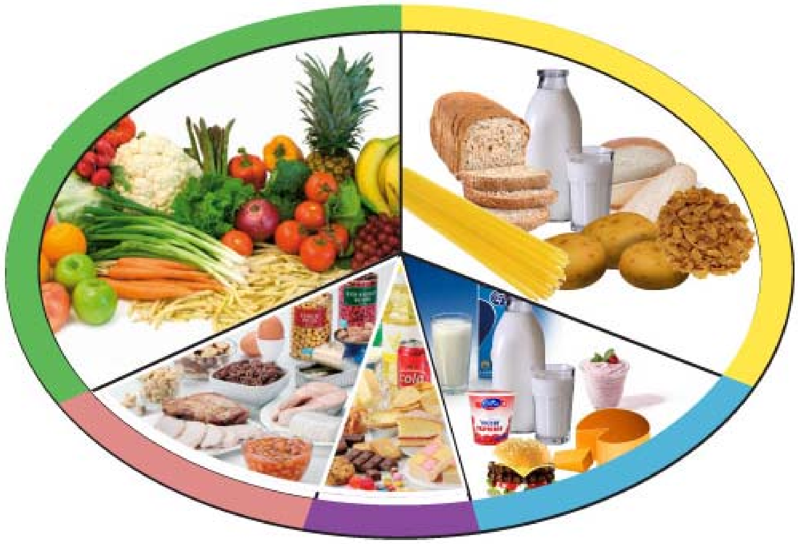


Illustration by Serge Mondon, September 2009

I hope you are now familiar with the 7 classes of food and their importance to the body. However, how much of each thing should we take in per day? Let's move on to find the answer.

Topic 10.4: Recommended daily amount of protein and energy

How long?

You will need 1 hour to complete Topic 10.1. It is advisable that you spend another 30 minutes of your own time to further review the Topic.

The energy need for the human body is measured in mega joules per day. The energy is used for:

a. Basal metabolism to maintain the life support processes in a person at complete physical and mental rest at normal room temperature.

b. Physical movement and locomotion in work and exercise.

A person's daily energy needs depend on the person's

- Age;
- Body weight;
- Sex, male or female;
- Work or Activity;
- Climate;
- Special conditions of pregnancy, breast feeding; and
- Illness and convalescence.

Table 10.4.1 shows the average daily energy needs for different age groups.

Age group	Average Energy Daily Needs (MJ)
Babies under 1 year old	0.46
Preschool children 2-3 years old	4.6
School children 8-9 years old	5.8
Male adolescent 14-16 years old	9.6
Female adolescent 10 -19 years old	7.3
Male adult 19-30 years old	10.5
Female adult 19-30 years old	7.9
Pregnancy (later half)	11.3
Lactation(first six months)	12.3
Elderly 71 +	6.4-8.3

Table 10.4.1: The average daily energy needs for different age groups.

Values taken from: http://www.hc-sc.gc.ca/fn-an/food-guide-aliment/basics-base/1_1_1-eng.php

Note it! / Important!

Please note that the amount of energy that you need also depends on what job you do.

Table 10.4.2 shows the daily energy requirements for light and heavy works carried out by both males and females in the age range of 19-30.

Type of work	**Energy (KJ) per day**
Woman doing light work	7955
Woman doing heavy work	9838
Man doing light work	10467
Man doing heavy work	12560

Table 10.4.2: The daily energy requirements for light and heavy works carried out by both males and females.

Values taken from: http://www.hc-sc.gc.ca/fn-an/food-guide-aliment/basics-base/1_1_1-eng.php

10.4.1 Energy Requirements Calculation

Now you are going to learn how to calculate the amount of energy that your body needs on a daily basis.

You can calculate how much energy your body needs using the equation below.

$$\text{Energy needs} = \text{Mass (kg)} \times \text{Average energy needs}$$

So, to work out your calculation you need to know your mass (which is measured in kilograms (kg)) and the age group to which you belong.

Activity

Activity 10.4.1

You are required to spend about 5 minutes on this activity.

Find your body mass. Refer to Table 10.4.2 above for your age group to find your average energy needs. Use the equation below to calculate your energy needs.

$$\text{Energy needs} = \text{Mass (kg)} \times \text{Average energy needs}$$

Well done, now you know how much energy you need in order for your body to function healthily and to be able to do all the activities that you want to do per day.

You can also calculate the amount of protein that your body need per day. You are now going to learn how to calculate your protein needs.

10.4.2 Daily Protein Needs

Not all food containing proteins will contain all the essential amino acids that your body needs. It is therefore advisable to consume a mixture of plants and animals source protein foods because they will provide you the correct quality of essential amino acids.

The protein quantity depends on the following factors shown in Figure 10.4.1 below.

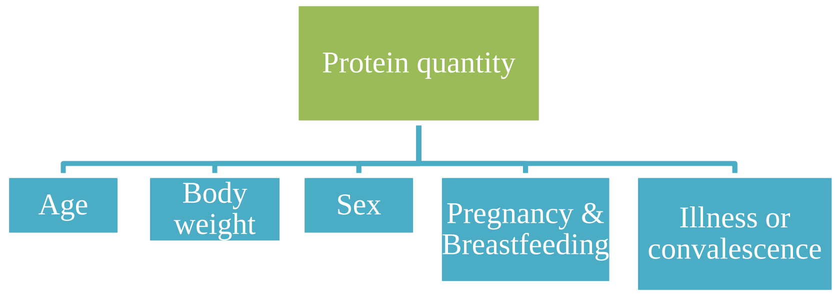


Figure 10.4.1: The factors affecting the quantity of protein that a person needs.

Table 10.4.3 shows the average daily protein needs for different age groups.

Age group	Average Protein Daily Needs(g)
Babies under 1 year	1.92
Preschool children 1-3 years	1.2
School children 4-9 years	0.93
Male adolescents 10-19	0.7
Female adolescents 10-19 years	0.64
Adult man	0.57
Adult woman	0.53
Pregnancy (later half)	0.69
Lactation (first 6 months)	0.83

Elderly	0.47

Table .10.4.3: The average daily protein needs for different age groups.

10.4.3 Protein Requirement Calculation

Previously you learnt how to calculate your daily energy needs; you can do likewise for protein. Try out the following activity in order to find out how much protein your body needs per day.

Activity

Activity 10.4.2

You are advised to spend about10 minutes on this activity.

You can now calculate how much protein your body needs. To work out your calculation you need to know your mass (kg) and in which age group you belong to. Refer to Table 10.4.3 for your age group and average protein needs.

$$\text{Protein needs} = \text{Mass (kg)} \times \text{Average protein needs}$$

I hope that you have been able to do this simple calculation by using the formula given above. Now that we know how much protein we require, let's learn about our other dietary requirements.

Topic 10.5: Dietary requirements

How long?

You will need 1 hour to complete Topic 10.1. It is advisable that you spend another 30 minutes of your own time to further review the Topic.

In order for your body to function properly you must be able to meet your dietary requirements. That means you should always bear in mind the activities that you have planned to do in a day. Hence, from there you should have a proper diet that will meet your energy and protein needs.

1. The daily diet is the food intake of one day and should consist of:

a. Variety of meals and foods that provide a mixture of the seven classes of food.

b. Correct amounts of:

   (i) energy providing foods.

   (ii) cell nutrients, water, proteins, minerals and vitamins.

   (iii) dietary fibres.

2. The **dietary balance** is achieved when **intake** of energy and nutrients **equals output** of energy and chemical materials.

INPUT	Dietary	**OUTPUT**
Energy and	$\longrightarrow$	Energy and
Nutrients	Balance	chemical Materials

Reflection

By looking back at the previous topics that you have studied, do you think that you are meeting your dietary requirements?

10.5.1 Malnutrition

It is the name given to all the body disorders as a result of a dietary imbalance, which involves both over-nutrition and under nutrition.

10.5.1.1 Under-nutrition

Under-nutrition is caused by a deficiency intake of energy providing foods and certain nutrients or excessive energy output in heavy physical work or strenuous exercise. Under-nutrition can lead to underweight and to some deficiency diseases.

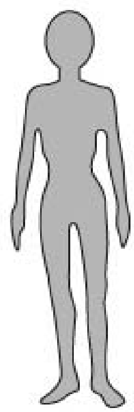


Figure 10.5.1: Illustration of an underweight person

Illustration by: Serge Mondon, September, 2009

10.5.1.2 Over-nutrition

Over-nutrition is caused by an excess dietary intake of energy providing foods and certain nutrients or by lack of energy output in physical work and exercise. Over-nutrition can lead to overweight and obesity.

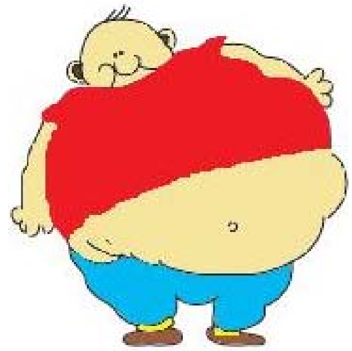


Figure:10.5.2: Illustration of an obese person

Illustration by: Serge Mondon, September, 2009

Adapted by: Carole Jacques, October, 2009

If your input of energy and nutrients is not equal to your output of energy and chemical materials, it can lead to over-nutrition and under-nutrition. Obviously this can cause harm to your body and you will experience some deficiency diseases.

10.5.1.3 Deficiency diseases

If you lack one or a few classes of food, your body will experience under nutrition disorder (deficiency diseases). If you have an excess of certain classes of food you will experience over nutrition disorder.

Activity

Activity 10.5.1

You should spend around 20 minutes on this activity.

Research the symptoms and the name of the disease or disorder that a person might suffer from if his or her diet lacks certain nutrients. Complete Table 10.5.1a below with your answers.

Nutrients lacking in the diet	Symptoms	Disorder
Vitamin A		
Vitamin B		
Vitamin C		
Vitamin D		
Iron		
Iodine		
Calcium		
Roughage (fibres)		
Proteins		

Table 10.5.1a: Table to complete with the symptoms and disorder caused by the lack of certain nutrients.

I hope that you have managed to complete the table with the necessary information. Table 10.5.1b summarises the under nutrition and over-nutrition disorders for the various classes of food. Read the table carefully and check how well you have done for the above activity.

Class of food	Over-nutrition disorder	Under nutrition disorder
Energy and Protein	Overweight and obesity Related disorders: • Heart disease • Diabetes • Bowel disorders • Joint disorders	• Starvation • Body wastage as in *marasmus* and *kwashiorkor* (swelling belly, reduced resistance to disease and poor mental development)

Class of food	Over-nutrition disorder	Under nutrition disorder
Vitamin A (Retinol) Fat soluble	• Poisonous in large doses	• Night blindness • Cornea disease- *Keratomalacia,* causing • Blindness • Poor skin health
Vitamin B_1 (Thiamine) Water soluble	• No effect	• Lethargy • Retarded growth • *Beri beri* (nerves and muscles degenerate)
Vitamin C (Ascorbic acid) Water soluble	• No effect- excess removed in urine	• *Scurvy* (bleeding gums, loose teeth, easily bruised) • Poor wound healing
Vitamin D (Fat soluble)	• Poisonous in large doses	• *Rickets* (bones softening) • Tooth decay
Calcium	• None	• *Rickets* • Stunted growth • Muscle spasm

Class of food	Over-nutrition disorder	Under nutrition disorder
Iron	• Can be poisonous in large doses	• *Anaemia* (due to insufficient haemoglobin causing reduced oxygen carrying capacity, causes breathlessness and weakness)
Iodine	• Harmful and poisonous in large doses	• *Goitre* (swelling of the thyroid glands) • *Cretinism* (stunted growth and mental retardation in children)
Roughage (fibre)	• Promotes healthy peristalsis and moves food rapidly through gut • Can affect iron and calcium absorption	• Constipation • Increases the risk of getting colon cancer and piles
Water	• None	• Dehydration • Death in 2-3 days

Table 10.5.1b: A summary of over-nutrition and under nutrition disorders.

We have now come to the end of this topic. I hope that you have found it very useful and will share what you have learned with your family, relatives and friends.

In the science laboratory, there are special ways of testing the presence of the different classes of food in a particular food. In the next topic, you are going to learn how to carry out different food tests.

Topic 10.6: Food tests

How long?

You will need 1 hour and 10 minutes to complete Topic 10.1. It is advisable that you spend another 35 minutes of your own time to further review the Topic.

When carrying out the different kinds of food tests, there are certain procedures that you must follow so that your results are effective

1. You should always carry out a standard test. For example, if you are testing foods for protein, begin by testing a food which is rich in protein such as egg albumen. Keep the result of this test, so that you can compare your results with other tests.

2. You should keep the food samples away from each other. This means using clean test-tubes, spatulas and pipettes for each kind of food.

3. You should use the same amount of reagents and food for each test as much as possible.

The procedures for the different food tests are given in Table 10.6.1 below.

Class of food	Chemical reagent	Procedure	Final observations
Reducing sugar (glucose)	Benedict's solution	1. Grind food and place in a clean and dry test tube. 2. Add some Benedict's solution to the food and heat gently.	If food is rich in glucose, the solution will change colour from blue to green, then yellow and finally to brick red (orange red). If glucose is absent solution will remain blue in colour.

Class of food	Chemical reagent	Procedure	Final observations
Starch	Iodine solution	Add drops of iodine solution to food.	If food rich in starch iodine will change colour from yellowish brown to blue black. If starch is absent, iodine will remain yellowish brown.
Protein	Biuret test: (Sodium hydroxide or potassium hydroxide and Copper sulphate)	1. Grind food and place in a clean and dry test tube. 2. Add some sodium hydroxide to the food. 3. Add drops of copper sulphate. 4. After each drop shake the mixture gently.	If food is rich in protein, the solution will change colour from blue to purple. If protein is absent, solution will remain blue in colour.
Fat	Grease spot test	1. Rub the piece of food on the grease paper or filter paper. 2. Leave to dry.	If a permanent grease spot or translucent spot is formed, fat is present. If there is no grease spot, then fat is absent.
	White emulsion test Alcohol (ethanol) and distilled water	1. Half fill a test tube with alcohol. 2. Grind food and add to the alcohol. 3. Shake the mixture gently until the fat in the food is dissolved. 4. Allow the mixture in the test-tube to	If a white emulsion is formed fat is present. If solution remains colourless, fat is absent.

Class of food	Chemical reagent	Procedure	Final observations
		settle. 5. Half fill another test-tube with distilled water. 6. Use a clean pipette and remove some alcohol mixture from the first test-tube and add in the distilled water. 7. Shake the mixture gently.	

Table 10.6.1: Procedures for food tests

Group activity

Group Activity 10.6.1

You should spend around 30 minutes on this activity.

In groups of four, carry out food tests on five food samples including bread. For each food sample you are advised to carry out the four tests stated below so that you get a good understanding of the different class of food that each food sample is rich in.

a. Starch test

b. Glucose test (Reducing sugar)

c. Protein test (Biuret test)

d. Fat test (Grease spot test or White emulsion test)

Use the information from Table 10.6.1 for you to carry out the different food tests.

Use the Table 10.6.2 to record your results. If the class of food is present, put a tick in the appropriate box.

	Class of food present			
Food	Starch	Glucose	Protein	Fat
Bread				

Table 10.6.2 – Table of results showing the class of food present in the sample food tested

Wasn't that interesting to do? Well, let us see what you should have noticed from the activity through the feedback.

Feedback

Feedback to Group Activity 10.6.1

I hope that you have found the activity interesting. From the tests, you may have noticed that some food contains different classes of food. For the food you tested, you should have put a tick to show the presence of:

- Glucose if a brick red /orange red colour was obtained with the Benedict's test;
- Starch if you got a dark blue/blue black colour with the iodine test;
- Protein if a purple colour was obtained with the Biuret test;
- Fats if the grease spot test resulted in translucent grease spot OR if the alcohol test resulted in a white emulsion.

We have now come to the end of this topic. What are some effects of over nutrition and under nutrition for some of the classes of food? How can you test for glucose, starch, protein or fat in your food?

Now let us summarise what you have learned in this unit.

Unit Summary

Summary

In this unit you learned about the importance of food in our everyday lives. You learned that food is a source of energy, it is needed for the formation of new protoplasm during growth, to repair body tissues and most importantly it is needed for all the metabolic reactions in order to keep the organisms healthy and warm. Also, from this unit you have learnt the importance of having a balanced diet. A balanced diet prevents your body from suffering from any malnutrition diseases. In addition to this you learnt about the amount of energy and protein that each age group needs on a daily basis, and more importantly you learned specifically about how to calculate the amount of energy and protein that your body needs per day.

Last but not least you had the opportunity to carry out the different food tests. This practical work has enabled you to experiment with the chemicals and equipments on your own or with your peers to find out the classes of food that some of the foods that you consume are rich in. In a way this will help you to better plan your diet.

Unit Assessment

Assessment

Self-Assessment 10.1

You are advised to spend 20 minutes on this self-assessment.

This self-assessment consists of two sections, section A and section B. Section A consists of five multiple choice questions and you are advised to spend five minutes on this section. Section B contains two structured questions and you advised to spend 15 minutes on this section.

Section A – Multiple choice questions

Each question consists of four suggested answers A, B, C and D. Select and circle the best answer for each question.

1. The largest amount of energy value per gram is provided by:

   A. Carbohydrate C. Protein

   B. Water D. Fibre

2. The food which is rich in protein:

A. Lettuce
C. Bean
B. Chocolate
D. Yam

3. The children may suffer from rickets if they have a deficiency of:

A. Vitamin A
C. Vitamin C
B. Vitamin D
D. Iron

4. Which of the following females, requires the greatest amount of protein per day? (*They all have the same body weight)*

A. 15 year old schoolgirl
C. 65 year old woman
B. 30 year old pregnant woman
D. 30 year old breastfeeding woman

5. A sample of food is mixed with water and then tested to find out its contents.

The results are shown below in the table.

Test	Result
Iodine solution added.	Yellowish brown colour.
Benedict's solution added and mixture heated.	Brick-red colour.
Mixture shaken with ethanol and poured into water.	White emulsion.
Dilute sodium hydroxide solution added, followed by few drops of dilute copper sulphate solution.	Blue colour.

What conclusion can be made from these results?

A. Fat and reducing sugar were both present.

B. Fat and starch were both present.

C. Only starch is present.

D. Only reducing sugar was present.

Section B:

This section consists of two structured questions and you are advised to spend 15 minutes. Read the questions very carefully before attempting to them.

1. The table below shows the percentages of the different classes of food in several food samples.

Food sample	**Carbohydrate (%)**	**Protein (%)**	**Fat (%)**	**Water (%)**	**Fibre (%)**
Fish	0.5	18	0.9	45	38
Beef	0.5	17	30	41	18
Rice	88	7	1	5	0
Soya bean	15	45	25	23	2
Milk	8	4	5	89	0
Orange	10	6	0	67	28
Lettuce	4	3	0	55	42

Use the information from the table to answer the following questions.

a. Which food sample will give the most energy?

b. Which food sample is good for the production of enzymes, hormones and anti-bodies?

c. Explain why orange and lettuce can be considered of two foods that can keep you healthy.

d. Why can fish prevent you from getting simple goitre?

e. If it happens that the world is faced with a food crisis whereby there is a shortage of protein and providing plant proteins is the only solution for the problem, which food sample from the table can be used to overcome this problem? Suggest reasons why this food can be used.

2. A series of tests were carried out by a group of students to confirm the presence of protein, starch and glucose.

	Name of reagent	Colour of reagent before testing	Final colour of solution
Protein			
Starch			
Glucose			

I hope that you have found the self-assessment easy. Once you have completed, refer to Answers to Self-assessment 10.1 for the correct answers.

Answers to self-assessment

Answers to Assessment

Answers to Self-assessment 10.1

Below are the answers for sections A and B of the self-assessment. Read the answers very carefully.

Section A- Multiple choice questions

1.A

2.C

3.B

4.B

5.A

Section B- Structured questions

1.(a) Rice

(b) Soya bean

(c) Both of them are good source of water and fibre. Water is needed for transport and to act as a solvent for most of the chemical reactions taking place in the body. Fibres assist in peristaltic movement and hence prevent constipation.

(d) Fish contains the mineral iodine which prevents goitre.

(e) Soya bean. This is because it has a high percentage of protein and it also can provide a good portion of other nutrients such as carbohydrates, fats and water. Moreover, dry soya beans are not perishable and therefore can easily be transported.

2.

	Name of reagent	**Colour of reagent before testing**	**Final colour of solution**
Protein	Sodium hydroxide and copper sulphate	Blue	Purple
Starch	Iodine solution	Yellowish brown	Blue black
Glucose	Benedict's solution	Blue	Brick red

Contents

Unit 11

Support and Movement

Introduction

In unit 6, we studied osmosis and discovered how it helps in keeping plant cells turgid. We shall learn more about how turgidity helps in the support of plant parts that are not woody in this unit. In addition we shall look at woody plants and their support mechanism.

Furthermore, in the section on specialized cells of unit 6, we had a look at skeletal muscle cells. In this unit, we shall also be considering the mammalian skeleton and its importance in the support and locomotion of mammals. This will allow us to look more closely at the skeletal muscle cells and the role they play in the movement of mammals.

In this unit you will learn about the following:

- The types of herbaceous plants and woody plants and the differences between them
- The importance of turgor pressure in the support of herbaceous plants and leaves of plants
- Lignin and its role in stiffening the cell walls of woody plants
- The role of xylem and phloem in the production of wood and bark of woody plants
- The differences in the stems of woody dicots and woody monocots such as palm trees
- Annual growth rings and how they are used to determine the age of exogenous trees
- Types of skeletons and the general functions of the skeleton
- Parts and functions of the human skeleton and the types of joints in the human body
- Types of muscles in the human body and the action of antagonistic muscles in allowing flexion and extension of body parts
- How some bones of the body function as levers.

Note it! / Important!

The outcomes for the unit are listed below. The outcomes written in **bold** are the extended outcomes and they are intended for students who are aiming for Grade B or higher in the examinations.

Outcomes

Upon completion of this unit you will be able to:

- *describe* the importance of lignin in supporting woody parts of plants and turgid cells in supporting non-woody parts of plants.
- *state* differences in properties of bone and cartilage which make up the skeleton of a mammal.
- *identify* the ulna, radius, humerus, scapula, tendons, biceps and triceps on the structure of the skeleton and muscles of the human arm.
- *describe* how the antagonistic muscles and bones act together to flex or extend the arm.
- *state* that a joint occurs where two bones meet.
- *explain* that a synovial joint allows for the movement of two bones and that cartilage and synovial fluid reduce friction between the bones.
- **explain that the contraction of the biceps produces a turning effect, with the elbow joint as a pivot.**
- **explain that the small distance between the attachment of the biceps and the pivot means that a large force is required to produce a large effect and relate this to the ability of muscles to produce large forces and their inability to contract over large distances.**

Terminology

appendicular skeleton:	The bones that form part of the limbs (arms and legs) in the body of a mammal.
axial skeleton:	The bones that make up the backbone and the skull.
cambium:	A cylindrical layer of cells in plant stems and roots that produces new secondary xylem, secondary phloem and cork tissues.

cardiac muscle:	Muscle found in the heart.
cartilage:	The strong elastic tissue that forms part of the nose, ears and throat of mammals and forms most of the skeleton in infancy, changing to bone as the baby grows.
cortex:	The tissue in plant stems and roots between the outer epidermal layer and the vascular cambium.
ecdysis:	Shedding of the exoskeleton by arthropods such as insects and crustaceans and reptiles by regular molting.
extension:	The act of straightening a hinge joint.
flexion:	The act of bending a hinge joint.
first order lever:	A lever system where the fulcrum lies between the load and the effort.
fulcrum:	A fixed point at which a lever pivots.
ligament:	A sheet of tough fibrous tissue that connects bone or cartilage at a joint.
lignin:	Lignin is a complex compound in the cell wall of plants that gives plants its rigidity and strength.
periderm:	The outer layer of plant tissue in the stem of woody plants.
pith:	The central tissue in the stem of vascular plants.
second order lever:	A lever system where the load lies between the fulcrum and the effort.
skeletal muscle:	A muscle that is attached to a bone and is concerned with the locomotion of the animal.
smooth muscle:	Muscle found in tubular organs, concerned with the movement of materials through the organs.
tendon:	A band and of tough white fibrous connective tissue that attaches a skeletal muscle to bone.
third order lever:	A lever system where the effort lies between the load and the fulcrum.

vascular bundle: The vascular bundle contains xylem and phloem vessels.

How long?

Study Time

Table 11.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	7 hours and 30 minutes	3 hours 45 minutes
Full-time student within the conventional school setting OR Part-time student	7 hours	3 hours 30 minutes

Table 11.0: The time needed for you to work on this unit

Topic 11.1: Support Mechanism of Herbaceous Plants

How long?

You will need 40 minutes at the most to do the activities in this topic. It is advisable that you spend another 20 minutes of your own time to further study examples of herbaceous and woody plants.

We saw earlier in Unit 1, that some plants are herbaceous (non-woody) and some are woody. Some herbaceous plants and some woody plants are shown below.

Figure 11.1.1: Herbaceous and woody plants

Photos taken by Mariette Lucas (2010)

Let us start by reviewing your knowledge of plants which are herbaceous and plants which are woody in Activity 11.1.1 below.

Activity

Activity 11.1.1

You should complete this activity in about 5 minutes.

a. Study the 6 plants above carefully, and then try to group them as herbaceous plants and woody plants in Table 11.1.1 below.

Herbaceous Plants	Woody Plants

Table 11.1.1: Herbaceous and woody plants

b. Based on the classification that you have completed above, write at least two of the criteria that you have used to differentiate between the herbaceous plants and the woody plants.

I hope that the task was easy for you. Refer to Feedback to Activity 11.1.1 to verify your answers.

Feedback

Feedback to Activity 11.1.1

You have surely realized that the woody plants, plants 2 and 6, stand upright and look sturdy. On the contrary plant 3, which is an herbaceous plant, needs to creep over fences or climb on some support. Plants 1, 4 and 5 are also herbaceous plants. Notice the leaves of plant 1; they look flabby.

You may also have noticed that plants 1, 4 and 5 are house plants. In fact most house plants and garden plants are herbaceous.

Reflection

Reflection 11.1.1

Take 5 minutes for this reflection.

As you have realized from the above activity, herbaceous plants, and plant leaves in general, easily become flabby. What could be the reason for that? Refer back to the section on osmosis in unit 6 and write your explanations below.

Feedback

Feedback to Reflection 11.1.1

Very good! I hope you realized that herbaceous plants and plant leaves in general are able to remain firm and erect due to turgor pressure within their cells.

Let us talk further about the importance of turgor pressure in herbaceous plants and in leaves in Activity 11.1.2 below.

Activity

Activity 11.1.2

You should do this activity in about 5 minutes.

Look at the two plants below.

Plant X

Plant Y

Figure 11.1.2

Photos taken by Mariette Lucas (2010)

Both Plant X and Plant Y are of the same type. The leaves of Plant X droop down, whereas those of Plant Y are erect.

Based on the reflection that you have made above and what you have learnt in Unit 1 on osmosis in plant cells, answer the question below.

How do the conditions of Plant X and Plant Y help you understand the support mechanism of herbaceous plants?

____

____

____

____

____

Feedback

Feedback to Activity 11.1.2

Good work! Due to lack of water, the leaves of Plant X have become **flaccid**. This happens when water moves out of the cells. The vacuoles shrink and the cell membrane detaches from the cell wall. **Plasmolysis** takes place. You must have realized that this happens when the plant does not get water to replace the water that it keeps on losing during transpiration.

The leaves of Plant Y are erect and retain their shape, because the plant cells have enough water. This makes the cells **turgid** and keeps the leaves firm. It is due to turgidity that herbaceous plants are able to stay firm and that the leaves can maintain their shape.

Summary

Summary 11.1.1

Take about 5 minutes to complete the activity below.

I have summarized the support mechanism in herbaceous plants in the text below.

To help you better learn the concepts, I have left some blank spaces in the text for you to complete using appropriate words.

Read the text carefully, and then answer the questions which follow.

The importance of turgor pressure in plants

We saw in Unit 6 in the section on plant cells, that cells of plants contain a large fluid-filled ______________ with substances such as salt and sugar dissolved in the liquid.

When a plant gets water, the water in the cell pushes the ________________ against the cell membrane. As the ______________ is strong and relatively inelastic, it exerts an opposing pressure, which prevents the entry of excess water into the cell. The pressure that is exerted helps to keep the ________ firm. When the cell is in this state it is said to be _______________. This pressure is known as _______________ ________________.

When a plant gets little or no water, the plant starts to _______. In this case the vacuoles ____________and as a result the cells become less stiff. This situation is known as _____________________.

Turgor pressure plays an important role in the support of __________________ plants. Herbaceous plants do not have ______________support. They rely on turgor pressure to keep the plant ____________ and ____________. It is for this reason that herbaceous plants live for shorter periods of time and do not grow ___________. Many herbaceous plants die at the end of one growing season.

____________ and soft stems of woody plants also use turgor pressure to keep them firm and erect.

Well done! I hope that you found the exercise a good way to ensure that you have mastered the concepts on support mechanisms of herbaceous plants.

I have provided the feedback at the end of the topic below. You are strongly advised to complete the text assignment above before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Summary of Topic 11.1.1

The importance of turgor pressure in plants

We saw in Unit 6 in the section on plant cells, that cells of plants contain a large fluid-filled vacuole with substances such as salt and sugar dissolved in the liquid.

When a plant gets water, the water in the cell pushes the cytoplasm against the cell membrane. As the cell wall is strong and relatively inelastic, it exerts an opposing pressure, which prevents the entry of excess water into the cell. The pressure that is exerted helps to keep the cell firm. When the cell is in this state it is said to be turgid. This pressure is known as turgor pressure.

When a plant gets little or no water, the plant starts to wilt. In this case the vacuoles shrink and as a result the cells become less stiff. This situation is known as plasmolysis.

Turgor pressure plays an important role in the support of herbaceous plants. Herbaceous plants do not have woody support. They rely on turgor pressure to keep the plant upright and firm. It is for this reason that herbaceous plants live for shorter periods of time and do not grow tall. Many herbaceous plants die at the end of one growing season.

Leaves and soft stems of woody plants also use turgor pressure to keep them firm and erect.

This brings us to the end of topic 11.1 but I hope you now understand the importance of turgor pressure for herbaceous plants.

We shall now see what keeps woody plants firm and upright in the next topic.

Topic 11.2: Support Mechanism of Woody Plants

How long?

You will need 1hour 30 minutes at the most to do the activities in this topic. It is advisable that you spend another 45 minutes of your own time to further look at woody and herbaceous plants.

Trees (single stem or trunk, tall, perennial and long lived), **shrubs or bushes** (woody plants with multiple stems and low in height; less than 5m) and certain **vines** (climbing plants such as grape, ivy, passion fruit and bougainvillea) are woody plants.

To help us better understand the support mechanism of trees, shrubs and certain vines (woody plants), let us start off by comparing the stems of herbaceous plants with those of woody plants.

11.2.1 Comparing herbaceous and woody plants

Activity

Activity 11.2.1

You should complete the activity in about 10 minutes.

Pictures of stems of herbaceous plants and woody plants are shown below.

Stems of herbaceous plants

Stems of woody plants

Figure 11.2.1

Photos taken by Mariette Lucas (2010)

Look carefully at the examples of herbaceous plants and woody plants in the photos above. Once you are sure that you can differentiate between herbaceous plants and woody plants, go out and look for similar plants.

You may wish to look for some twigs or small branches of trees or shrubs (stems of woody plants), as well as the stem of at least two herbaceous plants.

a. Draw the stems below and try to find the common name and the scientific name of each plant. Write the name of each plant next to its drawing.

Stems of herbaceous plants

Stems of woody plants

b. Observe the colour and texture of the stems of the herbaceous plants and try to bend them. Write your observations in the appropriate column in Figure 11.1.1 below. Then, repeat the same activity for the stems of woody plants.

In addition to the above, find out the approximate heights that the plants in each of the two groups usually grow and for about how long each type of plant lives.

Be attentive to any other important characteristics of the plants that you may notice. Note these down in the table in the space for "Other observations."

Features	Herbaceous Plants	Woody Plants

Colour		
Texture		
Malleability (bending potential)		
Height		
Life span		
Other observations		

Table 11.2.1: Differences between herbaceous and woody plants

Feedback to Activity 11.2.1

We are sure that you quickly realized that the stems of herbaceous plants are soft, mostly green and flexible, whereas the stems of woody plants are hard, brittle (hard and breakable), brownish/grayish in colour and dry with bark on the outside. The hard wood makes it possible for woody plants to live for many years and grow tall.

We shall learn about the structure of woody stems next.

11.2.2 Structure of woody stems

We saw earlier that trees, shrubs and some vines are woody. A woody plant is a plant that uses wood as a structural tissue. The main parts of the young stem of woody plants are shown in Figure 11 2.2 below.

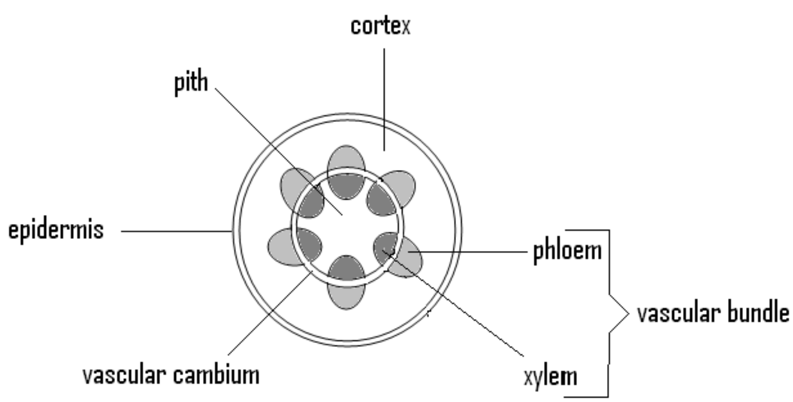


Figure 11.2.2: Cross section of a young woody stem.

Adapted from: http://en.wikipedia.org/wiki/Plant_stem

Each part of the stem has a specific function. These are described in Table 11 2.1 below.

	Parts of a young woody stem
1	Epidermis: The outermost layer of cells that cover the plant body and protect the stem from insects, diseases and water loss. In older stems the epidermal layer becomes bark. Bark is made of dead cells.
2	Cortex: Tissue between vascular cambium and epidermis. Acts as packing tissues, helps to support the stem and stores food. In green stems, the outer layer of the cortex contains chloroplasts and makes food by photosynthesis.
3	Vascular bundle: Consists of xylem and phloem tissues. Tissues transports food, water and mineral salts through the stem of the plant.
4	Phloem: Transports food from the leaves of the plant to all the other parts.
5	Xylem: Transports water and mineral salts from the roots to other parts of the plant.
6	Vascular cambium: Thin layer of cells that make new xylem and phloem cells.
7	Pith: Central tissue of the stem. Together with the cortex act as packing tissues which help to support the plant.

Table 11.2.1: Parts of a young woody stem

Now find a group of about six students doing the course and together test your understanding of the parts of a young woody stem through the quiz below.

Group activity

Group Activity 11.2.1

You should be able to do the quiz in 5 minutes.

This is a quiz game. Before you start the quiz study the contents of Figure 11.2.2 and Table 11.2.1 above carefully.

Invite one of the group members to be a quiz master. The quiz master should have the correct answers to all the questions.

The quiz master should award 2 marks for the correct answer the first time that the question is asked and if the question needs to be offered a second time, 1 mark should be awarded if the question is correct. If the question cannot be answered during the second round, the participant or group does not score any marks.

Good luck!

Quiz questions

Which of the following describes the vascular cambium?

A. Central tissue of the stem
B. Make new xylem and phloem
C. Consists of xylem and phloem tissues
D. Transports food to all parts of the plant

Which part of the stem has a protective role?

A. The xylem
B. The cortex
C. The epidermis
D. The vascular bundle

Which tissue is found between the vascular cambium and the epidermis?

A. Pith
B. Cortex
C. Xylem
D. Phloem

What is bark?

A. A layer of dead cells replacing the epidermis
B. The outer most layer of cells in young stems
C. Packing tissue which help to support the stem
D. Tissues which help in the transportation of water in the stem

Feedback

Feedback to Group Activity 11.2.1

That was a good exercise. I am sure that you enjoyed it and that all members of your team have scored full marks on the quiz. To ensure that you have all mastered the parts of a young woody stem, check your answers again with the information in Table 11.2.1 above.

We have seen above that xylem and phloem are transport tissues in vascular plants. Apart from being the transport tissues, xylem and phloem are also the support tissues of woody plants.

Let us learn more about the role of xylem and phloem in the support of woody plants in the text below.

The role of xylem and phloem in the support of woody plants

Most woody plants are dicots, but some are monocots.

In woody plants the cell walls of the vessels of the xylem tissue are thickened and impregnated with a substance called **lignin**. Lignin is the material which stiffens the stems of woody plants. It makes the cell wall very strong and impermeable. Water and nutrients cannot pass through lignified cell walls and as a result the cytoplasm dies. The lignified cell walls of the fibers and vessels do not however, affect the passage of water in the xylem tissue.

The structure of the stem of a woody dicot plant during its first year of growth is different from that of older stems. When a young plant starts to grow its shoots and roots, it produces primary tissues. This is called **primary growth**. During primary growth, **primary xylem** and **primary phloem** are made by the **vascular cambium**.

As the plant continues to grow and become older, new xylem, called **secondary xylem**, is produced by the **vascular cambium** each year. This gives rise to new layers of hard secondary xylem tissue known as **wood**, which grows toward the center in the roots of plants and toward the outside in most stems. This accumulation of annual layers of wood, produced by the cambium, causes the stems or trunks of trees, shrubs and woody vines to increase in diameter.

As the tree trunk expands with secondary growth, new secondary xylem (wood) forms on the inside of the vascular cambium tissue and new secondary phloem on the outside. The secondary phloem becomes the inner bark and it comprises of living cells of the cortex and secondary phloem.

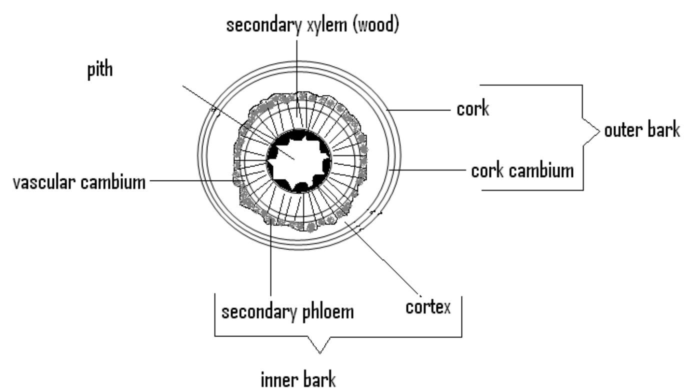
The periderm replaces the epidermis during secondary growth. It is a thick layer of dead tissue, formed of cork and cork cambium. This outermost layer of bark in old stems is known as the outer bark and consists of non-living cells.

As a woody stem grows older, the primary phloem, cortex and epidermis are completely lost. The pith and primary xylem are however always present although they may be greatly reduced.

Adapted from: http://www.answers.com/topic/woody-plant-1

In Figure11.2.3 below I have showed a cross section of a one year old tree trunk.

In the diagram, one year's annual growth (one growth ring) is shown by one ring of secondary xylem and one ring of secondary phloem with the



vascular cambium in between.

Figure 11.2.3: Cross section of a one year old tree trunk, showing the annual growth rings.

Drawn by Mariette Lucas (2010)

We shall now have a look at some real stems of plants to better understand the structure of the stem of woody dicot plants in Activity11.2.2 below.

Activity

Activity 11.2.2

You should complete the activity in about 10 minutes.

a. Cut a cross section of a young stem of a woody plant. Then look for a cross section of an older tree trunk. Carefully observe the two sections of wood and write down at least four differences that you can see between them in Table 11.2.2 below.

Differences between:	
Young woody stem	Old woody stem

Table 11.2.2 (a): Differences between a young woody stem and an older woody stem

b. Look for a variety of wood blocks with the bark still on them, such as the ones shown below.

Wood block A

Wood block B

Figure 11.2.4: Wood blocks

Photos taken by Mariette Lucas (2010)

Examine each of the wood blocks that you have gathered and try to identify the inner bark, the outer bark and the wood. Then make a sketch of two of the wood blocks that are most different in the space below.

On the drawing that you have made, clearly label the **inner bark**, the **outer bark** and the **wood**.

If possible find the common name and scientific name of the tree for each block of wood and write them down under your drawings.

c. Make a collection of the bark of as many trees as you can or make texture rubbings of the bark of the trees. Then conduct a research from the local people about the usefulness of a few of the bark that you have collected. Show the information that you have gathered below, including texture rubbings of the bark and any diagrams or other illustration.

We hope that you have made a lot of new discoveries about the bark of trees in the above activity.

I have provided the feedback to Activity 11.2.2 at the end of the topic. You are strongly advised to complete the exercises above before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Let us proceed by looking at woody monocots.

In the above section, we were looking at woody dicots. As we have already mentioned in Unit 6, not all dicot plants are woody; some dicot plants are herbaceous. Similarly, not all monocot plants are herbaceous; there are some monocot plants that are woody.

The stems of the woody monocot plants differ from those of woody dicot plants. I have summarized some of these differences in the text below.

Differences between woody dicots and woody monocots

Herbaceous plants (most monocots) and woody plants (most dicots) have basic types of tissues. These are the vascular tissue (xylem and phloem), pith, epidermis, and the outer protective layer.

The arrangement of the xylem and phloem are different in herbaceous plants compared to woody plants. In herbaceous plants, the vascular tissues (xylem and phloem) grouped in bundles are scattered throughout the pith that makes up most of the tree's internal structure. You will recall that in trees (woody dicot plants), the vascular tissues are arranged in a circle between the pith and the cortex.

In the stems of herbaceous plants there is also no sharp dividing line between the cortex and the pith as in woody plants.

The stems of herbaceous plants exhibit only primary growth. Hence in the stem of monocot plants there are no secondary growth as in the stems of dicot plants.

As there is no secondary growth in the stems of monocot plants, the diameter of the stem does not increase with the age of the tree. Therefore, annual growth rings are not apparent in monocot plants.

However, in some monocots such as palms, wood is formed in bundles from meristem cells (primary plant tissue found at the tip of shoots and roots) within the stem. Palms are examples of woody monocots.

Let us look closer at the cross section of the stem of a woody monocot plant (the coconut tree) and that of a woody dicot plant (the takamaka tree) in the activity below.

Activity

Activity 11.2.3

You should complete the activity in about 5 minutes.

A cross section of the trunk of a coconut tree (*Cocos nucifera*) and that of a takamaka tree (*Verticillium calophylli)* are showed in Fig 11.2.5 below.

Coconut (*Cocos nucifera*) Takamaka (*Verticillium calophylli)*

Figure 11.2.5: Cross sections of the trunk of the coconut tree and the trunk of the takamaka tree

Photo taken by Mariette Lucas (2010)

Use the information in the text above and the photos of the trunk of the coconut tree and that of the takamaka tree in Figure 11.2.5, to help you understand the differences and similarities in the stems of woody dicots and woody monocots.

1. Write two ways in which the trunk of the coconut tree and the trunk of the takamaka tree are similar.

    i.

ii.

2. Complete the table below to show the differences in the stems of woody monocots and woody dicots.

	Differences in the stems of	
	woody monocots (e.g. coconut)	woody dicots (e.g. takamaka)
Arrangement of xylem and phloem tissues		
Separation of pith and cortex		
Exhibition of primary and secondary growth		
Increase in the diameter of the stem		
Presence of annual rings		

Table 11.2.3 (a): Differences in the stems of woody monocots and woody dicots

Good observations and good thinking!

I have provided the feedback at the end of the topic. You are strongly advised to complete the above activities before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Let us now learn how to tell the age of a tree.

How old is a tree? Have you any idea of how the age of a tree is known?

Those of you who have some ideas write them below.

____

____

____

Good! If you do not have a single clue, do not worry. You will soon be showing your friends and relatives annual growth rings on tree trunks and getting them to find the age of the tree!!!

Woody plants have annual growth rings. I am sure that you have already seen the growth rings on tree trunks that have been cut. Let us read the text below to learn more about annual growth rings.

Growth rings in woody plants.

Trees may be grouped as exogenous and endogenous trees, according to the way in which their stem diameter increases.

Exogenous trees grow by the addition of new wood (secondary xylem) outwards. The great majority of trees including all conifers and almost all broadleaf trees are exogenous.

Endogenous trees grow by addition of new secondary xylem (wood) inwards. Most of the monocot trees are endogenous trees.

Exogenous trees create growth rings as new wood is laid down concentrically (around a center) over the old wood. The accumulation of annual layers of wood produced by the cambium causes the stem to enlarge in diameter. The oldest wood is found in the center of the stem or tree trunk.

The growth rings are visible by alternating light and dark rings. The number of growth rings that a tree has depends on the climate (the number of wet and dry seasons in one year). In temperate climates, and tropical climates with a single wet-dry season alternation, one pair of light and dark rings represent one year of growth; these are known as annual rings. In areas with two wet and two dry seasons each year, there may be two pairs of light and dark rings each year.

Light rings form in spring when there is plenty of rain and growth is rapid.

Dark rings form in summer when there is less rain and growth is slower. The rings look dark because the xylem tubes are close together.

The annual rings on trees can be used to determine the age of the tree. Age determination is impossible in endogenous trees.

Adapted from: http://en.wikipedia.org/wiki/Tree

Do you now see the growth rings? I am sure that the answer is yes. Below we shall be looking at some annual growth rings on tree trunks.

Activity

Activity 11.2.4

You have about 5 minutes to do the activity.

Cross sections of three different tree trunks are shown below.

Tree trunk A

Tree trunk B

Tree trunk C

Figure 11.2.6: cross sections of three tree trunks

Photos taken by Mariette Lucas (2010)

Note it! / Important!

Before you attend to the questions below, try to see if you can see the light rings and the dark rings on each tree trunk. Remember that one year's growth is indicated by one light ring and one dark ring.

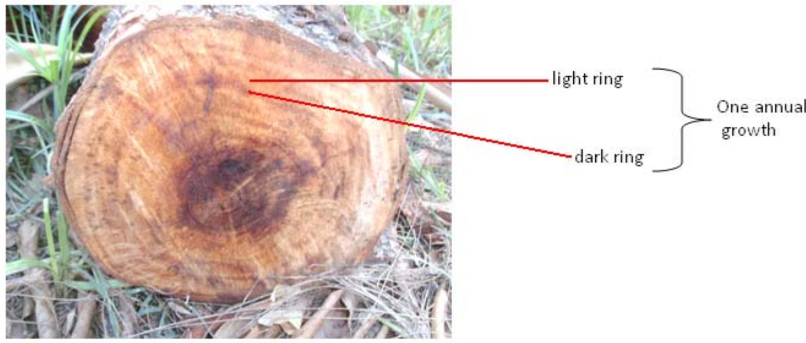


Figure 11.2.7: Light and dark growth rings on a tree trunk

Photo taken by Mariette Lucas (2010)

Now attend to the questions which follow.

a. Count the growth rings on each tree trunk and write them down below in (i):

   i. Tree trunk A: ___________________

      Tree trunk B: _____________________

      Tree trunk C: _____________________

   ii. Place the tree trunks in order by writing their respective label in the boxes. Start with the oldest tree trunk.

       Indicate the age of each tree trunk also in the boxes.

Oldest tree trunk → youngest tree trunk

iii. How many light and dark rings does the oldest tree trunk have?

b. How many light and dark rings are there usually in one year's growth?

c. What causes some of the growth rings to be dark and others to be light?

Well done!

I have provided the feedback at the end of the topic below. You are strongly advised to answer the above questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 11.2.2

a. Some of the observable differences between young and old woody stems are:

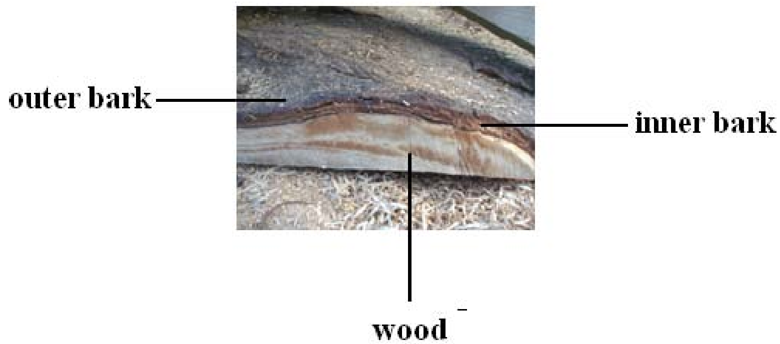
Differences

Young woody stem	Old woody stem
No bark present	Bark present
Does not contain hard wood.	Contains layers of hard wood
Growth rings are absent	Growth rings are present
Epidermis present	Epidermis absent

Table 11.2.2 (b): Differences between a young woody stem and an older woody stem

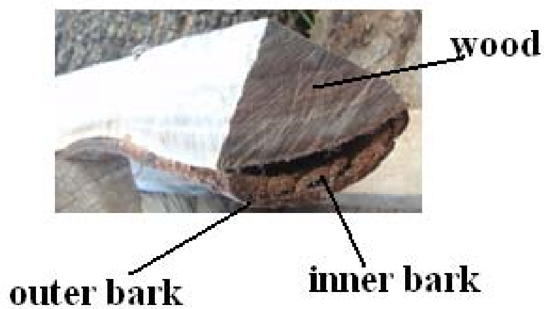
b. The **inner bark**, **outer bark** and **wood** in wood block A and wood block B above are illustrated below.

The wood blocks have been taken from the tree *Verticillium*



calophylli commonly known as the Takamaka Tree.

Wood block A



Wood block B

c. Some of the uses of bark include barks such as cinnamon bark that is used as spices and other flavourings. Other barks are used as medicine, dyes, varnish, paint, ink and glue. Barks have also been used to make cloths, canoes, ropes, and used as surfaces for paintings and maps. A number of plants are also grown for their attractive bark colorations and surface textures.

Feedback

Feedback to Activity 11.2.3

1. You probably noticed that both the coconut tree and the takamaka tree have vascular bundles made up of xylem and phloem tissues, and pith and bark.

2. The differences are in the way that the xylem and phloem are arranged and the position of the pith tissue.

	Differences in the stems of	
	woody monocots (e.g. coconut)	woody dicots (e.g. takamaka)
Arrangement of xylem and phloem tissues	The xylem and phloem are in bundles scattered in the pith.	The xylem and phloem are arranged in a circle between the pith and the cortex.
Separation of pith and cortex	There is no clear separation between the pith and the cortex. The pith makes most of the stem's internal structure.	Clear separation between the pith and the cortex. The pith is the central tissue of the stem and the cortex is the tissue separating the vascular cambium and the cork cambium.
Exhibition of primary and secondary growth	Only primary growth exhibited. No secondary growth.	Both primary and secondary growth is exhibited. Primary growth takes place in young stems and secondary growth in older stems.
Increase in the diameter of the stem	No marked increase in the diameter of the stem.	Stem diameter increases as wood is made as part of secondary growth.
Presence of annual rings	No annual rings apparent.	Annual rings clearly apparent.

Table 11.2.3 (a): Differences in the stems of woody monocots and woody dicots

Feedback

Feedback to Activity 11.2.4

Understanding growth rings of a tree is easy. We are sure that you had no difficulties answering the questions. Check the answers below against yours.

a. The number of growth rings on the tree trunks are as follows:

   i. Tree trunk A has about 21 growth rings

      Tree trunk B has about 13 growth rings

      Tree trunk C has about 7 growth rings

   ii. The tree trunks can be placed in the following order according to their age:

Oldest tree trunk → Youngest tree trunk

Tree trunk C. It is approximately 21 years old.	Tree trunk A. It is approximately 13 years old.	Tree trunk B. It is approximately 7 years old.

   iii. The oldest tree has approximately 21 dark rings and approximately 21 light rings. It is approximately 21 years old.

b. There is one dark ring and one light ring in each year's growth.

c. Light growth rings are produced during the rainy season. This is when growth is the fastest. When there is less rain, growth is slower. The rings look dark because the new secondary xylem produced is close together.

In Topic 11.2 you have learnt about the support mechanisms of woody plants. Now we shall have a look at how much and how well you have learnt the content of the topic. The Self-Assessment for Topic 11.2 below will help you evaluate your learning.

Assessment

Self-assessment 11.1

You should be able to do the self-assessment in 25 minutes. You are strongly advised to answer the above questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

1. A section of a woody stem is shown below.

a. How old was the tree when it was cut?

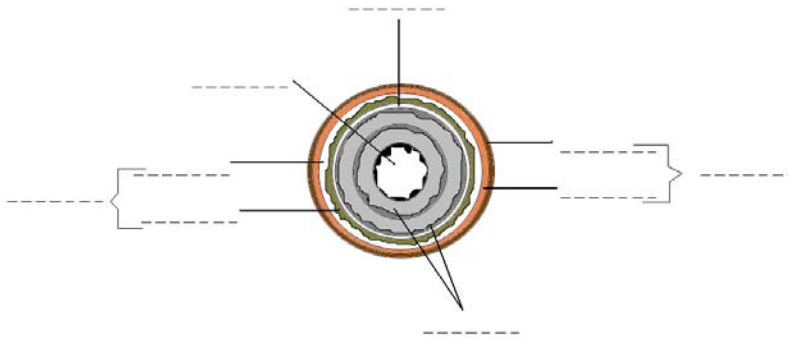
----

b. On the drawing, indicate with a label, wood that was made during the rainy season and wood made during the drier season.

c. How many light and dark rings does a plant usually produce in one year?

----

2. Show the following parts on the diagram of the woody tree trunk below: vascular cambium, cork, secondary xylem, inner bark, cork cambium, secondary phloem, outer bark, cortex, pith.



3. What is wood?

   ----

4. What makes woody stems hard?

   ----

5. Herbaceous plants do not have wood. How are they able to get their shape and remain firm?

   ----

6. Differentiate between primary growth and secondary growth.

I hope that the self-assessment questions have helped you to better understand the topic. I have provided the feedback at the end of the topic below.

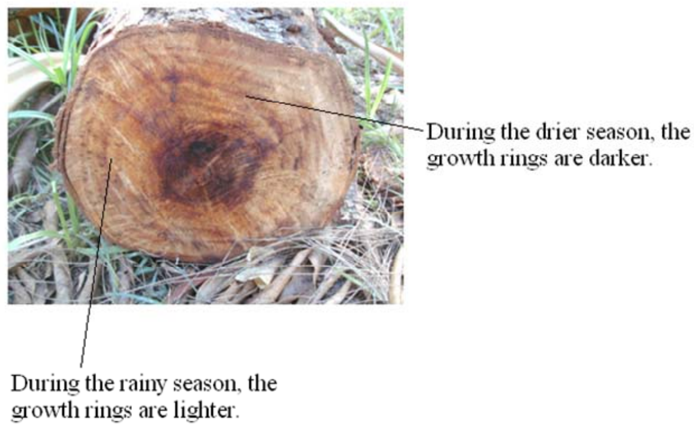
Answers to Self-Assessment for Topic 11.2

Answers to Assessment

1.

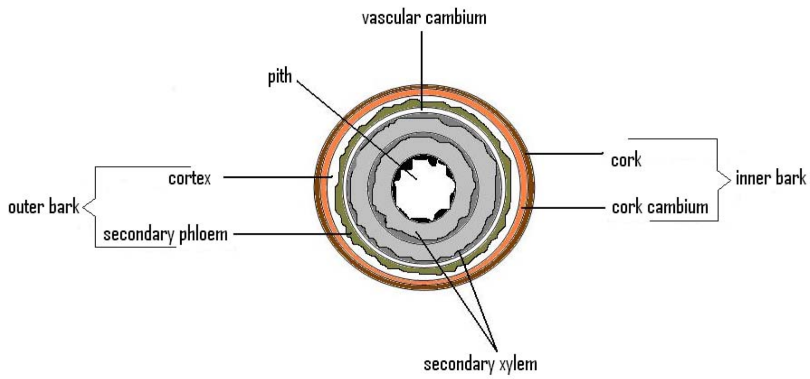
   a. The tree from which the cross section was taken is approximately 7 years old.

   b.



   c. A plant usually produces one light ring and one dark ring in one year.

2. The parts of a woody stem are as follows:



3. Wood is secondary xylem.

4. Lignin makes woody stems hard.

5. Herbaceous plants can have a shape and remain firm due to turgor pressure in their cells.

6. Primary growth happens in herbaceous plants. It is when the plant grows only from the shoot and root growth cells. During primary growth plants increase in length as new cells are produced.

   Secondary growth takes place in woody plants. This is when the vascular cambium produce new xylem cells which become wood and the cork cambium produce new phloem cells which become bark. During secondary growth a plant stem increases in diameter as new layers of wood are added each year.

This brings us to the end of topic 11.2 and to the end of the plant section of this unit. What did we learn about woody plants here? How are they different from herbaceous plants? Are you able to explain the difference to your friends and family? If you are, let’s move onto the next topic.

Topic 11.3: Types and Functions of Skeleton

How long?

You will need 1 hour and 20 minutes at the most to do the activities in this topic. It is advisable that you spend another 40 minutes of your own time to further review the different types of the skeleton and their functions.

Most animals possess some form of skeletal structure. This could be as simple as rods used as strengthening materials in unicellular animals or it can be the complex skeletal systems of vertebrates.

The design of the skeletal structure of an organism contributes towards the specific shape of the organism. The shape of the organism depends on the specific requirement of the organism according to where it lives. Let us reflect further about this in the activity below.

Activity

Activity 11.3.1

You should complete this activity in about 5 minutes.

Some animals are shown below.

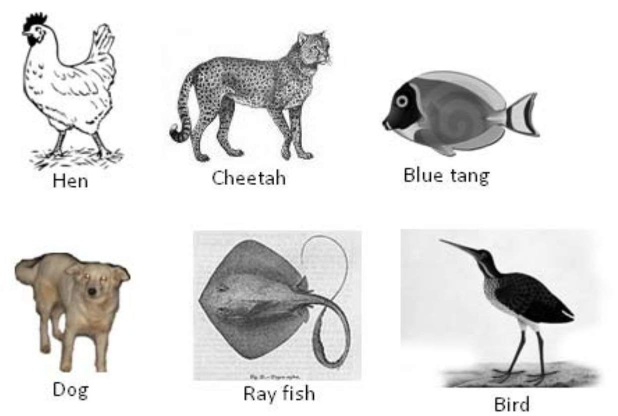
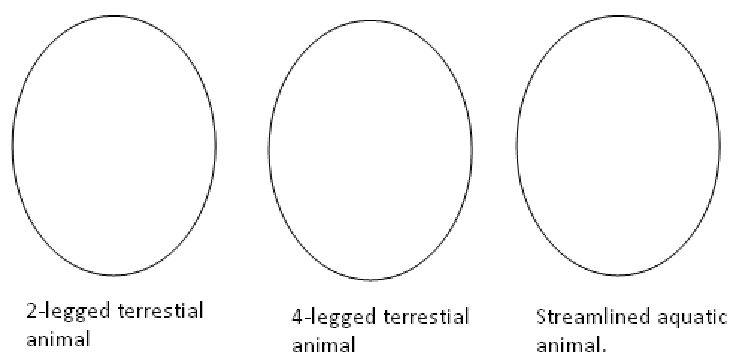


Figure 11.3.1: Different animals

Drawn by Serge Mondon (2010)

a. Group the animals according to their body structure and habitat.



b. In Table 11.3.1 (a) below show how the body of each group of animals is adapted to where they live and their daily pattern of life.

Animals	Body features	How the body features facilitate life in the specific habitat.

Animals	Body features	How the body features facilitate life in the specific habitat.
	2-legged terrestrial animals	
	4-legged terrestrial animals	
	Streamlined aquatic animals	

Table 11.3.1 (a): How the body shape of vertebrates is adapted to their habitat and daily pattern of life.

Those were very good reflections!

I have provided the feedback at the end of the topic. You are strongly advised to answer the above questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

You would have realized from the above activity that the skeleton of the animals allow them to have a shape. What are the other functions of a skeleton? This is what we are going to learn next.

11.3.1 Functions of the skeleton

A skeleton is a type of frame which animals have. It serves a number of important functions.

Reflection

Reflection 11.3.1

Take 5 minutes for this short reflection.

1. *What are some of the functions of a skeleton?*

Write and describe two functions below.

Good, let us find out more of these functions in activity 11.3.2 below.

Activity

Activity 11.3.2

You should complete this activity in about 10 minutes.

a. Think of how your body would be without a skeleton. Write a short paragraph describing how this would be like.

b. From what you have written above, write a series of questions that would help you know the main functions of the skeleton. An example has been done for you.

#	Checklist	☑
1	Does the skeleton help me to open and close my mouth?	❑
2		❑
3		❑
4		❑
5		❑

#	Checklist	☑
6		❑

Table 11.3.2: Questions about the functions of the skeleton

c. Test your checklist with a few friends and use the information that you gathered to write three functions of the skeleton below.

1.

2.

3.

Feedback

Feedback to Activity 11.3.2

You are surely on the right track.

Read the text below to learn about the main functions of the skeleton.

The **main functions** of the skeleton are:

Support: Skeletons provide a rigid framework for the body and help resist forces acting on the body of the organism. They help to maintain the shape of the body. Body organs are attached to and suspended from the skeleton

Protection: The skeleton protects the delicate internal organs. In mammals for example the skull protects the brain, the vertebral column protects the spinal cord and the ribs protect the heart and the lungs.

Locomotion: Skeletons provide a means of attachment for the muscles of the body. Parts of the skeleton operate as levers on which the muscles can pull to effect movement.

Activity

Activity 11.3.3

You should complete this activity in about 5 minutes.

Now that you know what the functions of the skeleton are, group the questions from your checklist above under the three main functions of the skeleton in Table 11.3.3 below.

Functions of the skeleton		
Support	Protection	Locomotion

Table 11.3.3: Grouping questions according to the functions of the skeleton

Feedback

Feedback to Activity 11.3.3

Very good! Together with two other colleagues check whether you have grouped the questions correctly.

I am sure that from the above exercise you have realised that you already have some good knowledge about the body, in particular about the skeleton. With this awareness, let us learn about the different types of skeleton that animals have.

11.3.2 Types of skeleton

All animals have a skeleton, but all are not of the same type.

Discussion

Discussion 11.3.1

You should complete this activity in about 5 minutes.

Look again at the animals at Activity 11.3.1 above. Do you see their skeleton? Where is their skeleton? How is their skeleton? Discuss with your colleagues.

Then think about the following animals: snails, clams, crabs and beetles. Do you see their skeleton? Where is their skeleton? How is their skeleton?

Think about this third group of animals: earthworms and jellyfish. Do you see their skeleton? Where is their skeleton? How is their skeleton?

Write about what you have discovered in your discussions for each group of animals in Table 11.3.4 below.

Group of animals	Do you see their skeleton?	Where is their skeleton?	How is their skeleton?

Group of animals	Do you see their skeleton?	Where is their skeleton?	How is their skeleton?
Hens, cheetahs, blue tangs, dogs, rays and birds.			
Snails, clams, crabs and beetles.			
Earthworms and jellyfishes.			

Table11.3.4: Skeletons of different groups of animals.

Feedback

Feedback to Discussion 11.3.1

I have no doubt that you could tell that animals such as hens, cheetahs, blue tangs, dogs ,rays and birds have bones inside their body which act as their skeleton, whereas animals such as snails, clams, crabs and beetles have a shell or hard covering (cuticle) outside their body.

The earthworms and jellyfishes do not have a cuticle, or a shell, or bones inside their body like birds and fishes. They have a special type of skeleton which you will learn about in the text below.

Hydro skeleton, exoskeleton and endoskeleton

There are three major types of skeleton: **hydro skeleton**, **exoskeleton** and **endoskeleton**. Each of these types of skeleton is discussed below.

Hydro skeleton: Soft bodied animals with fluid filled bodies have hydro skeletons. The fluid in the body of animals with a hydro skeleton is enclosed by the body wall muscles. The pressure of the fluid and action of the surrounding muscles are used to change the organism's shape and produce movement. Animals with hydro skeletons include jellyfish, nematodes and earthworms.

Exoskeleton: An exoskeleton is a skeleton outside the body possessed by animals that do not have bones inside their body. An exoskeleton can be **shells of calcium carbonate** such as the shells of molluscs, the **elastic covering** of animals such as the jellyfish and **chitin** (hard, light and flexible substance) which forms the cuticle of arthropods such as insects, arachnids and crustaceans.

The exoskeleton acts as a hard outer covering to the animal. In animals such as insects and crustaceans, the exoskeleton does not grow with the rest of the body of the animal. It must be shed periodically for growth to happen. This is known as **ecdysis** or **molting**. Molting allows for the exoskeleton to be extended and enlarged and often it also involves a change in the shape of the animal.

Endoskeleton: An endoskeleton is an internal skeleton of **bone** or **cartilage** in vertebrates. Most vertebrates have a bony skeleton in their adult form but with cartilage in certain parts of the body such as at the joints or between the vertebrae and also in some parts of the body such as the nose, ears, trachea and larynx (voice box). Bone is living and it is hard.

Cartilage is much softer than bone. Fish such as dogfish, sharks and rays have a whole cartilaginous endoskeleton. They are known as cartilaginous fish.

Tip

The next time you get the opportunity to enjoy some shark or a ray dish, look for any part of the cartilage skeleton and compare it with the bones of chicken, fish or other animals that you frequently come across in your meals.

Activity

Activity 11.3.4

You should complete this activity in about 10 minutes.

a. Classify the following animals according to the type of skeleton that they have:

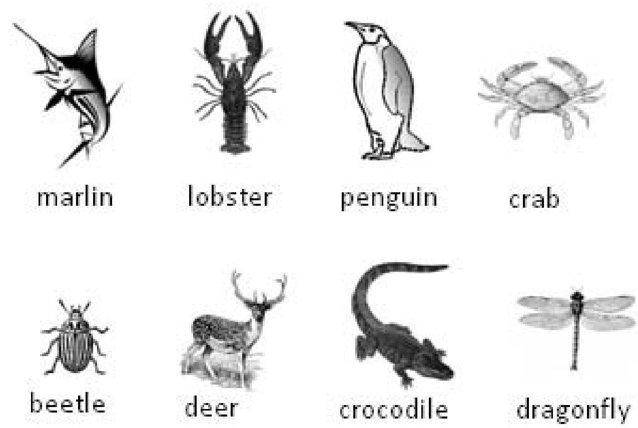
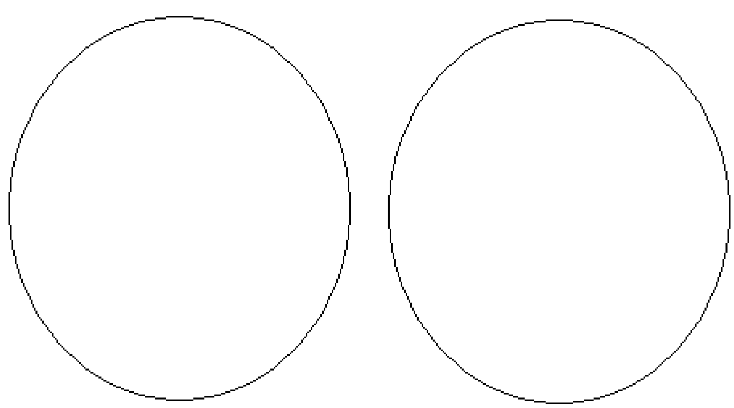


Figure 11.3.2: Animals for classification

Drawn by Serge Mondon (2010)

Label the groups and write the names of each animal in the correct group.



b. Write two ways how an exoskeleton is different from an endoskeleton?

Differences between	
Exoskeleton	Endoskeleton

Table11.3.5 (a): Differences between exoskeleton and endoskeleton

c. What are the functions of a skeleton?

d. The external part of the nose consists of cartilage. How different would this part of the nose be if it was made of bone?

This was not a difficult exercise at all was it?

I have provided the feedback at the end of the topic below. You are strongly advised to answer the above questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 11.3.1

You probably realized that the animals need to have different body features and shapes to be able to function well in the habitat where they live.

Some of these ideas are given in Table 11.3.1 (b) below.

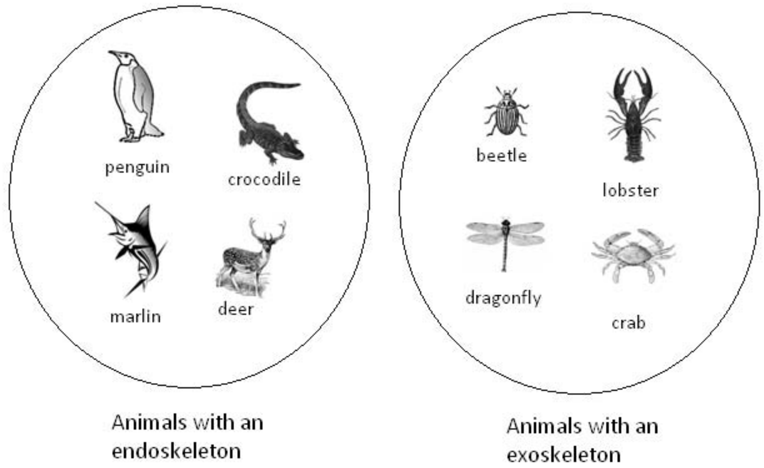
Animals	Body features	How the body features facilitate life in the specific habitat.
Hen and bird	2-legged terrestrial animals: the bipedals	Birds need to be light to be able to fly. They have only two legs that are not too bulky and inconvenient when in flight.
Dog and cheetah	4-legged terrestrial animals: the quadrupeds	The cheetah and the dog need to be able to run fast and so they need four strong legs.
Blue tang and ray	Streamlined aquatic animals	The blue tang and the ray fish need to have streamlined bodies to help them move easily in water.

Table 11.3.1(b): How the body shape of vertebrates is adapted to their habitat and daily pattern of life.

Feedback

Feedback to Activity 11.3.3

a. The animals can be classified as follows:



b. The following are some of the differences between an exoskeleton and an endoskeleton.

Exoskeleton	Endoskeleton
Found outside the body.	Found inside the body.
Made of different substances such as calcium carbonate, chitin and elastic tissue.	Made of bone and cartilage.
Invertebrates have exoskeleton.	Vertebrates have endoskeleton.
Is shed periodically in some animals namely insects and crustaceans.	Is not shed. Grows as the animal grows.

Table 11. 3.5 (b) Differences between an exoskeleton and an endoskeleton

c. The functions of the skeleton are:

- Support: Skeletons provide a rigid framework for the body and help resist forces. They help to maintain the shape of the body. Body organs are attached to and suspended from the skeleton
- Protection: The skeleton protects the delicate internal organs. In humans for example the skull protects the brain, the vertebral column protects the spinal cord and the ribs protect the heart and the lungs.
- Locomotion: Skeletons provide a means of attachment for the muscles of the body. Parts of the skeleton operate as levers on which the

muscles can pull to effect movement.

d. The external part of the nose would be hard and difficult to move. This is because bone is made of mineral substances such as calcium phosphate. Cartilage does not contain much mineral salts. This makes it softer and more flexible.

This brings us to the end of topic 11.3. Reflect back on what you have learned in this topic. What is the importance of having a skeleton? Do all organisms have the same kind of skeleton?

Now that you have mastered the basic concepts of the skeleton, let us proceed by looking at the skeleton of mammals.

Topic 11.4: Parts and Functions of the Mammalian Skeleton

How long?

You will need 1 hour and 10 minutes at the most to do the activities in this topic. It is advisable that you spend another 35 minutes of your own time to further review the parts and functions of the mammalian skeleton.

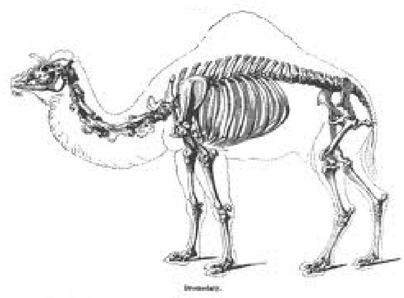
Recall from your studies of Unit 1 that mammals are vertebrates. All vertebrates have an endoskeleton made of bone and cartilage. In this topic, we shall be looking closely at the skeleton of mammals.

Reflection

Reflection 11.4.1

Spend about 5 minutes on this reflection.

I have put pictures of two mammalian skeletons below. Can you tell which animal each skeleton belongs to? Write the name of each animal on the line below their skeleton.

________________ ________________

Figure 11.4.1

Source of pictures:

http://en.wikipedia.org/wiki/File:Camel_Skeleton_-_Richard_Owen_-_On_the_Anatomy_of_Vertebrates_(1866).jpg

http://schools-wikipedia.org/wp/r/Red_Deer.htm

Feedback

Feedback to Reflection 11.4.1

I hope that you were able to easily recognize the camel and the deer.

As we, human beings, are mammals, it is easier to learn and understand the mammalian skeleton by referring to our own skeleton. Hence, throughout the topic, we shall be focusing on the human skeleton as an example of the mammalian skeleton.

Activity

Activity 11.4.1

You should complete this activity in about 10 minutes.

Before we proceed, test your knowledge of the human skeleton by comparing the skeletons of the camel and the deer above to your own skeleton.

a. Write at least five similarities between the skeletons of the camel, the deer and your own skeleton.

i. ______________________________

ii. ______________________________

iii. ______________________________

iv. ______________________________

v. ______________________________

____

b. Write at least four differences between the skeletons of the camel and the deer, and your own skeleton in Table 11.4.1 below.

Differences between	
The skeleton of the camel and the deer	The human skeleton

Differences between	
The skeleton of the camel and the deer	The human skeleton

Table 11.4.1: Differences between the skeleton of the camel, the deer and the human skeleton

Feedback

Feedback to Activity 11.4.1

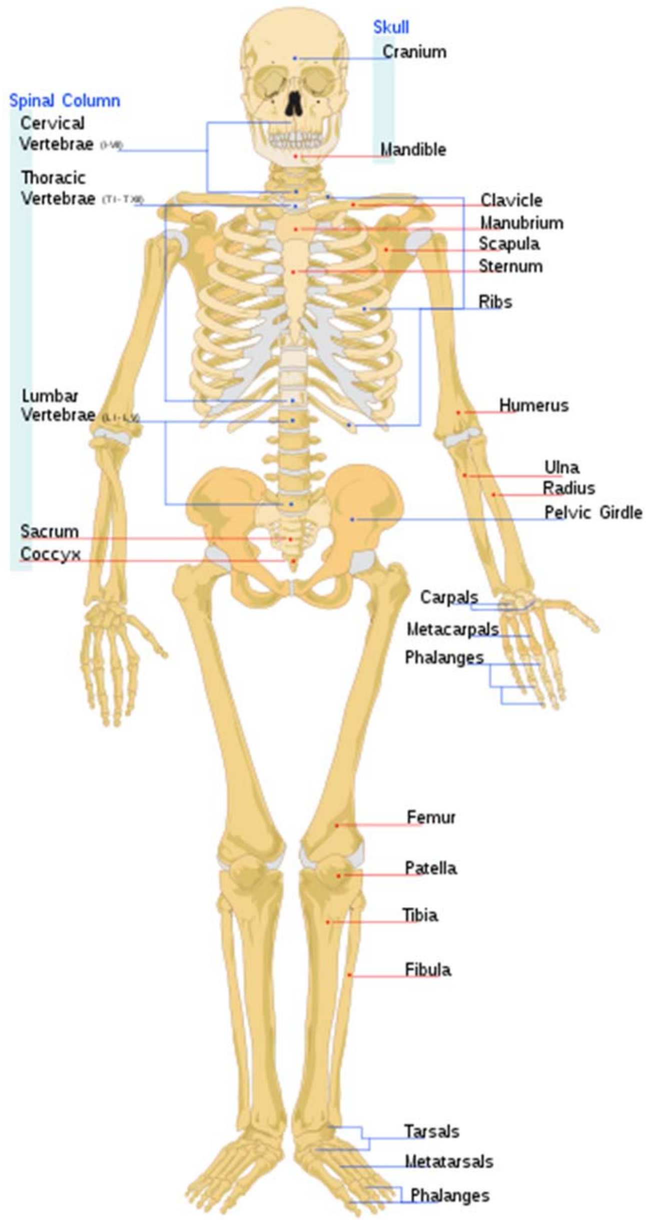
That was good thinking. We are sure you recognized and named some important bones of the human skeleton. Let us now learn more about the human skeleton.

11.4.1 Parts of the human skeleton

The mammalian skeleton is divided into two main groups; the **axial skeleton** which comprises of the skull, the vertebral column, the ribs and sternum, and the **appendicular skeleton**, comprising of the pelvic girdle and the limbs (arm, shoulder and leg bones in humans).

The adult human skeleton consists of 206 bones. Some of the bones are fused, whereas others are individual bones. The biggest bone in the human body is the **femur** bone in the upper leg and the smallest bone is the **stapes** in the middle ear.

The bones in our body are supported and supplemented by **ligaments**, **tendons**, muscles and cartilage. Some of the main bones of the human skeleton are showed in Figure 11.4.1 below.



Source: http://en.wikipedia.org/wiki/Human_skeleton

Fig 11.4.1: Parts of the human skeleton

Group activity

Group Activity 11.4.1

You should complete this activity in about 10 minutes.

Find two or three students, go to the laboratory and ask the laboratory technician for a model of the human skeleton. Together with your friends try to identify as many of the bones shown in Figure 11.4.1 above. As you identify the bones, discuss the importance of those bones to humans and other vertebrates.

Feedback

Feedback to Group Activity 11.4.1

I am sure that it was worth it having a closer look at the human bones! I have no doubt also that you have been able to mention some of the importance or functions of the bones of our skeleton. If you were not able to do so, we shall find out more about this in the section below.

11.4.2 Functions of the human skeleton

The various bones of the human skeleton have specific functions in the body. The main functions of the human skeleton and some of the associated bones are showed in Table 11.4.2 below.

Function	Bones
Protection	<u>Vertebral column </u>(bones of the cervical vertebrae, thoracic vertebrae and lumbar vertebrae): Protects the spinal cord. <u>Cranium:</u> Protects the brain, the inner and middle ear and the eyes. <u>Ribs:</u> Protect the heart and lungs.

Function	Bones
Movement	Leg and arm bones: Permit movement of legs and arms. Vertebral column: Allows some degree of movement. Cranium: Permits the nodding of the head. N.B: Muscles, bones and joints provide the mechanism for movement.
Support	Vertebral column (bones of the cervical vertebrae, thoracic vertebrae and lumbar vertebrae): Withstands compression and resists tensions and other forces acting on the body. Ribs and sternum: Supports the lungs. Pectoral girdle (clavicle and scapula): Supports the arms. Pelvic girdle: Supports the legs. Leg bones: Support the body weight.
Production of blood cells	Bone marrow in legs and ribs: Produce white and red blood cells.

Table11. 4.2: Functions of the human skeleton

Activity 11.4.2 below will help you review the above content on the parts and function of the human skeleton.

Activity

Activity 11.4.2

You should complete this activity in about 10 minutes.

a. The skull is the bony part of the head. Which bones make up the skull?

____

____

____

b. How many bones are there in the adult human body?

____

____

c. Refer back to Figure 11. 4.1 and classify the bones of the human skeleton according to the axial skeleton and the appendicular skeleton in Table 11.4.3 (a) below.

Axial skeleton	Appendicular skeleton

Axial skeleton	Appendicular skeleton

Table 11.4.3 (a): Bones of the axial and the appendicular skeleton

d. What are the main functions of the human skeleton?

____

____

a. Write the name of the bone(s) of the human skeleton next to their function.

Function	Bone
Protect the lungs and heart	
Support the body weight	
Permits the movement of legs and arms	
Protects the brain, the middle and inner ear and the eyes	

Table 11.4.4 (a): Bones of the human skeleton and their functions

I hope that the exercise above has helped you to become familiar with the bones of the human skeleton and their functions.

I have provided the feedback at the end of the topic below. You are strongly advised to answer the above questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 11.4.2

We are sure that you did the exercise well. If you are unsure of your answers, go over our suggestions below.

a. The cranium and mandible (lower jaw) make up the skull.

b. There are 206 bones in the human body.

c. The main bones in the axial and the appendicular skeleton are as follows:

Axial skeleton	Appendicular skeleton
Cranium	Clavicle
Mandible (lower jaw bone)	Scapula
Cervical vertebrae	Humerus
Thoracic vertebrae	Ulna
Lumbar vertebrae	Radius
Ribs	Pelvic girdle
Sternum	Femur
	Patella
	Fibula
	Tibia
	Hand and foot bones

Figure 11.4.3 (b): Bones of the axial skeleton and the appendicular skeleton

d. The main functions of the human skeleton are support, protection, movement and production of blood cells.

e.

Function	Bone
▪ Protect the lungs and heart	Ribs
▪ Support the body weight	Leg bones

Function	Bone
▪ Permits the movement of legs and arms	Leg and arm bones
▪ Protects the brain, the middle and inner ear and the eyes	Cranium

Figure 11.4.4 (b): Bones of the human skeleton and their functions.

This brings us to the end of the topic examining the parts of a skeleton. Quickly go from the top to the bottom of the body and do a review of all the skeletal parts. What are some of the functions of the human skeleton?

Notice how we can bend our arms, knees and fingers. How difficult would life be if we were not able to do this? In the next topic, we shall learn about joints.

Topic 11.5: Joints

How long?

You will need 40 minutes at the most to do the activities in this topic. It is advisable that you spend another 20 minutes of your own time to further review the different types of joints.

We have seen that **movement** (locomotion) is one of the functions of the skeleton. To allow for movement, the body has a mechanism involving joints, muscles and bones. In the previous topic we have learnt about the some bones in the human body and the types of movement that they allow.

Reflection

Reflection 11.5.1

You need about 5 minutes for this reflection.

Can you name at least two of the bones of the human body and the type of movement that they allow?

Feedback

Feedback to Reflection 11.5.1

That was easy wasn't it? You might have mentioned the arm bones, which allow for the movement of the lower arm. As I have pointed out above, the body mechanism for movement involves not only bones but also joints and muscles.

We shall now learn about the various types of joints, their structure and functions and proceed to muscles in the next topic.

11.5.1 Types of Joints

Reflection

Reflection 11.5.2

You should be able to complete this reflection in 5 minutes.

Just imagine that you were born with a serious defect. Your right arm bones were fused into one straight bone.

How would this affect the movement of your right arm?

You may wish to try this by tying a straight piece of wood to your right arm from the shoulder to the wrist and compare your arm movements with that of the left arm.

Write your observations below and give reasons to explain your ideas and observations.

Feedback

Feedback to Reflection 11.5.2

You have surely realized that joints in the body play an important role in movement of the bones.

Read the text below to learn further about joints.

What is a joint?

The point at which two bones meet each other is called a joint. Joints vary depending on their structure and the type of movement that takes place at the joint.

Types of joints

There are two main kinds of joints; **fibrous joints** and **synovial joints**.

Fibrous joints: Sometimes two bones are joined together quite firmly by fibers. Bones joined in this way do not move at all. The bones of the cranium and those of the pelvic girdle are held firmly together with fibers. Such types of joints are called **sutures**.

Fibrous joints are also found between the vertebrae, wrist and ankle bones. The bones are separated from each other by cartilaginous pads with fibers in them, called **intervertebral discs**. The cartilage is quite soft in the middle and so this allows for the bones to move a little bit.

Synovial joints: Bones of the arm and leg need to move freely. The place where such bones meet is known as synovial joints. Hence the elbow and shoulder joints of the arm and the knee and hip joints of the leg are synovial joints.

Different kinds of movement take place at synovial joints; because of this, different names are given for the different types of movement that takes place at these joints. Synovial joints that allow for the bones to bend and move up and down (in one plane) are known as **hinge joints**. The elbow joint which is shown in Figure 11. 5.1below, the finger joints and the knee joint are examples of hinge joints. Another type of synovial joint is the **ball-and-socket joint**. Ball-and-socket joints allow for the greatest range of movement. The shoulder joint shown in Figure 11.5.1 below and the hip joint are ball-and-socket joints. These joints make it possible for us to make circular movements (movement in all planes).

At the synovial joints, the bones are held together by **ligaments**. The ligaments are very strong and can stretch when the bones move. To prevent the bones form wearing away as they move, the bones also have cartilage at the ends. Some thick liquid, known as **synovial fluid** is found in synovial membranes to lubricate the bones so that they can move smoothly.

In Figure 11.5.1 below, I have shown a diagram of the lower and upper arm and I have shown an example of the two types of synovial joints.

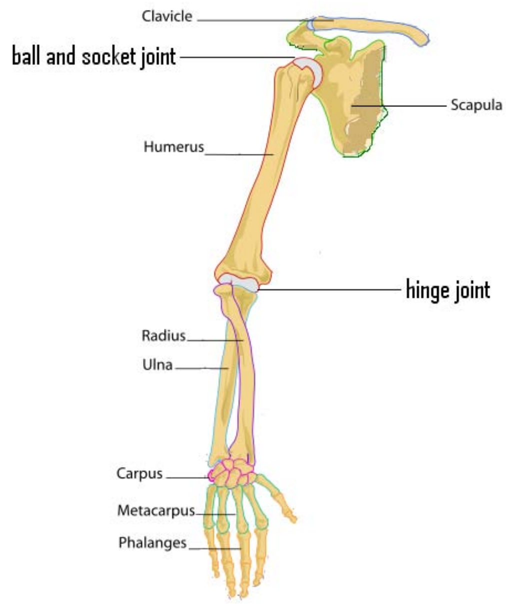


Figure 11.5.1: Hinge joints and ball-and-socket joints in the arm

Adapted from:
http://fiu-vro.wikipedia.org/wiki/Pilt:Human_arm_bones_diagram.svg

Now use the text above and Figure 11.5.1 to help you do the activities in Activity 11.5.1 below.

Activity

Activity 11.5.1

You should be able to complete this activity in 10 minutes.

1. In Table 11.5.1below, I have listed some bones of the arm and some bones of the leg.

    a. Move each bone and as you move them try to tell what type of movement was done and the type of joint that there is between the bones. Write your answers in the table.

    I have done one example for you.

Bone to move	Type of movement	Type of joint
Upper arm bone (Humerus)	Circular movement (movement in all planes)	Ball and socket joint.
Lower arm bones (Radius & Ulna)		
Wrist bones (Carpus)		
Finger bones of the arm (Metacarpus & Phalanges)		
Upper leg bone (Femur)		
Lower leg bones (Tibia & Fibula)		
Ankle bones (Tarsals)		
Bones of the toes (Metatarsals & Phalanges)		

Table 11.5.1 (a): Type of movement and joints for different bones moved.

b. From the exercise that you have done above, describe in your own words what a joint is.

____

____

2. The two kinds of joints are fibrous joint and synovial joint.

    a. Describe a fibrous joint.

____

b. What are the two types of synovial joints?

3. On the diagram of the human leg below, show the two types of synovial joints.

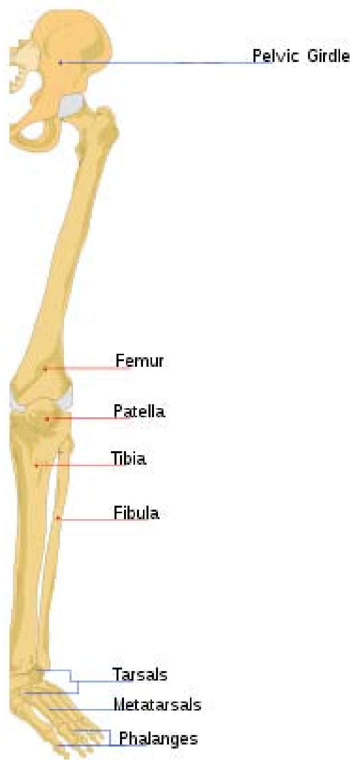


Figure 11.5.2: Human leg bones

4. What stops bones from rubbing against each other at the joints?

I hope you were able to learn a lot about the joints in our body. I also hope that you have tried to locate the joints in your legs and arms and have tried to move them.

I have provided the feedback at the end of the topic below. You are strongly advised to answer the above questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Feedback

Feedback to Activity 11.5.1

1. a.The type of movement performed by each bone and the type of joint that will allow the specific type of movement are:

Bone to move	Type of movement	Type of joint
Upper arm bone (Humerus)	Circular movement (movement in all planes)	Ball and socket joint
Lower arm bones (Radius & Ulna)	Up and down movement (movement in one plane)	Hinge joint
Wrist bones (Carpus)	Up and down movement but also limited side to side movement	Hinge joint (but more complicated than the elbow joint. Such type of hinge joints is known as the condyloid joint)
Finger bones of the arm (Metacarpus & Phalanges)	Up and down movement (movement in one plane)	Hinge joint
Upper leg bone (Femur)	Circular movement (movement in all planes)	Ball and socket joint

Lower leg bones (Tibia & Fibula)	Up and down movement (movement in one plane)	Hinge joint
Ankle bones (Tarsals)	Up and down movement (movement in one plane)	Hinge joint
Bones of the toes (Metatarsals & Phalanges)	Up and down movement (movement in one plane)	Hinge joint

Table 11.5.1 (b): Type of movement and joints for different bones moved.

b. A joint is the place where two bones join each other.

2. Fibrous and synovial joints.

    a. A fibrous joint is the place where two bones are joined firmly together by fibers. At such joints there is very little movement or no movement at all.

    b. The two types of synovial joints are the hinge joint and the ball and socket joint.

3. The ball and socket joint is found at the hip joint, between the pelvic girdle and the femur; the hinge joint is at the knee, ankle and toes.

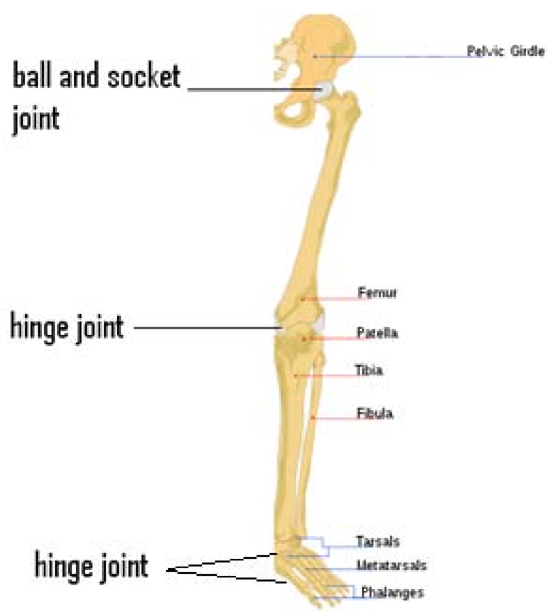


Figure 11.5.3: Human leg bones and joints

4. To prevent the bones form wearing away as they move, the bones have cartilage at the ends. Synovial fluid which is found in synovial membranes also lubricates the bones so that they can move smoothly.

This brings us to the end of the joint topic. How did you do on the assignment above? Please make sure to seek help if you are confused on anything. Think of 3 locations in the body where joints exist. What is the importance of joints and also the different types of joints?

Note that even if you have a solid skeletal structure and multiple joints, you still need something that helps you move. We will learn about how the body does this in the next topic.

Topic 11. 6: Muscles and Movement

How long?

You will need 1 hour 50 minutes at the most to do the activities in this topic. It is advisable that you spend another 55 minutes of your own time to further learn about the muscles and movement of our body.

In Topic 11.5 above, we saw that there are three main components that form the mechanism for the movement of the skeleton. I have shown these components in Figure 11.6.1 below.

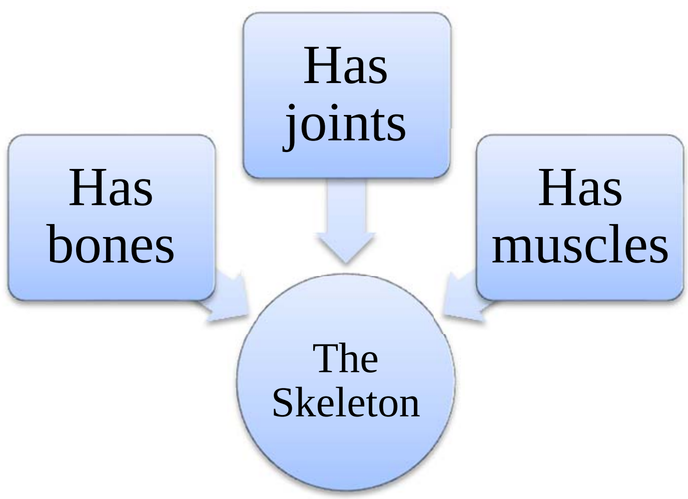


Figure 11.6.1: The main body mechanisms for the movement of the skeleton.

Reflection

Reflection 11.6.1

You have about 5 minutes for this reflection.

You have learnt about joints and bones above. Let us see how well you recall what you have learnt. Make a list of three ideas that you have learnt about bones and joints in columns 1 & 2 on Figure 11.6.2 below.

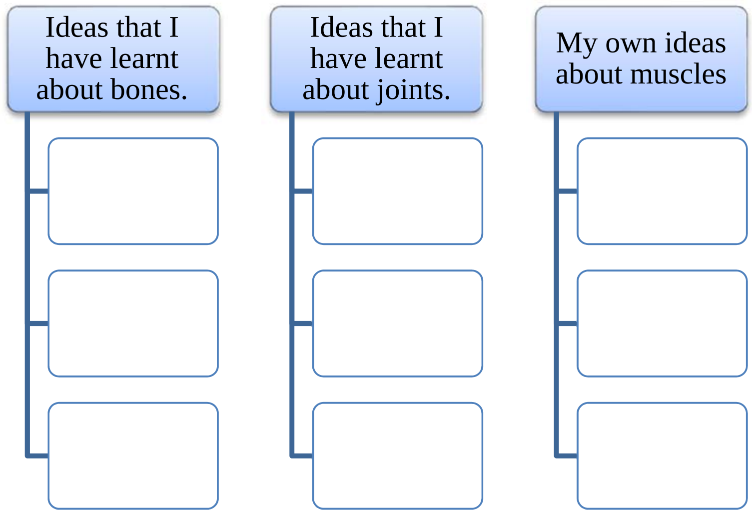


Figure 11.6.2: Students' ideas about bones, joints and muscles.

Very good! You still recall a lot about bones and joints. But what ideas do you have about muscles? In the third column, write any ideas that you have about muscles.

Does this bodybuilder help bring any ideas about muscles to mind?

Figure 11.6.3: A bodybuilder showing muscles in the body

Source of picture: http://en.wikipedia.org/wiki/Bodybuilding

Feedback

Feedback to Reflection 11.6.1

That was some good thinking!

I am sure that the body builder has helped you to realize that muscles contract (they get shorter) and relax. Muscles are elastic and so they regain their original size and form during relaxation. Muscles have a good supply of mitochondria to produce energy for contraction.

Some of you might also have realized that bones will not move at a joint if there are no muscles to pull the bones.

In the section which follows, we shall be looking more closely at the skeletal muscles, but first let us briefly learn about the three types of muscles in the body of vertebrates.

11.6.1 The three types of muscles in vertebrates

Vertebrates have three main types of muscles. These are the skeletal muscle, the smooth muscle and the cardiac muscle. We will look at each of these muscles in the text below.

Skeletal muscle (also called striated, striped or voluntary muscle): The skeletal muscle is attached to bone. It is concerned with locomotion of the animal. It contracts quickly and fatigues quickly. It is stimulated by the voluntary nervous system, which means that it is normally under the conscious control of the animal. The skeletal muscle is the only muscle that you can choose to move or not.

Smooth muscle (also called unstriated, unstriped, or involuntary): This type of muscle is found in tubular organs such as the stomach, the intestine and the blood vessels (veins and arteries). It is concerned with the movement of materials through these organs. It contracts slowly and fatigues slowly compared to skeletal muscles. It is spontaneously activated and is stimulated by the automatic nervous system; hence the animal does not have conscious control over it.

Cardiac muscle: Muscle found in the heart. It contracts spontaneously and without fatigue. It is involuntary; hence animals do not have control over the contraction of their heart muscles.

Let us now look more closely at skeletal muscles and the role they play in the locomotion of vertebrates.

11.6.2 Skeletal muscles

All the muscles that are attached to our bones are skeletal muscles. Skeletal muscles pull on the bones to make them move.

Activity

Activity 11.6.1

You have 20 minutes to complete this activity.

Your elbow joint allows for you to move your lower arm up and down. This is possible due to the skeletal muscles that are attached to your upper arm and lower arm.

Let us find out where the muscles are attached to allow us to move the lower arm. Follow the instructions below to make a model arm.

Get the following materials:

- A piece of card board about the size of an A4 paper.
- A pair of scissors.
- Drawing pins.
- A piece of string about 30cm long.

What to do:

- Place the cardboard in a portrait position on the table. Sketch the upper arm on one half of the piece of card board. Use the whole length of the card board.
- Sketch the lower arm on the other half of the piece of card board. Use the whole length of the card board.
- Cut out the two shapes (lower arm and upper arm).
- Join the lower arm and the upper arm together using the drawing pins as the elbow joint.

- Find out where you can attach the string to ensure that you can pull the lower arm up and down.

- Once the string is attached, pull on the string and see if you can get the lower arm to move up and down. If you cannot get this, then try to see how you can attach the string to allow for the expected movement.

What did you notice?

Draw a diagram of your model arm below. On the diagram label the upper arm, the lower arm, the elbow joint, and the muscle. You should also label the two points where the string (muscle) was attached to the arm. Label the upper part O and the lower part I.

On the lines below, write about where you attached the string (muscles) and how you used the string to move the lower arm up and down.

Feedback

Feedback to Activity 11.6.1

Good. Through your model arm you have an idea of where our muscles are attached to help us move our bones. Let us compare and enrich your ideas with the content of the text below.

A skeletal muscle is attached to bone in at least two places. One end of the muscle is attached to a *firm non-movable bone.* This point of attachment is called the **origin of the muscle**. The other point of attachment is the **insertion**. At the insertion, the opposite end of the muscle is attached to a *freely movable bone*. Skeletal muscles are very firmly attached to bone by means of tough, inelastic tissues called **tendons**. Tendons are made up almost entirely of collagen.

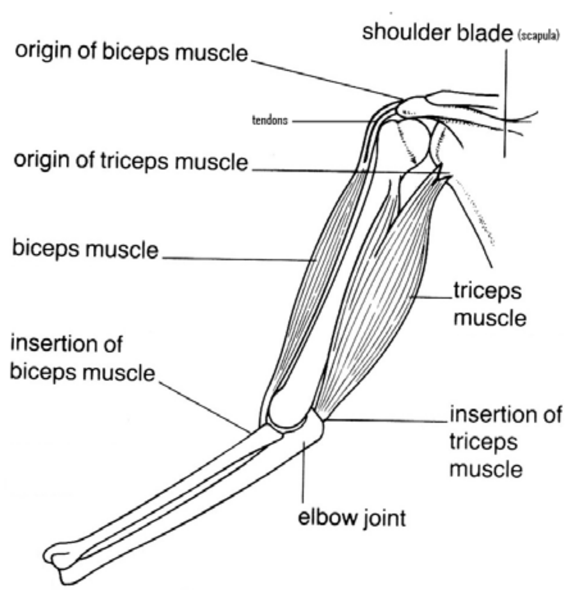


Figure 11. 6.4: Origin and insertion of upper arm muscles

Drawn by Serge Mondon (2010)

Activity

Activity 11.6.2

You should complete this activity in about 5 minutes.

Now go back to the diagram of your model arm and label the **origin of the muscle** and the **insertion of the muscle** next to the letters **O** and **I** on your diagram.

Then in the space below re-write your descriptions of how you moved the lower arm up and down in your model, by using the words from the text above.

____

____

____

____

____

____

Feedback

Feedback to Activity 11.6.2

That should not have been difficult. I am sure that you now have a clear idea of how muscles are attached to allow their movement.

The model arm that you made above with one piece of string does not show exactly how muscles work. We shall see below that muscles work in pairs.

How skeletal muscles work

It is possible for us to bend our arm at the elbow. The muscles attached to the bones in our arm make this movement possible. To move a bone two muscles are required. When one of the muscles contract, it moves the bone in one direction and when the other muscle contracts it moves the bone in the opposite direction. Two muscles that work together in this way are known as **antagonistic** muscles. Hence, when one of the antagonistic muscles contracts, the other muscle relaxes and the bone is moved in one direction.

Fig. 6.2 below shows how the antagonistic muscles in the arm, the **biceps** and the **triceps**, work when the forearm is raised.

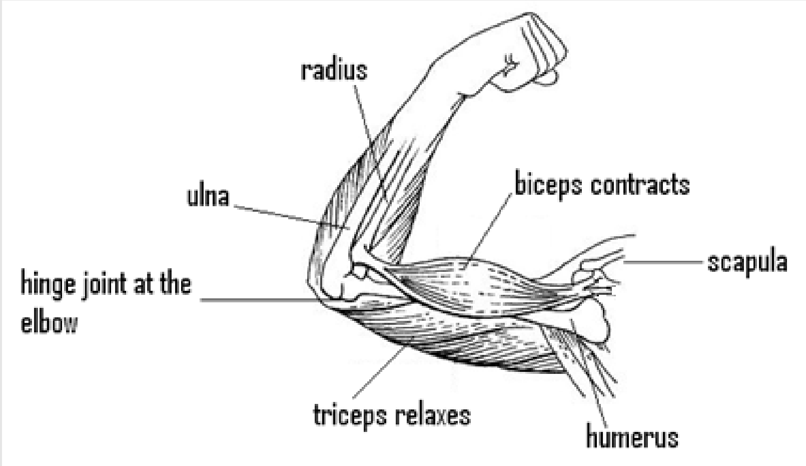


Figure 11.6.5: Antagonistic muscles in the arm

Adapted from: http://en.wikipedia.org/wiki/Biceps_brachii_muscle

Biceps and triceps are only examples of antagonistic muscles. Antagonistic muscles are also found in the legs and many other places in the body.

Now that you have read the text, you might be interested in improving on your model arm so that it represents the real way our muscles work. This is a challenge that I give to you.

Read the text below to learn more about antagonistic muscles.

Flexor and extensor muscles

We saw in Figure 11. 6.2 that the biceps muscle is attached to the scapular by two tendons at the top (the origin) and to the radius by one tendon at the bottom (the insertion). When the biceps contracts, it pulls the radius and ulna up towards the scapula and as a result our arm bends at the elbow joint. This action of bending a hinge joint is known as **flexion**. The muscle responsible for bending the joint is called the **flexor muscle**; hence the biceps muscle is a flexor muscle.

The triceps is attached by three tendons, one on the scapula and two on the humerus at the top (the origin), and to the ulna by one tendon at the bottom (the insertion). To straighten the elbow joint and hence lower the forearm, the triceps contracts, while the biceps relaxes. The action of straightening a hinge joint is known as **extension**. The triceps muscle is therefore an **extensor muscle**.

Flexor and extensor muscles are antagonistic muscles. They work together to allow bending and straightening of the joints. When bending the elbow joint or flexing the arm, the flexor muscle contracts while the extensor muscle relaxes. When straightening the elbow joint or extending the arm, the extensor muscle contracts while the flexor muscle relaxes.

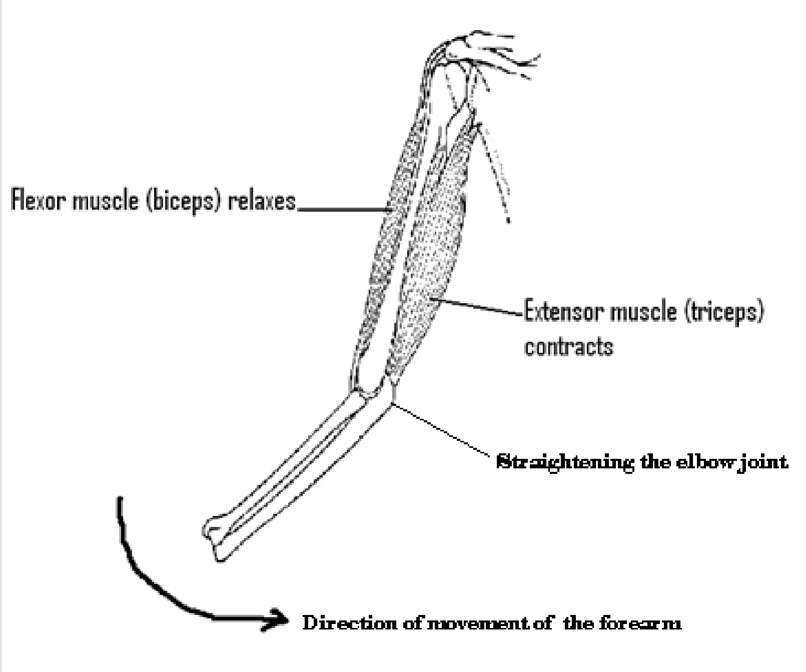


Figure 11.6.6: Flexor and extensor muscles in the upper arm

Adapted from: http://en.wikipedia.org/wiki/Biceps_brachii_muscle

To help you review what you have learnt about muscles above, I have provided below a summary of the content learnt in the form of questions. Try to answer the questions as best as you can.

Summary

Summary 11.6.1

You should be able to attend to this summary in about 20 minutes.

1. Name the antagonistic muscles in the upper arm.

2. On which bone is the origin of the biceps muscle found?

3. Describe the insertion of a muscle?

4. You decide to move your forearm upwards. Describe how your arm muscles will help you do that.

5. Name the flexor muscle in the arm.

6. Explain with the use of clearly labeled diagrams, what happens to the flexor and extensor muscles when straightening the elbow joint.

I am sure that you did not have much difficulty answering the questions in the summary.

I have provided the feedback at the end of the topic. You are strongly advised to answer the above questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

I am sure that your answers were not far from the suggestions that I have provided above. With the above activity we have completed the topic on Muscles and Movement. The self-assessment below will help you review what you have learnt in the topic.

Assessment

Self-Assessment 11.2

You should complete this self-assessment in approximately 20 minutes.

1. Name the three main types of muscles in the body of vertebrates.

2. Differentiate between the skeletal muscle and the smooth muscle.

3. Define the:

a). origin of muscles

b). insertion of muscles

4. On the diagram of the arm below, show the origin and insertion of the biceps and triceps muscles.

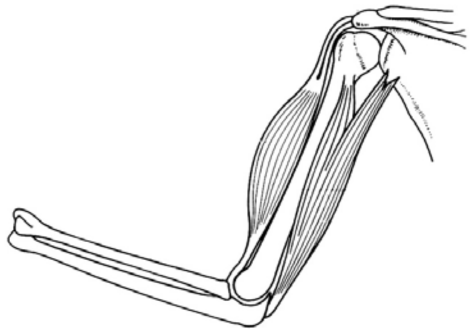


Figure 11.6.7 (a): Diagram of the arm

5. What are antagonistic muscles?

6. Describe what will happen at the elbow joint and consecutively what will happen to the forearm, when the flexor muscle of the arm relaxes and the extensor muscle contracts.

Feedback

Feedback to Summary 11.6.1

1. The biceps and triceps are the antagonistic muscles found in the upper arm.

2. The origin of the biceps is found on the scapula bone.

3. The insertion of a muscle is the point of attachment of the muscle to a freely movable bone.

4. To move the forearm upwards the biceps contracts while at the same time the triceps relaxes.

5. The flexor muscle in the arm is the biceps.

6. When straightening the elbow joint, the extensor muscle (the triceps) contracts, while the flexor muscle (the biceps) relaxes and the forearm is lowered.

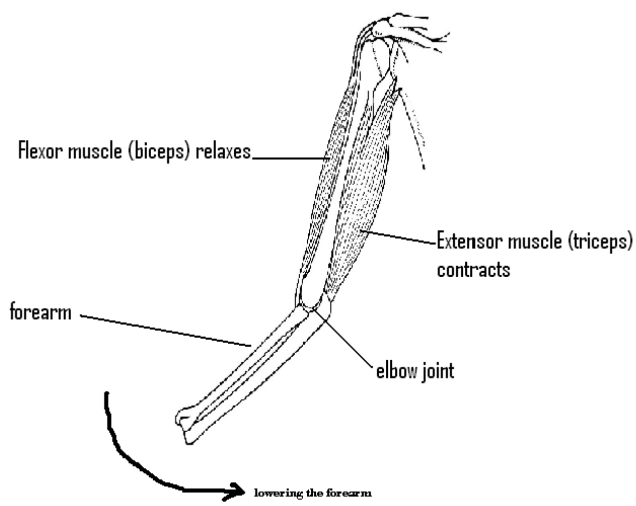


Figure 11.6.4: Straightening the elbow joint

Answers to Assessment

Answers to Self-Assessment for Topic 11.6

1. The three main types of muscles in the body of vertebrates are skeletal muscle (also called striated, striped or voluntary muscle), smooth muscle (also called unstriated, unstriped, or involuntary muscle), and cardiac muscle.

2. The skeletal muscle is attached to bone. It is concerned with locomotion of the animal. It contracts quickly and fatigues quickly. It is stimulated by the voluntary nervous system, which means that it is normally under the conscious control of the animal. The skeletal muscle is the only muscle that you can choose to move or not.

   The smooth muscle is found in tubular organs such the stomach, the intestine and the blood vessels (veins and arteries). It is concerned with the movement of materials through these organs. It contracts slowly and fatigues slowly. It is spontaneously activated and is stimulated by the automatic nervous system; hence the animal does not have conscious control over it.

3. Origin and insertion of muscles are defined as follows:

   a. The origin of a muscle is the point of attachment of one end of the muscle to a firm non-movable bone.

   b. The insertion of a muscle is the opposite end of the muscle which is attached to a freely movable bone.

4. The origin and insertion of the biceps and triceps muscles are shown in Figure 11.6.7(b).

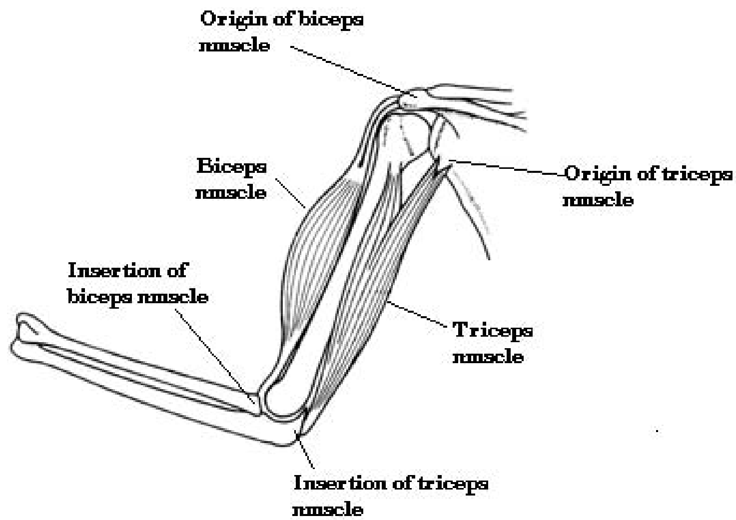


Figure 11.6.7 (b): Origin and insertion of biceps and triceps muscles.

5. Two muscles that work together to move a bone are known as antagonistic muscles. When one of the antagonistic muscles contracts, the other muscle relaxes and the bone is moved in one direction. Biceps (a flexor muscle) and triceps (an extensor muscle) are examples of antagonistic muscles. They work together to move the bones of the forearm.

6. When the flexor muscle of the arm relaxes and the extensor muscle contract, the elbow is straightened and the forearm is lowered.

We hope that you were able to answer the questions without much difficulty. This was a good test of your understanding of content from Topic 11.6. I hope you now understand how the muscles help the body move.

In the next section we shall look at how our skeleton functions as levers.

Topic 11.7: The Skeleton as Levers

How long?

You will need 1hour 50 minutes at the most to do the activities in this topic. It is advisable that you spend another 55 minutes of your own time to further learn about how the skeleton functions as levers.

In Unit 3 you learnt about the principle of levers. Before we proceed, let us review your knowledge about levers. We shall do that by completing the fill in the blanks exercise in reflection 11.7.1 below.

Reflection

Reflection 11.7.1

You should complete this reflection in about 5 minutes.

A lever is a ________________ _______that pivots at a fixed point

called the _______________. A lever is able to move or lift a

____________ about the fulcrum when an opposing force (the

____________) is applied.

Feedback

Feedback to Reflection 11.7.1

That was good. I am sure that you have used the words **rigid bar**, fulcrum, **load** and **effort** correctly in the text. I will ask you to go back to the fill-in-the-blanks exercise above to verify whether your words were correctly placed shortly. But now, it is time for us to see how our bodies also function as levers. You never thought about that, did you?

Indeed in our body some of the bones, especially the long ones, function as levers. These bones (the **rigid bar**) are able to move another bone (the

load) at a joint (the **fulcrum**) under the pull of muscles (**force/effort**) when they contract.

In everyday life we recognize three different orders of levers. These are also found in the body. They are as follows:

First order levers: These are cases where the fulcrum (F) is found between the load (L) and the force/effort (E) as shown in Figure 11.7.1(a) below.

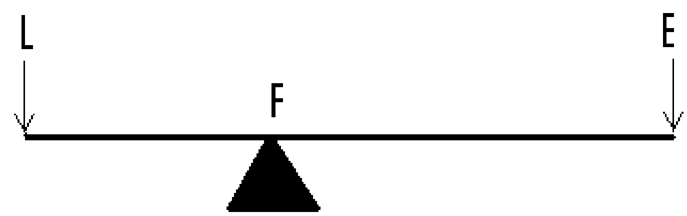


Figure 11.7.1 (a): Principle of first order levers

Drawn by Mariette Lucas (2010)

In Figure.11.7.1 (a) above, a rigid bar is pivoted at a point (F) with a load (L) at one end. To lift the load a force (E) must be applied at the opposite end. The amount of the force required to lift the load will depend on the position of the fulcrum in relation to the load and the effort. The closer the fulcrum is to the load, the easier it is to lift the load, so less effort is required. If the fulcrum is close to the effort it is more difficult to lift the load; you need much more effort than if the fulcrum was further away.

An example of when our bones operate as first order levers is when we straighten the elbow joint to lower the forearm-Figure.11.7.1 (b). The seesaw, the crowbar and scissors are everyday examples of first order levers. The scissor is also shown in Figure. 11.7.1 (b) below.

Examples of first order levers	
In the body	In everyday life

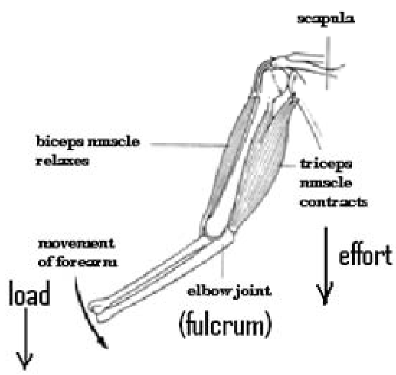
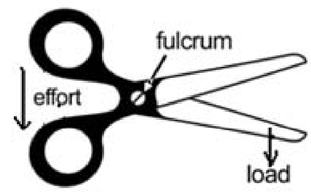
Examples of first order levers	
In the body	In everyday life
 Lowering the forearm	 Scissors

Figure 11.7.1 (b): Examples of first order levers

Drawn by Serge Mondon (2010)

You may wish to try a simple activity as the one in Activity 11.7.1 below to better understand how the position of the fulcrum in relation to the load and the effort affects the ease with which a load is moved, before proceeding to second and third order levers.

Activity

Activity 11.7.1

You need approximately 30 minutes to complete this activity.

This activity has two parts; Part A and Par B.

1. Look for the materials below and compose the following set up.

Figure 11.7.2: Experimenting with first order levers

Photo taken by Louisette Bonte (2010)

Materials:

- A meter ruler or a rod or straight piece of wood.
- A spring balance.
- A retort stand.
- A 200g, a 300g, a 500g and a 1kilogram load each tied to a piece of string.

Note it! / Important!

I advise you to first do the activity with a 500g load, then repeat the same with a 1000g (1kg) load, and check the pattern in your results.

If you find it difficult for you to get hold of the above conventional laboratory equipment you may wish to use related common everyday equipment such as a rigid bar or rod which is uniform in thickness or girth to replace the meter ruler, an elastic band to replace the spring balance, a bottle to serve as the fulcrum in the place of the retort stand and any load such as a 1.5volt battery to replace the 500g/1kg load.

Procedure:

Part A

1. Before you start the activity, label the Figure 11.7.2 above and show the load, the fulcrum and the effort.

2. Now place the load close to the fulcrum (about 10cm away), and hang the spring balance about twice the distance away on the opposite side of the fulcrum. Then pull on the spring balance to balance the bar.

   Note the force exerted by the spring balance in Table 11.7.1 below, next to the 10cm distance.

3. Then keeping the spring balance in the same position, move the load an extra 10cm away from the fulcrum and pull on the spring balance to keep the bar balanced.

4. Record the reading shown on the spring balance in Table 11.7.1 next to the 20cm distance.

5. Repeat the activity with the load at 30cm and then 40 cm away from the fulcrum and record the force exerted by the spring balance each time. Note that you should not move the spring balance. Keep it in the same position.

6. Repeat the activity with a 1kg load and record the results in the space provided in Table 11.7.1

Note it! / Important!

If you are using an elastic band instead of a spring balance, pull down on the elastic band and note the amount of force (a little force, a slightly greater force, a great force, etc.) that you require each time to keep the bar balanced.

Results:

Load (grammes)	Distance of load from the fulcrum	Force exerted by spring balance (Newtons)
500g	10cm	
	20cm	
	30cm	
	40cm	
1000g (1kg)	10cm	
	20cm	
	30cm	
	40cm	

Table 11.7.1 Force required to move load as distance of load from fulcrum is increased.

I am sure that you have made some very good observations and that you have got some very interesting results.

Study the results closely, and then answer the question below.

What do you notice as you increase the distance of the load from the fulcrum?

____

____

____

____

Part B

1. Repeat the above activity, but this time you should keep the load at a fixed distance to the fulcrum and change the position at

which you apply the force.

Note that this time you should use 200g and 300g loads instead of the heavier loads used above.

What results do you expect to get? Do you expect to get the same results as for the above activity or do you expect the results to be different? Write down what you think on the lines below.

____

____

____

____

____

____

Good, let us see what the results will be like.

2. Place the load at a fixed distance from the fulcrum (e.g. 20cm away) and hang the spring balance 10cm away from the fulcrum. Pull on the spring balance, and find out how much force is required to keep the bar balanced. Record the reading in Table 11.7.2 below.

3. Then move the spring balance 10cm further away from the fulcrum each time.

4. Record the force exerted each time you increase the distance of the effort in Table 11.7.2 below.

Load (grammes)	Distance of force applied from the fulcrum	Force exerted by spring balance (Newtons)
100g	10cm	
	20cm	

Load (grammes)	Distance of force applied from the fulcrum	Force exerted by spring balance (Newtons)
	30cm	
	40cm	
300g	10cm	
	20cm	
	30cm	
	40cm	

Table 11.7.2: Force required to move the load as distance of force from fulcrum is increased

This activity was a very interesting one. I am sure that you have made some very surprising observations and that you have got some very interesting results.

Study the results closely, and then answer the question below.

What do you notice as you increase the distance of the effort from the fulcrum?

____

____

____

____

We hope that this exercise helped you to better understand how first order levers work. See our feedback below for some comments on the activity.

Feedback

Feedback to Activity 11.7.1

- As the distance of the load from the fulcrum is increased, more force is needed to keep the bar balanced. Hence, the closer the fulcrum to the load, the easier it is to move the load or the further the fulcrum from the load the more difficult it is to move the load.

- As the distance of the force to the fulcrum is increased less force is needed to keep the bar balanced. Hence, the further the fulcrum to the effort, the easier it is to move the load or the closer the fulcrum to the effort the more difficult it is to move the load.

Let us now learn about second order levers.

Second order levers: In second order levers, the load is found between the fulcrum and the effort. This is shown in Fig. 6.8 (a) below.

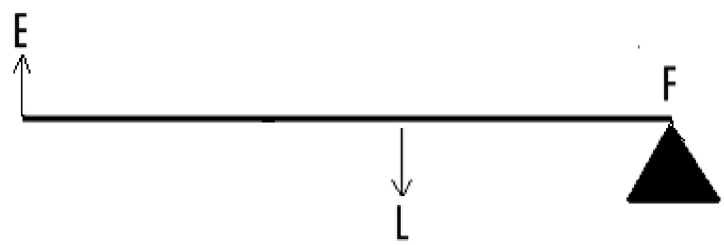


Figure 11.7.3 (a): Principle of second order levers

Drawn by Mariette Lucas (2010)

The wheel barrow is an everyday example of second order levers-Figure 11.6.8 (b). An example of when the second order lever principle is used in the human body is when you stand on your tiptoe.

Examples of second order levers	
In the body	In everyday life

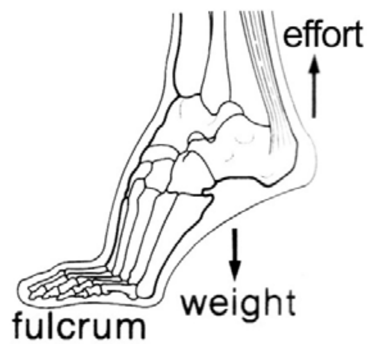
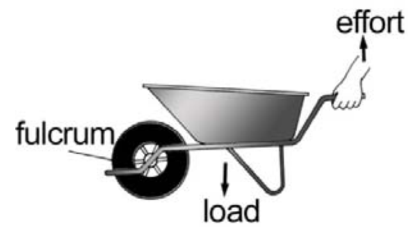
Examples of second order levers	
In the body	In everyday life
	
Standing on tiptoe	Wheel barrow

Figure 11.7.3 (b): Examples of second order levers

Drawn by Serge Mondon (2010)

Now, we shall learn about third order levers.

Third order levers: This is when the effort lies between the load and the fulcrum. Third order levers are shown in Figure 11.7.4 (a).

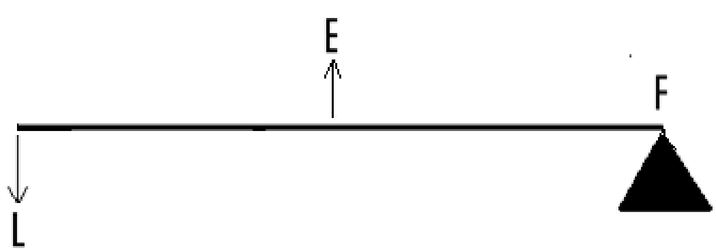


Figure 11.7.4 (a): Principle of third order levers
Drawn by Mariette Lucas (2010)

Tweezers, tongs and forceps are everyday examples of third order levers. In the human body when the elbow bends to lift the forearm, the third order lever principle is applied. These examples are shown in Figure 11.7.4 (b).

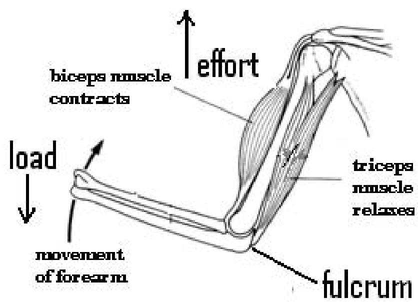
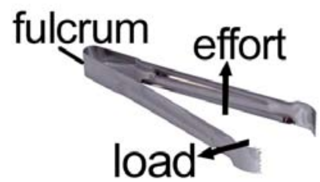
Examples of third order levers	
In the body	In everyday life
 Raising the forearm	 Ice tongs

Figure 11.7.4 (b): Examples of third order levers

Drawn by Serge Mondon (2010)

Group Activity 11.7.1 demonstrates the action of the biceps muscle to bend the elbow. You should note the amount of force required for such an effect and compare it with what you noticed in Activity 11.7.1 above.

Group activity

Group Activity 11.7.1

You should complete this activity in about 30 minutes.

For this activity you need to work with a group of students who are also doing this course. Once you have formed a group of about 4 members, get the following materials to set up the model shown below.

In the activity you will be investigating the action of the biceps muscle.

Materials:

Two flat pieces of wood of length 45cm.

Procedure:

Arrange the materials as shown below.

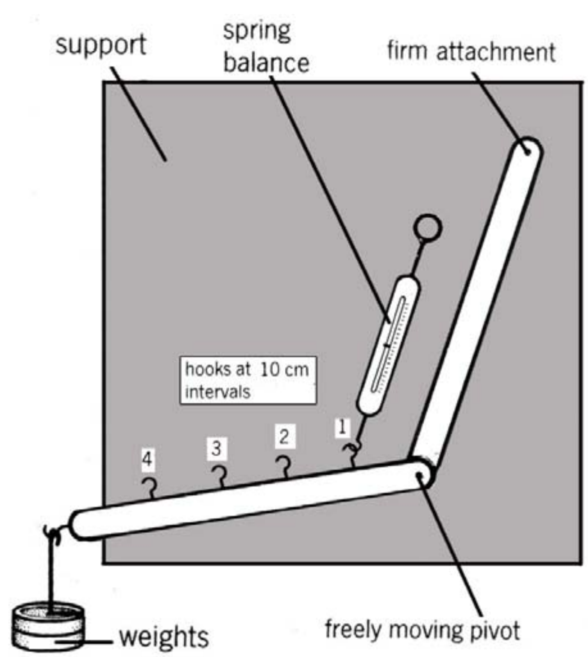


Figure 11.7.5 (a): Model showing action of biceps muscles

Drawn by Serge Mondon (2010)

1. Start by labeling the following parts of human arm next to their corresponding part on the diagram of the model before doing the

activity: **humerus**, **elbow joint**, **bones of the forearm** (**radius & ulna**), and **biceps**.

Indicate also in bold, the letters **F** for fulcrum, **E** for effort and **L** for load on the appropriate part on the diagram.

2. With the spring balance attached to hook 1, pull upwards parallel to the humerus until the forearm is exactly horizontal. Take the reading on the spring balance and record it in Table 11.7.3 below.

3. Repeat the activity with the spring balance puling on hook 2, then hook 3 and finally hook 4. Record each of the results next to the correct distance in Table 11.7.3 below.

Load (grammes)	Distance from elbow	Force exerted by spring balance (Newtons)
100g	10cm	
	20cm	
	30cm	
	40cm	

Table 11.7.3: Force required to move forearm as distance of force from fulcrum is increased

That must have been quite a discovery. Now attend to the questions below. They should help you make sense of the results that you have collected above as well as in Activity 11.7.2.

a. At which position was the force needed to lift the forearm the greatest?

b. Which position most closely represents the actual position of the attachment of the biceps muscle to the radius?

____

____

c. Skeletal muscles are able to exert considerable force, but they cannot contract by very large amounts. Can you suggest why the biceps is attached so close to the fulcrum?

____

____

d. Considering your answers to (a), (b) and (c) above, complete the following passage by using your own words:

The ________________ distance between the attachment of the biceps and the ________________ means that a large _______________ is required to produce a large effect. This shows that _______________ such as the biceps can produce large forces but are ________________ to contract over large distances.

With the above activity we have completed the topic on The Skeleton and Levers. Please refer to the feedback below to check your answers for group activity 11.7.1. This topic also brings us to the end of the unit on Support and Movement.

Feedback

Feedback to Group Activity 11.7.1

1. The corresponding parts of the human arm to the model are as follows:

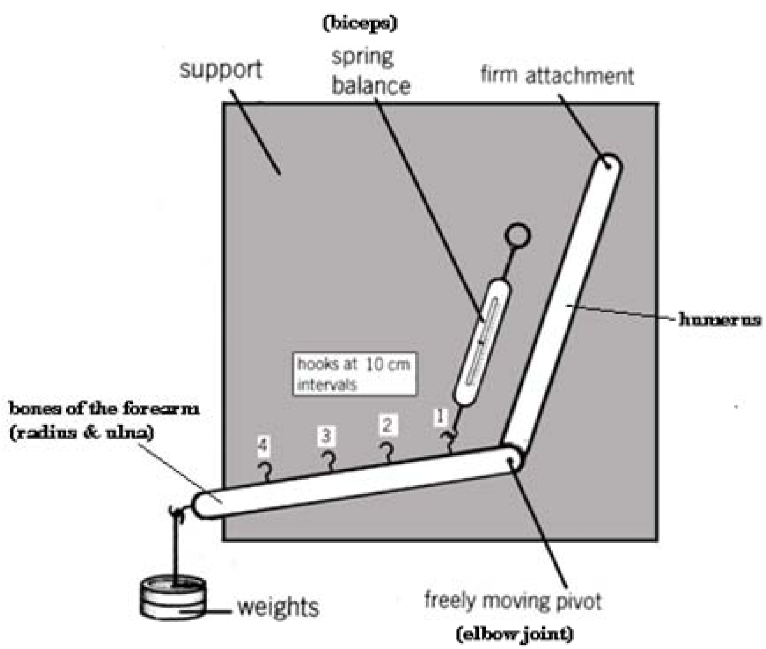


Figure 11.7.5 (b): Corresponding parts of human arm to model

Answers to questions (a) to (d).

a. Force for lifting the forearm was greatest at 10cm (hook 1) from the fulcrum.
b. Hook 1 most closely represents the actual position of attachment of the biceps muscle to the radius.
c. The biceps are attached so close to the fulcrum because of the fact that they cannot contract much, but can produce large forces.
d. The small distance between the attachment of the biceps and

the elbow joint (the pivot) means that a large force is required to produce a large effect. This shows that muscles such as the biceps can produce large forces but are unable to contract over large distances.

I hope you were able to successfully relate what you have learned about levers in the physics unit to the skeleton as levers. Understanding how levers work may help you lift something more efficiently or play sports more effectively.

You will now move on to study your next unit and I wish you good luck with your studies.

Unit summary

The first part of this unit dealt with support mechanisms of herbaceous and woody plants. We have seen that they have different support structures. In Herbaceous plants, the turgor pressure keeps the plant erect. In woody plants, the wood itself keeps them erect. This difference allows the woody plants to grow tall but not the herbaceous plants.

In this unit you also learned that vertebrates have three main types of muscles. These are the skeletal muscle, the smooth muscle and the cardiac muscle. You learned that skeletal muscle (also called striated, striped or voluntary muscle) is attached to bone and is concerned with locomotion of the animal. The smooth muscle (also called unstriated, unstriped, or involuntary) is found in tubular organs such the stomach, the intestine and the blood vessels (veins and arteries), and the cardiac muscle, which contracts spontaneously and without fatigue is found in the heart.

You also learned that skeletal muscle is attached to bone in at least two places; the origin and the insertion. The origin of the muscle is the point of attachment of one end of the muscle to a *firm non-movable bone.* At the insertion, the opposite end of the muscle is attached to a *freely movable bone*. In addition you learned that skeletal muscles are very firmly attached to bone by means of tough, inelastic tissues called tendons.

You further learned that pairs of muscles work together to move a bone. When one muscle relaxes the other contracts. Muscles that work together in this way are known as antagonistic muscles. Hence, when one of the antagonistic muscles contracts, the other muscle relaxes and the bone is moved in one direction. Biceps and triceps are only examples of antagonistic muscles. Antagonistic muscles are also found in the legs and many other places in the body

Flexor and extensor muscles are antagonistic muscles. They work together to allow bending and straightening of the joints. You learned that when bending the elbow joint or flexing the arm, the flexor muscle contracts while the extensor muscle relaxes. When straightening the elbow joint or extending the arm, the extensor muscle contracts while the flexor muscle relaxes.

Furthermore, you learned that in our body some of the bones, especially the long ones, function as levers. These bones (acting as the rigid bar of a lever) are able to move another bone (which is the load) at a joint (the fulcrum) under the pull of muscles (force/effort) when they contract. You saw that in everyday life three different orders of levers are recognized. These are first order levers, second order levers and third order levers.

First order levers are cases where the fulcrum (F) is found between the load (L) and the force/effort (E). An example of when our bones operate as first order levers is when we straighten the elbow joint to lower the forearm. The seesaw, the crowbar and scissors are everyday examples of first order levers

In second order levers, the load is found between the fulcrum and the effort. The wheel barrow is an everyday example of second order levers. An example of when the second order lever principle is used in the human body is when you stand on your tiptoe.

Third order levers are cases when the effort lies between the load and the fulcrum. Tweezers, tongs and forceps are everyday examples of third order levers. In the human body when the elbow bends to lift the forearm, the third order lever principle is applied.

Lastly, you learned that the muscles such as the biceps can produce large forces but are unable to contract over large distances.

Contents

Unit 12

Gravity

Introduction

Welcome to Unit 12 entitled *Gravity*. It consists of three main topics – gravitational field, mass and weight, and terminal velocity. The topic gravitational field will provide you with an insight into 'forces which act at a distance'. Hence, in this unit we will discuss *gravity, gravitational field, mass and weight, air resistance on falling objects and earth satellites* in general. We will, whenever possible, provide opportunities for you to try out some basic experiments and to apply formulae learnt within the unit. Think back to unit 8 (motion) and unit 9 (force and motion) as some of the concepts are related to what we are going to study this unit.

In this unit you will learn:

- That gravity is a force which acts between bodies;
- That earth is a source of a gravitational force
- About mass and weight
- About the part played by air resistance on falling bodies close to the earth
- About how objects orbit the earth.

We hope that this unit will be both interesting and enjoyable.

Outcomes

Upon completion of this unit you will be able to:

- *describe* gravity as a force which acts between bodies even though they are not in contact.
- *state* that the Earth is the source of a gravitational field.
- *distinguish* between mass and weight.
- *discuss* the part air resistance plays in the way objects fall when close to the Earth's surface.
- *explain* why it is possible for objects to orbit the Earth without falling to its surface.

Terminology

Air resistance:	Resistance exerted on a moving object by air particles
Mass:	The amount of matter in an object
Terminal velocity:	Maximum velocity achieved by a free falling object in a fluid (in fluid dynamics). In a free falling object, not in a fluid, this is obtained when the downward force of gravity equals the upward frictional force.
Weight:	The gravitational pull on an object

How long?

Table 12.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

Category of students	Number of formal study hours needed	Number of hours for self-study
Full-time student outside the conventional school setting	4 hours	2 hours
Full-time student within the conventional school setting OR Part-time student	4 hours	2 hours

Table 12.0: The time needed for you to work on this unit

Topic 12.1: Gravitational field

How long?

You will need 50 minutes at the most to complete this topic. It is advisable that you spend another 25 minutes of your own time to further review the activities learnt. Make sure you read and understand everything in order to achieve the specific objectives.

In Unit 9 you studied what forces can do. One of the things that we saw was that they can change the state of motion of objects. At this point we would like to draw your attention to one of the incidences that you experience on a daily basis. Have you ever asked yourself this question, ‘why is it that when something slips between your fingers, they always fall downwards. The same thing happens to fruits from the trees. In this unit we are going to shed more light on these occurrences. We will start off by looking at gravitational force.

12.1.1 Gravitational force

All objects exert a force of attraction towards each other because they have mass. This force of attraction between two objects is called *gravitational force* or simply *gravity.* The magnitude (size) of the force of gravity between two objects depends on two factors - the *quantity of matter* an object has (i.e. mass) and *the distance* between them. Therefore, the greater the mass, the greater the gravitational force of attraction, and the further apart they move, the weaker the force of gravity.

This means that a body with a large mass will exert a greater gravitational force of attraction than an object with a lesser mass. Likewise, as the distance between two objects increases the gravitational force of attraction between them becomes weaker. If the distance between them keeps on increasing the gravitational force between them will also continue to decrease until no force of attraction exists between them. This critical point gives rise to a boundary. The region within the boundary where the gravitational force of attraction can be felt is called the gravitational field. This means that two objects which lie outside each other's gravitational field do not experience a force of attraction between them.

As a matter of fact, the distance between you and your book is very small so their respective gravitational fields overlap. Also your mass and that of the book is very small so the force of attraction between you and the book is very small that it cannot be detected. However, if we now consider the attraction between your book, you and the earth which is a massive object, using the appropriate instruments the force will be measurable. In fact, this force of attraction by the earth:

1. is what holds you, your book and other objects firmly on it;
2. pulls objects on Earth towards the centre of the planet;
3. holds the Earth's atmosphere in place.

Hence, we can say that gravity attracts objects towards the centre of the Earth. Therefore, we can say that the earth acts like a big magnet that attracts objects towards its centre.

Figure 12.1.1: Diagram showing how the gravitational force acts on the earth

Sketched and photographed by: Lionel Goonetilleke, October 2010

If you were to place your book in a plastic bag and hang it on a spring balance, a reading will be obtained. The reading shows the size of the force of attraction by the earth on the book. This gravitational pull (force of attraction) on the book is called the **weight** of the book. Remember in "Unit 3: The strength of solids" force was addressed. Let us do a simple experiment to illustrate what we mean.

Activity

Activity 12.1.1

You should spend around 10 minutes on this activity.

You are invited to do this simple activity. For this experiment you will need five identical objects (e.g. books, weights, etc), a spring balance and two identical plastic bags.

Procedure: You are required to:

1. Select five identical objects (e.g. books) and two identical plastic bags.
2. Put one of the five objects in one bag and four in the other.
3. Lift the two bags at the same time but holding one in each hand.

Figure 12.1.2: Simple set up to compare mass and weight

Photographed by Louisette Bonte, September 2010

Use your observations to answer the questions given below.

1. Which plastic bag has more matter?

____

____

2 Which plastic bag was heavier?

3 Which bag do you think was being attracted with a greater force by the earth? Give reason for your answer.

4 Is there a relationship between the amount of matter and the weight (i.e. the downward pulling force)?

We hope that the task was easy for you. Please refer to the Feedback to Activity 12.1.1 to verify your answers.

Feedback

Feedback to Activity 12.1.1

1. The bag with 4 objects

2. The bag with 4 objects

3. The bag with 4 objects. This is because it has more matter (mass).

4. Yes. The more matter objects have the greater the weight.

   Well done! The bag with more objects (mass) felt heavier for it experienced a larger gravitational pull (weight).

We shall now focus our attention on the gravitational force on the moon.

12.1.2 Gravitational force on the moon

The moon is a natural satellite of the earth. The planet earth has a mass of 6.0 x 10^{24} kg and the moon has a mass of about one sixth of the mass of the earth as shown in Figure 12.1.3.

 Mass of earth: 6.0×10^{24} kg Source: http://en.wikipedia.org/wiki/Earth	 Mass of moon: $1/6 \times$ mass of earth

Figure 12.1.3: illustration of the Earth and its moon

Given that the gravitational force of attraction depends on the mass of an object, the moon exerts on any object a much smaller force compared to the earth. In fact the magnitude of the force of attraction by the moon is actually $1/_6$ the value of the force of attraction on the Earth. This means that on the moon if a mass of 1 kg is hung on a spring balance the reading will be 1.66 N (i.e. $10 \times 1/_6$ N).

Likewise, if an object is dropped within the gravitational field, close to the surface of the moon whose gravitational force is 1.66 N per kg, the object will accelerate at a rate of 1.66 m/s2 until it strikes the surface of the moon. Obviously, as it accelerates its velocity increases uniformly for there is no opposing force (friction) because the moon does not have an atmosphere.

If we were to sketch a graph of velocity (m/s) against time (s), a straight line graph passing through the origin is obtained as shown in Figure 12.1.4.

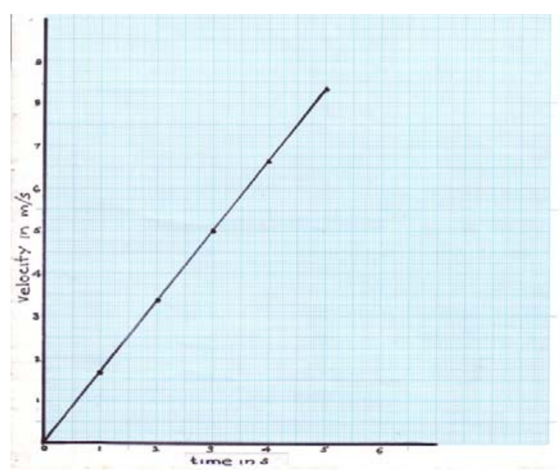


Figure 12.1.4: Graph of velocity against time of an object falling under the moon's gravity

Drawn by: Lionel Goonetilleke, October 2010

Now you are ready to apply the knowledge you have gained so far by going through activity 12.1.2.

Activity

Activity 12.1.2

You should spend approximately 10 minutes to do this simple activity.

For this experiment you will need a calculator, a ruler and Figure 12.1.4 above.

Procedure: You are required to:

Use the graph in Figure 12.1.4 to calculate the acceleration of an object due to the moon’s gravitational force for three different stages of the fall.

You will have to use the formula:

$$Acceleration = final\ velocity - \frac{initial\ velocity}{time\ taken}$$

Write you answers in Table 12.1.1. One example has been done for you.

Final velocity (m/s)	Time (s)	Acceleration (m/s^2)
$1.6 - 0 = 1.6$	$1 - 0 = 1$	1.6

Table 12.1.1: Velocity and acceleration of an object under the moon’s gravity

I hope that the task was simple for you. You should have noticed that the value of the acceleration due to the gravitational force of the moon is always a constant (i.e.1.6 m/s^2). This means that there is no change in the value of acceleration.

So far we have seen that an object of the same mass hang on a spring balance will give different readings depending on the gravitation field strength. This means that they will have different weight. So what is the difference between weight and mass? Well, we shall now focus our attention on the distinction between mass (a concept which you came across in unit 15) and weight.

Topic 12.2: Mass and weight

How long?

You will need 40 minutes at the most to complete this topic. It is advisable that you spend another 20 minutes of your own time to further review the activities learnt. Make sure you read and understand everything in order to achieve the specific objectives.

In Topic 12.1 you studied what gravitational force can do. One of the things that we saw was that it pulls all objects towards the centre of the earth, the moon, and other planets. The pull on stationary objects is what could be measured by a spring balance and was referred to as the weight of the object. In fact in this unit we are going to differentiate between mass and weight.

The terms *mass* and *weight* are commonly used in our everyday language. We often hear people talk about weight like, "my weight is 75 kg". We also hear people say they have lost weight. Someone would tell you that she has lost 3 kg, but on very few occasions, we hear people talk about their masses. Do you think they are using these terms correctly? These two terms appear to mean the same thing but in this section, we are going to discuss what they really mean.

In science, these the two terms have different meanings. When we talk about the mass of an object, we are referring to the amount of matter in that object. It is a measurement that depends on the number of particles that makes up the object and how heavy each particle is. The instrument that is normally used to measure the mass of an object is called a beam balance. The unit for mass is the kilogramme (kg) or the gramme (g). This does not mean that the kilogramme and the gramme are the only units of mass. However, the SI unit of mass is the kilogramme (kg).

Figure 12.2.1: Beam balance

Photographed by: Louisette Bonte, September 2010

Weight on the other hand is the gravitational pull on an object. This is the force that pulls objects towards the earth. The instrument that is normally used to measure the weight of an object is called a spring balance or newton balance. The SI unit of force is the newton (N). Since weight is a force it is also measured in newton (N).

Figure 12.2.2: Newton balance / Spring balance

Photographed by: Alex Souffe, September 2010

To help you get a feel of how large a force of one newton is like, we are going to invite you to carry out these two simple activities:-

1. Place a mass of 100 grammes (0.1kg) on the palm of your hand and feel the downward pushing force. Then hang it on a spring balance and note the reading;
2. Repeat the above activity but this time use a mass of 1kg. (*If you do not have access to a standard mass of 1kg, you may use a litre of water in a plastic container. It will have a mass of almost 1 kg*).

You should have noticed that the mass of 1kg exerted a larger downward force (weight) than the 100 g mass and the readings on the balance were 10N and 1N, respectively. Evidently, we can say that one kilogramme (mass) of an object experiences a force of 10 N. This is the force the earth pulls on a mass of 1kg and is known as the strength of the earth's gravitational force or simply gravity, (g). So it can be written as g = 10 N/kg. This value is constant (stays the same) close to or on earth. The pull of gravity like any other forces causes falling objects to accelerate. In a vacuum, the value of this acceleration, g, is about 10 m/s^2, therefore g = 10 m/s^2. This value of 10 m/s^2 is used for convenience in calculations but the exact value of gravity is 9.8 m/s^2.

Now let us see how we can calculate the weight of an object by going through an example:

Weight is the effect of any mass being pulled by gravity. Can you work out the weight exerted by a mass of 90 kg?

Weight can be calculated by using the formula:

$\text{Weight} = \text{mass} \times \text{gravity}$, which can be represented symbolically as

$\mathrm{W} = \mathrm{m} \times g$ (in N)

$\mathrm{W} = 90\,\cancel{\mathrm{kg}} \times 10\ \mathrm{N}/\cancel{\mathrm{kg}}$

$\mathrm{W} = 900\ \mathrm{N}$

The unit for mass (kg) cancels out each other

It looks very simple doesn't it? Now you can try some questions in Activity 12.2.1.

Activity

Activity 12.2.1

You should spend about 10 minutes to do this simple activity.

For this activity you will need a calculator.

Procedure: You are required to answer the questions below:

1. Use the equation $W = mg$ to calculate the weight of a car whose mass is 800 kg.

Follow the steps:

- Write down the given and missing data: m = 800 kg; g = 10 N/kg; W= ?
- Write the equation:
- Substitute values:
- Solve:
- Write the answer and the unit:

2. A book placed on a table exerts a weight of 20 N (g = 10 N/kg). Calculate the mass of the book.

3. If a person was to go to the moon, the attraction on him by the moon is less than when on the earth. Why do you think the attraction on the person by the moon is much less?

We hope that you found the activity very easy to complete. Please refer to the Feedback to Activity 12.2.1 to verify your answers.

Feedback

Feedback to Activity 12.2.1

1.

- Write down the given and missing data: m $=$ 800 kg; g $=$ 10 N/kg; W= ?
- Write the equation: W $=$ m $\times$ g (in N)
- Substitute values: W = 800 kg x $\frac{10\ N}{kg}$
- Solve: W = 800 ~~kg~~ $\times \frac{10\ N}{\cancel{kg}}$
- Write the answer and the unit: W = 8000 N

2.

- Write the equation: W $=$ m $\times$ g (in N)
- Rearrange the formula to get the mass: m $=$ W $\div$ g(in N)

- Substitute values: $m = \frac{20\ \text{N}}{10\ \text{N/kg}}$
- Solve: $m = = \frac{20\ \cancel{\text{N}}}{10 \cancel{\text{N}}/\text{kg}}$
- Write the answer and the unit: m = 2 kg

3. The mass of the moon is less than that of the earth and it exerts a smaller gravitational force on the person, so his weight is lower.

Good work! At this stage, we have established that the weight of a stationary object is due to the gravitational force being exerted on it. Now we are ready to consider the effects of gravitational force on an object falling within the earth's atmosphere. For example, 'what happens to its velocity?' Well, Topic 12.3 will surely provide the answer.

Topic 12.3: Terminal velocity

How long?

You will need 90 minutes at the most to complete this topic. It is advisable that you spend another 45 minutes of your own time to further practise the activities learnt. Make sure you read and understand everything in order to achieve the specific objectives.

In Topic 12.1 you learned that gravitational force not only makes things fall towards the earth but it also makes them accelerate. In this topic we are going to focus on the effect of gravitational force on falling objects.

Let us start off by considering an object of a given mass which is dropped from a hot air balloon.

Source: http://en.wikipedia.org/wiki/File:JoyRide.jpg

Figure 12.3.1: Hot air balloon

As the object leaves the balloon its starting velocity is zero and due to the earth's gravitational force, its velocity will obviously increase. Unlike around the moon, the earth has an atmosphere (air particles). These air particles will resist the fall of the object by exerting an opposing force. This means that the net force acting on the object will be reduced. A reduction in the net downward force will also result in a reduction in the rate of acceleration. Yet the velocity will increase but at a slower rate. Why? This is because there is a progressive reduction in the magnitude of the downward force (resulting force) as illustrated in Figure 12.3.2.

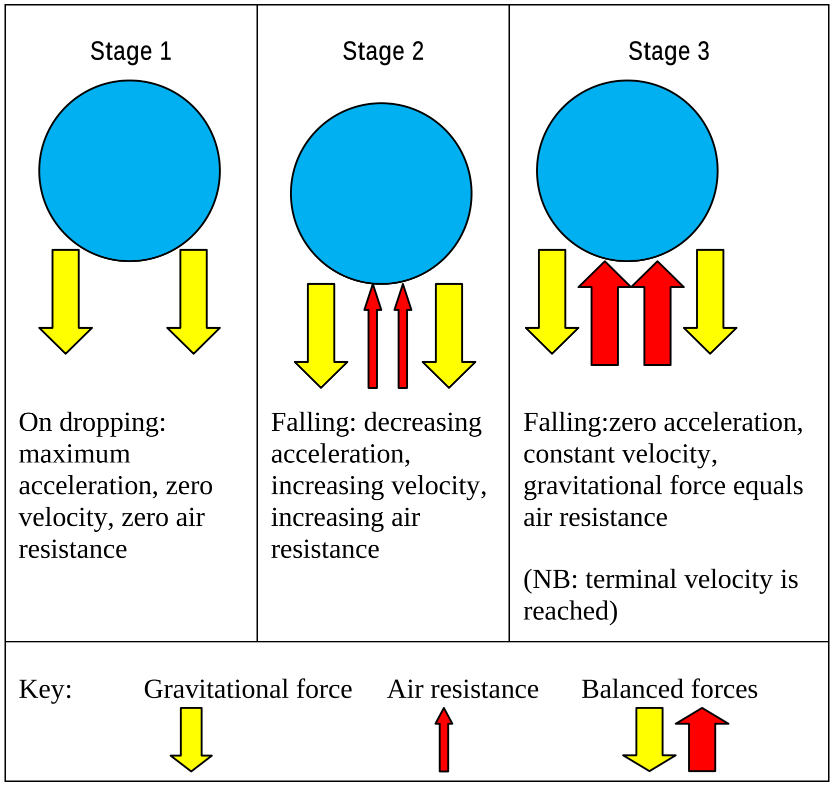


Figure 12.3.2: Diagrammatical representation of magnitude and directions of force acting during different stages of free fall.

Drawn by: Alex Souffe, October 2010

As depicted in figure 12.3.2, a stage is reached where the magnitude of the downward force due to gravity and the magnitude of opposing force due to air resistance are equal. At this stage the resultant force on the object is zero, so there is no acceleration. Hence, the object continues to fall at a constant velocity. Such constant velocity is referred to as terminal velocity.

At terminal velocity, the upward force due to air resistance is equal to the weight (mg) of the falling object. Also the higher the air resistance means the lower the terminal velocity, while increased weight means a higher terminal velocity. Evidently, the terminal velocity of an object can be affected by a change in air resistance, which in turn depends on the shape of the object or a downward force. This can be illustrated by the fall of sky divers without and with parachutes.

A  Source: http://en.wikipedia.org/wiki/File:Ilovechicago.jpg	The sky-divers (trainer and learner) jump from a helicopter or hot air balloon. At the start there is only one force – their weight. As their velocity increases so too does the air resistance. This continues until their weight is equal to air resistance (i.e. The two forces are balanced), so the resultant force is zero. At this point they continue to fall at constant velocity ($\cong$ 200km/h) referred to as **terminal velocity**. As this is a high velocity they will have to open their parachute.
B  Source: Adapted from http://en.wikipedia.org/wiki/Parachuting	When their parachute is opened the air resistance increases and the resultant force is upwards. It reduces the downward velocity until the weight is equal to the air resistance. At this stage the two forces are balanced and a new constant lower velocity is reached. The lower constant velocity will help them to land safely.

Figure 12.3.3: Sky-diving: A special case of terminal velocity

Sky-diving or parachuting is the action of performing acrobatics during freefall, followed by deployment of a parachute, giving rise to a special case of terminal velocity as illustrated in Figure 12.3.3. To help you understand better we will illustrate the change in the sky-diver's velocity on a graph in Figure 12.3.4. Before moving on, refer back to Figure 12.3.2, and ensure that you have understood the idea of terminal velocity well.

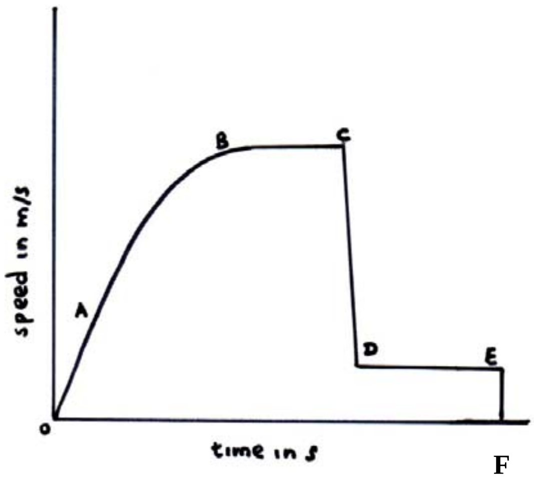


Figure 12.3.4: Graph of sky-diving: A special case of terminal velocity

Source: Adapted from Johnson, K. (1996). *Physics for you* (p. 99)

From the graph in figure 12.3.3, it is evident that the acceleration of the sky-divers varied throughout their fall with either a closed or an opened parachute. This is clearly shown by five regions A to F on the graph. Region A to B shows the velocity increasing and the acceleration decreasing. Region B to C shows high constant velocity and zero acceleration. Region C to D shows rapid decrease in velocity and rapid deceleration due to opening of the parachute. Region D to E shows constant low velocity and zero acceleration. Finally, E to F shows rapid change to zero velocity.

Now you are ready to try an activity involving falling objects in air.

Activity

Group Activity 12.3.1

You should spend about 15 minutes to do this simple activity.

For this activity you will need a calculator.

Procedure: You are required to:

Collect a very light feather and drop it from a height of one storey.

1. Observe and describe its motion carefully. (Caution: It has to be done at a time when the air is perfectly still).

2. If the same feather was to be dropped from the same height from the moon's surface, what difference would you expect in its motion? Give reasons for your answer.

Feedback

Feedback for group activity 12.3.1

1. The feather falls at a constant velocity due to the fact that it has low weight and a relatively large surface enabling it to reach its terminal velocity very quickly.

2. It will keep on accelerating uniformly until it lands without reaching the terminal velocity. This is because there is no air to offer resistance to its motion towards the moon's surface.

Good work! So far we have focused on objects moving/ falling towards the earth. Now we are going to consider how man-made objects, known as satellites, continue to move (without falling) at fixed distances above the earth's surface.

We will start off by inviting you to do a simple activity.

Activity

Activity 12.3.1

You should spend about 20 minutes to do this simple activity.

For this activity you will need a piece of string of 75 cm and a small solid object.

Procedure: You are required to:

1. Tie a small heavy object (e.g. a small stone) to a piece of string of 75cm long.
2. Hold the free end firmly in one hand and gently whirl in a circular motion above your head. As you whirl the stone above your head try to change its speed and observe what happens.

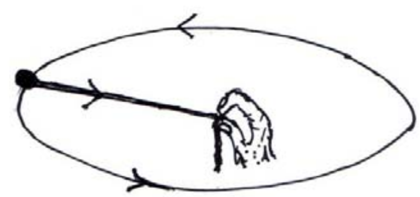


Figure 12.3.5: Diagram showing circular motion.

Drawn by: Lionel Goonetilleke, October 2010

Use your observations to answer the questions below.

1. From where did the stone get the energy to move?

___

___

2. What did you feel as the stone was whirled faster?

___

3. What happened when you reduced the force with which you were whirling the tied stone?

4. What do you think would happen if the string broke or slipped between your fingers?

5. Based on your observations what were the different forces involved while the stone was moving in a circular path?

Feedback

Feedback for activity 12.3.2

1. The energy came from the person’s hand.
2. The tension (force) in the string was increased as it was whirled faster.
3. It slowed down and did not maintain the circular motion (coiled around the person’s arm).
4. It will continue to move in a straight line at the point the string broke (at a tangent to the circular path).
5. Tension in the string pulling the stone inwards and in turn the stone exerts an equal outward pulling force on the person’s hand.

Good work! This was a simple activity after all, but the physics involved could be a bit difficult and has many applications. From this activity the stone was made to move in a circular path. The stone experienced a net force towards the centre (hand) of its point of rotation and this is called centripetal force. Centripetal force makes objects move in a circular path. We are going to use this idea to explain how satellites remain in orbit (i.e. move at a fixed distance above the earth surface)

Objects which have been placed into orbit by human endeavour are called artificial satellites to distinguish them from natural satellites such as the Moon. Satellites are used for a large number of purposes. Common types include military and civilian Earth observation satellites, communications satellites, navigation satellites, weather satellites, and research satellites. Satellites are usually semi-independent computer-controlled systems.

Figure 12.3.6: MILSTAR - A communication satellite

Source: http://upload.wikimedia.org/wikipedia/commons/e/e8/Milstar.jpg

A majority of artificial satellites are placed at a distance of about 320km to350 km, where they travel at about 8 km/s, making one complete revolution around the Earth in about 90 minutes.

Figure 12.3.7 shows different satellites orbiting the earth (in the centre) in different orbits. Centripetal force enables them to orbit the earth.

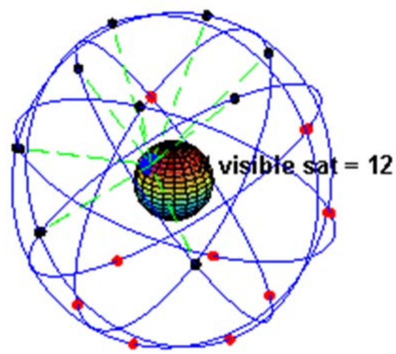


Figure 12.3.7: Different satellites orbiting the earth (in the centre) in different orbits.

Source: http://en.wikipedia.org/wiki/File:ConstellationGPS.gif

The force needed to keep a satellite in orbit depends on three factors:

i Its mass (i.e. Greater its mass ,greater the force needed);

ii Its speed (greater its speed, greater the force needed); and

iii The radius of the circular path (i.e. lesser the radius of circular path the greater the force needed).

We have come to the end of Unit 12. You should be ready to have a go at the self-assessment.

Unit summary

Summary

In this unit you learned when two objects are near each other, each one exerts a force of attraction. This force of attraction between two objects is called gravitational force or simply gravity. The magnitude (size) of the force of gravity between two objects depends on the mass and the distance between them. Therefore, the greater the mass the greater the gravitational force of attraction and the further apart they move, the weaker the force of gravity.

The planet Earth being a very large object with a large mass exerts a very large force of attraction which is called the earth gravitational force. The region around the object (e.g. earth) where this force is felt is called the gravitational field.

We also learned that the amount of matter in a body is called its mass and its magnitude is measured in kilogramme. The force of attraction on it by the Earth is called its weight and is measured in newton. The magnitude of the weight of a body depends on the gravitational force. Hence, a body with the same mass will have different weights on different planets.

We also saw that when a body is allowed to fall freely in air close to the Earth, its acceleration decreases as it falls due to air resistance until the downward force is equal to the opposing force. At this point the body falls at constant velocity, which is known as its terminal velocity.

Finally, we saw that the Earth's gravitational pull acts on satellites to keep them a circular path around the Earth. The force that keeps satellites in orbit (i.e. move at a fixed distance above the Earth's surface) is called the centripetal force. The centripetal force is affected by the mass and speed of the moving body and the radius of the orbit.

Assessment

Assessment

Self-assessment 12.1

You need about 30 minutes to do the self-assessment. This self-assessment is based on Unit 12 and the feedback is given at the end of the unit. Once again you are strongly advised to answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Part I

1. Which of the following units is used to measure weight?

   A. kilogram

   B. gramme

   C. newton

   D. pascal.

2. A marble and a cork sphere of the same volume were dropped from a height of 100 m above the moon's surface at the same time. Which statement about their motion is correct?

   A. Marble reaches moon surface quicker.

   B. Cork sphere reaches the moon surface quicker.

   C. Both reached the moon surface at the same time.

   D. None of them reached the moon surface.

3. A parachutist jumps from a stationary hot air balloon. His acceleration will be greatest

   A as he jumps from the balloon.

   B just before opening his parachute.

   C as he opens his parachute.

   D as he steps on the ground.

4. An astronaut wearing his space suit could jump to a maximum height of 0.5m on the earth. On the moon the same astronaut wearing the same suit would be able to jump to a maximum height of

   A 0.5m x 1/6

   B 0.5m x 6

   C 0.5m x 10

   D 0.5m x 10 x 1/6

5. Which statement about the mass of a falling object is correct?

   A. It decreases.

   B. It equals its weight.

   C. It increases.

   D. It stays the same.

Part II

(g is equal to 10 N/kg on the earth and 1.6N/kg on the moon)

1. Figure 12.3.8 shows a car of mass 800 kg being lifted by a crane.

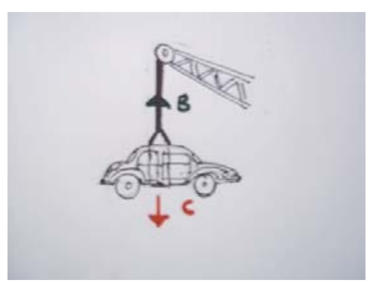


Figure 12.3.8

a. What is the weight of the car?

b. What force does “B” represent?

c. What force does “C” represent?

d. What is the minimum force needed to lift the car?

e. How could the force exerted by the crane engine be reduced to a minimum in order to lift the car?

2. Complete the table below by using the words provided.

   Weight, newton, force, mass, kilogram

   Use the word only once

	Amount of matter	Force of gravity
Quantity		
Unit		

3. The weight of an astronaut with all the equipment on the earth is 800 N.

a. What is the mass of the astronaut with the equipment?

b. What is the weight of the astronaut and the equipment on the moon?

4. Choose the correct word and complete the sentence.

It would be ______________ for an astronaut with all the equipment to do high jump on the moon because the moon's gravity is _______________ than the earth.

We hope that you have found this self-assessment easy to complete. You can now use the Answers to self-assessment 12.1 to verify your answers.

Answers to self-assessment

Answers to Assessment

Answers to Self-assessment 12.1

Part I

1.C;

2.C;

3.B;

4.B;

5.D;

Part II

1.

a. $W = mg$

$W = 800 \text{ kg} \times 10 \text{ N/kg}$

$W = 8000\text{N}$

b. Tensional force on the cable.

c. Weight of the car.

d. Minimum force is 8000N (i.e. the weight of the car).

e. Lubricate the pulleys and the gears to reduce friction.

2.

	Amount of matter	Force of gravity
Quantity	Mass	weight
Unit	kilogram	newton

3.

a. mass of astronaut

$W = mg$

$m = w/g$

$m = \frac{800N}{10N/kg}$

$m = 80\ kg$

b.

$W = mg$

$W = 80kg \times 1.6N/kg$

$W = 128\ N$

4. easier; less