

OPEN EDUCATIONAL RESOURCES

4

OPEN SCHOOLS

Taking Education to the People



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.

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Physical Science

Grade 10

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Continuous Assessment Manual Physical Science Grade 8-10 on NIED webpage:
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Physical Science for Namibia Grade 8, Heineman – 1992

Physical Science for Namibia Grade 9, Heineman – 1993

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About this Course material

Physical Science Grade 10 has been produced by COL Open Schools Initiative. All Course materials produced by COL Open Schools Initiative are structured in the same way, as outlined below.

How this Course material 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:

- whether 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;
- assignments and/or assessments, as applicable.



Resources

If you want to read more on extraction methods visit the following websites:

- Extraction of aluminium:
<http://www.chemguide.co.uk/inorganic/extraction/aluminium.html>
- Extraction of copper:
<http://www.chemguide.co.uk/inorganic/extraction/copper.html>

If you want to read more on the topic Light visit the following website:

<http://www.openschool.bc.ca/elementary/science4>

Your comments

After completing Physical Science Grade 10, 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. Click on the [constructive feedback](#) link to go to the document that you should complete.

Course overview

Welcome to Physical Science Grade 10

Physical Science Grade 10 enables candidates to better understand the technological world they live in, and take an informed interest in science and scientific developments. In this course, you will learn about the basic principles of physical science through a mix of theoretical and practical studies. You will also develop an understanding of the scientific skills essential for further study, and skills which are useful in everyday life.

Physical Science Grade 10—is this course for you?

This course is intended for people who would like to achieve the Junior Secondary Certificate [JSC] in their respective countries.

Course outcomes

On successful completion of Physical Science Grade 10 you will be able to:



Outcomes

- use methods and skills to increase variables in existing scientific models in order for models to reflect real-life situations;
- communicate their observations and conclusions using scientific and mathematical language and theories;
- realise the value of the natural environment and factors affecting the environment;
- acquire the knowledge and skills to maintain a safe and healthy lifestyle.



Timeframe



Time

Students at conventional schools normally take two years to prepare themselves for the Cambridge Overseas School Certificate examination in Physical Science. This is equivalent to six or seven hours per week for 40 weeks per year over two years, a total of roughly 525 study hours.

However, those who register with an open school often have to make time for their studies while fulfilling other responsibilities at home or at work. For this reason, a more flexible study schedule may be necessary. Nevertheless, it is essential that you create a timetable for yourself. If you do not set aside time on a regular basis to work through these materials, you may not be able to complete the course. To help you decide on a schedule please review the following examples.

Example Schedule 1

For example, If you decide on a schedule of , for example, one hour and 30 minutes a day for 5 days a week, you will most likely complete the course in 70 weeks (around 16 months).

$$1.5 \text{ hours} \times 5 \text{ days} = 7.5 \text{ hours (weekly)}$$

Total study time required for the course = 525 hours.

$$525 / 7.5 \text{ hours} = 70 \text{ weeks or just over 17 months.}$$

Example Schedule 2

For example, If you decide on a schedule of , for example, 2 hours a day for 5 days a week, you will most likely complete the course in 52.5 weeks (around 12 months).

$$2 \text{ hours} \times 5 \text{ days} = 10 \text{ hours (weekly)}$$

Total study time required for the course = 525 hours

$$525 / 10 \text{ hours} = 52.5 \text{ weeks or just over 12 months.}$$

Please note, that these are just guidelines, and the actual time that you take to complete the course will slightly vary from individual to individual.

Please review the following study hour guidelines for each unit of the course. These will be specified in more detail in each unit and section of the course.

Unit Number	Required Study Hours
1. Experimental Techniques	70
2. Matter	80
3. Materials	57

<i>Assessment and Revision Study Hours for Units 1, 2 & 3</i>	18
4. Environmental Chemistry	70
5. Mechanics – Work, Energy and Power	76
<i>Assessment and Revision Study Hours for Units 4 & 5</i>	14
6. Electricity & Magnetism	70
7. Waves, Sound & Light	56
<i>Assessment and Revision Study Hours for Units 6 & 7</i>	14
Total	520

Study skills



As an adult learner, your approach to learning will be different from that of your school days. You will choose what you want to study, you will have professional and/or personal motivation for doing so and you will most likely be organising 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. You may 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.

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” website 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, writing tests and anxiety.

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

This is the website 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 and memory skills (“remembering”).

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

This is another “how to study” website 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 and developing a learning plan.

The above web links are some suggestions to get you started. At the time of writing, these web links were active. If you would like to review further study skills websites go to www.google.com and type “self-study basics”, “self-study tips”, “self-study skills” or something similar.

Need help?



Help

The institution that is offering this course to students needs to provide the following information to their students. Please replace the questions in the shaded areas with the appropriate information.

1. Course web site address: www.namcol.edu.na
2. Course instructor: Ms U Kazombiaze
Tel: 264 61 320 5243
Fax: 264 61 216 987
Email address: kazombiaze@namcol.com.na
3. Learners Resource Centre: Yetu Yama Resource Centre Windhoek
Hours: 8h00 -17h00
Mr J Kavetuna
Tel: 264 61 320527
Email address: kavetuna@namcol.com.na
4. For technical issues contact:
Mr D Ngaujake

Assessment



Assessment

There will be an assessment at the end of Unit 3, Unit 5 and Unit 7. These end of unit assessments must be completed in hard copy. These can be submitted for marking to the nearest support centre.

Assessments consist mainly of sample questions from previous national examinations.

Feedback on the assessments is part of the teacher resources. This means that learners cannot access it.



Self-Mark Activity



Self-Mark Activity

There will be self-mark activities in each unit. These will not be submitted but marked by the students themselves. Answers to the self-mark activities can be found at the end of each unit.

Getting around this Course material

Margin icons

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

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

			
Self-Mark Activity	Assessment	Practical Activity	Basic Competence
			
Answers to Self-Mark Activities	Answers to Assessments	Outcomes	Reading
			
Summary	Reading	Terminology	Study skills
			
Time	Tip		



Unit 1

Experimental Techniques

Introduction

This unit is an introduction to some of the basic scientific skills that you use in your day-to-day activities. The skills in this unit should not be seen in isolation, as they form an integral part of the other units.

This unit consists of 6 sections:

Section	Study Hours
1. International System of Units (SI units)	12
2. Estimating and Measuring	21
3. Observing and Classifying	7
4. Recording Results	7
5. Presenting Results	9
6. Reasoned Explanation and Evaluation of Results	12
Review	2
Total	70



Outcomes

On successful completion of this unit you will be able to:

- *describe* how to use instruments and apparatus and how to observe and take readings;
- *explain* how to record the results of experimental investigations;
- *describe* the importance of communicating results to other people, both scientists and non-scientists (the use of ICT can be incorporated in this objective).

 Terminology	Mass	Amount of matter in a body.
	Volume	Amount of space that a substance occupies.
	Area	Measure of the size of a surface.

Section 1: International System of Units (SI Units)

Introduction

In some countries such as the United Kingdom and United States of America, length is measured in inches and feet, while others measure length in centimeters and meters. Equally, distance is measured in some countries in miles while others measure in kilometers. The same can be said about mass (pounds and kilograms) or volume (gallons and litres). In order to have a common system in science, we will use the S.I. unit system in this course. The abbreviation S.I. stands for International System of Units. This abbreviation, S.I. is taken directly from the French translation “Système International d'Unités”.

 Basic Competence	<p>Upon successfully completing of this section you will be able to:</p> <ul style="list-style-type: none"> • <i>recognize</i> and explain the relationship between symbols, units of measurement and the physical quantities they represent; • <i>recognize</i>, recall, from memory, and explain formulae representing physical quantities such as density, weight, Ohm’s Law, power and other terminology used in electricity, mechanics, light, waves, and chemistry. • <i>convert</i> physical quantities between different units of measurement such as metres, metre squared, kilogram and newton.
--	--

 Time	<p>This section will take you about 12 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
--	---



Symbols, Units and Definitions of Physical Quantities

The International System of units (S.I.) is the modern metric system of measurement. This is the language universally used in science. The terminology and symbols are also used internationally in commerce and trade.

The table on the next page shows you the symbols, units and abbreviations of the units that you will come across in this course. Read over them carefully because you will use them continuously throughout the course. The S.I. units are indicated in bold.

Quantity	Symbol	Unit	
length	l, h	km, m, cm, mm	kilometre, metre, centimetre, millimetre
area	A	m^2, cm^2	square metre, square centimetre
volume	V	m^3, cm^3, dm^3	cubic metre, cubic centimetre, cubic decimetre
weight	w	N	newton
mass	m	kg, g	kilogram, gram
time	t	h, min, s	hour, minute, second
density	ρ	$kg/m^3, g/cm^3$	kilogram per cubic metre, gram per cubic metre
speed	u	$km/h, m/s, cm/s$	kilometre per hour, metre per second, centimetre per second
velocity	v	$km/h, m/s, cm/s$	kilometre per hour, metre per second, centimetre per second
acceleration	a	m/s^2	metre per second squared
constant of gravitational force of 10 N on 1 kg of mass (10 N/kg) on or near the surface of the Earth, or the acceleration of free fall	g	m/s^2 or N/kg	metre per second squared or Newton per kilogram

force	F	N	newton
work done	W	J	joule
energy	E	J	joule
power	P	W	watt
temperature	T	$^{\circ}C, K$	degree Celsius, Kelvin
potential difference/voltage	V	V, mV	volt, millivolt
current	I	A, mA	ampere, milliampere
resistance	R	Ω	ohm

After studying this table, work through the following self-mark activity to improve your understanding.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 1:

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback at the end of the unit.

Answer the following questions:

Use the table of Symbols, Units and Definitions of Physical Quantities to complete blank boxes in the following table:

Quantity	Symbol	Unit
	a	m/s^2
area		m^2, cm^2
	ρ	
energy	E	J
		N
power	P	
temperature		
time		
weight		N
work done		J



Remember the following:

I want you now to go back to the table of Symbols, Units and Definitions of Physical Quantities and double check that your answers are correct by carefully looking at the upper or lower case of the symbols and units. For example, the symbol for *acceleration* is a lower case "a" while for *area* it is an upper case "A". The same applies for *work done* and *weight* as well as for *temperature* and *time*.

From these examples you should recognise that the symbol, as well as having it in either lower or upper case, plays an essential role. Further you should be very specific in indicating the units for physical quantities. The acceptable methods of stating units (e.g. metres per second or m per s) will be written as m/s or $m\ s^{-1}$ (Note: The solidus (/) will be used for a quotient and indicates units in labels of tables and graphs e.g., distance/cm)

When writing numbers for this course, you will need to place the decimal point on the line (e.g., 52.35). Numbers from 1000 to 9999 will be printed without decimal points or spaces. Numbers greater than or equal to 1, 000 will be printed without decimal points. (A comma will be left between each group of three whole numbers e.g., 1,000, 10,000, 100,000).

Throughout this course you will come across some formulae. It is recommended that you print out the following table and have it always handy in order to get well acquainted with these formulae. Again, great caution is urged in ensuring that upper and lower case rule for each symbol is strictly followed.

Formulae:

For this course, you are required to recognize and understand the formulae on the table shown below. Please memorise them.

Quantity		Formula
Density	density [ρ] = mass [m] \div volume [V]	$\rho = \frac{m}{V}$
Weight	weight [w] = mass [m] \times acceleration due to Earth's gravity [g] NOTE: $g \approx 10\ m/s^2$	$w = m \times g$
Work	work [W] = force [F] \times distance moved in the direction of the force [d]	$W = F \times d$
Pressure	pressure [p] = force [F] \div area [A]	$p = \frac{F}{A}$
Ohm's Law	voltage [V] = current [I] \times resistance [R]	$V = I \times R$

Power	power [P] = voltage [V] × current [I]	$P = V \times I$
Current	current [I] = charge [Q] ÷ time [t]	$I = \frac{Q}{t}$
Voltage	voltage [V] = energy [E] ÷ charge [Q]	$V = \frac{E}{Q}$
Billing Cost of Electricity	Energy [E] = power [P] × time in hours [t]	$E = P \times t$

Conversion of Units:

From the table on Symbols, Units and Definitions of Physical Quantities you will notice that some quantities, such as length, area and volume, have more than one unit. However they share only one symbol. Therefore, it is also important to be able to convert between units with a quantity.

Length:

Let us start with length. The **base** unit of length is meter (m). So, some conversions are as follows:

$$\begin{aligned} 1 \text{ m} &= 10 \text{ decimetres (dm)} \\ 1 \text{ dm} &= 10 \text{ cm} \\ 1 \text{ cm} &= 10 \text{ mm} \\ 1 \text{ kilometre (km)} &= 1,000 \text{ m.} \end{aligned}$$

In order not to learn all off the conversions by heart, there is an easier method of doing conversions. This method involves learning what the base unit of each quantity is and what the prefix of each unit means.

The **base** unit is the main unit of the quantity. For example, for length it is metre (m) and for mass it is gram (g). If you now know the meaning of the prefixes, you will be able to make correct conversions.

Some examples of prefixes and their meaning are in the table below:

Prefix	Means
kilo	thousand (1,000)
hecta	hundred (100)
deca	ten (10)
deci	tenth (1/10)
centi	hundredth (1/100)
milli	thousandth (1/1,000)



Now, let's work through an example. If we take the **base** unit of length to be a meter (m) then from looking at the table you can see that:

$$1 \text{ m} = 10 \text{ decimetres (dm)}$$

which means 1m is the same as 10 dm.

And

$$1 \text{ kilometre (km)} = 1,000 \text{ m}$$

Which means 1 km is the same as a thousand meters.



Tip

The trick is just to know when to multiply by the value (1,000, 100, 10, 1/10, 1/100 or 1/1,000) of the prefix. The **general rule of thumb** is that when you need to convert from a:

- bigger unit to a smaller unit, you need to multiply by the value of the prefix;
- smaller unit to a bigger unit, you need to divide by the value of the prefix.

See if you can follow how the following example conversions are done:

Example

- Write 30 cm in millimetres (mm).
- Express 3,000 m in kilometres (km).

Solution

- Write 30 cm in millimetres (mm).

To do this, we have to convert from a larger unit to a smaller unit. This requires multiplication.

$$30 \text{ cm} \times 10 = 300 \text{ mm [1 cm is 10 times larger than a millimetre]}$$

$$[1 \text{ cm} = 10 \text{ mm}]$$

- Express 3,000 m in kilometres (km).

To do this, we have to convert from a smaller unit to a larger unit. This requires division.

$$3,000 \text{ m} \div 1,000 = 3 \text{ km [1 km is a 1,000 times larger than a metre]}$$

$$[1 \text{ km} = 1,000 \text{ m}]$$

Try to understand how the following conversion is worked out:

The length of a line is 32 cm. This is 320 mm or 0.32 m.

You must be able to convert numbers between units. This will require either dividing by a certain factor or multiplying by another factor. Study the examples just provided and their solutions.

Now, try to do the following self-mark activity on your own.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 2

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

1. Calculate these values:

	Answers
a) Write 3 m as centimetres (cm).	
b) How many metres are there in 2.5 km?	
2. Convert:	
a) 5.34 m into millimetres	
b) 734 mm into centimeters	
c) 3.2 cm into metres.	

I hope you found it easy to convert the units of length.

Next, we will learn about the conversion of units of mass.

Mass

The base unit of mass is gram (g). This means that a kilogram is equal to a thousand grams. Larger masses are expressed in tonnes (t). One tonne equals 1,000 kg. Tonnes (t) is used more in industry.

The table below will guide you with conversion of units of mass. Study the table carefully.

Prefix	kilo	hecta	deca	BASE	deci	centi	milli
Abbreviation	k	h	da		d	c	m
Multiplication factor	1,000	100	10	1	1/10	1/100	1/1,000



Mass	kg	hg	dag	g	dg	cg	mg
------	----	----	-----	---	----	----	----

Let us work through an example of converting grams into kilograms.

Example

1. How much is 200 g in kg? Do you know? Yes, 0.2 kg.
2. Convert 2 kg to grams. Did you get 2,000 g? Good!

Now use the table above and the rule of thumb mentioned earlier to work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 3:

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

Calculate each quantity in the unit given in brackets.

	Answers
a) 100 g to (kg)	
b) 7.3 g to (mg)	
c) 2,024 kg to (t)	
d) 7 kg to (mg)	
e) 89 mg to (g)	

I hope you found it easy to complete the table.

Lets do the conversion of area and volume.

Area and Volume

Both area and volume share the same base unit as length. This base unit is a meter (m).

However, due to the formula for calculating *area*:

length in metres times width in metres) or (length in metres x width in metres), the base unit for *area* becomes m^2 (read square metres).

Also, due to the formula for calculating *volume*:

(length in metres times width in metres times height in metres) or (length in m x width in m x height in m), the base unit for volume becomes m^3 (read cubic metre).

It also means that the Prefix conversion table needs to be adapted accordingly.

Below we have the Prefix conversion table for length:

Prefix	kilo	hecta	deca	BASE	deci	centi	milli
Abbreviation	k	h	da		d	c	m
Multiplication factor	1,000	100	10	1	1/10	1/100	1/1,000

To adapt the Prefix conversion table from length to area, we have to square all the multiplication factors. Study the table of area (below) carefully to see how the multiplication factors have been squared. For example, $1,000^2$ ($1,000 \times 1,000$) = 1,000,000.

Area

Abbreviation	km^2	hm^2	dam^2	m^2	dm^2	cm^2	mm^2
Multiplication factor	1,000,000	10,000	100	1	1/100	1/10,000	1/1,000,000

To adapt the Prefix conversion table from length to volume we have to cube all the multiplication factors. Study the table of volume (below) carefully to see how the multiplication factors have been cubed. For example, $1,000^3$ ($1,000 \times 1,000 \times 1,000$) = 1,000,000,000.

Volume

Abbreviation	Multiplication factor
km^3	1,000,000,000
hm^3	1,000,000
dam^3	1,000
m^3	1
dm^3	1/1,000
cm^3	1/1,000,000



mm³	1/1,000,000,000
-----------------------	-----------------

Due to the large numbers we normally use only the bolded units in the tables above:

For *area* these are:

$$1 \text{ m}^2 = 10,000 \text{ cm}^2 \quad \text{or} \quad 1 \text{ cm}^2 = 1/10,000 \text{ m}^2$$

$$10,000 \text{ m}^2 = 1 \text{ hm}^2 \quad \text{or} \quad 1 \text{ hm}^2 = 10,000 \text{ m}^2$$

We usually do not say hecta square *metres* for hm^2 . Rather, we refer to hm^2 as “hectares”—a piece of land 100 m by 100 m (remember area = $\ell \times w$).

Now, use the tables above to work on the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 4

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

Complete the table by writing the answers in the open boxes:

	÷	x	Multiplication Factor	Answer
1. How many square metres are there in 2,450 hectares?				
2. Calculate				
(a) 7 m ² in square millimetres				
(b) 43 cm ² in square millimeters				

(c) 19.2 cm ² in square metres				
---	--	--	--	--

I hope your attempt at completing this self-mark activity went well. Are you ready to continue? Lets learn how to do conversions for volume.

Volume

For volume, conversions using the base unit of metre become a little complicated. The measurement of litre is commonly used but it is not an SI unit.

So for making conversions for volume:

- $1 \text{ m}^3 = 1,000 \text{ dm}^3$ or $1,000 \text{ litres} = 1,000, 000, 000 \text{ cm}^3$ or millilitres.
- 1 dm^3 or one litre = $1,000 \text{ cm}^3$ or 1,000 millilitres.

Practice conversions for volume by working on the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 5

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

Complete the table below:	÷	×	Factor	Answer
1a) Write 3 m^3 as cubic centimetres (cm^3)				
b) How many cubic metres are there in $1,700 \text{ cm}^3$?				
2. Calculate				
a) 7 m^3 in cubic decimetre				
b) 194 cm^3 in cubic decimetre				
c) $3,2 \text{ dm}^3$ in cubic metres				



d) 9.2 dm^3 in cubic millimetre				
---	--	--	--	--

I hope you did not find it difficult to do the conversions in this self-mark activity.

We will learn about the conversions for time next.

Time

The base unit of time is seconds (s). Sometimes the abbreviation “sec” is used, however please note that “sec” is NOT part of the S.I units. The common unit for time is an hour. A day has 24 of them. You also know that 60 minutes make an hour. Clocks indicate hours, minutes and seconds. As time does not work in units of 1, 10 and 100 the conversions of time is not as straight forward as length.

To convert units of time you can use the following information on conversions:

1 hour = 60 minutes

1 minute = 60 seconds

1 hour = 3 600 seconds

Use the information above to do the conversion of time in the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 6

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

1. Convert these values to 2 decimal places where necessary:	Answer:
a) 127 s into min	
b) 28 min in h	
c) 2.4 days into h	
d) 3.4 h into s	

I hope it went well with the conversion of time.

Now we are going to discuss the conversion of temperature.

Temperature and Zero Reading

Temperature has the base unit Kelvin (K). However, in every day life degrees Celsius ($^{\circ}\text{C}$), is usually used. Water freezes at 0°C and at sea level it boils at 100°C . For temperature intervals rather than specific temperatures $1\text{ K} = 1^{\circ}\text{C}$.

However, the main difference between Kelvin and Celsius is with respect to where Zero Reading starts.

For Celsius, Zero Reading starts at zero.

For Kelvin, Zero Reading starts at -273°C .

To convert from Kelvin to degrees Celsius calculate in this way:

$$^{\circ}\text{C} = \text{K} - 273.$$

To convert from degrees Celsius to Kelvin calculate in this way:

$$\text{K} = ^{\circ}\text{C} + 273.$$

You might ask, “Why does Kelvin start at -273°C ?” This is because this level of temperature is called “absolute zero.” In other words, it means that at this level of temperature, nothing can be cooled below -273°C .

Now do the conversion of degrees Celsius to Kelvin and vice versa in the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-mark Activity 7

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

1. Convert these values:	Answer:
a) 28°C into K	
b) -34°C into K	
c) 40 K into $^{\circ}\text{C}$	
d) 354 K into $^{\circ}\text{C}$	

Well done. This knowledge of units and conversion of units will help you in the next section which deals with estimating and measuring.



Section 2: Estimating and Measuring

Introduction

In our daily life, we have to *measure* or make *estimates* many times. In this section we will discuss how to do these.

You have done this many times in your life—estimating a value. I am sure that you have used the words: “I think this stick is one metre long”, or “It took about half an hour to write the letter”. It is not vital if you cannot estimate exactly, but it is quite useful. However, if you know the length of a ruler or the mass of one kilogram, then it is fairly easy to estimate in comparison.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>estimate</i> and <i>measure</i> length, mass, time, temperature, volume and area; • <i>estimate, measure</i> and/or calculate volume; • <i>convert</i> units of length, mass, time and volume; • <i>differentiate</i> between clinical and laboratory thermometers.
--	---

 Time	<p>This section will take you about 21 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
--	---

Measuring Length:

How high is the table that you sit at? Is it about 70 centimetres (cm)? Yes, because we know that a ruler is 30 cm or 300 millimetres (mm), and the table is about twice that, so it must be just more than 60 cm high. You can also estimate that a house or street is about 100 metres (m) from you, because we know more or less that the length of a sports field is 100 m. So, we can easily estimate length or distance.

It is essential to know that the metric unit of length is based on a metre (1 m).

We also use smaller and longer lengths to measure. Remember from the previous topic that:

1 m = 10 decimetres (dm), and 1 dm = 10 cm, and 1 cm = 10 mm

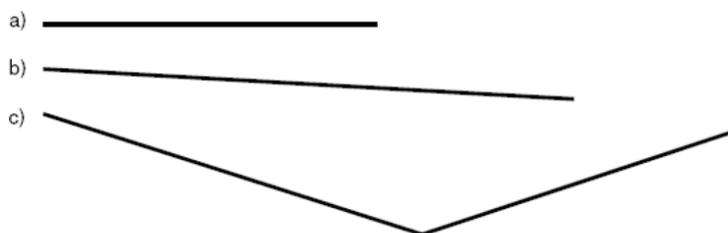
1 kilometre (km) = 1,000 m

Remember to use appropriate units to indicate lengths. For example, your shoe is 32 cm long, a room is 5 m long and it is 30 km to the next town.

The way we measure length is by using a ruler or odometer. Most of us are familiar with a ruler which is used to measure small lengths. An *odometer* on the other hand, is used to measure big distances. For example, trying to find out the distance to another town when we are in our cars.



Let us try some smaller lengths. Estimate first and then measure the lengths of these lines (you might need to print them out for that purpose).



How did you do? I am sure, just fine. Try to do this exercise using longer distances and remember, to estimate is not the same as finding out the exact distance.

The same principle works for mass.

Mass

Mass is the amount of matter in a body. We know that mass does not differ from place to place. You are familiar with mass, for we buy many products by mass. Sugar comes in 1 kg and 2.5 kg bags. Maize meal also comes in a 5.0 kg bag. The basic unit for mass is gram (g). This is a fairly small unit in comparison to kilogram (kg) which we are more familiar with. A paperclip weighs about 1g, an A4 type page is 80 g and one dm^3 (one litre) of water is 1 kg. Larger masses are expressed in tonnes (t). One tonne equals 1,000 kg and is used more in industry.

Why don't you try the following and test your skill and knowledge?

Estimate and measure the mass of:

- a) an apple;
- b) a building brick;
- c) a person.



Now use a scale to find the correct mass. An apple is about 200 g, a brick 2 kg and a person about 70 kg.

How much is 200 g in kg? Do you know? Yes, 0.2 kg. Now write 2 kg in grams.

Did you get 2,000 g? Good!

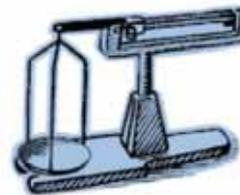
It is important that we use the correct instruments to measure mass. In science and in everyday life, we use instruments such as a bathroom scale, a beam balance or an electronic scale to measure mass.



Balance



Bathroom scale



Beam balance

Its now time to work through the following self-mark activity. Good luck with it!

Self-Mark Activity



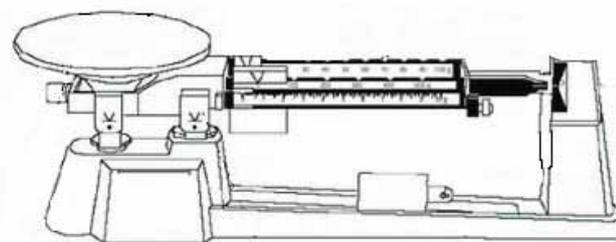
Self-Mark Activity

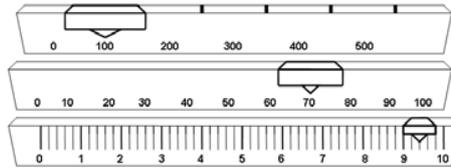
Self-mark Activity 1

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

For the following objects, read the mass of the object from the triple beam balance reading.

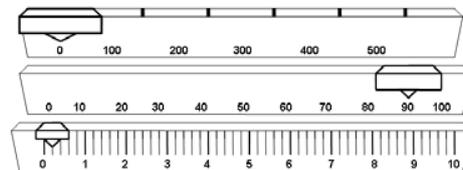




If we were to read this scale the mass would be $100\text{g} + 70\text{g} + 9.4\text{g} = 179.4\text{g}$.

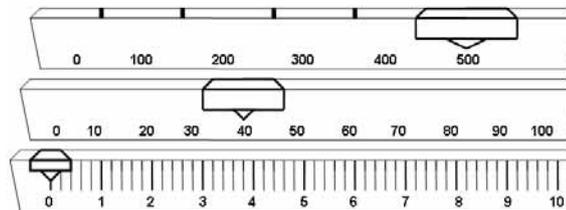
Use this example to find out the mass for the following objects:

1. Object A



mass: _____ g

2. Object B



mass: _____ g

I hope you did not find the self-mark activity too difficult.

Let's now look a time.

Time

Time is common to us. We usually do not have enough of it to do whatever we want or need to do. Often people say: "Time is money", but it is sad to say, money can't buy time. We know time as years, days, hours, etc. You probably also have a wristwatch which you use when you run your errands. How many times have you said: "See you in five minutes?" This indicates a certain time span. The common unit for time is an hour. A day has 24 of them. You also know that 60 minutes make an hour. Clocks indicate hours, minutes and seconds. You are indeed able to



What did you get?

- a) probably 02:30 or 30 minutes past 2;
- b) did you say 10 past 10 or 10:10;
- c) this looks like 5 o'clock.

The question would be, is this day time or night time? I think 02:30 at night, because the zero in front of the 2 signifies am. However in order to make sure that there is no confusion, we write a.m. or p.m.

A 12-hour clock is a time conversion convention in which the 24 hours of a day are divided into two periods called ante meridiem (a.m., Latin: "before noon") and post meridiem (p.m., Latin: "after noon"). The capitalization and punctuation of a.m. and p.m. may vary (consistently) in different texts. Each period consists of 12 hours numbered 12 (acting as zero), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.

(Source: Wikipedia.)

There is also an alternative to writing a.m. and p.m. after the time. This is done by indicating the time in a 24-hour cycle called the 24-hour clock notation. For example 1 p.m. becomes 13:00 hours and 3 p.m. becomes 15:00 hours.

State what the following would be using the 24-hour system?

- a) 8:00 p.m.
- b) 11:00 p.m.
- c) 8:00 a.m.

You can use the following to check your answer:

Clock system			
12-hour	24-hour	12-hour	24-hour
Midnight 12:00 a.m.	00 00	Noon 12:00 p.m.	12 00
01:00 a.m.	01 00	01:00 p.m.	13 00
02:00 a.m.	02 00	02:00 p.m.	14 00
03:00 a.m.	03 00	03:00 p.m.	15 00
04:00 a.m.	04 00	04:00 p.m.	16 00
05:00 a.m.	05 00	05:00 p.m.	17 00
06:00 a.m.	06 00	06:00 p.m.	18 00
07:00 a.m.	07 00	07:00 p.m.	19 00

08:00 a.m.	08 00	08:00 p.m.	20 00
09:00 a.m.	09 00	09:00 p.m.	21 00
10:00 a.m.	10 00	10:00 p.m.	22 00
11:00 a.m.	11 00	11:00 p.m.	23 00
		Undefined (midnight)	24 00

Something to think about:

The indication of noon and midnight in the 12-hour system is disputed.

The 24-hour clock notation avoids all of those ambiguities by using 00:00 for midnight at the start of the day and 12:00 for noon. From 23:59:59, the time shifts (one second later) to 00:00:00, the beginning of the next day. Some variants of the 24-hour notation (including the world standard ISO 8601) use 24:00 when referring to midnight at the end of a day. (Source: Wikipedia)

Can you estimate:

- The time it takes to write a sentence?
- How long it takes for water to boil?
- How long it takes to run a certain distance?

The correct instrument for performing this exercise would be a stopwatch.



a)



b)

Activity:

Read the time on the stopwatch in (a).

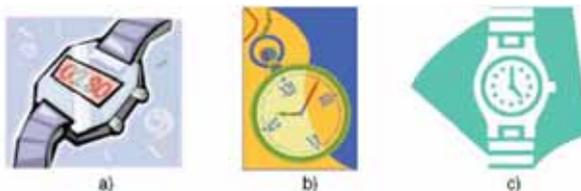
Write down how the reading on stopwatch (b) would look like after a time of 1 minute and 38.4 seconds.



In the past, most people used their wristwatch to keep track of time. However, these days most people use their cell phones to read the time. Did you know that most cell phones also have a stopwatch function? Investigate your own cell phone in order to find the stopwatch function.



read time, I am sure of that! Let us see, “What is the time on these watches?”



Now, try to answer the questions in the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 2

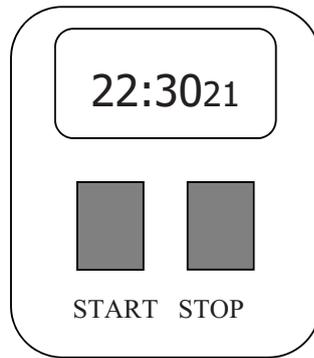
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

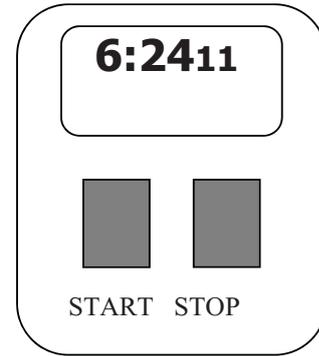
Read the times of the following stop watches and enter your answer in the spaces below:

1.

2.

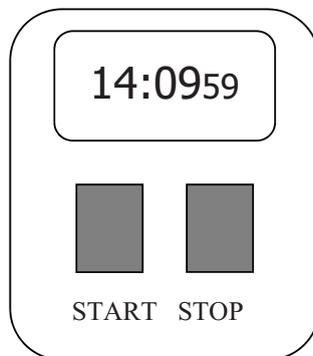


_____ min _____ s



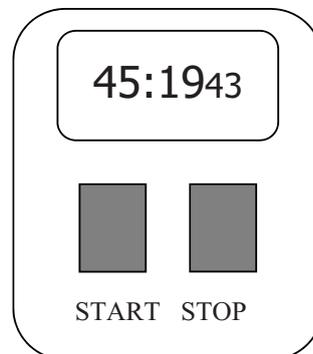
_____ min _____ s

3.



_____ min _____ s

4.





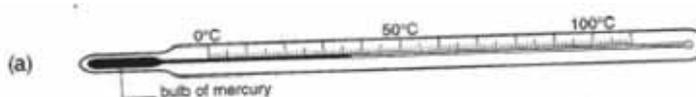
_____ min _____ s

I hope you found it easy to do this self-mark activity.

Temperature

What is the temperature today? We listen to the weather forecast to find out the temperature of the day. We know that water boils at 100°C , where $^{\circ}\text{C}$ represents degree Celsius, the unit for temperature.

The instrument used for this is the thermometer. Instrument **(a)** is a simple thermometer used in a science laboratory.



Instrument **(b)** is a clinical thermometer, used by hospital personnel to measure temperature in the human body. The clinical thermometer has a constriction close to the bulb which prevents the liquid from moving back while recording temperature.



A thermometer is a thin glass tube into which a coloured liquid or mercury has been poured. The tube is then sealed at both ends. The marks you see on a thermometer are used as the temperature scale. Creating the marks on this scale is known as calibration. The temperature scales are called the fixed points. These temperature scales enable you to measure temperature accurately.

The lower fixed point generally used indicates the melting point of water at 0°C . The upper fixed point indicates the boiling point of water, which is 100°C at standard pressure. To calibrate a thermometer, it is placed first into melting ice and then into boiling water. The positions of the coloured liquid in the tube are then marked as 0°C and 100°C respectively.

Because the length of the fluid is directly proportional to the temperature, the scale is divided up into equal length divisions. This means that if the length between the 0°C and the 100°C marks is 10cm, a temperature change of 1°C would be 1mm in length. This means that there is a linear relationship between the change in temperature and the length of the fluid.

Now its time to work through the following self-mark activity.

Self-Mark Activity



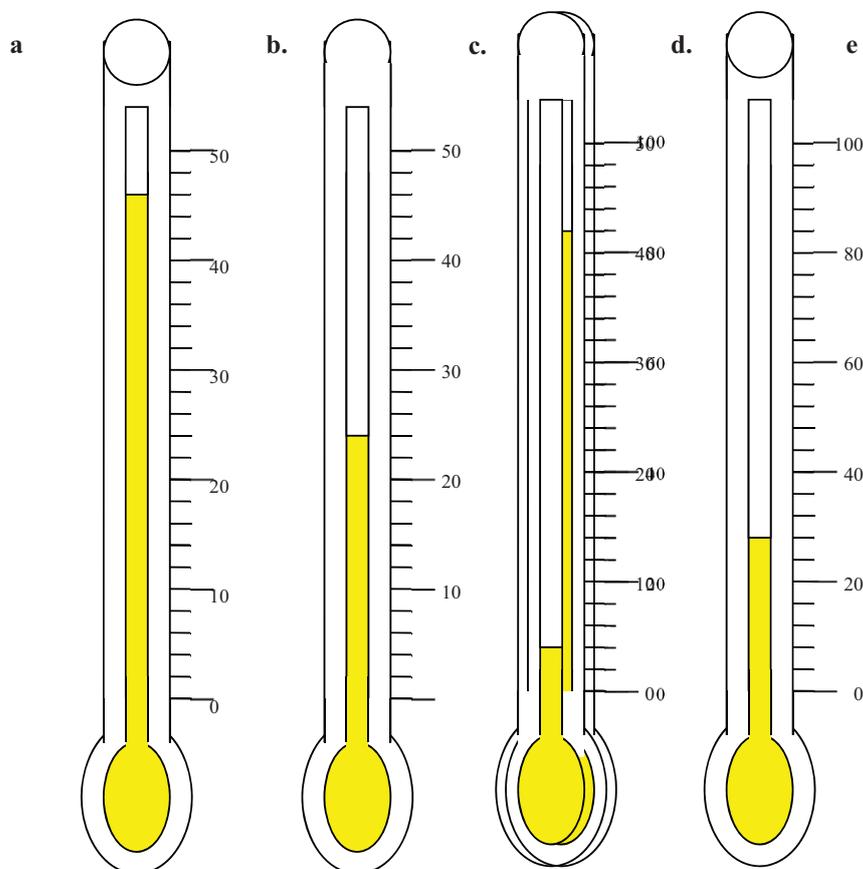
Self-Mark Activity

Self-Mark Activity 3

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Calculate the difference in temperature if the maximum temperature today was 32°C and the minimum was 24°C .
2. Water at room temperature is about 25°C . If it goes in a freezer which has a temperature of -4°C , by how many degrees did the temperature fall?
3. Differentiate, in terms of structure, a clinical thermometer from a laboratory thermometer.
4. NOTE: Thermometers have different scales. Read the temperatures of the following thermometers, paying close attention to their scales.



I hope you found reading the thermometers easy.

Let's continue by discussing volume. You have already introduced to making conversions in volume in section 1 of this unit. Now we will look at how to estimate and measure volume.

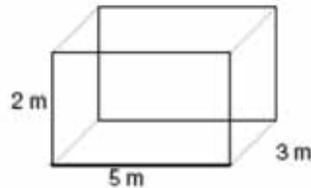
Volume

Volume is an indication of how much substance is in a certain object or how much matter can go into an object. One can also say that volume is the amount of space that a substance occupies. It is sometimes a little more difficult to estimate volume, but once we have a standard unit or quantity this can be easier. We are familiar with the quantity associated with standard cold drink bottles, for example, 300 ml or 1 litre. This is also volume, but we would rather use the units cm^3 (centimeter cubed) or m^3 (metre cubed). Please note that cm^3 is also referred to as cubic centimetre and m^3 is a cubic metre).

Measuring and Calculating Volume in a Regular Shaped Object

You can easily determine the volume of an object that can be measured and then use a formula to calculate the volume.

Here is an example: Your room has the following measurements.



The volume can be calculated with the following formula:

Volume = length \times breadth \times height

$$V = l \times b \times h$$

$$= 5 \text{ m} \times 3 \text{ m} \times 2 \text{ m}$$

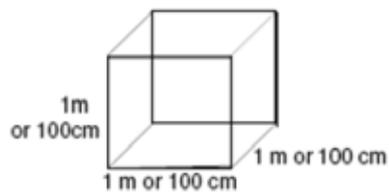
$$= 30 \text{ m}^3$$



Tip

How about converting 30 m^3 to cm^3 ? To do this we multiply by

1,000,000. This will then give us $3,000,000 \text{ cm}^3$. How come? Look at the following cube:



$$\text{Volume} = l \times b \times h \text{ OR } \text{Volume} = l \times b \times h$$

$$= 1 \text{ m} \times 1 \text{ m} \times 1 \text{ m} = 100 \text{ cm} \times 100 \text{ cm} \times 100 \text{ cm}$$

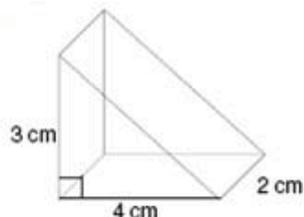
$$= 1 \text{ m}^3 = 1,000,000 \text{ cm}^3$$

When you convert from metre to centimetre you need to multiply by one million.

The same method is used to calculate the volume of a prism or cylinder.



Measuring and Calculating Volume in a Prism:

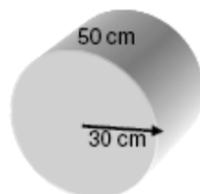


Volume = $\frac{1}{2} bh \times \text{length}$ ('b' is for base and 'h' for height)

$$V = \frac{1}{2} \times 4 \times 3 \times 2$$

$$= 12 \text{ cm}^3$$

Measuring and Calculating Volume in a Cylinder:



Volume = $\pi r^2 \times h$ ('r' is for radius and 'h' for height and ' π ' is pi)

$$V = 3.142 \times 30^2 \times 50 \text{ (}\pi \square = 3.142 \text{ or } \pi \square \text{ on calculator)}$$

$$= 141,390 \text{ cm}^3 \text{ (or } 0.141 \text{ m}^3\text{)}$$

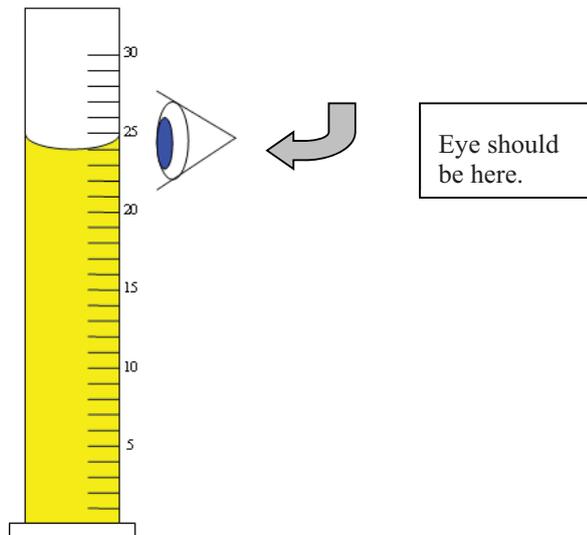
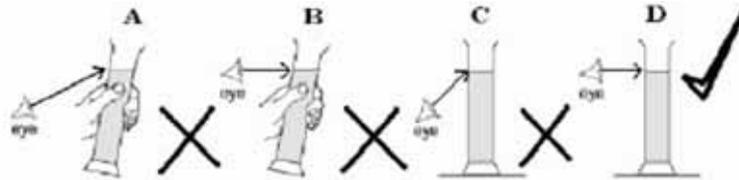
Measuring the Volume of Liquids

You can easily find out the volume of liquids if you have a measuring cylinder or measuring beaker. We have to be very careful when readings are taken for liquids in cylinders. Liquids form a *meniscus*. This is the curve of the liquid due to the attraction and repulsion between the liquid particles and the container particles.

The following shows a meniscus for water.



Other reading mistakes can be made, for example the *error of parallax*. This happens when the reading is not taken on a horizontal level. In the example below, D is the correct method whereas A, B and C are the common mistakes made in this regard.



Note: Volume is measured from the bottom of the meniscus (the curve of the liquid).

For example, the reading for the volume of the liquid above is 24 cm^3 .



Measuring Small Volume of Liquids

Very small volumes of liquid can be measured by using a glass pipette.

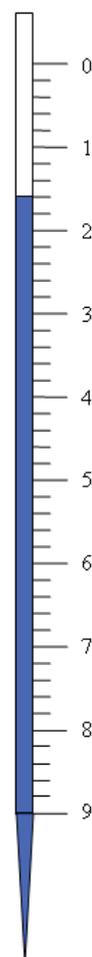
To do this you suck the liquid into the pipette using your mouth (only when using water).

Use a suction bulb for other kinds of liquid.

When the liquid is in the pipette, you remove the bulb and then place your index finger over the top of the pipette.

You then allow the excess liquid to drain up to the required mark.

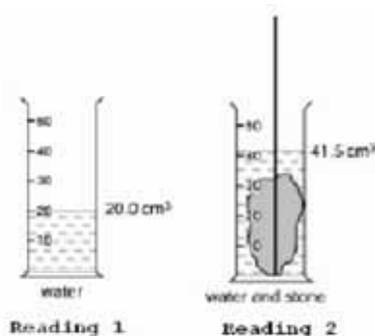
In this course you will use pipettes with set volumes 10, 25 or 50 ml.



Volume of an Irregular Shaped Object.

There are two methods used for finding the volume of an irregular shaped object, like a stone or plasticine.

1. The easiest method is by using a measuring cylinder. To do this:
2. You simply pour some water in a measuring cylinder (see Reading 1 below).
3. You then lower the stone or object into the water. The water level will rise in the cylinder.
4. Read the new water level (see Reading 2 below).
5. You then subtract reading 1 from reading 2. This will give you the volume of the object.



$$\text{reading 2} = 41.5 \text{ cm}^3$$

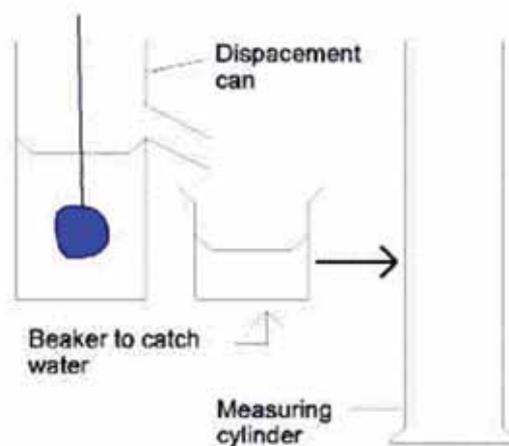
$$\text{reading 1} = 20.0 \text{ cm}^3$$

volume

$$\text{of stone} = 21.5 \text{ cm}^3$$

The second method is by making use of a displacement can. We use this method mostly when the object is too large for the measuring cylinder. To use this method use the following procedure:

1. Fill the displacement can with water till it reaches the outflow spout.
2. Put a measuring cylinder at the end of the spout.
3. Place the object into the can.
4. The water will then be displaced into the measuring cylinder and you will know exactly what the volume of the object is.



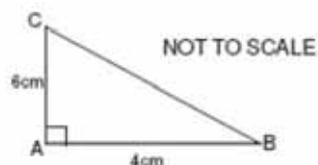
Let's continue by discussing area. You have already been introduced to making conversions in area in Section 1 of this unit. Now we will look at how to estimate and measure area.

Area

Area is the measure of the size of a surface. For example, if you want to know how much carpet you need to cover a floor, then it is the area of the floor which matters. Area is measured in m^2 .

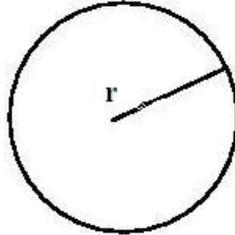
To measure the area of a right-angled triangle:

The area of the triangle is given by
area of triangle = $\frac{1}{2}$ x base x height



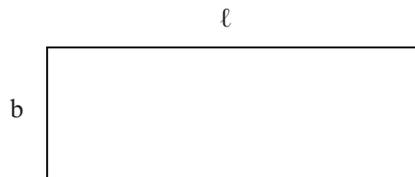
$$\begin{aligned}\text{Area } \triangle ABC &= \frac{1}{2} \times AB \times AC \\ &= \frac{1}{2} \times 4\text{cm} \times 6\text{cm} \\ &= 12\text{cm}^2\end{aligned}$$

To measure the area of a circle:



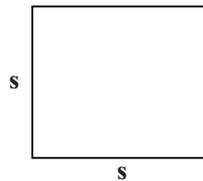
The area of a circle = πr^2 ($\pi \times r \times r$)

To measure the area of a rectangle:



The area of a rectangle = $l \times b$

To measure the area of a square:



The area of a square = s^2 ($s \times s$)

I hope you studied the different methods of measuring area well enough. Try to see how much you have learned by doing the following self-mark activity.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 4

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

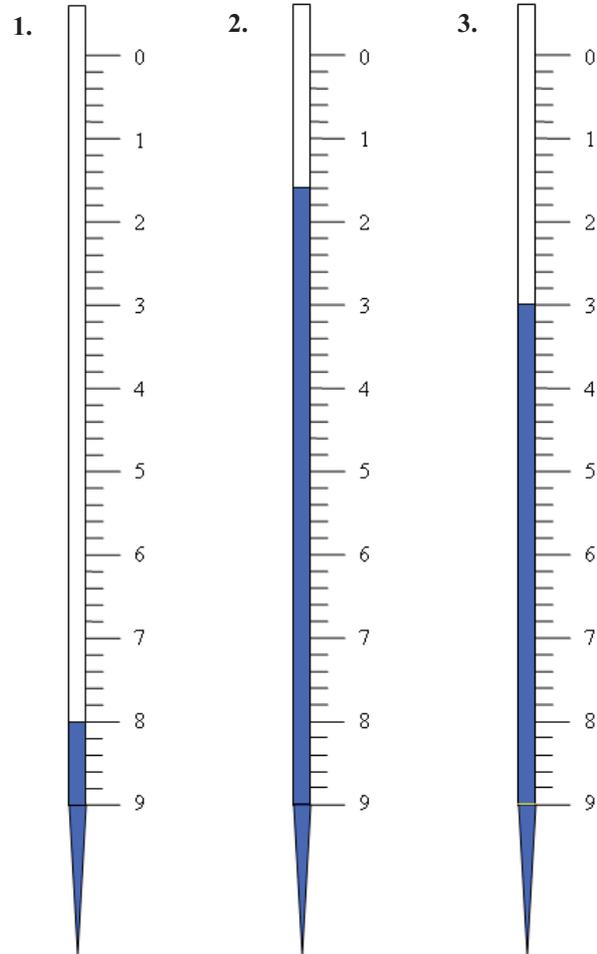
Question 1:

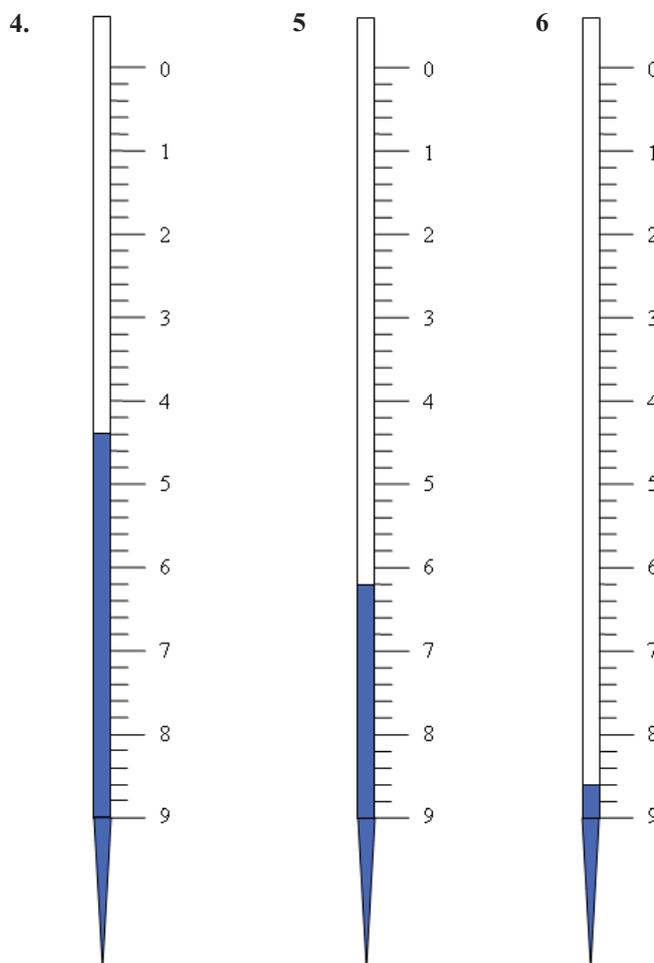
Volume measurement using pipettes. Note that the scale for pipettes begins with zero at the top! The following (shown below) are 10 cm³ pipettes.

To read measurement, you subtract the measurement from 10.

For example, for number 1, the correct answer is $10 - 8 = 2 \text{ cm}^3$.

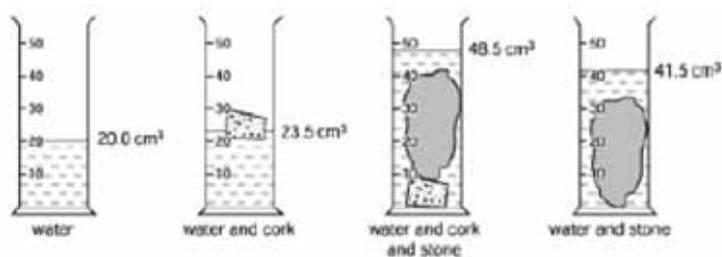
Read the measurements for the rest of the pipettes:





Question 2:

A student has to determine the volume of a piece of cork. The following are sketches of a plan the student decided to do in this experiment. From the studying the sketches, determine the volume of the cork.



If you were successful in answering this self- mark activity, you can continue with Section 3. If not, review the different methods for measuring area again.

Section 3: Observing and Classifying

Introduction

To observe simply means to ‘see’ and ‘look’ and then decide in what group a substance belongs. An easy experiment is to look at people around you and see which are men and which are women. You might also observe trees around you and classify them into tall trees or shrubs.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>apply</i> the five senses: sight, smell, hearing, touch and taste to making observations in science; • <i>describe</i> how to group (classify) objects in a variety of ways.
--	--

 <p>Time</p>	<p>This section will take you about seven hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
--	--

When we are asked to observe something, we usually only use our eyes..

 <p>Tip</p>	<p>SOMETHING TO REMEMBER: However, observing in science includes the use of the five senses: sight, smell, hearing, touch and taste. We do not usually use sense of taste as this could be dangerous.</p>
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For example, what do you observe what do you observe when you look at the two kettles below?



Source: <http://www.industryplayer.com/licenceinfo.php?licid=012021>

- the colour (one is grey while the other is light blue);
- both have a round shape;
- both have a handle;
- both have steam (NOT water vapour as water vapour is invisible) coming out of them;
- Figure two has an electrical input area.

BUT the following are not observations:

- both are boiling;
- one is an electric kettle, while the other is an kettle for a gas stove.

Very often people confuse conclusions and observations. For example, water boils is a conclusion while bubbles formed is an observation.

To explain the example above: We can observe with our senses, in this case our eyes, so the observation is condensed water vapour in the form of steam is coming out, THEREFORE, our conclusion is that the water in the kettle is boiling.

We saw the electrical plug or electrical cord, THEREFORE our conclusion is that it is an electrical kettle.

Activity:

Below is a block of ice that is left for a while in the sun.

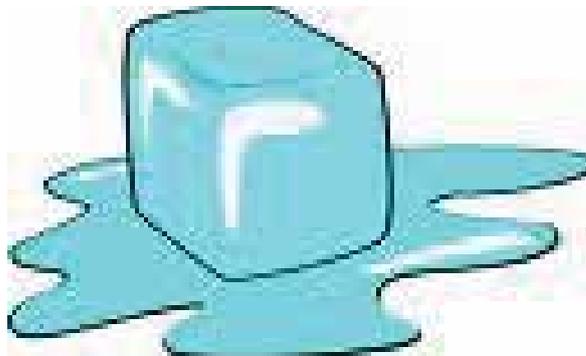


Figure Three: Melting ice

Source: <http://www.fundraw.com/clipart/clip-art/00001488/Melting-Ice-Cube/>

Describe your observation of Figure three in the space below:

Your correct observation should be that you see ice and water. However, saying that the ice is melting would NOT be your observation but your conclusion.

A general guideline to help you differentiate observations from conclusions is as follows:

When you write the conclusion of an experiment you will use statements such as the examples shown in the following statements:	When you record observations of practical activities you must use your five senses: sight, smell, hearing, touch and taste. Some examples of observations are as follows:
• water boils	• steam and bubbles are formed
• ice melts	• the ice forms water
• the reaction is exothermic	• the test tube feels hot
• a gas is formed	• fumes of a gas can be seen



Another scientific experiment is as follows:

You will need a teaspoon of different substances. If you have a magnifying glass this will also be very useful.



In the observation above, we concentrate on specific properties or features that in scientific language are called **variables**. In this case, we will look at colour, size, texture, sound, shape and smell which are all variables in this investigation.

Substance	Colour	Size	Texture	Sound	Shape	Smell
sugar	white	very small	rough	quiet rattle	tiny crystals	none

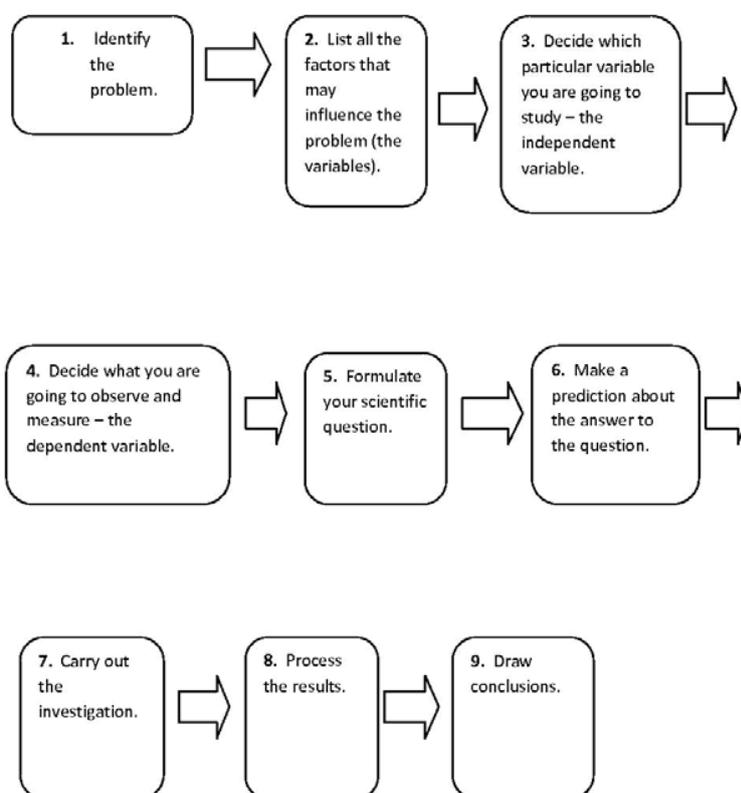
You might come to a conclusion that is similar to this:

Substance	Colour	Size	Texture	Sound	Shape	Smell
sugar	white	very small	rough	quiet rattle	tiny crystals	none
salt	white	very small	a bit rough	very soft rattle	tiny crystals	none
sand	brownish	small	very rough	rattle	sort of crystals	none
pepper	grey	very small	soft	no sound	powdery	itches when

						sniffed
flour	whitish	very small	soft	no sound	powdery	none

Recording of observations

Making and recording observations of practical activities and investigations accurately are the basis of Science. The processes of planning a practical investigation are outlined below. The first four steps will depend highly on your skills to observe.



Source: Continuous Assessment Manual Physical Science Grade 8-10 on the NIED website: <http://www.nied.edu.na>

As an example to illustrate this process, let's look at the factors that affect the period of a pendulum. We will look at the first 6 steps in this section. Step 7 (carry out the investigation), Step 8 (process the results) and Step 9 (draw conclusions) will be dealt with in future sections.

Step 1: Identify the problem.

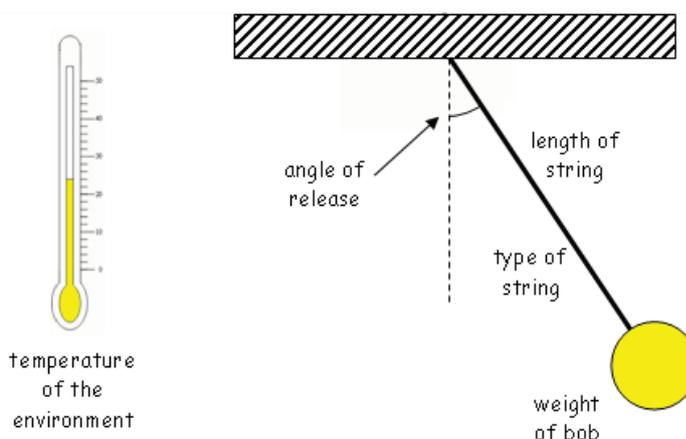


What are the factors that affect the period of a pendulum?

Step 2: List all the factors that may influence the problem (the variables).

Here we list every variable we can think of, for example:

- weight of the pendulum bob;
- angle at which the bob is released;
- temperature of the environment;
- length of string;
- type of string used.



Step 3: Decide which particular variable you are going to study—the independent variable.

This is the variable you as the experimenter or researcher will be changing, adjusting or manipulating. In other words, it is the one you are going to test. In our example, let's choose length of string as our independent variable. This means that for our investigation we will be varying the length of the string. All other variables must remain constant. This means that, the weight of the bob, the release angle, the temperature of environment and the type of string used must be the same or remain constant.

Step 4: Decide what you are going to observe and measure—the dependent variable.

This is the variable that you will be measuring. It is the variable that changes as a result of the adjustment you make to the independent variable. In other words, the changes that happen to the dependent variable are dependent on how the independent variable is adjusted. For this problem, we are interested in factors that affect the period of the pendulum, so we will choose period (or time) as our dependent variable.

Step 5: Formulate your scientific question.

Now we will formulate our question so that we can answer it by conducting our experiment. The question is: how does the length of a pendulum affect the period? Length is our independent variable; period (or time) is the dependent variable.

Step 6: Make a prediction about the answer to the question.

A prediction is an important part of the experimental process. It allows you to use your prior knowledge and experiences to make a judgment about what will occur. Often our predictions are correct; these reinforce our understanding of the world. Sometimes, however, our predictions are wrong; these experiences help us to dismantle our personal concepts which are wrong through direct observation.

Source: Continuous Assessment Manual Physical Science Grade 8-10 on NIED website: <http://www.nied.edu.na>

We will continue this experiment later.

Now try to reinforce your understanding by working through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity :

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- | |
|---|
| 1. Compare why substances such as sugar rattle in a bottle while others do not. |
| 2. State whether all crystals of a substance have the same shape. |
| 3. State whether crystals of different substances have the same shape. |



4. Write down a general conclusion.

If you feel you have mastered the contents of Section 3, you can move on to Section 4.

Section 4: Recording Results

Introduction

Recording results or data is very important in any scientific investigation. People often think that during an experiment, they will be able to remember all the results that happen until the experiment ends. They think that they will be able to keep all the results in their heads and then write it all down, once the experiment is finished. This has been shown to be quite impossible.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>record</i> the results of experimental investigations in a logical manner in different formats such as tables and tallies. • <i>present</i> results of an investigation in tables using each of the columns with appropriate headings of the physical quantity and the units of measure (e.g. time/s).
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 Time	<p>This section will take you about seven hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Recording Data in a Table

The first step in recording data is usually to create a table for noting down results. In some instances you would use a tally slip. How do these differ? A table is for directly recording quantitative data and a tally sheet is used for recording items as you count them.

A simple table is used for recording quantitative data when you know the numbers for each category in the table. See the example below.

Write down the names of a few friends and their ages.

Ndapewa	Paulus	Loide	Sara	Jacob
13	14	14	16	15

A tally sheet is used to record the counting of the individual items for each category in the table. For instance, the example below shows, how to count and record the number of different cold drink tins in a rubbish bin.

Coca cola		19
Fanta		14
Sprite		8
7-up		12

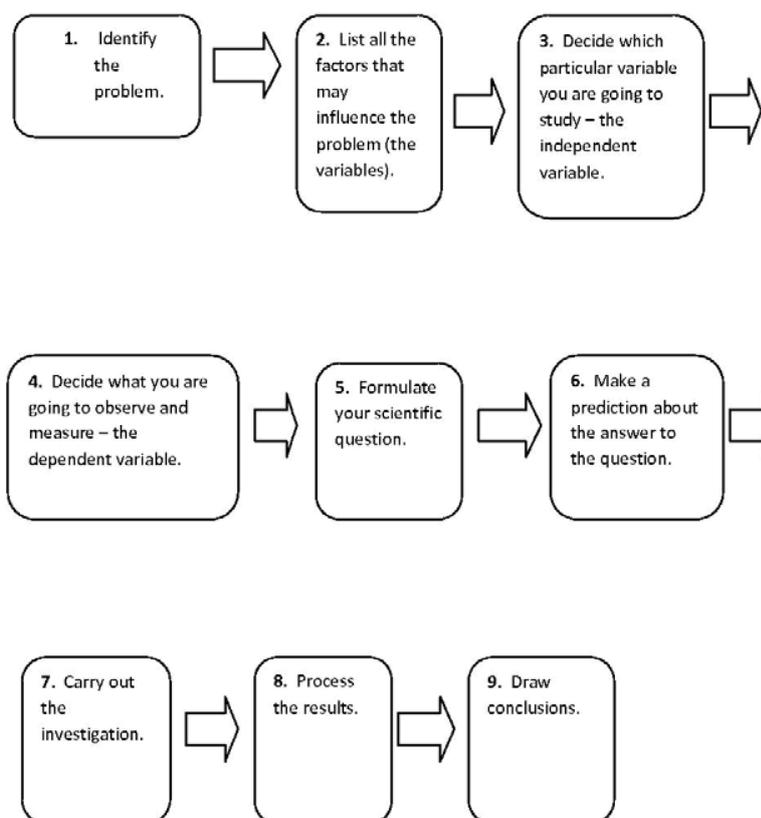
This is fun. You can do a similar recycle exercise by comparing masses of different types of rubbish. Use plastic, glass, paper, tin, etc. Make a tally slip and record your data.

Pendulum Investigation

Review the steps in making and recording observations of practical activities and investigations shown in the diagram below.

Once you have done this, we will continue using pendulum investigation example, that was described in the previous section (See Section 3).

Note: If you can't remember please return to Section 3 and review the first 6 steps. Once you are ready, we will continue with Step 7.



(Source: Continuous Assessment Manual Physical Science Grade 8-10 on the NIED website: <http://www.nied.edu.na>)

We will now look at Step 7:

Step 7: Carry out the investigation.

At this stage you are ready to perform the experiment. You need to decide which of the variables you listed in Step 2 will remain constant. Constant variables are those you suspect may influence the results of your experiment. However, you are not focusing on them. Therefore, you want them to remain constant.

For example, you may suspect that the weight of the bob will influence the period. Therefore you will need to keep the bob weight constant for each trial.

Similarly, the angle at which you release the bob might also influence the period. This, you will need to release the bob from the same angle each time you run the experiment (each time you try a different length of string). You only want the variable you are interested in (the independent variable—in this case length of string) to influence the results.



Maximum and minimum temperatures for a few days.

“A couple of friends come together to do some recycling of waste materials. Each collected the following:”

In the space below type in a possible heading for the table

Below is the possible solution

Number of waste materials collected

If we want to use the result to draw up a line graph, the title needs to be written in a specific way. The correct scientific way is always as follows:

Dependent variable vs. Independent variable

To refresh your memory on what these terms mean, we have reproduced them from the previous section.

From Unit 1, Section 3, the recording of observations:

Step 3: Decide which particular variable you are going to study—the independent variable. This is the variable you as the experimenter or researcher will be changing, adjusting or manipulating. In other words, it is the one you are going to test.

Step 4: Decide what you are going to observe and measure—the dependent variable. This is the variable that you will be measuring. It is the variable that changes as a result of the adjustment you make to the independent variable. In other words, the changes that happen to the dependent variable are dependent on how the independent variable is adjusted.

Now in the space below enter a possible heading for the table of the pendulum experiment

The solution is:

Period vs. Length of string

Or

Time vs. Length of string

Dependent variable vs. Independent variable

The independent variable is the variable you as the experimenter will be changing, adjusting or manipulating. It is the one you are going to test. For our example, let's choose length of string as our independent variable. This means that for our investigation we will be varying the length of the string.

The dependent variable is the variable that you will be measuring. It is the variable that changes as a result of the adjustments you make to the independent variable). For this problem, we are interested in factors that effect the period of the pendulum. We will therefore choose period (or time) as our dependent variable because it will depend upon the independent variable, which is the length of the string.

Just as each table needs a heading, each column in the table also needs a heading. Furthermore each reading should be associated with a unit. This can be done in two ways:

Firstly by writing the unit as a heading in the table and NOT repeating the unit in the table as shown in the table below:

Time / min	Length / m
2	0.20
4	0.35

Or secondly by repeating the unit in the table with each reading BUT not in the heading, as in the table below:



Time	Length
2 min	0.20 m
4 min	0.35 m

Generally we prefer to write the unit only once and that is as a heading of each column.

Now, work through the following self-mark activity to reinforce your understanding.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity :

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Let us imagine you had to collect the maximum and minimum temperatures for a few days. The temperatures that you collected were:

- Monday: 12°C & 28°C;
- Tuesday: 12°C & 29°C;
- Wednesday: 15°C & 31°C;
- Thursday: 19°C & 33°C;
- Friday: 22°C & 33°C;
- Saturday: 23°C & 31°C;
- Sunday: 20°C & 29°C.

Draw a table to show how you would write the data. This will not be a tally slip.

2. A couple of friends come together to do some recycling of waste materials. Each collected the following:

- James: 10 soda cans, 15 plastic bottles, 6 books and 12 planks;
- Uwatera: 3 plastic bottles, 2 boxes, 18 tin cans;
- Peter: 5 cans, 9 pieces of wood, 10 plastic bottles;
- Jetrivo: 14 plastic bottles, 5 planks, 5 glass bottles, 10 books.

Complete a tally list with this information.

Cans		
Plastic bottles		
Glass bottles		
Wood		
Paper		

Well done, I hope you are coping so far. You can now start studying Section 5.

Section 5: Presenting Results

Introduction

Raw data is usually collected during scientific investigations. However, it needs to be transformed into some format that allows for interpretation and analysis between the variables. Data can be presented in a variety of formats such as tables, graphs, maps, diagrams illustrations, flow charts etc.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>present</i> results of an investigation by drawing charts and graphs using data provided in tables, appropriate titles, and correctly labeled x and y axes; • differentiate between straight-line graphs and curved-line graphs in terms of their mathematical relationship and the way they are constructed.
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 Time	<p>This section will take you about nine hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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DISPLAYING DATA:

In the previous section we used tables as a way to organise and arrange data so that it is more easily understood by the viewer. In this section, we are going to look at how you can use graphs to do the same.



Tables and graphs are related in the sense that the information used in tables is frequently also used for creating graphs. It is important to know how to create and interpret tables and graphs as they are used in many important areas of research. They are also often used to help people in decision making.

Tables, charts and graphs are convenient ways to clearly show your data. Be sure to consider how to best to show your results with appropriate graph forms. Be sure to give your charts and graphs an appropriate title that explains what the data is measuring. On line and bar graphs, the x and y axes must be appropriately labeled with correct units of measurement (in metrics where applicable).

 Tip	<p>As in the previous section, when presenting data in a table or graph, certain information is essential.</p> <ul style="list-style-type: none"> • Firstly, a graph needs a name — in scientific language this is called the title. Be sure to give your charts and graphs appropriate titles that explain what the data is measuring. • When we use line or bar graphs, the title needs to be written in a specific way which is the “dependent variable vs independent variable”. This is consistent throughout Mathematics and Science. • Each graph needs to have labels. • On line and bar graphs, the x and y axes must be appropriately labeled with correct units of measurement (in metrics where applicable) (e.g. height /m). • The x (horizontal) axis is the independent variable and the y (vertical) axis is the dependent variable.
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There are a number of types of graphic representations of data. For now, however, you should be familiar with three of the more basic types. These are as follows:

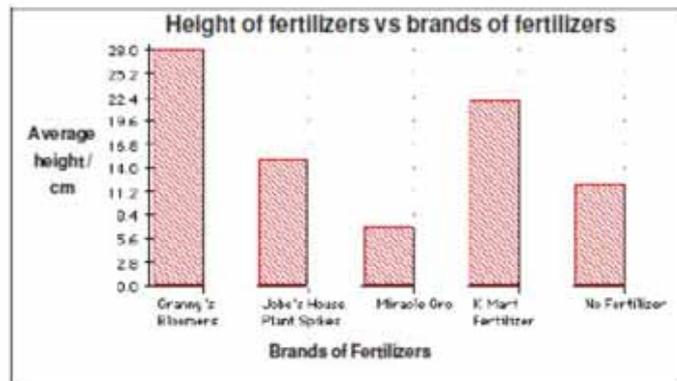
The **bar graph**, the **line graph** and the **circle (or pie) graph**.

Notice how each of the following examples are used to illustrate different kinds of data. Choose the best graph form to express your results.

A Bar Graph:

A bar graph is used to show relationships between groups. Note that the horizontal axis is not numerical. The two items being compared do not need to affect each other. It is a quick way of showing big differences.

Notice how easy it is to see what was done in the experiment below with bean growth and different brands of fertilizer. A typical chart or table for this graph might look like this:

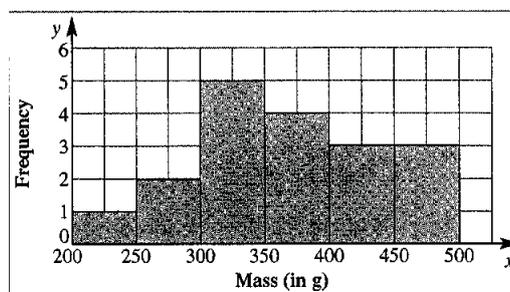


[Source: www.uwsp.edu/psych/stat/4/graphing.htm]

One has to differentiate between a bar graph and a histogram. In a bar graph the columns have spaces between them whereas in a histogram the columns are next to each other.

The bar graph and histogram show different types of data. The histogram shows continuous data (e.g. height, age, etc). Histograms frequently used in geography and mathematics. A bar graph shows discontinuous data.

The following histogram shows the frequency of fish caught by Nangolo when he went fishing in the Oshana.



Now, try working through the following self- mark activity.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 1:

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

1. Take temperature recordings for a week and then complete the task below the table:

day	minimum temperature/°C	maximum temperature/°C
monday	12	28
tuesday	12	29
wednesday	15	31
thursday	19	33
friday	22	33
saturday	23	31
sunday	20	29

Draw a bar chart with the information on the minimum and maximum temperatures.

Well done if you could draw the bar chart correctly. Lets continue with the pie graph.

A Circle (pie) Graph:

A circle graph is used to show how a part of something relates to the whole. This kind of graph is used to effectively describe percentages.

To construct a pie chart:

1. Add all the frequencies (items).
2. Write each frequency as a sum of all the frequencies.
3. Change each frequency that you worked out into degrees by multiplying by 360° .
4. Draw a table showing the above data.
5. Draw a circle with a protractor. Construct the angles at the centre that correspond to each sector.

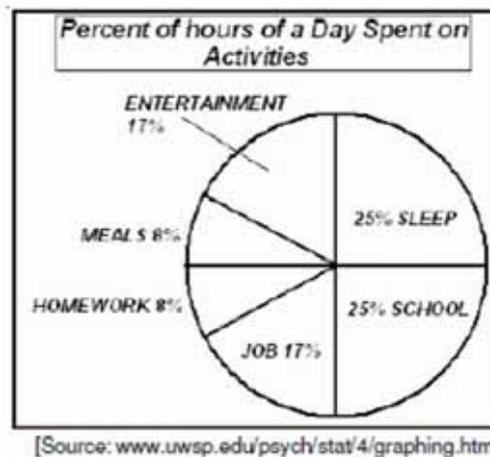
6. Label each sector.

Example

1. The sum of all the hours: $4 + 6 + 6 + 2 + 2 + 4 = 24$
2. Change each number into a fraction of the whole (24 hours), then multiply it with 360° .
3. Entertainment: $4/24 \times 360^\circ = 60^\circ$
4. Sleep: $6/24 \times 360^\circ = 90^\circ$
5. School: $6/24 \times 360^\circ = 90^\circ$
6. Meals: $2/24 \times 360^\circ = 30^\circ$
7. Homework: $2/24 \times 360^\circ = 30^\circ$
8. Job: $4/24 \times 360^\circ = 60^\circ$
9. A typical table for this graph might look like this:

	entertainment	sleep	school	meals	homework	job
time	4 hrs	6 hrs	6 hrs	2 hrs	2 hrs	4 hrs
degree of pie	60°	90°	90°	30°	30°	60°

10. Below is the completed pie chart.



In the table above the chart, the number of hours in a whole day devoted to certain activities is listed. You will also notice that the degrees for each of these activities are also shown. The pie chart is then divided very much as a baker's pie would be into slices that represent the proportional amounts of time spent on each activity. In addition, the percentages



(hours of a day spent on activities) are also near the pie slice that represents that particular amount of time spent.

Are you ready to do the next self-mark activity? I hope so.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity 2:

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

1. The following waste materials were collected for recycling by a few friends.

Soda cans	33
Plastic bottles	42
Glass bottles	5
Wood	26
Paper	18

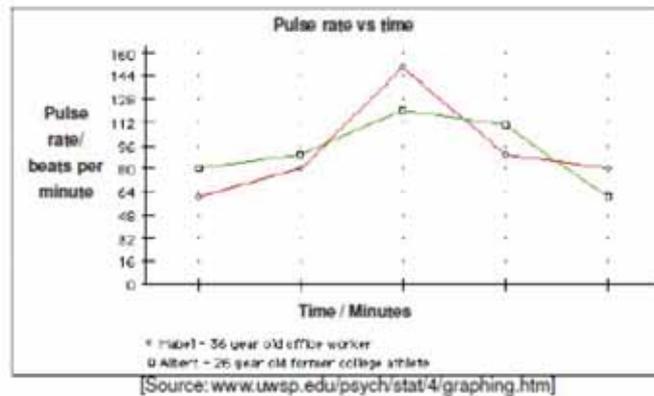
- a) Calculate the degrees for each part of the waste.

I hope you find it easy to do the calculations.

Now we can continue with the discussion of the line graph.

A Line Graph:

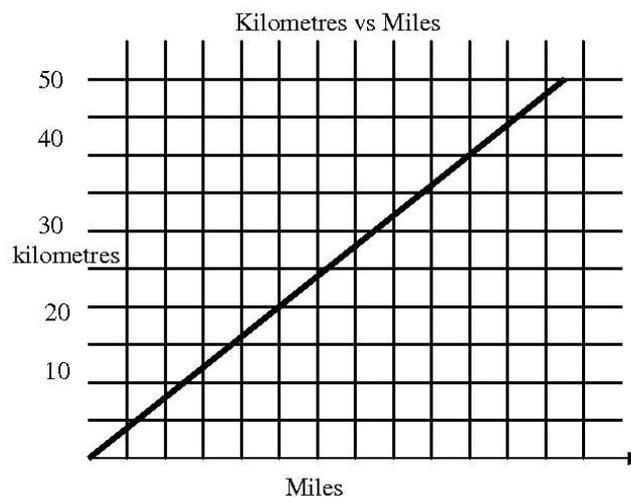
A line graph is used to show continuing data. In other words, it is used to answer the question “how is one thing is affected by another?”. Both axes are numbered in a line graph. The effect is shown by the fluctuations on the graph. In the sample below, the pulse rate of a person is shown over time. As time continues, the pulse rate changes.



In some countries (eg., U.S.A.), miles are used to measure distance instead of km.

We can use the data in the table below to present this in a line graph:

Kilometres	0	8	16	32
Miles	0	5	10	20



When we draw graphs there are a few criteria to remember. These are as follows:

1. The graph needs a title describing what the graph is all about.
2. The two axes need labels and units. The reader must know at first sight what to expect.
3. The scale of the intervals on the axes are constant and do not change.



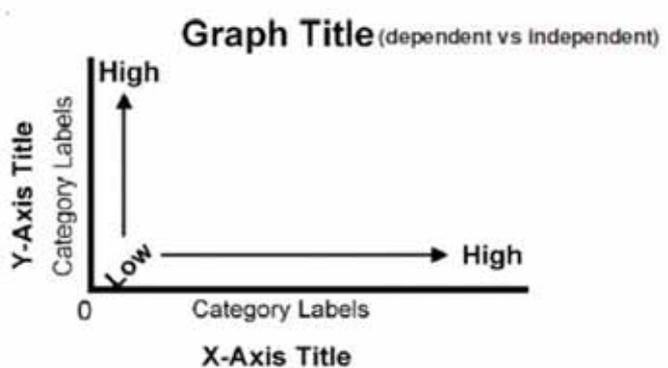
4. Choose the type of graph which will best present your data.

A straight line graph and curved line graph:

The graph that you will use the most in this physical science course is the straight line graph representing mathematical equations. Remember from your mathematics class that $y = mx + c$ is the function of a straight line. If the value of $c = 0$ then the graph will start at the origin or 0.

In addition to the straight line graph, the curved line graph adheres also to the mathematics function of proportionality.

The two-dimensional graph has two axes called the X-axis or **abscissa** and the Y-axis or **ordinate**. Example:



[source: <http://www.uwsp.edu/psych/stat/4/graphing.htm>]

The major difference between the straight line graph and curved line graph is the mathematical relationship. We always join points by drawing the best straight line of fit and in the case of curved line graphs the best smooth curve of fit.

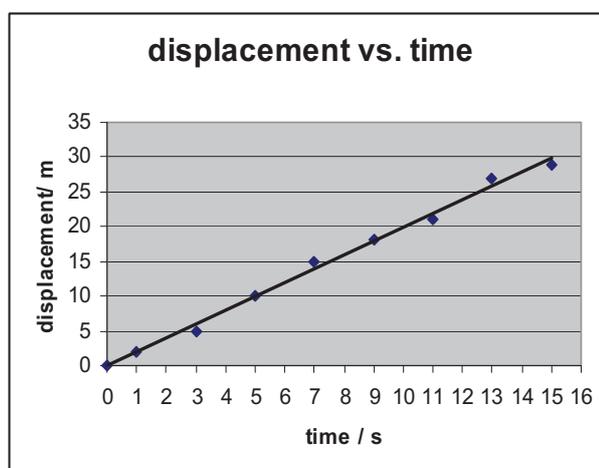
Further, always remember to insert:

- a title on the graph (dependent vs. independent); and
- labels and units on the two axes (label / unit).

The following is an example of drawing the best line of fit.

displacement vs. time	
Time / s	Displacement / m
0	0
1	2
3	5
5	10
7	15

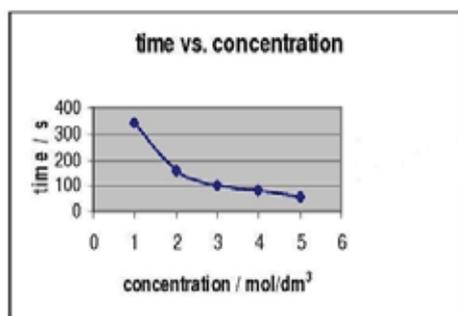
9	18
11	21
13	27
15	29



Note: In this case, the plotting points are not joined but the straight line of best fit is drawn.

Let's look at the results of a chemical reaction to show an example of a curved line graph.

time vs. concentration	
concentration / mol/dm ³	time / s
1	345
2	160
3	100
4	80
5	60



Note: In this case, the plotting points are not joined but the curved line of best fit is drawn.

If you feel you have mastered this section, you can start studying Section 6.

Section 6: Reasoned Explanation and Evaluation of Results

Introduction

Graphs always "say" something. They are like pictures or paintings that show or tell us something. One can make many conclusions from a graph. You can read a tendency. For example, is the graph going up or down? You can predict possible outcomes. You can give possible reasons for changes based on the tendency.

Controlling variables are always part of experiments and observations. The aim is always to try to compare only two variables while keeping changes in all other variables to a minimum. These variables might take the form of different kinds of influences and environmental changes.

 Basic Competence	<p>On successfully completing this section you will be able to:</p> <ul style="list-style-type: none"> • <i>explain</i> the importance of a zero reading and the use of a control; • <i>discuss</i> trends in results in terms of inferences that can be made and the patterns showing in the graphs; • <i>identify</i> sources of error in results such as those derived from counting, calculating, incorrect plotting of points and the accuracy of instruments used; • <i>describe</i> possible preventative measures such as
--	---

	looking for possible deviations, extra checks to work, repetition of the experiments, and ensuring the use of the correct instruments.
--	--

 Time	This section will take you about 12 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.
--	--

Zero Reading

Zero reading becomes an issue when the initial reading is not zero. For example, this could occur when a measuring cylinder is used to measure water, but the measuring cylinder is not empty at the start of measuring. If you measured 12 cm^3 at the beginning and 37 cm^3 at the end then the volume measured will be the final reading (37) minus the initial reading (12) which results in 25 cm^3 .

For example: $37 \text{ cm}^3 - 12 \text{ cm}^3 = 25 \text{ cm}^3$.

Controlling variables are always part of experiments and observations. What is the aim of controlling variables? The aim is always to try to compare only two variables while keeping changes in all other variables to a minimum. These variables might take the form of different kinds of influences and environmental changes.

If we would refer to our pendulum investigation in Section 4, we would find the following:

The scientific question was “how does the length of a pendulum affect the period (time) of the pendulum?”. The two variables mentioned become the independent variable (length) and the dependent variable (period or time).

You will need to identify all other variables that may influence the results of your experiment. However, you will not be focusing on them. Therefore, you will want them to remain constant. These variables were as follows:

- weight of pendulum bob;
- angle at which the bob is released;
- temperature of the environment; and
- type of string used.

For example, you may suspect that the weight of the bob will influence the period. This means that you will need to keep the bob weight constant for each trial. Similarly, the angle at which you release the bob might also influence the period. Therefore you will need to release the bob from the same angle each time you run the experiment (each time you try a different length of string).

You only want the variable you are interested in (the independent variable—in this case length of string) to influence the results. When



carrying out an investigation, always keep a meticulous record of what you are doing, and include a list of all the constant variables.

A control is often used when conducting experiments. The control is used for comparison purposes. All variables are kept constant and the experimental treatment (independent variable) is not applied. For example, suppose if we want to test fertilizer A, B and C. In order to test these, we could plant flowers and investigate the growth of the flowers each day. For this we will need 4 flower beds.

Bed 1	Bed 2	Bed 3	Bed 4
No fertilizer	Fertilizer A	Fertilizer B	Fertilizer C

In order to control the variables,

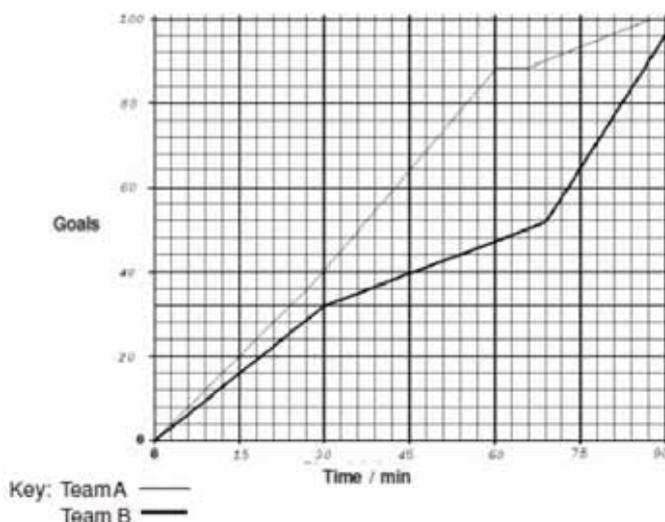
- all 4 beds need to be the same size and be exposed to the same amount of light.
- the same number and type of seeds need to be planted in each bed.
- the same amount or mass of fertilizer needs to be applied to beds 2, 3 and 4.
- the same amount of water needs to be given to each bed.

Bed 1 acts as the **control of the experiment**, as no fertilizer is used. Growth of plants in the other 3 beds with different fertilizers used can then be compared to the control, where no fertilizer was used.

An Example

Two teams play basketball: team A and team B. The teams score points as the ball is thrown into the basket. The scores can jump in ratios of 1, 2 or 3 points per throw. The game takes 90 minutes to complete, so all the points should be scored within this time.

Goals vs. Time

**BEFORE PLOTTING:**

Before plotting you have to decide what is going to be plotted.

Plot the scores of team A and team B at different times during the basketball game.

What does the graph show?

The graph shows how the scores change during the game. The team ahead at any time will be the one on top in the graph. It will be the one with the highest rising line.

What do you expect the graph to roughly look like?

Both teams will start at a score of 0 and every now and then the scores will jump up by 1, 2, or 3 points. The scores will never go down. The highest a score will get to is around 100. Sometimes the score may stay constant for a while (not very good shooting). At other times it will jump up quickly. The X-axis represents time. It goes from 0 when the game starts and should go up to about 90 minutes.

LOOK AT THE DATA. WHAT DO YOU SEE?

Do the numerical values of the data look right?

Do the values seem to change the way you expect?

Are there any values that look bizarre?

The numbers look correct and the times are in minutes starting at 0 and getting larger.

The final scores are Team A = 100 and Team B = 96.

LOOK AT THE GRAPH. WHAT DO YOU SEE?



Does the graph seem to agree with the data?

Yes. It starts at 0 and the two go up to 96 and 100 respectively.

Do the values of the two axes agree with the data?

Yes. The Y-axis goes from 0 to 100 and the X-axis goes from 0 minutes to 90 minutes. This is exactly what the data tells us.

1. How does the overall shape of the graph look?

About as expected. The graph shows what happened:

The two teams' scores were tracking quite well until 60 minutes into the game when team A's score stood still when they got 0 baskets in 6 minutes. After that, team A's score went up slowly and team B's score went up quickly.

2. How to describe trends on graphs:

A pattern on a graph can be used to make inferences (draw conclusions).

Make sure the pattern of a graph is well understood before explaining it.

Trends can be described more fully by adding words and phrases such as:

gradually	smoothly	fluctuated	erratically
slowly	reached a peak	regularly	became constant
unevenly	leveled off	rapidly	steadily

A general statement to use as a starting point for describing trends is:

As the (FIRST VARIABLE) increased/decreased, the (SECOND VARIABLE) increased/decreased/stayed constant. Lets go back and have a look at our graph about the basketball game. Team A scored well up to 60 minutes after which their game deteriorated. Team B started off poorly but increased their goal scoring after 69 minutes.

3. Identify sources of error in results:

- counting errors;
- calculation errors;
- incorrect plotting of points; and
- accuracy of instrument.

4. Suggest possible preventive measures. For example:

- look at possible deviations;
- let someone else check your work;
- repeat the experiment several times then work out the average;
- use the appropriate instrument for measurement. For example, do not use a metre ruler to measure the length of a book. A 30 cm ruler would be more suitable.

STRAIGHT LINE AND CURVED GRAPHS:

Remember from the previous section that the major difference between a straight line graph and curved line graph result from the mathematical relationship, function or proportionality. A lot of information can be obtained by looking at the presentation of data in tables and straight line and curved line graphs.

For example, Susan investigates the distance an insect crawls at certain time intervals. In the table below she has recorded her data.

Time/s	Distance/cm
0	0
5	10.5
10	17
15	30
20	42
25	49

Study the table (remembering what we have learned in the previous sections) and point out corrections that could be made.

The answer follows:

Firstly, the table should have a title.

Secondly, you should decide to have the unit in the heading or in all measurements in the table.

From the table, we can already identify the independent and dependent variable:



Distance and Time

Decide which one of the two variables shown above is independent and which is dependent?

independent	
dependent variable	

Dependent variable vs. Independent variable

The independent variable is the variable you as the experimenter or researcher will be changing, adjusting or manipulating. It is the one you are going to test. In our example below, the independent variable is time.

You have noticed that every 5 seconds Susan measured the distance.

The dependent variable is the variable that you will be measuring. It is the variable that changes as a result of the adjustment you make to the independent variable. For this problem, we are interested in how far (distance) the insect crawled in a certain time.

So the correct way of presenting the table should be in one of the following ways:

Distance vs. Time

Time/s	Distance/cm
0	0
5	10.5
10	17
15	30
20	42
25	49

Distance vs. Time

Time	Distance
0 s	0 cm
5 s	10.5 cm
10 s	17 cm
15 s	30 cm
20 s	42 cm
25 s	49 cm

When we look at the data in the “distance” column, we notice another potential concern of accuracy. We notice that all readings are done in centimeters.

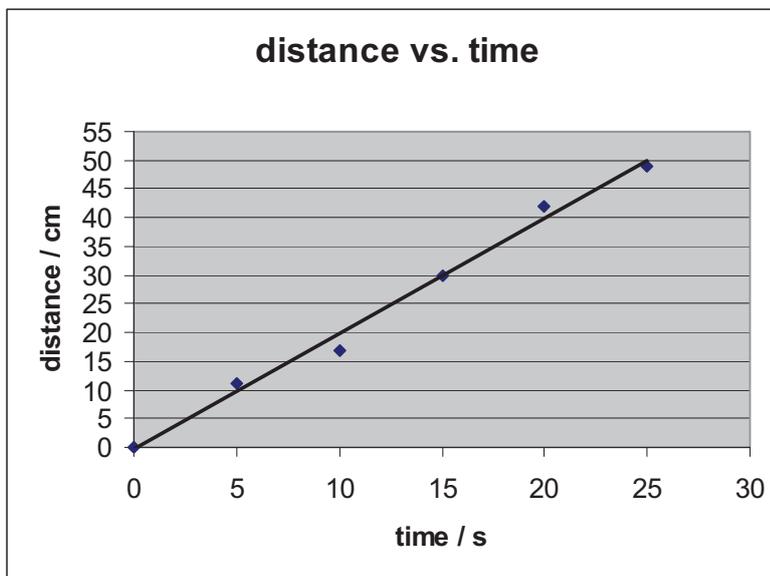
Susan needs now to ask the question—did I measure all readings precisely in centimeters or did she round off the numbers? Rounding off the numbers can have a big effect on the presentation of her results.

To round off the numbers to the closest cm, we now get the following:

Distance vs. Time

Time/s	Distance/cm
0	0
5	11
10	17
15	30
20	42
25	49

If we now use the data in the table above, we will be able to plot a graph such as the one shown below:



Remember: We NEVER join points on the graph. We ALWAYS draw the best straight line of fit. In the case of curved line graphs, we draw the best smooth curve of fit.

Looking at the graph and the best fit straight line, we notice that the distances for 10 seconds and 20 seconds are not on the straight line. The reason for this could be that the plotting of points has been done incorrectly. The reason may also be that the incorrect measurements have been made since they are not on the line. More likely, the insect slowed down or speeded up during his trip.

IMPORTANCE OF ZERO READING AND THE USE OF A CONTROL

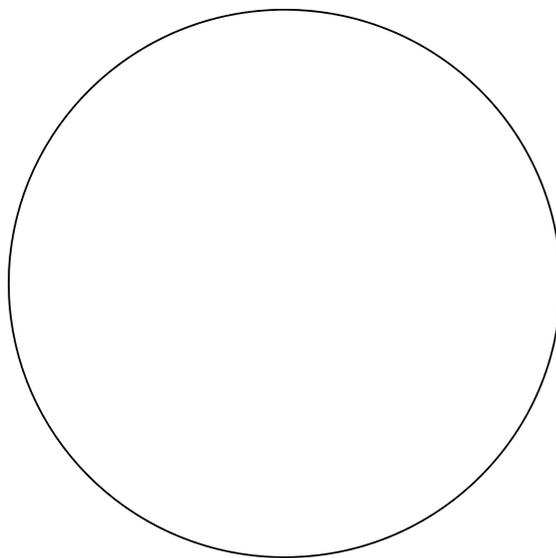
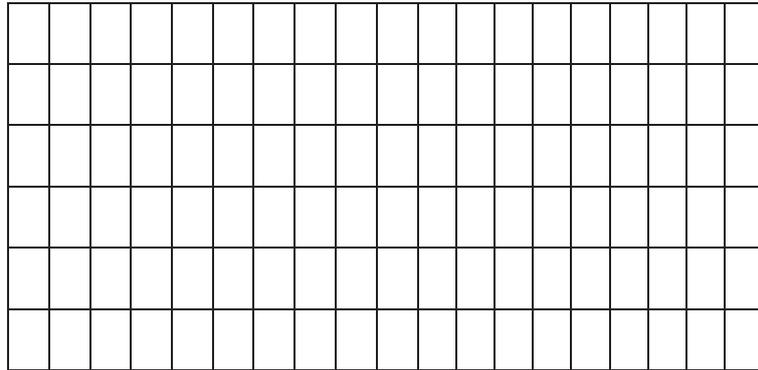
Before we collect and examine data in tables and graphs, we need to consider two important issues. The issues that need to be considered are zero reading and the use of a control (controlling variables).



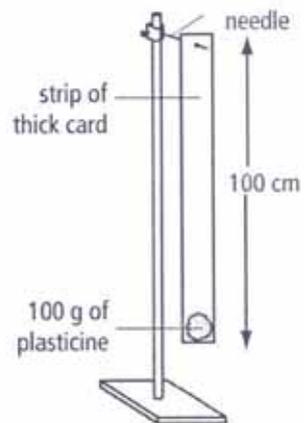
Tip

Points to remember when doing experiments:

1. All measuring must be done accurately and consistently using metrics where applicable.
2. Keep a detailed daily record or log book for measurements, changes and problems.
3. Take photographs and/or make diagrams or drawings of various phases of your experiment.
4. Observations and measurements should be organised in tables or charts that are clearly labelled.
5. Results should be graphed using one of the three methods described above (i.e. bar graph, line graph and circle (or pie) graph).



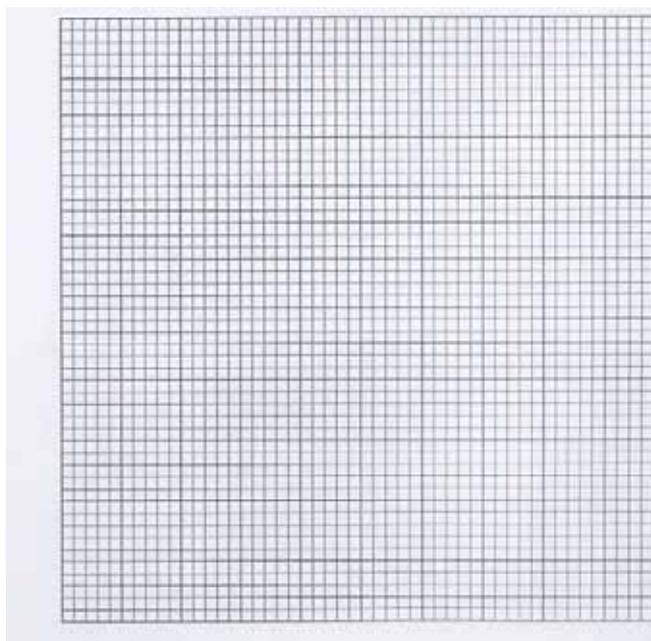
2. A student made a pendulum as shown in the diagram.



He did an experiment, keeping the mass of the pendulum constant and varied the length of the pendulum. His results are shown in the following table.

Length, ℓ , of pendulum/cm	Period, T ,/s
100	2.00
80	1.80
60	1.55
40	1.20
20	0.90
10	0.40

Plot a graph of T (y-axis) against ℓ (x-axis) on the grid.



We have come to the end of this unit. To ensure that you have understood the concept, spend a few hours reviewing what we have covered in this unit.

Unit summary



Summary

In this unit you learned that:

- mass is the amount of matter in a body;
- to measure mass, we use a bathroom scale, a beam balance or an electronic scale;
- a thermometer is used to measure temperature;
- volume is the amount of space that a substance occupies;
- the variable you are testing is the independent variable;
- the variable you measure is the dependent variable;
- tables, charts and graphs are used to clearly show your data;
- the title of a graph is always dependent variable

	vs. independent variable; <ul style="list-style-type: none"> a line graph is used for presenting continuing data.
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Section 1: SI Units

Self-Mark Activity 1



quantity	symbol	unit
acceleration		
	A	
density		kg/m ³ , g/cm ³
force	F	
		W
	T	°C, K
	t	h, min, s
	w	
	W	

Self-Mark Activity 2

1(a) $3 \times 100 = 300 \text{ cm}$

(b) $2.5 \times 1,000 = 2,500 \text{ m}$

2(a) $5.34 \times 1,000 = 5,340 \text{ mm}$

(b) $734 \div 10 = 73.4 \text{ cm}$

(c) $3.2 \div 100 = 0.032 \text{ m}$

Self-Mark Activity 3

(a) $100 \div 1,000 = 0.1 \text{ kg}$

(b) $7.3 \times 1,000 = 7,300 \text{ mg}$

(c) $2,024 \div 1,000 = 2.024 \text{ t}$

(d) $7 \times 1,000,000 = 7,000,000 \text{ mg}$



(e) $89 \div 1,000 = 0.089 \text{ g}$

Self-Mark Activity 4

	\div	x	factor	answer
1.		$\sqrt{\quad}$	10,000	24,500,000
2(a)		$\sqrt{\quad}$	1,000,000	7,000,000
(b)		$\sqrt{\quad}$	100	4 300
(c)	$\sqrt{\quad}$		10,000	1.92×10^{-3}

Self-Mark Activity 5

1.		x	factor	answer
(a)		$\sqrt{\quad}$	1,000,00	3,000,00
(b)	$\sqrt{\quad}$		1,000,000	0.0017
2(a)		$\sqrt{\quad}$	1, 00	7,000
(b)	$\sqrt{\quad}$		1,000	0.194
(c)	$\sqrt{\quad}$		1,000	0.0032
d		$\sqrt{\quad}$	1,000,000	920,000

Self-Mark Activity 6

1(a) $127 \div 60 = 2.12 \text{ min}$

(b) $28 \div 60 = 0.47 \text{ h}$

(c) $2.4 \times 24 = 57.6 \text{ h}$

(d) $3.4 \times 60 \times 60 = 12.240 \text{ s}$

Self-Mark Activity 7

1(a) $28 + 273 = 301 \text{ K}$

(b) $-34 + 273 = 239 \text{ K}$

(c) $40 - 273 = -233 \text{ }^\circ\text{C}$

(d) $354 - 273 = 81 \text{ }^\circ\text{C}$

Section 2: Estimating and Measuring**Self-Mark Activity 1**

1. Mass = $0 + 90 + 0.2$ g
= 90.2 g
2. Mass = $500 + 40 + 0$ g
= 540 g

Self-Mark Activity 2

1. 6 min 24 s
2. 22 min 30 s
3. 14 min 9 s
4. 45 min 19 s

Self-Mark Activity 3

1. $32 - 24 = 8^{\circ}\text{C}$
2. $25 - (-4) = 29^{\circ}\text{C}$
3. The clinical thermometer has a constriction close to the bulb while the simple thermometer does not have this.
4. (a) 46°C
(b) 24°C
(c) 4°C
(d) 84°C
(e) 28°C

Self-Mark Activity 4**Question 1**

2. $10 - 1.6 = 8.4 \text{ cm}^3$
3. $10 - 3 = 7 \text{ cm}^3$
4. $10 - 4.4 = 5.6 \text{ cm}^3$
5. $10 - 6.2 = 3.8 \text{ cm}^3$
6. $10 - 8.6 = 1.4 \text{ cm}^3$

Question 2

Volume of water with cork and stone = 48.5 cm^3

Subtract volume of stone and water = -41.5 cm^3



Volume of cork = 7.0 cm^3

Section 3: Observing and Classifying

Self-Mark Activity

- The substances that rattle are relatively hard.
- No, they do not although this will be difficult to see without a magnifying glass. The crystals can be of different sizes.
- No, crystals of different substances have different shapes.
- Possible answers could be:
 - 'by doing investigations we can tell something about substances',
 - 'we can distinguish between substances according to their properties',
 - 'different substances have different properties'.

Section 4: Recording Results

Self-Mark Activity

1.

Mon	Tues	Wed	Thurs	Fri	Sat	Sun
12 28	12 29	15 31	19 33	22 33	23 31	20 29

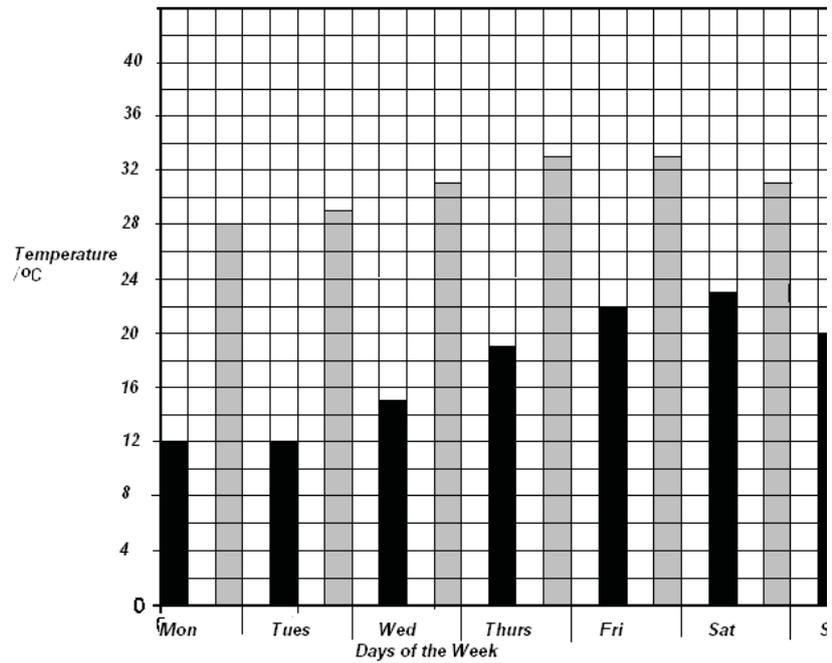
2.

Soda cans	 111	33
Plastic bottles	 11	42
Glass bottles	 	5
Wood	 1	26
Paper	 111	18

Section 5: Presenting Results

Self-Mark Activity 1

- Temperature vs. Days of the Week



Self-Mark Activity 2

1(a)

Soda cans	33
Plastic bottles	42
Glass bottles	5
Wood	26
Paper	18
total	124

Soda cans:

$$33/124 \times 360$$

$$= 95.5^\circ$$

Plastic bottles:

$$42/124 \times 360$$

$$= 121.9^\circ$$

Glass bottles:

$$5/124 \times 360$$



$$= 14.5^\circ$$

Wood:

$$26/124 \times 360$$

$$= 75.5^\circ$$

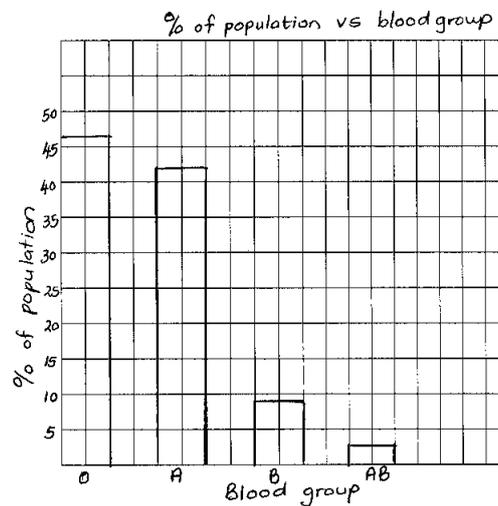
Paper:

$$18/124 \times 360$$

$$= 52.2^\circ$$

Section 6: Reasoned Explanation and Evaluation of Results

1. The bar graph:



The pie chart:

The sum of the % population:

$$46 + 42 + 9 + 3 = 100$$

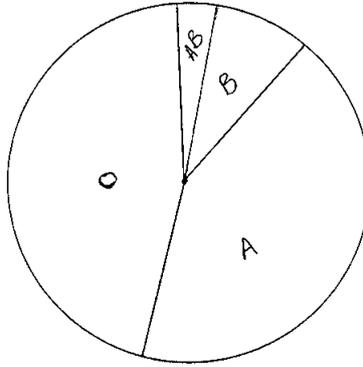
$$O = 46/100 \times 360^\circ = 166^\circ$$

$$A = 42/100 \times 360^\circ = 151^\circ$$

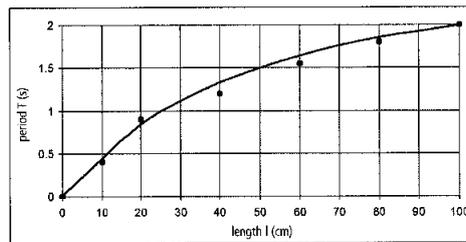
$$B = 9/100 \times 360^\circ = 32^\circ$$

$$AB = 3/100 \times 360^\circ = 11^\circ$$

Blood group	O	A	B	AB
Angle	166°	151°	32°	11



2.





Unit 2

Matter

Introduction

In Unit 1, you learned about the use of SI Units, estimation and measuring, observing and classifying, how to record results and how to present results.

When you do the plotting of temperature during a phase change in Unit 2 you will need the skills that you have learned under the topic that dealt with how to present results in Unit 1.

Before you start reading this unit, I would like you to look around. What do you see? You may see objects such as desks, tables, glasses, walls, doors, etc. All these things are called matter. Matter, as we will see exists in different forms.

This unit consists of the following sections:

Section	Study Hours
1. The Kinetic Particle Theory of Matter	10
2. The Behaviour of Gases	2
3. Thermal Expansion	6
4. Thermal Energy	2.5
5. Atoms, Elements, Compounds and Molecules	9
6. The Structure of the Atom	14
7. Isotopes	2
8. Group Properties	12
9. Covalent Bonding	6
10. Ionic Bonding	7
11. Metallic Bonding	2.5
12. Relationship Between the Periodic Table, Bonding and Balancing Equations	4

Review	3
Total	80



Outcomes

On completion of this unit you will be able to:

- *explain* the differences between phases in terms of behaviour and arrangement of particles;
- *extrapolate* from the kinetic particle theory of matter the behaviour of gases from phenomena such as gas pressure;
- *distinguish* between atoms, elements, mixtures, compounds and molecules;
- *use* the atomic model to *explain* the atomic structure within the Periodic Table;
- *differentiate* between isotopes and radioactive isotopes and provide examples of isotopes of the elements carbon, hydrogen, helium, chlorine and uranium;
- *explain* the Periodic Table as a classification of elements according to their properties;
- *explain* the nature, properties and uses of the elements in the groups of the Periodic Table;
- *illustrate* covalent bonding as the sharing of electrons when atoms bind;
- *illustrate* ionic bonding, as the attraction between positive and negative ions after electrons have been transferred between atoms;
- *explain* metallic bonding as a unique type of bonding;
- *demonstrate* with examples the Periodic Table as an arrangement of elements in Periods and Groups according to their atomic structure and atomic number;
- *identify* trends in the electron and atomic structure of elements in Periods and in Groups on the Periodic Table;
- *demonstrate* that the properties of elements are determined by their electron structure (especially the outer electron structure);
- *explain* that elements with similar outer electron structures have similar properties (e.g. metals, non-metals, noble gases);



	<ul style="list-style-type: none"> • <i>explain</i> the relationship between the Periodic Table and atomic structure; • <i>demonstrate</i> with examples the relationships between group number of the Periodic Table and number of electrons in the outer shell and the relationship between the period and the total number of shells; • <i>write</i> word equations and balance simple chemical equations.
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 <p>Terminology</p>	Diffusion	Movement of different particles among each other, so that they become evenly mixed.
	Atoms	The smallest building blocks of matter.
	Elements	Found on the Periodic Table.
	Compounds	Chemical combinations of two or more elements.
	Immiscible	When two liquids form two layers when you try to mix them.
	Miscible	Liquids that do mix.
	Isotopes	Atoms of the same elements which have the same atomic number but different atomic mass.
	Molecule	The smallest unit of a covalently bonded substance consisting of two or more atoms.

Section 1 The Kinetic Particle Theory of Matter

Introduction

In this section you will learn about matter, the Periodic Table and how to write word equations. You are expected to know the names and symbols of the first 20 elements of the Periodic Table. You can now start thinking about any substance that is a solid, a liquid or a gas and how they behave.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>discuss</i> the particle theory of matter; • <i>describe</i> using the particle model the processes of expansion, compressibility and diffusion in solids, liquids and gases; • <i>explain</i> the differences between phases in terms of behaviour and arrangement of particles; • <i>explain</i> that the change from one phase of matter to another involves an energy change (heat energy either given out or taken in); • <i>explain</i> why the temperature of matter will be constant during a phase change.
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 <p>Time</p>	<p>This section will take you about 10 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Particle Theory of Matter

All the substances that you see around you are made up of matter. You might remember that matter is anything that has **mass** and **occupies space**. For example, this study guide has mass and occupies space, therefore, it is matter.

Matter occurs in three states namely: solids, liquids and gases. Can you think of examples of these three states of matter?

There are many examples:



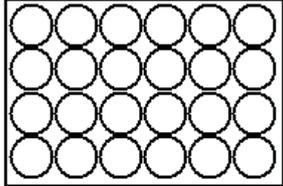
- Examples of solids include wood, sugar, a ruler, your pen, etc.
- Examples of liquids include milk, water, etc.
- Examples of gases include carbon dioxide, oxygen, hydrogen, etc.

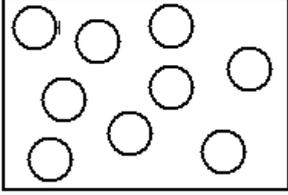
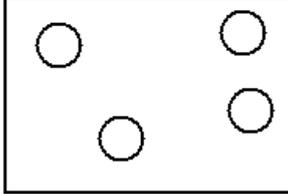
All matter is made up of small particles that we cannot see. These particles are always moving, but we cannot see the movement with the naked eye. Kinetic theory is a model (an idea) that states all matter is made up of particles that move. The theory explains the physical properties of matter that govern the movement of particles.

The **principle of kinetic theory** describes the particulate (*i.e. related to particles*) nature of matter and it states the following:

- all matter consists of tiny particles;
- these particles move continuously;
- there are spaces between the particles;
- there are forces of attraction between the particles.

Solids, liquids and gases have particles that obey the particulate nature of matter differently. With the help of a diagram, I will now show you how the particles are arranged and some of their properties:

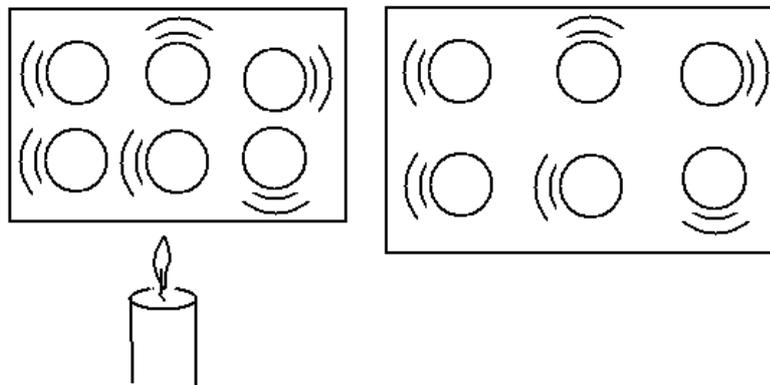
State	How the particles are arranged	Diagram of particles
Solids (eg., ice)	The particles in a solid are packed tightly in a fixed pattern. There are strong forces holding them together so they cannot leave their positions. The only movements they make are tiny vibrations to and from one another.	

Liquids (eg., water)	The particles in a liquid can move about and slide past each other. They are still close together, but are not in a fixed pattern. The forces that hold them together are weaker than those in a solid.	
Gases (eg., steam)	The particles in a gas are far apart and they move about very quickly. There are almost no forces holding them together. They collide with each other and bounce off in all directions.	

Processes of Expansion, Compressibility and Diffusion in Solids, Liquids and Gases

A. Expansion:

This phenomenon usually occurs when matter is heated. The particles in solid matter absorb energy and vibrate faster. Eventually, these particles vibrate so much, resulting in more bumping and pushing of particles, which now move further apart. The volume in solids becomes greater which is due to expansion.

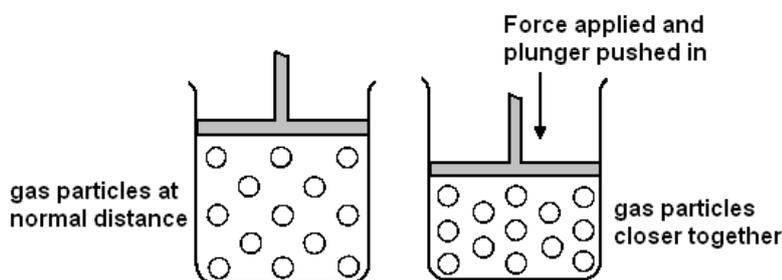




Particles remain the same size. They only move further away from each other.

B. Compressibility:

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. There is the number of particles which remains the same. However, the distance between particles becomes smaller.

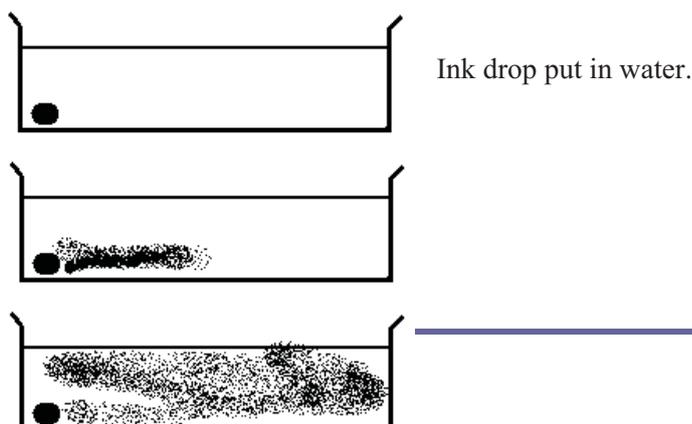


If enough force is applied to the plunger (above), the particles get so close together that the gas turns into a liquid. Liquids and solids cannot be compressed because their particles are already close together.

C. Diffusion:

The movement of different particles among each other so that they become evenly mixed, is called diffusion. This mixing happens without outside help or an outside force.

There are many instances where diffusion can happen. Think of a cup of tea or some dye in water. You can do the following experiment easily. Pour some water into a saucer or glass. Add a drop of dye or ink to the water. Without stirring, leave to stand and see what happens. The same happens when you leave a teabag in water or when someone walks into a room with a nice smelling perfume. The smell reaches everybody by diffusion.



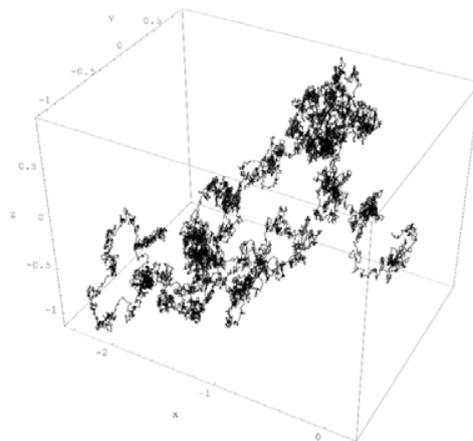
Ink starts to spread.

Ink spreads through all the water and colours the water.

Diffusion happens, because the water particles move constantly. Ink molecules (is the same as particles) get pushed along through the water and eventually spread all over inside the container. All this happens because the water molecules bump the ink molecules and spread them until an equilibrium is reached. Gases diffuse much faster than liquids, because gases have more spaces between the particles.

Brownian Motion

Smoke can be watched by trapping it in a small glass box, shining a light through it sideways and looking at it with a microscope. The smoke specks show up as bright shiny spots that dance around. The smoke specks move, because they are knocked by the moving particles of air. This is called Brownian motion. Thus, Brownian motion is the random movement of particles in liquids or gases caused by collision with the surrounding molecules. The movement of smoke was discovered by a scientist named Robert Brown in 1827. This is why it is called the Brownian motion.



Source:

http://upload.wikimedia.org/wikipedia/commons/f/f8/Wiener_process_3d.png



The diagram above shows how particles experience jerky movements (Brownian motion).

Below is a table summarising the properties of solids, liquids and gases:

Differences in the Behaviour and Arrangement of Particles between Phases.

	Solids	Liquids	Gases
Space between particles	No spaces between particles	Larger spaces	Very large spaces
Vibration of particles	Vibrate at one position	Vibrate faster	Vibrate very fast
Force of attraction	Strong force	Weaker force	Very weak force
Shape	Has a definite shape	Takes the shape of the container	Takes the shape of the container
Volume	Has a definite volume	Has a definite volume	Fills any container
Ability to be compressed	Cannot be compressed	Cannot be compressed	Can be compressed
Ability to flow	Cannot flow	Flows	Flows

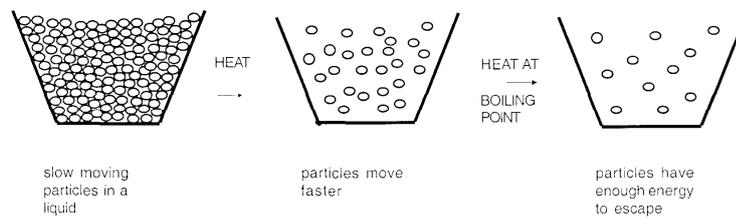
Changes from one phase of matter to another involve an energy change. Heat energy is either given off or absorbed.

Melting

When a solid is heated, its particles get more energy and vibrate faster. This causes the solid to expand. At melting point, the particles vibrate so much that they break away from their positions. The solid then becomes a liquid, for example ice melting. More heat is absorbed by the particles to move faster.

Boiling

When a liquid is heated, its particles get more energy and move faster. They bump into each other more often and bounce further apart. This makes the liquid expand. At boiling point, the particles get enough energy to overcome the forces holding them together. They break away from the liquid and form a gas.



Cooling and freezing

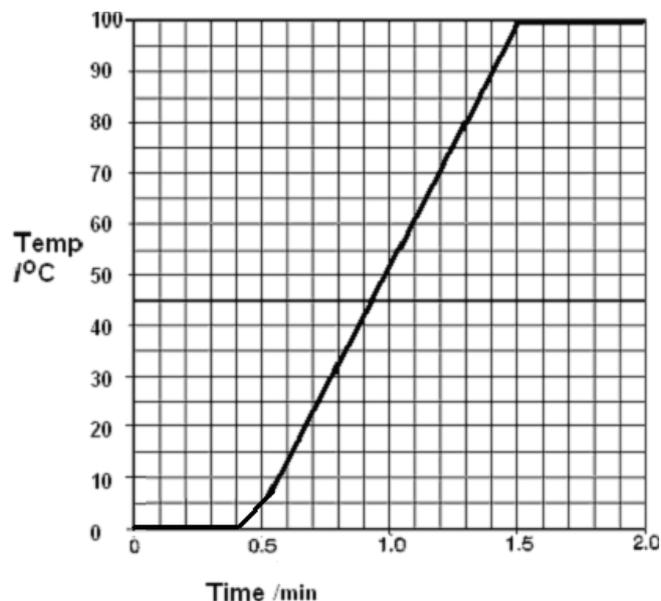
In these instances, heat energy is given off to reduce the amount of heat and reduce the amount of energy. This will cause the particles to move less and therefore move closer together.

The temperature of matter will be constant during a phase change.

The melting point of a substance is the temperature at which the substance changes from solid to liquid. The boiling point of a substance is the temperature at which the substance changes from liquid to gas.

The temperature of a substance remains constant during these changes in phase, because all energy is used to overcome forces holding the particles in the original phase. Only when the substance has changed phase completely will the temperature rise, showing an increase in the motion of the particles.

The temperature stays at 0°C as ice melts. The temperature increases to 100°C as water boils (see the graph below).





The boiling point of a substance depends on the surrounding atmospheric pressure. If particles in a substance have sufficient energy to overcome the force of the atmospheric pressure pushing them down, they will escape into the atmosphere. The substance is said to boil when all the particles in the substance can overcome atmospheric pressure. This happens throughout the liquid. That is why, when a substance boils, bubbles form everywhere in the liquid.

Now its time to answer the questions in the following self-mark activity.

Self-Mark Activity



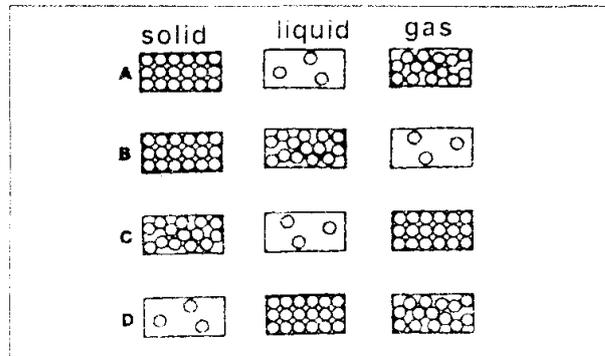
Self-Mark Activity

Self-Mark Activity:

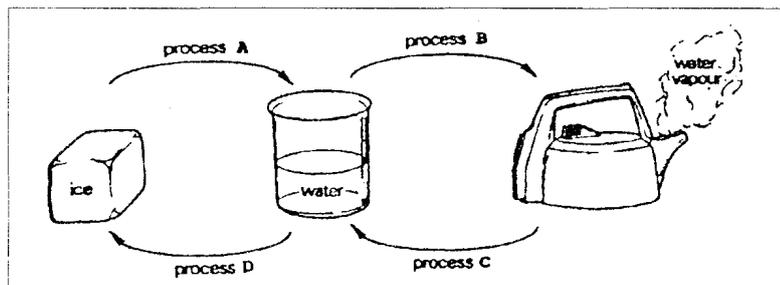
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

1. Which three diagrams show the arrangements of particles in a solid, a liquid and a gas?



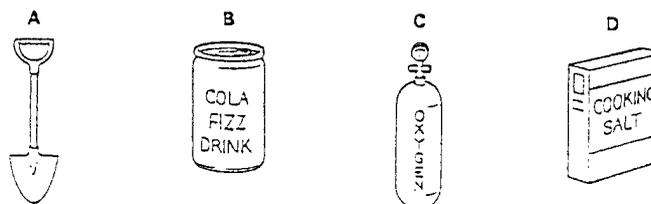
2. The diagram shows changes of state for water. Which process is melting?



3. A molecule is the smallest unit of a covalently bonded substance consisting of two or more atoms. The molecules of a gas:

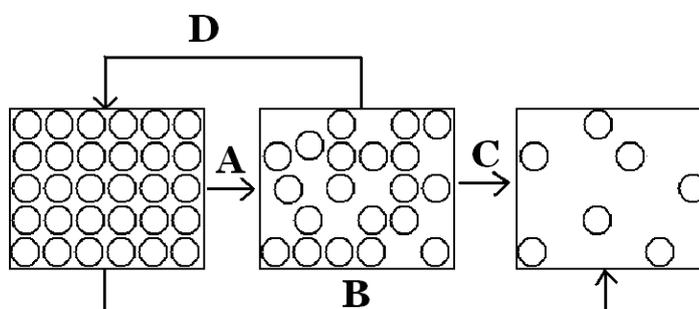
- A do not move;
- B move about randomly;
- C move around each other in orbits;
- D vibrate about fixed points.

4. Which object contains substances of all three states of matter?





5. The diagram shows the particles in a solid, a liquid and a gas. Which arrow represents ice melting?



6. Which change of state produces the biggest increase in the movement of particles?
- A gas to liquid;
 - B liquid to gas;
 - C solid to liquid;
 - D solid to gas.
7. Which of the following particles are the furthest apart at room temperature?
- A petrol;
 - B sodium chloride crystals;
 - C sugar;
 - D water vapour.
8. Which of the following contains a regular arrangement of particles?
- A a gas;
 - B an aqueous solution;
 - C a solid salt;
 - D water.
- 9(a) What is meant by the melting point of a substance?
- (b) What happens to the temperature of a substance when it melts?
- (c) What happens to the energy of a substance while it is

melting?

- 10(a) What happens to the particles in a substance when the substance is heated?
- (b) What happens to the size of a substance when it is heated?
- (c) How does the change in size of a substance when heated compare for solids, liquids and gases?

If you feel you have understood the content of Section 1 in this unit, you can move on to Section 2.

Section 2 The Behaviour of Gases

Introduction

Pressure in gases is caused by collisions between gas particles. The pressure on the walls of a container is caused by collisions of the particles with the container's walls. The magnitude or amount of the pressure depends on the following:

- The speed with which the particles collide, which depends on the temperature of the gas. The higher the temperature the faster and harder the particles collide with each other and with the walls of a container.
- The size of a container. The larger the container, the further the particles are from each other, the fewer the collisions and the lower the pressure.
- The number of particles in a container, which is measured in moles. The more particles there are, the greater the number of collisions that can occur.



**Basic
Competence**

On successful completion of this section, you will be able to:

- *derive* and *explain* from the particle theory, the behavior of gases such as gas pressure;
- *explain* how gas pressure is caused by particles colliding with the wall of a container;
- *discuss* qualitatively, the relationship between volume and pressure of a gas by, for example, increasing the pressure of air in a closed syringe and then releasing the plunger.



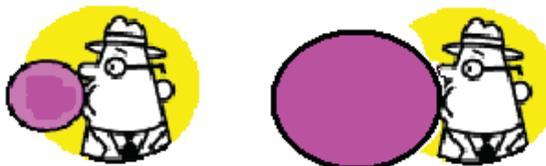
Time

This section will take you about two hours to complete. Make sure you read and understand everything in order to achieve all the basic competencies.

The behaviour of gases: gas pressure

When you blow up a balloon, you fill this balloon with air particles which move at high speed. The particles bump against the sides of the balloon and pressure is exerted on it. The pressure in turn causes the balloon to stay inflated. The more you blow air into the balloon, the greater the pressure inside the balloon.

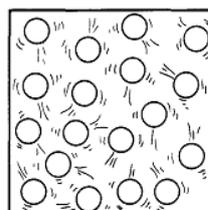
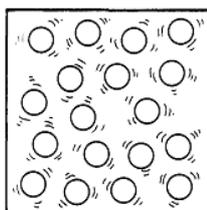
Pressure and constant temperature



When the pressure of a gas increases, its volume increases when the temperature is kept constant.

Pressure and increase in temperature

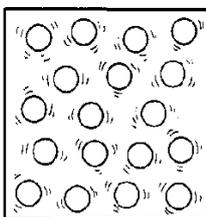
gas particles move and exert pressure on sides of the container.



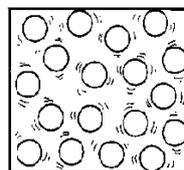
gas particles move more and increase the pressure on the container



If the volume of a gas is constant, its pressure increases with an increase in temperature. The particles absorb heat energy and move even faster. They then strike the walls of the container more often and with more force. The gas exerts a higher pressure when the temperature is high.

Pressure and decrease in volume

particles colliding with the walls of a container



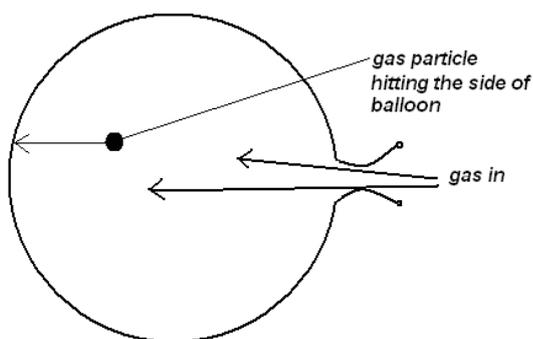
the gas has a smaller volume; the particles now hit the walls more often and the pressure is greater

When the volume of a container decreases, the pressure increases if the temperature is kept constant.

How is gas pressure caused by particles colliding with the walls of a container?

We said earlier that gas particles move freely. We also said that matter has mass. Gas particles are also matter and they also have mass. Gas particles do have forces between them, but these are very weak forces. This means that gas particles move at very high speeds in all directions. It also means that the spaces between the gas particles are very large.

These gas particles bump against the side of a container and this mass at a certain velocity exerts a force. This force causes pressure to be applied to the side of a container, like in the balloon.

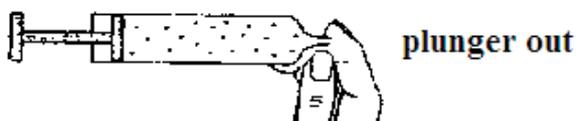
**The relationship between volume and pressure of a gas**

The simple principle that applies here is as follows. When a gas is squeezed into a smaller volume, its pressure increases.

If, a plunger in a syringe is pressed inwards and the hole is closed, pressure builds up inside the syringe. When the plunger is released and the hole is kept closed, the pressure will cause the plunger to be forced outward. The particles inside the syringe bump against each



other vigorously and push the plunger outward.



The diagram above shows that there are spaces between the air particles and when pushed together, the particles bump vigorously against each other because they have much energy.

Now, try and work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity:

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Describe the effect of pressure if:
 - (a) volume decreases;
 - (b) temperature increases.
2. Write a short paragraph to explain how gas particles exert pressure in a container.
- 3(a) Write down which heat changes take place when a substance changes from a gas to a liquid.
 - (b) Discuss how this influences the pressure.

If you feel you have understood this section, you can now move on to Section 3.

Section 3 Thermal Expansion

Introduction

When it is very cold, we tend to sit in the sun or drink a cup of hot tea, soup or coffee. When we do these things, heat energy is transferred to our bodies.

In this section, you will learn more about these effects.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>state</i> a condition required for the transfer of heat; • <i>describe</i> heat transfer by conduction; • <i>describe</i> the conduction of heat transfer in terms of kinetic theory; • <i>identify</i> good and bad conductors of heat; • <i>explain</i> the applications of conduction of heat; • <i>describe</i> thermal expansion in solids, liquids and gases; • <i>explain</i> the applications and consequences of thermal expansion.
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 <p>Time</p>	<p>This section will take you about six hours to complete. Make sure you read and understand everything in order to achieve all the basic competencies.</p>
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Transfer of heat

When you hold a metal object in a flame it gets hot. As it gets hot, it gets to a stage when you can no longer hold it. This happens because metal is a good conductor of heat and the heat is transferred to your hand. During the conduction of heat energy, the heat energy is transferred through an object. You cannot see how the heat moves. You can only feel the heat with your hand.



Conduction

When a material receives heat energy, the particles begin to vibrate faster. The heat energy passes on from one particle to the next as they vibrate and bounce into one another. This is called heat transfer in terms of kinetic theory.

Metals have free electrons that can transfer heat energy to the next electrons and so heat is transferred through the object.

Good and bad conductors of heat

Metals are good conductors of heat due to the free electrons that they have to help during the transfer of heat energy. Bad conductors are called insulators. In insulators, the particles do not have enough space to move to transfer heat energy from one particle to another.

Good conductors: copper, aluminum, iron, etc.

Insulators or bad conductors: glass, stone, plastic, wood, etc.

Applications of conduction of heat

1. On a cold day, we put on warm clothes like jerseys, jackets and coats. The warm clothes trap the air and insulate our bodies from the cold.



Source: http://en.wikipedia.org/wiki/File:Well-clothed_baby.jpg

2. Birds and animals have feathers and fur to keep them warm. The feathers and fur trap the air to keep their bodies warm.



Source: http://en.wikipedia.org/wiki/File:Close-up_of_a_dog%27s_head.jpg

3. Pots and pans in our kitchens are made from metals that are good conductors of heat. They transfer the heat from hot plates to pots where in food is cooked.



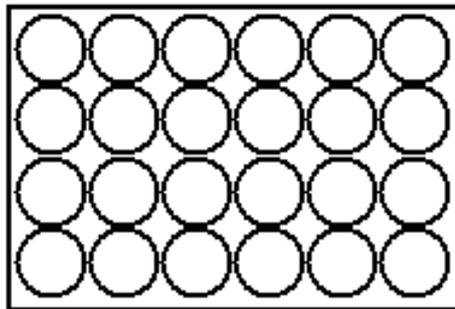
Source: [http://en.wikipedia.org/wiki/File:Pfanne_\(Antihftbeschichtung\).jpg](http://en.wikipedia.org/wiki/File:Pfanne_(Antihftbeschichtung).jpg)

4. Handles of pots and pans are made from plastic or wood that are insulators. This prevents our hands from burning when we handle a pot or pan.

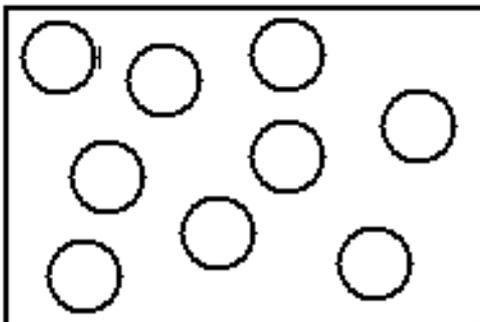
Thermal expansion in solids, liquids and gases

The kinetic theory of matter states that:

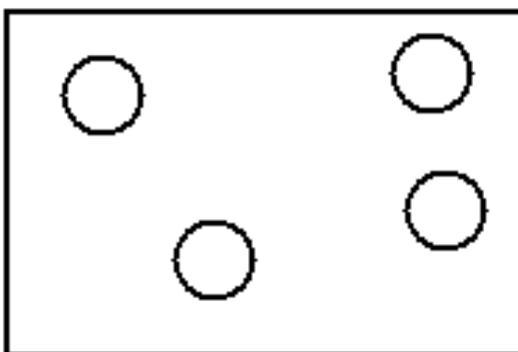
Solids have very strong forces holding the particles in their fixed position.



Liquids have weaker forces and the particles move freely.



In gases, the forces are the weakest and therefore particles move around very fast.



Solids expand the least and gases expand the most when they are heated. The forces holding a solid together are very strong. The gas particles have more open spaces and weak forces holding onto them, so they can expand the most.

Applications and consequences of expansion

1. Overhead power lines

During winter these cables will contract and in summer they will expand and hang down more. When they are built, they are not put up very tightly.



Source: http://en.wikipedia.org/wiki/File:Electric_transmission_lines.jpg

2. Railway tracks

Gaps are left between railway lines to allow space for expansion. During the summer, railway lines expand and during winter they contract.



Source:

http://en.wikipedia.org/wiki/File:Twin_track_of_train_rails_in_a_wooded_area.JPG

3. Bridges

Expansion joints are used during the building of bridges to allow them to expand without buckling.



Source: <http://en.wikipedia.org/wiki/File:Arpadhid.jpg>

4. Expansion can be used to fit train wheels. Below is a picture of train wheels. The wheel is heated to expand so that it fits around the axle.



Source:

http://en.wikipedia.org/wiki/File:Vykolejeni_EC_107_v_Praze_5.jpg

5. Getting stubborn screw tops off from bottles or jars can be difficult sometimes. If you hold it under running hot water from a tap, or pour boiling water from a kettle over it, the metal of the screw top will expand and then you can unscrew it easily.



Source:

http://en.wikipedia.org/wiki/File:Bread_and_butter_pickles.jpg

Now answer the questions in the following self-mark activity to reinforce your understanding.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- Thermal expansion can be useful in a variety of ways. For example, a metal wheel is heated to a high temperature before being put on an axle.
 - State what happens to the diameter of the wheel when it is heated.
 - Explain why heating the wheel makes it easier to fit on the axle.
- Will oxygen gas expand more or less than water when heated? Explain why.
- Why are gaps left between the slabs of a concrete road?

If you feel you have understood this section, you can now move on to Section 4 which talks about thermal energy.

Section 4

Thermal Energy

Introduction

When heat is absorbed by an object, it becomes hotter. When an object has lost heat, it feels colder. The “hotness” or “coldness” of an object is called temperature. In this section you will learn more about measurement of temperature.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> <i>describe</i> the structure of liquid-in-glass thermometers; <i>list</i> properties of liquids used in thermometers; <i>explain</i> temperature in terms of the movement of particles; <i>determine</i> the melting and boiling points of different substances;
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- *interpret* temperature-time graphs;
- *explain* latent heat;
- *describe* the effect of impurities on boiling and melting points.



Time

This section will take you about two and a half hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Liquid-in-glass thermometers



Source:

<http://simple.wikipedia.org/wiki/File:Kwikthermometers.jpg>

Liquid-in-glass thermometers contain a liquid in the glass bulb of the thermometer. The liquid in the glass bulb expands when it is heated. One can see how the liquid expands or contracts as the temperature changes because the liquid moves up or down.

The liquids most commonly used in thermometers are mercury or coloured alcohol.

Properties of mercury as a liquid in a thermometer

Mercury:

- expands regularly with a change in temperature;
- can't be used for very low and very high temperatures;
- is clearly visible;
- is expensive and poisonous.

Properties of alcohol as a liquid in a thermometer

Alcohol:

- is less expensive than mercury;
- can be used to read much lower temperatures;
- cannot be used to read very high temperatures;
- is a colourless liquid, so a dye has to be added to make it visible.

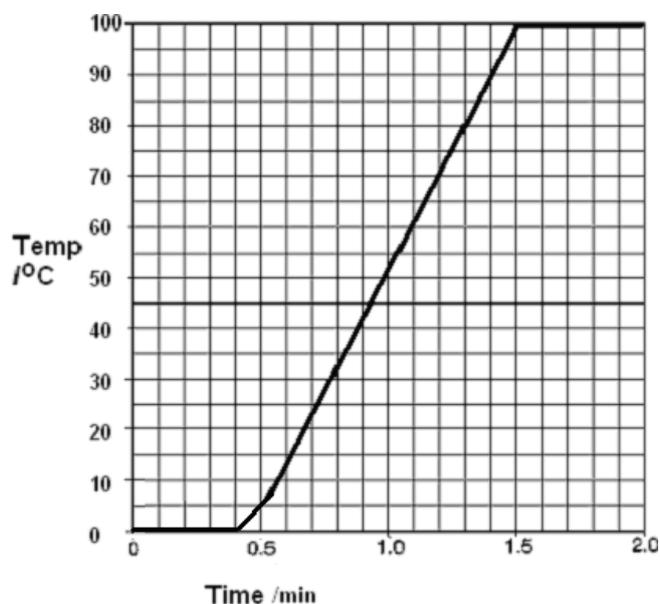
Melting-and boiling points

When an object is heated, its temperature rises. However, the temperature stays constant when boiling or melting takes place. This happens when a phase change takes place.

When ice melts, the reading on a thermometer does not change as the ice melts. The melting takes place through the energy emitted from a burner or the sun. This energy is called latent heat.

Specific latent heat is the amount of energy required to convert 1 kg of a substance from solid to liquid (or vice-versa) without a change in temperature.

The graph below shows the temperature change during the melting and boiling of water.



Ice melts at 0°C. The temperature stays constant because a phase change takes place. After all the ice has melted to a liquid, the liquid becomes hotter and the temperature rises to 100°C. The temperature then stays constant but this time at 100°C. A phase change called boiling then takes place.



The effect of impurities on boiling and melting points

An impurity lowers the melting point of a substance and raises its boiling point.

You can now work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Which two liquids are most commonly used in thermometers?
2. Give some advantages of using alcohol in a thermometer.
3. Give the disadvantages of using mercury in a thermometer.
4. Define latent heat.

If you answered all the questions correctly, well done. If not, review this section again. When you are done, continue with Section 5.

Section 5 Atoms, Elements, Molecules and Compounds

Introduction

This should be a very easy exercise, but it is often misunderstood. To speak the language of science, you have to know what each of these concepts means. We often speak of an atom but we actually mean a molecule or a mixture. It is true that water is a molecule, but sea-water is a mixture? The question can now be asked, but how?

Remember this:

- elements are on the Periodic Table;

- compounds or molecules can only be separated by chemical methods;
- mixtures are separated by physical methods.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>distinguish</i> between atoms, elements, mixtures and compounds; • <i>state</i> and <i>explain</i> that atoms combine to form molecules, which are the building blocks of all material; • <i>describe</i> separation techniques.
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 Time	<p>This section will take you about nine hours to complete. Make sure you read and understand everything in order to achieve all of the outcomes.</p>
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Atoms

Atoms are the smallest building blocks of matter. In other words, they are the smallest particles that can bond to form bigger and more visible structures.

Atoms consist of smaller particles known as electrons, protons and neutrons. An atom is the smallest unit of an element. An atom is the smallest particle of an element that can combine chemically with other atoms.

Molecules

Each molecule of a compound is made up of two or more atoms. One atom of iron combines with one atom of sulphur to form one molecule of iron sulphide.

Molecules of some gaseous elements, for instance, oxygen and hydrogen, are made up of two identical atoms. Atoms of elements join in many ways.

There will be more on this in the next section.

Elements



As you already know, elements are found on the periodic table. Elements are simple substances. Let's for example take hydrogen and oxygen. These are two gases which when combined form water. Hydrogen and oxygen have different chemical properties. These gases are regarded as simple forms of matter. Hydrogen and oxygen are regarded as simple forms of matter because they cannot be broken down any further and still keep their properties. A substance that cannot be broken down into simpler substances by chemical means is called an element. Elements are nature's building blocks. All materials in the universe are made up of either one element or two or more elements chemically combined.

There are over 100 different elements. Most of these elements exist on the earth in varying amounts. Some are common while others are very rare. Scientists have been able to make a few of these elements in special laboratories.

Elements can be identified by chemical symbols. Each element has a symbol. A symbol is a shorthand way of writing the name of an element. The chemical symbol also stands for one atom of an element.

Chemists label elements by using one or two letters. For example, O is the symbol for oxygen, H is for hydrogen, C is for carbon, Al is for aluminum, Mg is for magnesium, S is for sulphur, Cl is for chlorine, and Ca is for calcium.

The symbols for the early-known elements were taken from the shortened form of their Latin names. Some examples of these symbols are Au (aurum) for gold, Ag (argentum) for silver, Pb (plumbum) for lead, Cu (cuprum) for copper, and Fe (ferrum) for iron.

Compounds

Compounds are chemical combinations of elements. If a sample of an iron-sulphur mixture is placed in a test tube and heated with a hot flame, the iron will unite chemically with the sulphur. The new substance formed will be iron sulphide, which is a compound. The physical and chemical properties of iron sulphide will be different from those of the two original elements. It will no longer be possible to separate the iron from the iron sulphide by a magnet.

A compound is composed of two or more elements that are chemically joined. The iron sulphide formed in the above reaction is an example of a chemical compound. Although mixtures can be separated by physical means, a compound can be broken down only by chemical means. The smallest part of a covalently bonded compound is called a molecule. A covalently bonded compound is a compound where sharing of electrons takes place, this type of bonding will be discussed in detail in Unit 2, Section 9.

Mixtures

Mixtures are physical combinations of materials. From the 26 letters in the alphabet, you can put together an endless number of words. In the same way, from about 100 elements, an almost endless number of both physical and chemical combinations can be made. Millions of these combinations exist in nature or have been made by chemists. A mixture contains substances that have not been chemically joined. Air, for example, is a mixture of many gases, mainly nitrogen and oxygen. Can you suggest a way to separate a mixture of powdered iron and sugar without using a magnet? One should note that in a mixture, the substances that make it up can each be present in any amount. You can mix a large amount of iron and a small amount of sulphur, or a small amount of iron and a large amount of sulphur.

Methods for separating mixtures

Sometimes we need to separate substances from mixtures to make them more useful. For example, water needs to be purified in order to make it more useful to humans.

Mixtures can be separated using the following methods:

1. Hand sorting

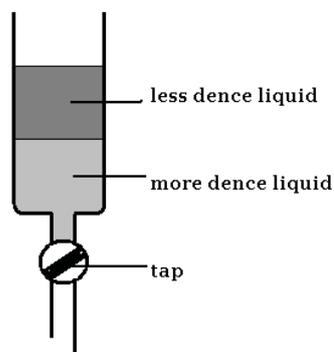
The simplest separation method is that of hand sorting. This is done when a mixture is made up of two or more solids. For example, a heap of coins consisting of a mixture of various coins such as 5c, 10c and 50c can easily be sorted by hand. Can you think of other things that can be sorted by hand?

2. Using a magnet

We can use a magnet to separate two solids, wherein one solid is magnetic and the other is of non-magnetic material. For example, in a mixture of iron filings and sulphur, only the iron filings will be attracted to the magnet. Why is this? Iron filings are magnetic. Magnets are used in mining to lift out pieces of scrap metal, such as broken tools, which may have been mixed up with the ores.

3. Using a separating funnel

Some liquids do not mix with one another. When two liquids form two separate layers when you try to mix them, they are said to be **immiscible**. For example, water and paraffin are immiscible. We can separate a mixture of water and paraffin with a separating funnel. We pour the mixture of water and paraffin into the separating funnel. We wait until the liquids have separated into two layers. Then, we place a beaker under the funnel, and run off the lower layer by carefully opening the tap. The upper liquid layer can be collected in another clean beaker.



4. Distillation

Some mixtures contain only liquids and others a liquid and a dissolved solid. In both cases these mixtures are called **solutions**. In order to purify liquids from solutions, distillation should take place. We use distillation to separate substances that have been mixed. The whole process revolves around the fact that substances have different boiling points. However, we have two types of distillation namely simple and fractional distillation.

(a) Simple distillation is used when a liquid needs to be purified from a solid in a solution. For example, salt water or dirty water are solutions that need to be purified from the solids they contain to get pure (clean) water.

(b) Fractional distillation is used when separating miscible liquids that have different boiling points. For example, ethanol (boiling point 78°C) and water (boiling point 100°C) will need to undergo fractional distillation to separate them from each other..

4.1 Simple distillation

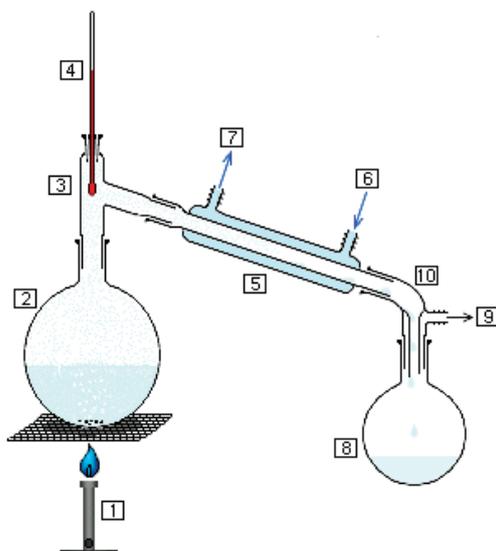
This method is used to retrieve a liquid from a solution containing miscible substances such as salts. In simple terms, one boils the liquid off and condenses it in a Liebig condenser so that the miscible substance remains. Let's find out how this can be done. The picture below shows a way of purifying water out of seawater. In order to do this, we use a special piece of apparatus for turning steam into liquid. The apparatus is called a **Liebig condenser**. It is named after the German chemist Justus von Liebig (1803 – 1873).

This is what happens during the process of distillation:

(a) The water is heated in a flask; it boils, and steam rises into the condenser. The salt is left behind.

(b) The water condenses in the condenser because it is colder than water.

(c) The pure water drips into the beaker.

**Source:**

http://upload.wikimedia.org/wikipedia/commons/0/0e/Simple_chem_distillation.PNG

The labels of the above diagram of simple distillation are:

- 1 = bunsen burner;
- 2 = distilling flask;
- 3 = distilling head;
- 4 = thermometer;
- 5 = condenser;
- 6 = water in;
- 7 = water out;
- 8 = receiving flask;
- 9 = vacuum source;
- 10 = vacuum adapter.

4.2 Fractional distillation

This method is used to separate two or more miscible (liquids that mix) liquids. Let's take an example of a water and alcohol mixture. This method works, because different liquids have different boiling points. The liquid with the lowest boiling point will evaporate first through a Liebig condenser to condense into a liquid. The second liquid evaporates, but the gas quickly condenses before it gets to the Liebig condenser and stays in the flask. The temperature needs to be controlled very precisely to prevent both liquids from evaporating. With the help of a diagram, we are now going to find out how this method works:

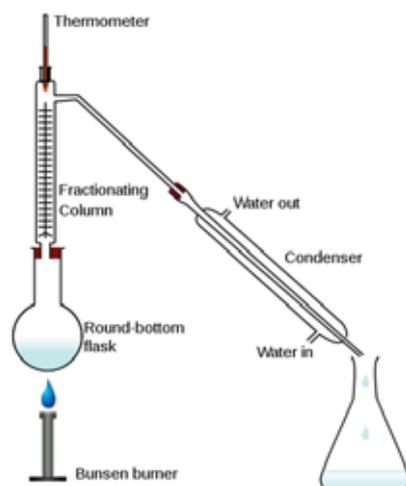
1. The mixture (water and ethanol) is heated.
2. When the temperature at the top of the fractional column reaches 78°C,



molecules of ethanol remain as vapour and pass over into the Liebig condenser. Water molecules with a higher boiling point, condense and fall back into the flask.

3. This continues until most of the ethanol has boiled off.

4. Then, the temperature rises to 100°C and water vapour passes into the condenser.



Source:

http://en.wikipedia.org/wiki/File:Fractional_distillation_lab_apparatus.svg
http://en.wikipedia.org/wiki/File:Fractional_distillation_lab_apparatus.svg

5. Filtration and evaporation

To explain these two concepts, let's look at rock salt as an example. Rock salt is an impure form of salt because sand is mixed with it. We can dissolve salt in water. A substance that can dissolve solid substances is called a **solvent** and the solid that is dissolved in a liquid is called a **solute**.

Filtration

We can purify rock salt by filtering the sand from the salt solution. The salt will dissolve in the water but the sand will not. When we filter the solution, the solution of salt will filter through the tiny holes in filter paper. Sand particles will remain in the filter paper as they are too big to pass through the filter holes.

The substance that cannot filter through the paper is called the **residue**. The **filtrate** (the name given to the liquid that filters through the paper) is the salt dissolved in water.

Evaporation

So as I have said, we can pour the liquid into the filter paper in a funnel. The sand stays behind on the filter paper while the salt solution passes through. The salt solution passes through into a container or basin.

After this has happened, we can heat the liquid in an evaporating basin until all the water has evaporated. Pure salt will be left in the basin.

The salt is then said to have crystallised (formed crystals). In other words, it has been transformed from its liquid form into a solid or crystalized form.

6. Chromatography

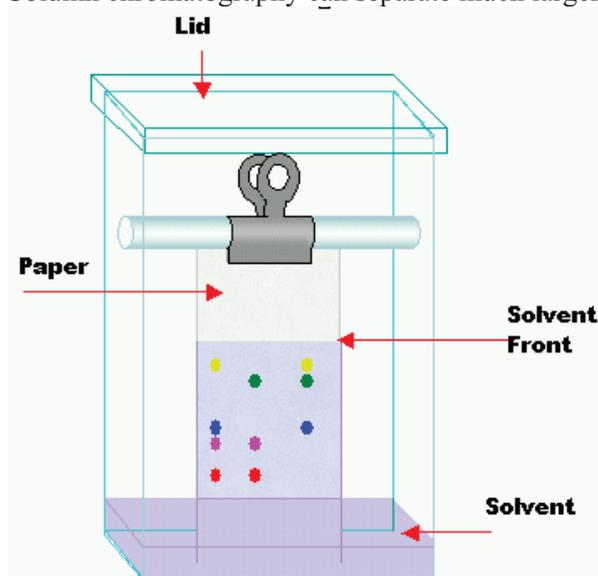
One can separate one solid from another solid when they are both dissolved in a solution by a process called chromatography. This method is used mainly for the identification of substances that might be found in a mixture. This is a very important process in the chemical industry. It is used in the production of medicine.

The ink in a pen is a mixture of dyes. The dyes can be separated by chromatography.

Because paper is used to separate the dyes, it is called paper chromatography.

In the chemical industry, a fine powder similar to very pure sand is used instead of paper. This powder is held inside a tube or column. This is called column chromatography.

Paper chromatography can separate only very small amounts of substances. Column chromatography can separate much larger amounts.



Source: http://en.wikipedia.org/wiki/File:Cromatography_tank.png

**Practical Activity**

We can separate dyes in a water-soluble felt marking pen by doing the following:

- (a) Cut filter paper into strips about 2 cm wide.
- (b) Make a dot on the paper with a water-soluble felt marking pen about 1 cm from the bottom. Usually, it has written on the pen whether it is water-soluble or not.
- (c) Put a little water in a jar. Hang up the filter paper so that the end with the dot just touches the water. The dot should be above the water. Wait for a while. The dot from the felt pen will separate into the different colours (dyes) of which it consists.

Now try working through the following self-mark activity.

Self-Mark Activity

**Self-Mark Activity****Self-Mark Activity:**

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Define each of the following terms:
 - (i) element;
 - (ii) mixture;
 - (iii) compound.
2. Write down which of the terms in question 1:
 - (i) can be made simpler by physical means and
 - (ii) are pure substances.
3. List which of the following are elements, mixtures or compounds:
hydrogen, water, milk, salt, salt water, gold, cold drink,

sodium chloride solution, brass, chlorine, copper oxide, plastic.

4. Describe the difference between fractional distillation and simple distillation.
5. Explain how you would show what colours are formed in the pigment of beetroot.
6. Write down the meaning of the following terms:
 - (a) immiscible;
 - (b) evaporation;
 - (c) residue.
7. Explain what the purpose of each of the following are in distillation:
 - (a) separating funnel;
 - (b) thermometer.

If you feel you have understood this section, you can start studying Section 6 which is about the structure of the atom. If not, go back and review Section 5.

Section 6: The Structure of the Atom

Introduction

In this section, you will learn that matter is made up of atoms. You will also learn about the atomic structure, the atomic number, mass number, group number and the periodic number of elements. By following the explanations and examples carefully and by working through the exercises, you should be able to master this section.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>outline</i> the development of the atomic model; • <i>draw</i> the Bohr structure for the first 20 elements; • <i>analyse</i> the structures of the first 20 elements in terms of atomic and mass numbers; • <i>state</i> the relative charge, approximate relative mass and atomic mass of a proton, a
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	<p>neutron and an electron and their position in an atom;</p> <ul style="list-style-type: none"> • <i>analyse</i> the relationship between the group number of the Periodic Table and the number of electrons in the outer shell; • <i>analyse</i> the relationship between the period number of the Periodic Table and the number of shells in atoms.
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 Time	<p>This section will take you about 14 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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The Development of the Atomic Model

A brief history of the development of the atom

Remember that an atom is so small that we cannot see it with the naked eye. Scientists, however have managed to find out a lot about the atom. They have used models to represent the atom. Do keep in mind that a model is just an idea. These models have changed and developed over the years into what we think an atom looks like today. The following scientists have made contributions to the development of the atom as we know it.

Democritus (\pm 2000 B.C)

Democritus reasoned that matter was made up of tiny particles that could not be split into smaller particles.

J. Dalton (1803)

Dalton suggested the name “atom” for particles that make up all matter.

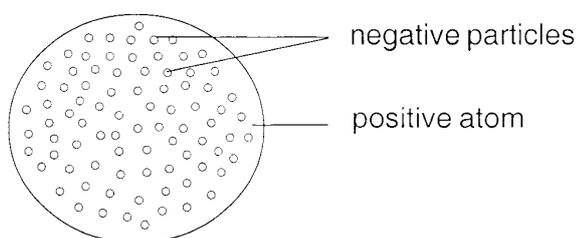
His theory states the following:

- all matter is made up of particles called atoms;
- atoms cannot be made or destroyed;
- atoms of the same element are all the same;
- atoms of different elements are different from each other;
- atoms can join together to form larger particles.

Dalton was also the first person to propose a set of symbols which represent the elements.

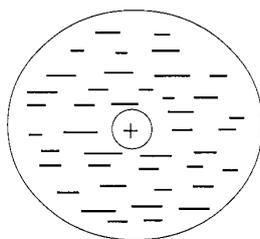
J. J. Thompson (1897)

Thompson discovered a small particle with a negative charge. He called it an electron. He suggested that atoms consist of lumps of positively charged matter with negatively charged electrons inside them. He presumed that the negatively charged electrons might look like currants in a currant bun. This is illustrated in the drawing below.



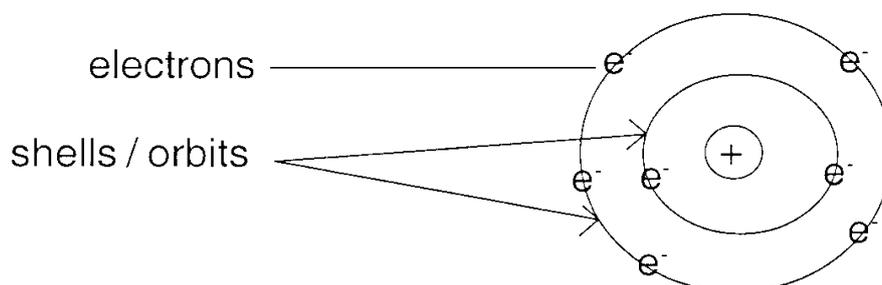
Ernest Rutherford (1913)

Rutherford suggested that the atom had a tiny dense positive centre called the nucleus. According to Rutherford, the nucleus is surrounded by an empty space in which the electrons moved around. He thought that the positive charge in the nucleus is caused by positive particles called protons.



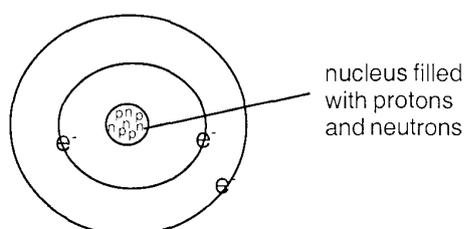
Niels Bohr (1923)

Neil Bohr found that electrons move around the nucleus only in certain shells or orbits. The size and shape of these shells depend on the amount of energy the electrons have. The shells can hold a certain number of electrons i.e., the first shell can hold a maximum of two electrons, the second shell can hold up to eight electrons, etc.



James Chadwick (1932)

James Chadwick discovered the third particle in the atom called the neutron. The neutron has the same mass as the proton but has no charge. The neutrons are also part of the nucleus.



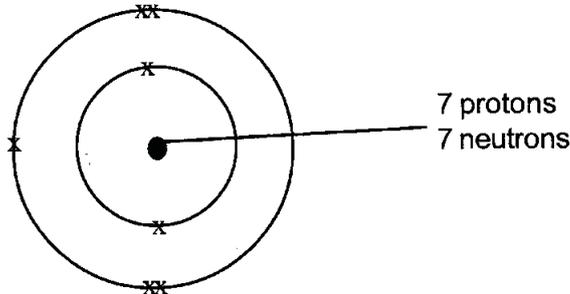
All these discoveries contributed to the model we use today. So, let us discuss this model now. First, please note the following points:

- The nucleus is made up of small particles called protons and neutrons.
- The protons and neutrons together form the nucleus.
- Protons are positively charged and have a relative mass of 1.
- The neutron has no charge but its relative mass is also 1.
- The electrons orbit in shells around the nucleus.
- Electrons are negatively charged and have a relative mass of 0.

So, how do we determine the number of protons, neutrons and electrons of each atom and how do we draw atoms? We can do this with the help of the Periodic Table (see the Periodic Table later in this section). In the Periodic Table, you will see that each element has a name and a symbol.

Remember that you need to master the structures of atoms of the first twenty elements.

When you draw the structure of an atom, make sure you use the notation below.



This is the structure of Nitrogen.

The Periodic Table of the Elements

Group																																																																																												
I	II	III										IV	V	VI	VII	O																																																																												
7 Li Lithium 3	8 Be Beryllium 4	Transition Elements																9 He Helium 2																																																																										
11 Na Sodium 11	12 Mg Magnesium 12	13 Al Aluminum 13	14 Si Silicon 14	15 P Phosphorus 15	16 S Sulphur 16	17 Cl Chlorine 17	18 Ar Argon 18	19 K Potassium 19	20 Ca Calcium 20	21 Sc Scandium 21	22 Ti Titanium 22	23 V Vanadium 23	24 Cr Chromium 24	25 Mn Manganese 25	26 Fe Iron 26	27 Co Cobalt 27	28 Ni Nickel 28	29 Cu Copper 29	30 Zn Zinc 30	31 Ga Gallium 31	32 Ge Germanium 32	33 As Arsenic 33	34 Se Selenium 34	35 Br Bromine 35	36 Kr Krypton 36	37 Rb Rubidium 37	38 Sr Strontium 38	39 Y Yttrium 39	40 Zr Zirconium 40	41 Nb Niobium 41	42 Mo Molybdenum 42	43 Tc Technetium 43	44 Ru Ruthenium 44	45 Rh Rhodium 45	46 Pd Palladium 46	47 Ag Silver 47	48 Cd Cadmium 48	49 In Indium 49	50 Sn Tin 50	51 Sb Antimony 51	52 Te Tellurium 52	53 I Iodine 53	54 Xe Xenon 54	55 Cs Cesium 55	56 Ba Barium 56	57 La Lanthanum 57	58 Ce Cerium 58	59 Pr Praseodymium 59	60 Nd Neodymium 60	61 Pm Promethium 61	62 Sm Samarium 62	63 Eu Europium 63	64 Gd Gadolinium 64	65 Tb Terbium 65	66 Dy Dysprosium 66	67 Ho Holmium 67	68 Er Erbium 68	69 Tm Thulium 69	70 Yb Ytterbium 70	71 Lu Lutetium 71	72 Hf Hafnium 72	73 Ta Tantalum 73	74 W Tungsten 74	75 Re Rhenium 75	76 Os Osmium 76	77 Ir Iridium 77	78 Pt Platinum 78	79 Au Gold 79	80 Hg Mercury 80	81 Tl Thallium 81	82 Pb Lead 82	83 Bi Bismuth 83	84 Po Polonium 84	85 At Astatine 85	86 Rn Radon 86	87 Fr Francium 87	88 Ra Radium 88	89 Ac Actinium 89	90 Th Thorium 90	91 Pa Protactinium 91	92 U Uranium 92	93 Np Neptunium 93	94 Pu Plutonium 94	95 Am Americium 95	96 Cm Curium 96	97 Bk Berkelium 97	98 Cf Californium 98	99 Es Einsteinium 99	100 Fm Fermium 100	101 Md Mendelevium 101	102 No Nobelium 102	103 Lr Lawrencium 103

Atomic Mass	→ 7
Symbol	→ Li
Atomic Number	→ 3

Key:



Bohr's Structure of the First 20 Elements

Atomic models help you picture the atomic structure. Atoms are too small to be seen by any known methods. What scientists know about atoms has been learned by observing the way a large number of samples of matter behave. Scientists find it useful to make diagrams or actual physical models to show what atoms “looks” like.

Models are ideas about how and why things behave the way they do. Models are always subject to change. Future findings may improve present models. It is unlikely that anyone will ever see an atom in the same sense that you see diagrams and drawings of atoms.

Scientists now know that atoms of all elements contain three different kinds of basic particles: **electrons, protons and neutrons**.

Electrons and protons are electrically charged particles.

The electron has a negative charge (—).

The proton has a positive charge (+).

The neutron has no net charge (0).

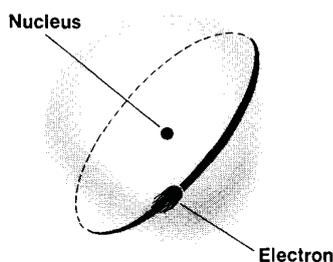
Opposite charges (that is those unlike each other) attract each other, just like a falling object is attracted to the earth. While like charges repel each other. These electrical forces act within the atom.

All elements are made up of three basic particles: electrons, protons and neutrons. The simplest atom is the most common form of hydrogen, which has one proton and one electron. Its single electron may be pictured as travelling in a path around the proton.

Except for hydrogen atoms, atoms of all other elements also contain neutrons.

The protons and neutrons are grouped closely together in a central core, called the nucleus. Protons and neutrons are called nucleons.

Electrons move rapidly around the nucleus some distance away.

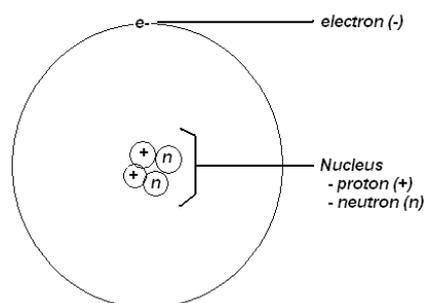




Tip

Mass number or nucleon number

This is the sum of the protons and neutrons (nucleons) of an atom ($p + n = \text{mass number}$)



Each element has a different atomic mass number. The actual mass of single atomic particles is very small. These small values are not easy to use in calculations. The chemists of the world have agreed to set the mass of the most common kind of carbon atom (known as carbon-12) at exactly 12 atomic mass units. Using this standard, ordinary hydrogen has an atomic mass of about 1 and oxygen about 16. This means that the oxygen atom has a mass of about 16 times that of hydrogen. The relative atomic mass for each element is shown in the Periodic Table.

For many uses, chemists find it helpful to express masses in whole numbers, called mass numbers. The mass number is the whole number closest to the atomic mass shown in the Periodic Table. The mass number gives the total number of protons and neutrons found in the nucleus of an atom.

The number of neutrons in the nucleus of an atom can be found. This can be understood by noting the following points:

1. The nucleus of any atom, except the common form of hydrogen, is made up of protons and neutrons.
2. Therefore, the atomic mass number of an atom is equal to the sum of the protons and neutrons.



Tip

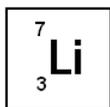
Proton number, Z (also called atomic number)

The proton number (Z) of an element is the number of protons in the nucleus of each atom of that element.



The atomic number, however, is equal to the number of protons or the number of electrons. To find the number of neutrons in an atom, subtract the atomic number (protons) from the mass number (protons + neutrons).

On the Periodic Table each element has two numbers next to it. The diagram below shows the notation for the Lithium atom on the Periodic Table:



This notation tells you the following:

- (i) the element is Li or Lithium;
- (ii) atomic number is 3;
- (iii) mass number is 7.

Mass number - Atomic number = number of neutrons
(7 - 3 = 4)

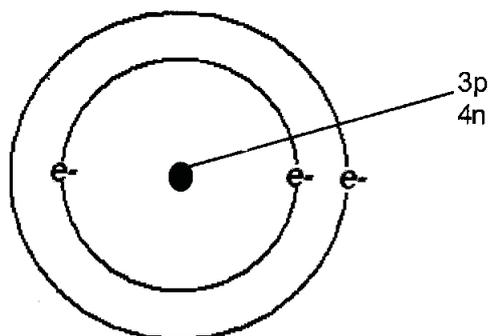
- (iv) number of neutrons = 4;
- (v) number of protons = 3;
- (vi) number of electrons = 3.

Build-up of electrons in “shells” by using the Bohr diagram method

The build-up of the atom shows us that the electrons do not just form a cloud of electrons. These electrons are arranged very specifically and this arrangement determines the properties and bonding of electrons.

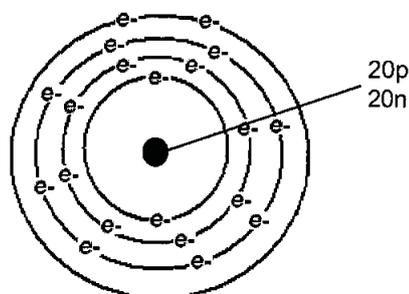
It was found that the first shell takes only two electrons to become full. The second, third and fourth take up to eight electrons. Electrons can be represented by any of the three symbols: e⁻, • and x.

The atomic structure for Lithium looks like this:



The structure shows the three electrons (e-), the three protons (p) and the four neutrons (n).

Shown below is the atomic structure for Calcium:



The Calcium atom is bigger.

The difference is that calcium has four shells of electrons with :

- the first shell having two electrons;
- the second shell having eight electrons;
- the third shell also having eight electrons and
- the fourth shell having two electrons
- making 20 electrons in total.

You can complete the electron structures for the rest of the first 20 elements.

In the examination as well as in your assignments, you will receive a Periodic Table. This means that you do not have to study all the atomic numbers and mass numbers by heart! *All you need to learn are the first twenty elements of the Periodic Table. You will also need to memorise the three rules for determining the number of protons, electrons and neutrons of an element.*

You should now be able to complete the following table. Use the Periodic Table to help you complete it.

Symbol of	Name of element	Atomic num-	Mass num-	Num-ber of	Number of	Number of	Electron structure



element		ber	ber	protons	electrons	neutrons	
H	Hydrogen	1	1	1	1	0	1
	Helium	2	4	2	2	2	2
Li				3	3	4	2,1
	Beryllium					5	2,2
							2,3
	Carbon					6	2,4
							2,5
	Oxygen	8			8	8	2,6
							2,7
Ne				10	10		2,8
		11	23				2,8,1
						12	2,8,2
				14	13		2,8,3
Si			14				2,8,4
	Phosphorus						2,8,5
				32			2,8,6
					17	17	2,8,7
			18			18	2,8,8
K							2,8,8,1
	Calcium						2,8,8,2



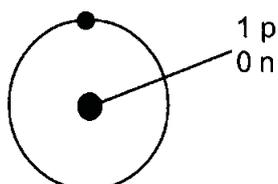
Tip

Hint: The mass number is always the bigger number and the atomic number the smaller number on the Periodic Table.

Have you noticed that the number of electrons and the number of protons of all the atoms are equal? This is because all the atoms are neutral. They do not have any charge. How are you doing so far?

We will now learn how to draw these atoms. But first we will need to determine the number of protons, electrons and neutrons they contain.

Let us take hydrogen as the first example.



Number of protons = 1

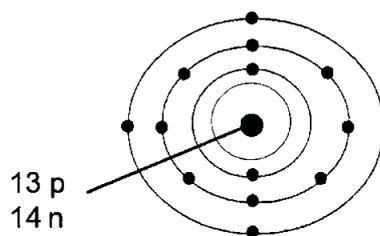
Number of electrons = 1

Number of neutrons = 0

The 1 p means 1 proton, 0 n means 0 neutrons. The dot means 1 electron. You can also use an X or an e^- to represent the electrons. The protons and neutrons appear in the nucleus. That is why no electrons appear there.

The first shell can only contain a maximum of two electrons. The second and the other shells can contain a maximum of eight electrons before they are filled.

Let us take aluminium (Al) as a second example:



number of protons of aluminium = 13;

number of electrons of aluminium = 13;

number of neutrons of aluminium = 14.

Always remember that the first shell can take a maximum of two electrons and the second shell can take a maximum of eight electrons. I hope these two examples will help you to draw the atomic structures of all the other atoms.

Draw the atomic structure of the following atoms:

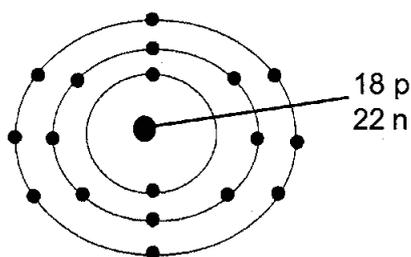
(a) carbon (C);



- (b) sodium (Na);
- (c) potassium (K);
- (d) neon (Ne).

All noble gases found in the last group of elements in the Periodic Table called Group 0, have full outer shells. This means that they have stable electronic structures. Let us take an example of a noble gas such as argon (Ar).

The atomic structure of argon is:



What do you see in the last shell?

Can you see that its last shell has eight electrons. This means that it is full. This is why we say they have stable electronic structures. All the noble gases have full outer shells. That is why they do not form compounds.

Relative charge

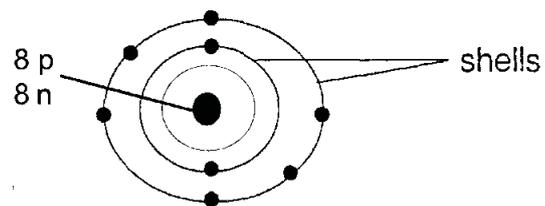
Protons have a positive charge (+1), electrons a negative charge (-) and neutrons no charge. The mass of a proton is one unit, the mass of an electron almost nothing and that of a neutron one unit.

The relationship between group number and the number of electrons in the outer shell

Now you have learnt how to determine the group number and period number of the elements. Now, let's examine their relationship. The groups are the vertical rows and the periods the horizontal rows on the Periodic Table. However, to have a complete understanding of this relationship, we need to know the meaning of the term **valence electrons**. Valence electrons are electrons found in the outer shell. The valence electrons of each atom tell you in which group that specific element will fall. If an atom has 4 valence electrons, it is in Group IV on the Periodic Table.

The relationship between the period number and the number of shells

The period number is equal to the number of occupied shells. If an atom has two occupied shells, it is in Period 2. To determine these two numbers, you must first draw an atom. So, let us take oxygen (O) as an example.



Because oxygen has six valence electrons, it is in Group VI. Check on the Periodic Table if this is the case. Also, because it has two occupied shells, it is in Period 2.

Note: --Isotopes-- You cannot talk about a term if you have not first defined it.

Its now time to answer the questions in the following self-mark activity.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Name the three particles that make up an atom.
2. Which particle has:
 - (a) a positive charge?
 - (b) no charge?
 - (c) no mass?
3. Draw a sketch of the sodium atom.

Choose the correct answer from the possible answers given, for questions 4 – 7.

4. In which group of the periodic table will you find the element sulphur?
 - A group I;
 - B group II;
 - C group V;
 - D group VI.
5. How many electrons are there in an atom of sodium (Na)?
 - A 11;
 - B 12;
 - C 23;
 - D 34.
6. All of the elements in Group VI of the Periodic Table have the same:
 - A number of protons and neutrons;
 - B number of electrons in their outer shell;
 - C physical properties;
 - D relative atomic number.

7. The table below shows the structure of four atoms.

ATOM	ELECTRONS	NEUTRONS	PROTONS
A	4	4	4
B	6	6	6
C	12	13	12
D	6	7	6

Which atom has a nucleon (mass) number of 12?

Well done, you can now start studying Section 7.

Section 7: Isotopes

Introduction

In this section, you will learn about radioactivity. Did you know that we mine radioactive elements in Namibia? An example of a radioactive element is Uranium, which is mined at the Rossing mine. We will discuss how people use radioactive isotopes. We will also look at the dangers of radioactive isotopes.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>explain and discuss</i> the terms isotopes and radioactive isotopes and give examples of isotopes of the elements hydrogen, helium, chlorine and uranium; • <i>relate</i> isotopes to the nucleon numbers of atoms of the same element; • <i>state</i> the uses of radioactive isotopes such as in medicine, power generation and research, and the dangers such as radioactive wastes.
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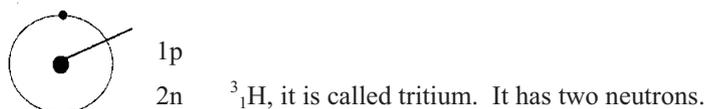
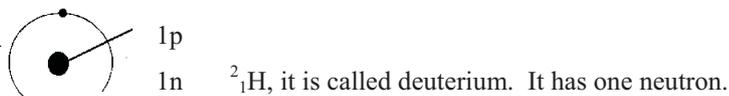
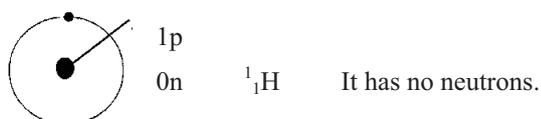
 Time	<p>This section will take you about two hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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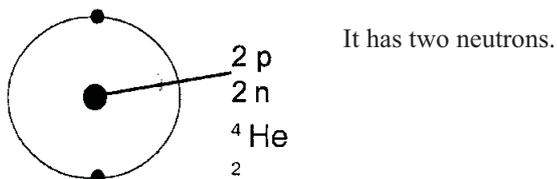
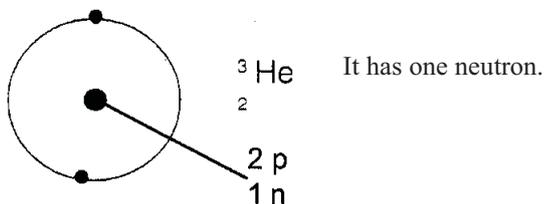
A Radioactive atom can give off radiation from its nucleus. When this happens, the number of neutrons in the nucleus becomes less. This process is called radioactive decay. Only radioactive atoms can do this. Let us look at some examples of isotopes:

Isotopes: atoms of the same elements that have the same atomic number but different atomic mass.

Isotopes of hydrogen:



Isotopes of helium:



Chlorine has two isotopes namely:

${}^{35}_{17}\text{Cl}$ has 18 neutrons;

${}^{37}_{17}\text{Cl}$ has 20 neutrons.

Uranium has three isotopes namely:

^{234}U has 142 neutrons;

^{235}U has 143 neutrons;

^{238}U has 146 neutrons.

Radioactive isotopes are used by people for the following reasons:

1. Radioactive isotopes are used to kill cancer cells inside the body (radiotherapy).
2. Medical instruments are sterilised by using radioactive isotopes.
3. Radioactive isotopes are used in tracer studies. A radioactive isotope called a tracer is introduced, to detect leaks in underground water pipes or to follow the movement of body fluids like blood, urine, etc.
4. Radioactive isotopes are also used for carbon dating; that is, to check the age of ancient documents, or how long it has been since an animal or plant died.

Radioactive isotopes can also be dangerous:

1. They can cause cancer if they are not handled carefully.
2. Radioactive waste causes problems because these waste materials will remain dangerous to humans and animals for hundreds of years.

Now, try working through the following self-mark activity to determine how much you can recall.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity:

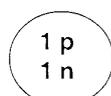
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following question:

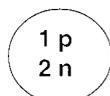
1. Uranium has three isotopes ^{238}U , ^{235}U and ^{234}U . Define the term isotope.

2. Choose the correct answer.

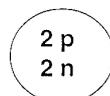
The diagrams below show the number of neutrons (n) and the number of protons (p) in the nuclei of four different atoms.



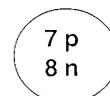
(i)



(ii)



(iii)



(iv)

Which two represent isotopes?

- A (i) and (ii);
- B (ii) and (iii);
- C (i) and (iv);
- D (ii) and (iii).

You can now start studying Section 8.

Section 8: Group Properties

Introduction

The Periodic Table contains useful data. To study the properties of the elements and to predict the behaviour of compounds formed

from various elements, chemists have grouped the elements in the order of their increasing atomic numbers in a special way. In this arrangement, nuclei of the atoms of one element differ from the nuclei of atoms of the next element by the addition of one proton and usually by one or more neutrons. This grouping forms the basis of the Periodic Table.

All elements except hydrogen, which stands alone are placed in seven numbered horizontal rows called **periods**. The vertical columns numbered from I to VIII are called **groups**. Elements in each group have chemical and physical properties that are somewhat alike.



**Basic
Competence**

On successful completion of this section, you will be able to:

- *state* the group properties of groups of elements;
- *describe* lithium, sodium and potassium in Group I and II in terms of their quality as relatively soft metals that show a trend in melting point, density and reaction with water;
- *describe* how Group I and II metals form soluble hydroxides with water and cannot be precipitated;
- *predict* the properties of other elements in the group given data, where appropriate;
- *identify* trends in other groups given data about the elements concerned;
- *describe* chlorine, bromine and iodine in Group VII in terms of their quality as a collection of diatomic non-metals that show a trend in colour, reactivity and phase state;
- *describe* the structures and associated uses of the Group IV elements (carbon in diamond and graphite) and the relative high melting point;
- *describe* the transition elements as a collection of metals having high densities, high melting points and forming coloured compounds;
- *describe* the noble gases as being unreactive;
- *describe* the use of the noble gases in providing an inert atmosphere (argon in lamps and helium for filling weather balloons).



Time

This section will take you about 12 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Group Properties

Group I and II and III

I	II												III	IV	V	VI	VII	VIII
Li	Be																	
Na	Mg																	
K	Ca																	

The six elements in Group I are chemically very active. That is, they combine readily with certain other elements. For instance, Group I elements react with water in the following ways:

- lithium reacts slowly;
- sodium, fast;
- potassium, very fast; and
- rubidium (below K, but not shown on the above table), violently.

Group VIII contains the family of rare gases. These elements are very stable. This means that they do not react readily with other elements. Chemists have only been able to prepare a few compounds containing these elements. On the left side of the Periodic Table, the most active elements are at the bottom. On the right side, the most active elements are at the top.

Notice the place of metals and non-metals in the table. You already know some of these metals such as iron, zinc, lead, copper, tin and gold.

Metals are elements with a shiny surface. They are commonly solid at room temperature and have a high density. Metals can be easily hammered or molded into different shapes. They are good conductors of heat and electric current.

As one moves across a period of the Periodic Table, a gradual change in the properties of the elements occurs. A summary of the physical and chemical properties of the elements from sodium to argon across Period 3 is shown below in the table below.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
State at room temp	solid	solid	solid	solid	solid	solid	gas	gas

I	II		III	IV	V	VI	VII	VIII
Na	Mg		Al	Si	P	S	Cl	Ar

The most obvious pattern across each period is the change from metals to nonmetals. In Period 3:

- sodium, magnesium and aluminum are metals with high boiling points and good electrical conductivity;
- silicon, in the middle of the period, is a metalloid with a high boiling point and moderate conductivity;
- phosphorus, sulphur, chlorine and argon on the right-hand side of the period are non-metals with low boiling points and poor electrical conductivity.

The most reactive elements are near the edges of the Periodic Table and the least reactive elements are in the centre, excluding the noble gases (Group VIII).

From left to right in any period, the atoms gradually decrease in size.

Also, going from left to right, each element has one more electron than the previous element. However, this electron goes into the same energy level. In addition, the extra positive charge on the nucleus, caused by the extra proton, increases the attraction on the electrons and makes the atom slightly smaller.



Test yourself, see if you can answer the following questions:

1. (a) What is the name of the horizontal rows of elements on the Periodic Table?
- (b) What is the name of the vertical columns of elements on the Periodic Table?
- (c) What property is used to determine the order of the elements on the Periodic Table?
- (d) Explain briefly the meanings of the terms:
 - (i) periodic pattern;
 - (ii) atomic number;
 - (iii) Periodicity.

Could you answer these questions? Look at the following possible answers.

- 1(a) Periods
- (b) Groups
- (c) Number of protons in the nucleus
- (d) (i) The same thing occurs to form a certain arrangement. Things such as gases at one end of the periodic table and metals at another end, etc.
- (ii) This is the number of protons in an atom.
- (iii) The gradual change of physical properties (melting point, boiling point, etc.) for elements as we go across the Periodic Table.

Trends

You have already learnt about the properties of the elements in the three groups as shown in the following figure. **In each group, the elements have similar properties with a gradual change in properties down the group. This is because they have the same number of electrons in their outer shells. In other words, with each group, the number of valence electrons are the same.**

Group I Alkali metals	Group VII Halogens	Group VIII Noble Gases
		He
Li	F	Ne
Na	Cl	Ar
K	Br	Kr
Rb	I	Xe
Cs	At	Rn
Fr		

For example, in Group I, the metals are all reactive but they get more reactive with an increase in relative atomic mass as you move down the group. Potassium is more reactive than lithium. Potassium is more metallic than lithium and francium is more metallic than potassium. Group I elements will lose one electron when they react and form a positive ion.

Non-metals

I	II		III	IV	V	VI	VII	VIII
								He
			B	C	N	O	F	Ne
				Si	P	S	Cl	Ar
							Br	Kr
							I	Xe

Well-known non-metals include such elements as nitrogen, oxygen, and chlorine. Non-metals are mostly very poor conductors of heat and electric current. They differ in colour. For example, sulphur is yellow, chlorine is greenish-yellow and carbon is black. Non-metals have a low density.

Group IV elements

The Group IV elements include two very important non-metals: carbon and silicon. Carbon chemistry is very important to living things because carbon is the basis of molecules found in living beings (past or present). Carbon forms complex bonds in living organisms. Furthermore, we have the earth's crust which consists



of mainly iron, oxygen and silicon. Carbon and silicon might not look like the same type of elements, but consider the following table:

I	II												III	IV	V	VI	VII	VIII
														C				
														Si				
														Ge				
														Sn				
														Pb				

Carbon is in Group IV on the Periodic Table. This places it firmly in the realms of the non-metals. It generally forms four covalent bonds, which allow its outer electron shell to be filled. Carbon exists in three different forms which are called allotropes. These allotropes are described below:

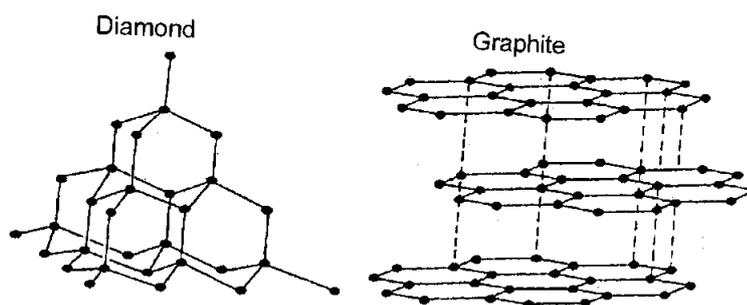
- Diamond is a hard three-dimensional crystal form of carbon.
- Graphite is a soft grayish black, two-dimensional crystal form.
- The third allotropic form of carbon is Fullerite, which has hollow, typically spherical molecules of 36 to 84 carbons. Although fullerite is not part of our syllabus content, they are included for interest.

The compact three-dimensional structure of diamond and the strength of the covalent bonds are responsible for its hardness, high density and high melting point which is about 3700°C. Covalent bonding will be discussed in the next section. All of the valence electrons (electrons found in the outer shell) are used in forming bonds, which result in no electrons being available to conduct electricity. Diamond is however, an excellent conductor of heat due to the fact that the kinetic energy gained due to heat is transferred from one carbon atom to the next. Diamond is used in the making of jewellery due to its high refractive index when cut and polished. It is also used in the manufacture of cutting, drilling and grinding tools due to its hardness. It is the hardest natural substance.

Graphite is a soft substance which is easily crushed. The atoms in graphite are arranged in thin hexagonal plates. The layers of atoms in graphite are closer together than the atoms are in diamond. However, the atoms in the layers are further apart than the atoms in diamond. The strongly bonded covalent network is responsible for the high melting point of about 3600°C for diamond as well as graphite. Being joined together in layers means there are only three covalent bonds between adjacent carbon atoms compared to the four in diamond. The fourth electron is not used in a bond, being

free to move through the layers. This allows electricity to be conducted through this nonmetal.

Weak intermolecular forces called dispersion forces hold the layers of atoms together. Dispersion forces are much weaker than ordinary covalent bonds. These forces allow the migration of electrons between the layers.



Graphite is used:

- for coating moulds used in metal casting;
- to increase the carbon content of steel;
- to make clay-graphite crucibles in which metals can be melted;
- for mixing with petroleum jelly or motor oil to make lubricants;
- for lubricating machine parts that operate at high temperatures;
- for making pencil leads by powdering the graphite and then mixing with clay;
- as electrodes for electric-arc steel-making furnaces;
- for the electrolysis of salt water for producing chlorine and sodium hydroxide;
- to make carbon fibres by combining synthetic fibres with plastic resins and heating under pressure. These are less dense than steel, but stronger and stiffer. They are used in aircraft and sporting goods.

Fullerite, such as Buckminsterfullerene (Bucky ball) are carbon balls often resembling soccer balls, that were created in the 1980s and have since been found in nature. They have interesting electrical, magnetic and optical properties due partly to their small size compared to the giant structures of the other carbon allotropes. Research continues to find practical applications for these molecules. Professors Smalley, Curl and Kroto received the Nobel



Prize in chemistry in 1996 for their discovery and pioneering work on fullerenes.

Whenever a carbon containing substance such as petrol, wood and candle wax is burnt, the products formed include carbon dioxide and carbon monoxide. Carbon dioxide is the result of complete combustion of the carbon. This happens when there is an abundance of oxygen. Carbon monoxide on the other hand, results from incomplete combustion of the carbon.

Transition Elements

Uses of Transition Metals

The properties of transition metals make them very useful. Iron is the most widely used metal. It is hard, strong and malleable (that means it can be hammered into different shapes). Iron is also the cheapest metal used in manufacturing. It is used to make steel for cutlery, tools, machines, vehicles and girders. You will learn more about the other useful transitional metals. One important use of many transition metals is their use as catalysts in many industrial processes. Iron is a catalyst in the industrial process of making ammonia. Vanadium is a catalyst in the industrial process of making sulphuric acid.

A catalyst is a substance that changes the rate of a chemical reaction, but remains chemically unchanged at the end of the reaction.

I	II										III	IV	V	VI	VII	VIII
				Cr	Fe	Co	Ni	Cu	Zn							
								Ag								
							Pt	Au	Hg							

This figure shows some of the common transition metals on the Periodic Table. The elements between Groups II and III are not usually put into groups. Instead, they are called the **transition elements**. The transition metals have very similar properties. Unlike other parts of the Periodic Table, there are **similarities** in the transition metals **across the periods** as well as **down the groups**.

Common properties include:

- hard and strong metals;
- high densities;
- high melting and boiling points;
- more than one valency;
- usually coloured which distinguishes them from Group I and II elements which are mainly white;
- often use as catalysts.

The colour seen in transition metal compounds is the colour that the substance reflects when white light shines on it, while all other colours are absorbed. The compounds raise the energy of their electrons by absorbing the other colours of light.

The following table shows some of the transition elements and the colours of the compounds they form. It is important to understand that the colour may vary for the same element in the same oxidation state depending on the other elements present in the compound.

Element	Some Possible Colours of Compounds
copper	yellow, red blue, blue-green, black
iron	blue-green, green brown-yellow, yellow, red

From the above explanations and descriptions, it should become clear that transition elements generally have more than one valency and these generally form coloured compounds.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1.
 - (i) Explain why the Periodic Table is split up into groups.
 - (ii) Explain why the Periodic Table is split up into periods.
 - (iii) Write down the type of elements which are found on the left hand side of the Periodic Table.
 - (iv) Write down the type of elements which are found on the right hand side of the Periodic Table.
 - (v) List the elements that are found on the dividing line between metals and non-metals.

2. Write down which of the following elements Li, Be, B, C, N, O, F and Ne in Period 2:
 - (a) are metals;
 - (b) exist as diatomic molecules;
 - (c) have the highest boiling point;
 - (d) are the most reactive non-metal;
 - (e) are gases at room temperature;
 - (f) exist as diatomic molecules at room temperature.

3. Write down which groups in the Periodic Table contain:
 - (a) metals only;
 - (b) metals and non-metals;
 - (c) non-metals only.

You can now start studying Section 9.

Section 9: Covalent Bonding

Introduction

Can you remember that in the previous section we learnt that only the noble gas atoms have full outer shells? All atoms that do not have full outer shells will react with other atoms to obtain a full

outer shell. This reaction can also be related to bonding. We distinguish between ionic, covalent and metallic bonding.

Ionic bonding takes place between metals and non-metals. If you look at the Periodic Table, it will be between elements on the left and those on the right of the Periodic Table. Covalent bonding takes place only between non-metals. It is between the elements on the right of the Periodic Table. Metallic bonding takes place only in metals such as iron, lead, copper, etc.

If we want to understand the properties of chemical compounds, we must know how their atoms are arranged. We call this the structure of the compound. How can atoms bond to make their outer shells complete? How can they do this knowing that there are eight electrons in the outer shell. There are three ways they can do this:

- covalent bonding;
- ionic bonding;
- metallic bonding.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>explain</i> covalent bonding as the sharing of electrons when atoms bind and diatomic molecules; • <i>sketch</i> (using Bohr's model) simple molecules to illustrate covalent bonding as the sharing of electrons when atoms bind.
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 Time	<p>This section will take you about six hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Covalent Bonding

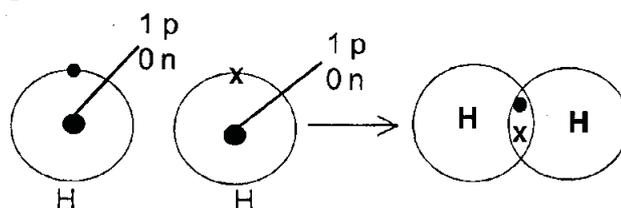
Covalent bonding takes place between non-metals and it involves the sharing of electrons.

Look carefully at how bonding takes place in the examples that follow.

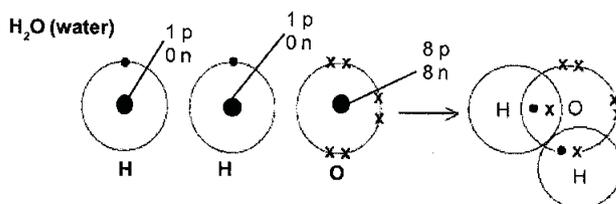
Let us take the hydrogen molecule shown in the diagram below. It consists of two H atoms. When we do illustrations of covalent bonding, we only draw the valence electrons.

Hydrogen has one valence electron because it is in Group 1. So we will draw only one electron when we draw the hydrogen atom. Each H-atom has one valence electron. The cross and the dot represent the two electrons in the two respective H-atoms. These two electrons are shared when covalent bonding takes place so that the molecule can have a full shell of two electrons.

H₂ (hydrogen)

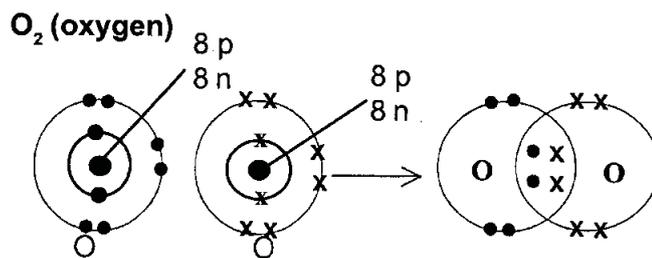


The water molecule is another good example of a molecule formed by the sharing of electrons. Notice in the diagram below that oxygen needs two electrons to complete the outer shell. Hydrogen needs one electron to complete the outer shell. The electron from each of two hydrogen atoms, and two electrons from a single oxygen atom, are shared electrons by the outer shells of each atom. Thus, a molecule of water, H₂O is formed. Review the figure, below.



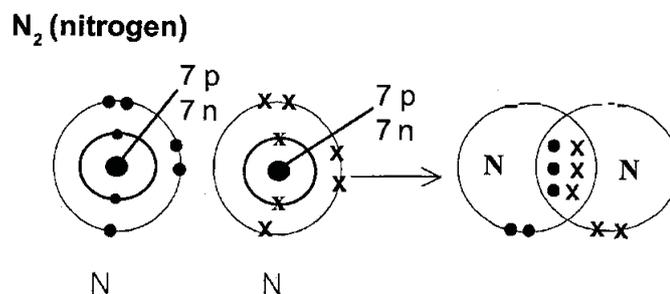
Molecules of common gases such as oxygen, hydrogen, chlorine and

nitrogen are also formed by the sharing of electrons. The hydrogen atom for example, has only one electron. Since the first shell can hold only two electrons, two hydrogen atoms share their electrons with each other. When this happens, a hydrogen molecule is formed. Chemists write this molecule as H_2 (say “H two”). Molecules of other common gases are written as O_2 for oxygen, Cl_2 for chlorine and N_2 for nitrogen. These are called **diatomic** molecules.



When two pairs of electrons are shared, a double bond is formed.

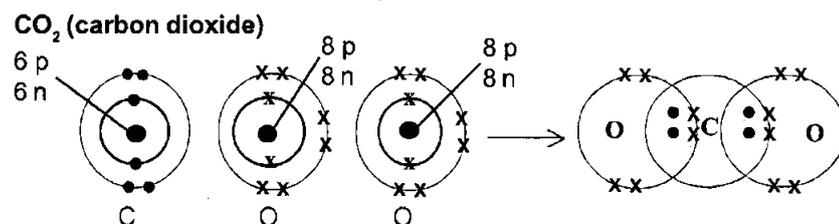
Because oxygen has six valence electrons, it is in Group VI. Two pairs of electrons are shared to get a full shell of eight electrons.

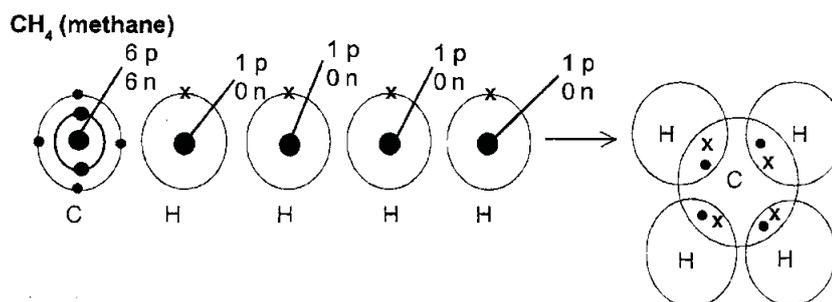
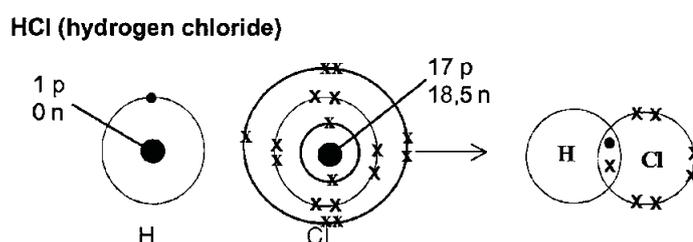
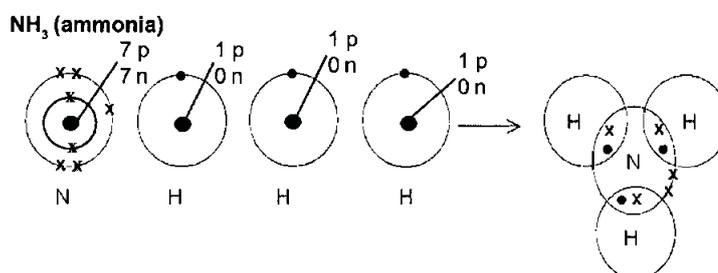


When three pairs of electrons are shared, a triple bond is formed.

Five valence electrons are drawn, because nitrogen is in Group V.

The following show more examples of covalent bonding in compounds.





I hope that you have understood in each case how bonding takes place. If not, please read through the section again and make sure you understand the explanations.

Molecules as Giant Structures

Molecules such as H₂O, CO₂, HCl etc. and diatomic molecules including H₂, O₂, N₂, etc., are small molecules. However, much larger molecules are also held together with covalent bonds. Proteins and plastics for example, exist as huge molecules with thousands of single covalent bonds. They are called **macromolecules**. Covalently bonded substances which are made from single molecules (small or large) are generally gases, liquids or solids which melt easily. While they have strong bonds within their molecules, the molecules are not attracted to one another very strongly, thus they can melt easily.

Giant structures are found in substances such as diamond or graphite which are forms of carbon with the covalent bonds forming a network in three dimensions throughout the structure. These are called giant structures. Giant structures are very difficult to melt.

Now, work through the following self-mark activity to reinforce your understanding of this topic.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. The table provides information about the electron structure of four atoms.

Atom	Electron structure		
A	2	4	
B	2	8	1
C	2	8	6
D	2	8	7

Which atom is most likely to form two covalent bonds?

2. How many elements does carbon dioxide contain?

- A. 1;
- B. 2;
- C. 3;
- D. 4.

3. What type of bond do you expect to find in a water molecule?

- A. covalent;
- B. ionic;



- C. metallic;
- D. none of the above.

You can now start studying Section 10.

Section 10: Ionic Bonding

Introduction

In this section, we will discuss ionic bonding in detail.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none">• <i>outline</i> ionic bonding as a transfer of electrons from one atom to another to form positive and negative ions which attract each other and predict the positive and negative charges of ions;• <i>relate</i> the electronic structure of cations and anions to ionic bonding as the attraction between positive and negative ions;• <i>describe</i> nitrate, carbonate and sulphate as complex anions bonding similar to elements in Groups VI and VII;• <i>describe</i> ammonium as a complex cation bonding like metals in Group I;• <i>write</i> formulas and <i>draw</i> Bohr structures of ionic compounds.
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 <p>Time</p>	<p>This section will take you about seven hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Ionic Bonding

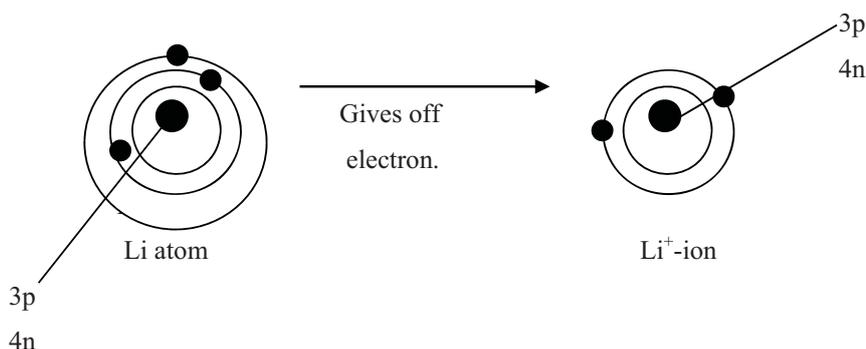
This type of bonding usually takes place between metals and non-metals. Electrons are transferred from one atom to another. Usually, a metal gives off electrons and a non-metal receives the electrons.

Atoms form ions by losing or gaining electrons. A **positive ion** is formed when an atom **loses electrons** and is called a **cation**. A **negative ion** is formed when an atom **gains electrons** and is called an **anion**. The size of the charge of an ion depends on the number of electrons that the atom loses or gains.

For example, let us take Lithium (Li). It is in Group I, so it will have one valence electron.

Do you remember that the group number is equal to the number of valence electrons of an atom? Lithium will lose this one outer electron in order to form an ion. It will be a positive ion or cation. Atoms form ions to become stable, or to have full outer shells.

In this section you will learn how different atoms fuse (attach to one another) chemically to form compounds.



The charge on the Lithium ion:

The charge on 3 protons: +3

The charge on 2 electrons: -2

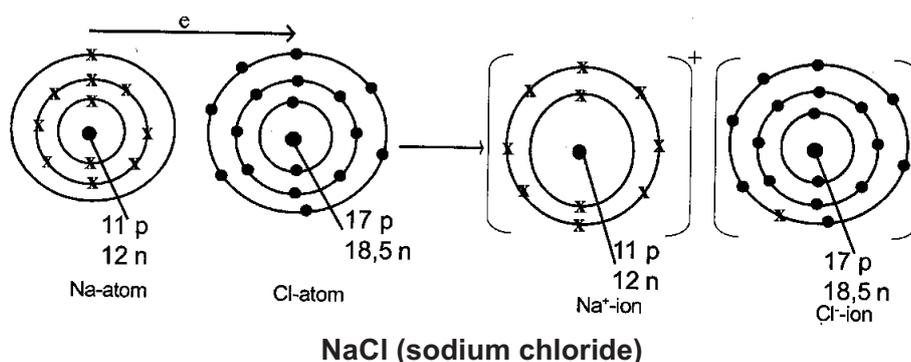
Total charge: +1



The charge of an ion is determined by its position on the Periodic Table or by subtracting the charge on the number of protons and the number of electrons as I have shown you above.

 Tip	<p>All Group I elements will form +1 ions. All Group II elements will form +2 ions. All Group III elements will form +3 ions. All Group IV elements will form +4 ions. All Group V elements will form -3 ions. All Group VI elements will form -2 ions. All Group VII elements will form -1 ions.</p>
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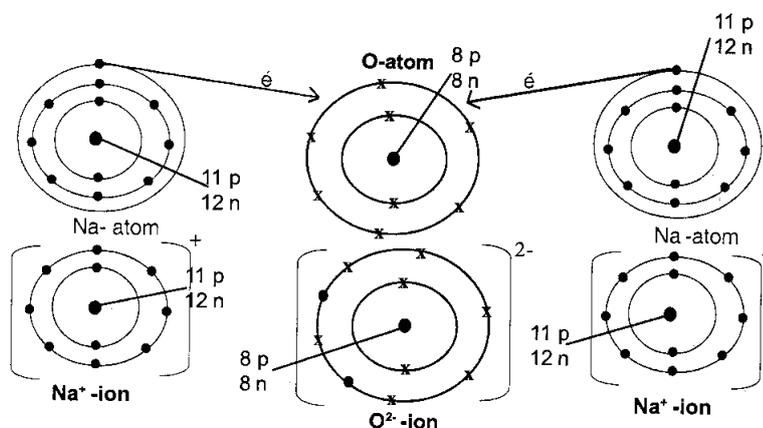
Let us take ionic bonding in sodium chloride as an example.



The Na-atom will lose the one outer electron to form the Na-ion. Because Na loses one electron it becomes an ion. The Cl-atom will receive the one electron to become a Cl-ion. The positive and negative ion will now attract each other to form the compound NaCl (which is ordinary table salt).

 Tip	<p>Please note: For ionic compounds, the name of the metal element comes first when naming a compound.</p>
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Another example can be the formation of sodium oxide.



Na₂O (sodium oxide)

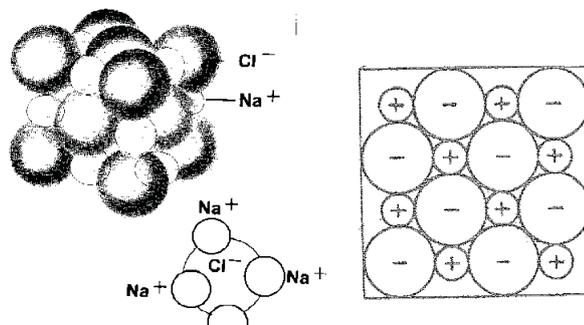
The oxygen atom has six valence electrons so it needs two electrons to become stable. But the sodium atom can only give one electron. This is why two sodium-atoms take part in the bonding so that they can give two electrons to oxygen. The formula of sodium oxide is Na₂O because it consists of two sodium atoms and one oxygen atom.

Other examples of ionic compounds are: lithium chloride, potassium oxide, sodium fluoride etc. Try to draw their bondings.

Positive and negative ions attract each other during ionic bonding. That is why this bond is such a strong bond.

Ionic compounds also have high melting and boiling points due to this strong bond. Ionic compounds have crystal lattices due to positive and negative attraction of ions.

The arrangement of ions in sodium chloride





Cations are metal ions that have lost their outside electron/s and became positive ions. In this regard, Group I elements become +1 and Group II elements become +2. The transition elements also are cations and are identified as +3 and even +4 ions. For example, we get aluminium as a Al^{3+} and Iron(III) Fe^{3+} .

How do ionic compounds behave?

Ionic compounds are made up of both positive and negative ions joined by an ionic bond. The positive ion has a positive charge and the negative ion has a negative charge. A current of electricity is a movement of charge. If we can get the ions in an ionic compound apart from each other so that they can move, the compound will conduct electricity.

In the solid state, the ions are too strongly held together by the attraction of positive and negative charges and the ions cannot move. Therefore, the ions must be separated.

There are two ways in which we can separate the ions:

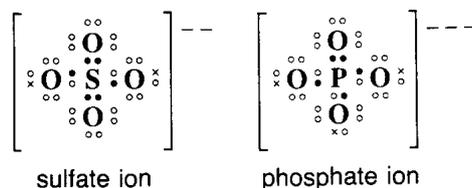
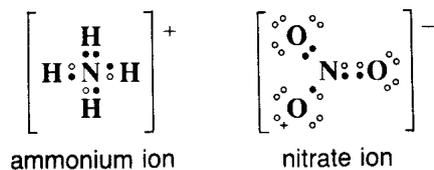
- by melting the solid;
- by dissolving the solid in water.

Ionic compounds will not conduct electricity in solid form, but they will conduct electricity when melted or when in a solution.

Some anions are comprised of more than one element. They are called polyatomic or complex ions. The common ones are: NO_3^- , SO_4^{2-} , CO_3^{2-} and NH_4^+ .

The formation of complex ions

NO_3^- , SO_4^{2-} and CO_3^{2-} ions as well as the NH_4^+ ion are examples of polyatomic (ions made up of more than one atom) ions. They are charged particles made up of more than a single atom. These familiar ions have covalent structures. Their ionic charge is the sum of all the atoms present. Because of their small size and their stability, they behave just like single-atom ions. They go through many chemical reactions unchanged.



The name complex ion is ordinarily restricted to ions composed of a metal ion combined with a specific number of ions. The charge on the complex ion is the sum of all the units. Complex ions vary in stability, but none is as stable as the common polyatomic ions mentioned above.

The most common complex ions are formed by ions of the transition metals with chemical species such as chloride ions (Cl^-), ammonia molecules (NH_3), water molecules (H_2O). The transition cation is always the central ion upon which the complex is formed. The number of units covalently bonded to the central ion is its coordination number for that complex ion.

Now answer the questions in the following self-mark activity to deepen your understanding of this section.

Self-Mark Activity



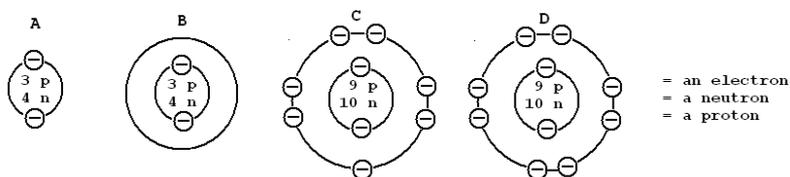
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Which diagram shows a positively charged ion?



2. Which substance in the table has ionic bonding?

Substance	Boiling point/ $^{\circ}\text{C}$	Electrical conductivity		
		Solid	Molten	Aqueous solution
A	-80	poor	poor	quite good
B	-26	poor	poor	poor
C	1206	poor	good	good
D	4875	good	good	insoluble

3. The table gives the arrangement of electrons in the atoms of four elements.

Element	Arrangement of electrons
A	2,8,1;
B	2,8,2;
C	2,8,7;
D	2,8,8.

Which element is unlikely to form an ion?

4. Which of the following substances would you expect to have an ionic bond?

- A. calciumchloride;
- B. carbondioxide;
- C. hydrogen fluoride;

D. hydrogen phosphide.

5(a) Draw a diagram to show the structure of an atom of sodium. You must also show the number of protons and neutrons.

(b) When sodium combines with chlorine, sodium chloride is formed.

(i) Write a word equation for this reaction.

(ii) Describe how bonding takes place in sodium chloride.

6. Use the information in the table below to answer the questions that follow. [Source: JSC 1998]

Element	Atomic number	Mass number	Electron number
A	3	7	2,1
B	18	40	2,8,8
C	8	16	2,6
D	12	24	2,8,2
E	19	39	2,8,8,1

7a) Which element has 22 neutrons?

b) What type of chemical bonding would occur between:

(i) element C and E?

(ii) two atoms of element C?

c) Which element is a noble gas?

d) Which two elements form ions with the same electron structure as neon, ${}^{20}_{10}\text{Ne}$? (Use the Periodic Table to get the answer.)

Now, you can start studying Section 11 of this unit.

Section 11: Metallic Bonding

Introduction



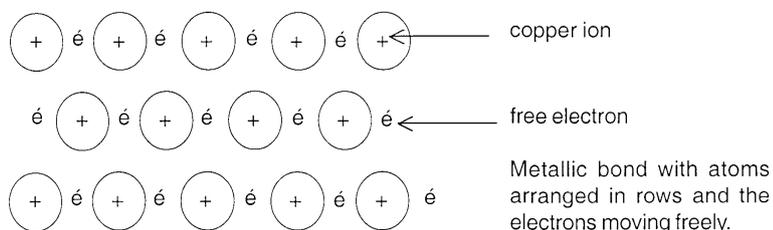
Metallic bonding between metal atoms will be discussed in this section.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>describe</i> metallic bonding in terms of its arrangement of positive metal ions with delocalized electrons originating from the outer shell electrons of metal atoms.
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 Time	<p>This section will take you about two and a half hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Metallic bonding

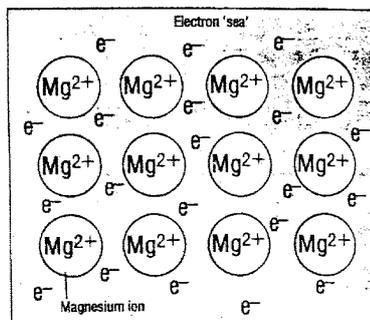
This bond holds metal atoms together. In a metal, the atoms are packed tightly together in a regular pattern. This causes outer electrons to get separated from their atoms and the result is a lattice of ions in a sea of electrons.



We have seen how non-metal atoms bond together by sharing electrons (covalent bonding). We have also seen how metal and non-metal atoms bond together by transferring (losing or gaining) electrons (ionic bonding). How do metal atoms bond together? We know that they do bond together as metals and that they are generally strong solid materials.

Metals have one, two or three electrons in their outer shells. Therefore, the easiest way to obtain a full shell of electrons is to give away these electrons leaving a full outer shell. But how can they do this when there are no atoms present which are short of electrons to give these electrons to?

In a metal, the atoms are arranged in rows. The electrons from the outer shell move between the atoms. It is these moving electrons that hold the atoms together through attraction between positive and negative charges. This structure is called the metallic bond.



Metallic bonding involves metal ions held together by a "sea" of electrons

This metallic bonding results in positive ions surrounded by a sea of electrons, which do not belong to the individual atoms any more. Instead they act as a sort of "glue" holding the positive ions together. This results in a giant structure (one that can be extended in all directions) of metal ions kept together by the electron pool. The metal ions are all the same in a pure metal. In an alloy, there can be two or more different metals e.g., brass contains copper and zinc.

Now, try working through the following self-mark activity.



Self-Mark Activity



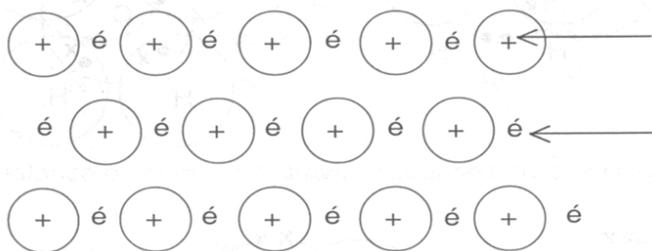
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Do metals tend to form cations or anions? Explain your answer.
2. This is a representation of a specific type of bond.



- a) This type of bond is found in metals. Make a similar sketch of what it would look like if this metal was mixed with another metal.
 - b) When two metals mix, write down what it is called.
- You can now start studying the last section in this unit.

Section 12: Relationship Between the Periodic Table, Bonding and Balancing Equations

Introduction

In this section we will discuss the relationships we found between the periodic table and bonding. We will also learn about the balancing of equations for chemical reactions.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>describe</i> the relationship between the group number of the periodic table and the number of electrons in the outer shell; • <i>explain</i> how in each material, the bonding type relates to properties of a substance; • <i>identify</i> the type of bonding in different materials according to properties such as malleability, boiling point and melting point; • <i>distinguish</i> between covalent, ionic and metallic bonding as different types of bonding; • <i>relate</i> bonding to the position of elements in the Periodic Table; • <i>write</i> word and balanced equations for chemical reactions.
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 Time	<p>This section will take you about four hours to complete. Make sure you read and understand everything in order to achieve all of the outcomes.</p>
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Group number and electrons in the outer shell

The number of outer electrons will determine in which group the elements are located. For example, sodium has one valence electron and is in Group I.

Bonding type and properties

Ionic and covalent compounds have different properties. The properties are summarised in the table below.

Ionic compounds	Covalent compounds
1. These have high melting and boiling points because the bonds are strong due to electrostatic bonds. It takes a lot of heat energy to break the lattice.	These have low melting and boiling points, because molecules are held together by weak forces that do not need much heat energy to separate them.
2. These are usually soluble in water.	These are usually insoluble in water.
3. These are insoluble in many other solvents, e.g., tetra-chloromethane and petrol.	These are soluble in tetra-chloromethane and petrol.
4. These do not conduct electricity when solid. They do conduct electricity when they are melted or dissolved because the ions are free	These do not conduct electricity, even when melted.



to move.	
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In molecules such as hydrogen and water, the atoms are held together by covalent bonds. Positive and negative ions attract each other during ionic bonding. Ionic compounds have crystal lattice due to the positive and negative attraction of ions.

Properties of metals due to bonding

1. Metals are good conductors of electricity because the free electrons can move and carry charges.
2. Metals are good conductors of heat because the free electrons can take in heat energy and pass it onto neighbours during collisions.
3. Metals can be hammered into different shapes (they are malleable).
4. Metals can also be drawn into wires (they are ductile). The layers of ions can slide over each other causing malleability and ductileness.
5. Metals have high melting points because it takes a lot of heat energy to break the lattice.

Covalent, ionic and metallic bonding related to the position of elements in the Periodic Table

	covalent	ionic	Metallic
Different types of bonding	Share electrons Molecules form	Exchange electrons Become ions Electrostatic force between ions Form crystal lattice	Happens in same element Lose outside electron Electrons the glue for ions Three-dimensional arrangement of ions
Position (group) of elements	Non-metals	Metals with non-metals Group I with VII Group II with VII	All metal elements

Writing word equations and balancing equations

This can be a very frustrating part of chemistry. It is however not nearly as difficult as people make it out to be. The secret lies in a simple formula, no new formula but a sequence of steps to take. We balance equations simply to determine how much of one substance reacts with another substance and how much it will produce. To write this quickly, we use symbols.

Word equations

We could write a sum like this, **one plus two is equal to three**. Or we can use symbols,

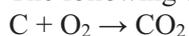
$$1 + 2 = 3.$$

The same principle applies to chemical reactions and equations.

Writing an equation for a reaction requires that you consider the following:

1. Make sure the reaction takes place.
2. Write down a word equation.
3. Write down the correct formula for each reactant (the compounds that react during the chemical reaction) and product.

The following example shows reactants and the product:

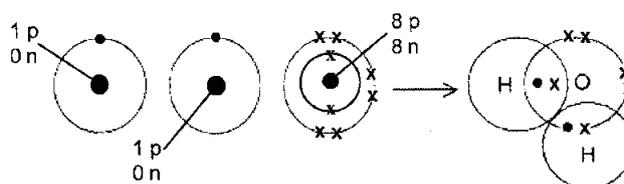


Reactants \rightarrow product

4. Balance the equation by using multiples of these formulae. Remember to balance the ionic charges also.
5. Never change the formula of a compound or element to balance the equation.

Balanced equations

It looks very demanding, but let's start with a simple example.



Yes, hydrogen and oxygen bond to form water. Which are the reactants and which are the products?

Reactant + reactant \rightarrow product + product

Let's write the words: Hydrogen + oxygen \rightarrow hydrogen oxide



Now symbols: $\text{H} + \text{O} \rightarrow \text{H}_2\text{O}$

Knowledge: $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$ [hydrogen and oxygen are diatomic gases]

Balance: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

This means we have 4 hydrogen atoms bonding with 2 oxygen atoms to form 2 water molecules.

BUT, the number of hydrogens on the left side is 4 and the number on the right side is also 4.

There are also 2 oxygen atoms on the left and 2 on the right.

No atoms got lost or gained. It follows the same principle as balancing equations in mathematics.

Now, let's try and understand this better by working through a few questions in the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Write word equations for the following reactions:
 - (a) carbon reacts with oxygen;
 - (b) sodium with chlorine;
 - (c) magnesium and fluorine;
 - (d) nitrogen and hydrogen;
 - (e) iron and sulphur;
 - (f) hydrochloric acid and zinc.
2. Now write chemical balanced equations for these reactions.

We have come to the end of this unit. To ensure that you have understood the material, spend a few hours reviewing what we have covered in this unit.



Summary

In this unit you learned that:

- all substances around us are made up of matter;
- matter is anything that has mass and occupies space;
- matter occurs in three states namely solids, liquids and gases;
- the movement of different particles among each other so that they become evenly mixed is called diffusion;
- pressure in gases is caused by the collisions between gas particles;
- atoms are the smallest building blocks of matter;
- compounds are chemical combinations of elements;
- protons and neutrons are found in the nucleus;
- the first shell of an atom can take only 2 electrons while the next shells can take a maximum of 8 electrons each;
- the number of valence electrons of an atom indicate the group number of the atom on the Periodic Table; valence electrons are the number of electrons in the outer ring;
- isotopes are atoms of the same elements which have the same atomic number but different atomic masses;
- covalent bonding takes place between non-metals



	<p>and involves the sharing of electrons;</p> <ul style="list-style-type: none">• ionic bonding is between metals and non-metals and electrons are transferred from one atom to the other.
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Answers to Self-Mark Activities

Section 1: The Kinetic Particle Theory of Matter

1. B, shows the arrangement of particles in a solid, a liquid and a gas.
2. A is melting.
3. B The molecules in a gas move about randomly (in any direction).
4. B Cola fizzy drink contains substances of all three states of matter: solid - can, liquid - cola, gas - fizz.
5. A ice melting (solid \rightarrow liquid)
6. D The change of state from solid to gas produces the biggest increase in the movement of particles.
7. D Water vapour is the furthest apart at room temperature because it is a gas.
8. C A **solid** salt contains a regular arrangement.
- 9(a) The melting point of a substance is the temperature at which the substance changes phases from solid to liquid.
(b) The temperature of the substance remains constant during phase change.

(c) Energy is used to overcome forces holding the particles in the original phase.

10(a) The particles in solid matter get energy and therefore start to move more.

(b) The volume in solids increases, which is expansion.

(c) Eventually these particles vibrate so much, bumping and pushing particles further apart, which leads to expansion.

Section 2: The behaviour of Gases

1(a) If volume decreases, there will be an increase in pressure. When a container becomes smaller, but the same amount of gas particles are inside the container, the pressure will be higher.

(b) The pressure will increase. The particles get more energy, thus moving faster and bumping with more intensity against the side of a container which will increase the pressure.

2. Gas particles have mass and move with greater speed, making them bump against the container and exerting a force. Many of these particles exert a force and cause pressure on the sides of the container.

3(a) Gas has to lose heat so particles can move about less and come closer together to become a liquid.

(b) The pressure will decrease, because the particles will have less kinetic energy.

Section 3: Thermal Expansion

1(a) The wheel expands.

(b) The wheel expands during heating so that it fits easier onto the axle.

2. Oxygen gas will expand more because the forces between the particles are weak.

3. This make provision for space during expansion.

Section 4: Thermal Energy

1. alcohol and mercury



2. Alcohol is cheaper.
Alcohol can be used to read much lower temperatures.
3. Mercury cannot be used for very low and very high temperatures.
Mercury is expensive.
Mercury is poisonous.
4. Latent heat is the amount of energy required to convert 1 kg of a substance from solid to liquid or vice versa without a change in temperature.

Section 5: Atoms, Elements, Molecules and Compounds

- 1(i) A substance that cannot be broken down into simpler substances by chemical means is called an element.
- (ii) A mixture contains substances that have not been chemically joined.
- (iii) A compound is composed of two or more elements that are chemically joined.

- 2(i) mixtures
- (ii) elements and compounds

3.

elements	mixtures	Compounds
hydrogen	milk	Water
gold	salt water	Salt
brass	cold drink	copper oxide
chlorine	sodium chloride solution	Plastic

4. Simple distillation is used to separate a liquid from miscible substances. Fractional distillation is the separation of two or more miscible liquids.
5. Squash some beetroot to extract a sample of the juice. Place a drop of the juice on chromatography paper. Place the chromatography paper in a solvent-like water and observe how the chromatogram develops.
- 6(a) when substances do not mix;
- (b) when a liquid turns into a gas;
- (c) substance that remains on the filter paper after filtration.

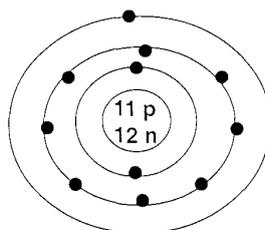
- 7(a) to separate two immiscible substances;
(b) to make sure the temperature remains constant.

Section 6: The Structure of the Atom

1. The three particles that make up an atom are protons, electrons and neutrons.

- 2(a) Protons have a positive charge.
(b) Neutrons have no charge.
(c) Electrons have no mass.

3. The following is an atom of sodium.



4. D Sulphur is found in Group VI of the Periodic Table.
5. A There are 11 electrons in a sodium atom.
6. B All elements in Group VI have the same number of electrons in their outer shells.
7. B The number of protons + the number of neutrons give the mass number. For atom B, it is $6 + 6 = 12$.

Section 7: Isotopes

1. Isotopes are atoms of an element that have different numbers of neutrons, but the number of protons remain the same.
2. A represents isotopes.

Section 8: Group Properties



- 1(i) Groups identify the elements with similar properties.
- (ii) Periods identify the elements with the same number of shells.
- (iii) metals
- (iv) non-metals
- (v) boron, aluminium and silicon

- 2(a) Li, Be
- (b) N, O, F
- (c) C
- (d) F
- (e) N, O, F and Ne
- (f) N, O, F

- 3(a) Group I, II and Transitional metals.
- (b) Group III, IV, V and VI.
- (c) Group VII and VIII.

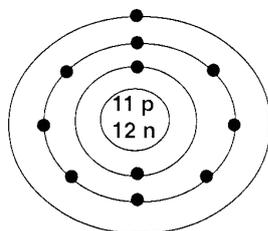
Section 9: Covalent Bonding

1. C is most likely to form two covalent bonds
2. B, carbon dioxide contains 2 elements, carbon and oxygen.
3. A, water molecules will have covalent bonds.

Section 10: Ionic Bonding

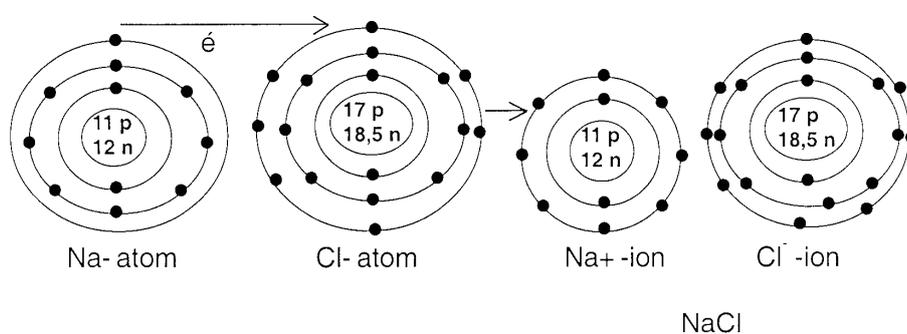
1. A shows a positively charged ion because the protons are more than the electrons.
2. C has ionic bonding because an ionic compound conducts electricity only when melted or dissolved.
3. D will not form an ion because it has a full outer shell.
4. A calcium chloride has an ionic bond because it is a bond between a metal and a non-metal.

- 5(a) Sodium atom



(b)(i) The word equation for sodium chloride is
sodium + chlorine \rightarrow sodium chloride

(ii)



The sodium atom loses one electron and the chlorine atom will receive it. Thereafter, the sodium atom becomes a Na^+ ion and chlorine atom becomes a Cl^- ion. The Na^+ ion and Cl^- ion will attract each other to form the compound NaCl.

6(a) B $40 - 18 = 22$ neutrons

(b)(i) Ionic bonding will occur between C and E.

(ii) Covalent bonding will occur between two atoms of element C.

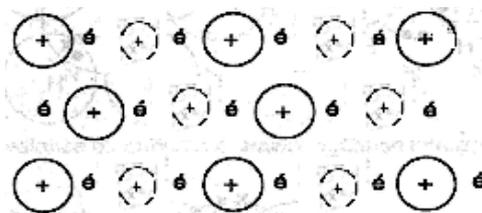
(c) B is a noble gas. It has a full outer shell.

(d) C and D form ions with the same electron structure as neon. C will gain 2 electrons and D will lose 2 electrons to form an ion with the same electron structure as neon.

Section 11: Metallic Bonding

1. Metals tend to form cations (positive ions). Metals tend to lose their outside electrons as free electrons and then become positive.

2(a)



(b) alloys

Section 12: Relationships Between the Periodic Table, Bonding and Balancing Equations

1(a) carbon + oxygen \rightarrow carbon dioxide

(b) sodium + chlorine \rightarrow sodium chloride

(c) magnesium + fluorine \rightarrow magnesium fluoride

(d) nitrogen + hydrogen \rightarrow ammonia

(e) iron + sulphur \rightarrow iron sulphide

(f) hydrochloric acid + zinc \rightarrow zinc chloride + hydrogen

2(a) $C + O_2 \rightarrow CO_2$

(b) $2Na + Cl_2 \rightarrow 2NaCl$

(c) $Mg + F_2 \rightarrow MgF_2$

(d) $N_2 + 3H_2 \rightarrow 2NH_3$

(e) $Fe + S \rightarrow FeS$

(f) $2HCl + Zn \rightarrow ZnCl_2 + H_2$

Unit 3

Materials

Introduction

In Unit 2, we discussed matter, thermal energy, thermal expansion, atoms and different types of bonding.

While discussing the structure of materials and cleaning materials in this new unit we might refer to bonding again.

In this unit, we will discuss different materials around us and that we use in our environment.

This unit consists of the following sections:

Section	Study Hours
1. Types of Materials	14
2. Metals	14
3. Uses of Materials	6
4. Structure and Properties of Materials	5
5. Building Materials	2
6. Fibres	6
7. Cleaning Materials	8
Review	2
Total	57



Outcomes

On successful completion of this unit you will be able to:

- *distinguish* the differences between materials such as wood, metals, glasses, ceramics, concrete, plastics and fibres and realise that some materials occur naturally and others are synthetic;
- *explain* that most metals occur naturally and are combined with other elements;



	<ul style="list-style-type: none"> • <i>explain</i> the methods of extraction of aluminium (electrolysis), copper, zinc and iron (reduction with carbon); • explain the uses of materials in the home; • <i>explain</i> polymers and giant covalent structures in terms of their qualities as types of covalent compounds; • <i>describe</i> the relationship of the properties of some materials to their molecular structure and bonding; • <i>describe</i> a building in terms of its different constituent materials such as bricks (mud or ceramic), concrete, wood, metal, thatch and glass; • <i>describe</i> how the use of materials depends on their properties; • <i>state</i> that natural and synthetic fibres are polymers; • <i>describe</i> the molecular structure of fibre polymers in terms of the properties of a fabric; • <i>explain</i> how the properties of soaps and detergents are related to their generalised molecular structures and their impact on the environment. 																						
 <p>Terminology</p>	<table border="0"> <tr> <td>Polymer</td> <td>Substance made of molecules containing long chains of atoms.</td> </tr> <tr> <td>Electrostatics forces</td> <td>Forces where there are positive and negative charges.</td> </tr> <tr> <td>Ductile</td> <td>Pulled into wire.</td> </tr> <tr> <td>Malleable</td> <td>Flattened and hit into shapes.</td> </tr> <tr> <td>Transparent material</td> <td>Material through which light can shine so that you can see through it.</td> </tr> <tr> <td>Polythene</td> <td>Made from small ethene molecules in a long chain.</td> </tr> <tr> <td>Compressive strength</td> <td>Measurement of strength of a brick, to be able to support a heavy mass on it.</td> </tr> <tr> <td>Tensile strength</td> <td>The ability of a brick to carry weight or mass hung from it.</td> </tr> <tr> <td>Insulation</td> <td>The ability of a material to trap heat.</td> </tr> <tr> <td>Ores</td> <td>Rock from which metal can be extracted.</td> </tr> <tr> <td>Blast furnace</td> <td>Tall oven in which heating takes place during extraction of some</td> </tr> </table>	Polymer	Substance made of molecules containing long chains of atoms.	Electrostatics forces	Forces where there are positive and negative charges.	Ductile	Pulled into wire.	Malleable	Flattened and hit into shapes.	Transparent material	Material through which light can shine so that you can see through it.	Polythene	Made from small ethene molecules in a long chain.	Compressive strength	Measurement of strength of a brick, to be able to support a heavy mass on it.	Tensile strength	The ability of a brick to carry weight or mass hung from it.	Insulation	The ability of a material to trap heat.	Ores	Rock from which metal can be extracted.	Blast furnace	Tall oven in which heating takes place during extraction of some
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		metals.
	Case hardening	Heating and cooling steel rapidly to make the outside very hard.
	Alloys	Two or more metals melted together.
	Cellulose	Polymer of wood.
	Biodegradable	Materials that can be destroyed and/or degraded by bacteria.

Section 1: Types of Materials

Introduction

In this section, you will study different types of materials. You will also learn about the properties of materials and how these properties determine the uses of different materials.

You need to know the properties of materials to be able to determine what they can be used for. In Namibia, we build houses with all types of material. Firstly, because they are available and secondly, because some are cheap. We use different materials for different purposes.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>classify</i> materials into categories such as wood, metal, glass, ceramics, concrete, plastic and fibre; • <i>identify</i> examples of these materials in the local environment; • <i>distinguish</i> between materials that occur naturally and those that are synthetic; • <i>describe</i> experiments to identify common physical properties of each category (hardness, tensile strength, compressive strength, elasticity, conductivity of heat and conductivity of electricity).
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 Time	<p>This section will take you about 14 hours to complete. Make sure you read and understand the content of this section in order to achieve all of the basic competencies.</p>
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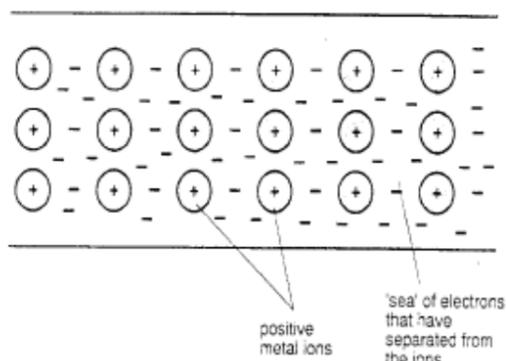
Differences between materials:

1. Wood

If you hammer wood, it will not break easily because it is a strong material. However, if you heat a piece of wood, it will burn and form ash. Wood is not a metal. It is made from the polymer called cellulose. It has a complicated structure containing atoms of carbon, hydrogen and oxygen. Wood is an example of a natural polymer. Covalent bonds and strong electrostatic forces hold the polymer chains together. These chains all line up next to each other to form the grain of wood. Because of the bonds and forces that hold the molecules together, wood has great strength. It is possible to bend it at right angles towards the direction of the polymer chains. However, it is almost impossible to stretch or break it by pulling. This is why wood is such a useful material. If wood is crushed, it forms long thin pieces of cellulose fibres. These fibres can be used to manufacture paper.

2. Metals

Let us now look at metals and their characteristics. When you hit a metal with a hammer, it will flatten without shattering or breaking. Metals can be pulled into wires, therefore we say that metals are **ductile**. Furthermore, metals are flattened and hit into shapes, making them **malleable**.



Examples of metals are copper, lead, zinc, aluminium, lithium and iron. Do you still remember the properties of metals? For example, metals conduct electricity and heat. Name a few more properties.

3. Glass

Glass breaks or shatters easily when it is hit with a hammer. Glass is usually a hard, brittle and transparent material. A transparent material is one through which light can shine so that you can see right through it. Glass has a structure like a liquid, but the molecules are too large to move around. So glass is actually a liquid that behaves like a solid. Common kinds of glass are made by heating limestone (calcium carbonate) with

sodium carbonate and sand (silicon dioxide) in a furnace. The three compounds of limestone, sodium carbonate and silicon dioxide melt and run out of the bottom of the furnace as a clear liquid. The liquid can be cooled as a flat sheet of glass, or it can be moulded into any shape before it cools and turns solid.

Glass is not a solid but a liquid. Glass does not flow like a liquid, because the molecules are too big. Glass is a mixture of ionic substances and so it shatters easily when hammered. Like other materials, it is rigid and cannot be bent easily.

4. Ceramics

When ceramics are hit by a hammer, they also shatter or break. People use ceramics to make pots, ornaments and tiles. Ceramic objects are made of clay and then hardened by heating.

5. Concrete

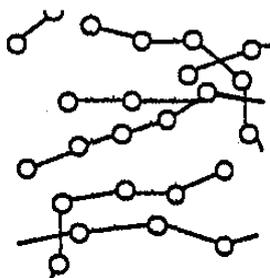
Concrete also shatters when hit by a hammer. It is made out of sand, gravel, cement and water. When water is added to the sand, gravel and cement, crystals in the cement will start to form. These crystals lock together. This makes the concrete very strong and hard. But since concrete is made out of crystals, it is quite easy to break. The crystals are strongest if the concrete is allowed to dry out slowly. This is why it is a good idea to wet concrete with water for several days after it has been made.

6. Plastic

Plastic will not shatter when hit by a hammer. Plastic is made of long chains of carbon atoms that are bonded together. Materials which are made of these long molecule chains are called **polymers**. Plastics are formed from long chains of carbon atoms together with atoms of other elements. The atoms are held together by strong covalent bonds. Plastic is an example of either artificial or synthetic polymers. The diagrams below show plastic called polythene. Polythene is made from many small molecules of a gas called ethane. We can distinguish between four types of plastics; namely polythene, nylon, melamine and polyurethane. We will now discuss the structures of these four plastics.

6.1 Polythene

In polythene, the molecules are not held together strongly. The molecules line up in different directions. The diagram below shows the structure of polythene.

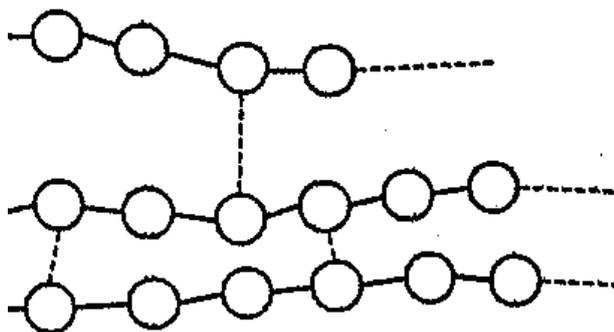




Polythene is used to make shopping bags. It is cheap and flexible and not very strong.

6.2 Nylon

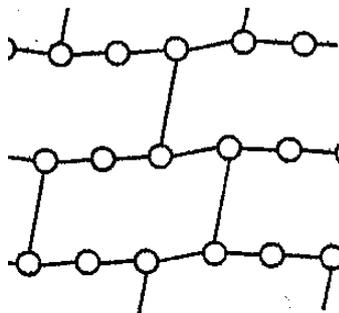
Nylon consists of nitrogen and oxygen atoms, which attract each other by electrostatic forces. These forces are strong. Because the forces are electrostatic, the molecules can slide next to each other. This makes nylon stretchable. The diagram below shows the structure of nylon.



Nylon is used to make clothes, fishing line and ropes.

6.3 Melamine

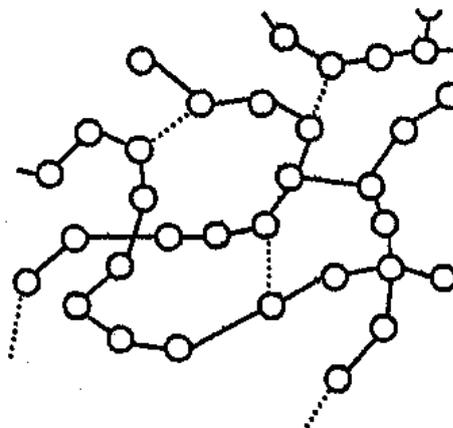
In this plastic, there are very strong covalent bonds. Melamine is hard and does not shatter easily. It cannot be stretched and will not melt. Below is the structure of melamine.



Melamine is used mainly for making table tops and doors.

6.4 Polyurethane

In this plastic, the molecules are joined together very loosely in a random way. This plastic can be squashed or stretched without permanently changing its shape. It is not strong. The diagram below shows the structure of polyurethane.



Polyurethane is used to make foam mattresses.

7. Fabrics

Fabrics do not break when they are hammered. Fibres are used to make thread which in turn can be made into cloth. Examples of fibres include cotton, wool, silk, linen, etc.

Natural and synthetic materials

If a material occurs naturally, it means that we find it in nature. A synthetic material, however, is artificial (man-made) and made by adding different chemicals together.

Wood	This material occurs naturally and comes from trees and bushes.
Metals	Metals are also found naturally but are extracted from the earth. Alloys are synthetic because they are made by mixing metals. An example is brass.
Glass	Glass is synthetic because it is made from mixing chemicals together, as we have discussed earlier.
Ceramics	Ceramics is synthetic though it is made from clay, which is found in nature.
Concrete	Concrete is also synthetic because it is made by mixing water, gravel, cement and sand.
Plastics	Plastics are synthetic materials because they are manufactured by adding different chemicals together.



Fibres can be classified into two groups, namely natural and synthetic fibres. Study the table to see the difference between these two groups.

Natural fibres			Synthetic fibres
From plants	From animals	From minerals	
cotton sisal linen	Wool Mohair silk	Asbestos	Nylon Terylene polythene

By doing simple experiments, you can determine the hardness, tensile strength, compressive strength and elasticity, conductivity of heat and electricity, and stability to heat of several objects.

Try doing the following experiments on your own to identify these properties:

HARDNESS

Any substance can be tested for hardness. We might not want to test how hard a soft material is. However, we might want to test the strength of harder substances. Such substances might include materials such as concrete, bricks, metals, wood, etc.

1. To test the strength of bricks or concrete slabs, one can conduct the following experiment. Make several bricks out of different materials.

Try the following mixtures for your bricks:

- (a) two parts of cement added to two parts of sand;
- (b) one part of cement added to three parts of sand;
- (c) three parts of cement added to one part of sand;
- (d) only mud.

Add water to each mixture until it forms a firm paste. Mould each mixture into a box and label it carefully. Leave the bricks to dry for a week.

Testing your bricks:

Test the compressive strength of a brick by filling a bucket with water. First put a piece of wood on a brick and then place the bucket of water on top of it. If the brick breaks easily, this means it has a weak **compressive strength**.

You can also test the **tensile strength** of a brick. You can do this by following these instructions:

1. Put water in a bucket.
2. Determine the mass of the bucket with a scale.
3. Write the mass in the table on the next page.
4. Move two tables a certain distance from each other and put the brick across them.
5. Hang the bucket of water on the brick.
6. If it is difficult to break the brick then it has a good tensile strength.
7. Hit each type of brick with a hammer to test its hardness.

Write your results in a table like the one below and decide which brick is the best to use for building.

MIXTURE	Compressive strength		Tensile strength		Hardness Hit with hammer	
	Mass on brick/kg	Break Yes/no	Weight in bucket/kg	Break yes/no	Shatter	Break
two parts of cement added to two parts of sand						
one part of cement added to three parts of sand						
three parts of cement added to one part of sand						
only mud						
brick bought for control						

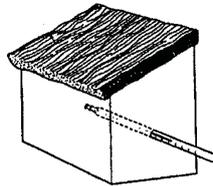
INSULATION



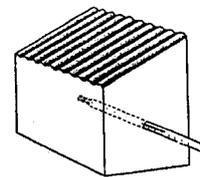
A good insulator will trap the heat inside. You can test different roof materials to decide which is the best insulator. You can do this by following these instructions:

1. Build two model cardboard houses. They must have the same size and shape.
2. Do not create any windows or doors.
3. Put a thatch (grass) roof on one and a metal roof on the other.
4. Place in the sun outside.
5. Put a thermometer through a hole in the side of each house.
6. Record the temperature inside each house every five minutes for half an hour.
7. Plot your results on graph paper.

thatched roof



metal roof

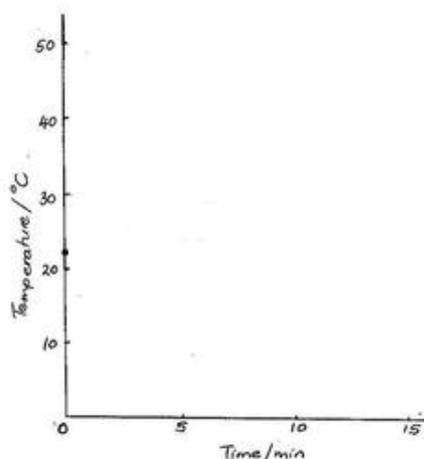


Result

You can use the table below to write down your results.

ROOF MATERIAL	Time / minutes	Temperature / °C	Temperature /	
			Good	Poor
Metal / Corrugated				
Thatch				

This graph shows you how to plot your readings of temperature and time.



The thatched roof house will be cooler inside than the metal roof house. This is because the thatched roof is a good insulator, while metal is a good conductor of heat. Thatch keeps heat out on a hot day and retains it on a cold day. This happens because air is trapped in the grass. Air is a good insulator. Do you still remember what an insulator is?

ELASTICITY / STRETCHABILITY

You can test the elasticity of fibres in the following way:



Practical Activity

1. Take threads of wool, cotton, nylon and polyester.
2. Put a ruler flat on a table.
3. Hold a 20cm length of fibre between your fingers.
4. Do not stretch it.
5. Place one finger at zero on the ruler.
6. Stretch the fibre as far as it will go and measure the new length.
7. Allow the fibre to go back to its original length.
8. Measure it again to see if it is stretched permanently.
9. Repeat this with all four fibres, and record your results in a table.

Stretch: means to make something wider or longer.

The following table can be used to record your results:

FIBRE	Original length / cm	Stretched length / cm	Length after stretched / cm	Stretched – original lengths / cm



Wool				
Cotton				
Nylon				
Polyester				

Results

You will find that wool stretched the most, while nylon stretched the least. This happens because of their structures.

Keratin in wool is curled up. When wool stretches, the molecules uncurl. When you stop stretching the wool, the molecules return to their original shape. Nylon molecules are long and straight so they cannot stretch easily. This is why nylon will stretch the least.

CONDUCTIVITY OF ELECTRICITY



Practical Activity

y.

Problem: To determine whether different materials will conduct electricity.

What you need:

circuit board;
two batteries (cells);
copper wire;
light bulb;
piece of wood;
piece of plastic;
piece of wool;
piece of pencil lead;
piece of iron;
piece of copper;
piece of steel;

crocodile clips to complete the circuit. A crocodile clip is an electrical connector. It function like a jaw with springs to grip an object in order to connect it in a circuit.

What to do:

1. Connect the cells, light bulb and the piece of wood with copper wires and crocodile clips.
2. Remove the piece of wood and replace it with another object.
3. Determine whether the objects are conductors. If the light bulb burn when the object is connected in the circuit the object is a conductor.
4. If the light bulb do not burn when the object is connected, it is not a conductor.

Complete the table below.

MATERIAL	Conductor		MATERIAL	Conductor	
	Yes	No		Yes	No
Wood			Iron		
Plastic			Copper		
Wool			Steel		
Pencil lead					

It should be evident to you that the metal objects conduct electricity. Surprisingly, so will the lead of a pencil. The other substances will be poor conductors or good insulators of electricity.

CONDUCTIVITY OF HEAT

You can conduct an experiment such as the one below to test how well substances conduct heat. You can do this by following these instructions:



Practical Activity

Problem: To determine how well a substance conduct heat.

What you need:

- Make a hot water tank with a metal can. It

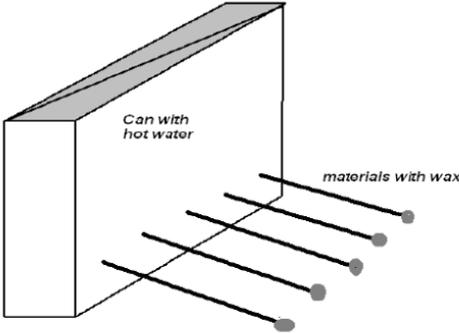


should look like the tank illustrated below.

- Make small holes in it to put similar pieces of materials in it. Put the following pieces of material in the holes:
copper;
steel;
wood;
aluminium;
plastic.

What to do:

- Attach candle wax to the tips of the materials you have selected.
- When the heat is conducted, the wax melts and you will know which the better conductors are.



The diagram shows a rectangular tank with a slanted top. A label 'Can with hot water' points to a small container on the side of the tank. Several rods of different materials are attached to the side of the tank, with small circles representing wax at their ends. A label 'materials with wax' points to these rods.



Practical Activity

Testing the heat stability of different fibres

You can test the heat stability of different fibres by following the instructions below:

1. Take 5 small plastic or tin containers.
2. Surround four of the containers with wool, cotton, nylon and polyester.
3. Pour boiling water quickly into each container.
4. Note the initial temperature of the water in each container.
5. Note the temperature every five minutes for about half an hour.
6. Write all your results in the table below.
7. Plot a graph of your results. This is called a cooling curve.

	Time/ min	Control no fabric	Wool	Cotton	Nylon	Polyester
	1					
	2					
	3					
	4					

Results

The container without any fabric wrapped around it will cool the fastest. This container is called the control. The fabrics in the other containers prevent the heat from escaping from the water quickly, as it does in the control. We say the fabrics insulate the containers.

If you look again at the structure of wool, you will see that the molecules are curled up. In nylon, the molecules are straight. Air is trapped much more easily in the curls of the wool than in nylon. That is why wool is such a good insulator.

You are now equipped with useful knowledge on the properties of materials.

You can now work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Which of the following materials will shatter when hammered?

- A ceramics;



- B** paper;
- C** rubber;
- D** wool.

2. An experiment was carried out to test the stretchability of fibres.

Fibres were measured both unstretched and stretched, and the measurements taken are recorded as follows:

Fibres	Original	Stretched	Difference
cotton	24.3cm	25.0 cm	0.7 cm
nylon	5.0 cm	5.3 cm	0.3 cm
polyester	30.0 cm	30.4 cm	0.4 cm
wool	20.0 cm	28.3 cm	8.3 cm

Which fibre is the least stretchable?

- A** cotton;
- B** nylon;
- C** polyester;
- D** wool.

3. Mary did an experiment to find out which of three materials is the best insulator.

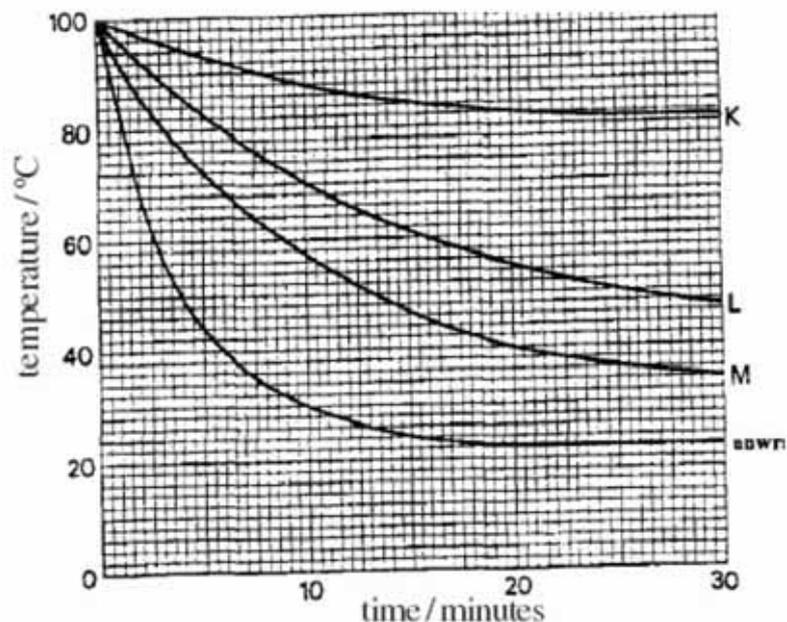
She wrapped material **K** around a beaker of water, which has reached boiling point temperature.

A reading was taken every few minutes and the readings were plotted on a graph.

She repeated the experiment with materials **L and M**.

She then did the experiment again with the beaker unwrapped.

[Source: JSC 1998]



Using the graph and the information provided above, answer the following questions:

- Calculate by how much the temperature of the water in the beaker wrapped with material **L** fell in the first ten minutes. Show your working.
- State or explain the function of the unwrapped beaker.
- Identify the material that was the worst insulator.
- In cold weather, many people wear thick woollen coats. Select which of the materials used in the experiment was probably wool.
- Give a reason for your choice in (d).
- Select which material (**K, L or M**) would be the best to keep a tin of cool drink cold on a hot summer day.

4. Describe how would you test the compressive strength of a brick.

Well done! You can start studying Section 2.



Section 2: Metals

Introduction

How can we recognise a metal? You may already know many of the properties of metals. We have already discussed the properties of metals but here is a reminder. Most, but not all metals are:

- solids at room temperature;
- sonorous, i.e., ring when struck;
- malleable, i.e., can be beaten into various shapes;
- ductile, i.e., can be drawn out into wires;
- good conductors of electricity;
- good conductors of heat.

Let us now discuss the production of metals in mines.



Basic Competence

On successful completion of this section, you will be able to:

- *state* the constituents of metals in terms of combination with other elements in compounds known as ores;
- describe the uses of the metals extracted from the ores mined;
- *describe* the methods of extraction of aluminium (electrolysis), copper, zinc and iron (reduction with carbon);
- *explain* how the method of extraction of a metal from its ore depends on the position of the metal in the reactivity series;
- *describe* the production of steel using an electric arc furnace;
- *deduce* that the properties and uses of steel depend on the amount of carbon or other elements in it;
- *explain* alloys in terms of their constituents as mixtures of metals and in terms of the usefulness of their properties;
- *explain the usefulness of metals when their properties are changed when mixed as alloys*;
- *describe* the reaction of acid with metal and carry out a test for the hydrogen produced.



Time

This section will take you about 14 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Ores:

An ore is a piece of rock from which a metal in a pure form can be extracted. Most ores are oxides, carbonates, sulphides, sulphates or chlorides. In Namibia, ores are mined at Kombat, Otjihase, Tsumeb and Khusib Springs (Ongopolo Group), Rössing, Rosh Pinah, Brandberg West and Uis.

The next table shows some metals with their ores and method of extraction.

Metal	Ore	Method of extraction
Al (aluminium)	Bauxite, aluminium oxide (Al_2O_3), found in clay, rocks and minerals	electrolysis of molten bauxite dissolved in cryolite which is another ore of aluminium
Zn (zinc)	Zinc blende, zinc sulphide (ZnS)	heating the ore with oxygen to form zinc oxide which is then heated together with carbon
Fe (iron)	Haematite, iron oxide (II) (Fe_3O_2), found in rocks	heating the ore together with limestone and carbon, in a blast furnace
Cu (copper)	Copper pyrites, copper sulphide (CuS), found in many semi-precious stones	heating the ore in oxygen to form copper oxide which is then heated together with carbon
U (uranium)	"Yellow cake" which is uranium oxide	process of acid leaching with sulphuric acid

The method used to extract a metal depends on its position in the reactivity series. In order to do this we need to explain the following words:

Reactive: When a metal is reactive it is able to enter fairly readily into chemical changes.



Reactivity series: The reactivity series provide a comparison of the reactivity of metals. The use of reactivity series is very helpful in the processes in extraction of the metals from their ores. f.

REACTIVITY SERIES

↑ Increasing reactivity	Potassium Sodium Calcium Magnesium Aluminium	electrolysis
	Zinc Iron Lead	reduced from ore by carbon
	Copper	roasting in air
	Silver Gold	found as pure uncombined state

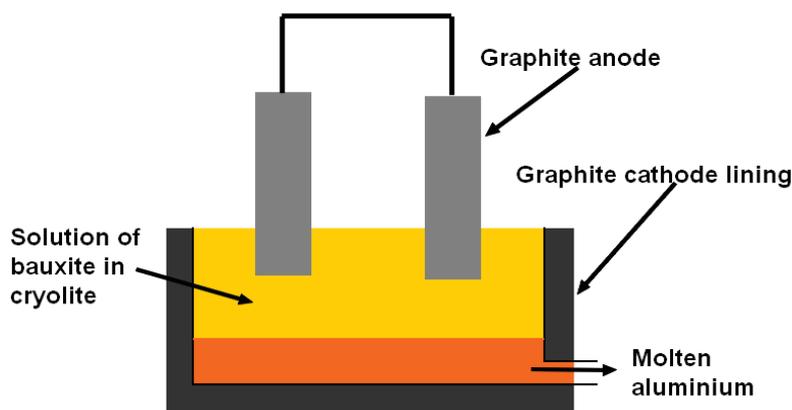
The method of extraction depends on the position of the metal in the reactivity series. In order to use a metal, it needs to be pure. This means that it needs to be in its element form. To get an element into its pure or element form we need to extract it from the ore.

EXTRACTION OF METALS FROM THEIR ORES

Extraction of metals using electrolysis/ Extraction of aluminium

All the metals above zinc in the reactivity series can be extracted from their ores by the electrolysis of their molten or dissolved salts. Aluminium is above zinc in the reactivity series and can therefore be extracted by the process of electrolysis. Aluminium has a high melting point (2,015°C) and therefore does not melt easily. Aluminium dissolves in another compound called cryolite (sodium aluminium fluoride) at a much lower temperature. This mixture is then electrolysed in a cell with carbon electrodes. The electrodes can be negative or positive. When they are negative, we refer to them as cathodes. When the electrodes are positive, they are called anodes.

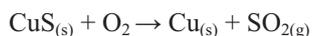
An electrolysis cell is shown below:



Extraction of metals by reduction with carbon

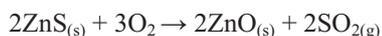
Extraction of copper

The ore of copper is called copper pyrite or copper (II) sulphide, CuS . To extract copper, the copper (II) sulphide is heated in air. It then produces copper and sulphur dioxide.



Extraction of zinc

Zinc is extracted from its main ore, zinc blende, which is zinc sulphide (ZnS). The zinc blende is firstly roasted in air to produce zinc oxide and sulphur dioxide. The reaction is



The zinc oxide is mixed with coke and then heated vigorously producing zinc metal. Coke is one form of carbon. Zinc boils at 913°C , so it will escape with the waste gases as zinc vapour. The gases are cooled down and the zinc condenses.

Extraction of iron

To extract iron from its ore, haematite or iron (III) oxide, three substances are needed:

1. iron ore;
2. limestone, this is a common rock made of calcium carbonate, CaCO_3 ;
3. coke, this is made from coal and is nearly pure carbon.

These three substances are mixed together and then heated in a tall oven called a blast furnace. The blast furnace gets its name because a blast of hot air is blown in at the base of the furnace to increase the temperature. Several reactions take place and finally liquid iron is produced.

The process of extracting iron from its ore is as follows:

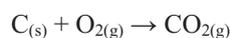
1. A blast of hot air is blown in at the base of the furnace to increase the temperature.



2. Haematite is added to coke and limestone (calcium carbonate) which is fed into the blast furnace from the top.
3. The limestone reacts with the impurities, mainly silicon dioxide or sand, forming calcium silicate, also called slag.
4. Most of the slag ends up as solid waste in large piles near the furnaces.
5. The carbon reacts with the oxygen to produce heat and carbon dioxide, which is converted to carbon monoxide.
6. Carbon monoxide is used as the reducing agent for reducing the iron oxide to iron.
7. Molten iron is more dense than slag and sinks to the bottom of the blast furnace, where it is drained off.

The reactions involved in the blast furnace are:

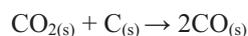
1. The coke reacts with oxygen in the air and then forms carbon dioxide.



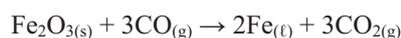
2. The limestone decomposes to calcium oxide and carbon dioxide.



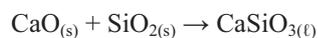
3. The carbon dioxide reacts with more coke giving carbon monoxide.



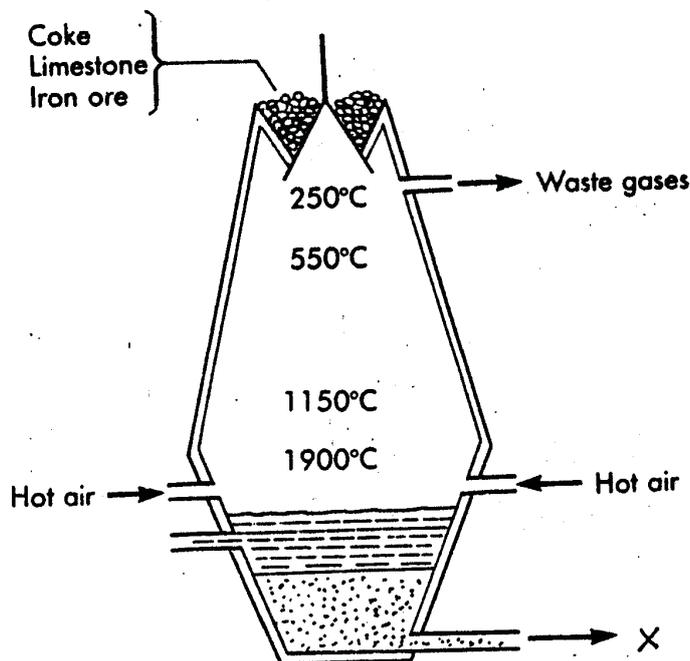
4. The carbon monoxide reacts with iron oxide in the ore to give liquid iron.



5. The iron flows to the bottom of the furnace. Calcium oxide, which was mentioned in step 2, reacts with sand in the ore to form calcium silicate or slag.



The slag then runs down the furnace and floats on the iron. The slag and iron are drained from the bottom of the furnace. The diagram below shows a blast furnace in which all of the reactions take place.



The production of steel

Steel is an alloy which you will learn more of in the next section. When iron is pure—that is in its element form plus also 0.2 – 2.1 % carbon , it becomes an alloy called steel. The properties of steel are equal to the combined properties of the elements from which the steel is made. For example, the hardness of steel can be altered by increasing or decreasing the amount of carbon in it. This is done by burning the carbon only partly with oxygen in the blast furnace. There are many kinds of steel. The hardness of the steel depends on how much carbon remains dissolved in it. The properties of steel can be changed to suit different uses. You can achieve this in three different ways:

- by altering the amount of carbon in it;
- by heating it and then cooling it rapidly in water;
- by adding other metals to it.

Pure iron is not used to make things because it is difficult to produce. It is very soft and not very useful as it reacts with oxygen very fast (it rusts).

Steel is iron with a small amount of carbon in it. Steel is a very common and useful alloy. It is produced in the blast furnace as described above.

If the alloy steel still contains about 4% of the carbon from the coke it produces, it is called cast iron. Cast iron is very hard, but breaks easily.

Can you think of an everyday use of cast iron? One example is the cast iron pot one uses on the fire. From experience, you could probably



understand now why your parents or grandparents always warned you not to drop the pot as it could easily break.

In order to reduce the hardness of the steel, the carbon content has to be reduced to 0.5% to 1%. This produces a steel that is still hard but becomes more flexible and therefore does not break easily. The reduction of carbon content in the steel can be controlled by the amount of oxygen blown through the molten metal in the furnace. The more oxygen, the less carbon content.

Another way of increasing the hardness, called hardening, is heating the steel and then rapidly cooling it in water. This makes the outside of a piece of steel very hard. This process is called case hardening. It is useful in the making of tools that need sharp cutting edges.

Steel is a very useful metal. This is partly because not only is it quite cheap, but also because its properties can be changed to suit different uses. We can change its properties by adding other metals. Doing this will produce alloy steels with desired properties. The following table shows some different types of steel, their compositions, properties and uses.

Steel	Composition	Properties	Uses
cast iron	96% Fe + 4% C	hard and brittle	engine block, drain covers, cast iron pots
hard steel	99% Fe + 1% C	tough and brittle	cutting tools, razor blades, chisels, railway lines
mild steel	99% Fe + between 0.1 to 0.9% C	easily worked, not very brittle	car bodies, cans, rivets,
chromium steel	Up to 5% Cr	shiny, hard and does not corrode	ball bearings, shiny car parts
manganese steel	87% Fe + 13% Mn	tough and springy	drills bits, springs
stainless steel	74% Fe, 18% Cr + 8% Ni	tough, does not corrode	cutlery, kitchen sinks, surgical tools
tungsten steel	95% Fe + 5% W	tough, hard at high temperatures	edges of high speed cutting tools
vanadium Steel	98% Fe + 2% V	tough, hard at high temperatures	hard tools

Alloys

A substance made up of two or more metals melted together is called an alloy. Over 35 metal elements go into making thousands of alloys. Different alloys are obtained from the same elements by mixing them in different proportions.

There are several ways in which metals can be blended in an alloy. One way is by making a solid solution. If one metal dissolves in another when they are melted together, and stays dissolved when cooled, the two metals form a solid solution. For instance, copper and zinc mix in all proportions. On the other hand, only a limited amount of zinc will mix with lead to form an alloy. In fact, most common alloys are solid solutions.

Sometimes metals form metallic compounds. These alloys have crystal structures with unusual formulae.

There is yet another class of alloys is called metallic mixtures. In this class, crystals of one substance are scattered throughout the mass, somewhat like raisins in a cake. Alloys in this class have a wide range of properties. Steel is an example of the metallic mixture class of alloys.

Alloys have desirable properties. The properties of alloys are usually quite different from those of the basic metals that they contain. For one thing, an alloy is often harder than the basic metals. Brass, which is composed of zinc and copper, is harder than either of these metals. The ability of brass to resist stretching is:

- more than twice that of copper and
- more than four times that of zinc.

Alloys are poorer conductors of heat and electricity than the pure metals. Impurities in copper greatly reduce the amount of electric current it can carry. Further, the melting point of an alloy is often lower than that of any of the metals of which it is made. Many other properties of metals are changed in alloys. These properties include colour, elasticity, expansion and magnetism.

Uses of copper

1. Copper is used in water pipes because it is very unreactive and does not corrode.
2. Copper is also used in electric wiring because it is an excellent conductor of electricity.

Uses of zinc

1. Zinc is used to coat iron to protect it from rusting. This process is called galvanizing.
2. Zinc together with copper forms brass (an alloy which is used in making musical instruments and ornaments.)

Uses of uranium

1. Uranium is used to generate electricity in nuclear power stations.



- It is also used to make nuclear weapons.

Uses of tin

- Tin is used to coat steel cans to prevent them from rusting.

Uses of lead

- Lead and zinc together form solder, which is used to join wires.

Reaction of metals with acid

Most metals react with acids, but not all of them. Hydrogen gas is formed, and the metal then dissolves in the acid to form a metal salt.

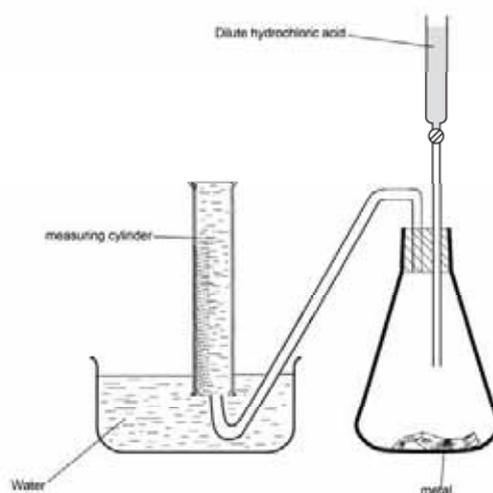
Metal + acid → metal salt + hydrogen

The table below indicates how different metals react with acids.

Metal	Symbol	Reaction	Equation
potassium	K	violent reaction to produce hydrogen	potassium + acid → potassium salt + hydrogen
sodium	Na		sodium + acid → sodium salt + hydrogen
calcium	Ca		calcium + acid → calcium salt + hydrogen
magnesium	Mg	react to form hydrogen and the salt of the metal	magnesium + acid → magnesium salt + hydrogen
zinc	Zn		zinc + acid → zinc salt + hydrogen
iron	Fe		iron + acid → iron salt + hydrogen
lead	Pb	do not react	

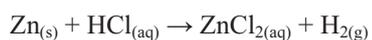
copper	Cu		
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The method for the reaction of a metal with an acid and collecting the gas is illustrated below.



In this experiment, the zinc (Zn) metal is used and the acid is hydrochloric acid (HCl). The word and balanced equations are as follows:

Zinc + hydrochloric acid → zinc chloride + hydrogen



Test for hydrogen

Once you have collected the gas in a test tube, bring a flame to the opening of the test tube. Be careful now. The flame will cause the hydrogen to react with oxygen and this causes a small explosion. We refer to it as a "pop sound".



 Reading	<p>You can read more on extraction methods at the following websites:</p> <p>Extraction of aluminium - http://www.chemguide.co.uk/inorganic/extraction/aluminium.html</p> <p>Extraction of copper - http://www.chemguide.co.uk/inorganic/extraction/copper.html</p> <p>Extraction of aluminium, copper, zinc and iron - http://www.docbrown.info/page04/Mextract.htm</p>
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The following self-mark activity will test how well have you learned this material.

Self-Mark Activity



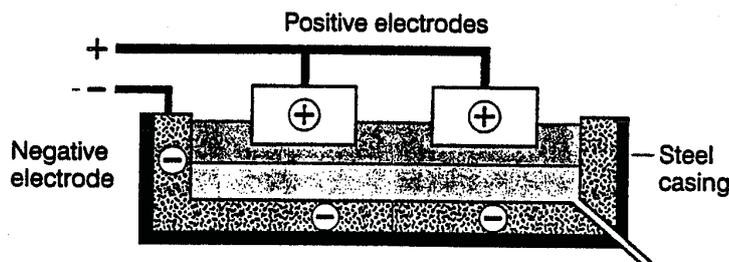
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

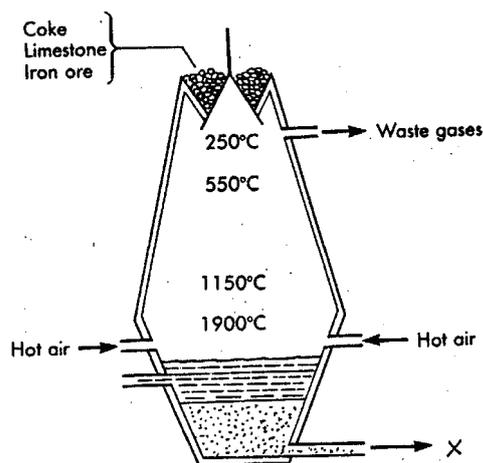
Answer the following questions:

1. Aluminium can be purified by electrolysis. The apparatus in the diagram illustrates this process. [Source: JSC: 1996]



- (a) Identify the ions that collect at:
- (i) the positive electrode;
 - (ii) the negative electrode.
- (b) Explain why aluminium is such an expensive metal.
- (c) Write down one use of aluminium (other than that of a conductor).
- (d) Write down the energy conversion that takes place during the process of electrolysis.
- (e) Aluminium is a good conductor of electricity. Give an example of another metal mined in Namibia, which is also a good conductor of electricity.

2. The diagram shows a blast furnace. What substance leaves the furnace at X? [JSC: 1994]



- A carbon dioxide;
 - B iron;
 - C limestone;
 - D slag.
3. Gold occurs as a pure metal in the earth's crust, but metals such as aluminium and zinc always occur in compounds with other elements.



- (a) Explain why this happens.
- (b) Describe a metal ore.
- (c) Give the name and formula of the compound of aluminium that is also present in the ore, bauxite.
- (d) Write down the process that is used to extract aluminium from bauxite.

4. To make steel, oxygen is blown into molten iron. Oxygen is used to:

[Source: JSC 1999]

- A convert the iron into an oxide;
- B help the slag float to the surface;
- C make the iron less dense;
- D remove some of the carbon from the iron.

5. The table below shows ores and extraction methods of three different metals. [Source: JSC 1999]

METAL	ORE	EXTRACTION METHOD
copper	(i)	roasting air
aluminium	bauxite	electrolysis of molten ore
iron	(ii)	reduction with carbon in blast furnace

- (a) Identify the ores numbered (i) and (ii).
- (b) Discuss what is meant by electrolysis.

6. Which metal is best used for the purposes listed below?

[Source: JSC 1998]

- A. aluminium for food containers;
- B. copper for car bodies;
- C. mild steel for cutlery;
- D. stainless steel for aircraft parts.

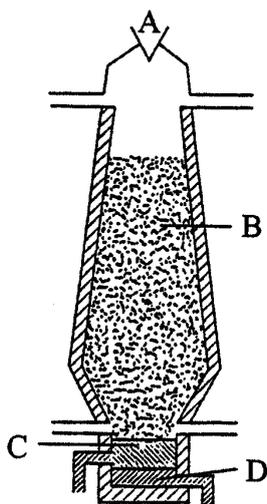
7. The table shows some of the properties of four compounds.

[Source: JSC 1998]

Compound	Solubility in water	Products of electrolysis of molten compound	
		Positive electrode	Negative electrode
A	soluble	metal	oxygen
B	soluble	oxygen	metal
C	insoluble	metal	oxygen
D	insoluble	oxygen	metal

Select which compound could be aluminium oxide.

8. Iron is extracted from haematite (iron oxide).
- Name a substance which is used to react with haematite to produce iron metal.
 - State the type of chemical reaction involved when haematite is changed to iron.
 - Steel, a very useful alloy, is iron with a small amount of carbon. State three ways the properties of steel can be changed to suit different uses.
9. The diagram shows a blast furnace.



Write down the labelled part in which iron ore changes to iron. [Source: JSC1996]



10. Define the terms:
- (a) alloy;
 - (b) reactivity series;
 - (c) corrode;
 - (d) case hardening;
 - (e) galvanizing.
11. Write the tests and results for hydrogen.
12. Acids react commonly with metals. Complete the following word equations:
- (a) an acid + a metal \rightarrow
 - (b) hydrochloric acid + magnesium \rightarrow
 - (c) $\text{HCl} + \text{Ca} \rightarrow$
13. Which substance reacts with dilute sulphuric acid to give no gas?
- A copper;
 - B magnesium;
 - C sodium;
 - D zinc.

Now, you can now start studying Section 3.

Section 3: Uses of Materials

Introduction

For many years, humans have depended on different materials for various reasons. For example, we have used materials to cook our food, for shelter and clothing, and so on. During the discussion of this topic, you will see that the uses of many materials depend on their properties and structures.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>analyse</i> and <i>deduce</i> uses of the materials listed (wood, metal, glass, ceramics, concrete, plastic and fibre) in the home, for building, heat insulation, packaging, electrical conductivity, transport and textiles.
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 <p>Time</p>	<p>This section will take you about six hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Uses of wood

Can you think of things that are made of wood in your home? You obviously thought of your wall unit, your table, etc.

Here are some other examples

1. people use wood for furniture, doors and ornaments;
2. people use wooden crates to store things;
3. wood is used to make paper, which is used for books, magazines, newspapers, etc.

Paper is made from cellulose. The raw material for making paper is wood. Paper fibres are non-woven fabrics, called "formed fabrics". This term means that the fibres are bonded together by methods that include heat, adhesion, solvents and pressure. However, paper is basically a tangled mass of cellulose fibres.

Uses of metals

Metals have many uses in our lives. However, we are only going to mention a few.

1. Metals are used to make window frames and door frames.
2. Water pipes in houses are also made from copper.
3. Pots and pans are made from aluminium.
4. Roofs of houses are made from corrugated iron.
5. Copper wires are used in houses for conducting electricity.
6. Brass is used to make ornaments and door handles.

Metals are useful because they are:

- shiny;
- conduct electricity;
- bend and stretch;
- conduct heat;



- have high melting and boiling points;
- are strong in solid form.

Uses of glass

Glass has always fascinated people because of its structure. It is a mixture with no definite melting or boiling points and is also known as an "under-cooled" liquid. It is very useful for the following:

1. windows and some doors are made of glass;
2. ornaments, plates, cups, drinking glasses etc. are made from glass and are used in most homes.

Uses of ceramics

Silicates (SiO_4) are used as the basis of ceramics. Ceramics are much better electrical and thermal insulators than metals. They, and have greater rigidity, hardness and temperature stability than organic polymers.

1. People make beautiful ceramic tiles, which we can use when building houses.
2. Pots and ornaments are also made from ceramics.
3. Ceramics are used to insulate electrical appliances.

Uses of concrete

This mixture of sand, gravel, cement and water makes very hard structures. Cement forms long thin crystals which overlap. It is very hard when set.

1. People use concrete to build houses.
2. People also use concrete to construct bridges and big buildings.

Uses of plastics

The word plastic has a dual meaning. Firstly, it means any substance that can be shaped into a desired shape or moulded form. Secondly, it means a synthetic substance. Plastics are formed when simple monomers (small molecules) are linked together to form large polymers (large molecules).

1. Many things in our houses are made from plastic, e.g., drinking mugs, plates, knives, forks, etc.
2. Polythene is used to make shopping bags.
3. Nylon is used to make clothes, fishing line and ropes.
4. Melamine is used to make the surface of many desks and tables.
5. Polyurethane is used to make foam mattresses.

Uses of fibres

You have learnt about natural and synthetic fibres, which also contain organic compounds. Fabrics come in four basic groups depending on

their origin: animal, plant, mineral and synthetic. All animal fibres are proteins, that is, compounds that contain carbon, hydrogen, nitrogen and oxygen. Plant fibres are mostly cellulose, a carbohydrate composed of carbon, hydrogen and oxygen. Coal and petroleum are the basic raw materials for making synthetic fibres. Over 70% of the fibres in use today are synthetic.

Fibres are used to:

1. make clothes;
2. make many articles that are useful in our homes. For example, curtains, linen (bedding), table cloths and blankets are made from various fibres.

Did you notice any connection between the properties of metals and the uses of metals that you have already studied in this unit? Now, try working through the following self-mark activity to find out how well you have understood the material in this section.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. What do people use nylon for?
 - A clothes;
 - B foam mattresses;
 - C shopping bags;
 - D surfaces of tables.
2. The main use of man-made (synthetic) fibres, such as nylon and terylene, is to make:
 - A clothes;
 - B plastic bags;
 - C plastic boxes;
 - D tyres.
3. The diagram shows a person about to lift a hot frying pan from a stove. Although the pan is hot, the handle is cool. [Source: JSC 1997]

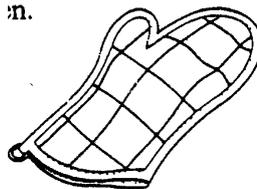


Which material was possibly used for the handle?

- A aluminium;
- B copper;
- C iron;
- D wood.

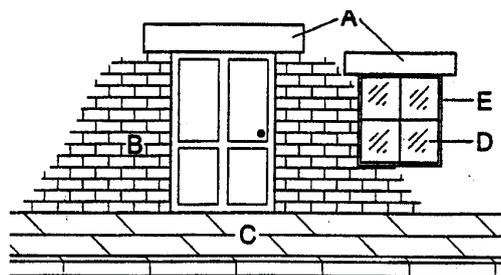
4. Ndapandula decides to buy cotton to make oven gloves. They would be used to handle hot dishes from the oven. [Source: JSC 1999]

n.



Suggest one reason why cotton would make good oven gloves.

5. The picture shows part of the outside of a house. The part labelled A is made of wood. Study the diagram and answer the questions that follow. [Source: JSC 1996]



- (a) Select what materials are normally used for making the parts labelled B, C, D and E.
- (b) Give a property for each of these materials that will make each suitable for its specific use.

6. A vehicle contains many different materials such as metals, plastic and rubber.

Of the following materials, please indicate how these would be used in a vehicle and which properties make them suitable for the particular use.

Steel (a metal) is given as an example.

Material	Use in vehicle	Properties
steel	body	strong easy to shape in any form (malleable)
rubber		
fabric		
glass		

7. The filament of a light bulb must be made of a metal because it has a high melting point and should be able to conduct electricity.

For each of the examples below, state which type of material the object is best made from: metal, ceramics, glass, plastic or fibre.

Give a reason for your choice. If more than one type of material is suitable, say so.

- (a) a tea pot;
- (b) a fishing line;
- (c) a cool drink bottle;
- (d) electrical wires;
- (e) a blanket.

8(a) Give one reason why concrete bricks are used for building a house.

(b) Sometimes materials other than concrete bricks are used for walls.

Name two such materials.

9. The table shows some of the properties of common metals. Use this information to answer the questions that follow. [Source: JSC 1997]



metal	aluminium	duralumin	copper	iron	steel
corrosion resistance	very high	very high	high	low	very low
cost per ton	high	high	very high	low	low
conductivity of electricity	high	medium	very high	medium	medium
density in g/cm ³	2.7	2.8	8.9	7.9	7.9
melting point/°C	933	910	1,083	1,540	1,500
strength	low	very high	very low	low	very high
malleability	high	low	high	high	low

Explain in terms of the properties listed in the table why each of the following metals have their particular uses:

- (a) Aluminium (instead of steel) is used as foil for wrapping food whilst it is being cooked.
- (b) Aluminium (instead of copper) is preferred for overhead high voltage cables.
- (c) Aircrafts are built from duralumin rather than aluminium.

How did you find the self-mark activity? Did you enjoy it? You can now start studying Section 4.

Section 4: Structure and Properties of Materials

Introduction

The structure of materials will be discussed in this section.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>describe</i> polymers (e.g. polythene) and giant covalent structures as types of covalent compounds <i>relate</i> the properties of some materials to their molecular structure and bonding; • <i>deduce</i> the way in which properties of the following materials depend on their molecular structure and bonding: metals, concrete and glass as ionic compounds; cellulose as a natural polymer in wood; and polythene, nylon, polyurethane and melamine as examples of synthetic polymers; • <i>draw</i> and <i>sketch</i> the simplified generalised structure of polymers.
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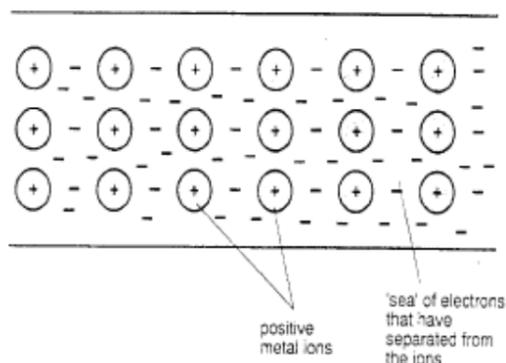
 <p>Time</p>	<p>This section will take you about five hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Polymer:

Carbon atoms can join in long chains. Materials that are made up of these long-chained molecules are called **polymers**. For example, plastics are synthetic polymers because they are man-made. Natural polymers include cellulose from which wood is made. Your hair is made of a natural polymer called keratin. Fibres are also made from polymers. The atoms in the polymer molecules are held together by covalent bonds. This is why they are called covalent compounds.

Metals

Metal atoms are held strongly together by metallic bonds. The outer electrons of each metal atom in a crystal are able to move around freely between the atoms. This means that metal is made of rows of positive ions surrounded by a “sea “of moving electrons. These negative electrons attract the positive ions strongly. The diagram below shows the metallic bonding between ions. Do you remember that we discussed electrons in the first unit? An electron is found moving around the nucleus of the atom.



The metallic bonding model above explains the following properties of metals.

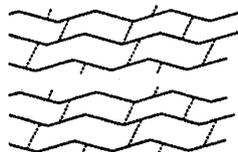
1. The atoms are held together very strongly and a lot of energy is needed to pull them apart. This explains why the melting points of metals are high.
2. The “sea” of electrons can move through the metal and carry an electric charge. This makes metals good conductors of electricity.
3. The moving electrons transport heat energy through the metal and this makes metal a good conductor of heat.

Concrete

Concrete is a mixture of crystalline substances. The crystals are formed as the concrete is allowed to set. The slower it sets, the bigger the crystals formed and the stronger the concrete. The crystals in concrete are ionic. This means that concrete shatters easily when hit with a hammer. However, being ionic also means that concrete does not melt easily.

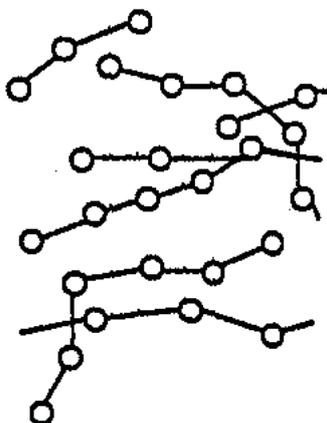
Cellulose

Cellulose is a natural polymer. Wood is made of cellulose. Covalent bonds and strong electrostatic forces hold the cellulose polymer chains together. This makes wood strong and hard. Cellulose cannot be stretched or broken. However, it can be bent at right angles to the polymer chains, which are held tightly. The diagram below shows the structure of cellulose.



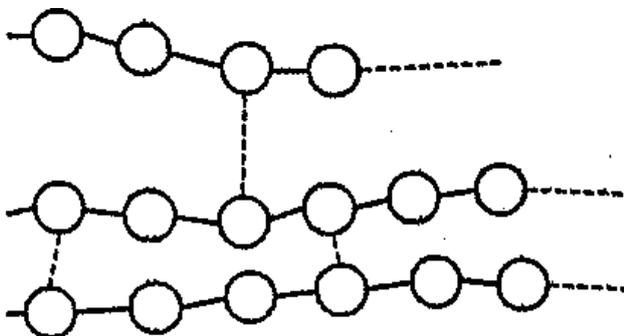
Polythene

In polythene, the molecules are not held strongly. That is why you can tear this kind of plastic easily. The molecules are lined up in different directions, which make polythene very flexible.



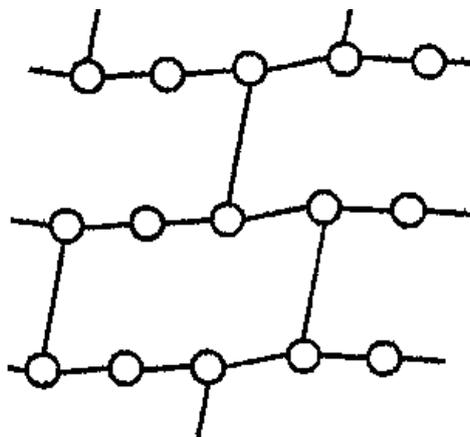
Nylon

The nylon polymers are held together by electrostatic forces. These strong forces also make nylon very strong. Because the forces between the molecules are electrostatic, the molecules can slide next to each other. This allows for nylon to stretch to a certain degree before it breaks. Nylon is used to make clothes, fishing lines and ropes.



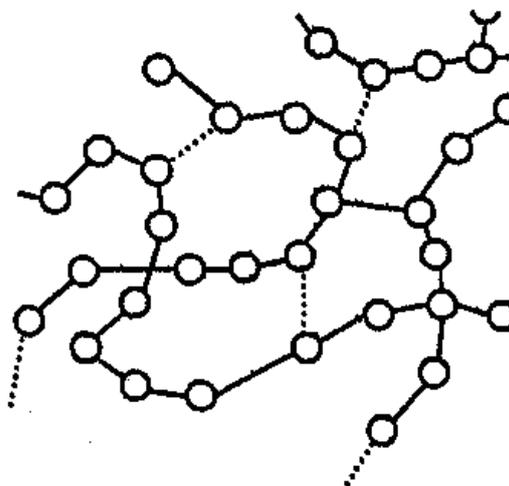
Melamine

Melamine has strong covalent bonds between the polymers, which makes it very hard and rigid. Thus, melamine does not break or melt easily. This is why people use melamine to make surfaces for desks and table tops. Laboratory table tops and kitchen cupboard surfaces are made from melamine. Melamine is also used to manufacture plates, bowls, cups and saucers.



Polyurethane

The molecules in polyurethane are joined very loosely in a random way. This allows polyurethane to be squashed or stretched without permanently changing its shape. The forces between the polymers are not very strong. This makes it a weak plastic. It is used to make mattresses and lounge suites.



Now, its time for you to work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- 1(a) Write down what is meant by the term polymer.
- (b) Name an element which is present in all plastic structures.

2. Which of the following is a polymer? [Source: JSC 1996]
 - A ethane;
 - B ethene;
 - C methane;
 - D polythene.

3. Identify one substance which has the structure of a liquid, but behaves like a solid.
 - A cement;
 - B ceramic;
 - C glass;
 - D polythene.

- 4 (a) Name four synthetic polymers.
- (b) Name the natural polymer in wood.

5. Concrete is made out of:
 - A sand, ceramic, cement;
 - B sand, gravel, cement;
 - C sand, glass, cement;
 - D sand, plastic, cement.

6. Which type of force hold the polymer chains in cellulose together?
 - A covalent;
 - B ionic;
 - C metallic.

7. Explain what happens when concrete sets.

If you feel you have understood this section, you can now start studying Section 5.



Section 5: Building Materials

Introduction

In this section, you will again learn about different materials used in the construction of some of the different kinds of houses built in Namibia. You will also learn about the advantages and disadvantages of using these materials.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>observe, classify</i> and <i>explain</i> the use of building materials used in the local environment including: bricks (mud or ceramic), concrete, wood, metal, thatch and glass; • <i>study</i> how the use of building materials used in the local environment depends on the properties of those materials; • <i>describe</i> how the compressive and tensile strength of building materials such as concrete, wood and bricks depends on the molecular structure and type of bonding in the materials; • <i>explain</i> the insulating properties of different roofing materials; • <i>explain</i> how concrete is made using cement, crushed stones and sand by adding water; • <i>explain</i> how cement is made from clay and limestone; • <i>evaluate</i> the use of different building materials for the same purpose (for walls and roofing); • <i>compare</i> the use of different building materials for the same purpose (mud bricks, ceramic bricks and concrete for walls or thatch and corrugated iron for roofing) in terms of various factors including costs.
--	--

 <p>Time</p>	<p>This section will take you about two hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
--	--

Materials used for building houses

In Namibia, there are many different kinds of houses. The materials that are used in the building of houses depend on a number of things such as:

- the availability of the materials;
- the cost of the building materials;
- the space available for building;
- the size of the house;
- interest of the people.

Most people use bricks to build houses, while others use mud, thatch, wood, metal and glass.

Materials used for making roofs

Most people in Namibia use galvanized iron roofs. Galvanised iron is steel coated in zinc. The zinc stops it from rusting.

Advantages of using galvanized iron

- It is waterproof.
- It is easy to put up.

Disadvantages of using galvanized iron

- It makes the house hot in summer.
- One must put a ceiling inside to make the house cooler.

Some traditional houses in Namibia have thatched roofs. Some people in cities and towns also prefer thatched roof houses.

Advantages of using thatch

It makes a house cool in summer and warm in winter. Do you remember what we discussed about the structure and properties of materials that make good insulators. Air is trapped in the thatch and air is a good insulator.

Disadvantages of thatch

Thatch can easily catch fire. It can also result in a decrease in grass for cattle.

Cement

Cement is a mixture of two substances called calcium silicate and aluminium silicate. These two substances are made by heating limestone together with clay at a temperature of about 1400° C in a gas-fired



furnace. The crystals in cement start forming when water is added to the dry cement powder. In Namibia, cement is manufactured in Otjiwarongo.

Since this section is shorter than the other four you have studied, I assume that you have found it very easy. Now you must complete the following self-mark activity to see how well you have understood what you have just read.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. How would you improve your home to make it cooler in summer and warmer in winter? Give reasons for your suggestions.
2. Give the advantages and disadvantages of using thatch for a roof.
3. Write down what galvanized iron is.
4. Give advantages and disadvantages of using galvanized iron for a roof.

Now its time to start studying Section 6.

Section 6: Fibres

Introduction

What are polymers? They are tiny molecules strung in long repeating chains forming polymers. Why should this interest you? Well for one thing, your body is made of them.

Many other things are also made of them such as the proteins and starches in the food we eat, the wheels of our skate boards and in-line skates, and the tyres of our bikes and cars. In fact, we are surrounded by polymers every day, everywhere we go. There are many reasons why one should learn about polymers. Understanding their chemistry can help us use polymers and fibres wisely. We are fairly familiar with the many polymers that people make. One example is plastics.

Fabrics come in four basic groups depending on their origin: animal, plant, mineral, and synthetic.

All animal fibres are proteins: that is, compounds that contain carbon, hydrogen, nitrogen, and oxygen.

Plant fibres are mostly cellulose, a carbohydrate compound of carbon, hydrogen, and oxygen.

Mineral fibres are made from organic substances, including some metals.

Coal and petroleum are the basic raw materials used for making synthetic fibres. Over 70 of the fibres in use today are synthetic.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>classify</i> fibre polymers as natural or synthetic, giving examples of both especially with reference to the different fibres used in the home; • <i>describe</i> how fibres are made into fabrics taking into consideration the usefulness of the properties of fabrics such as strength, stretch, insulation, ability to absorb moisture and dry quickly; • <i>predict</i> and <i>describe</i> the properties of insulation (ability to trap air), water retention, strength and stretch of different fabrics. • <i>carry</i> out experiments to investigate these properties.
--	---

 Time	<p>This section will take you about six hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
--	--

Classify fibre polymers

Natural fibres

Wool comes from many animals. Wool comes from the fleece of sheep. The curly, kinky hairs of these animals mat together, trapping "dead hair". This insulating property makes wool an ideal cold weather fibre because it prevents the loss of body heat. The use of wool dates back several thousand years. Wool is mostly used for making cloth.

Fibre goes through processes that gives it the strength needed to begin the spinning process. This spinning process is used in the making of strand into yarn. The yarn is then woven into cloth.



Wool is made up of polymers. These polymers are made up of molecules that have a long structure. Chemically, wool is very much like hair, feather and horn. Wool is easily dissolved by strong bases, such as sodium and potassium hydroxides.

If you look at wool fibres through a microscope, you can see that they have tiny, scale-like plates. The fibres of wool tend to spring back into their original shape after they bent or folded. This is the reason why your woollen clothes hold their shape better than cotton, rayon, or linen garments.

Cotton comes from a plant, which is grown from seeds that are planted yearly. The length, colour, and cleanliness of cotton fibres vary. Under the microscope, cotton fibres look much like flattened, twisted tubes, quite unlike wool. Alkalis are not as harmful to cotton as they are to wool, but acids are.

Body moisture is easily absorbed by cotton fibres and then lost through evaporation. This makes cotton garments comfortable for summer clothing. Cotton is nearly pure cellulose.

Silk comes from a caterpillar. Silk, like wool, comes from an animal. The cocoons of the mulberry silkworm provide the source of silk fibre. Silk starts as liquid that comes from tiny glands below the mouth of the caterpillar. When the fluid comes in contact with air, it changes into a solid and becomes a strand of silk. A molecule of silk is a large protein polymer. Silk is the strongest natural fibre. It is elastic and wrinkle resistant. Silk is weakened by exposure to sunlight and perspiration, and tends to yellow with age.

Linen comes from the flax plant. Linen is the oldest fibre known, dating back many thousands of years. Linen is much smoother and more lustrous than cotton. Linen is not wrinkle resistant. However, most cloth made from linen today have wrinkle resistant finish added.

Cloth made from linen readily absorb moisture, making them popular for warm-weather clothing.

The flax plant provides two main products. Linen fibre from the stems and seeds from the flowers.

Leather is made from the hides of animals. Leather is a substance that is strong, soft and warm. It can be made into footwear, clothing, luggage, furniture coverings, sporting goods, and many other items. At the tannery, the hides are soaked in cold water to remove salt and any dirt. Since salt has a drying effect on the hides, the soaking also restores some of the moisture. The hides are then placed into a bath of lime and sodium sulphide to remove the hair.

Paper is made from cellulose. The raw material for making paper is wood. Paper fibres are non-woven fabrics, called “formed fabrics”. This term means that the fibres are bonded together by methods that include heat, using adhesion, solvents and pressure.

Some fibres are called mineral fibres. Mineral fibres are made from organic substances, including some metals. Two important mineral fibres in common use are asbestos and fibreglass.

Asbestos is a silky, fibrous mineral that can be spun into threads and woven into cloth. These fibres are waterproof and are unaffected by most common acids. Asbestos products are used as insulation for hot-water and steam pipes, fireproof clothing, and in the brake lining of cars.

When a blast of high-pressure steam is directed against molten glass, forcing it through tiny holes, **fiberglass** is formed. These fluffy, very fine fibres can be spun into yarn and woven into cloth. Fiberglass is often used as a heat insulator for ovens, home freezers, and hot water heaters.

Synthetic fibres

Most synthetic fibres are made by forcing liquids through small holes. Synthetic fibres can be placed into two broad groups:

(1) those fibres that are made from cellulose, the most common examples are rayon and acetate; and

(2) those fibres that are made by joining monomers (small molecules) to form polymers (large molecules). Common examples in this group of fibres are nylon, acrylic, and polyester.

Each synthetic fibre has two names. One is generic, or the group name, such as those mentioned above. The other is the brand name, used by the maker of the fibre as a copyrighted trademark.

Most synthetic fibres are made by forcing liquids through tiny holes in a metal plate and allowing them to harden. A wide range of liquids produce a great variety of fibres.

Rayon and acetate are the oldest of the synthetic fibres. The basic material for the making of rayon fibre is cellulose from purified wood pulp.

Acetate is another well-known fibre made from wood pulp. The reaction between cellulose and acetic acid is the basis for this process. Acetate is the only fibre used in cigarette filters because it is an efficient smoke remover.

The common synthetic fibres we know are plastics such as nylon, terylene and melamine. Plastics are also hydrocarbons and are prepared in laboratories at very cheap prices. They are very strong, durable, and depending on the composition, hard or soft.

Unfortunately, they are non-biodegradable (i.e. they do not break down or decay naturally). This means that they are regarded as a problem pollutant all over the world.

Properties and trends of different fabrics

Fibres have the ability to trap air and absorb water. This property is useful in the making of fabrics.

Water retention properties

The property of water retention in materials can be observed easily through a simple experiment.



Practical Activity

To conduct this experiment, you will need a few samples of fabric (all the same size), a scale and some beakers or tins to hold water.

1. Pour the same amount of water into all of the beakers and weigh them to ensure that each beaker has the same mass.
2. Put the samples of the materials into the beakers with water.
3. Remove the soaked material as swiftly as possible.
4. Weigh the beakers with the remaining water to determine the mass of water removed by the materials. For example, 1st measurement – 2nd measurement = amount of water soaked up by the materials.
5. This will tell you what material traps the most water.

Now, its time to do the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Which of the following is a natural polymer? [Source: JSC 2000]

- A cellulose;
- B nylon;
- C polythene;
- D terylene.

2. The diagrams show the particle arrangement of different materials.

Which material can hold the most water?



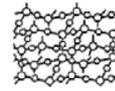
A diamond



B melamine

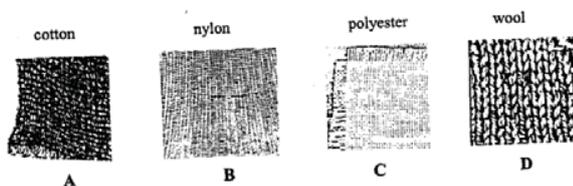


C polyurethane

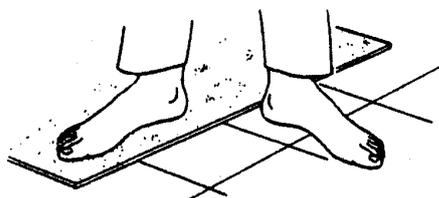


D silicon dioxide

3. The diagrams show fabrics made from different fibres. Which fabric is the best insulator? [Source: JSC 2000]



4. On a cold night, a person who is bare-footed stands in a bathroom with one foot on a woolen mat and the other one on uncovered tiles as shown in the diagram. [Source: JSC: 1999]



Why does the woolen mat feel warmer than the tiles?

- A the mat is a better conductor of heat;
 - B the mat is a poor insulator;
 - C the mat traps air that is a good conductor of heat;
 - D the mat traps air that is a poor conductor of heat.
5. The main use of man-made fibres, such as nylon and terylene, is in the making of:
- A clothes;
 - B carton boxes;
 - C plastic bags;
 - D tyres.
6. Which fibres are the least stretchable?
- A cotton;
 - B nylon;
 - C polyester;
 - D wool.

If you feel you have understood this section you can now start studying the last section in this unit.



Section 7: Cleaning Materials

Introduction

We have discovered so many interesting things about materials, such as their properties and uses. Now that you know the types of materials you can use to build your house, you will now learn about the cleaning materials you have to use in your home.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>sketch</i> the generalised structure of a soap or detergent; • <i>relate</i> the generalised structure of a soap or detergent to an oil droplet being soluble in water; • <i>identify</i> common cleaning materials such as soaps or detergents; • <i>describe</i> the preparation of soap using alkali and fat or oil; • <i>test</i> the effectiveness of different soaps or detergents; • <i>explain</i> the meanings of the terms biodegradable and non-biodegradable in terms of their impact on the environment; • <i>outline</i> the advantages and disadvantages of the uses of soaps and detergents.
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 <p>Time</p>	<p>This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Common cleaning materials

What examples come to mind when you hear the words cleaning materials?

We use a variety of cleaning materials in our homes. These include soaps and detergents. Examples of soaps include washing powder and those we use to wash clothes and our bodies. Examples of detergents include dishwashing liquids that we use in our kitchens.

Both soap and detergents are washing compounds that mixes with grease and water. Nonetheless soaps and detergents are not the same, Soaps are made from materials found in nature. Detergents are synthetic or man-made.

Have you ever wondered why it is much easier to clean your hands with soap and water than when you use water alone?

The following activity explains why.

 <p>Practical Activity</p>	<p>Problem: What happens when oil is mixed with water?</p> <p>What you need to do this activity: oil (cooking oil or lubricating oil) and a bottle</p> <p>What you should do:</p> <ol style="list-style-type: none"> 1. Put a small quantity of water in a bottle. 2. Add a few drops of oil. Observe what happens. 3. Shake the mixture. Allow it to stand for a short time. What happens? <p>Results:</p> <p>You will notice that although the oil and the water are both liquids, they do not mix.</p>
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The oil contains atoms of hydrogen and carbon. We call molecules like these hydrocarbons. Water, however, contains hydrogen and oxygen. We find that liquids only mix with each other when they have molecules that are similar to each other.

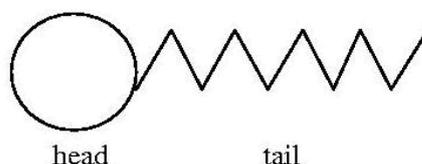
Properties and structures of soap or detergent molecules:

Oil and water are both liquids but they do not mix. Do you know why? To find out, let us look at the structure of the molecules of oil and water.

Petrol and paraffin will mix with oil, because petrol and paraffin are also hydrocarbons. However, they do not mix with water. When you add a detergent to oil and water, the oil and the water will mix. Do you know why?



Generalised structure of a soap or detergent



The answer lies in the structure of the detergent molecule. The molecule consists of a “head” and a ‘tail’. The head of the detergent has oxygen atoms joined to hydrogen atoms, which are also present in water molecules. This end will mix easily with water.

The tail of the detergent has a long chain of carbon atoms attached to many hydrogen atoms, as is the same with oil molecules. This part will mix with the oil.

Soap is a substance made of fat or oil and an alkali. It is used for washing and cleaning.

It comes in the form of a powder and it removes dirt from the surface of things made of fat or oil. Soaps can be in the form of liquids or powders. A synthetic substitute for soap is detergent.

Soap and Water Solution

Soap decreases the pull of surface tension. We commonly say that soap makes water “wetter”. Soap molecules are made up of long chains of carbon and hydrogen atoms (polymers). At one end of the chain is a group of atoms, which like to be in water (hydrophilic). The other end chain pushes water away (hydrophobic) but attaches easily to grease.

In a soap-and-water solution, the greasy ends of the soap molecule do not want to be in the liquid at all. Those that find their way to the surface squeeze their way between the surface water molecules. As they are doing this, they push their hydrophobic ends out of the water. This separates the water molecules from each other.

Soap or detergent is made from animal and vegetable fats, oils, and greases. Most soaps remove grease and other dirt because some of their components are surfacants (surface active agents). Surfactants have a molecular structure that acts as a link between water and the dirt particles. They loosen the particles from the underlying fibres or other surfaces to be cleaned. The surfactant molecule can perform this function because one end is attracted to water and the other is attracted to substances that are not water soluble.

The hydrophilic end is similar in structure to water-soluble salts. The hydrophobic part of the molecule often consists of a

hydrocarbon chain. This hydrocarbon chain is similar to the structure of grease, oil, and many fats. The result of this structure allows soap to reduce the surface tension of water by making it increasingly wetter. It also reduces the surface tension of water by making soluble, substances that are otherwise insoluble in water.

Detergents are substances that remove dirt from the surface of things made of fat or oil. They come in the form of liquids or powders. Detergents are a synthetic substitute for soap.

Not too long ago, soap was the only important detergent. Today, soap is just one of many detergent products.

Some detergents became a public nuisance because, unlike soaps, they are neither soluble nor biodegradable. Detergents tend to create foam in cesspools and in sewage-disposal plants as well.

Detergent molecules can turn a droplet of oil into one drop that can mix with water. The tail mixes with the oil and the head with the water, so they arrange themselves around the oil droplet.

Common cleaning materials such as soaps and detergents

We use these daily. Think of the following: washing yourself, your hair, clothes, dishes, etc. And for each of these activities, we use a different product and brand and we decide on personal preferences. Eventually, we buy any soap, and sometimes our choices are determined by the cheaper product. We know that all soaps do the cleaning job.

A very interesting activity is to find out the pH of a soap or detergent.



Practical Activity

Problem: What is the pH of the soap I use?

What you need to do this activity: Different brands of soap or detergents, a bottle/beaker, funnel and filter paper, as well as universal indicator paper.

What you should do:

1. Pour some water (1 cm) in a bottle/ beaker.
2. Put a small piece of soap or a drop of detergent in the water.
3. Shake well.
4. Pour the mixture through the filter paper.
5. Use the universal indicator paper and test the pH of the filtrate.
6. Record your results in a table.

Results:



	The different soaps will have different pH colours. Most will be more alkaline.
--	---

Advantages of the use of soaps and detergents

1. With the help of soaps and detergents, one can clean “fatty” dishes and fat stains on clothes.
2. Soaps and detergents can help water to wet skin and fabric, so that they can be washed more easily.

Disadvantages of the use of soaps and detergents

1. The use of non-biodegradable detergents can cause water pollution.

 Practical Activity	<p>Preparation of soap</p> <p>This is a favourite laboratory exercise.</p> <ol style="list-style-type: none"> 1. Melt some fat (10cm³) over a low temperature flame. 2. Add some methanol (20cm³). 3. Then add about 5cm³ concentrated sodium hydroxide solution. 4. Warm this solution gently until it gets a syrup-like consistency. 5. Make a salt solution (25cm³) and heat until boiling point. 6. Then, add the mixture of fat, methanol and sodium hydroxide already made to the salt until solution. 7. Heat this mixture until most liquid has evaporated. 8. Pour into shaped holders to cool.
--	---

The effects of soaps and detergents on the environment

After we throw away our dirty water, it might pollute our rivers and dams. We must therefore use soaps and detergents that can be destroyed by bacteria in the water. Soap is made of animal fats or vegetable oil. You know that animal and plant remains are destroyed by bacteria. This is the process we call rotting or decomposition. Because soap is made of animal fats or vegetable oils, it is easily destroyed (degraded) by bacteria in waste water. In other words, we say that soap is biodegradable.

Detergents are made from oil or coal. Because of this, they are not easily broken down by bacteria. They are non-biodegradable. We

say, that a non-biodegradable substance is **persistent**. If we care for our environment, we should avoid using chemicals that are persistent. Some detergents contain substances such as phosphates that are persistent. As a result, these detergents cause pollution problems. However, most of the detergents you buy nowadays in shops are biodegradable and do not cause water pollution.

Now work through the following self-mark activity.

Self-Mark Activity



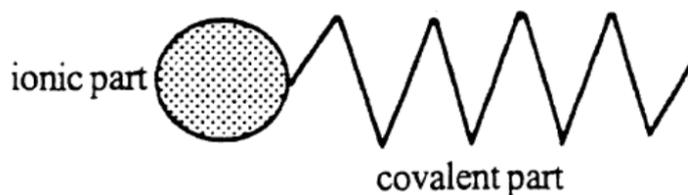
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

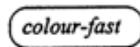
1. Discuss why it is much easier to wash oil off your hands with soap or detergents rather than just using water.
2. The diagram represents a simplified structure of a soap molecule. [Source: JSC 1999]



- a) Explain how soap functions during the washing of fatty stains.
 - b) Most soaps are non-biodegradable. Discuss what is meant by this.
3. In a shop a variety of detergents and soaps are offered. Which label indicates an environmental friendly product? [Source: JSC 2000]



A



B



C



D

We have come to the end of this unit. To ensure that you have understood the concept, spend a few hours reviewing what we have covered in this unit.



Summary

In this unit you learned that:

- wood does not break easily; it is made from cellulose;
- metals can be pulled into wires, flattened and hit into shapes;
- glass is hard, brittle and transparent;
- ceramic objects are made from clay which is hardened by heating;
- concrete is made from sand, gravel and cement;
- plastic is made of long chains of carbon atoms that are bonded together;
- polythene is cheap, flexible and not strong;
- nylon is strong and stretchable;
- melamine is very hard;
- polyurethane can be squashed and is not very strong;
- fibres are classified into natural fibres and synthetic fibres;
- bricks can be tested for compressive strength and tensile strength;
- metals are extracted from ores;
- electrolysis is used to extract aluminium;
- iron is extracted in a tall oven called a blast furnace;
- the hardness of steel depends on the amount of carbon in it;
- alloys are formed when two or more metals are melted together;
- soap is biodegradable because it can easily be degraded;
- non-biodegradable substances are persistent.

Assessment



Assessment

The completed assessment can be submitted to the nearest government/program support centre or can be submitted via electronic form, in scanned pdf format.

Before you complete the assessment, it is best if you spend at least 12 hours revising the material you covered in units 1, 2, and 3.

ASSESSMENT 1

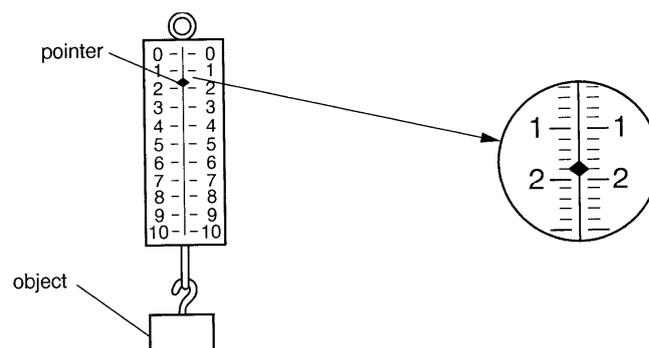
Assessment for units 1, 2 and 3	
Revision Study Hours	12 hours
Time dedicated to completing the assessment	6 hours

Answer all questions

Section A – Multiple Choice Questions

Choose the correct answer from the possible answers given.

1. The diagram shows a spring balance, marked in newtons.



What is the reading shown?

- A 1.4 newtons;
- B 1.8 newtons;

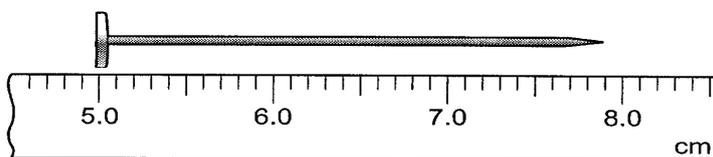


- C 2.1 newtons;
- D 2.2 newtons.

2. Which instrument is used to measure mass?

- A barometer;
- B beam balance;
- C thermometer;
- D watch.

3. A ruler is used to measure the length of the nail.



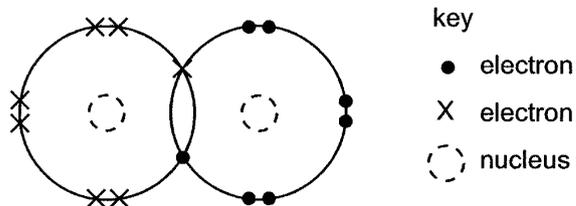
What is the length of the nail?

- A 2.9 cm;
 - B 5.0 cm;
 - C 7.9 cm;
 - D 8.1 cm.
4. If the mass of the object is 500 g and the volume 20 cm^3 , what is the density of the object?
- A 25 g/cm^3 ;
 - B 480 g/cm^3 ;
 - C 520 g/cm^3 ;
 - D $10,000 \text{ g/cm}^3$.
5. In which group of the Periodic Table would you find the element neon?
- A group I;
 - B group II;
 - C group VII;
 - D group VIII.
6. How many electrons are there in an **atom** of fluorine?
- A 9;
 - B 10;

C 19;

D 28.

7. The diagram shows the outer shell electron in a molecule.



What could this molecule be?

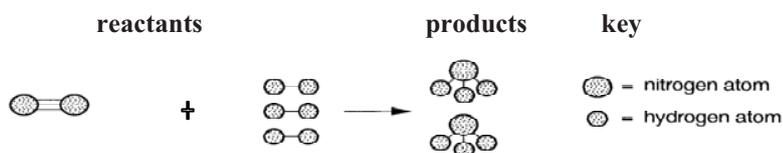
A ammonia;

B chlorine;

C hydrogen;

D water.

8. The diagram shows the molecules involved in a chemical reaction.



Which of the following equations represents this reaction?

A $N + N_3 \rightarrow NH_3$;B $N + 3H \rightarrow NH_3$;C $N_2 + 2H_2 \rightarrow 2NH_2$;D $N_2 + 3H_2 \rightarrow 2NH_3$.

9. Which one of the following sets consists of an element, a mixture and compound?

A air, water, copper sulphate;

B aluminium, potassium chloride, copper sulphate;

C iron, air, potassium chloride;

D water, aluminium, manganese;

10. An element X reacts with chlorine to form a solid substance with a formula XCl_2 . What could be the electron structure of X?



- A 2: 8: 1;
- B 2: 8: 2;
- C 2: 8: 6;
- D 2: 8: 7.

11. Which statements concerning the alkali metals are correct?

- 1. they have high melting points;
- 2. they have low densities;
- 3. they have colourless compounds;
- 4. they conduct electricity.

- A 1 and 2;
- B 1 and 4;
- C 2 and 3; D 2 and 4.

12. The molecules of a gas:

- A do not move;
- B move about randomly;
- C move around each other in orbits;
- D vibrate about fixed positions.

13. What do all the elements in group VII of the Periodic Table have in common? They have the same:

- A number of electrons in outer shell;
- B number of protons and neutrons; C physical properties;
- D relative atomic mass.

14. The diagram shows an ion.



What is the charge on the ion?

- A +1;
- B +2;
- C -1;
- D -2.

15. Why is argon used to fill electric bulbs?

- A it conducts electricity;
- B it glows when heated;
- C it is less dense than air;
- D it is not reactive.

16. The table shows four elements in Group I of the Periodic Table.

A	lithium
B	potassium
C	rubidium
D	sodium

Which element is the **least** reactive?

17. A sodium atom can be written as ${}_{11}^{23}\text{Na}$. The number of electrons in an **ion** of sodium is:

- A 10;
- B 11;
- C 12;
- D 23.

18. Which one of the following elements is always present with iron in steel?

- A carbon;
- B chromium;
- C copper;
- D nickel.

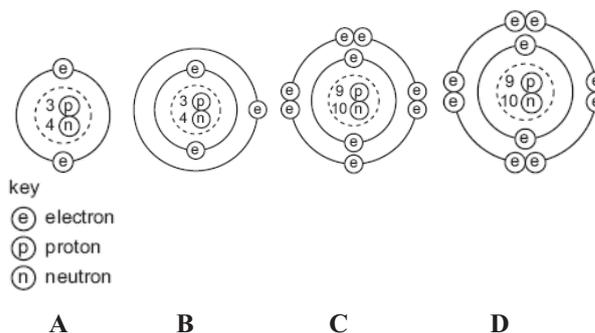
19. Which metal is obtained from galena?

- A aluminium;
- B copper;
- C lead;
- D zinc.



20. Which type of bonding makes concrete a stronger material than wood?
- A covalent;
 B ionic;
 C metallic;
 D polar.

21. Which diagram shows a negatively charged ion?



22. Which method is used to extract aluminium from its ore?
- A electrolysis;
 B heating;
 C oxidation;
 D reduction.
23. Which one of the following materials is a natural fibre?
- A acetate;
 B cotton;
 C polythene; D rayon.
24. Which one of the polymers is used to make laboratory table tops?
- A cellulose;
 B melamine;
 C nylon; D polyurethane.
25. Which one of the following is the use of diamond?
- A cutting tool;

- B** electrodes;
C lubricants;
D pencil leads.
26. The element used to galvanise iron is:
A aluminium;
B carbon;
C copper;
D zinc.
27. Which of the following materials is the best insulator?
A ceramic tile roof;
B iron roof with ceiling;
C iron roof without ceiling;
D thatched roof.
28. Which of the fibres is obtained from plants?
A asbestos;
B linen;
C silk;
D wool.
29. Which soap is environmentally friendly?
A biodegradable;
B colour fast;
C highly concentrated.**D** non-biodegradable.
30. The diagram shows a simplified structure of a soap molecule.



Why can soap remove oily stains during washing?

	Part A	Part B
A	soluble in water	soluble in water



B	soluble in water	soluble in oily stains
C	soluble in oily stains	soluble in oily stains
D	soluble in oily stains	soluble in water

30 marks

Section B – Structured Questions**Answer all questions on the spaces provided.**

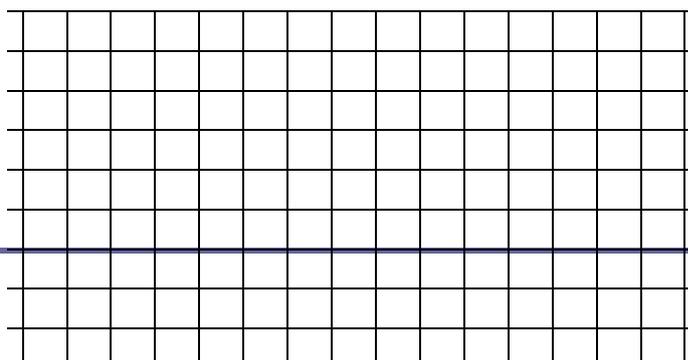
1. A student carried out an experiment to determine the boiling point of a pure liquid substance. The substance was heated until it boiled. The temperature of the substance was measured every 10 seconds for one minute. The table below shows the results of the investigation.

Time (s)	Temperature (°C)
0	20
10	30
20	40
30	50
40	60
50	60
60	60

- (a) Define boiling point.

.....
(1)

- (b) Plot a graph of temperature against time.



(5)

(c) Write down the boiling point of this substance.

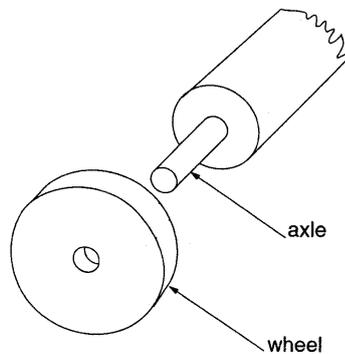
------(2)

(d) Explain, in terms of particles, what happens when the substance is heated until it boils.

 -----(2)

[10]

2(a) A metal wheel is to be fitted in to an axle. The metal wheel is heated to a high temperature before being put on the axle.



(i) State what happens to the diameter of the wheel when it is heated.

 -----(1)

(ii) Explain why heating the wheel makes it easier to fit on to the axle.

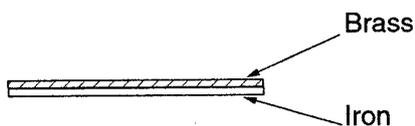
 -----(2)



(iii) Explain what happens to the wheel when it is put on the axle and allowed to cool.

 -----(2)

(b) A bimetallic strip, made up of brass and iron, is shown below.



(i) Brass expands more than iron for the same temperature.
 Draw a diagram to show what happens to the thermostat when the temperature rises.

(3)

(ii) Write down two uses of bimetallic strip in everyday life.

 -----(2)

(c) The kinetic theory of matter can be used to explain many properties of matter. Explain why:

(i) washing dries better on a warm day than on a cold day.

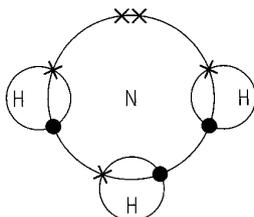
 -----(1)

(ii) gases are easily compressed than solids and liquids.

 -----(1)

[12]

3. The diagram shows bonding between hydrogen and nitrogen atoms.



(a) Name the gas represented by the structure above.

-----(1)

(b) Write down the formula of the gas you mention in (a) above.

-----(2)

(c) State the type of bonding which is formed between the hydrogen and nitrogen atom.

-----(1)

(d) Water has the formula H_2O . Draw a diagram of the water molecule.

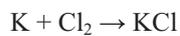
(3)

4. Chlorine exists as two isotopes, ^{35}Cl and ^{37}Cl .

(a) Define the term isotope.

----- (1)

(b) Chlorine reacts with potassium to form potassium chloride:



(i) Balance the equation above. (2)

(ii) Would you expect the same reaction for each isotope of chlorine? Why?

----- (2)

(c) Some isotopes are radioactive. State what makes an isotope radioactive.



----- (1)

(d) Describe the uses of radioactive isotopes in:

(i) medicine

----- (1)

(ii) power generation

----- (1)

(iii) radioactive dating

----- (1)

[16]

5. Paper is made from natural polymer.

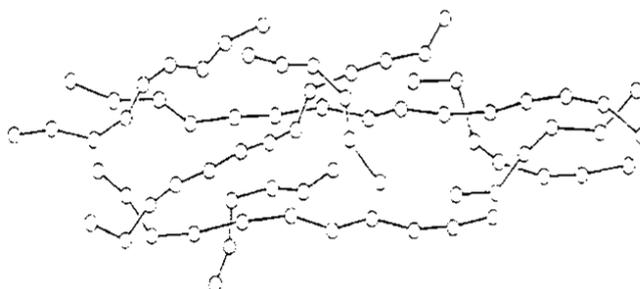
(a) Define the term *polymer*.

----- (1)

(b) Name the *natural* polymer found in paper.

----- (1)

(c) The diagram shows a simplified molecular structure of polythene.



(i) Explain why polythene is *soft* and flexible.

----- (2)

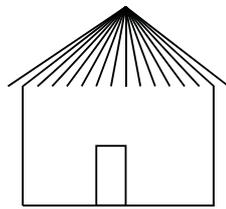
(ii) Write down the **main** use of polythene.

----- (1)

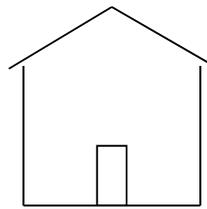
[5]

6. A metal and thatch were used for roofing for the two houses respectively.

thatched roof



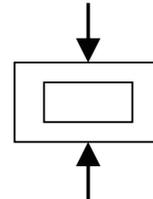
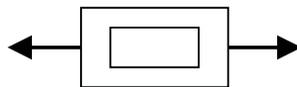
metal roof without ceiling



(a) State which of the two houses will be cooler in summer and warmer in winter. Explain your answer.

 -----(3)

(b) The walls of the houses are made from bricks. The compressive and tensile strength are physical properties of bricks.



----- (2)

Label the drawings above for tensile and compressive testing.

(c) Name the type of bond found in the fired clay bricks.

-----(1)

(d) Sometimes materials other than bricks are used for walls. Name a material that can be used to make walls.

-----(1)

7(a) Both iron and aluminium metals must be extracted from their ores.

(i) For each metal, name the method used in the extraction process.

Aluminium:-----(1)

Iron:-----(1)

(ii) Give a reason why aluminium is more expensive to extract than iron.

 -----(2)

(iii) Iron can be converted to steel. State how steel differs from pure



iron.

----- (1)

(iv) Many food cans are made of steel coated with a thin layer of tin.

Explain why it is important to coat steel with tin.

----- (2)

(v) Name **two** properties of aluminium which makes it suitable to make cooking pots.

----- (2)

(b) Brass is an alloy of copper and another metal.

(i) Define the term *alloy*.

----- (1)

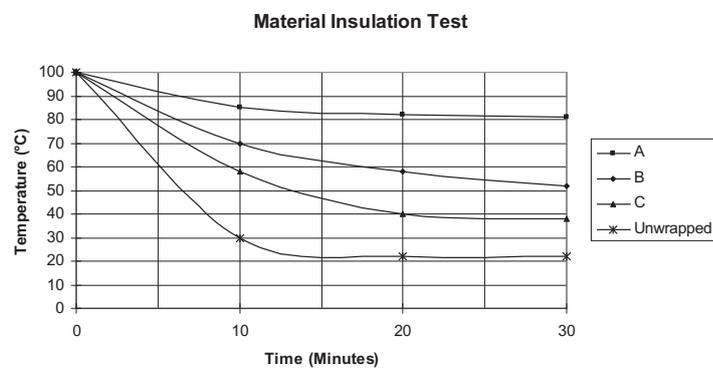
(ii) State the name of the other metal in brass.

----- (1)

(iii) Write down **one** use of brass.

----- (1)

8. An experiment was conducted to determine which material was the best insulator. Materials **A**, **B** and **C** were wrapped around a tin can containing boiling water. The temperature of the water was measured every few minutes, and the results recorded. The same experiment was repeated with the can **unwrapped**. The graph below shows the result of the experiment. **Source:** JSC 1998.



(a) Calculate how much the temperature of the water in the beaker wrapped with material B fell in the first ten minutes. Show your working.

-----(3)

(b) Give the function of the unwrapped beaker.

-----(1)

(c) Identify the material that was the worst insulator.

-----(1)

(d) In cold weather, many people wear thick woollen coats. Select which of the materials used in the experiment was probably wool. Give a reason for your choice.

----- (2)

(e) Select which material (A, B or C) would be the best to keep a tin of cool drink cold on a hot summer day.

-----91)

[8]

[70]

Total: 100 marks



Answers to Self-Mark Activities

Section 1: Types of Materials

1.A, ceramics will shatter when hammered.

2. B, nylon is least stretchable.

3(a) $100^{\circ}\text{C} - 70^{\circ}\text{C} = 30^{\circ}\text{C}$

(b) The unwrapped beaker acts as a control for the experiment.



- (c) Material marked M is the worst insulator.
 - (d) Material marked K was probably wool.
 - (e) K because it maintained its high temperature for a longer period. It did not lose heat easily.
 - (f) Material K would be the best to keep a tin of cool drink cold on a hot summer day.
4. Fill a bucket with water and put it on top of the brick. If the brick breaks, it has a weak compressive strength. If it does not break, it has a good compressive strength.

Section 2: Metals

- 1 (a) (i) Oxygen collects at the positive electrode.
(ii) Aluminium collects at the negative electrode.
- (b) Electrolysis is an expensive process.
 - (c) Aluminium is used to make pans and food containers.
 - (d) Electrical energy changes to chemical energy during the process of electrolysis.
 - (e) Copper is an example of a metal (mined in Namibia) that is a good conductor of electricity.
2. B, iron leaves the furnace at X.
- 3(a) Only the least reactive metals, such as silver and gold are found in a pure, uncombined form. Aluminium and zinc are more reactive that is why they are found combined with other elements.
- (b) A metal ore is the mineral rock from which a metal is obtained.
 - (c) Aluminium oxide, Al_2O_3 is present in the ore, bauxite.
 - (d) Electrolysis is used to extract aluminium from bauxite.
4. D, during the production of steel, oxygen is used to remove some of the carbon from the iron.

5(a)(i) = copper pyrites

(ii) = haematite

(b) Electrolysis is the decomposition of an ionic compound molten, or in solution, by an electric current.

6. A, aluminium is used for food containers.

7. D, could be Aluminium oxide.

8(a) Limestone (CaCO_3) or Carbon (coke) is used with haematite to produce iron metal.

(b) During the chemical reaction **reduction**, haematite is changed to iron.

(c) Properties can be changed:

-by altering the amount of carbon, the more carbon there is, in the steel, the harder it is;

-by heating it and then cooling it rapidly in water, this makes the outside of the steel very hard. It is called case hardening;

-by adding other metals to it to make alloy steel.

9. D, iron ore is changed to iron at D.

10 (a) Alloy refers a mixture of metals or metals with non-metals.

(b) Reactive series refers to when metal elements are arranged in order of their decreasing chemical reactivity with water or diluted acids.

(c) Corrode refers to when a metal reacts with oxygen.

(d) Case hardening refers to the process of heating steel and then cooling it rapidly with water.

(e) Galvanising refers to the coating of iron with zinc to protect it from rusting.

11. test: bring a flame to the gas

result: popping sound is heard



- 12(a)** an acid + a metal → metal salt + hydrogen
(b) hydrochloric acid + magnesium → magnesium chloride + hydrogen
(c) $2\text{HCl} + \text{Ca} \rightarrow \text{CaCl}_2 + \text{H}_2$

13. A, copper is unreactive with most acids.

Section 3: Uses of Materials

- 1.** A, nylon is used for clothes.
- 2.** A, nylon and terylene are used in the making of clothes.
- 3.** d, wood was used for the handle of the pan; wood is the only insulator from the given possibilities.
- 4.** Cotton is a poor conductor of heat.
- 5 (a)** B = bricks
C = cement/concrete
D = glass
E = steel/wood (most houses on the coast have wooden or aluminium window frames because steel rusts easily)
- (b)** B = bricks are hard and can last very long.
C = cement or concrete is hard and can last very long.
D = glass is transparent. One can see through it.
E = steel is strong and it will hold the glass firmly in position;
wood is strong and does not rust.

6.

Material	Use in vehicle	Properties
steel	body	strong easy to shape in any form (malleable)
rubber	tyres	can be shaped into any form
fabric	seats	soft and comfortable
glass	windows	transparent; one can see through it

7(a) ceramics or a metal - must not melt easily;

(b) plastic - must be strong;

(c) glass - must get cold easily and be attractive;

(d) metal - must be able to conduct electricity;

(e) fibre - must be soft and comfortable and able to retain heat.

8(a) The concrete bricks are strong and can last a long time.

(b) stones, clay

9(a) Aluminium has a higher corrosion resistance than steel.

The density of aluminium is lower than that of steel.

Aluminium is more malleable than steel.

(b) The corrosion resistance of aluminium is much higher than that of copper.

The cost of copper is higher than that of aluminium.

The strength of copper is lower than that of aluminium.

The density of aluminium is lower than that of copper therefore aluminium is lighter than copper.

(c) The strength of duralumin is higher than that of aluminium.



Section 4: Structure and Properties of Materials

- 1(a) Materials made of long chain molecules are called polymer.
(b) Carbon is present in all plastic structures.
2. D, polythene is a polymer.
3. C, glass has the structure of a liquid but behaves like solid.
- 4(a) Polythene, nylon, melamine, polyurethane are examples of polymers.
(b) Cellulose is a natural polymer found in wood.
5. B, concrete is made of sand, gravel and cement.
6. A
7. Crystals in cement start forming when water is added. The crystals lock together when the concrete is allowed to dry slowly. This is why it is good to wet concrete regularly.

Section 5: Building Materials

1. Make the roof from grass (thatched roof), because thatch is a good insulator. It keeps the heat out on a hot day and in on a cold day. This happens because air is trapped in the thatched roof.
2. **Advantages:**
thatch is cool in summer and hot in winter;
thatch is cheap.
Disadvantages:
thatch easily catches fire;

cattle feed will become less if people cut too much of it and soil erosion may result;
it can be destroyed by termites.

3. It is steel which is coated with zinc.

4. Advantages:

galvanised iron is waterproof;
it does not rust;
it is easy to put up;
it lasts a long time.

Disadvantages:

galvanised iron can become too hot in summer and too cold in winter;
one must use a ceiling with it;
it is expensive.

Section 6: Fibres

1. A

2. C

3. D

4. D

5. A

6. B

Section 7: Cleaning Materials

1. A soap or detergent has one end that mixes with water. This end contains oxygen atoms. The other part is made up of carbon and



hydrogen atoms and mixes with oil. If you wash your hands only with water, the water cannot mix with the fat because they do not contain similar molecules.

- 2(a)** The ionic part contains oxygen atoms and mixes with water. The covalent part mixes with oil. It is made up of carbon and hydrogen atoms.
- (b)** They are made from oil and coal, which cannot be broken down easily by bacteria.
- 3.** A

Unit 4

Environmental Chemistry

Introduction

In Unit 3, we discussed different types of materials, metals, uses and structure of materials, building materials, fibres as well as cleaning materials.

Now, we will learn about different chemical reactions and tests. This unit consists of the following sections:

Section	Study Hours
1. Chemical and Physical Changes	8
2. Acid, Bases and Alkali	15
3. Neutralisation	7
4. The Air Around Us	7
5. The Commercial Preparation and Uses of Gases	7
6. Pollution of the Air	8
7. Water	15
Review	3
Total	70



Outcomes

On successful completion of this unit you will be able to:

- *describe* the differences between chemical and physical changes;
- *explain* chemical reactions in terms of their absorption and release of heat energy;
- *explain* the pH scale from 0 to 14 in terms of a measure of acid and alkali strength;
- *relate* the pH of strong and weak acids and alkalis and the pH of pure water;
- *explain* the reactions between an acid and a metal;
- *conduct* a test for the hydrogen produced during the reactions between an acid and a metal;
- *describe* neutralisation as a reaction between bases and acids;
- *explain* the reactions between metal oxides, metal hydroxides and acids and test any gas released;
- *describe* the reactions between metal carbonates and acids;
- *conduct* tests for gases released during reactions between metal carbonates and acids;
- *describe* the composition of air;
- *explain* the laboratory tests used in the preparation of carbon dioxide, oxygen and hydrogen;
- *differentiate* between combustion reactions and the products of combustion;
- *describe* the commercial preparation and uses of oxygen, nitrogen and carbon dioxide;
- *explain* the formation of carbon monoxide and its dangers to humans;
- *describe* that non-metal oxides in terms of their acidic qualities and impact on the environment;
- *discuss* the distribution, availability and effective utilisation of water in Namibia taking into consideration their existence in various places such as in dams, underground rivers and lakes;
- *appreciate* the need to save water;
- *describe* a test for the presence of water and the most important physical and chemical properties of water;
- *explain* what causes hard and soft water and how their properties differ.



Terminology

Temporary changes

Physical changes in which no new substance is made.

Permanent changes

Chemical changes in which new substances are made.

Endothermic reaction	Reactions that take heat from the surroundings for the reaction to occur.
Combustion	When substances burn in air or react with oxygen.
Decomposition	Larger or more complex compounds are broken down into simpler substances.
Synthesis reactions	Reactions in which two or more substances combine to form a new compound.
Neutralisation	A reaction between bases and acids.
Soft water	Water that lathers easily when soap is added to it.
Scum	The product of soap and the calcium and magnesium salts in water.
Hard water	Water that does not lather easily with soap.
Temporary hard water	Hard water that can turn into soft water after boiling.
Permanent hard water	Hard water that cannot turn into soft water after boiling.

Section 1: Chemical and Physical Changes

Introduction

The concepts in this section are very common to our everyday lives, yet we may not necessarily be familiar with them. We are constantly involved with things that change permanently or temporarily. We separate things and experience energy changes, but we call these by other names, rather than using chemical vocabulary.

When adding sugar to our tea, we make a solution where one substance, a solid, dissolves in a liquid. It is, however, possible for us to separate the tea from the water and remove the sugar from the solution. We equally know about decomposition and synthesis reactions, but just by other names. We see how rust forms, or how



rotting matter decomposes. These are nothing but synthesis and decomposition reactions.

While studying this section, think of similar situations where these types of reactions can be observed.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>distinguish</i> between chemical and physical changes; • <i>describe</i> that chemical reactions in terms of their absorption and release of heat energy; • <i>explain</i> combustion, decomposition and synthesis reactions.
 <p>Time</p>	<p>This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>

Have you ever forgot cubes of ice outside? What happened to them? Yes, of course they started to melt. After the melting did you have a totally new substance? No. Of course not. Why? Because both are water, they were just in different phases. The ice was in a solid phase and the melted ice in a liquid phase.

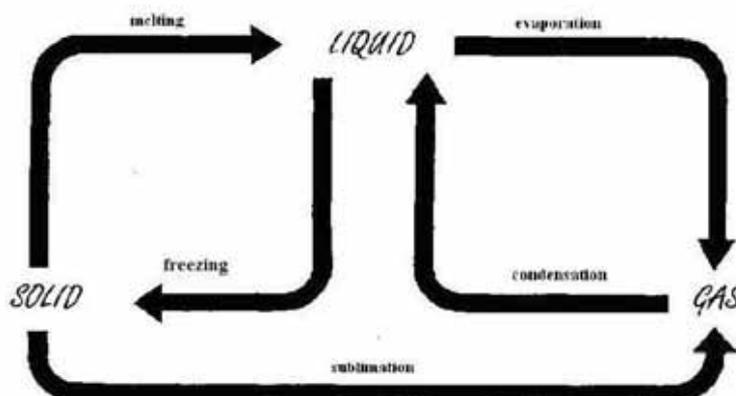
This was just an introduction to chemical and physical changes. If you read further you will understand the two terms much better.

Chemical and physical changes

Substances can undergo different kinds of changes. These changes can be temporary or permanent.

1. Temporary changes (like ice melting) are usually physical changes in which no new substance is made. Physical changes are simple changes that can be reversed. Examples of physical changes include the changes of state, size, shape and temperature.

It is possible that matter can change from one phase to another. For example, when water boils and steam is released. This is a phase change and is an example of a physical change. Physical changes are temporary changes. They have nothing to do with changing the molecular structure of matter and can easily be reversed. Look at the following diagram:



There are ways in which these physical changes can be reversed: evaporation, condensation, filtration and distillation.

2. Permanent changes (like wood burning) are usually chemical changes in which new substances are made. Chemical changes are not easily reversed and are often called chemical reactions.

Changes in the molecular structure of matter are chemical changes. An example of this happens when red mercury oxide is heated. After a while, shiny droplets form and a gas is released. This change cannot be reversed very easily. Chemical changes happen during chemical reactions and can be represented with a chemical equation;



The table below summarizes differences between physical and chemical changes:

Physical changes	Chemical changes
No new substances are formed.	New substances are formed.
Not difficult to reverse.	Difficult to reverse.
Energy is not always absorbed or released.	Energy is absorbed or released. The reaction is either exothermic or endothermic.
There are no specific colour changes.	Colour changes permanently.
There are changes in size, shape, volume.	There are usually changes in size, shape and volume.



I hope you understand the two terms much better after we summarised it for you in the table above.

Just think back again to chemical changes. What happens when wood burns? What do you have to do for wood to burn? Of course you have to light it. This means, it needs energy to start the reaction. Some reactions need energy while others release energy. Read carefully through the explanations that follow.

Change in energy

Reactions need energy to occur.

1. Exothermic reactions release heat energy to the surroundings. In other words, the surroundings become hot. A very common example is burning which releases heat.

When you add some hydrochloric acid to a piece of zinc in a laboratory, the two substances start to react and almost immediately, the test tube becomes hot.

2. Endothermic reactions absorb heat from the surroundings for a reaction to occur. Add some hydrochloric acid to potassium hydrogen carbonate. Do you feel how cold the test tube becomes? Refrigeration is a typical example of an endothermic reaction.

Chemical reactions can be classified as:

combustion reactions;
decomposition reactions;
synthesis reactions.

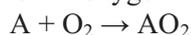
The next part explains them in more detail. Try to understand them when reading through the explanations.

Combustion, decomposition and synthesis reactions

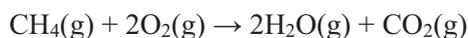
1. Combustion in simple terms is called burning. An example of this happens when substances burn in air or react with oxygen. Usually there will be a flame and heat energy is released. Wood that burns or petrol used in an engine are examples of combustion. Oxides such as carbon dioxide, sulphur dioxide and magnesium oxide are formed. Combustion reactions are usually exothermic (i.e., they release heat). For example, when wood burns, it must do so in the presence of O_2 and a lot of heat is produced.



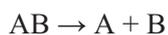
element + oxygen \rightarrow element oxide



An example of a combustion reaction is:



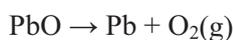
2. Decomposition reactions: As the word indicates, something is broken down (i.e., “split-up”). That is what happens during these types of reactions. Larger or more complex compounds are broken down into simpler substances, usually through electrolysis. An example of decomposition is as follows:



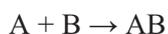
or



An example of a decomposition reaction is shown below:



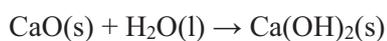
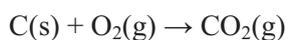
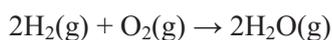
3. Synthesis reactions are the same as joining things to make something more complicated. Also known as a composition reaction, a synthesis reaction is a reaction in which two or more substances combine to form a new compound. Compounds are synthesised from elements. For example, ammonia is synthesised from nitrogen and hydrogen. The reactants may be elements or compounds and the product will always be a compound. The general formula for this type of reaction can be shown as:



or



Some examples of synthesis reactions are shown below:



I hope you are ready to do the self-mark activity to test whether you understand the work covered so far.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Find the correct word (s) in column B to match the statement in column A. Write down only the correct combinations.

Column A	Column B
(a) heat is released	A chemical reaction
(b) reaction with oxygen	B endothermic reaction
(c) new substance formed	C physical change
(d) complex substance	D combustion reaction
(e) water removed by acid	E synthesis reaction
(f) reactants \rightarrow products	F decomposition reaction
(g) milk turning sour	G exothermic reaction
(h) candle wax + oxygen	H dehydrating agent
	I copper sulphate
	J permanent change

2. In conclusion to the following reaction, which type of reaction does it represent best?



- A** combustion reaction;
B neutralisation reaction;
C respiration reaction;
D synthesis reaction.
3. Choose from the list the best example of a decomposition reaction.

Substance	Appearance	Product after heating
A ammonium dichromate	orange crystals	green solid and water
B copper carbonate	green powder	copper and steam
C mercury oxide	yellow powder	mercury and

		oxygen
D sodium chloride	white crystals	salt and hydrogen

4. When a Bunsen burner burns gas, it produces heat. What is such a reaction called when heat is released?
- A** decomposition reaction;
B endothermic reaction;
C exothermic reaction;
D synthesis reaction.
5. In question 6, you see the candle burning. This is a good example of which type of reaction?
- A** endothermic reaction;
B exothermic reaction;
C physical reaction;
D temporary reaction.
6. A candle burning is a typical chemical reaction that happens daily.



Source: <http://en.wikipedia.org/wiki/Candle>

- (a) Complete the equation with relevant products from the reactants given.

candle wax + oxygen \rightarrow +

- (b) Explain your choice.

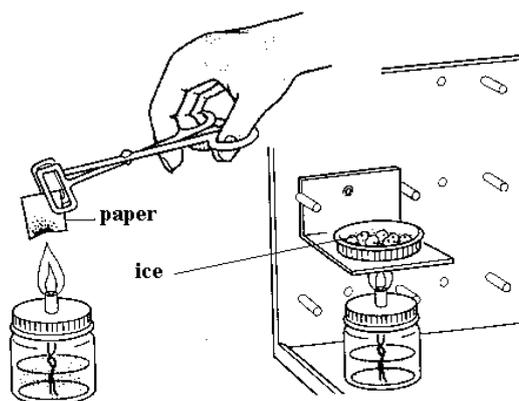
- (c) In the decomposition reactions of a substance, the following is a chemical representation: $C_6H_{12}O_6 \rightarrow 6C + 6H_2O$
 Explain what happens during this decomposition reaction.

7. When chemical reactions occur they can be temporary or permanent, due to different classifications.

- (a) Write a simple descriptive definition to explain what is meant by:
- (i)** synthesis reaction;
(ii) combustion reaction;
(iii) exothermic reaction.



(b)

**Fig 4.1**

[Source: Physical Science for Namibia Grade 8, Heinemann-1992]

In the experiment (**Fig 4.1**) we see a physical change and a chemical change of substances.

- (i) Describe which is the chemical reaction.
- (ii) Give three reasons why you say that this is a chemical reaction.

Section 2: Acids, Bases and Alkali

Introduction

We are confronted with acids, bases, metals and non-metals daily. We are often required to distinguish between these. It is also very useful to know the properties of each. This makes it useful when you want to use them for a specific purposes. Study these properties diligently. Do so not only for examination purposes but to gain knowledge and for the purpose of using these substances accordingly.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>compare</i> the properties of acids and alkalis (bases that are soluble in water); • <i>explain</i> the effect of the properties of acids on indicators such as litmus and universal indicator (liquid or paper);
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	<ul style="list-style-type: none"> • <i>understand</i> the properties of metals and non-metals (including their compounds, e.g., oxides and hydroxides) and of acids and bases; • <i>measure</i> the pH of a variety of solutions by placing them on a pH scale and classifying them as strong or weak acids, alkalis or neutral; • <i>distinguish</i> between weak alkalis such as soap water and lime water and strong alkalis such as sodium hydroxide, using a universal indicator and by referring to the pH scale; • <i>distinguish</i> between weak acids, such as acetic acid or vinegar and strong acids, such as hydrochloric and sulphuric acids, using a universal indicator and by referring to the pH scale; • <i>investigate</i> the reaction of an acid and a metal; • <i>carry</i> out a test for the hydrogen produced during the reaction between an acid and a metal; • <i>write</i> down word and balanced equations for the reactions involving acids and bases.
--	---

 <p>Time</p>	<p>This section will take you about 15 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Properties of acids and alkalis

The word acid sounds dangerous! Acids are very dangerous when they are concentrated. You have to handle acids with great care, but when these acids are diluted with water, they are less hazardous. Diluted hydrochloric acid will not burn your skin if it is washed away quickly with water. It will, however, sting in a cut and will slowly destroy clothing. Safety spectacles should always be worn when using diluted or concentrated acids.

Acids are not all dangerous. Many acids are part of life. These are found in living things. Citric [sit-rik] acid gives orange and lemon



juices their sharp taste. Acetic acid [ah-see-tik] is the main ingredient of vinegar.

Acids have certain properties.

CAUTION: Do not taste unknown liquids to find out if they are acids. Some chemicals will burn your tongue, and others are very poisonous. There is a better way of identifying acids. The easiest way to recognize an acid is to test a solution with an indicator.

You can use litmus paper or universal indicator paper or any other indicator. **When a piece of blue litmus paper is dipped into acid, the paper turns red.** All acids have the same effect on blue litmus. Litmus is a plant dye that changes colour when it comes into contact with acids. The effect of acids on indicators is one of their best-known properties. Substances that change colour in the presence of acids or bases are called indicators. Acids have a pH of less than 7.

Common acids are hydrochloric acid (HCl), sulphuric acid (H₂SO₄) and nitric acid (HNO₃) in addition to the weaker acids, mentioned above.

We mentioned earlier that acids have certain properties. These are listed below:

Properties of acids are as follows:

- Acids change the colour of indicators.
- Acids are colourless but have a sour taste.
- Acids corrode most metals.
- Acids are neutralized by metal oxides and hydroxides (bases).
- Acids make your fingers feel rough.

Acids have properties that are opposite to those of another group of compounds called bases. Acids and bases react with each other to neutralise each other's properties.

The term base is a technical word used in chemistry. The word alkali (al-ka-lie) is better known. Bases are antacids that mean "against-acid". They are the chemical opposites of acids. A base will neutralise an acid and when this happens, a salt is formed. Bases that dissolve in water form alkaline solutions.

The alkali or base solution turns litmus blue. They have a pH that is above 7. An alkali is a base that is soluble in water. Common alkalis are sodium hydroxide (NaOH), potassium hydroxide (KOH), calcium hydroxide (Ca(OH)₂), ammonia (NH₄OH) and sodium carbonate (Na₂CO₃).

Alkalis are used in the home for two purposes: to neutralise acids and to remove grease from clothes and dishes. Toothpaste is mildly alkaline. It neutralises the acids that attack teeth.

Properties of bases are as follows:

- Bases change the colour of indicators.
- Bases are colourless and feel soapy.
- Bases neutralise acids (a neutral substance has a pH of 7).

We have completed reviewing the properties of acids and bases. Lets now look at the properties of metals and non-metals.

Properties of metals and non-metals

About three-quarters of the elements in the periodic table are metals. Some metals have higher reactivity than others. Metals range from the densest element to a liquid, mercury. The more common properties of metals are described below:

Metals are shiny

All metals have a shiny surface when freshly cut or polished. Many, however, lose their shine when they come in contact with air. Jewellery, such as gold and silver stay shiny even in air.

Metals conduct electricity

You know that copper is an excellent conductor of electricity and is used in the making of electrical wire. Other metals, such as lead are also conductors but have properties more relevant for their purpose. Lead is too soft to be used as electrical cables.

Metals bend and stretch

Metals can be hammered or rolled into shape, because they are malleable. Metals can be pulled into wire, because they are ductile. The hot and cold rolling processes in steelmaking depend on the steel's ductility and malleability. They are important methods for shaping this alloy and for changing its properties.

Metals have high melting points

In general, you know that metals melt at high temperatures, much higher than non-metals for instance. Not all metals melt at high temperatures. We have already mentioned mercury (Hg) which is a liquid at room temperature. Sodium and potassium on the other hand, melt below 100°C. Tungsten is used to make the filaments of light bulbs because of its very high melting point. Metals can be exposed to high temperatures. Think of the inside of an engine such as when a car or machine is running.

Metals are strong



You have to agree that the term “strength” has many meanings. The most common type of strength is tensile strength. This strength is the ability to support a heavy load. For other purposes, hardness is a very important property.

Metals undergo reactions with oxygen, water and acids. We will describe these reactions now.

Metals in the air

Metals tend to corrode slowly in moist air at normal temperature. Some metals burn easily in air because of the oxygen available. They then form metal oxides. Magnesium burns with a bright white flame.

Metals in water and steam

The reactions of sodium and potassium in water and steam are quite common. These metals react spontaneously when they come in contact with water. Only the more reactive metals, such as potassium, sodium, lithium and calcium will react with cold water.

Metals and acids

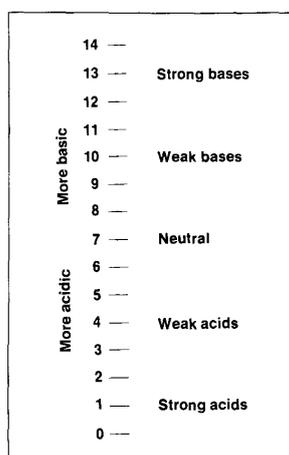
Many of the metals, not all, react with acids. Hydrogen gas is formed in these reactions and the metal usually dissolves in the acid to form a salt, (metal + acid → salt + hydrogen). The following table compares the properties of metals and non-metals as discussed earlier.

Property	Metal	Non-metal
state at room temperature	all solids except for mercury that is a liquid	mostly solids e.g., sulphur, carbon; 11 gases e.g., oxygen, nitrogen; one liquid, e.g., bromine
appearance	shiny when polished	dull
densities	usually high	usually low
melting and boiling points	usually high	usually low
electrical conductivity	good conductors	poor conductors (insulators); except for carbon (graphite) which is a good conductor of electricity
effect of bending	can bend	snap when bent

effect when hammered	changes shape	crumble or shatter
effect with air	oxidises	not much, iodine sublimates
effect in water	corrodes faster	gases dissolve mostly
state of oxides	basic	acidic
effect with acid	faster corrosion	no effect

How do we measure the acidity level of a solution. Well, we use the term pH to measure the acidity of a solution. Lets start talking about pH level.

Measurement of the pH of a variety of solutions



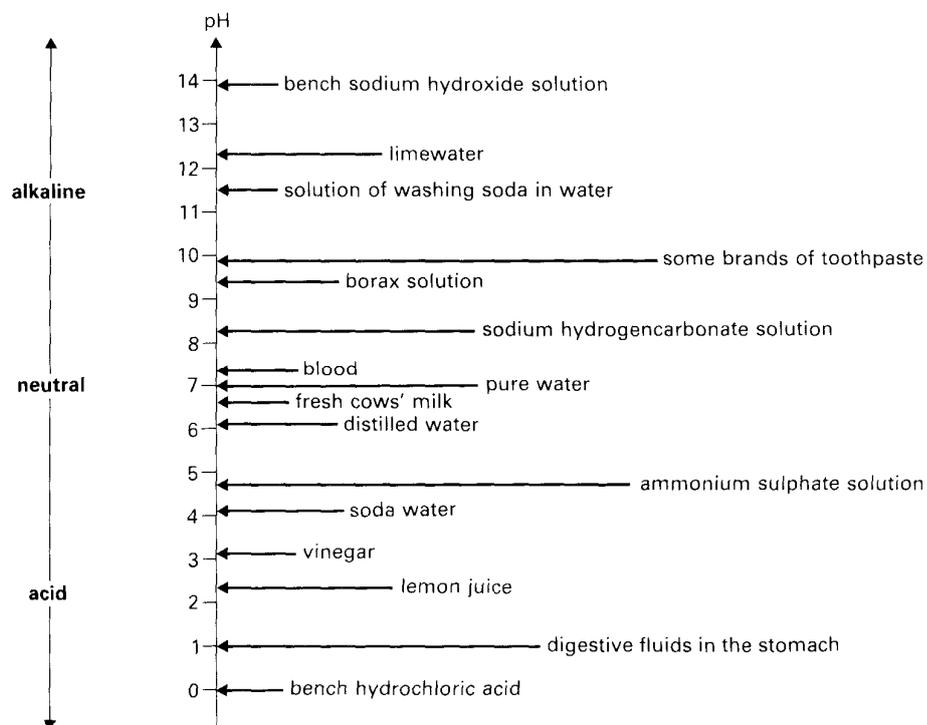
The pH of a solution tells you how acidic or basic a solution is. It is helpful to use a pH scale to determine how acidic or basic a solution is. This scale ranges from 0 to 14. A pH of 1, for instance, shows a strong acid solution. A pH of 14 shows a strong basic solution. Pure water is neutral and therefore has a pH of 7. Any solution with a pH of less than 7 is acid and a pH greater than 7 is basic.

The pH of a solution can be determined by using universal indicator paper. When this paper is moistened with the solution, it changes colour. This colour is represented by a numerical value.

When you test a solution, the colour strip is compared (with a colour scale) and the pH number can be read directly from the scale. A full range indicator is a synthetic indicator. It turns to shades of orange and red, depending on the strength and concentration of an acid.



The following table places a variety of solutions on a pH scale.



Some acids or alkalis are stronger or weaker than others. What determines the strength of an acid or an alkali? Read through the next part carefully to understand the difference.

Distinguish between weak alkalis and strong alkalis

Sodium hydroxide (NaOH) and potassium hydroxide (KOH) are very soluble in water. Their solutions are strongly basic because of the high numbers of hydroxide (OH⁻) ions. These bases are said to be strong.

The word alkali is often used in reference to strong bases. When these alkalis dissolve in water, the NaOH breaks up into sodium (Na⁺) ions and hydroxide (OH⁻) ions. We say that they ionise or dissociate. A base that forms many hydroxide ions is a strong alkali.

Ammonia water is an example of a base that is weak because it is only slightly ionised. Calcium hydroxide, even though it ionises completely in water, is moderately basic because it is only slightly soluble in water. Examples of weak alkalis are soap water and lime water, while an example of a strong alkali is sodium hydroxide.

Distinguish between weak acids and strong acids

Dilute hydrochloric acid reacts quickly with magnesium ribbon. But when ethanoic acid is used instead, the reaction is much slower. It could take all day. The hydrochloric acid reacts faster because it contains more hydrogen ions.

In hydrochloric acid, nearly all the acid molecules break up to form hydrogen (H^+) and chlorine (Cl^-) ions. It is called a strong acid. In ethanoic acid however, only some of the acid molecules form ions, so it is called a weak acid.

In a strong acid, nearly all of the acid molecules form ions; it ionises completely. In a weak acid, only some of the acid molecules form ions; this is incomplete ionisation.

A strong acid always has a lower pH number than a weak acid of the same concentration. Acetic acid or vinegar is a weak acid, while hydrochloric and sulphuric acids are strong acids.

Lets see what happens when an acid and a metal reacts.

**Practical Activity**

Problem: What is the pH of the soap I use?

What you need to do this activity:

Different brands of soap or detergents, a bottle/beaker, funnel and filter paper, as well as universal indicator paper.

What you should do:

1. Pour some water (1 cm^3) in a bottle/beaker.
2. Put a small piece of soap or a drop of detergent in the water.
3. Shake well.
4. Pour the mixture through the filter paper.
5. Use the universal indicator paper and test the pH of the filtrate.
6. Record your results in a table.

Results:

The different soaps will have different pH colours. Most will be more alkaline.

**Practical Activity****Investigate the reaction of an acid and a metal**

A very interesting investigation to do is the reaction between an acid and a metal.

You need: Test tubes, dilute hydrochloric acid, a piece of zinc metal, universal indicator solution or paper, matches, and rubber stoppers with delivery tubes.

Do the following:

1. Pour about 2 cm³ of the acid into a test tube. Test the pH of the acid with the indicator.
2. Place a piece of zinc into the test tube with acid.
3. Close the test tube with the rubber stopper and delivery tube.
4. Collect any gas produced in a test tube by the downward displacement of air.
5. When the reaction has stopped, light a match and hold it at the opening of the gas filled test tube.
6. Test the pH of the resulting solution with litmus paper.

Did you note the colour change in the solution?

The gas that is formed is hydrogen. The lighted match in the test tube will make a pop sound to indicate the presence of hydrogen gas.

Answer the following questions about the reaction that takes place.

Questions

1. A gas is formed in the two reactions.
 - (i) Which gas is this?
 - (ii) Explain the test and result for this gas.
2. What was the colour of the solution after the litmus was added?
3. Describe any colour change that took place during the reaction.

4. What colour is litmus in an acid?
5. What colour is litmus in a base?
6. Write a word and balanced equation for the reaction that took place between zinc and the acid. If you can't answer this question, follow the discussion below and then write the balanced equation.

Writing word and balanced equations

Chemical equations represent the chemicals that take part in a reaction. These chemicals are called the reactants. The substances that they form are called the products.

reactant A + reactant B → product AB

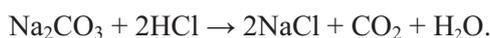
or

reactant A + reactant B → product C + product D

Word equations are written using the names of the reactants and products in the reaction. Chemical equations are written using the formula of the reactants and products.

A balanced chemical equation tells us the ratio in which the reactants combine and the ratio in which the products are formed. For example, the reaction between sodium carbonate and hydrochloric acid is represented by the following word and chemical equations:

sodium carbonate + hydrochloric acid → sodium chloride + carbon dioxide + water;



Formulae of compounds

You need to know the first 20 elements, as well as the following metals: iron, copper, zinc, lead, mercury, gold, silver, tin and uranium.

Diatomic elements are hydrogen, oxygen, nitrogen and the group seven elements.

The formula of a compound reflects two things about the compound, namely the elements that are present in the compound and the ratio in which they combine. The formula for water, H_2O shows that the elements in water are hydrogen and oxygen. In addition, the formula shows that they combine in the ratio hydrogen : oxygen 2 : 1.



If there is no number below and to the right of an element in a formula, there is only one atom of that element in the compound. In the formula Fe_2CO_3 there are two atoms of iron, one atom of carbon and three atoms of oxygen.

A more complex example is that of ammonium sulphate. In the formula of ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$, the elements are nitrogen, hydrogen, sulphur and oxygen. The brackets show that there are two ammonium (NH_4^+) ions for every sulphate (SO_4) ion. This means that the ratio $\text{N} : \text{H} : \text{S} : \text{O} = 2 \times 1 : 2 \times 4 : 1 : 4 = 2 : 8 : 1 : 4$

Now how do we write word and chemical equations? We will teach you now how to do this.

Word equations and chemical equations

How to balance a chemical equation

All elements have symbols. These are shown on the Periodic Table. A symbol contains either:

- one letter (for example, I for iodine) or
- two letters (for example, Na for sodium), where the 2nd letter is written in the lower case.

Compounds contain the symbols of elements from which they are made. The formulae shows the ratio in which the atoms are present. To understand this better, review the examples that follow.

One molecule of SO_2 or sulphur dioxide has two atoms of oxygen for every sulphur atom.

One molecule of SO_3 or sulphur trioxide has three atoms of oxygen for every sulphur atom.

To show the number of molecules, a number is simply put in front of the formula.

For example, e.g.,

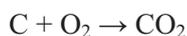
5SO_3 means five molecules of sulphur trioxide.

One molecule of sulphuric acid H_2SO_4 has the elements H, S, and O and they are in the ratio $2 \times \text{H} : 1 \times \text{S} : 4 \times \text{O} = 2 : 1 : 4$.

Word Equations

The burning of charcoal is a chemical change. Charcoal is made up of carbon atoms. When charcoal burns, the carbon atoms combine with oxygen atoms in the air to form carbon dioxide. Carbon plus oxygen produces carbon dioxide.

It is time consuming as well as difficult to understand the reaction described above when written in sentences. Thus we have also used symbols and a formula to represent the element and compound as seen below.



It is quicker and easier to use formulae instead of names when writing equations.

Now, we are going to take a few examples of some chemical reactions and show you how to write an equation in symbols from the word equation.

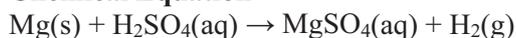
Example 1

Magnesium ribbon reacts with cold, diluted sulphuric acid to give hydrogen gas and a solution of magnesium sulphate.

Word equation

cold, diluted magnesium(s) + sulphuric acid(aq) → magnesium sulphate(aq) + hydrogen(g)

Chemical Equation



The next step is to count the number of atoms on each side of the equation.

How many magnesium atoms on the left? How many on the right?

How many hydrogen atoms on the left? How many on the right?

How many sulphur atoms on the left? How many on the right?

How many oxygen atoms on the left? How many on the right?

Element name	Number of atoms on left	Number of atoms on right
Magnesium	1	1
Hydrogen	2	2
Sulphur	1	1
Oxygen	4	4

The total number of atoms on the left and right are equal.

In this case, the equation is already balanced, so nothing further is needed. Magnesium and sulphuric acid on the left side of the reaction are called the reactants. They combine to give magnesium sulphate and hydrogen, the products that are on the right side of the reaction.

Example 2



Hydrogen burns in chlorine to form the gas hydrogen chloride.

burn

hydrogen(g) + chlorine(g) → hydrogen chloride(g)



Although the formulas written are correct and should not be changed, we find by counting that the equation is not balanced.

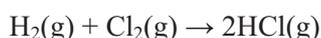
There are two hydrogen atoms and two chlorine atoms on the left. On the right, however, we find only one of each so the equation is not yet complete.

We now need to balance it. We cannot write H or Cl on the left because these are diatomic molecules.

Can we write H_2 and Cl_2 on the right, because we need two hydrogen and two chlorine atoms on the right? We could write $\text{HCl} + \text{HCl}$, but we can also write it in a shorter way.

To make it shorter, we write it as 2HCl .

Note that we now produce two molecules of hydrogen chloride, but we have not altered the formula for hydrogen chloride in any way from the correct HCl . The full equation now becomes:



Tip

Rules for Balancing Equations:

Let us summarise the process in four steps.

1. The correct reaction must be represented.
2. The correct symbols and valencies must be known. From these, the correct formulae of reactants and products must be written in the correct places. Note: Valency is the number of chemical bonds formed by the atoms of an element.
3. The numbers of each different atom must be counted and made the same on both sides. This is done by changing, where necessary, the number of molecules taking part or being produced. Changing the number of numerals is, in turn done

	<p>by using a numeral before a symbol or formula.</p> <p>4. Equations are never balanced by changing correct formulae once they have been written. In other words, never change the formulae. Only change the number of molecules when balancing an equation.</p>
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I hope you have understand the contents in this section. It might be best to re-read the part on balancing of equations again if you found it difficult.

After you have done this, do the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Complete the following word equations:

- (i) an acid + a metal \rightarrow
- (ii) hydrochloric acid + magnesium \rightarrow

2(a)(i) Write down what colour change an acid causes on moist litmus paper.

(ii) Write down what colour change a base causes on moist litmus paper.

(iii) Complete the following table by filling in the colours of the universal indicator as solutions of the given pH.

pH of solution	0 - 2	3	4 - 5	6	7	8	9	10	11-14
Colour of universal indicator									

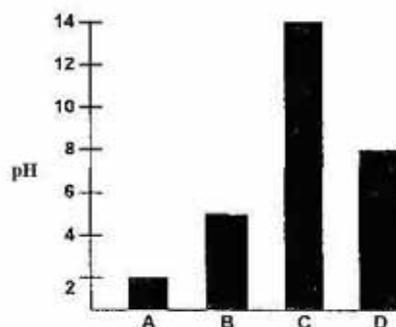
(b) Write down the pH range for:

- (i) acids;



- (ii) bases.
- 3(a)(i) Explain the difference between weak acids (or bases) and strong acids (or bases).
- (ii) Explain the difference between a weak acid and a dilute acid.
- (iii) Explain why sulphuric acid is considered a strong acid, but acetic acid a weak acid.
- (iv) Will a concentrated acid always react quicker than a dilute acid? Explain your answer.
- 4(a)(i) Explain what is meant by the pH of a solution.
- (ii) Write down which ion is responsible for the acidic nature of a solution.
- (iii) Write down which ion is responsible for the basic nature of a solution.
- (b) Explain how can pH be measured.
- (c) Suggest an approximate pH for solutions of each of the following and explain your reason for assigning each value:
- lime water (calcium hydroxide solution);
 - vinegar;
 - salt;
 - baking soda.
5. Dilute hydrochloric acid reacts with a solution of magnesium hydroxide to form a salt and water.
Write a chemical equation for the reaction using state symbols. State symbols are usually written in brackets below the symbol of the compound in the chemical equation. State symbols show the phase of the compound at the reaction temperature. The compound can be a solid(s), liquid(l), gas(g) or dissolved in water(aq).
6. Choose the correct answer:
- A. alkalis are bases that are not soluble in water;
B. alkalis are bases that are soluble in water;
C. alkalis have no effect on red litmus;
D. alkalis will turn blue litmus red.
7. Acids have the following properties:
- A. react with alkalis to form hydrogen;
B. react with metals to form salt; can neutralise acidic oxides;
C. sharp sour taste; no effect on the colour of red litmus;
D. sharp sour taste; slippery feel to the touch.

8. Study the following graph:



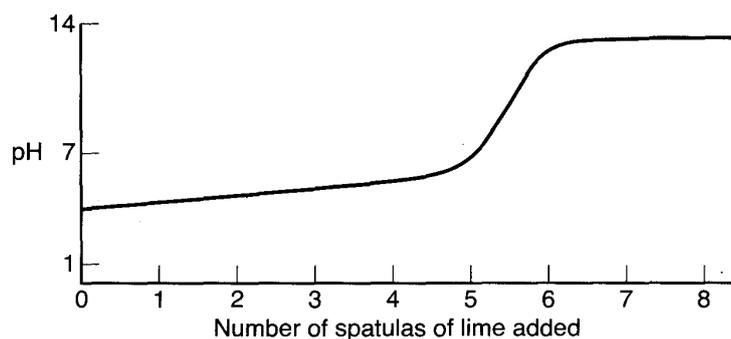
The weak acid and the strong base are represented by:

- A. A and C;
- B. A and D;
- C. B and C;
- D. C and D.

9. A neutralisation reaction is

- A when a metal and an acid react;
- B when an acid and a base react;
- C when any number of substances react;
- D when only two substances react.

10. In an experiment, the pH of an acid is neutralised by a base and the following graph was drawn with the information gathered from the experiment.



(a) Write the numerical values for:

- (i) acid;
- (ii) base;
- (iii) neutral.

(b) Write down how much of the lime was needed to



neutralize this reaction.

(c) Select whether lime is an acid or a base.

(d) Complete: acid + base \rightarrow
+.....

(e) Write two relevant and distinguishing properties for:
(i) acids;
(ii) bases.

11. List 3 properties of metals.

I hope this activity was not too difficult. It is not time to start studying Section 3.

Section 3: Neutralisation

Introduction

In this section, we shall cover work leading to an understanding of the process of neutralisation which is a reaction between bases and acids. Neutralisation is a very common reaction, which I am sure many of you have experienced before. An example of this might include drinking an antacid to relieve heartburn.

Neutralisation is also common in soap making. Knowing the reactions between metal oxides, metal hydroxides and acids and testing any gas released, is very useful knowledge. You will realise that these are processes common in our daily environment and in our lives.

When you experience the reaction between metal carbonates and acids and test any gas released, you will realise that you are on your way toward simple engineering. Concentrate on what happens in these reactions, and try and visualise these reactions in your environment.



On successful completion of this section, you will be able to:

- *relate* the reaction of a base and an acid

<p>Basic Competence</p>	<p>to neutralization;</p> <ul style="list-style-type: none"> • <i>describe</i> neutralisation in terms of the preparation of salts such as table salt; • <i>describe</i> the preparation of examples of well known salts such as copper sulphate or table salt by a neutralisation reaction; • observe with a magnifying glass the crystals of the salt formed after a neutralisation reaction; • investigate the reactions between metal oxides, metal hydroxides and acids after neutralisation and test for the gas produced; • <i>investigate</i> the reactions between metal carbonates and acids and test for the carbon dioxide produced; • <i>write down</i> word and balanced equations for the following neutralisation reactions: reactions between metals (Group I and II) oxides and acid; reactions between metals (Group I and II) hydroxide and acid; reaction between an acid and a carbonate.
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Time

This section will take you about seven hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

In Section 2, we learned about the properties of acids and bases.

In this section, we will continue to look at reactions that can take place to form salts. A salt is defined as a compound made up of the positive ions of a base and the negative ions of an acid.

These reactions include those between:

- acids and bases;
metal oxides and acids;
- metal carbonates and acids.

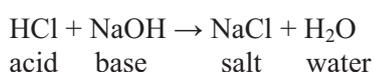


Reaction of a base and an acid

A salt is one of the products of an acid-base reaction. When proper amounts of an acid and a base are mixed, the properties of the two solutions cancel each other. The products formed are salt and water. The following is a word equation of the reaction that takes place:

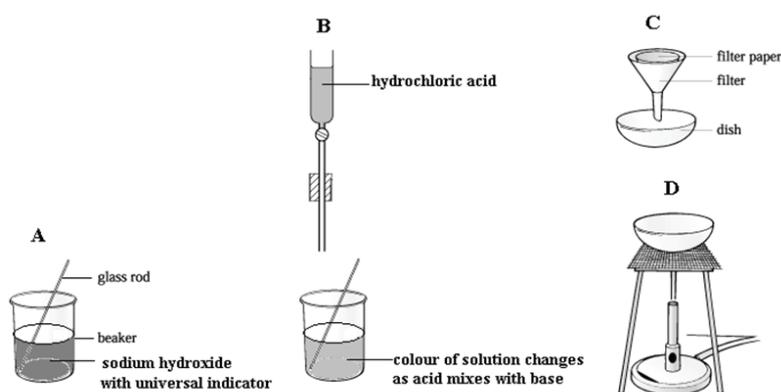


When solutions of hydrochloric acid and sodium hydroxide are mixed, the reaction is written as:



If the solution is heated slightly to let the water evaporate, white crystals of sodium chloride (table salt) remain in the container. The reaction of any acid with any base produces a salt. In this case, sodium chloride was produced by the reaction of hydrochloric acid and sodium hydroxide.

The diagram below illustrates the steps to follow when sodium hydroxide reacts with hydrochloric acid.



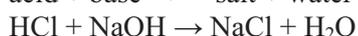
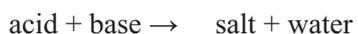
So in other words:

- In A, you add some universal indicator to the base. This will give the solution a blue colour.
- In B, acid is added very slowly, until the solution starts to turn colour. The colour of a neutral solution is green. If too much acid is added, the solution will have a red colour.
- In C, the green solution is filtered, to remove any solid particles.

- The filtrate is then heated slightly in D, to let the liquid evaporate to produce white salt crystals.

As we said earlier, a salt is defined as a compound made up of negative ions of an acid. Sodium chloride is only one example of the many thousands of salts used in chemistry.

The first method of preparing salts then is the reaction of an acid and a base:



Preparation of well known salts

After you have prepared a salt, it is very interesting to look at these crystals through a magnifying glass.

You must now realise that a salt is formed by an ionic reaction. Remember the previous work done in Unit 2, Section 10 about ionic bonding? We talked about the reaction between metals and non-metals, where ions are formed and these positive (Na^+) and negative (Cl^-) ions attract each other in a crystal lattice.

But there are also other reactions to consider in the preparation or making of salts. Let's look at another one of them.

Reaction between metal oxides and acids

The reaction between metal oxides and acid. We shall use hydrochloric acid and magnesium oxide. This combination will produce a salt and water.

In other words, the reaction looks like this:

hydrochloric acid + magnesium oxide \rightarrow magnesium chloride + water



Acid + metal oxide \rightarrow metal salt + water

Or a metal hydroxide, which is in fact a base, will be the same reaction as an acid and a base.

In all of these cases, one can use the same method as with the neutralisation reaction to make salt crystals.



The last type of reactions that form salts are reactions between metal carbonates and acids. See if you can follow how it works.

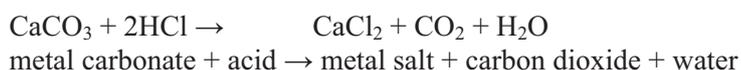
Reactions between metal carbonates and acids

This reaction is very common to us, especially in areas where acid rain corrodes buildings. Building materials have marble or materials in them that react with the acid in rainwater.

The third method for salt making is a metal carbonate reacting with acid. Here we take calcium carbonate (marble) to react with hydrochloric acid.

The reaction looks like this:

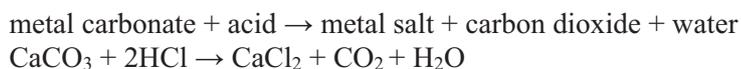
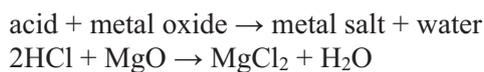
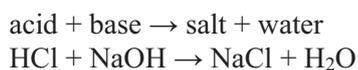
calcium carbonate + hydrochloric acid → calcium chloride +
carbon dioxide + water



Some of these reactions release a gas. In Section 4, you will learn how to test for gases. The gas released is carbon dioxide. Remember it.

Summary

Reactions that produce salts:



Now, see if you can answer the questions in the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- Which one of the following is a word equation for the reaction of sodium with chlorine.
 - sodium + chlorine \rightarrow sodium chlorate;
 - sodium + chlorine \rightarrow sodium chloride;
 - sodium + chlorine \rightarrow sodium dioxide;
 - sodium + chlorine \rightarrow sodium oxide.
- Acid rain is formed when the air is polluted by sulphur dioxide. Which of the following is the main concern of sulphur dioxide pollution?
 - forming of acid rain;
 - greenhouse gases are released;
 - nuclear power stations are over used;
 - ozone is depleted.
- Complete the following reactions:
 - sulphuric acid + copper oxide \rightarrow +
 - sodium hydroxide + hydrochloric acid \rightarrow +
- We studied the following experiment during class.



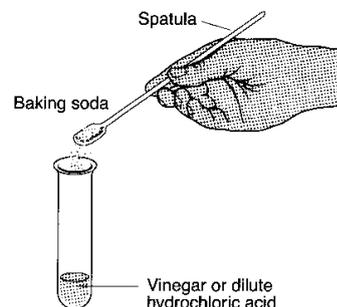
PROBLEM: What happens when an acid is added to an alkali?

WHAT YOU NEED

Test tube (or jar)
Spatula
Dilute hydrochloric acid (or vinegar)
Baking soda

WHAT TO DO

- 1 Put some acid in the bottom of the test tube.
- 2 Add a spatula full (half a teaspoon) of baking soda.
- 3 Watch what happens.



4 Add a suitable indicator to the solution.

Source: Physical Science for Namibia Grade 9, Heinemann - 1993

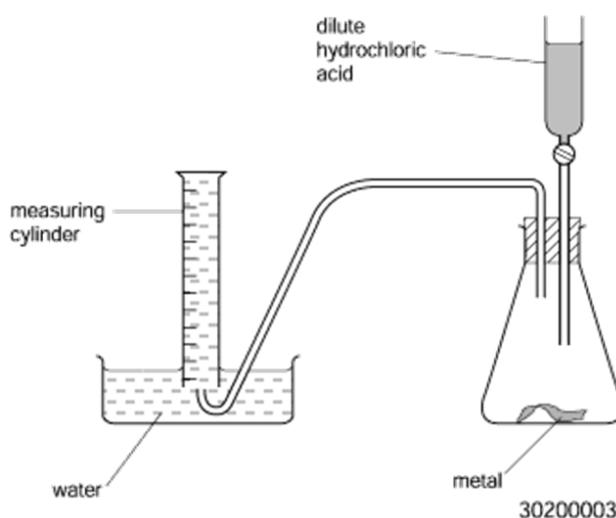
- (a) Complete the following word equation:
sodium hydrogen carbonate + hydrochloric acid \rightarrow (i) + (ii) + carbon dioxide
- (b) (i) What do we call a reaction of an acid and a base?
(ii) Describe in simple terms what happens in this type of reaction.
- (c) (i) Give the colour change that we will see in the indicator as the reaction goes on.
(ii) Describe how will you know that the result is satisfactory.
- (d) The following is a table of the results obtained from the experiment.

pH	3	3,5	4	5	7	9	10	11
Spa- tulas of ba- king soda	1	2	3	4	5	6	7	8

- (i) Plot the points on a grid and draw a graph with the relevant results.
- (ii) Write down how much of the baking soda made the solution neutral.
- (iii) Explain what was the condition of the solution after the reaction was completed, basic or acidic.

5. The chemical reaction between magnesium ribbon and

hydrochloric acid can be shown using this apparatus.



(a) The following results were noted by the scientist.

Time/minutes	0	1	2	3	4	5	6	7
Volume of gas produced/cm ³	0	15	22	34	39	40	40	40

(i) Which gas is produced?

(ii) Write a balanced equation for this reaction.

(b) Plot a graph with these results on a grid.

(c) From the graph, write down how long it took before the reaction was over.

Well done so far! Now you should be ready to start studying Section 4 which covers the air around us.

Section 4: The Air Around Us

Introduction

The earth is the only planet that we know of that has life on it. Air and water are essential to us and to all other living things. As you already know, air is made up of different gases. Did you know that



one could produce carbon dioxide, oxygen and hydrogen? In the following sections, you will learn how to prepare these gases.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>discuss</i> the composition of air specifically stating the levels of nitrogen concentrations; • <i>describe</i> the process of combustion in terms of its reaction with oxygen in the air; • <i>explain</i> the combustion of fuels within the context of the production of carbon dioxide and carbon monoxide; • <i>prepare and</i> test for carbon dioxide, oxygen and hydrogen in a laboratory.
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 Time	<p>This section will take you about seven hour to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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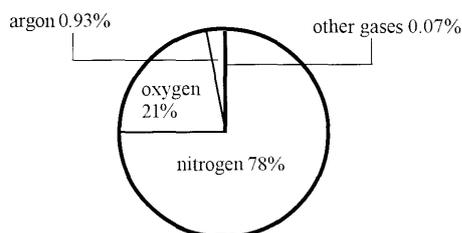
What does air consist of? It consists of many different gases as stated earlier in the introduction. Lets now find out which gases air consist of.

Composition of air

The air around us consists of many different gases. Do you know what they are? Air consists of:

- 78% nitrogen;
- 21% oxygen;
- 0.93% argon;
- and 0.07% other gases including carbon dioxide.

Air also contains water vapour but this cannot be shown in the diagram because the amount of water vapour changes all of the time. The pie chart below shows the composition of air.



Combustion

Combustion is the process whereby substances burn in oxygen. You know that there is oxygen in the air. When substances like fuels burn, they combine with oxygen.

Do you know what fuels are? They are substances that release energy when they burn. Examples of fuels are coal, oil, wood and natural gas.

These fuels contain the element carbon, so they produce the gas carbon dioxide when they burn. However, if there is a limited supply of air, the reaction will produce carbon monoxide.

In the introduction, I stated that you can prepare oxygen, carbon dioxide and hydrogen in a laboratory. You will now learn how to do this.

If you are in a position to carry out these experiments, please do them.

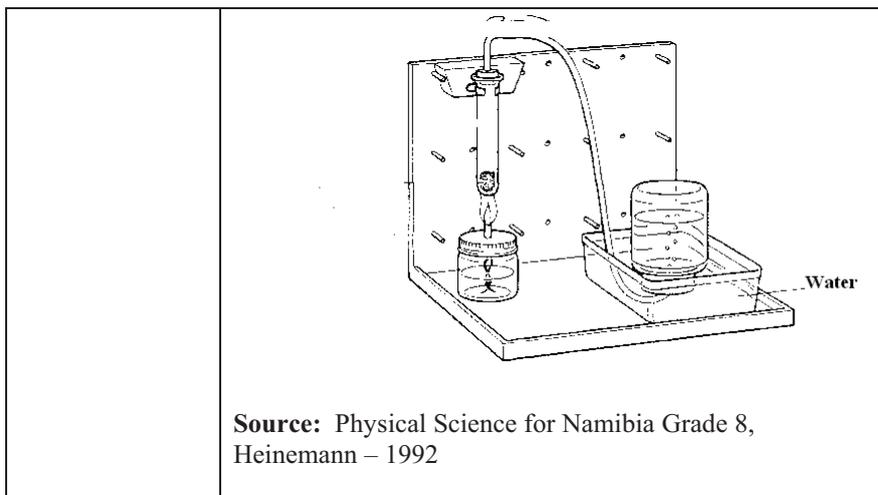
Preparation and tests of gases



Practical Activity

Preparation of oxygen in a laboratory:

1. Put a mixture of potassium chlorate and manganese dioxide in a test tube.
2. Put a delivery tube on top of the test tube and lead it to a jar which is upside down in a bowl of water.
3. Heat the mixture in the test tube slowly.
4. Oxygen gas will bubble into the jar. The drawing below shows the apparatus that we use to make oxygen.



Test for oxygen

One can also test whether the gas produced is really oxygen. If you put a glowing stick in a jar of oxygen, it will ignite.

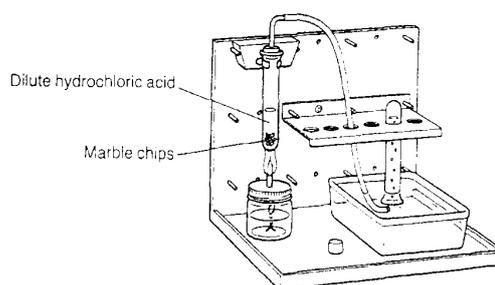


Practical Activity

Preparation of carbon dioxide

Carbon dioxide is an atmospheric gas comprised of one carbon and two oxygen atoms. It is a very widely known chemical compound, frequently called by its formula CO_2 . In its solid state, it is commonly known as dry ice.

Firstly, we have to set up an apparatus as shown in the diagram.



Source: Physical Science for Namibia Grade 8, Heinemann – 1992

1. Put a few marble chips (calcium carbonate) in the test-tube and add dilute hydrochloric acid until the tube is half-full. The carbon dioxide that is produced

will accumulate in the inverted tube that is filled with water.

2. When most of the water in the inverted tube has been forced out, put a rubber stopper on it. You now have a test-tube full of carbon dioxide.

Test for carbon dioxide

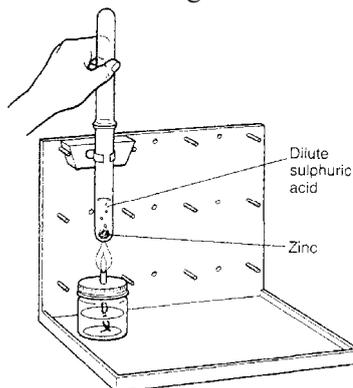
Clear limewater will turn milky when carbon dioxide is mixed with it. Limewater is a mixture of water and calcium hydroxide.



Practical Activity

Preparation of hydrogen in a laboratory

1. Put zinc and sulphuric acid in the test tube.
2. Put another test tube on top of the first test tube.
3. Heat the mixture of zinc and sulphuric acid.
4. Hydrogen gas will be released into the test tube above. This happens because hydrogen is less dense than air. The diagram shows how to do this preparation.



Source: Physical Science for Namibia Grade 8, Heinemann – 1992

Test for hydrogen

You can test whether the gas that is released is really hydrogen gas. If you put a burning stick or match in a container that contains hydrogen gas, it will make a popping sound. Hydrogen gas burns easily and can cause a fire.

I hope you enjoyed this section. Now its time to answer the questions in the following self-mark activity.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

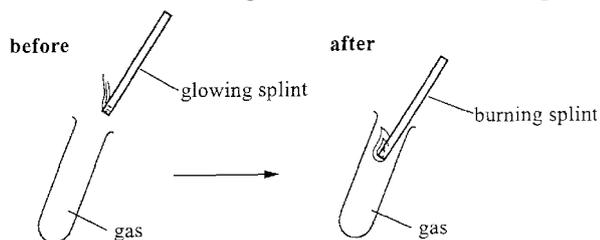
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. The pie chart shows the composition of clean atmospheric air. What is gas X? [Source: JSC 2004]



- A argon;
B carbon dioxide;
C hydrogen;
D nitrogen.
2. The diagrams show how a learner tried to identify the gas in a test-tube. Which gas was in the test-tube? [Source: JSC 2004]



- A carbon dioxide;
B hydrogen;
C nitrogen;
D oxygen.

3. When some metals react with water, like sodium, a gas is given off and when tested with a flame, it makes a popping sound.

Which gas is given off?

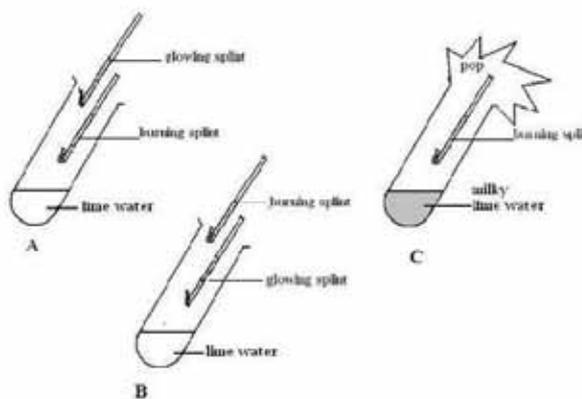
- A carbon dioxide;
- B helium;
- C hydrogen;
- D oxygen.

4(a) One of the by-products of burning fossil fuels is sulphur dioxide. Describe the effects of this product on the environment.

(b)(i) Describe how to test for oxygen and what the result will be.

(ii) Describe how to test for hydrogen and what the result will be.

5. Complete the table. Use the diagrams below to complete the last column of the table:



Test tube	Test for gas	Result of test	Gas produced	Diagram representing this gas
A	insert a glowing splint into gas	(a)	(b)	(c)
B	(d)	lime water milky white	(e)	(f)
C	(g)	(h)	hydrogen	(i)



6. Name the gas produced when:
- (a) zinc reacts with hydrochloric acid;
 - (b) manganese dioxide reacts with hydrogen peroxide.
- 7(a) Describe an experiment to show how the gas carbon dioxide can be prepared.
- (b) State two uses of carbon dioxide.
8. Which gas do fuels produce when they burn?
9. How is carbon monoxide produced?

I hope you could answer the questions. If you are satisfied with your progress you can start studying Section 5.

Section 5: The Commercial Preparation and Uses of Gases

Introduction

In Section 4 you learned how to prepare gases, such as oxygen, carbon dioxide and hydrogen in a laboratory. What about if you want to prepare gases in big amounts commercially? How will you prepare them?

Well, in this section, you will learn how to prepare gases commercially. You will also learn about the use of gases.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none">• <i>describe</i> the commercial preparation of oxygen, nitrogen and carbon dioxide;• <i>describe</i> the industrial process of converting nitrogen to ammonia and nitrates;• <i>discuss</i> the uses of oxygen in hospitals, for welding and making of steel;• <i>discuss</i> the uses of carbon dioxide as “dry ice”, in soda water, baking soda, fire extinguishers and as a cooling agent;• <i>discuss</i> the use of nitrogen in fertilizers
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for agriculture.



Time

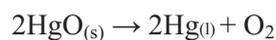
This section will take you about seven hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Metallic Commercial preparation of gases:

Oxygen (O₂)

Many oxygen-containing compounds can be decomposed to give oxygen, like the following reactions:

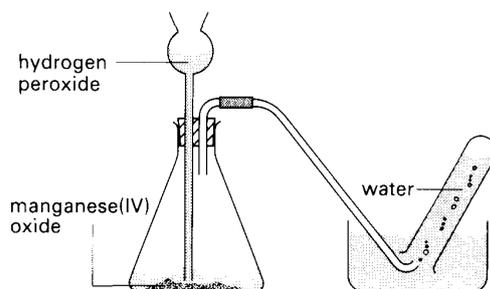
1. When you heat mercury oxide, you obtain mercury and oxygen:



2. Heating potassium nitrate, KNO₃, oxygen and a solid product (potassium nitrite, KNO₂) were formed:

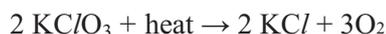


3. All nitrates decompose to provide oxygen as one of the products when they are heated.
4. In a laboratory, oxygen is usually prepared by allowing a solution of hydrogen peroxide, H₂O₂ a colourless liquid, to come into contact with powdered manganese(IV) oxide (manganese dioxide), MnO₂.





5. Small amounts of oxygen can be made in another way. Mix and heat equal parts of potassium chlorate ($KClO_3$) and manganese dioxide (MnO_2). The heat will break down the potassium chlorate into potassium chloride (KCl) and oxygen. The equation for this reaction is:



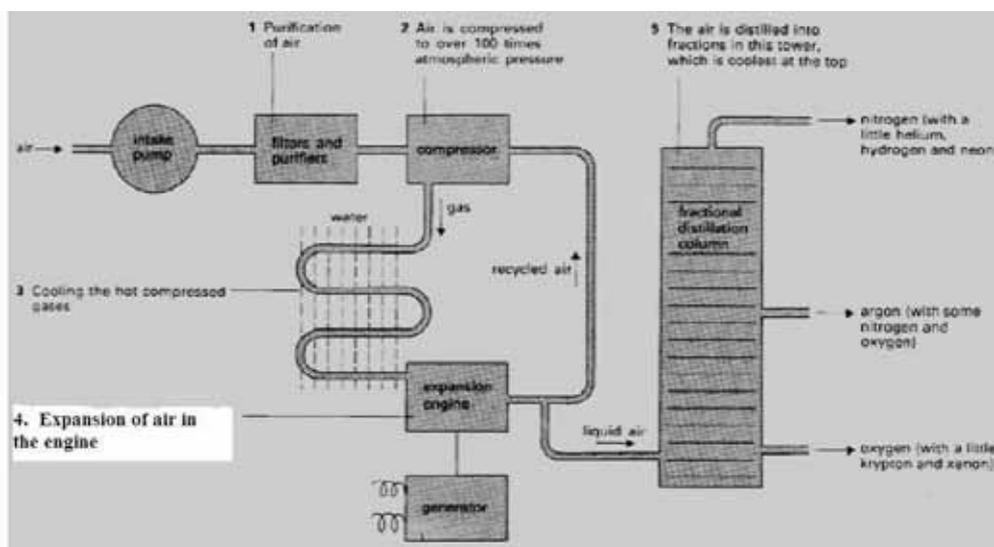
These methods of making oxygen that have been described are not suitable for making large amounts of oxygen. Oxygen for consumer use is usually made in large amounts either by electrolysis of water or by evaporation of liquid air.

One can use an electric current to break down water into its elements, oxygen and hydrogen. This process is called electrolysis. When using this method to make oxygen, hydrogen gas is an important by-product.

Lets see how can we use air to produce large amounts of gases for consumer use.

Commercial preparation of gases:

You can follow the steps numbered on the diagram below. Each step is explained in the paragraphs below the diagram.



Purification (1)

The air is filtered to remove dust, and then water and carbon dioxide are removed.

Liquefaction of air (2—4)

When a gas is compressed and then allowed to expand quickly, it cools. The air is compressed to over 100 times atmospheric pressure. As this happens, it

becomes hot. Still under pressure, it is cooled again by flowing water over the pipes. In the expansion engine, air expands rapidly and the temperature falls. By recycling the air, compressing it, then allowing it to expand, very low temperatures, low enough for the air to become liquid are reached. There is an energy bonus because the expansion engine can drive generators which provide electricity for other parts of the process, such as the compressor.

Fractional distillation of liquid air (5)

Fractional distillation takes place in a rectangular tower (see figure above) which is cooler inside at the top than at the bottom.

Components with the lowest boiling points become gases easily and are obtained as gases from the top of the tower. Thus nitrogen, with a little helium, hydrogen and neon, are obtained at the top.

Oxygen, a little krypton and xenon all with higher boiling points, are obtained from the bottom of the tower.

Argon mixed with some nitrogen and oxygen, comes out from the middle.

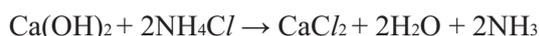
Pure gases are not obtained from the main column. More fractional distillation processes are needed.

Industrial process of converting nitrogen to ammonia and nitrates

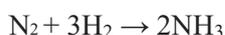
Ammonia is a colourless gas, less dense than air with a choking odour.

Ammonia is poisonous and extremely soluble in water. One litre of water can dissolve about 700 litres of ammonia gas at room temperature.

In a science laboratory, ammonia (NH_3) can be made by heating a mixture of calcium hydroxide ($\text{Ca}(\text{OH})_2$) and ammonium chloride (NH_4Cl). The chemical change that takes place is described by the following reaction:



Large amounts of ammonia are made for the commercial market by reacting nitrogen (N_2) with hydrogen (H_2), using a catalyst to speed up the process. This reaction takes place at about 600°C and at a pressure of about 1000 times normal air pressure. The equation for this reaction is:



Making nitrogen

In industry, nitrogen is separated from the air. The air is first passed through a filter to remove the dust particles. The air is then turned into a liquid by cooling it down to 200°C below zero (-200°C). As the air cools down, any water vapour turns to ice and is removed. At about -80°C , the carbon dioxide changes to solid carbon dioxide. This is a white solid that looks like ice but is much colder. The solid carbon dioxide is removed from the liquid air. Solid carbon dioxide is called 'dry ice' and is used for keeping things cold, because its temperature is -78°C and changes directly from solid to gas.



If you touch it, it will burn you!

The liquid air is pumped into the bottom of a tall tower. It is slowly heated. The gases boil off one at a time and are collected in cylinders. Nitrogen boils off first at $-196\text{ }^{\circ}\text{C}$, and then oxygen boils off at $-183\text{ }^{\circ}\text{C}$. Any other gases boil off at different temperatures. This process is called fractional distillation of liquid air.

Like oxygen, nitrogen gas is made up of pairs of nitrogen atoms joined to form molecules. The two atoms, making up each nitrogen molecule, are held together by three bonds. It takes a lot of energy to break these bonds before nitrogen can react with other elements. Because of this, nitrogen gas is very unreactive.

Where do we use nitrates in our daily life?

Nitrates

Some compounds contain nitrogen along with other elements. Ammonia (NH_3) is a compound of nitrogen and hydrogen, and nitric acid (HNO_3) contains nitrogen, hydrogen and oxygen). Bases are oxides of metals. Nitric acid will react with bases to form salts called nitrates.

Nitrates are important because they are needed by plants for growth. Plants get their nitrates either from the remains of other plants when they die and rot, or from dung from animals such as cattle that eat plants. We can also provide plants with nitrates by making artificial nitrate fertilisers. To make nitrates, it seems sensible to use nitrogen from the air. But because nitrogen gas is so unreactive, this is very difficult.

Making ammonia

In 1908, a German chemical engineer called Fritz Haber was the first person to combine nitrogen from the air with hydrogen to make ammonia, a useful product. His method is called the Haber process. It is quite easy to make nitrates from ammonia.

nitrogen + hydrogen \rightarrow ammonia
 $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$

The hydrogen used to make ammonia is made from natural gas. The hydrogen is mixed with nitrogen from the air and the mixture is compressed and heated to $450\text{ }^{\circ}\text{C}$. This mixture is then passed over iron, which acts as a catalyst. A catalyst is a substance that increases the speed of a chemical reaction. The gas mixture leaving the catalyst chamber is cooled and the ammonia gas condenses at $-33\text{ }^{\circ}\text{C}$ to form liquid ammonia. This is removed from the gas mixture.

The ammonia is used to make nitric acid. The nitric acid is then used to make nitrate salts, which are made into fertilisers.

Although we have to use the Haber process to make nitrates out of the nitrogen in the air, there are a few bacteria that make nitrates easily all of the time. These bacteria live on the roots of plants such as thorn trees called acacias common in Namibia and also peas and beans. These bacteria are called nitrogen-fixing bacteria and the process is called nitrogen fixing.

Nitrogen-fixing bacteria turn nitrogen from the air into nitrates. Plants use the nitrates to produce proteins and other compounds that contain nitrogen. Animals eat the plants and so they also obtain the nitrogen they need to make them grow.

Nitrates are all very soluble in water. This can cause a problem when it rains. The nitrates dissolve easily in fast-flowing water and so the soil in Namibia does not contain a high concentration of nitrates. If too much nitrate gets into water, it causes pollution.

Now, you will learn about the uses of carbon dioxide and oxygen.

Uses of gases

Uses of Carbon dioxide

- 1.** Carbon dioxide extinguishers have a strong, steel cylinder that holds liquid carbon dioxide under great pressure. When you open the valve of an extinguisher, carbon dioxide rushes out through a cone-shaped nozzle. The cooling effect of the sudden expansion changes most of the escaping gas into carbon dioxide “snow.” The “snow” is about -80°C and is so cold that it lowers the temperature of burning material below its kindling point. The heat from a fire causes the “snow” to change to heavy CO_2 gas, pushing away the oxygen. The carbon dioxide does not harm home furnishings. The liquid CO_2 extinguisher works well against oil and electrical fires. Carbon dioxide is also used in fire extinguishers as a desirable alternative to water for most fires.
- 2.** Carbon dioxide is also popular in the carbonation of cold drinks, to put the fizz in the cold drink known as soda drinks or carbonated drinks.
- 3.** Large quantities of solid carbon dioxide (i.e. in the form of dry ice) are used in processes requiring large-scale refrigeration. Liquid and solid carbon dioxide are important refrigerants, especially in the food industry, where they are used during the transportation and storage of ice cream and other frozen foods. Solid carbon dioxide is called “dry ice” and is used for small shipments where refrigeration equipment is not practical.
- 4.** It is a constituent of medical gases as it promotes exhalation. Carbon dioxide has begun to attract attention in the pharmaceutical and other chemical processing industries as a less toxic alternative to more traditional



solvents such as organo-chlorides. It is used by some dry cleaners for this reason. In medicine, up to 5% carbon dioxide is added to pure oxygen to stimulate breathing after apnoea (*a condition in which somebody stops breathing temporarily while they are sleeping*) and to stabilize the $O_2:CO_2$ balance in blood.

5. The leavening agents used in baking powder produce carbon dioxide which cause dough to rise. Baker's yeast produces carbon dioxide by fermentation within the dough, while chemical leaveners such as baking powder and baking soda release carbon dioxide when heated or exposed to acids.

Uses of Oxygen

You will see cylinders of oxygen in Namibia in hospitals and in some repair garages. Oxygen is used in hospitals to help people breathe when they are seriously ill.

In repair garages, oxygen is used with another gas called acetylene to weld pieces of steel together. The flame produced when acetylene burns in pure oxygen is so hot it can melt steel.

Oxygen is used for steel making. The crude iron extracted from iron ore contains a lot of impurities such as carbon and sulphur. Oxygen is blown through the liquid iron. These impurities burn in it and come out as the gases carbon dioxide and sulphur dioxide.

Oxygen is also used for breathing or burning in places where there is not enough air. Examples where oxygen is used include diving under water, in high-flying aircraft and in rockets.

Try the next self-mark activity to see how well you have understood the preparation of different gases.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. You are given two tubes of a colourless gas. Describe how you would find out which tube contains oxygen.
2. Name the gas that would be produced when a fuel burns.
3. Some wet rotting leaves were placed in a jam jar. A small open tube of limewater was also put in the jar. The lid was then screwed onto the jar. After a day or two, the limewater turned milky.
 - (a) Explain why the limewater turned milky.
 - (b) Explain what the experiment tells you about the events that occur when organic material (leaves) rot.
4. Write down which chemicals we can add together to produce hydrogen.
5. Describe how you would test for hydrogen.
6. Give an example of a fuel.
7. Name the three main methods involved in the commercial preparation of gases.
- 8(a) What is the process called whereby ammonia is produced from nitrogen and hydrogen.
 - (b) Write a word equation of the process.



Section 6: Pollution of the Air

Introduction

When we pollute something, we make it dirty or impure. With air pollution, we mean the process by which we make air impure. Can you think of any substance that can pollute the air? Air pollution is caused by solid particles or by gases. Did you know that air pollution is usually caused by human activities? Air pollution damages the environment. We will now discuss pollution in this section.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none">• <i>investigate</i> and <i>describe</i> the pollution of air by gases such as carbon monoxide, carbon dioxide, sulphur dioxide and nitrogen oxides caused when substances burn;• <i>explain</i> the incomplete combustion of carbon in the formation of carbon monoxide within the context of a problem of confined spaces and the dangers to humans;• <i>describe</i> sulphur dioxide and nitrogen oxides in terms of their quality as acidic oxides which combine with water in the air to form acid rain;• <i>outline</i> the consequences of acid rain for the environment;• <i>describe</i> the main pollutants resulting from vehicle exhausts such as unburned hydrocarbons, carbon monoxide, nitrogen oxides and lead compounds;• <i>discuss</i> the dangers of lead pollution in conjunction with the use of lead-free petrol as one measure to reduce the pollution of the air;• <i>describe</i> the use of catalysts in the exhaust systems of vehicles to reduce the emission of harmful gases;• <i>investigate</i> the pollution of air by solid particles, such as smoke and dust;• ;• <i>identify</i> the causes of air pollution in
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your area.



Time

This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Pollution of air by gases

Many gases are harmful to the environment. We will discuss different gases that pollute the air. We will also see how they affect the environment. As you may remember, carbon monoxide is one of the gases that pollute the air.

Pollution of air by carbon monoxide

Incomplete combustion takes place when a fuel is burnt in little oxygen. We have already discussed the term combustion in Unit 4, Section 1. Do you remember what it means? Yes, combustion is the burning of substances in oxygen. Therefore, when there is not enough air, combustion cannot take place completely. Thus, carbon monoxide and unburnt hydrocarbons are produced.

Carbon monoxide is a poisonous gas which can kill a person. How does it kill a person? When it gets into the bloodstream, carbon monoxide prevents the blood from taking oxygen around the body because it carries the carbon monoxide instead of oxygen. The unburnt hydrocarbons can cause both lung problems and lung cancer.

Carbon dioxide

Carbon dioxide is produced when fuels burn. Do you still remember what fuels are? Plants use carbon dioxide during the photosynthesis process to produce carbohydrates. Scientists worry that more carbon dioxide is released into the air than is used up by plants during photosynthesis.

When there is too much carbon dioxide in the air, it allows heat to reach the earth from the sun, but it stops heat from escaping back into space. This process is known as the greenhouse effect. This greenhouse effect causes the earth temperatures to rise which in turn causes changes in the climate. This is called global warming. The following activities have caused increased greenhouse gas concentrations:

1. fossil fuel burning;



2. deforestation.

Sulphur dioxide

When fuels that contain sulphur burn in oxygen, they release sulphur dioxide. Most power stations like the Van Eck power station in Windhoek, releases sulphur dioxide as one by-product of burning coal. At Tsumeb, where melting of copper ore takes place, a lot of sulphur dioxide is produced and released into the air. This sulphur dioxide gas is a colourless, poisonous gas that has an irritating smell. Sulphur dioxide produces acid rain that damages the waxy coating of plant leaves and prevents chlorophyll formation. It also damages stone and concrete buildings.

Nitrogen oxides

These gases are released by cars. They are formed when nitrogen and oxygen present in the air combine inside the engine of a car at high temperatures and pressure. Nitrogen oxides are poisonous gases. They can harm people who have lung diseases. Nitrogen oxides also dissolve in rainwater to produce acid rain. Acid rain has the following consequences for the environment. It:

- damages plants and animals;
- corrodes buildings;
- damages the waxy coating of plants that protect the leaves;
- prevents chlorophyll-formation.

Lead pollution

Petrol burns very easily. Because of this, a compound containing lead is added to it to prevent it from exploding. This is why the exhaust gases from cars contain some lead. These lead compounds are poisonous and can cause brain damage in young children who are exposed to high amounts of these substances. Unleaded petrol is used these days to prevent lead pollution.

Solution to Pollution caused by Vehicles



New cars are now being built to give off much smaller amounts of nitrogen

oxide. Small devices in their exhaust pipes called catalytic converters change these gases into less harmful substances. Cars with catalytic converters must use unleaded petrol because lead in the fuel destroys the catalysts. Unleaded petrol that is also sold in Namibia, does not contain lead.

Pollution of air by solid particles

Most solid particles come from burning objects that release smoke and ash into the air. Dust is also a solid particle that can cause pollution. Dust comes from the soil. Solid particles such as dust can make buildings and clothes dirty. They can also get into people's lungs and cause breathing problems.

Now that we have completed the section on air pollution. Now its time to answer the questions in the following self-mark activity.



Self-Mark Activity



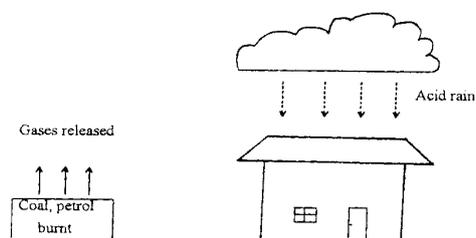
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Study the diagram below and answer the questions that follow.
[Source: JSC1996]



- (a) Name two gases that are mainly responsible for acid rain.
- (b)(i) Write down the name of the town in Namibia that acid rain is mostly likely to be found.
(ii) Give a reason for your answer.
- (c) Explain the effect of acid rain on plants.
2. Which gas in car exhaust fumes is a product of the incomplete combustion of petrol? [Source: JSC 1999]



- A carbon monoxide;
B nitrogen oxides;
C sulphur oxides;
D water.

3. When a car burns petrol, other gases are also produced. The following table shows some of these.

Harmful gases	Percentage (%)
Carbon monoxide	6.5
Hydrocarbons	0.2
Oxide of nitrogen	0.25
Sulphur dioxide	0.005

- (a) Explain why carbon monoxide is present in the exhaust fumes.
- (b) Explain how carbon monoxide can affect the health of people.
- (c) Explain how the oxides of nitrogen are formed in the car engine.
- (d) Explain the effects of nitrogen oxide and sulphur dioxide on the environment.
- (e) Explain how the amounts of these gases produced are being reduced in modern cars.
4. Which measurement is taken to prevent lead pollution.

Now that you have completed this activity, you can now move on to the last section of this unit.

Section 7: Water

Introduction

Water is very important for all forms of life, including human beings. In this section, we will discuss the different sources of water, its importance and the difference between hard and soft water. We hope you will find this section interesting.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>discuss</i> the distribution, availability and effective utilisation of water in Namibia taking into consideration their existence in various places such as in
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	<p>dams, underground rivers and lakes;</p> <ul style="list-style-type: none">• <i>compare</i> a test for water such as the chemical test (using anhydrous copper sulphate) with an alternative test using cobalt (II) or a physical test (using physical properties of water such as melting and boiling points and density).• <i>determine</i> the density of water and ice by conducting an experiment to calculate the density of ice;• <i>explain</i> the unusual expansion of water when the temperature drops from 4°C to 0°C and examine the practical implications of this phenomenon and its importance for the survival of aquatic animals and plants;• <i>evaluate</i> soft and hard water in terms of the ease with which they form a lather with soap and explain how lather is formed;• <i>identify</i> hard water as containing dissolved salts of calcium and magnesium;• <i>distinguish</i> between temporary and permanent hardness of water and establish that temporary hard water is caused by the presence of calcium and/or magnesium hydrogen carbonate;• state how temporary hard water can be made soft by boiling and why “scale” is formed in hot water kettles and geysers;• <i>describe</i> the removal of scale from a kettle by the reaction with dilute acid;• <i>analyse</i> the water consumption of your family and your area in terms of spillage, leaking water pipes and taps.
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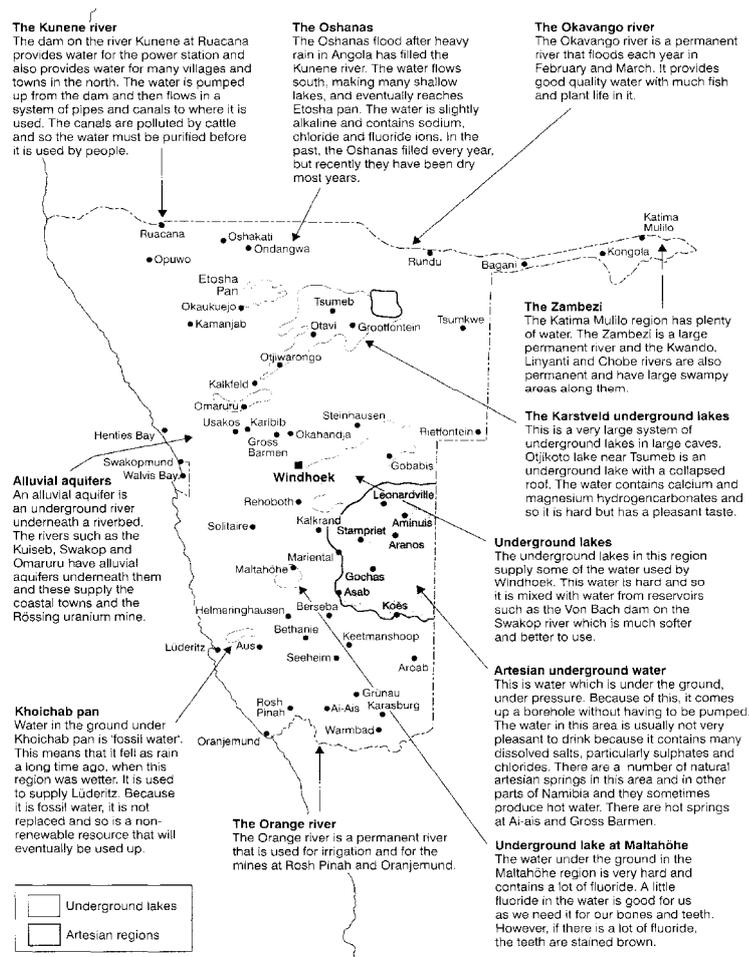


Time

This section will take you about 15 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Distribution and availability of water in Namibia

The availability of water varies in Namibia from place to place. The map below shows different types of water available in different areas of the country.



Source: Physical Science for Namibia Grade 10, Heinemann - 1994

Namibia is classified as an arid (dry) country. The water at our disposal is mainly from underground sources. Some water comes from dams and some from purification plants, such as in Windhoek. Water is very important for all forms of life, including human beings.

Drinking water comes from many sources. The source of your drinking water depends on where you live. In rural areas, water is pumped from wells, springs or streams.



Wells should be dug as far away as possible from places where organic materials might make the water unfit for human use. Health officials report that many farm wells are a danger to health because they are poorly located or poorly built. If a well is built with loose stones, impure surface water may seep into the water supply.

How do you test if a liquid is really water? There are the physical properties of water that can be used to test if a liquid is really water. In addition, there are also chemical tests that can be used. We will now discuss various ways that you can use to test for water.

Test for Water: The Physical properties of water

The physical properties of water describe how it should look and taste. Water is colourless, odourless and tasteless. It has a freezing point of 0°C and a boiling point of 100°C. You have seen it exist in all three phases: solid, liquid and gas.

Water that is fit to drink is called potable water. It must be clear, colourless, pleasant tasting, free of harmful bacteria and fairly free of dissolved solids. A small amount of dissolved air gives water a better taste.

Test for Water: A Chemical test for water

There are many colourless liquids that are not water. How can we test that they are not water? You can do this by performing the following actions:

1. Get some anhydrous white copper sulphate. If you add water to it, the solution will turn blue. However, if you add any other liquid to the anhydrous white copper sulphate, the solution will not turn blue.
2. Get some anhydrous blue cobalt chloride. If you add water to it, the solution turns red or pink.

Test for Water: The Density of water and ice

The density of water can also be used to test whether a liquid is water.

The density of water is determined by weighing the mass of 1.0 cm³ of water. This will be 1 gram. Density can be calculated by the formula $\frac{\text{mass}}{\text{volume}}$. Therefore, the density of water is $\frac{1\text{ g}}{1.0\text{ cm}^3}$ which is 1.0 g/cm³.

The density of ice will be determined the same way. Weigh the mass of 1.0 cm^3 of ice. You will find that this is less than 1.0 g/cm^3 . The volume of ice is about 1.1 times that of the water from which it was formed. In other words, the ice is less dense than the water, therefore it floats.

The simplest way to show that ice is less dense than water is to put a piece of ice in a glass of water. The ice cube immediately rises to the top of the water and floats partially on the water. This shows that ice is less dense than water.

Expansion of water

When water cools to below 4°C , it expands. This means that it occupies a bigger space. What happens when you freeze a bottle full of water? The bottle will burst because water expands when it freezes. Ice is less dense than water. Thus, ice floats on water.

Water, like almost any other substance, will shrink as it cools. However, unlike other substances, this quality of water reverses at 4°C . In other words, at 4°C water expands as it is cooled to freezing point. When water is heated from 0°C to 4°C , it contracts. This behaviour of water between 4°C and 0°C is of great value to all of us.

Because of this odd property, lakes freeze on top instead of at the bottom. Otherwise, lakes would freeze from the bottom up. Also, if this were the case, in the summers, much of the ice would not melt. In addition as a consequence, in time, all lakes and oceans would be mostly ice.

Fortunately, water does expand near freezing point. When cooled below 4°C , water becomes less dense and rises. When it freezes into ice, it expands still more. Ice floating serves as a blanket to protect the rest of the water from freezing quickly. Water close to the surface of an ice-covered lake is at 0°C . Water at the bottom of a lake is at 4°C .

Water is at its greatest density at 4°C and thus stays at the bottom when there is some ice on top. If you have ever broken through ice in a bucket in winter, you know that there is water at the bottom of the bucket. The water at the bottom is about 4°C warmer than at the surface.

Water is the most important exception to the common rule that a substance contracts when it changes from a liquid to a solid.



Survival of aquatic animals and plants

Plants, animals, and other life forms have adapted to live and reproduce in aquatic habitats. Namibia's waters are home to thousands of plant and animal species.

Plants

Aquatic plants are essential in aquatic ecosystems. They provide oxygen, food, shelter and protect shorelines and stream banks from eroding. They have adapted to living in, on or near water and are divided into several groups.

Algae and plants

Algae are single-celled aquatic plants. They often are the producers in aquatic food webs. Algae are unique. This is the case because although they may form spheres, sheets or filaments, each cell acts like an independent organism. They are the simplest of all plants.

Sub-emergent plants are rooted and grow in water depths from about one foot to the depth where sunlight reaches the bottom. Sub-emergent plants provide hiding places for small fish and invertebrates.

Floating-leafed plants grow in water from about one to ten feet deep. They are rooted and have long, flexible stems with leaves that float on the water's surface. There also are free-floating plants that have small leaves with roots dangling in the water. Duckweed is a well known free-floater that is essential food for waterfowls.

Fish

There are many species of fish found in Namibian waters. Some are found throughout the year in many different kinds of water.

Amphibians

Amphibians have smooth, moist skin with many glands. They have four limbs and digits without claws. There are five kinds of salamanders and 16 types of frogs.

Reptiles

Reptiles (like amphibians) are cold-blooded. They have dry, scaly skin with almost no glands and their digits have claws. This group includes turtles and snakes. Some species of reptiles are dependent on aquatic habitats. However, most can live and reproduce great distances from water.

Birds

Of the many species of birds that have been seen in Namibia, many are usually found in some sort of wetland habitat. Lakes and streams provide essential habitat for many other species. The lagoon area (Walvis Bay) and other such areas house many of these birds.

Waterfowl (e.g., swans, geese, ducks) are built to manoeuvre in water. They float, have webbed feet for speedy, over-water locomotion. They also have waterproof feathers and insulating fine feathers, and some can even use their wings to propel them under water. Fish eagles can be seen near water scouting for fish. Fish eagles mate for life and usually use the same nest year after year.

Mammals

Many small mammals are associated with aquatic habitats. Mice, voles and shrews can be found tunnelling through grass at the water's edge. Several species of bats can be seen in foraging flights for insects over water in the evenings. Muskrat and river otters are larger mammals that are closely linked to water.

The otter is a playful furbearer that has rich brown fur with a light underside and greyish throat and chin. These graceful swimmers like to use abandoned lodges of beavers for their home.

Now, let us look at the different types of water, namely hard and soft water.

Soft and hard water

Water that lathers easily when soap is added to it is called soft water. Hard water does not lather easily with soap. The hardness of water is caused by substances that are dissolved in water. These substances are the salts of calcium or magnesium which have been dissolved in the water of rivers or underground water sources.

Scum is formed when soap and the salts of calcium or magnesium react with each other. Scum is the product of soap and the calcium and magnesium salts in water.

Water can be hard or soft. This does not mean it is ice or liquid. Making water drinkable, is only one problem that people face. If you live in an area of our country where the water is hard, then you are well aware of the problems it creates.



Hard water is water that precipitates. This means that it forms a solid dust that makes the water milky like in soap. The word “hard” means “it is hard to make lather with.” Clothes cannot be properly cleaned with ordinary soap in hard water. The scum that forms leaves a greasy film on the fabric and gives it a dirty look. Distilled water is free of hardness and is called soft water.

When water falls as rain, it dissolves some carbon dioxide in the air. When it rains, the water soaks through the ground, dissolving more carbon dioxide from dead roots and other plant matter. If this carbon dioxide water flows over limestone (CaCO_3), a reaction takes place. This reaction forms calcium bicarbonate. The calcium bicarbonate dissolves in the water, forming calcium ions in solution. This is the greatest cause of hard water. Soluble magnesium and iron salts also produce ions that cause hardness in water.

When soap is added to hard water it forms a solution in which the soap does not seem to dissolve. An oily like, sticky material (curd solution) is produced as a result of the reaction of the calcium ions in the water with the soap. In other words, an insoluble calcium compound is formed. You may have seen this curd as the greasy ring that forms around a washbowl or bathtub.

To get a lasting lather with soap and hard water, all of the curd-forming ions must first be precipitated out of the solution. More soap is required for this. Obviously, this method of taking out the unwanted ions is wasteful and better means of softening water have been developed.

Temporary and permanent hardness of water

Sometimes hard water can be turned into soft water by boiling the water. This kind of hardness is caused by the presence of calcium hydrogen carbonate (calcium bicarbonate) in water. This is called temporary water hardness. The calcium hydrogen carbonate decomposes when the water is boiled and the water becomes soft. Temporary hard water is found in the area around Tsumeb.

Carbon dioxide is released into the air and the calcium carbonate precipitate settles out. The action of the soap is not affected by the calcium carbonate, because the calcium carbonate does not break down into calcium ions. However, softening large amounts of water containing calcium bicarbonate by boiling is costly because it uses too much energy.

Hard water that is permanent cannot be changed into soft water after boiling. It is caused by calcium sulphate. The calcium sulphate cannot be removed by heating or boiling.

Removal of scale

One can remove the scales that form on the element and bottom of a kettle by reaction with dilute acid. The scales are nothing other than a carbonate. Scales are formed when water is boiled, the water evaporates and only the salts remain behind. These salts are carbonates that are found in water, such as calcium hydrogen carbonate.

Carbonates react with acids to produce a soluble salt, water and carbon dioxide.

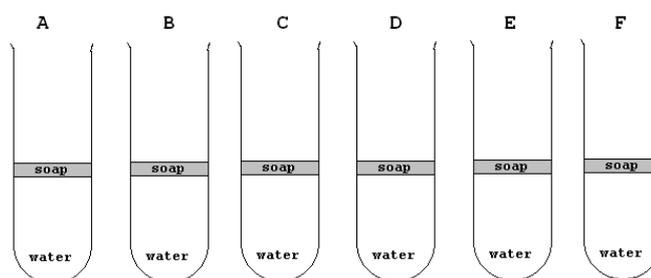


Practical Activity

Activity

How can we test for hardness in water?

Materials needed: Six test tubes, liquid soap (not detergent) dropper, samples of water from different places (tap water, rainwater or distilled water, river water, pond water, borehole water)



Method:

1. Pour about 10cm^3 of each type of water into the different test tubes.
2. Put a drop of liquid soap in each test tube.
3. Put your finger over the top of each test tube and shake it to produce lather.
4. Add more liquid soap and shake again.
5. Keep adding drops until the lather lasts for at least one minute.
6. Write your results in a table like the one here.

Table:



	Water	Drops of soap	Height of lather	Hard/soft water
	A			
	B			
	C			
	D			
	E			
	F			

Compare the number of drops of soap you needed and the height of the lather to determine whether it is hard or soft water.

Hard water will need more drops of soap and the height of the lather will be low compared to soft water.

Water consumption

We waste much of our water. About 65% of our water is lost through bathrooms and 20% when washing clothes. The rest goes to watering plants and some for cooking.

We should conserve water because it is the right thing to do. Encourage people around you to be part of a water saving community. Report any significant water spills and broken pipes to the relevant people. Encourage your community to do the same. Try to do one thing each day that will result in saving water—remember each drop counts.

A dripping tap is very annoying. Just consider the following for a minute:

60 drops per minute result in 800 litres of water lost per month
 90 drops per minute result in 1,400 litres of water lost per month
 120 drops per minute result in 1,900 litres of water lost per month

ALL WATER IS RECYCLED

We drink the same water that Brontosaurus, Cleopatra and Julius Caesar did. Future generations will drink that very same water. That is why it is important that we use water wisely and protect water supplies whenever and wherever possible. If we each save a small amount of water each day, our combined savings will add up to millions of litres each year.

Water saved is money saved! Water conservation can save on water and sewer fees. Also, when you use less water, your water bills are lower. Even if you use well water, saving water reduces both electricity costs and the waste load going into your septic system.

Each day, as you drink water and use water, think of things you could do to help conserve and protect it. For starters, here is a list of household water conservation tips:

- Stop unnecessary running taps.
- Fix leaking taps and leaking pipes.
- Don't run water down the drain for no reason at all.
- Don't over water a garden.
- Lawns need about 10 minutes of sprinkler water every third day. Install sprinkler systems in gardens.
- Use a broom instead of a water hose to clean a driveway.
- What other tips could you add?

Do the self-mark activity now to test whether you have understood the work covered in this section well enough.



Self-Mark Activity



Self-Mark Activity

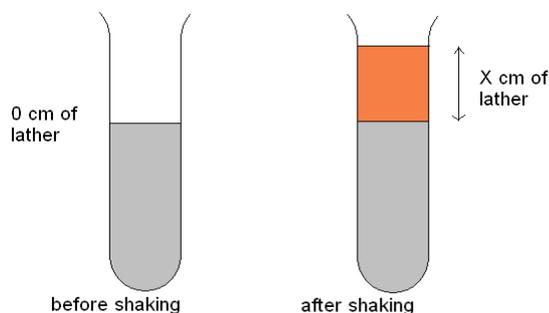
Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- Describe the chemical test for water.
- Give the physical properties of water.
- 3(a)** Learners investigated FIVE samples of water (O, P, Q, R and S) for hardness. They used the same volume of soap solution and samples of water in all experiments.

The experiment was done with unboiled water and with boiled water. The diagram shows the test tubes with water and soap solutions before and after shaking. [Source: JSC 2000]



The height of lather formed after shaking for 20 seconds was measured for samples of unboiled and boiled water and recorded in the table.

Water sample	Height, x cm of lather after 20 seconds	
	Unboiled water	Boiled water
O	1	5
P	0.2	3
Q	0.2	0.2
R	1	4

S	0.2	0.2
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- (i) Suggest why learners used the same volume of soap solution and samples of water in all experiments.
- (ii) Write down which samples of water were permanently hard.
- (iii) Give a reason why none of the samples contained soft water.
- (iv) Name two samples of water that were temporarily hard?
- (v) Name what causes temporary hardness of water.
- (b) Write down what product is formed when soap mixes with hard water.
- (c) Calvin's aunt asks him to clean the scale formed inside the kettle. Describe briefly how Calvin can remove the scale chemically.
4. Which ions are responsible for permanently hard water?
- A calcium bicarbonate;
B calcium carbonate;
C calcium nitrate;
D calcium sulphate.
5. Consider the following scenario:
The Case of the Mysterious Water Use
Mrs. Jackson has called the water detectives to help her solve a serious problem. She has heard that the detectives have an excellent record for solving mysteries.
What seems to be the problem?" asked one of the water detectives.
"Well," said Mrs. Jackson, "as you know, I rent out several apartments to college students. I never allow more than four students to stay in one apartment. But, in apartment 319, I just know that there are more than four people. I just can't prove it."
One of the water detectives interrupted her with a question, "Have you ever tried making surprise visits?"
"Yes," she answered, "but every time I go there, four people or less are at home. Those college students come and go at all hours of the day and night. There is no way for me to keep track of how many students actually share the apartment."
"Very interesting," said one of the detectives. "I think we can help you, but first we'll need to see last month's water bill for the apartment."



“How will that help?” asked Mrs. Jackson.

“We’ll be able to see how many litres of water were used last month,” said another water detective.

Mrs. Jackson found the bill. It revealed that last month the occupants used 67,500 litres.

“Let’s see,” said one of the detectives. “Last month was September, which has 30 days.

If we divide 67,500 litres by 30 days, we know that they used 2,250 litres a day.”

“Yes,” said Mrs. Jackson, “but is that a little or a lot?”

“We’ll have to investigate and get back to you. We’ll do a survey to find out how much the average person uses,” said the detective.

With that, the water detectives left Mrs. Jackson with a promise to return soon with an estimate of how many people were sharing the apartment. The water detectives decided that they needed to do some research to determine how much water people use in one day. In order to come up with an estimate, they decided to find out how much water their own families use in one day. Here’s how:

5.1 Record the facts of the case.

(a) The people in the apartment used _____ litres of water in September.

(b) September has _____ days.

(c) The average number of litres of water used per day was _____ litres.

5.2 Form a hypothesis.

Write down how many litres of water a day you think a person uses. _____ litres.

5.3 Fill out the water survey.

SURVEY:

Determine how much water you use.

DIRECTIONS: This is a survey to find how much water you use in your home during one full week. Place a tally mark in the Times Per Day column every time someone in your family does the activity.

NOTE: Another significant seasonal water use is lawn and garden watering. This survey deals with daily water use in the home, but most of us use additional amounts of water at school, at work, and other places throughout the day.

These are estimated values.

ACTIVITY	TIMES PER DAY							WEEKLY TOTAL	WATER PER ACTIVITY*	TOTAL WATER USED
	Sun	Mon	Tues	Wed	Thurs	Fri	Sat			
Toilet Flushing	<input type="checkbox"/>	=	_____ x 23 litres	= _____						
Short Shower (5-10 minutes)	<input type="checkbox"/>	=	_____ x 113 litres	= _____						
Long Shower (>10 minutes)	<input type="checkbox"/>	=	_____ x 158 litres	= _____						
Tub Bath	<input type="checkbox"/>	=	_____ x 158 litres	= _____						
Teeth Brushing	<input type="checkbox"/>	=	_____ x 9 litres	= _____						
Washing Dishes with Running Water	<input type="checkbox"/>	=	_____ x 135 litres	= _____						
Washing Dishes Filling a Basin	<input type="checkbox"/>	=	_____ x 45 litres	= _____						
Using Dishwasher	<input type="checkbox"/>	=	_____ x 90 litres	= _____						
Washing Clothes	<input type="checkbox"/>	=	_____ x 180 litres	= _____						
GRAND TOTAL								=	_____	= _____

5.4 Record your conclusions.

(a) Write down how many total litres of water your family used in one day. _____ litres

(b) Write down the average number of litres of water used per person per day in your family. _____ litres

(c) Based on your results, write down how many people you think are living in Mrs. Jackson's apartment.
_____ people

(d) Compare your answer with the answers of other students.

6. To find the average use per person in your family, divide the grand total by the number of people in your family. The answer is: _____

6.1 In your home, select which activity takes place most often.

6.2 Write down which activities use the most water each time they occur.

6.3 Write down what other activities at home consume large amounts of water.

6.4 Discuss why might your answer differ from that of other people.



7. What is the density of water.

8. What happen to water when cools below 4°C.

We have come to the end of this unit. To ensure that you have understood the material, spend a few hours reviewing what we have covered in this unit.



Summary

In this unit you learned that :

- substances can undergo temporary or permanent changes;
- temporary changes are physical changes in which no new substances are made;
- permanent changes are chemical changes in which new substances are made;
- exothermic reactions release heat energy to the surroundings, in other words, it becomes hot;
- endothermic reactions take heat from the surroundings for reactions to occur;
- combustion is called burning, when substances burn in oxygen;
- during decomposition reactions, larger or more complex compounds are broken down into simpler substances;
- a synthesis reaction is a reaction in which two or more substances combine to form a new compound;
- blue litmus paper turns red in the presence of an acid;
- an alkali turns red litmus blue;
- metals are shiny, good conductors of heat and electricity, have high melting and boiling points and can bend and stretch;
- the pH of a solution tells you how

	<p>acidic or basic a solution is;</p> <ul style="list-style-type: none">• pure water has a pH of 7 and is therefore neutral;• any solution with a pH less than 7 is acid, and a pH greater than 7 is a basic solution;• the pH of a solution can be determined by using universal indicator paper;• neutralisation is a reaction between bases and acids to form a salt and water;• the test for oxygen is putting a glowing stick in oxygen and it will ignite;• carbon dioxide will turn limewater milky;• a burning stick in hydrogen gas will make a popping sound;• white anhydrous copper sulphate will turn blue in the presence of water;• anhydrous blue cobalt chloride turns pink if water is added to it;• soft water lathers easily with soap while hard water does not;• calcium hydrogen carbonate causes temporary hard water which turns soft after boiling.
--	---



Answers to Self-Mark
Activities

Section 1: Chemical and Physical Changes

1(a) G

(b) D

(c) J

(d) I

(e) H

(f) A

(g) F

(h) E

2. D

3. C

4. C

5. B

6(a) candlewax + oxygen \rightarrow carbon dioxide + water

(b) combustion reaction

(c) Substance burns in air and forms an oxide, in this case, carbon dioxide.

(d) Sugar is decomposing and dehydrated to carbon and water.

7(a)(i) Simple substances combine to form a complex substance.

(ii) Complex substance is broken down into simple substances.

(iii) Heat energy is given off to surroundings.

(b)(i) The burning paper is the chemical reaction because new substances are formed.

(ii) colour changes permanently, new substance, ash, difficult to reverse.

Section 2: Acid, Bases and Alkali

1(i) an acid + a metal \rightarrow **metal salt + hydrogen**

(ii) hydrochloric acid + magnesium \rightarrow **magnesium chloride + hydrogen**

2(a)(i) blue litmus paper turns red

(ii) red litmus paper turns blue

(iii)

pH of solution	0-3	4	5	6	7	8	9-10	11-14
Colour of universal indicator	red				green			violet

(b)(i) $0 < 7$

(ii) $>7 - 14$

3(a)(i) In a strong acid, nearly all the acid molecules form ions; it ionises completely. In a weak acid, only some of the acid molecules form ions, therefore ionisation is incomplete. So, a strong acid always has a lower pH number than a weak acid of the same concentration.

(ii) Weak acid does not ionise completely and a dilute acid has more water molecules than acid molecules in solution.

(iii) Sulphuric acid is a strong acid because it ionises completely, but acetic acid is a weak acid because not all H-ions are ionised.



(iv) Yes, there are more acid ions to corrode the substance.

4(a)(i) It is a numerical indication to show if a substance is a base or an acid.

(ii) H-ion

(iii) OH-ion

(b) Use universal indicator.

(c) lime water (calcium hydroxide solution) – pH of 12.5, strong alkali
vinegar – pH of 3, weak acid
salt – pH of 7, no hydrogen nor hydroxide ions
baking soda – pH 10, ionises, because it has OH ions



6. B

7. C

8. C

9. B

10(a)(i) acid $1 - < 7$

(ii) base $> 7 - 14$

(iii) neutral 7

(b) 5 spatulas

(c) base

(d) Acid + Base \rightarrow salt + water

(e) acids - sour taste
- litmus goes red
bases - soapy feeling
- litmus goes blue

11. Metals are shiny.

Metals conduct electricity.

Metals bend and stretch.

Metals have high melting points.

Metals are strong. (any three)

Section 3: Neutralisation

1. B

2. A

3(a) sulphuric acid + copper oxide \rightarrow copper sulphate + water

(b) sodium hydroxide + hydrochloric acid \rightarrow sodium chloride + water

4(a) sodium hydrogen carbonate + hydrochloric acid \rightarrow

sodium chloride + water + carbon dioxide

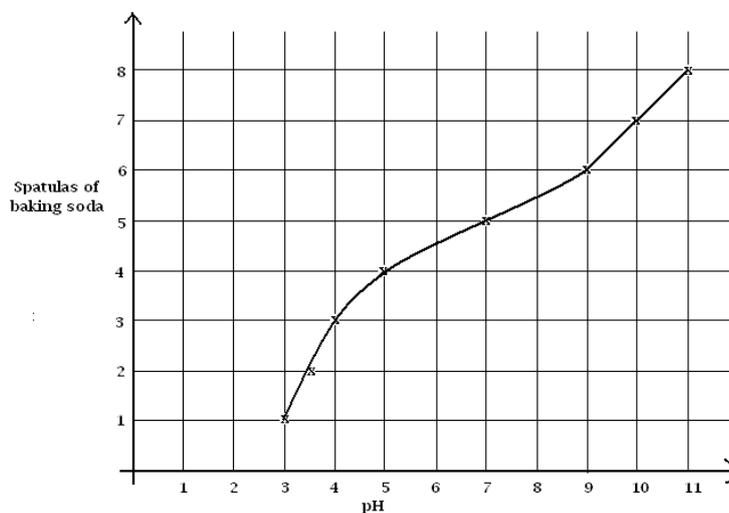
(b)(i) neutralisation reaction

(ii) The acid and base destroy each other and a salt and water will be formed.

(c)(i) blue \rightarrow green \rightarrow red

(ii) green solution is neutral

(d)(i)



(ii) 5 spatulas of baking soda turn the solution to a pH of 7.

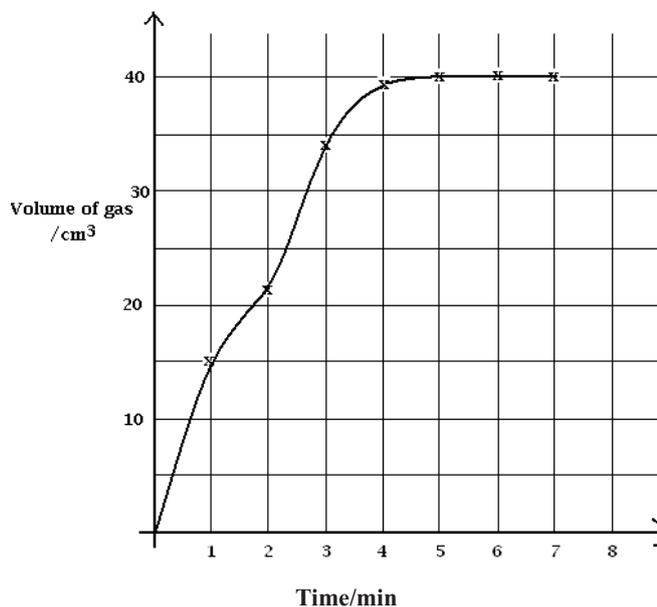
(iii) Basic, because the pH went to 11, which is alkaline.

5(a)(i) hydrogen

(ii) $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$



(b)



(c) 5 minutes

Section 4: The Air Around Us

1. D

2. D

3. C

4(a) Sulphur dioxide bonds with rain water to form acid rain.

This reacts with lime stone buildings and destroys them.

It also eats away the waxy layer on plants.

(b) (i) Insert a glowing splint and it will ignite the splint.

(ii) Bring a flame to the gas and this will cause a popping sound.

5(a) relights the splint

(b) oxygen

(c) A

(d) bubble gas through lime water

- (e) carbon dioxide
- (f) B
- (g) burning splint to gas
- (h) popping sound
- (i) C

- 6(a) hydrogen
- (b) oxygen

- 7(a) React a carbonate with an acid. Collect gas in a glass cylinder.
- (b) Use in fire extinguishers and cool drink for the fizz.

8. Carbon dioxide

9. Fuels that burn in a limited supply of air produce carbon monoxide.

Section 5: The Commercial Preparation and Uses of Gases

1. Put a glowing stick in the tubes. If it ignites, the gas that is present is oxygen.
2. Carbon dioxide is produced when fuels burn.
- 3(a) Carbon dioxide was released and turned the lime water milky.
(b) Rotting/rotten things release carbon dioxide.
4. Zinc and sulphuric acid can be added together to produce hydrogen.
5. If you put a lit splint or match in hydrogen gas, it will make a popping sound.
6. Coal, oil, wood and natural gas are examples of fuels.
7. Purification



Liquefaction of air.

Fractional distillation

8(a) Haber process

(b) Nitrogen + hydrogen \rightarrow ammonia

Section 6: Pollution Of the Air

1(a) Sulphur dioxide and nitrogen oxides are responsible for acid rain.

(b)(i) Acid rain is most likely to be found in Tsumeb or Windhoek.

(ii) The burning or melting of copper in Tsumeb releases large amounts of sulphur dioxide into the air. There is a coal power station in Windhoek.

(c) Acid rain damages plants by destroying the waxy coating that protects leaves, and it prevents chlorophyll formation.

2. A

3(a) Carbon monoxide is formed by the incomplete combustion of fuels, when petrol burns under limited supply of oxygen.

(b) It prevents the blood from taking oxygen to the rest of the body.

(c) It is formed when nitrogen and oxygen in the engine combine under high temperature and pressure.

(d) They combine with rainwater to form acid rain.

(e) New cars have catalytic converters in their exhausts that reduce the amount of poisonous gases released into the air.

4. The usage of lead-free petrol.

Section 7: Water

1. We need to determine if the liquid will turn anhydrous white

copper sulphate blue or anhydrous blue cobalt chloride pink.

2. It is a colourless, odourless and tasteless liquid. It freezes at 0°C and boils at 100°C .
- 3(a)(i) To have equal amounts to compare results. Also to have the experiment controlled.
- (ii) Q and S
- (iii) All examples either gave a better lather after boiling or nothing. Soft water would have a high lather without boiling.
- (iv) O, P or R
- (v) Calcium hydrogen carbonate
- (b) Scum
- (c) Pour some dilute acid into the kettle. This will react with the scales and decompose it to clear the kettle of scales. He can use vinegar that is easily available and safe to use.

4. D

- 5.1(a) 67,500 litres
- (b) 30 days
- (c) 2,250 litres per day

5.2 100 litres

5.3 Question 5.3 to 6.4 is part of a survey. Answers to the questions will depend on the outcome of the survey.

7. 1 g/cm^3

8. It expands.



Unit 5

Mechanics

Introduction

In Unit 4, we discussed different reactions like chemical and physical changes, acids, bases, alkali and neutralisation. We also looked at air and water.

In this unit, we will discuss *speed* and *velocity*, how they differ and how to calculate velocity. We will also discuss forces like *weight*, *friction*, and the effects of *forces*. This will lead us to *pressure* which also involves force.

In the last part of the unit we will discuss *energy*, *work* and *power*. We will also look at how simple machines like levers, gears and pulleys make our work easier.

Finally, we will specifically look at *energy*, how it is converted from one form to another and conserved as well as the sources of energy.

I hope that this unit will be both interesting and enjoyable.

What is in this unit?

This unit consists of 9 sections:

Unit	Section	Study Hours
5	1. Speed and Velocity	8
	2. Mass and Weight	15
	3. Forces and Their Effects	8
	4. Friction	8
	5. Pressure	8
	6. Work, Energy and Power	7

	7. Simple Machines	8
	8. Energy, Energy Conversions and Conservation	9
	9. Sources of Energy	3
	Review	2
	Total	76



Outcomes

On successful completion of this unit, you will be able to:

- *explain* the concepts of velocity and speed;
- *describe* why velocity and speed are different;
- *differentiate* between mass and weight;
- *explain* the concept and effect of force;
- *recall* the existence of forces in nature and everyday life and state that they are measured in newtons;
- *describe* the effect of friction on objects and how friction depends on surfaces;
- *define* pressure as the relationship between force and the area the force acts on;
- *elaborate* that work is done when a force is applied over a distance;
- *define* that energy is the ability to do work and that joule is the unit of both work and energy;
- *explain* and appreciate that levers, gears and pulleys are used for making work easier;
- *explain* how pulleys and gears change the direction of effort;
- *state* that energy is transferred



	<p>when work is done and that energy means work done;</p> <ul style="list-style-type: none"> • <i>describe</i> the law of conservation of energy; • <i>describe</i> renewable and non-renewable sources of energy and explain their advantages and disadvantages.
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 Terminology	Speed	Rate of change of distance in a given time.
	Velocity	How fast an object moves in a given direction.
	Mass	The amount of matter in an object.
	Weight	The gravitational pull on an object.
	Inertia	The property of mass that resists change in motion.
	Contact forces	Forces acting on objects that touch each other.
	Non-contact forces	Forces that act at a distance.
	Friction	A force that opposes the movement of objects that touch each other.
	Pressure	A force that is exerted per unit area.
	Energy	The ability to do work.
	Work	When a force moves an object in the direction of the force.
Power	The speed of doing work.	

Section 1: Speed and Velocity

Introduction

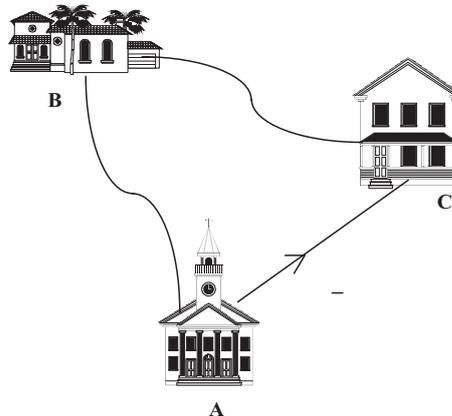
Speed is a commonly used term. We hear about the speed of cars, runners and so on. Velocity is not commonly used in our everyday language but its meaning is different from speed. In this section, we are going to discuss the difference between these two terms. We will also find out when they should be used.

Two other terms are distance and displacement. Distance is commonly used in our everyday language when we talk about the distance between places. Displacement is not commonly used in everyday language. We are going to discuss the difference between distance and displacement and do calculations on velocity and speed.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>explain</i> velocity as the rate of change of displacement with time; • <i>explain</i> the following: <ul style="list-style-type: none"> distance as the physical distance moved (without considering direction); displacement as the distance moved in a particular direction; speed as the rate of a change of distance with time; • <i>calculate</i> velocity in simple everyday examples; • <i>use</i> a stopwatch to determine average time of distance /displacement travelled to determine velocity.
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 <p>Time</p>	<p>This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Let's start with **displacement** and **distance**. Which one are you familiar with? Well, when we talk about distance, we mean the length of a journey while displacement is the distance moved in a specified direction.



Let us look at the diagram showing displacement and distance. If you move from point A to point C, there are two possible routes you can take. If you decide on the route ABC, this is the physical distance covered. It all depends on the route taken. If you change positions from A to C, it involves the distance AC, in the direction of C. This is called displacement. Displacement is the shortest distance from A to C. So, do 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 for both distance and displacement is kilometre (km), metre (m) or centimetre (cm), depending on what you are asked. Take note that these are not the only units for distance.

Now, we are going to discuss **speed** and **velocity**. What do we mean when we talk about the velocity or speed of an object? Speed is the rate of change of distance in a given time. Simply put, speed is how fast an object moves. For example, a car was moving at 30 km/h. In the case of speed, the direction in which a car moves is not mentioned.

Velocity is the rate of change of distance with time in a given direction. Simply put, velocity is how fast an object moves in a given direction. With velocity, the direction in which a car moves must be mentioned. Since distance in a given direction is called displacement, we can also say that velocity is the rate of change of displacement. For example, a car was moving at 30 km/h in a northern direction. Do you realise that velocity is the speed of an object in a given direction? Now do you see the difference between speed and velocity? The unit for velocity is the same as that of speed: km/h, m/s or cm/s.

You can determine the velocity of an athlete using a stopwatch. If it is a 100 m run for example, you can take the time to complete this distance to calculate velocity. Divide the displacement by the time taken. I hope you realise that the distance or displacement is already known. The only thing to determine is the time it takes to complete the race.

Now, let us use the explanations to write down the formula for velocity.

Speed = distance travelled/time taken

Speed = d/t

Velocity = distance in a given direction/time taken

Velocity = displacement/time taken

$$v = s/t \text{ or } v = d/t$$

Note: we use a lower case s to represent displacement.

This information was shared in the first sections of Unit One. If you are not comfortable with deciding on upper and lower case of units for displacement, distance, speed and velocity please refer to Unit one.

Velocity is calculated in the same way as speed. Here is an **example** on how to calculate velocity.

A car covered a distance of 37 km in a northern direction. If it covered the distance in 0.6 hours, calculate its velocity.

Velocity = displacement/time

$$\begin{aligned} v &= s/t \\ &= 37\text{km}/0.6\text{h} \\ &= 61.7\text{km/h} \end{aligned}$$

For speed, the formula is:

speed = distance travelled/time

$$\text{speed} = d/t$$

Consider this example:

A car covered a distance of 250 km in three hours. The speed would be:

$$\begin{aligned} \text{speed} &= d/t \\ &= 250\text{km}/3\text{hrs} \\ &= 83.3\text{km/h} \end{aligned}$$

If the answer is required in m/s, then kilometres should be changed to metres and hours to seconds. Let us see how it can be done.

You know that 1 km = 1,000 m.

Therefore, 250 km will be:

$$250 \text{ km} \times 1,000 \text{ m/km} = 250,000 \text{ m}$$

$$\begin{aligned} 3 \text{ hours} &= 3\text{hrs} \times 60\text{min/hr} \times 60\text{seconds/min} \\ &= 10,800 \text{ seconds} \end{aligned}$$

$$\begin{aligned} \text{Speed} &= d/t \\ &= 250,000\text{m}/10,800\text{s} \\ &= 23.1\text{m/s} \end{aligned}$$

Now that we worked through some examples please do the following practical activities.

**Practical
Activity****Practical Activity 1****Problem:**

To calculate the velocity of a car.

What you need:

stopwatch (timer);
a car driven by someone;
a straight part of a road (without traffic).

What to do:

1. Choose a straight stretch of a road.
2. While driving at a steady speed, reset the odometer at zero and start the timer.
3. Note the odometer reading at the end and stop the timer.

Calculations:

Calculate the velocity by using the odometer reading and the time taken in km/h.

**Practical
Activity****Practical Activity 2****Problem:**

To calculate the velocity of an athlete.

What you need:

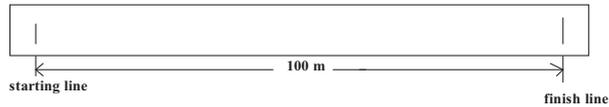
measuring tape (if you are not using a running track);
stopwatch;
plane ground;
two flat pieces of wood.

What to do:

1. Use the measuring tape to measure a distance of 100 m as shown in the diagram below.
2. One person stands at the starting line with two flat pieces of wood (or a starter gun if available).
3. The other person (timekeeper) stands at the finish line with a stopwatch.
4. When the athlete is ready to start running, she hits the flat pieces of wood together. At the same time, the time keeper starts the stopwatch. Although this is not as accurate as a gun which also produces smoke, it is

good enough.

5. As the athlete crosses the finish line, the timekeeper presses the stop button on the stopwatch and the time for the race is recorded in the table.



Results

distance/ m	time/s
100 m	

Note that the velocity found in this way may mean that the athlete was running at the same speed from the starting line to the finish line. This is not correct, that is why the average velocity is usually used.

Question

Calculate the velocity of the athlete from the values of distance and time recorded in the table of your results.



Practical Activity

Practical Activity 3

This activity is done in the same way as Practical Activity 2. The only change is that the athlete makes more than one run in order to find the average time.

Problem:

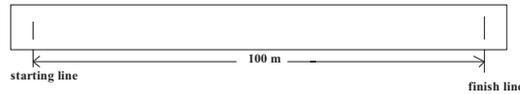
To determine the average time of distance/displacement travelled to determine velocity.

What you need:

- measuring tape (if you are not using a running track);
- stopwatch;
- plane ground;
- two flat pieces of wood (or starter's gun).

**What to do:**

1. Repeat, steps 1-5 of Practical Activity 2 at least twice.

**Results for 100 m**

run	time/s
1	
2	
Average	

Questions

1. Calculate the average time for the two races.
2. Calculate the velocity of the athlete.

After completing the practical activities you should work through the following self-mark activity.

Self-Mark Activity

**Self-Mark Activity****Self-Mark Activity**

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Which of the following statements are true about speed and velocity?
 - A speed has direction only;
 - B speed has size and direction;

- C** velocity has direction only;
D velocity has size and direction.
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. In 1996, Frankie Fredericks ran 100 m in 9.86 s.
Calculate his velocity.
4. A car covers a distance of 950 m in 120 seconds due north.
Calculate its velocity in:
- (a)** m/s;
(b) km/h.
5. An athlete took part in a 400 m race and the times for two runs were recorded in a table as shown.

run	Time/s
1	20
2	22
Average time	

Calculate the:

- (a)** average time for the two runs
(b) velocity of the athlete

Good! Now we will look at the concept of mass and weight.



Section 2: Mass and Weight

Introduction

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. On very few occasions, we hear people talk about their mass. Do you think they use these terms correctly?

These two terms appear to mean the same thing, but in this section we are going to discuss the difference between them.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>determine</i> how mass can be determined through its weight; • <i>describe</i> the mass of a body as the number of particles building up matter; • <i>calculate</i> the weight of a body from its mass; • <i>explain</i> inertia as mass having the property to “resist” change in motion and relate the importance of wearing seat belts with reference to inertia; • <i>relate</i> weight to the force due to gravitational attraction and explain the earth’s gravitational field strength (g) as a constant of gravitational force of 10 N on 1 kg mass (10 N/kg) on or near to the earth; • <i>describe</i> the factors affecting stability of objects; • <i>identify</i> different states of equilibrium; • <i>determine</i> the centre of gravity of a regular sheet.
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 Time	<p>This section will take you about 15 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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In everyday language, the terms mass and weight are often confused and appear to mean the same thing. In science however, the two terms have different meanings. When we talk about the mass of an object, we mean

the amount of matter in that object. It is the number of particles in an object. This means that the mass of an object is the same anywhere. The unit for mass is kilogramme (kg) or gramme (g). This does not mean that kilogramme and gramme are the only units of mass. The SI unit of mass is kilogramme (kg). A beam balance is used to determine the mass of an object.



Beam balance

Weight on the other hand is the gravitational pull on an object. This is the force that pulls objects towards the earth. The earth acts like a big magnet that attracts objects towards its centre. The SI unit of force is Newton.

Since weight is a force, it is also measured in Newtons (N). How strong is this force of gravitational pull? Well, every kilogramme of an object experiences a force of 10 N. This is the earth's gravitational field's strength, "g". So it can be written as $g = 10 \text{ N/kg}$. This value is constant (stays the same) near to or on earth.

The pull of gravity causes falling objects to accelerate. In a vacuum, the value of this acceleration g , is about 10m/s^2 . Therefore $g = 10\text{m/s}^2$. The instrument used to measure weight is a spring balance or force meter. This is because when you hang an object, the force due to gravitational pull, pulls it down.



Force meters/spring balances

Let us see how to calculate the weight of an object using an example.

How much force will a 0.9 kg mass experience? In this case, you just use the formula:



$$\begin{aligned}\text{weight} &= \text{mass} \times g \\ &= 0.9 \text{ kg} \times 10 \text{ N/kg} \\ &= 9 \text{ N}\end{aligned}$$

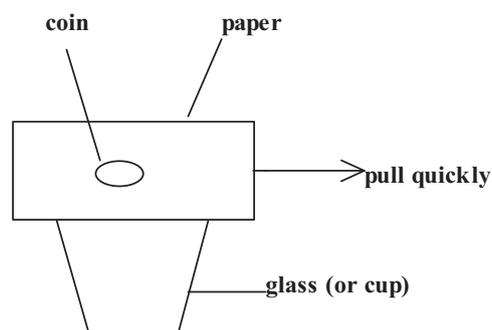
This means that if you hang the 0.9 kg mass on a spring balance, it should read 9N.

Weight and mass can be compared using a beam balance. In Namibian schools, triple beam balances are commonly used.

If mass **A** is 0.5 kg and balances with mass **B**, it means that mass **B** is also 0.5 kg. This is because the force of gravity acting on both is the same and therefore they cancel each other out. If the mass of an astronaut is 70 kg on earth, will her mass change on the moon where the force of gravity is less? No, because the number of particles in the body stays the same. Obviously the weight will be less because the force of gravity on the moon is less than that on earth.

What is inertia? Inertia is the property of mass that “resists” change in motion. It is the “laziness” of objects to start moving when they are at rest or to stop when they are moving. For example, if you leave your empty schoolbag on the floor, it will stay there until you move it. When the schoolbag is full of books, it is more difficult to move it than when it is empty. Therefore, the more the mass, the more the inertia. You can define the mass of an object as the measure of its inertia because inertia is directly proportional to mass.

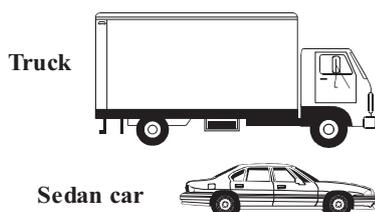
Inertia can be shown by doing a simple experiment as shown in the following diagram. When you pull the paper fast enough, the coin drops into the glass instead of moving with the paper. This shows that the coin resists movement.



When you are in a car, your body moves at the same speed as the car. When the driver quickly applies the brakes, your body would continue moving forward. This can be dangerous when you are in the front seat, because you can hit the windscreen. Do you realise the importance of

wearing seatbelts? Seatbelts are important, because they prevent you from being pulled forward quickly.

Let us compare the inertia of a big truck and a small sedan car. A big truck has more mass than a sedan car. When both start from the same line and increase speed (accelerate) to a speed of say 100 km/h, which one do you think will reach the highest speed first? Can you suggest why? The sedan car is likely to reach the speed of 100 km/h first. This is because of the difference in inertia. The sedan has less mass therefore less inertia than the big truck.



If the truck and the sedan car were to stop after a short distance, which one will stop easily? Can you suggest why? It is all about inertia. The big truck has more inertia than the sedan car and therefore, the big truck will take longer to stop than a sedan car.

The momentum of a body is the product of its mass and velocity. A fast-moving car has greater momentum than a slow-moving one when they are of the same mass. A big truck has greater momentum than a sedan car when they travel at the same speed. Therefore, the greater the momentum a body has the more difficult it is to stop. This means that the impact of the body with greater momentum is more than the one with less momentum during a collision.

Having been introduced to weight, mass, inertia and momentum, please do the following practical activities:

 <p>Practical Activity</p>	<p>Practical Activity 1</p> <p>Problem: To determine the mass of an object.</p> <p>What you need: beam balance; an object of unknown mass.</p> <p>What to do:</p> <ol style="list-style-type: none"> 1. Zero the beam balance (the pointer is zero). 2. Place the unknown mass on the pan of the beam balance. 3. Move the masses until they balance with the
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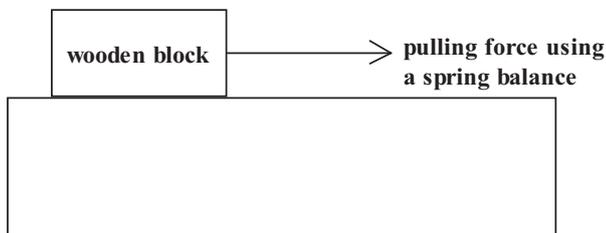


	<p>unknown mass.</p> <p>4. Note the reading (in grams).</p> <p>Results: Mass of object g</p> <p>Question: From the mass, calculate the weight of the object. Weight = N</p>
--	---

 Practical Activity	<p>Practical Activity 2</p> <p>Problem: To determine the weight of an object.</p> <p>What you need: the object used in Activity 1 above; spring balance; a stand or surface where the spring balance can hang.</p> <p>What to do: 1. Hang the object on the spring balance. 2. Note the balance reading (in newtons).</p> <p>Results: Weight of object = N</p> <p>Does the weight you calculate in Practical Activity 2 correspond with the weight you have calculated in Practical Activity 1? Explain your answer.</p>
--	---

 Practical Activity	<p>Practical Activity 3</p> <p>Problem: To investigate the effects of inertia in pulling a spring balance.</p> <p>What you need: a flat surface like a table; two wooden blocks with hooks; a spring balance.</p> <p>What to do: 1. Hook the spring balance to the wooden block</p>
--	---

- and pull slowly until it starts to move slowly.
- Note the minimum force required to make the block start to move.
 - Repeat step 1 using two blocks.



Observations and results:

- Explain why the block didn't move until the force is increased to a certain value (ignore friction).
- Explain what happened to the size of the force required to start the movement when another block is added.



Practical Activity

Practical Activity 4

Problem:

To investigate the effects of inertia in pulling a plug out of a basin of water.

What you need:

- a plug;
- a deep basin of water;
- a spring balance.

What to do:

- Hook a spring balance to a plug that lies deep under water.
- Slowly pull it out of the water and note the force required.
- Quickly pull it out and note the amount of force required.

Observations and results

Describe what happened to the amount of force required when:

- (a) pulling slowly;
- (b) pulling quickly.



A ball has inertia that affects its movement. When you kick a ball into a net, it does not bounce back. What does it mean in terms of the force that it exerts on the net? When an object stops (slowly) over a longer time, the force it exerts is reduced. This is true for the net. That is why the ball does not bounce off. On a hard surface, the force it exerts is very large, because it stops over a very short time. This causes the ball to bounce off because of the large force it exerts.



Practical Activity

Practical Activity 5

Problem:

To investigate the effects of inertia in catching a ball.

What you need:

- a net;
- a hard flat surface like a wall;
- a ball.

What to do:

1. Kick the ball on to a hard surface.
2. Kick the ball into the net.

Question:

Explain how the goalkeeper reduces the force of the ball when he catches it.

Imagine a fast moving car crashing into a concrete wall. The sudden loss of kinetic energy can cause the occupants of the car to be thrown forward because of inertia. To reduce this effect, cars are designed with crumple zones behind (in the rear) and in front. These zones consist of springs that make the car come to rest slowly. This reduces the force by acting over a longer time therefore reducing the impact.



Practical Activity

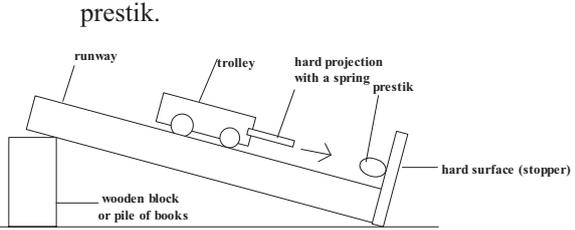
Practical Activity 6

Problem:

To investigate the effects of inertia in crumpling zones.

What you need:

- two trolleys;
- a flat plank as shown in the diagram;
- a wooden block or pile of books;



What to do:

1. Let the trolley run down the runway as shown in the diagram.
2. When it hits the prestik, note the size of the hole made in it.
3. Then, use a trolley without a spring and repeat steps 1 and 2.

Observations and results:

1. Explain what the size of the hole was when the trolley with the spring was used.
2. Explain what the size of the hole was when the trolley without a spring was used.

We will now look at the new concept of equilibrium.

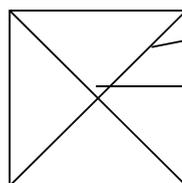
Equilibrium and centre of gravity

The centre of gravity of an object is the point in the object where its weight is concentrated. This point is also called the centre of mass. For a regularly shaped solid with uniform density, the centre of gravity coincides with the geometric centre of the object.

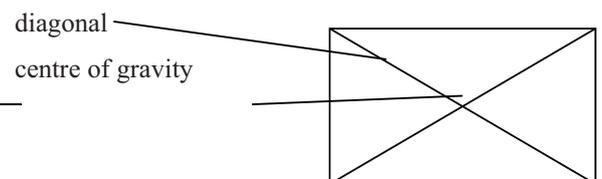
How to determine the centre of gravity:

1. Regular sheet

(a) square



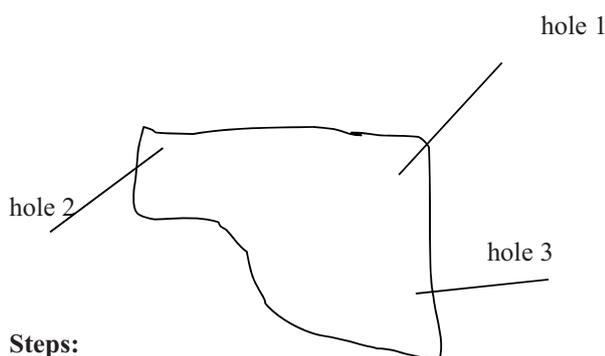
(b) rectangle





For regular sheets like the square and rectangle, draw diagonal lines. Where the diagonal lines cross, you'll find the centre of gravity. You can further test this point by balancing it horizontally on a sharp pivot.

2. Irregular sheet (lamina)



Steps:

- (i) make three holes at the edge of the lamina as in the example;
- (ii) freely suspend the lamina through hole 1 using a pin;
- (iii) suspend a mass to the same pin using a string (plumb-line);
- (iv) draw a straight line along the plumb-line;
- (v) repeat steps (ii)-(iv) for hole 1 and hole 2;
- (vi) mark the point where the three lines intersect.

The point where the three lines intersect, is the **centre of gravity**. You can further test this point by balancing it horizontally on a sharp pivot.

Factors affecting stability of an object:

An object is said to be stable if, when displaced slightly, it does not topple over. There are **two** factors that affect the stability of an object.

1. Position of the centre of mass

An object will be more stable when the centre of gravity is lower. The lower the centre of mass, the more stable the object is. Examples in real life are many. However, I will mention only a few. You should be able to recognise more examples.

(i) Wine glass

A wine glass is more stable when it is empty than when it is full. This is because when full, its centre of mass rises. It is heavier at the top.

- (ii) When a tin is half-full of sand, its centre of gravity is lowered. It is heavier at the bottom. This makes it more stable than when it is

empty. The same principle applies to double-decker buses. When the lower deck is full of passengers, it is more stable than when only the top deck is full.

(iii) Racing cars are lower than ordinary cars. This lowers the centre of gravity making them more stable.

2. The size of the base area

An object is more stable if its base area is larger. The larger the base area the more stable the object will be. Try to drop different objects on to level ground. On which area do they come to rest? Is it the smallest or largest area? Well, we take things for granted sometimes but now you should realize that they all rest on their largest area. This is the most stable position. Let us take the Bunsen burner as an example. The base area is larger. This makes it more stable. Even if you tilt it slightly, it will not topple over. What will happen to the stability of the Bunsen burner if you inverted it? In this position, it will rest on its smallest area. Therefore it will be unstable. If pushed slightly, it will easily topple over.



larger base area

The same principle applies to racing cars. The wheel span of racing cars is larger than that of ordinary cars. This increases their stability.

We now want to look at a new concept but still using the Bunsen burner as an example.

Equilibrium states

There are three kinds of equilibrium states:

1. Stable equilibrium:

An object is in stable equilibrium if, when displaced slightly, it reverts to its original position. The Bunsen burner resting on its base is a good example of stable equilibrium.



stable equilibrium

2. Unstable equilibrium:

A body is unstable if, when slightly displaced, it moves to a new position or topples over. The upside-down Bunsen burner is a good example of unstable equilibrium.



unstable equilibrium

3. Neutral equilibrium

A body is in neutral equilibrium when, displaced slightly, the centre of gravity remains at a constant level. If a ball is displaced slightly on level ground, it rolls and rests in a new position. A Bunsen burner which lies on its side is also an example of neutral equilibrium.



neutral equilibrium

Now that you have completed this section, please work through the self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. A body is taken from earth to the moon where the force of gravity is less. Which statement is correct about its weight and mass?

	weight	mass
A	decreases	constant
B	decreases	increases
C	increases	constant
D	increases	constant



2. Which statement is true about the instruments used to measure weight and mass?

	weight	mass
A	spring balance	spring balance
B	spring balance	beam balance
C	beam balance	spring balance
D	beam balance	beam balance

3. A body has a mass of 100 g. The force of gravity acting on it is:

- A** 1,000 N;
- B** 100 N;
- C** 1 N;
- D** 0.1 N.

4. Calculate the:

- (a) weight of a 500 g packet of rice;
- (b) mass of a 250 N girl.

- 5(a) A bus full of passengers needs more force to turn at a corner than when it is empty. Explain this statement in terms of inertia.

(b) State and explain the relationship between mass and inertia.

(c) In Namibia, it is a requirement to wear seat belts whenever travelling in a car. Explain the importance of wearing seat belts.

6. Describe factors affecting the stability of objects.

7. Identify different states of equilibrium.

Section 3: Forces and Their Effects

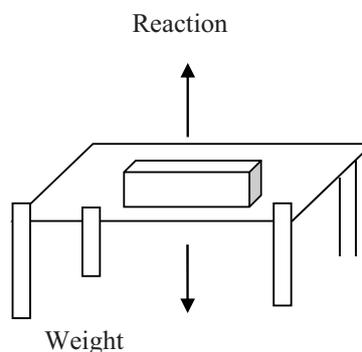
Introduction

There are many different types of forces we experience in our everyday lives. If we pay a little more attention, we will see their effects. In most cases, we take the effects for granted. In this section, we will identify some forces and their effects.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>outline</i> that a force may produce a change in size, shape, position or velocity of a body; • <i>describe</i> ways in which a force may change the motion of a body; • <i>identify</i> different forces in everyday life; • <i>identify</i> the agent applying the force in everyday life; • <i>identify</i> the object the force is applied to in everyday life.
--	--

 Time	<p>This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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What is a **force**? A force is a pull or push. A force is something that changes or tends to change the state of rest or uniform motion in a straight line. The SI unit of force is Newton (N).



When an object is on a table, it exerts force on the table called weight. The table reacts by exerting an equal but opposing force to the weight, called the reaction



force. Since these forces are equal and opposite in direction, the object will remain at rest.

A force is a **vector quantity**. What is a vector quantity? A vector is a quantity that has both magnitude (size) and direction. A straight line with an arrowhead represents a vector. The length of the straight line represents the size, while the arrowhead indicates the direction. Let us use weight as an example. The weight is always directed downward, hence the arrow pointing down. The length of the line tells us the size of the weight.

Representing vectors:

A vector can be added algebraically, but the direction of the vector is important. Let us examine some examples. The vector pointing to the right is positive while the one pointing to the left will be negative.

$$\begin{array}{c} 2\text{N} \\ \longrightarrow \end{array} + \begin{array}{c} 2\text{N} \\ \longrightarrow \end{array} = \begin{array}{c} 4\text{N} \\ \longrightarrow \end{array}$$

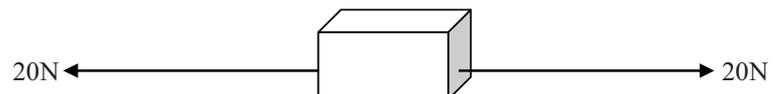
$$\begin{array}{c} 2\text{N} \\ \longrightarrow \end{array} + \begin{array}{c} \longleftarrow \\ -2\text{N} \end{array} = 0$$

$$\begin{array}{c} 4\text{N} \\ \longrightarrow \end{array} + \begin{array}{c} \longleftarrow \\ -2\text{N} \end{array} = \begin{array}{c} 2\text{N} \\ \longrightarrow \end{array}$$

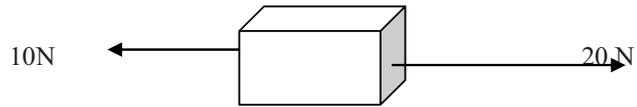
$$\begin{array}{c} 2\text{N} \\ \longrightarrow \end{array} + \begin{array}{c} \longleftarrow \\ -4\text{N} \end{array} = \begin{array}{c} \longleftarrow \\ -2\text{N} \end{array}$$

Note that if the vector pointing right is positive, then the vector pointing left will be negative. In that case, the normal addition using the number line applies. When adding, the resultant vector takes the sign of the bigger value.

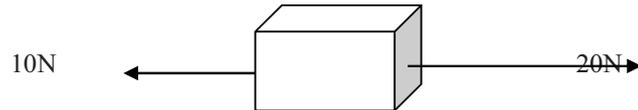
If an object is stationary, it will remain at rest.



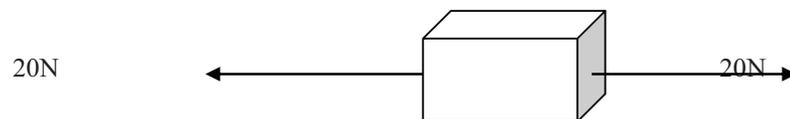
If the object was stationary, it will move to the right.



If the object was moving, it will accelerate to the right.



If the object was moving, it will maintain constant speed. When an object is in motion, force is not needed to keep it at a steady speed.



The effects of forces can be observed in our everyday lives.

Let me give you some examples of the effects of forces:

- (a) a force can move or stop or change the position of an object;
- (b) a force can change the direction of a moving object or change the velocity of an object;
- (c) a force can change the shape of an object.

There are two types of forces: **contact** and **non-contact** forces. Let's talk about these forces separately.

1. Contact forces:

These forces act on objects that touch each other.

- When you kick a ball, your foot must be in contact with the ball to make it move.
- If you squeeze a piece of foam mattress or stop a moving ball, both involve contact forces.
- Tension is also a contact force. It is the force exerted by pulling a string or rope. Can you think of any contact forces involving tension in your everyday life?
- Frictional force is also a contact force. Objects that are in contact experience it. Frictional force will be dealt with in detail in Section 4.

2. Non-contact forces:



These are forces that act without the objects actually touching each other. In other words they act at a distance. Can you think of any forces that cause some effects without objects touching each other? Here are some examples of non-contact forces:

- **Gravitational force** is the force that pulls objects which are near to or on the earth, towards the centre of the earth. It is also referred to as weight.
- **Magnetic force** is force experienced by magnets that are placed near each other. It is a force experienced when a magnet is placed near magnetic materials such as iron, nickel and cobalt. What happens when you place a magnet on a table and bring another magnet as close to it as possible without touching? The magnet on the table might move towards the one in your hand or it might move away. When a magnet is brought close to iron filings, the iron filings jump onto the magnet. These examples show that magnetism is a non-contact force.
- **Electrostatic force** is the force existing between charged particles. Charged particles can have negative or positive charges. This is another non-contact force. If you take a plastic pen and rub it in your hair, then put it near pieces of paper, it pick up these small pieces of paper. Bring a charged plastic ruler near a stream of water from a tap. What do you see? The stream of water gets attracted to the ruler.

The existence of force in nature and everyday life

Forces are part of our everyday life. Some of the forces are large for example pulling a cart, while others are small, such as locking a door. When locking a door, your hand applies force using the key on the lock.

Now try to work through the following practical activities.

 Practical Activity	<p>Practical Activity 1</p> <p>Problem:</p> <p>To investigate a force that may produce a change in size and shape of a body.</p> <p>What you need:</p> <p>A small piece of foam mattress.</p> <p>What to do:</p> <ol style="list-style-type: none"> 1. Hold the piece of foam mattress in one hand and squeeze as hard as you can. <p>Observations/results:</p> <ol style="list-style-type: none"> 1. Describe what happens to the shape and size of the piece of foam mattress.
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Practical Activity

Practical Activity 2

Carry out this activity in a similar way to Activity 1. Use any material of your choice.

Problem:

To investigate force that may produce change in size and shape of a body. Complete the parts below as you do the activity.

What you need:

What to do:

Observations/results:



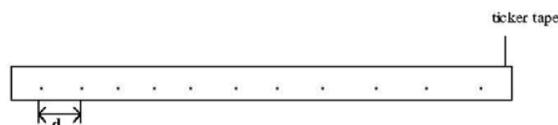
Practical Activity

Practical Activity 3

In this activity, you are going to use an instrument called a ticker timer. A ticker timer is used to measure time between short distances. This is possible because it vibrates at 50 times per second – also called 50 Hz. The time between two dots will be $1/50$, which is 0.02 seconds.

The distance between two dots can be found by measuring it with a ruler. This means that if you are pulling with the same amount of force, the distance between the dots should be the same.

What would happen to the distances between the dots if the pulling force is increased? This would mean that the distances between the dots would also increase. The velocity between each distance can easily be found by dividing the distance between dots by 0.02 s.



To calculate velocity:

1. Measure distance **d** with a ruler.
2. You know that it takes 0.02 s to cover the distance between two dots.
3. Velocity will be equal to $d/0.02$ s.

$$v = d/0.02 \text{ s}$$

Problem:

To investigate force that may produce a change in the velocity of a body.

What you need:



	<p>a ticker timer; a ticker tape; a working surface.</p> <p>What to do:</p> <ol style="list-style-type: none"> 1. Arrange the apparatus as shown in the diagram. 2. Switch on the ticker timer. 3. Pull the ticker tape from one end using the same amount of force (call it tape 1). 4. Cut the used tape out and pull the tape again, now increasing the pulling force (call it tape 2). 5. Compare the two tapes. <p>Observations and results:</p> <ol style="list-style-type: none"> 1. Compare the distances between dots. Are they the same or not? <ol style="list-style-type: none"> (a) tape 1; (b) tape 2. 2. Calculate the velocity between any three distances between dots that follow each other. <ol style="list-style-type: none"> (a) tape 1; (b) tape 2. 3(a) Select which tape shows that there was a change in velocity. Select whether the velocity increases or decreases. <ol style="list-style-type: none"> (b) Use your results in (a) to describe the effect of force on the velocity of an object.
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 Practical Activity	<p>Practical Activity 4</p> <p>Problem: To investigate the effects of force in pulling a string.</p> <p>What you need:</p> <p>a spring; a retort stand or any suitable object where the spring can hang.</p> <p>What to do:</p> <ol style="list-style-type: none"> 1. Hang the spring from any suitable object e.g., stand. 2. Gently pull the spring down. Care should be taken not to damage it. <p>Observations/results:</p> <ol style="list-style-type: none"> 1. Describe the changes that the force had on the spring.
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 <p>Practical Activity</p>	<p>Activity Practical 5</p> <p>Problem: To investigate effects of force in kicking a ball.</p> <p>What you need: a ball.</p> <p>What to do:</p> <ol style="list-style-type: none"> 1. Place the ball at a given spot and kick it. 2. Let your friend kick the ball and kick it before it hits the ground. 3. Note what happens to the ball in steps 1 and 2. <p>Observations/results:</p> <ol style="list-style-type: none"> 1. Describe the effect of the force in step 1. 2. Describe the effect of the force in step 2.
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 <p>Practical Activity</p>	<p>Practical Activity 6</p> <p>Problem: To investigate the effects of force in pulling a rubber.</p> <p>What you need: a rubber band; metre rule.</p> <p>What to do:</p> <ol style="list-style-type: none"> 1. Take the rubber band and measure its length when not stretched. 2. Gently pull the rubber band over the metre rule and measure its length. <p>Observations and results:</p> <ol style="list-style-type: none"> 1. Describe the change(s) the force had on the rubber band.
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Now that you have looked at the practical activities, try to do the following self-mark activity.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. The effect of force when you kick a ball is
 - A a change of direction;
 - B a change of shape;
 - C a change of size;
 - D a stopping movement.
2. Which one is a non-contact force?
 - A force between charged objects;
 - B kicking a ball;
 - C pulling a rope;
 - D pushing a car.
3. Which force is a contact force?
 - A electrostatic force;
 - B frictional force;
 - C gravitational force;
 - D magnetic force.
4. The unit of force is
 - A joule;
 - B kilogram;
 - C metre;
 - D newton.
5. Forces can be described as contact or non-contact. Using an example, describe:
 - (a) a contact force;
 - (b) a non-contact force.

Section 4: Friction

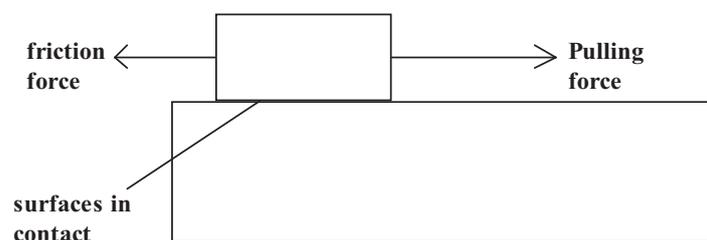
Introduction

Although we do not frequently talk about friction in our everyday experiences, it is a very important force to us. There are many effects of friction. For example, if you wear a pair of very tight pants for some time, it gets worn out between the legs. This is because of friction between the legs when you walk. In this section, we will discuss friction, its effects, advantages and disadvantages.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>explain</i> the effect of friction on objects and how friction depends on the surface and area of contact; • <i>examine</i> how to reduce friction and discuss the advantages and disadvantages of friction in everyday life.
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 Time	<p>This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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What is friction? Friction is a force that opposes the movement of objects that touch each other. Friction is an example of a contact force as mentioned earlier in Section 3.



When you slide a wooden block along a table, it eventually stops. Do you know what causes it to stop moving? It is the force of friction. Although surfaces appear to be smooth, they are in fact rough. Sand paper is used to scrub surfaces of metals or wood. It has a rough surface on one side in order to increase friction. Files for



sharpening tools like knives, also have rough surfaces in order to increase friction. This type of friction does not depend on the size of the surface area in contact, as long as the roughness and force pressing the surfaces together remains the same. For example, if you pull a brick on a table when lying on its largest area, the frictional force will be the same as when using its smallest area.

Friction does not only take place between solid surfaces. It also takes place when surfaces move through liquids and gases. This type of friction is called fluid friction. Fluid friction depends on the surface area of an 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 this friction. Can you tell where the friction comes from? It is caused by air particles. When an aircraft flies, the air particles oppose its movement. This kind of friction is also called air resistance.

There are **two** factors upon which solid friction depends:

1. **how rough surfaces are**; the rougher the surface, the greater the force of friction;
2. **the size of the normal force**; the normal force is a force acting perpendicular to a **surface**. Weight is a normal force because it acting perpendicular to the horizontal.

The size of the frictional force does not depend on the size of the surface area in contact. You can test this by doing Practical Activity 1.

Friction can be useful or a nuisance. Therefore, it has advantages and disadvantages.

Some advantages of friction are:

1. it makes it possible for us to walk by pushing us forward to stop;
2. it enables us to hold a pen firmly when we write;
3. you can make fire by rubbing sticks, or by striking a match stick against a rough surface.

Can you list some advantages of friction in your everyday experiences?

Now let us look at some **disadvantages** of friction:

1. It can cause surfaces that rub against each other wear out (to be damaged). For example, the moving parts in a car, or other machines.
2. It can cause overheating. Sometimes we do not want moving parts to get hot, like in a car. Do you know why it is important to put water in a radiator of a car? This is to cool parts that rub against each other.

This prevents overheating.

How can we reduce friction? There are two basic ways of reducing friction. One is to separate solid surfaces that rub against each other and the other is to make

surfaces in contact smoother. How can we reduce fluid friction then? Let us first look at how to reduce friction between solid surfaces.

1. Lubrication is the application of oil or grease on surfaces that are sliding against each other. Oil and grease are called lubricants. How does lubrication help reduce friction? It helps to reduce friction by separating the surfaces that rub against each other. In this way, the moving parts are not in contact with each other.

Try this: rub your hand on a table and note the amount of friction. Then pour some detergent or cooking oil on the table and rub again. Is there any difference in terms of friction? Yes. Detergent or oil prevents your hand from being in direct contact with the table's surface. This reduces the amount of friction. Graphite, which is a form of carbon, is also used to reduce friction in the same way.

Many people have fallen badly after stepping on a banana skin. Can you explain why stepping on a banana skin can be dangerous? The banana skin prevents your foot from being in contact with the ground where there is friction.

2. Rollers reduce friction by separating the surfaces in contact. Instead of surfaces rubbing against each other, they roll over each other. You can use pencils or straws to make rollers.



Rollers

3. Ball bearings reduce friction by separating the surfaces in contact. Instead of surfaces rubbing against each other, they roll over each other.

4. Making surfaces in contact smoother.

Sometimes, we need more than normal friction. How then can we increase friction?

1. by increasing the roughness of surfaces;
2. by increasing the **normal force** on sliding surfaces.

Now that we looked at some advantages and disadvantages of friction please work through the following practical activities.

 Practical Activity	<p>Practical Activity 1</p> <p>Problem:</p> <p>To investigate the effects of a surface area on the amount of friction.</p> <p>What you need:</p>
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a spring balance;
a flat surface like a tabletop;
a brick;
a string.

What to do:

1. Arrange the experiment with the string attached to the brick and the spring balance. Use the same surface for the whole experiment.
2. Pull gently until the brick moves at roughly the same speed and note the force.
3. Repeat steps 1 and 2 for the other sides of the brick.

Observations/results:

Complete the table for the amount of force required in each case.

Conclusion:

1. From your results, explain the size of area and the amount of friction.



Practical Activity 2

Problem:

To investigate effects of the roughness of surfaces on the amount of friction.

What you need:

a spring balance;
different surfaces e.g., floor, table;
a brick;
a string.

What to do:

1. Arrange the experiment with the brick attached to the spring balance with the spring.

	<ol style="list-style-type: none"> 2. Use the different surfaces. 3. Pull gently until the brick moves at roughly the same speed and note the force. 4. Repeat steps 1 and 2 for the different surfaces. <p>Observations/results:</p> <p>Complete the table below for the amount of force required in each case.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="width: 50%; height: 20px;"></td><td style="width: 50%; height: 20px;"></td></tr> <tr><td style="height: 20px;"></td><td style="height: 20px;"></td></tr> <tr><td style="height: 20px;"></td><td style="height: 20px;"></td></tr> <tr><td style="height: 20px;"></td><td style="height: 20px;"></td></tr> </table> <p>Conclusion:</p> <ol style="list-style-type: none"> 1. From your results, explain the roughness of the surfaces and the amount of friction. 								



Practical Activity

Practical Activity 3

Problem:

To investigate the reduction of friction using rollers or ball bearings.

What you need:

a brick;

a string;

a spring balance;

straws or any thin cylindrical objects like pencils.

What to do:

1. Arrange the experiment by attaching the brick to the spring balance with the string (**Rollers or ball bearings are needed**).
2. Use the same surface e.g., table top.
3. Pull gently until the brick moves at roughly the same speed and note the force.
4. Place straws or pencils parallel to each other under the brick and repeat steps 1-3 and note the



	<p>amount of force.</p> <p>Observations/results:</p> <p>Complete the table for the amount of force required in each case.</p> <table border="1"> <tr> <td></td> <td></td> </tr> <tr> <td>straws/pencils</td> <td></td> </tr> <tr> <td>straws/pencils</td> <td></td> </tr> </table> <p>Conclusion:</p> <ol style="list-style-type: none"> From your results, explain the amount of friction. 			straws/pencils		straws/pencils	
straws/pencils							
straws/pencils							

 Practical Activity	<p>Practical Activity 4</p> <p>Problem:</p> <p>To investigate the reduction of friction using oil/grease.</p> <p>What you need:</p> <p>a brick; a string; a spring balance; oil/grease.</p> <p>What to do:</p> <ol style="list-style-type: none"> Arrange the experiment with the string attached to the brick and the spring balance. Use the same surface e.g., table top. Pull gently until the brick moves at roughly the same speed and note the force. Pour some oil on the surface under the brick repeat steps 1-3 and note the amount of force. <p>Observations/results:</p> <p>Complete the table for the amount of force required in each case.</p> <table border="1"> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td></td> </tr> </table>				

	Conclusion: <ol style="list-style-type: none">1. From your results, explain the amount of friction.	

You should now be able to proceed to the self-mark activity of this section.



Self-Mark Activity



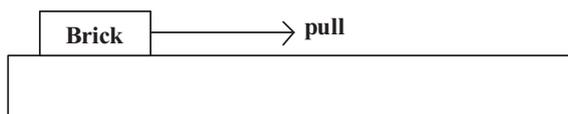
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Explain frictional force.
2. Name one factor on which friction between solid surfaces depends.
3. Explain why:
 - (i) after mopping a floor, you must walk carefully otherwise you might fall.
 - (ii) there are more car accidents where cars slide on tarred roads after the first rains.
4. Describe any situation that is not mentioned in this section where friction is:
 - (a) useful;
 - (b) a nuisance.
5. Loide pulls a brick along a dry table surface as shown in the diagram below.



- (a) Explain how the size of the force of friction changes when she pours some water on the table.
- (b) On the diagram draw arrows to show the direction of the weight on the brick.

Now its time to read about pressure.

Section 5: Pressure

Introduction

Pressure is a familiar word to you. We usually talk about pressure of work, pressure of water and so on. In this section, we will define pressure and do a few calculations. We will deal with solid and fluid pressure.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>recognise</i> and <i>calculate</i> pressure as a force that is exerted per area; • <i>interpret</i> the relationship between force and area; • <i>describe</i> fluid pressure.
--	---

 Time	<p>This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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What is pressure? It is a force that is exerted per unit area. The formula for pressure is:

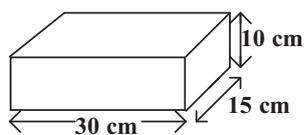
$$\text{Pressure} = \text{Force}/\text{Area}$$

$$P = F/A$$

Since force is measured in Newtons and area is measured in square metres, the SI unit of pressure is the N/m^2 . This unit is also called pascal (Pa). $1 \text{ pascal} = 1 \text{ N}/\text{m}^2$. Pascal is a very small unit, therefore kilopascal is used. To get pressure in kilopascal, you divide pascal by 1000. If pressure is N/cm^2 , this is not equivalent to a pascal. You have to change cm^2 to m^2 . You should realise that pressure can be found in N/cm^2 as long as you do not call this a pascal!

From the formula we can deduce that pressure is directly proportional to force applied and inversely proportional to the area. This is true when you change only one quantity at a time. Let me use a brick to explain the relationship between pressure and area, and pressure with force.

A concrete brick with a mass of 5 kg is used to find the effect of area on pressure.





Calculate the pressure in N/m² when the brick lies on:

1. its largest area;
2. its smallest area.

First, you have to change the mass into weight (force):

$$\text{Weight} = m \times g$$

$$w = 5 \text{ kg} \times 10 \text{ N/kg}$$

$$= 50 \text{ N}$$

Convert centimeters into metres and calculate the areas:

$$30 \text{ cm} = (30/100) \text{ m}$$

$$= 0.3 \text{ m}$$

$$15 \text{ cm} = (15/100) \text{ m}$$

$$= 0.15 \text{ m}$$

$$10 \text{ cm} = (10/100) \text{ m}$$

$$= 0.1 \text{ m}$$

1. Largest area:

$$A = \ell \times b$$

$$= 0.3 \text{ m} \times 0.15 \text{ m}$$

$$= 0.045 \text{ m}^2$$

$$P = F/A$$

$$= 50 \text{ N} / 0.045 \text{ m}^2$$

$$= 1,111 \text{ N/m}^2$$

$$= 1,111 \text{ Pa} \text{ or } 1.1 \text{ kPa}$$

2. Smallest area

$$A = b \times h$$

$$= 0.15 \text{ m} \times 0.10 \text{ m}$$

$$= 0.015 \text{ m}^2$$

$$P = F/A$$

$$= 50 \text{ N} / 0.015 \text{ m}^2$$

$$= 3,333 \text{ N/m}^2$$

$$= 3,333 \text{ Pa} \text{ or } 3.3 \text{ kPa}$$

You should notice that the force is the same in both cases. Can you compare the amount of pressure on the largest and smallest areas? Which area exerts more pressure? You should have noticed that the smallest area exerts more pressure than the largest area. Pressure is therefore directly proportional to the force exerted. That is, when you increase the force, the pressure also increases. Pressure is inversely proportional to area. That is, when you reduce the area, the pressure increases.

To test these statements, hold the ends of your sharpened pencil between your thumb and the index finger.

Gently press the two ends as hard as you can. Which finger feels more pain? Can you explain why? With the same pressure applied to both ends of the pencil, the sharp end causes more pain because the area is smaller. The pressure is greater because the area is smaller.

Can you explain why it is easier to cut meat with a sharp knife than a blunt one? This is because when cutting with a sharp knife, the area is smaller. Keeping the force constant, the sharp knife exerts more pressure than the blunt one.

Next we will focus on pressure in liquids and gases.

Fluid pressure

The term fluid refers to liquids and gases. Therefore, fluid pressure is pressure due to liquids and gases.

A manometer is an instrument used to measure liquid or gas pressure. It consists of a U-tube with a liquid in it. The liquid can be water or mercury. When pressure is applied on the liquid surface of one arm, the liquid is pushed to the other arm. The difference in the levels of the liquid gives an indication of the pressure applied.



Mercury manometer

Source: http://en.wikipedia.org/wiki/File:Mercury_manometer.jpg

Pressure in liquids

Liquid pressure increases with depth. The deeper an object is, the greater the pressure. This means that pressure in liquids is directly proportional to depth.



Pressure increases with depth

Liquid pressure acts in all directions. The pressure experienced by an object at any depth or point in the liquid happens equally in all directions.



Pressure acts equally in all directions.

At any depth in a liquid, even if a funnel is set in different directions, the pressure is still the same.

Gas pressure

When a manometer is not connected to a gas supply, the level of water in the two arms is the same. When connected to a gas supply, the level of the water drops in one arm and rises in the other. The gas pressure is equal to the pressure which is influenced by the height of water, h , and the prevailing atmospheric pressure.

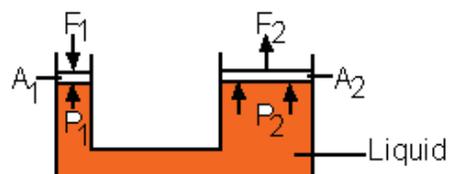


Gas pressure

Gas pressure = atmospheric pressure + pressure due to the height of water, h .

Applications of fluid pressure

Hydraulics machines



Hydraulic machines use liquid pressure to lift heavy loads. A small force, F_1 , exerted on the small area A_1 , creates pressure in the liquid. This pressure is transmitted equally throughout the liquid.

At the large area A_2 , the same pressure acts over the larger area. So, since the pressure P_1 is equal to pressure P_2 , the force F_2 is greater.

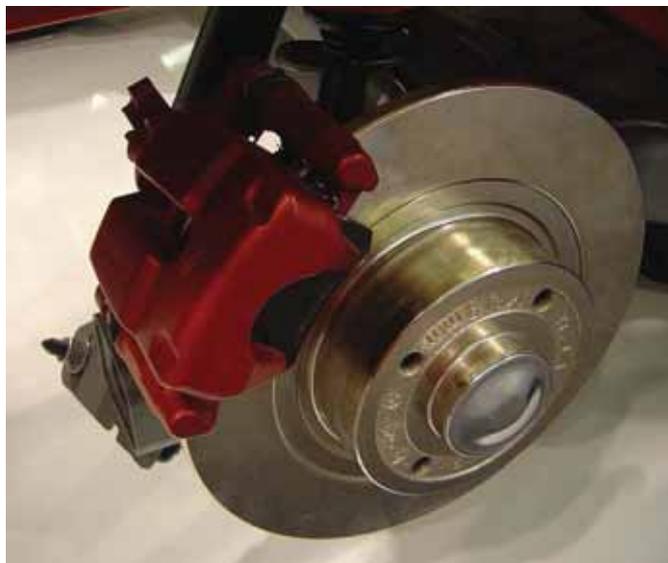
Therefore, hydraulic machines are force multipliers. This principle of hydraulics is used in many devices such as car hydraulic jacks, hydraulic brakes and hydraulic cylinders for earth moving vehicles.



Hydraulic Press

You can conduct a simple experiment by connecting two syringes of different sizes as shown. Coloured water is used so that the liquid levels can be easily seen. Compare the amount of force applied to the small syringe in order to move the big one and vice versa. You will discover that much less force is needed on the smaller syringe in order to move the big syringe. This demonstrates the principle of hydraulics.

Car hydraulic brakes



Disc brake

Source: http://en.wikipedia.org/wiki/File:Disk_brake_dsc03682.jpg

When a brake pedal is depressed, the piston of a master cylinder exerts a small force on the brake fluid. This pressure created is transmitted

equally to the fluid in the slave cylinders. Since the area of the fluid surface in the slave cylinders is larger, the force acting on the pistons is made bigger. When the brake pads press on a wheel disc, the car can stop.

Hydraulic jack



Earth moving vehicle



Siphon

A siphon is used to transfer liquids from one container to another where it is difficult to pour directly. To make the siphon work, the container where the liquid is taken from should be placed at a higher level than the other. For example, if you want to transfer fuel from a jerry can to a car's fuel tank, the jerry can should be placed at a higher level than the opening of the fuel tank. The tube should then be dipped into the fuel and filled with the fuel.





Source: <http://en.wikipedia.org/wiki/File:Siphoning.JPG>

After completion the section on pressure, please try completing the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

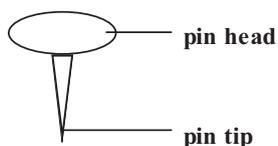
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- The unit of pressure is
 - N/m;
 - N/m^3 ;
 - Nm;
 - N/m^2 .
- Which changes of area and force would result in the most increase in pressure?

	area	force
A	increase	constant
B	decrease	constant
C	increase	decrease
D	decrease	decrease

- Maria uses a force of 20 N to push a drawing pin into a notice board. The area of the tip of the pin is 0.06 cm^2 .



Calculate the pressure in:

- (a) N/cm^2 ;
 (b) pascal.

4. Describe fluid pressure.

Congratulations on completing another section involving forces! The next section will also deal with forces but in a slightly different way.

Section 6: Work, Energy and Power

Introduction

The terms work, energy and power can be very confusing. The reason for this is that the way they are used in science is very different from how they are used in everyday language. When referring to work, we usually mean a job where you earn a salary or carry things that make you sweat.

If you ask people what is power, they are likely to tell you that if you can lift a very heavy load, it means you have power. Others will just show you their muscles.

You may also hear someone say, “I don’t have the energy to watch television,” when in fact they mean is that they lack interest. Are these words used correctly? You will soon find out in this section.



Basic Competence

On successful completion of this section, you will be able to:

- *explain* that energy is the ability to do work and that joule is the unit of both work and energy;
- *state* that work done as the force that is applied over a distance and use the formula to calculate work;
- *state* power as the amount of work done per unit time and use the formula to calculate the power output in everyday applications.

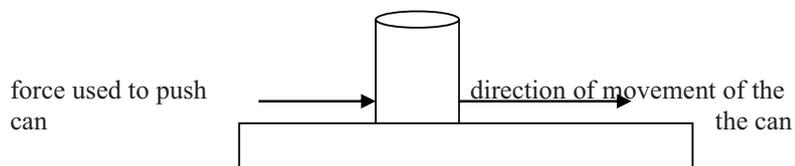


Time

This section will take you about seven hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Energy and work done

What is energy? Energy is the ability to do work. The SI unit of energy is joule (J). When is work said to be done? The scientific meaning of work is different from its meaning in everyday language. Work is said to be done when a force moves an object in the direction in which the force moves. Look at the diagram in which work is done. This is because the force and the movement of the can are in the same direction.



For a body to do work it must have energy. Therefore, the SI unit of work done is also joule. Do you still remember what the unit of force is? If you are not sure, please go back to Section 2 of Unit 5. You could also refer to Unit 1. In order to find the energy in joules, the force must be in Newton (N) and the distance must be in metres (m).

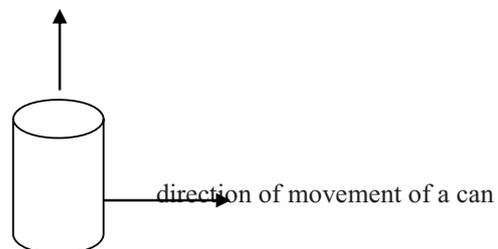
If you use 40 N to push a trolley over 2 m, the work done can be calculated as follows:

Work done = Force x distance

$$\begin{aligned} W &= F \times d \\ &= 40 \text{ N} \times 2 \text{ m} \\ &= 80 \text{ Nm} \\ &= 80 \text{ J} \end{aligned}$$

We have discussed that work is done when a force moves an object in the direction of the force. What if the force and the movement of an object are not in the same direction? For example, if you carry a can of cool drink in your hands and move on level ground, the force is directed upwards while the can moves horizontally. This means that the force and the distance are at right angles or perpendicular to each other.

force keeping the can up



In this case, no work is done. Can you think of situations where the force and the direction of movement are perpendicular to each other?

Power

Power is:

- the speed of doing work or
- the rate at which energy is transferred or
- the rate at which work is done.

Power = work done/time taken or energy transferred/time taken

$$P = W/t$$

The unit of work done is watt (W). From the earlier example, when you pushed the trolley over 2 m in 3 seconds, the power of your muscles would have been calculated as follows:

Power = work done/time taken

$$\begin{aligned} P &= W/t \\ &= 80 \text{ J}/3 \text{ s} \\ &= 26.7 \text{ J/s} \\ &= 26.7 \text{ W} \end{aligned}$$

All of the above formulas have already been introduced in Unit 1. As stated at the beginning of this course, special effort and attention should be given to ensure that the correct upper and lower symbols are used.

If you are comfortable with the topics work, energy and power, then proceed to doing the next self-mark activity.



Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

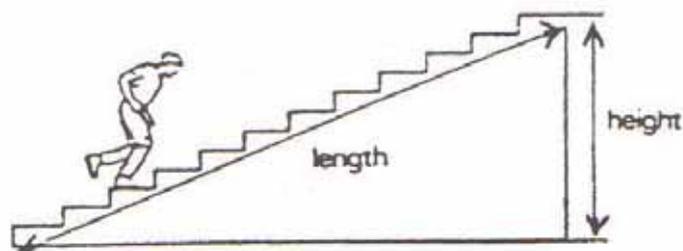
1. A mass m was pushed at a distance along a horizontal surface by a constant force F .



Which quantities must be known in order to calculate the work done by the force?

- A d and F only;
- B d , F and m .
- C d and m only;
- D F and m only.

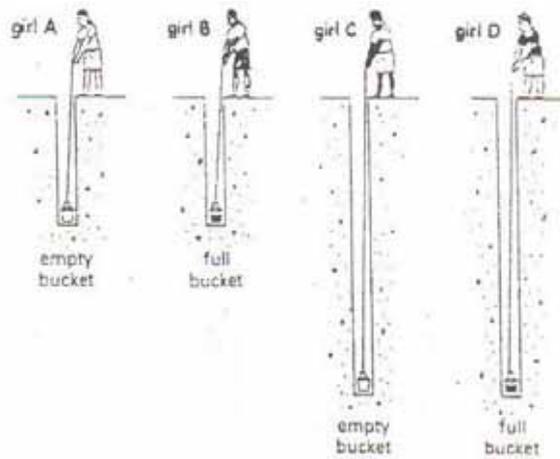
2. A student runs up a flight of stairs.



What information is not needed to calculate the rate at which the student is doing work?

- A the height of the flight of stairs;
- B the length of the flight of stairs;
- C the time taken to run up the stairs;
- D the weight of the student.

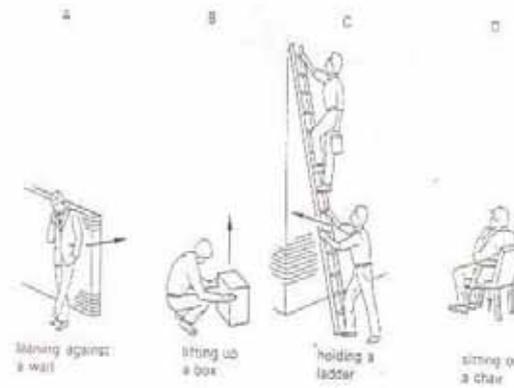
3. Each of the four girls has to lift a bucket from the bottom of a well. Which girl does the most work?





4. A man weighing 600 N runs up a flight of stairs with a height of 4 m in 3 seconds. What power is exerted by the man?
- A 200 W;
 - B 450 W;
 - C 800 W;
 - D 2,400 W.

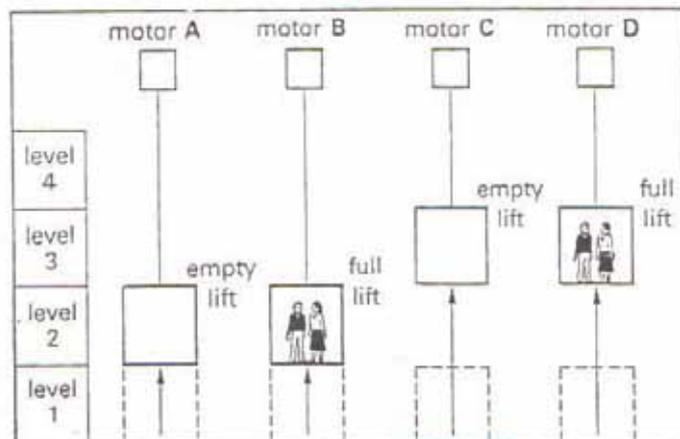
5. Which picture shows work being done?



6. Which unit is used for work?

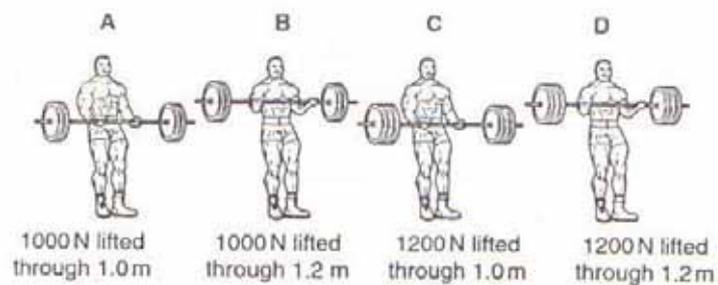
- A joule;
- B kilogram;
- C newton;
- D watt.

7. The diagram shows four lifts moving up from level 1. [Source: JSC 1997]



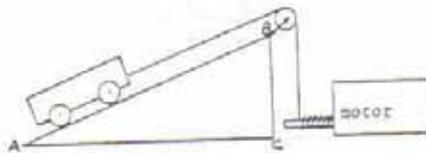
Which motor does the most work in the moving of the lifts?

8. Four weight lifters lift weights to different heights. Which weight lifter does the most work?



9. A trolley is pulled with a constant velocity from A to B as shown in the sketch below. The force exerted by the motor on the trolley is 4000 N and the distances are as follows:

AB = 5 m, BC = 3 m; CA = 4 m



- (a) Calculate the work done by the motor.
 (b) Calculate the power of the motor, if the time taken to raise the



trolley from A to B is 20 seconds.

10. The diagram shows a girl lifting a box of books from the floor onto a table.



- (a) The box containing books weighs 30 N. Calculate how much work is done lifting 10 similar boxes of books onto the table. Show the method used to obtain your result.
- (b) It takes 30 seconds to do this work. Calculate her rate of work (power). Show the method used to obtain your result.

Now you have studied work, energy and power. In the next section of this unit we will look at simple machines that make work easier.

Section 7: Making Work Easier: Levers, Gears and Pulleys

Introduction

Simple machines are very important in our everyday life because they make work easier. From now on, try to identify simple machines used at home and other places that make work easier. These can be levers, gears or pulleys. In this section we will look at different types of simple machines and how they help to make our work easier.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>identify</i> examples and uses of levers, gears and pulleys and explain how they are used to make effort easier; • <i>identify</i> the fulcrum, effort and load when using a lever;
--	---

	<ul style="list-style-type: none"> • <i>explain</i> how pulleys change the direction or reduce the effort needed; • <i>explain</i> the ratios of force, effort and speed in gears and pulleys by calculating these ratios given the number of teeth in the gear.
--	--

 Time	<p>This section will take you about eight hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
--	--

Making work easier

When work is done, a lot of energy is transferred. Did you know that people have invented machines that can make work easier? This means that less force is used. In this section, we will discuss how work can be made easier by using simple machines.

Let us look at some simple machines:

1. Levers

All levers have three main parts in common; the fulcrum, effort and load.

Look at the example of a lever below.



Source: <http://en.wikipedia.org/wiki/File:Palanca-ejemplo.jpg>

We can make work easier by making use of levers. An example of a lever is a bottle opener used to open a bottle. The bottle opener makes the work easier by making the force that you use to open the bottle smaller. Levers reduce the force required to lift a load. Increasing the distance between the lever and the load reduce the force. From the formula of work done, you should notice that work is directly proportional to force and distance.

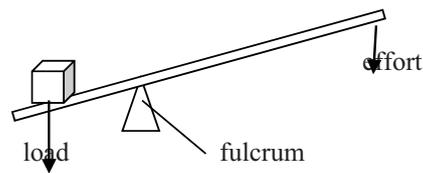


If the work has to remain the same when the distance is increased, then the force must decrease.

Classes of levers

First class levers:

First class levers have the fulcrum between the load and the effort. Can you think of some examples of first class levers? Yes. A see-saw is an example of first class levers.



Examples of first class levers include:

see-saw;
bottle opener;
beam balance;
scissors.

Second class levers:

Second class levers have the load between the fulcrum and the effort. Examples of second class levers include:

wheelbarrow



Third class levers:

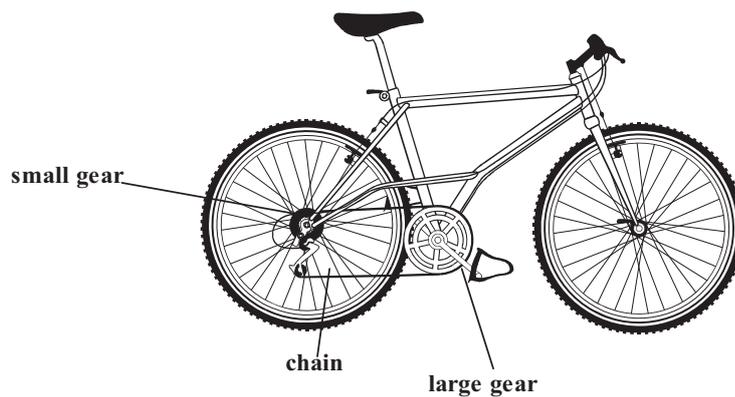
Third class levers have the effort between the fulcrum and load. Examples of third class levers include:

forceps



2. Gears

We can also use gears to make work easier. Gears are used in cars, bicycles and other moving machines. They are used to pass the turning forces from your feet to the back wheel of a bicycle. For example, a bicycle has two gears that are connected by a chain.



The larger gear in front, is connected by the chain to the smaller gears at the back wheel. When the larger gear turns once, the smaller one will turn many times depending on the ratio of the gears. This makes the back wheel turn many times causing the bicycle to go faster.

Car gears work in the same way as gears on a bicycle, except that there is no chain to connect them. The gear wheels touch each other. The top gears in a car are used for high speeds.



3. Pulleys



pulley

Pulleys are also used to make work easier. They are used to lift things that are too heavy or too big to lift directly.

Inclined planes

Lifting a load up into a container can be very difficult. A ramp makes it easier to push a wheelbarrow up to the container. You can also slide an object up into the container without having to lift it vertically.



Wedge

Axes, chisels and knives are examples of wedges. Wedges are similar to inclined planes. An axe for example, has two sides which resemble inclined planes.



A wood splitting wedge

Source: <http://en.wikipedia.org/wiki/File:Wedge-1.jpg>

Ratio calculations in a gear:



The figure above shows two gears labeled A and B. When you count the number of teeth of gear A you will get 9 teeth. Gear B has 18 teeth. When gear A rotates once then gear B has passed only half way. Why? The solution lies in:

the ratio of teeth of A : the ratio of teeth of B.
 = 9 : 18
 = 1 : 2

If B has rotated 3 times how much did A rotate?
 Yes, of course A will rotate 6 times.

Good, if you feel comfortable with simple machines, do the following self-mark activity.

Self-Mark Activity



Self-Mark
Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

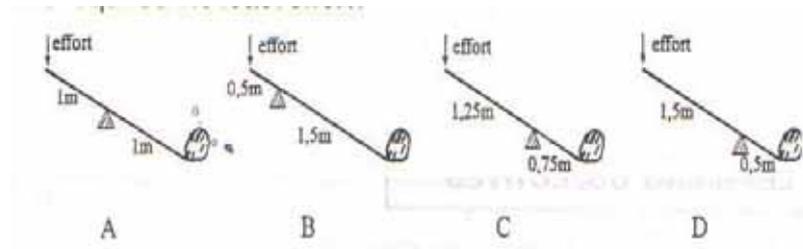
1. The two gears of a bicycle are connected by a chain. The small gear on the back wheel has 16 teeth and the big gear at the pedals has 48 teeth. [Source: JSC 1999]



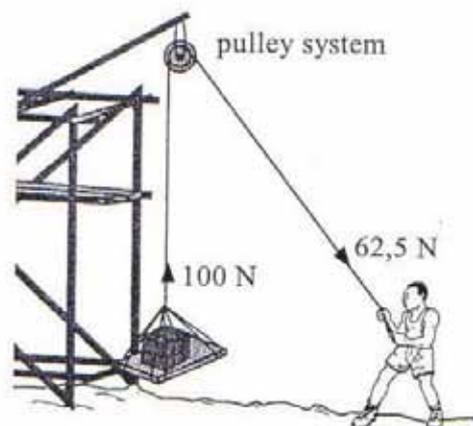
When you pedal two full cycles, how many times will the back wheel turn?

- A 2;
- B 4;
- C 6;
- D 8.

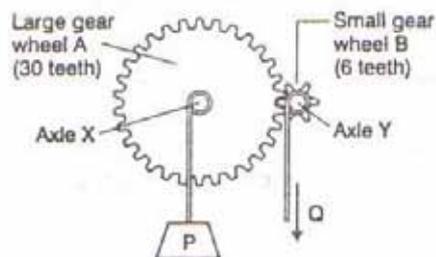
2. The diagram shows four ways of using a lever to lift a rock. Which one requires the least effort? [Source: JSC 1997]



3. The diagram shows a pulley system used by John to lift a load of bricks. John finds that he applies a force of 62.5 N to lift a load of bricks of 100 N through a distance of 1 metre. During the lifting of the bricks, John moves through a distance of 2 metres. [Source: JSC 2004]



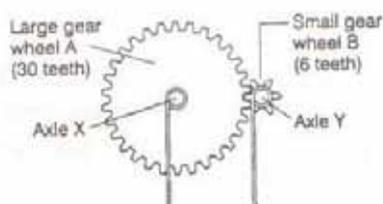
- (a)(i) Calculate how much work John is doing on the pulley system.
 (ii) Calculate how much work is done by the pulley system.
- (b) It takes John 10 seconds to lift the load of bricks over one metre from the ground. Calculate the amount of power used by John to lift the bricks.
- (c) State two advantages of using a pulley system as a machine.
4. The diagram shows a machine that will pick up the load (P) when a force (Q) is applied.



- (a) Calculate how many times the small wheel (B) must turn in order to make the large wheel (A) turn once.

5. The diagram shows a machine that can be used to make work easier.

[Source: JSC 1997]



- (a) The diameters of axles X and Y are the same in length. A force is applied on the cable of axle Y over a distance of 5 m. Calculate the distance that the load on axle X will move.
- (b) Select which one of the two gear wheels the load should be attached to in order to make the lifting easier.
- (c) Explain your answer.

Congratulations on completing another self-mark activity. Now we have only two sections left in this unit. We have looked at forces, work, energy and power in the previous sections. In the last two sections, we will concentrate on the conservation and conversion energy and on the sources of energy.

Section 8: Energy Conversions and Conservation

Introduction

In this section, we will learn about how energy can be changed from one form to another and how it can be conserved.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>state</i> that energy can only be changed from one kind to another, but cannot be destroyed or created, and recognise that, in all of the examples studied, energy is conserved; • <i>describe</i> what is meant by conservation of energy; • <i>explain</i> and <i>calculate</i> the efficiency in the transfer of energy in machines; • <i>identify</i> and <i>describe</i> processes by which energy is converted from one form to another; • <i>investigate</i> and <i>explain</i> how energy from the sun can be harnessed (used in greenhouses, solar ovens and stored in solar panels).
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 Time	<p>This section will take you about nine hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Energy

You have learned that energy is the ability to do work and that work is done whenever energy is transferred. In this section, I will introduce you to some examples of energy conservation and conversion.

The Law of conservation of energy

The **law of conservation of energy** states that energy can neither be created nor destroyed. It can only be converted from one form to another. I will now give you different examples where energy is being converted.

Before studying energy conversions, I want to introduce some forms of energy. I am sure you are familiar with some of them.

(a) Potential energy (p.e.): this is stored energy. The following are some examples of stored energy.

(i) Chemical energy: this is the energy which is stored in food and fossil fuels (oil, gas, coal) and wood. Batteries are also sources of chemical energy.

(ii) Gravitational potential energy (g.p.e.): this is the



energy due to the position of an object (height). For instance, water in a mountain reservoir. Any object at a height has g.p.e.

(iii) Strain energy: this is the energy due to a condition. For instance, a wound-up spring, or stretched rubber band; both have strain energy.

(b) Kinetic energy (k.e.): this is the energy a body has due to motion (movement). A moving object has kinetic energy.

(c) Electrical energy: this is the energy produced at power stations and from batteries.

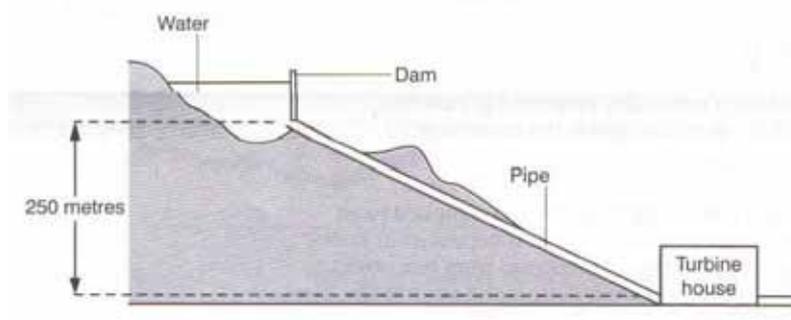
(d) Heat energy: this is the form of energy that often results from other energy changes.

(e) Nuclear energy: this is the energy that results from the splitting up of heavy unstable radioactive nuclei of atoms.

(f) Other forms of energy: these include light and sound.

Let us look at some situations where energy is converted from one form to another.

1. Water stored behind a dam wall contains stored energy (potential energy). When the water flows, energy changes from potential energy to kinetic energy. The kinetic energy of the water drives generators and electricity is produced. At Ruacana Falls, electrical energy is produced from water. Thus, the main changes in the production of electricity are:



potential energy → kinetic energy → kinetic energy → electrical energy

2. When a person cycles, chemical energy stored in the muscles is converted into kinetic energy.



Source: http://en.wikipedia.org/wiki/File:Urban_cycling_III.jpg
chemical energy → kinetic energy

3. When you stretch a rubber band or bowstring and then let it go, potential energy is converted into kinetic energy.



Source: http://en.wikipedia.org/wiki/File:Elastic_money.jpg
potential energy → kinetic energy

4. In a fire, chemical energy stored in the fuel is changed into heat and light energy.



Source: http://en.wikipedia.org/wiki/File:Montana_16_bg_062406.jpg
chemical energy → heat energy + light energy



5. When an athlete runs, chemical energy in the body of the athlete is converted into kinetic energy and heat energy.



Source: <http://en.wikipedia.org/wiki/File:MNSTATE.jpg>

chemical energy \rightarrow kinetic energy + heat energy

6. When you rub your hands together, chemical energy from your muscles is changed into kinetic energy and finally changed into heat energy.

chemical energy \rightarrow kinetic energy \rightarrow heat energy

The efficiency of energy conversions

During energy conversions, not all the energy put into a machine or human body is converted from one form to another. In the process, some of the energy is lost. For example, if you run 100 m, it is expected that the chemical energy in your muscles required for running will all be converted into kinetic energy. This, however, does not happen. Some energy is used to overcome air resistance while some is lost in the form of heat and sound. Machines, just like the human body also lose energy in a similar way. Therefore, it is practically impossible to find a machine which is 100 % efficient.

What is meant by efficiency?

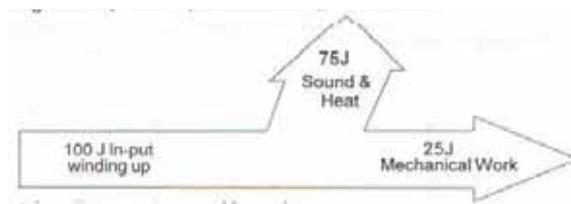
Efficiency is the ratio of useful energy to the total energy input. The formula of efficiency is:

$$\text{efficiency} = \frac{\text{useful energy}}{\text{total energy input}}$$

Or

$$\text{efficiency} = \frac{\text{energy output}}{\text{energy input}}$$

Look at the diagram below that shows the distribution of energies when a mechanical clock operates for every 100 J input when winding up the clock. It is expected that the 100 J will be converted into mechanical work but this is not so. Some energy is converted into other forms, like sound and heat.



I will give you examples of how to calculate the efficiency of the clock's machine.

(a) Efficiency as a percentage:

$$\begin{aligned} \text{efficiency} &= \frac{\text{energy output}}{\text{energy input}} \times 100 \\ &= \frac{25}{100} \times 100 \\ &= 25\% \end{aligned}$$

(b) Efficiency as a fraction:

$$\begin{aligned} \text{efficiency} &= \frac{\text{energy output}}{\text{energy input}} \\ &= \frac{25}{100} \\ &= 0.25 \text{ or } \frac{1}{4} \end{aligned}$$

The answer can be expressed as a percentage or fraction depending on what you are asked. Although you have studied various energy conversions, I will include a few more.

In the earlier examples, you noticed that energy is converted from one form to another. Energy is only useful when it is changed from one form to another. You should remember that energy cannot be created or destroyed. It can only be changed from one form to another. There are many examples of energy conversions in everyday life.

Other examples of energy conversion involve the following:

(i) Chemical energy:

When you burn coal, oil, gas, wood, you get heat energy

chemical/fuel energy \rightarrow heat

(ii) Energy from water:

When water falls from a height, its kinetic energy can be used to drive electricity generators. This type of energy is called hydroelectric energy. Waves and tides have kinetic energy that can be used to drive generators to produce electricity.

**(iii) Geothermal energy:**

This involves hot rocks deep underground. Cold water is pumped down the hot rocks and is heated. When it comes out, it can be used for heating or producing electricity. Steam from hot springs can be used directly to drive turbines.

(iv) Nuclear energy:

When the nuclei of a radioactive isotope of uranium undergo fission, a lot of energy is produced. This heat energy can be used to heat water and the steam produced can be used to drive turbines in generators.

(v) Solar energy (solar panels):

Solar panels trap solar energy that is converted into electrical energy. Solar energy can also be stored in solar panels that change it into electrical energy. Solar ovens work by trapping solar energy that is used for cooking.

(vi) Wind energy:

Wind energy is used to turn windmills. When windmills turn, they drive generators that produce electricity. Windmills can also be used to pump water from underground.

Now that we have looked at different kinds of energies work through the following practical activity.

**Practical Activity****Practical Activity**

A solar oven is a way of harnessing the sun's energy to cook food. It is cheap because you do not receive an electricity bill. They can be in many different forms, but all work in the same way. The materials are also cheap to get. All you need is the effort to build one.

Problem:

To build a solar oven.

What you need:

a metal box (or cardboard if you are not using very strong reflectors);
reflectors (large mirrors or aluminium foil);
a pot;
a glass cover.

What to do:

1. Make a metal box with reflectors to focus the sunlight at one point inside as shown in

the diagram below.

2. Make the inside of the box black, to absorb more heat.

3. Cover the box with glass so that you can create a greenhouse effect inside the box.

4. Put the pot at the point in the box where the sunlight will be focused.



Source:

<http://en.wikipedia.org/wiki/File:Solar-Panel-Cooker-in-front-of-hut.jpg>

You must take extra care because the oven can get as hot as 200° C. At this temperature, a fire can start if the oven is near some papers or leaves. You can also get burnt, so handle it with extra care!

There is a lot of information on the Internet if you have access. If you do not have access, ask your teacher or tutor to help you.

Are you ready to build one?

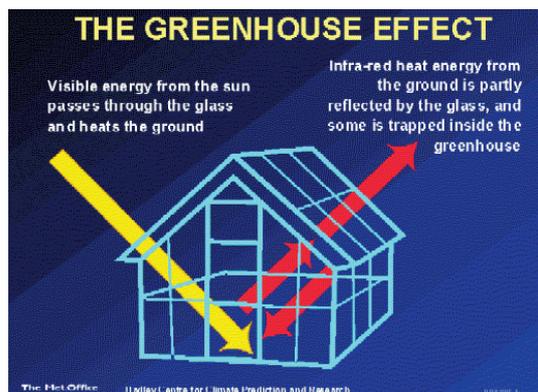
I hope that your solar cooker activity went well as it could potentially save a lot of electricity in our homes.

Greenhouses

Another way of harnessing the energy from the sun is by using greenhouses. A greenhouse works in the following way:

- The glass in a glass house allows heat radiation from the sun (short wavelength energy) to pass through the glass and warm the inside.
- The warmed glasshouse, in turn, gives off heat radiation, but as long wavelength energy.
- The glass absorbs most of this radiation and then emits (gives off) some of it back towards the inside. Glass does not let all of the long wavelength radiation through. Much is kept in the house, increasing the inside temperature.

This process is called the greenhouse effect.



Source: <http://www.realscience.org.uk/science-discussion-climate-change-clouds.html>

The same greenhouse effect applies to the earth, where carbon dioxide and other gases have the same effect as the glass in the greenhouse effect.



Source: http://www.odec.ca/projects/2005/stro5c0/public_html/

The detailed study of the greenhouse effect of the earth is not part of this course. However if you are also enrolled in the Life Science course you will be able to learn much more about this topic.

Now, you try to complete the next self-mark activity.

Self-Mark Activity



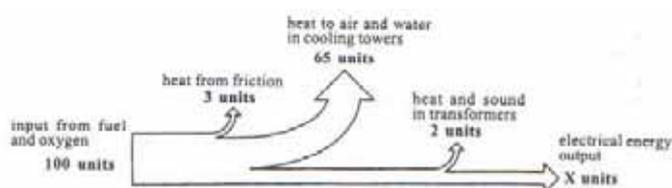
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- The diagram shows the energy conversion of a transformer.



- Calculate the value of X. Show how you arrive at your answer.
 - Calculate the percentage of the total energy input that is lost as heat energy.
 - Calculate the efficiency of the transformer.
- Explain how solar energy could be harnessed.

Now that you have completed this self-mark activity, you can now proceed to the last section of this unit.

Section 9: Sources of Energy

Introduction

Energy can be obtained from various sources. These sources can be put into two groups: renewable sources and non-renewable sources. In this section, we will examine these sources and their advantages and disadvantages.



On successful completion of this section, you will be able to:

- compare* and *distinguish* the advantages and disadvantages of renewable energy sources and



Basic Competence	non-renewable energy sources; <ul style="list-style-type: none"> • <i>evaluate</i> the use of renewable energy sources.
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 Time	This section will take you about three hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.
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In this section, you will learn about different sources of energy. Remember, that the law of conversion of energy states that we cannot make or destroy energy.

In most countries, the main sources of energy are fossil fuels such as coal, oil and natural gas. Once these sources have been used, they cannot be replaced and so they are called non-renewable sources. Those sources of energy that can be replaced once used, such as wind and hydroelectric energy, are called renewable energy sources.

Let us look at the advantages and disadvantages of non-renewable energy sources such as oil and coal and renewable energy sources such as hydroelectric and wind energy.

Advantages of renewable sources

1. They can never be used up. They can be recycled.
2. They do not pollute the environment.

Disadvantages of non-renewable sources

1. These sources can be used up. They cannot be recycled.
2. They can cause air pollution when they are burned.

In Namibia, we are fortunate that most of our electricity comes from the hydroelectric energy from in the Kunene River. As long as the river flows, this kind of energy is never used up. That is why it is a renewable source of energy.

Renewable sources of energy

1. Energy from the sun is renewable, because it can never be used up. Almost all the energy used on the earth originally comes from the sun. Energy from the sun is called solar energy. The sun provides energy that we use to dry our clothes after we have washed them and to dry products such as tobacco, fruit and meat (biltong). The sun also provides green plants with energy to make their own food (photosynthesis). Solar energy is also used for solar powered calculators.

2. Energy that comes from moving water is called hydroelectric energy. It is also renewable, because it will not be used up.

3. Energy from wind is also renewable. People use wind to drive wind generators and windmills. Wind generators convert the energy of the wind into electricity. Windmills can also use the energy from the wind to draw water from underground.

4. Solar energy can be used in greenhouses. What is a greenhouse? This is a house made of glass. The strong rays of the sun enter the house and get absorbed by the plants and any materials inside. The plants and the other materials then release rays of less energy that cannot go out through the glass. This causes the temperature inside the house to be higher than outside. Greenhouses are commonly used in very cold countries. A simple example of a greenhouse effect is a car parked in the hot sun. When you get inside it after a while, you will notice that the temperature inside is higher than that outside.

Solar energy can be stored in solar panels and solar cells. In solar panels and cells, it is converted into electrical energy.

5. Radioactive isotopes are isotopes of certain elements whose nuclei are heavy and unstable. The heavy unstable nuclei can then split to release a lot of energy in the form of heat. This heat energy can be used to heat up water to produce steam. The steam then drives the turbines (propellers) just like water does. Although nuclear energy can produce a lot of heat energy, it can cause some health problems. When the nuclei split, radiation is also produced. This radiation can damage the cells of living organisms.

With this new information on renewable sources of energy and their advantages and disadvantages, we conclude this unit. All that remains for this unit is to work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Describe what we mean by:
 - (a) renewable energy sources;
 - (b) non-renewable energy sources;
- (c) Name one example of a:
 - (i) renewable energy source;
 - (ii) non-renewable energy source.



2. (a) Name one advantage of using renewable energy sources.
(b) Name one disadvantage of using a non-renewable energy source such as coal.
3. Describe how electricity can be generated from:
(a) hydroelectric energy;
(b) wind energy.
4. Describe how solar energy is used in:
(a) greenhouses;
(b) solar panels.
5. Radioactive isotopes, like uranium, are a source of heat energy. Apart from being non-renewable, describe one disadvantage of using this source of energy.

We have come to the end of this unit. To ensure that you have understood the material, spend a few hours reviewing what we have covered in this unit.

 Summary	<p>In this unit you learned that:</p> <ul style="list-style-type: none">• distance is the physical distance moved, while displacement is the distance moved in a specified direction;• speed is the rate of change of distance in a given time;• velocity is the rate of change of distance with time in a given direction;• weight is the gravitational pull on an object; it is measured in Newton;• mass is the amount of matter in an object;• inertia is the property of mass which “resists” change in motion;• a force is a pull or push and is
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	<p>measured in Newton;</p> <ul style="list-style-type: none">• the effects of forces are:<ol style="list-style-type: none">1. a force can move or stop an object;2. a force can change the direction of a moving object or change the velocity of an object;3. a force can change the shape of an object.• contact forces act on objects that are touching each other;• non-contact forces act without the objects touching each other;• friction opposes the movement of objects that are touching each other;• friction depends on:<ol style="list-style-type: none">1. type of surface;2. size of area of contact.• pressure is a force that is exerted per unit area;• energy is the ability to do work; it is measured in Joule;• work is done when a force moves an object in the direction of the force;• power is the speed of doing work;• levers, gears and pulleys make work easier;• the law of conservation of energy states that energy cannot be created or destroyed; it can only be changed from one form to another;• renewable energy sources can be replaced once used;• non-renewable energy sources cannot be replaced.
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Assessment



Assessment

The completed assessment can be submitted to the nearest government/program support centre or can be submitted via electronic form, in scanned pdf format.

Before you complete the assessment, it is best if you spend at least 8 hours revising the material you covered in units 4 and 5.

ASSESSMENT 2

Assessment for units 4 and 5	
Revision Study Hours	8 hours
Time dedicated to completing the assessment	6 hours

Answer all questions

Section A – Multiple Choice Questions

Choose the correct answer from the possible answers given.

1. In an exothermic reaction:

- A energy is created;
- B energy is destroyed;
- C energy is given out;
- D energy is taken in.

2. Nitrogen + hydrogen \rightarrow ammonia

What type of reaction is this?

- A burning;
- B combustion;
- C decomposition;
- D synthesis reaction.

3. Which of the following changes is temporary?

- A chocolate melting;
B coal burning;
C iron rusting;
D making glass from sand.
4. A sample of air was bubbled through distilled water. The pH of the water changed from 7 to 6. Which gas in the sample caused the change?
A argon;
B carbon dioxide;
C nitrogen;
D oxygen.
5. Lactic acid is a weak acid because.....
A it does not react with least reactive metals;
B it ionises completely in aqueous solution; C it ionises only partially in aqueous solution; D it is not very soluble in water.
6. Which of the following substances is used to neutralise acidic soil?
A ammonium nitrate;
B calcium hydroxide;
C magnesium sulphate;
D sodium chloride.
7. Which of the following pH values is of a strong alkali?
A 1;
B 5;
C 8;
D 11.
8. The following symbol appears on a bottle in the laboratory.

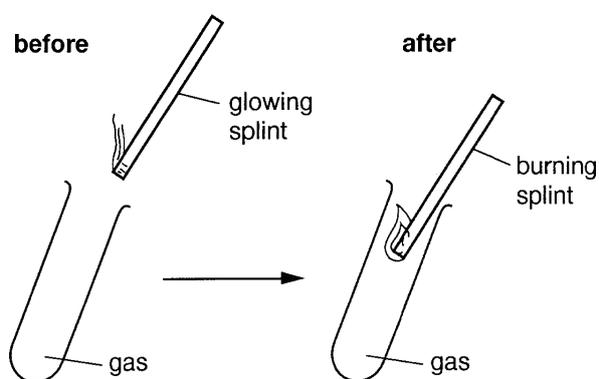




What does the symbol mean?

- A corrosive;
- B harmful;
- C irritant;
- D toxic.

9. The diagram shows how a student tried to identify the gas in a test tube.

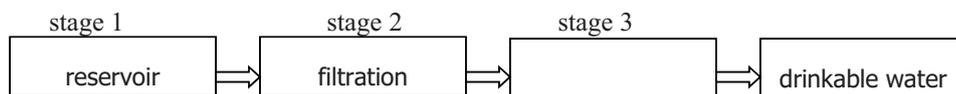


Which gas was in the test-tube?

- A carbon dioxide;
 - B hydrogen;
 - C nitrogen;
 - D oxygen.
10. Which one of the following processes can decrease the amount of carbon dioxide in the atmosphere?
- A combustion;
 - B deforestation;
 - C photosynthesis; D respiration.
11. What is the name of the acid found in vinegar?
- A carbonic acid;
 - B citric acid;
 - C ethanoic acid;

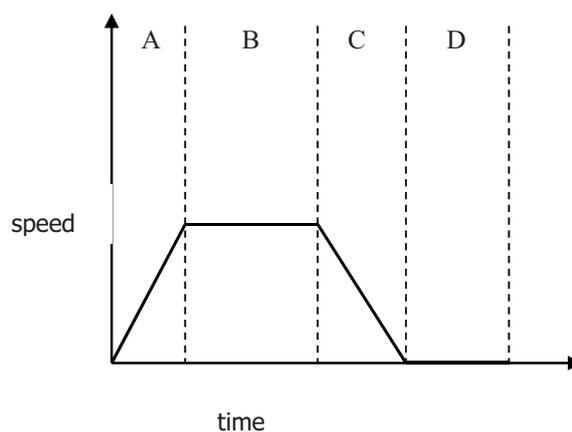
D tartaric acid.

- 12.** The diagram shows the steps involved in making the water safe for drinking.



What happens in stage 3?

- A** aeration;
B chlorination;
C evaporation; **D** sedimentation.
- 13.** A given colourless liquid is tested for the presence of water. Which chemical can be used for the test?
- A** anhydrous copper sulphate;
B anhydrous magnesium sulphate;
C hydrated copper sulphate;
D hydrated magnesium sulphate.
- 14.** The graph shows how the speed of a car changes over a period of time.



During which stage is the car moving at constant speed?

- 15.** When you are on the Earth, there is a force acting on you. What is this force called?



- A electrostatic;
- B friction;
- C moment;
- D weight.

16. If a 2 kg mass is lifted 1 m high, how much energy is transferred?

- A 2 kg;
- B 2N;
- C 20 J;
- D 20 N.

17. The table compares four lamps. Which lamp is more efficient?

Lamp	Light energy output in 1 second	Electrical energy input in 1 second
A	0.5 J	15 J
B	1.3 J	20 J
C	2.1 J	25 J
D	2.7 J	30 J

18. What type of energy is stored in a stretched rubber band?

- A chemical energy;
- B gravitational potential energy;
- C kinetic energy; D strain energy.

19. Which energy conversion takes place in solar cells?

- A electrical energy \rightarrow solar energy;
- B electrical energy \rightarrow kinetic energy;
- C kinetic energy \rightarrow electrical energy;
- D solar energy \rightarrow electrical energy.

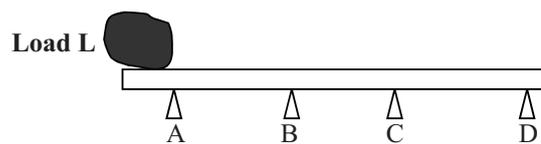
20. A motor, powered by a battery, is used to drive a pulley system.

What is the type of energy stored in the battery?

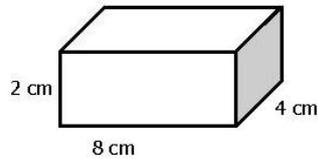
- A chemical energy;
- B heat energy;
- C kinetic energy;

D sound energy.

21. An object has a mass of 5 kg. What is its weight here on earth?
- A** 0.5 N;
 - B** 5 N;
 - C** 50 N;
 - D** 500 N.
22. A lever is to be used to lift a heavy load L. Where should the pivot be in order to use the least effort?



23. Amani carried a bag of potatoes with a force of 300 N along 15 m distance. What is the amount of work done by Amani?
- A** 0.05 J;
 - B** 20 J;
 - C** 450 J;
 - D** 4,500 J.
24. A man weighs 800 N. The area of **one** shoe is 0.02 m^2 . What pressure is exerted on the ground when standing on his **two** feet?
- A** 32 N/m^2 ;
 - B** 16 N/m^2 ;
 - C** $20,000 \text{ N/m}^2$;
 - D** $40,000 \text{ N/m}^2$.
25. The diagram shows a solid with dimensions 8 cm x 4 cm x 2 cm. It has a mass of 500 g.



What is the pressure exerted by the large area?

- A 1,562.5 N/m²;
- B 3,125 N/m²;
- C 156,250 N/m²;
- D 312,500 N/m².

26. A farmer has two carts. The carts have the same weight, but one has four narrow wheels and the other has four wide wheels.



narrow wheel



wide wheel

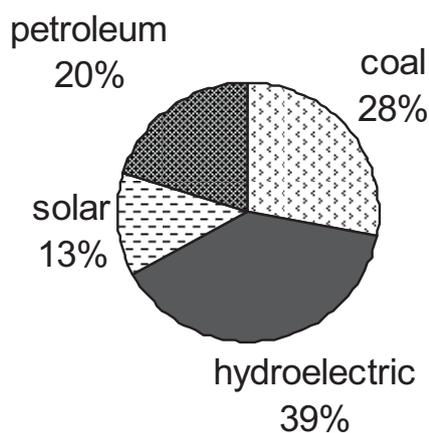
In soft ground, which cart sinks less? Why?

	Cart wheels	Why
A	narrow	greater pressure on the ground
B	narrow	less pressure on the ground
C	wide	greater pressure on the ground
D	wide	less pressure on the ground

27. Which one of the following persons experiences more inertia?

- A a boy weighing 540 N;

- B** a man with a mass of 65 kg; **C** a man with a mass of 90 kg;
- D** a woman with a weight of 800 N.
28. What is the average speed of a car which travels 2,400 metres in 2 minutes?
- A** 1,200 metres per hour;
B 20 metres per minute;
C 20 metres per second;
D 1,200 metres per second.
29. Which energy source may lead to large area of land being flooded?
- A** hydroelectric;
B nuclear.; **C** solar;
D wind.
30. The pie chart shows the sources of energy a country uses to generate electricity.



What is the total percentage of renewable energy sources?

- A** 13%;
B 48%;
C 52%;
D 72%.

30 x 1 = 30

Section B – Structured Questions

1(a) The table shows some substances and their pH values.



substance	pH value
lemon juice	3.1
beer	5.2
blood	7.4
Handy Andy	9.8
salt solution	8.5

(i) Write down the substance which is most acidic.

-----(1)

(ii) State the substance which has a pH closest to neutral.

-----(1)

(iii) Write down the substance which is the strongest alkali.

-----(1)

(b) If you have a stomach upset it could be due to too much acid. You can use Milk of Magnesia to cure the stomach upset.

(i) State how the pH changes when the Milk of Magnesia neutralises excess acid in the stomach.

-----(1)

(ii) Write a general equation to represent the neutralisation reaction in your stomach.

-----(2)

(c) Ammonia is manufactured by reacting nitrogen with hydrogen in the presence of a catalyst.

(i) Balance the equation for the reaction.

$N_2 + H_2 \rightarrow NH_3$ -----(2)

(ii) Name the catalyst used in the manufacture of ammonia.

-----(1)

(iii) Give a reason why a catalyst is used in the process.

-----(1)

[10]

2. Sally added a few drops of the Universal Indicator to some potassium hydroxide. The indicator turned purple.

(a) Predict the pH of potassium hydroxide solution.

----- (1)

(b) Sally added an acid until the solution was neutral. State the colour of the Universal Indicator when the solution is neutral.

----- (1)

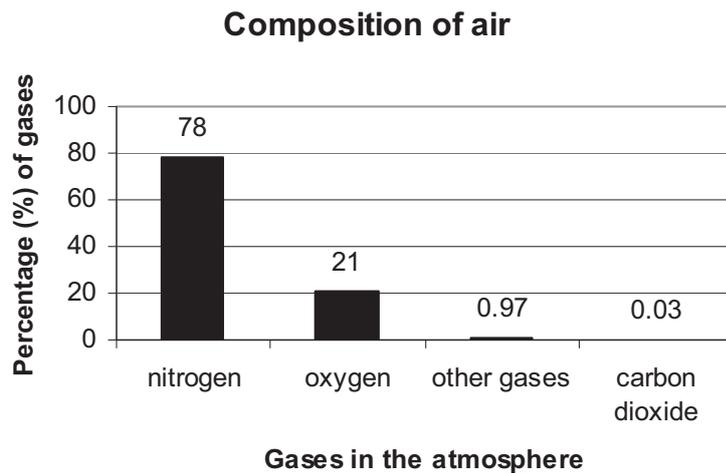
(c) Write down the name of the acid that must be added to potassium hydroxide to make potassium sulphate.

----- (1)

(d) Sally noticed that the solution got warm when the acid reacted with the alkali. In terms of energy, state what type of reaction it is.

----- (1)

3(a) The diagram below shows the percentage composition of air in the atmosphere.



(a) Name the gas which makes up most of the air.

----- (1)

(ii) Write down the name of the gas that is produced by plants during photosynthesis.

----- (1)

(iii) The amount of carbon dioxide gas in the atmosphere is slowly increasing. Suggest a reason why this is happening.

----- (1)



(iv) Describe the effect of the increased amount of carbon dioxide in the atmosphere over a long period of time.

-----(2)

(b) You are given two test tubes of a colourless gas. Describe how you would find out which test tube contains oxygen.

-----(2)

[7]

4(a) Petrol burns in a car engine.



(i) Describe how carbon monoxide gas is formed in the car engine.

-----(2)

(ii) Explain the effect of carbon monoxide on human health.

-----(2)

(b) Modern cars are fitted with catalytic converters in their car exhausts.

(i) Explain how the catalytic converter helps to reduce acid rain.

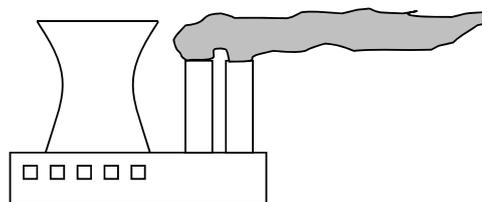
-----(2)

(ii) State whether a catalytic converter help to reduce the greenhouse effect.

Explain your answer.

-----(2)

(c) The von Eck Power Station in Windhoek uses coal as fuel to generate electricity.



(i) State the gas, present in the air, that is needed for any fuel to burn.

-----(1)

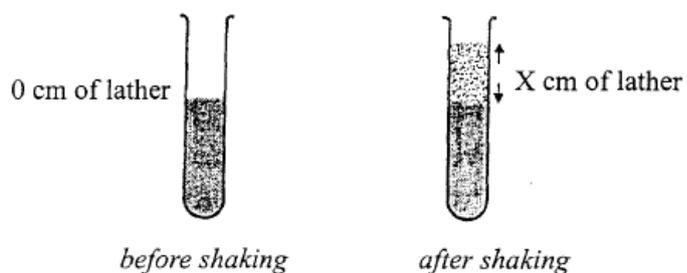
(ii) The burning of coal produces sulphur dioxide. When sulphur dioxide escapes into the environment it dissolves in water to produce acid rain. State **one** effect of acid rain on the environment.

-----(1)

[10]

5(a) Five samples of water **P, Q, R, S** and **T** were tested for hardness.

The same volumes of soap solution and water samples were used in all experiments. The experiment was done with un-boiled and boiled water. The diagram shows the test tubes with water and soap solutions before and after shaking. **Source:** JSC 2000.



Water samples	Height, X cm of lather after 20 seconds	
	un-boiled water	boiled water
P	1.0	5.0
Q	0.2	3.0
R	0.2	0.2



S	1.0	4.0
T	0.2	0.2

The height of lather after shaking for 20 seconds was measured for samples of un-boiled and boiled water and recorded in the table.

(i) Suggest a reason why the same volume of soap solution and samples of water in all experiments are used.

-----(1)

(ii) State which samples of water were permanent hard.

-----(2)

(iii) Give a reason why not one of the samples above contained soft water.

-----(1)

(iv) Name the **two** samples of water that are temporary hard.

-----(2)

(v) State what causes temporary hardness of water.

(b) Name the product formed when soap mixes with hard water.

-----(1)

(c) Hard water causes scale to build up in a kettle. Briefly describe how to remove the scale chemically.

----- (2)

[10]

6(a) Differentiate between **renewable and non-renewable** sources of energy. Give **one** example of each.

Renewable:----- (1)

Example:----- (1)

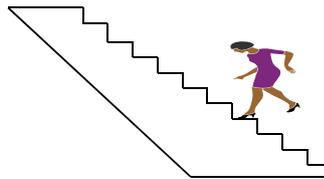
Non-renewable:----- (1)

Example:----- (1)

- (b) Describe **two** advantages that renewable energy resources have over non-renewable energy resources.

----- (2)

- (c) Missy-Bok runs up a staircase. Each step is 25 cm high. There are 10 steps to the top. Missy's weight is 650 N.



- (i) Calculate how much work must be done to reach to the top.

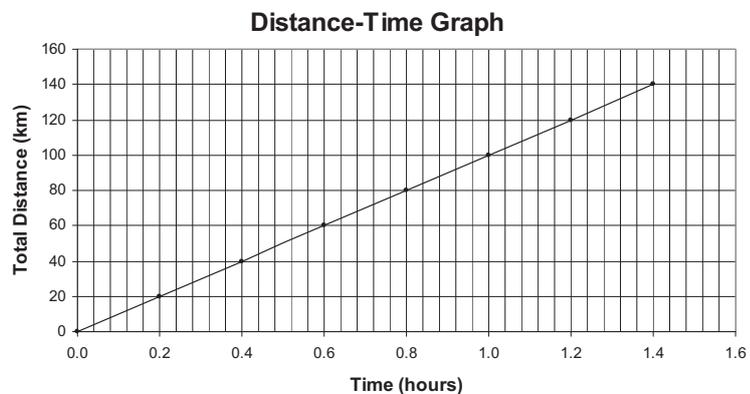
----- (3)

- (ii) Calculate the amount of power she develops if it takes her 5 seconds to reach to the top.

----- (2)

[11]

7. The distance-time graph shows part of a journey taken by a car. The car is travelling at a constant speed.





(a) Define the term speed.

------(1)

(b) Use the graph to determine the distance covered in 0.6 hours.

------(1)

(c) Determine the time the car took to travel a distance of 120 km.

------(1)

(d) Calculate the speed of the car.

 -----(3)

[6]

8. A crate of cool drink is dragged across a room. The force to do this can be measured.

(a) Name the instrument that is used to measure the force.

------(1)

(b) When the crate was dragged across the floor, there is a force between the crate and the floor that tries to stop the crate from moving. Name this force.

------(1)

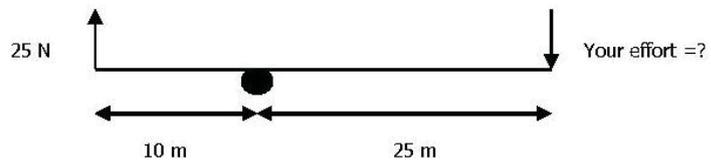
(c) State one way in which the force you mention in (b) above can be

(i) increased------(1)

(ii) decreased------(1)

[4]

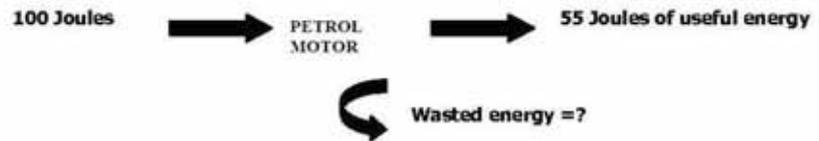
9(a) The picture below represents a simple lever machine.



Calculate the amount of force that you would need to balance the 25 N force.

 -----(3)

(b) The diagram below shows the efficiency of a petrol motor.



(i) Calculate the efficiency of the petrol motor.

 -----(3)

(ii) Write down the value of the energy wasted.

----- (2)

[8]

[70]

TOTAL: 100 MARKS



Answers to Self-Mark Activities

Section 1: Speed and Velocity

1. D

2. C

$$\begin{aligned}
 3. v &= s/t \\
 &= 100 \text{ m}/9.86\text{s} \\
 &= 10.14 \text{ m/s} \\
 &= 10.1 \text{ m/s}
 \end{aligned}$$

$$\begin{aligned}
 4(a) v &= s/t \\
 &= 950 \text{ m}/120 \text{ s} \\
 &= 7.9 \text{ m/s}
 \end{aligned}$$



(b) In km/h

$$950 \text{ m} = 950 \text{ m}/1,000 = 0.95 \text{ km}$$

$$120 \text{ s} = 120 / (60 \times 60)$$

$$= 0.033 \text{ h}$$

$$v = s/t$$

$$= 0.95 \text{ km} / 0.033 \text{ h}$$

$$= 28.8 \text{ km/h}$$

5(a) Average time = $(20+22)/2$

$$= 42/2$$

$$= 21 \text{ s}$$

(b) $v = s/t$

$$= 400 \text{ m} / 21 \text{ s}$$

$$= 19.0 \text{ m/s}$$

Section 2: Mass and Weight

1. A

2. B

3. C

4(a) $w = mg$

$$= 0.5 \text{ kg} \times 10 \text{ N/kg}$$

$$= 5 \text{ N}$$

convert 500 g to kg: $500/1,000 = 0.5 \text{ kg}$

(b) mass = $\frac{w}{g}$

$$g$$

$$= \frac{250 \text{ N}}{10 \text{ N/kg}}$$

$$= 25 \text{ kg}$$

5(a) Mass is directly proportional to inertia, therefore the more the mass,

the more the inertia. When making a turn, all the passengers still tend to continue in a straight line. When empty, the inertia is less.

- (b) Directly proportional, the bigger the mass is the more the inertia.
- (c) Using seat belts help us from not being thrown out when the car stops very quickly or hits a solid object like a concrete wall and stops.

6. Position of the centre of mass.

The size of the base area.

7. Stable equilibrium

Unstable equilibrium

Neutral equilibrium

Section 3: Forces and Their Effects

1. A

2. A

3. B

4. D

5(a) Contact force is a force that acts between objects that rub against each other, e.g., when car tyres rub against the road surface.

(b) Non-contact force is a force that acts at a distance. The objects do not touch each other, e.g., magnetic force, gravitational force and electrostatic force.

Section 4: Friction

1. It is a force that opposes the movement of objects that are in contact. It slows down or stop the movement of objects.
2. It depends on the roughness of the surfaces. The rougher the surfaces, the greater the force of friction. Weight is also a factor that affects the amount of friction. The greater the weight, the greater the force of friction.



- 3(i)** The cleaning liquid or water separates your feet from the floor. This reduces friction and can lead to sliding.
- (ii)** During the first rains, the oils on the tarred roads float on top of the water itself. This reduces friction a lot, causing the tyres of the cars to slide.
- 4(a)** when paging through a book, opening a mayonnaise bottle, etc.;
- (b)** when you buy new shoes, after some time their soles wear out.
- 5(a)** Friction will be reduced. This is because the film of water separates the two surfaces, thereby reducing the amount of friction.
- (b)** Draw the weight directed downwards.

Section 5: Pressure

1. D

2. C

$$\begin{aligned}
 \mathbf{3(a)} \quad P &= \frac{F}{A} \\
 &= \frac{20 \text{ N}}{0.06 \text{ cm}^2} \\
 &= 333.3 \text{ N/cm}^2
 \end{aligned}$$

(b) In pascals: convert 0.06 cm^2 to m^2

$$\begin{aligned}
 &\frac{0.06}{1,000} \\
 &= 6 \times 10^{-6} \text{ m}^2 \\
 P &= \frac{F}{A} \\
 &= \frac{20 \text{ N}}{6 \times 10^{-6} \text{ m}^2}
 \end{aligned}$$

$$= 3.3 \times 10^6 \text{ Pa}$$

4. It is pressure due to liquids and gases.

Section 6: Work, Energy and Power

1. A

2. B

3. D

4. C

5. B

6. A

7. D

8. D

$$\begin{aligned} \mathbf{9(a)} \quad W &= F \times d \\ &= 4,000 \text{ N} \times 5\text{m} \\ &= 20,000 \text{ J} \end{aligned}$$

$$\begin{aligned} \mathbf{(b)} \quad P &= \frac{W}{t} \\ &= \frac{20,000 \text{ J}}{20 \text{ s}} \\ &= 1,000 \text{ W} \end{aligned}$$

$$\begin{aligned} \mathbf{10(a)} \quad W &= F \times d \\ &= 30 \text{ N} \times 0.5 \text{ m} \times 10 \\ &= 150 \text{ J} \end{aligned}$$



$$\begin{aligned} \text{(b) } P &= \frac{W}{t} \\ &= \frac{150 \text{ J}}{30 \text{ s}} \\ &= 5 \text{ W} \end{aligned}$$

Section 7: Making Work Easier: Levers, Gears and Pulleys

1. C

2. D

$$\begin{aligned} \text{3(a)(i) } W &= F \times d \\ &= 62.5 \text{ N} \times 2 \text{ m} \\ &= 125 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{(ii) } W &= F \times d \\ &= 100 \text{ N} \times 2 \text{ m} \\ &= 200 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{(b) } P &= \frac{W}{t} \\ &= \frac{62.5 \text{ N} \times 1 \text{ m}}{10 \text{ s}} \\ &= 6.25 \text{ W} \end{aligned}$$

(c) It reduces the force (effort). You can use your own weight to pull the *rope down*, thereby making the *lifting easier*.

4(a) 5 times

5(a) 25 m

(b) axle X

(c) Axle X will turn only once when axle Y turns 5 times more.

Section 8: Energy Conversions and Conservation

$$\begin{aligned}
 \text{1(a) first find X: } & 100 - (3 + 65 + 2) \\
 & = 100 - 70 \\
 & = 30 \text{ units}
 \end{aligned}$$

$$\begin{aligned}
 \text{(b) Total heat lost:} \\
 \text{total heat} & = 3 + 65 + 2 \\
 & = 70 \text{ units}
 \end{aligned}$$

$$\begin{aligned}
 \% \text{ loss as heat} & = \frac{70}{100} \times 100 \\
 & = 70\%
 \end{aligned}$$

$$\begin{aligned}
 \text{(c) efficiency} & = \frac{\text{useful energy}}{\text{energy input}} \times 100
 \end{aligned}$$

$$\begin{aligned}
 & = \frac{30}{100} \times 100 \\
 & = 30\%
 \end{aligned}$$

2. Solar oven

Solar cooker

Green houses

Section 9: Sources of Energy

1(a) The energy sources do not get used up. After using them, they can be replaced.

(b) The energy sources cannot be used over and over again. Once used, they cannot be replaced.

(c)(i) water, wind, solar

(ii) fossil fuels, nuclear

2(a) You can keep on using them forever.

Do not get used up.



Do not pollute.

- (b) Can cause pollution when burned.

Once used, cannot be replaced.

Fossil fuels are difficult to extract (expensive).

Nuclear energy can cause more damage than just air pollution.

- 3(a) Water falls from a height through the dam wall. The kinetic energy of the water drives the turbines, which in turn drive the generators. The generators produce electricity.

- (b) Wind can drive the propellers of the windmill. The kinetic energy can drive generators.

- 4(a) A greenhouse is made of glass. The strong rays of light enter the house, but get weak and fail to go out. This causes the inside of the house to get warmer.

- (b) Solar panels are exposed to sunlight. They trap sunlight and convert it into electricity.

- 5. It gives out radiation, which can be harmful to living organisms by damaging cells.



Unit 6

Electricity and Magnetism

Introduction

In Unit 5 we discussed different aspects of mechanics.

This is the second to last unit of the physics component of this programme. This section deals with magnetism and electricity. You will first learn about magnets, their properties and their applications in various devices. Next, we will introduce you to a very practical area, namely electricity, including the safe use of electrical energy in the home. This unit consists of the following sections:

Section	Study Hours
1. Revision of Earlier Work on Magnets and Charges	3
2. Current	7
3. Voltage	7
4. Resistance	9
5. Relationships Between Current and Voltage in an Electrical Conductor (Ohm's law)	9
6. Electrical Power	5
7. Electricity in the Home	9
8. Magnetism	9
9. Magnetic Effect of an Electric Current	9
Review	3
Total	70



Outcomes

On successful completion of this unit you will be able to:

- *explain* the basic concepts of charge and current;
- *explain* the basic concepts of electric potential;
- *describe* the concept of resistance, how it is measured and calculated, its unit, how resistors can be connected in an electrical circuit and factors that influence the magnitude of the resistance of a resistor;
- *differentiate* the meaning of the terms electrical current, potential difference, resistance and Ohm's Law and use them in simple experiments and calculations;
- *measure* and *calculate* current, voltage and resistance at any point or between any two points in a circuit;
- *describe* power as the rate of doing work, the unit of power as watt and interpret the watt value of bulbs and other electrical appliances;
- *differentiate* between mains electricity and electricity from batteries and between direct and alternating currents;
- *apply* general terminology, conventions and use of electricity in and around the house;
- *explain* magnetism, magnetic properties and uses of magnets;
- *describe* the magnetic effect of an electrical current in a straight conductor and a solenoid;
- *explain* how to build electromagnets in loudspeakers and electric motors;
- *describe* how electrical energy is generated and transmitted in Namibia and explain why this process requires the use of transformers.



Terminology

Magnetic field	Area around a magnet where its force can be detected.
Ferromagnetic materials	Materials that can be attracted by a magnet.
Non-ferromagnetic materials	Materials that are not attracted to a magnet.



Static electricity	Charges that do not move.
Electroscope	An instrument used to detect small amounts of electric charge.
Current electricity	Electricity that involves the moving of charges.
Current	Number of charges moving per unit of time.
Conventional current	Current flowing from the positive terminal of the cell to the negative terminal.
Electron current	Current flowing from the negative terminal of the cell to the positive terminal.
Direct current	Current from a battery that flows in one direction: only from the positive terminal of the battery to the negative terminal.
Alternating current	Current from the power station that reverses direction many times in a second.
Potential difference	Energy that drives charge across a component in a circuit.
Resistance	Opposition of a conductor to the flow of charges.

Section 1: Revision of Earlier Work on Magnets and Charges

Introduction

Magnets are found in houses or schools among other things to keep posters against a fridge or blackboard. In this section we will have a discussion of magnets and static electricity.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>recall</i> from earlier work in units 2, 3 and 5, the properties of magnets and the nature of magnetic forces and fields; • <i>recall</i> from earlier work in units 2 and 5, the
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	meaning of static electricity and charges;
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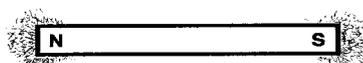


Time

	This section will take you about three hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.
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Magnets

A magnet is a piece of metal that has two poles: **north** and **south**.



If we sprinkle some iron filings onto a magnet, most of the iron filings are attracted to the end poles. This happens because the magnet is strongest there.

When like poles are brought together, they repel and when unlike poles are brought together, they attract. Only certain metals like cobalt, nickel, and iron are attracted to magnets. Alloys like steel, that contain iron, can also be attracted by magnets. Such materials are called ferrous materials.

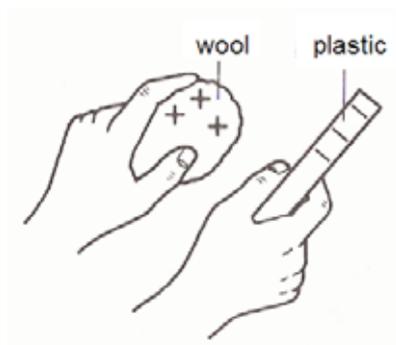
The rest of the metals are not attracted to metals. Materials that are not attracted to a magnet are called non-ferrous materials.

A magnet exerts a force around it. The area around a magnet where its force can be detected is called its **magnetic field**.

Static electricity

Static electricity involves charges that do not move.

After you have rubbed a plastic ruler with a cloth, the ruler will be able to pick up small pieces of paper.



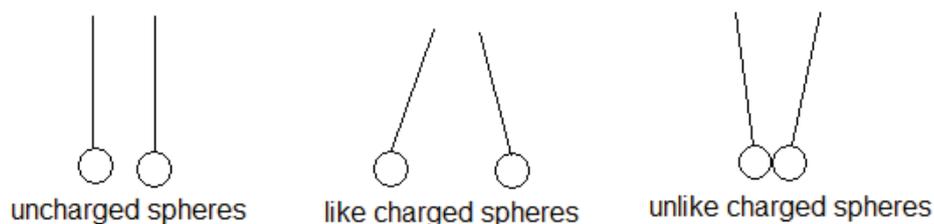


What happened when you rubbed them? You simply separated the negative and positive charges and some negative charges can move from one object to another.

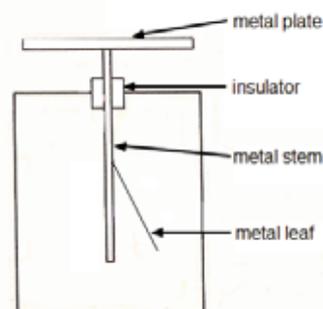
This imbalance in the number of charges causes objects with opposite charges to attract. At times, these charges can move and form sparks. For example, when you take off your jersey in the night, it crackles (sparks of light are seen).

Remember the following:

- like charges (two positive or two negative charges) will repel each other;
- unlike charges (positive and negative) will attract each other;
- electric charge is measured in **coulomb (C)**.



An **electroscope** is an instrument that can be used to detect small amounts of electric charge. The following is a diagram of an electroscope.



Uses of static electricity

- Many photocopiers use static electricity to form an image of a document on a charged drum.
- Electrostatic smoke and dust precipitators are used in chimneys to attract tiny particles of smoke and dust. This can reduce the amount of air pollution.

Lightning

In stormy weather, electric charges build up in the clouds, because of high winds and air particles rubbing against water droplets in the clouds. There is friction between them that causes a transfer of electrons and the clouds become charged. The underside of a thundercloud becomes negatively charged. This induces a positive charge on the ground beneath

it. The difference in charge can accumulate to a very high voltage. When these charges move, it can be seen as lightning.

There are two types of electricity: static and current electricity. The latter, current electricity involves moving charges.

Now try and work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. State the properties of magnets.
2. Outline the nature of magnetic forces and fields.
3. State, in terms of charges, what static electricity involves.

Section 2: Current

Introduction

Electricity is part of our daily life. In this section, we will learn about current.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>explain</i> charge as the imbalance of electrons and protons; • <i>explain</i> that electric current is determined by the flow of charges and is measured in ampere using an ammeter; • <i>explain</i> that current (I) can be calculated as the number of charges (Q) per time (t) and measured at any point in an electrical circuit using an ammeter; • <i>distinguish</i> between electrons and conventional currents; • <i>distinguish</i> between direct and alternating currents.
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Time

This section will take you about seven hours to complete. Make sure that you read and understand everything in order to achieve all of the basic competencies.

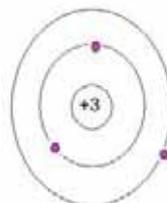
Electric current

Before I explain what a charge is, let us look at the structure of an atom.

An atom consists of a nucleus, which is in the centre of the atom. The nucleus contains protons and neutrons. The protons are positively charged while the neutrons have no charge, they are neutral. This makes the whole nucleus to be positively charged.

Moving around the nucleus in shells are electrons, which are negatively charged. In a neutral atom, the number of positive charges in the nucleus is equal to the number of negative charges in the shells.

How then are charges formed? Charges are formed when atoms gain or lose electrons. This causes the number of protons and electrons to be unequal.



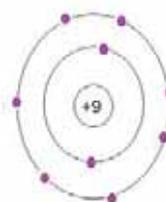
Lithium atom

If the lithium atom, (shown above) loses one electron, it becomes positively charged.

This is because there are more positive charges in the nucleus than negative charges (the electrons).

On the other hand, if a fluorine atom gains an electron, it becomes negatively charged.

Can you explain how this is possible? Yes, there are nine electrons in the shells of a fluorine atom and nine protons in its nucleus.



Fluorine atom

So, if the atom gains an electron, it will have more negative than positive charges.

This will make the atom negatively charged. When an atom becomes charged, it is no longer called an atom but an ion. So charges are formed by the imbalance between electrons and protons. Now that we have explored the idea of charge let us look at current.

What is current? Current is the flow of charges per unit of time. An instrument called an ammeter is used to measure current. The unit of current is ampere (A). So current can be defined as the number of charges moving past a point in a circuit per unit of time.

We can use a formula to relate current to charge and time:

$$\text{current} = \frac{\text{charge}}{\text{time}} \text{ or in symbols } I = \frac{Q}{t}$$

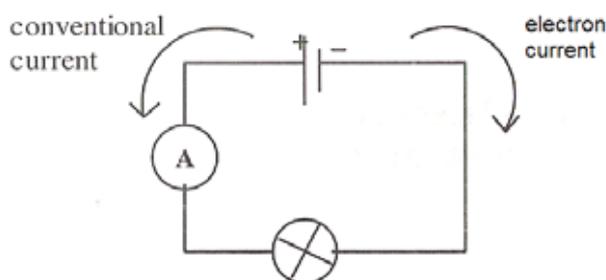
where **I** is in ampere(A); **Q**, in coulomb(C) and **t**, in seconds (s).

Let me give you an example of how to use the formula.

If 3 coulomb of charge flow through a conductor in 2 seconds, the amount of current flowing will be:

$$I = \frac{Q}{t} = \frac{3C}{2s} = 1.5A$$

As shown in the diagram, electrons flow from the negative terminal of the cell through the circuit to the positive terminal. The conventional current flows from the positive terminal of the cell to the negative terminal. We shall use the conventional current direction when indicating the current on circuit diagrams.



If we look closely, we would find two different directions:

- one direction from the positive to the negative, called conventional current and
- one direction flowing from the negative to the positive, called electron current.



Now, if we sit down and analyse which charges move, we will need to revert back to something that we have learned earlier in this lesson. That is:

- positive and positive repel and
- negative and negative repel,
- while positive and negative attract.

If we go back to the Lithium atom and ion above, we would see that the charges exist as electrons (negative) and cations (positive). Why do protons not move?

Well the answer is easy, the protons are in the centre of the atom—so for a positive charge to move, the cation must move! So in conventional current, in terms of flow of positively charged particles, the protons are unable to move. However, in electron current the electrons move. So electrons are negative and they are attracted to the positive terminal, while cations are positive and they are attracted to the negative terminal.

Most textbooks use conventional current to indicate the direction of current. From the Wikipedia dictionary a convention is a meeting or a large gathering of people who share a common interest.

(source: <http://en.wiktionary.org/wiki/convention>). This precisely happened many years ago when people decided by convention that current is the flow of positive charges.

BUT as explained above, positive charge can only flow as cations as the protons are in the centre of the atom. In copper cables, it is actually the electrons that flow. So you need to take special care to note that most textbooks use the convention, as decided many years ago to indicate current as conventional current.

So I will try to explain again:

Most textbooks in use, refer to conventional current. We defined the concept of current as the movement of charge, regardless of positive or negative charge, rather than the movement of electrons. Current is the flow of charge—regardless if positive or negative charge moves. Further:

- (a) electrical current in a metallic conductor is the movement of negative charge—the movement of electrons;
- (b) by convention we use conventional current to indicate current direction—and that is why most books still use conventional current as direction of flow;
- (c) movement of positive charge in a metallic conductor is difficult if not impossible as it would require the atom (nucleus or material) to move;
- (d) true conventional current can only happen in semi-conductors, pastes and ions in solution which you will only learn about if you continue with science in your senior secondary phase;
- (e) the direction of current can be identified easily by means of attraction and repulsion as established in static electricity—positive charge will be attracted to negative—therefore the movement of electrons will be from negative to positive and for conventional current vice versa.

Good. As we have now mastered the concepts of electron and conventional current, let us discuss the two types of current.

There are two types of current. These are differentiated depending on how they flow. One type of current is produced by a power station and the other by a battery. Now, let us see how they differ.

Current that is produced by a battery is called **direct current** or **d.c.** for short. From its name, you should be able to tell that this type of current flows in one direction only. It flows from the positive terminal of the battery to the negative terminal.

Current that is produced by a power station is called **alternating current** or **a.c.** for short. Alternating current is also popularly called “mains”. Alternating current reverses direction many times in a second. In Namibia, this current changes direction 50 times in a second.

Therefore, we can say that it has a frequency of 50 Hz. If you check on household plugs, you will be able to find this value written on them. Please note that alternating current is **not** the same as alternative current. It is not correct to say alternative current.

Now try work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. State two types of charges.
2. Give the charge of an ion when an atom:
 - (a) gains an electron;
 - (b) loses an electron.
3. Current is the flow of charges.
 - (a) Name the charges.



(b) Name the instrument used to measure current.

4(a) If 200 C of charge flows in 60 s, calculate the electric current flowing.

(b) A current of 10A flows through the cable of a cooker in 2 minutes. Calculate how many coulombs of charge flow.

Section 3: Voltage

Introduction

Voltage and Current are quite hard to grasp, because we can't see them directly.

Voltage attempts to make a current flow and current will flow when a circuit is complete. Voltage is sometimes described as the 'push' or 'force' of electricity. It isn't really a force, but this may help you to imagine what happens. It is possible to have voltage without current, but current cannot flow without voltage.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>relate</i> electric potential to the ability to drive charge around a complete circuit and explain that potential difference: <ul style="list-style-type: none"> is measured in volt; is measured across an electrical component in a circuit using a voltmeter; can be calculated by the energy (E) per charge (Q); is the same as voltage, both are measured in volt (V) and that both share the abbreviation "V". • <i>outline</i> that current is made to flow round a circuit by the difference in electrical potential between the poles of a cell; • <i>recognise</i> that increasing the number of cells in series in a circuit increases the current flowing round the circuit and increases the potential difference across components in the circuit; • <i>measure</i> the potential difference across individual components in a circuit; • <i>measure</i> potential difference across the whole circuit.
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Time

This section will take you about seven hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Voltage or potential difference

In Section 2, we saw that current is the flow of charges. But for charges to move, they must have energy. Where does this energy come from?

This energy comes from a source which could be a battery or cell. These sources have the ability to drive charge round a complete circuit. Therefore, we can say that they have electric potential between the negative and positive poles.

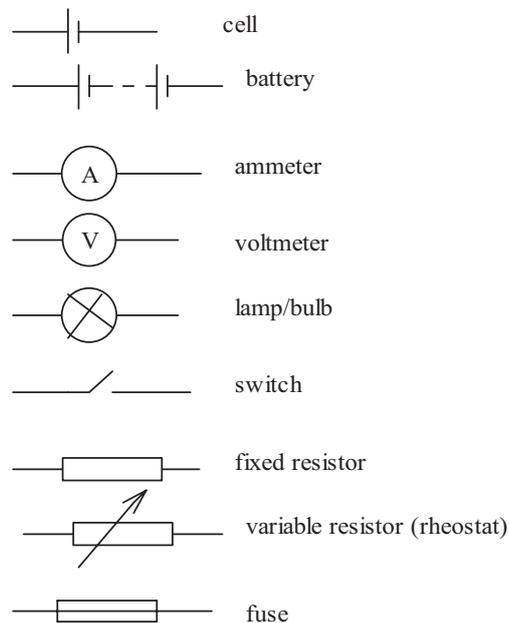
Potential difference (p.d. for short) is the energy that drives charge across a component in a circuit. Therefore:

$$\text{p.d.} = \frac{\text{energy}}{\text{charge}} \quad \text{or in symbols} \quad V = \frac{E}{Q}$$

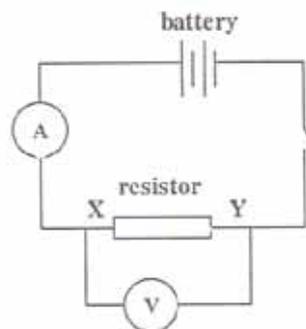
Since potential difference is the voltage difference across a component, it is measured in volt (V) using an instrument called a voltmeter.

Now that you have learned what potential difference is, let us find out what makes current flow round a circuit. Current flows round a circuit because of the difference in electrical potential between the poles (terminals) of a cell. This potential difference drives charge (which is current) round a circuit. Increasing the number of cells in the circuit increases the potential difference across components in the circuit.

In electricity, we use symbols to represent instruments. These symbols don't necessarily look like the instruments. However, it is important to know them because they will be used throughout your study of electricity. Here are some of the symbols.



Examine the circuit diagram below in which a voltmeter is used to measure the potential difference across a resistor. The voltmeter will measure the potential difference between X and Y.



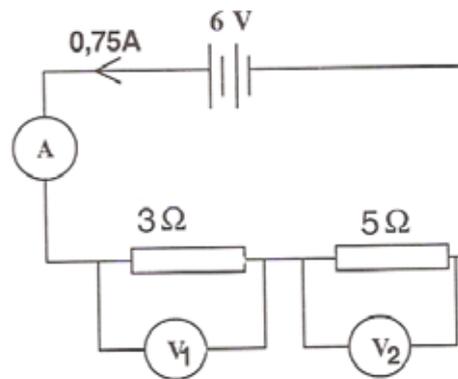
Voltmeter

When we connect cells or any other instruments in series, they are linked one after the other. Parallel connection means the instruments are linked on top of each other as in the diagram above where the voltmeter is connected to the resistor.

Since the voltmeter measures the difference in electric potential between the terminals of a component, it is always connected in parallel to the component.

When resistors are connected in series as shown in the diagram below, the sum of the potential difference across the individual resistors is equal to the voltage of the source.

Let us do some calculations in order to clarify this statement. Remember that the current through the circuit is the same throughout.



Calculate V_1 and V_2 :

$$\begin{aligned} V_1 &= I \times R \\ &= 0.75 \text{ A} \times 3\Omega \\ &= 2.25 \text{ V} \end{aligned}$$

$$\begin{aligned} V_2 &= I \times R \\ &= 0.75 \times 5 \Omega \\ &= 3.75 \text{ V} \end{aligned}$$

The total of the potential difference across the two resistors will be:

$$\begin{aligned} V_1 + V_2 &= 2.25 \text{ V} + 3.75 \text{ V} \\ &= 6 \text{ V (which is the voltage of the battery)} \end{aligned}$$



Practical Activity

Practical Activity 1

Problem:

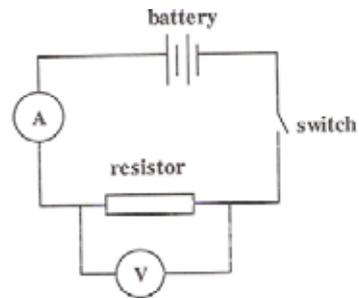
To measure potential difference.

What you need:

a battery;
 an ammeter;
 a voltmeter;
 connectors;
 a switch;
 resistance wire or fixed resistor or bulb.

What to do:

1. Connect the components as shown in the diagram below.



2. When the switch is closed, take the voltmeter reading.
3. You can increase the number of cells and take voltmeter readings.

Results: How do the voltmeter readings compare when the number of cells increase?

You will find that the voltmeter reading will increase when the number of cells increase.



Practical Activity

Practical Activity 2

Problem:

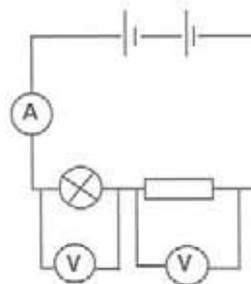
To measure potential difference across individual components.

What you need:

- a battery;
- an ammeter;
- a voltmeter;
- connectors;
- a switch;
- resistance wire or fixed resistor and bulb.

What to do:

1. Connect the components as shown in the diagram below.



2. Take the readings of the voltmeters and find the sum of the voltage across the bulb and fixed resistor.
3. Measure the voltage across the battery.

Results: How does the total voltage across the components compare with the voltage of the battery?

You will find that the total voltage across the components will be the same as the voltage of the battery.

Now try to work through the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. The unit of potential difference is:
 - A ampere;
 - B ohm;
 - C volt;
 - D watt.



2. Which statement describes the correct connection of a voltmeter and ammeter in a circuit?

	voltmeter	ammeter
A	parallel	parallel;
B	parallel	series;
C	series	parallel;
D	series	series

3. What does the formula $\frac{\text{energy}}{\text{charge}}$ represent?

- A** current;
- B** energy;
- C** potential difference;
- D** resistance.

Section 4: Resistance

Introduction

Resistance is a term we use in electricity. In this section, you will learn more about it.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>describe</i> that resistance is the opposition of a conductor to the flow of charges and is measured in ohms; • <i>describe</i> an experiment to determine resistance using a voltmeter and an ammeter; • <i>describe</i> qualitatively the proportionality between resistance and length of a wire and the inverse proportionality between resistance and cross-sectional area of a wire; • <i>explain</i> the relationship between resistance and temperature of a wire; • <i>calculate</i> the total resistance for a combination of resistors in a circuit; • <i>set up</i> from circuit diagrams, electric circuits involving cells and bulbs and/or resistors in series and in parallel and be able to measure or calculate resistance between any two points.
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Time

This section will take you about nine hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Resistance

What is resistance? In electricity, **resistance is the opposition of a conductor to the flow of charges**. Since the flow of charges is an electric current, we can also say that resistance is the opposition to the flow of current. Resistance is measured in **ohms (Ω)** using an instrument called an **ohmmeter**.

Using an ohmmeter is the direct way to measure resistance.

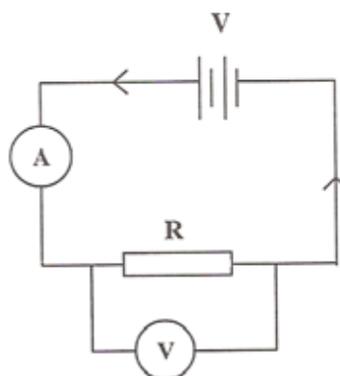
Resistance can also be measured by way of calculation. This is an indirect way where you use voltmeter and ammeter readings. This way of measuring resistance is called the **ammeter-voltmeter method**.

I will use a circuit diagram to describe how to determine resistance. As mentioned earlier, this is an indirect way because you need both the voltmeter and ammeter readings.

You can set up a circuit as shown in the diagram. A resistor **R** is connected to a battery and a voltmeter is connected across it as shown. The voltmeter and ammeter readings can be taken.

To calculate the resistance we use the following formula:

$$\text{resistance} = \frac{\text{voltage}}{\text{current}}$$



If the ammeter reading was 0.2 A and the voltmeter reading 3 V, then the resistance R can be calculated as follows:

$$R = \frac{V}{I} = \frac{3V}{0.2A} = 15\Omega$$



The resistance of a wire can change depending on some factors such as the length of the wire, thickness, temperature and type of material.

Now, we are going to look at the relationship between the resistance of a wire, length, cross-sectional area and temperature.

1. Wire length

Resistance is directly proportional to the length of a wire. This means that a longer wire has a higher resistance than a shorter wire of the same type. It is also true to say that a shorter wire has a lower resistance than a longer wire of the same type. When you double the length of wire, its resistance also doubles.

2. Cross-sectional area of a wire

What do you understand by the phrase “cross-sectional area of a wire”? The cross-sectional area is simply the diameter or thickness of a wire. You must not get confused when any of these terms are used. What is the relationship between resistance and the cross-sectional area of a wire?

It is inversely proportional. This means a thicker wire has less resistance than a thinner wire of the same type. Compare this with the same volume of water flowing through a narrow and a wide pipe. The particles in a narrow pipe experience high resistance from the walls of the pipe and each other because they are squeezed together. This leads to high resistance. For a wide pipe on the other hand, there is more space for the articles to move, resulting in lower resistance due to reduced friction. This relationship can be very confusing, so you should make sure you study it thoroughly.

3. Temperature

The resistance of a wire is directly proportional to its temperature. The hotter the wire becomes, the higher the resistance. It is important to link this to the characteristic graph of a non-ohmic conductor like a bulb. You will notice that as the temperature of a bulb filament increases, the resistance also increases.

Calculating resistance

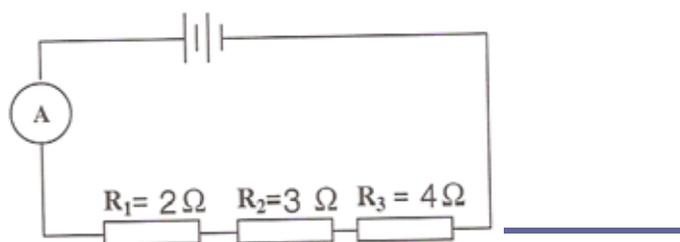
We are going to find out how to calculate resistance when resistors are connected in series and parallel.

1. Resistors in series

To calculate the total resistance in series, just add up the resistances given. It does not matter how many resistors are involved. All you have to do is to add them up.

Total resistance (effective resistance) = sum of resistances

Look at the circuit diagram below and see if you can find the total resistance.



Total resistance = $R_1 + R_2 + R_3$

$$R_T = 2\Omega + 3\Omega + 4\Omega = 9\Omega$$

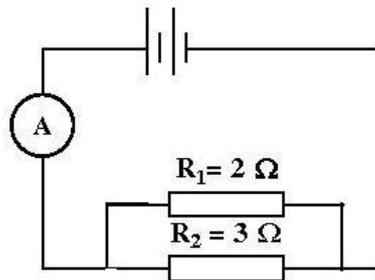
2. Resistors in parallel

For resistors in parallel, the reciprocals of the resistances are used:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

Making R_T the subject of the formula gives:

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$



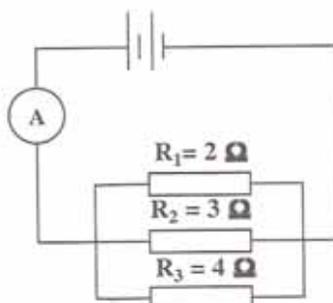
In short, total resistance for two resistors connected in parallel (such as in the diagram above) equals the product of the resistances divided by the sum of the resistances:

$$R_T = \frac{(2 \times 3)}{(2 + 3)} = \frac{6}{5} = 1.2\Omega$$

What about three resistors in parallel? The total resistance can be found in a similar way to the two resistors.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Then, substitute the values of the resistances into the formula.



$$\frac{1}{R_T} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4} = \frac{13}{12}$$

$$\frac{R_T}{1} = \frac{12}{13}$$

$$R_T = 0.92\Omega$$

Please take note that bulbs can be used in place of the resistors. After all, filaments in the bulbs are resistance wires.

What do you notice about the size of the total resistances when the same resistors in series are then connected in parallel?

Compare the total resistances in the two examples. It is clear that when resistors are in parallel, their total resistance is reduced.

This also means that the amount of current flowing increases.



Practical Activity

Practical Activity 1

Problem:

To investigate the effect of wire length on resistance.

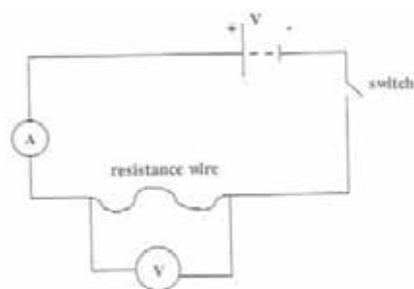
What you need:

a battery or low voltage power supply;
 an ammeter;
 a voltmeter;
 connectors;
 pieces of the same resistance wire with different lengths;
 a switch.

What to do:

1. Connect the components as shown in the

diagram below.



2. Measure the length of the resistance wire and record it in the table below.
3. Take the ammeter and voltmeter readings and record them in the table for different lengths of wire.
4. Calculate the resistance using the formula given in the table.
5. Repeat steps 2 to 4 for different lengths of wire.

wire length (l)	l	$2l$	$3l$	$4l$
voltage (V)				
current (I)				
Resistance ($R = \frac{V}{I}$)				

6. Plot a graph of wire length (y-axis) against resistance (x-axis).

Observations and results:

1. From your graph, describe the relationship between resistance of a wire and its length.



Practical Activity

Practical Activity 2

Problem:

To investigate the effect of changing the **diameter** of a wire on resistance.

What you need:

a battery or low voltage power supply;

an ammeter;

a voltmeter;

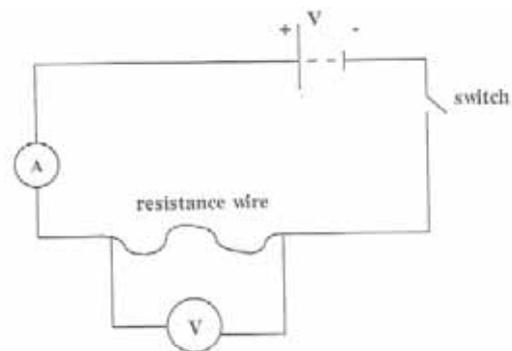
connectors;

wires of different diameters but same type and length;

a switch.

What to do:

1. Connect the components as shown in the diagram.
2. Use wires of different diameters and record the ammeter and voltmeter values in the table below.



wire diameter (d)	d	$2d$	$3d$
voltage (V)			
current (I)			
Resistance ($R = \frac{V}{I}$)			

	<p>3. Plot a graph of diameter of wire (y-axis) against resistance (x-axis).</p> <p>Observations and results:</p> <p>From your graph, describe the relationship between resistance of a wire and its diameter.</p>
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Good, now try doing the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

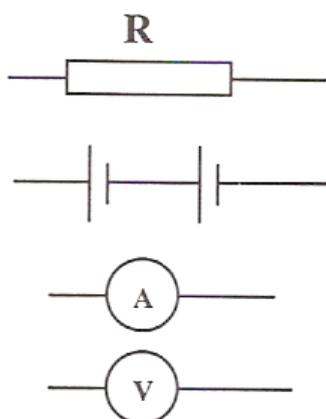
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. Which instrument can be used to measure resistance directly?

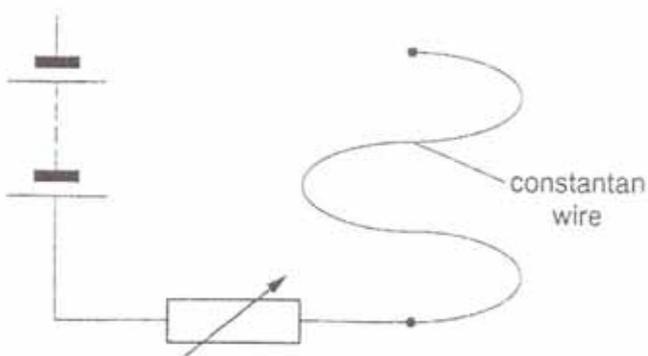
- A ammeter;
- B amperemeter;
- C ohmmeter;
- D voltmeter.

2. You are provided with the apparatus shown.





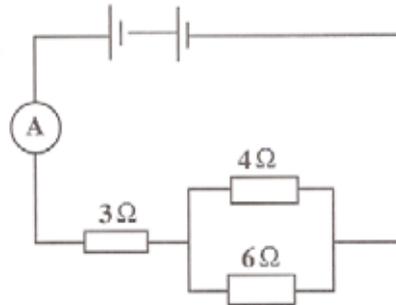
- (a) Draw a circuit diagram to show how you would connect them in order to measure resistance, R .
- (b) Write the formula for calculating R .
- (c) If the voltage across R was 4.5 V and the resistance $0.5\ \Omega$, calculate the current flowing in the circuit.
3. The resistance of a 2 m long wire is $20\ \Omega$.
- (a) State the relationship between wire length and resistance.
- (b) Find the resistance of the 10 m long wire.
4. A student wanted to measure the resistance of a length of constantan wire. She starts to connect the circuit as shown below.



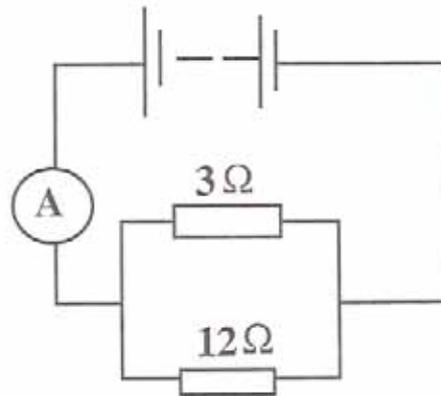
She needs to add an ammeter and a voltmeter.

- (a) Complete the circuit diagram to show how these should be connected.
- (b) In the experiment, the voltmeter reads 6.0 V and the ammeter reads 1.5 A .
Calculate the resistance of the wire.
- (c) She now wants to reduce the current through the constantan wire.
Explain how this could be done.
5. Calculate the total resistance in each of the following cases.

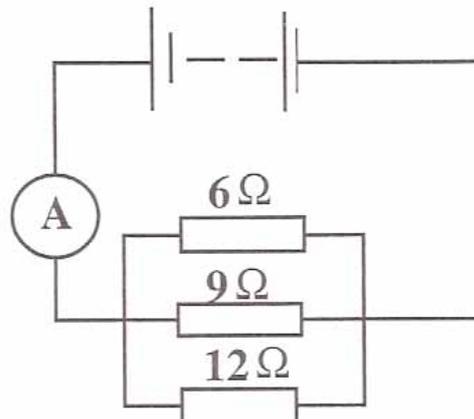
(a)



(b)



(c)





Section 5: Relationship Between Current and Voltage in an Electrical Conductor (Ohm's Law)

Introduction

You will now learn how to set up circuit diagrams and the relationship that exists between current and voltage.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>recall, interpret</i> and <i>analyse</i> the relationship between current, resistance and voltage in electrical conductors and circuit diagrams involving cells and bulbs or resistors in series and in parallel; • <i>set up</i> electric circuits using circuit diagrams as a guide; • <i>draw</i> circuit diagrams involving cells and bulbs or resistors in series and in parallel; • <i>measure</i> and <i>calculate</i> the current at any point in the circuits, the potential difference between any two points and the resistance between any two points; • <i>investigate</i> the relationship between current and potential difference across various conductors (nichrome, copper, eureka wires and light bulbs); • <i>interpret</i> graphically and by calculation the relationship between current and voltage in an electrical conductor; • <i>distinguish</i> between ohmic and non-ohmic conductors and sketch the V/I characteristic graphs for ohmic conductors and non-ohmic conductors such as bulbs.
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 <p>Time</p>	<p>This section will take you about nine hours to complete. Make sure that you read and understand everything in order to achieve all of the basic competencies.</p>
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The relationship between current, voltage and resistance

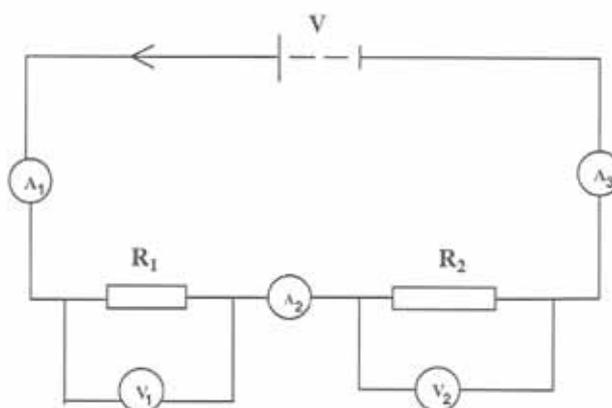
In Section 4, you learnt how to calculate resistance. Can you recall the formula? We said that resistance is calculated by dividing voltage by current.

A conductor offers 1ohm resistance to the flow of 1 ampere of current when 1 volt is applied across its ends.

Now, we are going to look at series and parallel connections in terms of resistance, voltage and current.

Series connection:

Look at the diagram below involving a series connection. You can also refer to Section 4.



Current

In a series connection, the same current passes through every point in the circuit. So A_1 , A_2 and A_3 should show the same readings.

Voltage

In series connection, the total voltage (p.d.) across all components equals the voltage of source.

Resistance

The effective (total) resistance (R_T) is simply the algebraic sum of all resistances i.e.,

$$R_T = R_1 + R_2$$

We can therefore summarise the three statements as follows:

$$I_1 = I_2 = I_3$$

$$V = V_1 + V_2$$

$$R_T = R_1 + R_2$$



Parallel connection:

In a parallel connection, current divides in the ratio of the inverse of the resistances, therefore:

- less current in the branch of higher resistance;
- more current in the branch of lower resistance.

Voltage (p.d.) is the same in each branch. It is equal to the voltage of the source.

Effective resistance (R_T) is less than either resistor by itself.

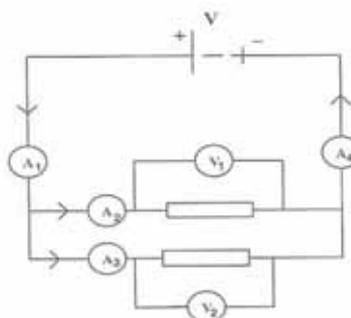
For two resistors, reciprocals of the resistances are used.

For resistors in parallel, the reciprocals of the resistances are used.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

or

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$



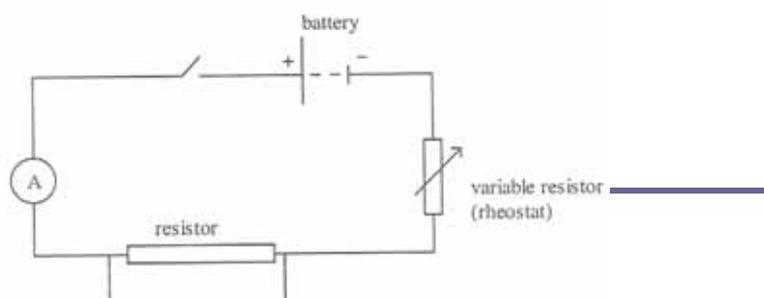
Ohm's Law

Ohm's law states that at constant temperature, current through a conductor is directly proportional to the potential difference across its two ends. This means that if you double the potential difference across the ends of a conductor, the current also doubles and so on.

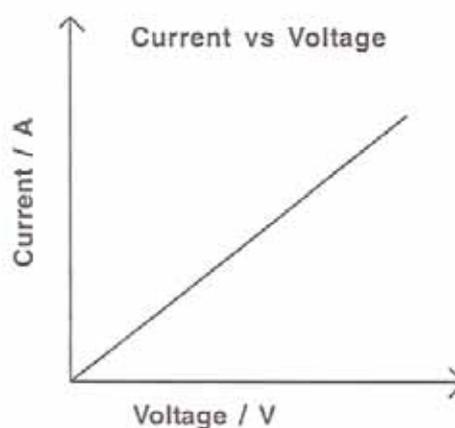
Conductors that obey this law are called ohmic conductors. Those that do not obey this law are called non-ohmic conductors.

Ohmic conductors

You can set up a circuit as shown and record the ammeter and voltmeter readings, after adjusting the current with a variable resistor (rheostat). When the values obtained are plotted, a graph such the one shown on the next page can be obtained. In this case, it is assumed that the temperature remains constant.



When current through an ohmic conductor and the potential difference across its two ends are drawn, a graph like this is obtained. This type of graph is called a V/I characteristic graph.

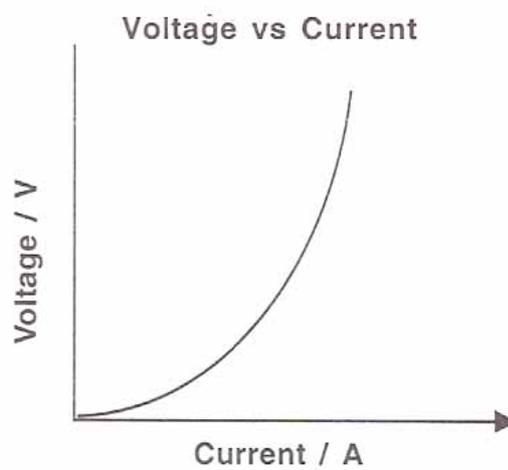
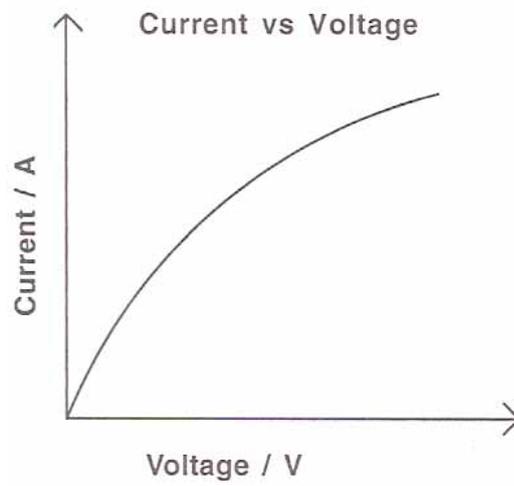
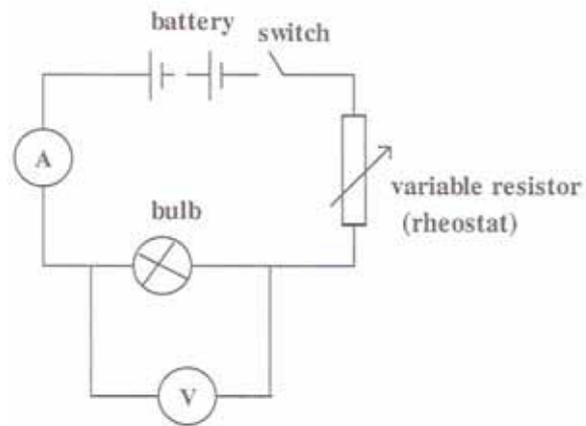


The graph above indicates the relationship between voltage and current of an Ohmic conductor.

Non-ohmic conductors

For non-ohmic conductors like a light bulb, current through the filament (which is a conductor) and potential difference across its ends, are not directly proportional. The ratio of voltage and current (V/I) increases as the filament gets hotter.

Remember that for Ohm's Law to be obeyed, the temperature must not change. This means that a rise in temperature results in an increase in resistance.





Practical Activity

Practical Activity 1

Problem:

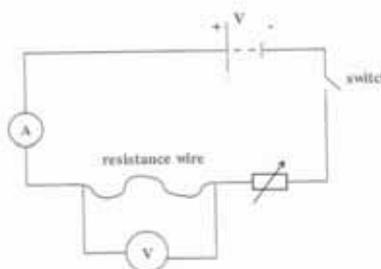
To investigate ohmic and non-ohmic conductors.

What you need:

a battery;
 an ammeter;
 a voltmeter;
 connectors;
 a switch;
 bulb and eureka, copper and nichrome wires;
 a variable resistor.

What to do:

1. Connect the components as shown in the diagram below.



2. When the switch is closed, take the ammeter and voltmeter readings.
3. Increase the resistance by adjusting the variable resistor.
4. Take the ammeter and voltmeter readings each time and record them in the table.
5. Plot the points and draw a graph of voltage against current.
6. Repeat steps 1-5 using eureka, copper and nichrome wires.

Observations and results:

- 1(a) Record the ammeter and voltmeter readings in the tables.

(i) bulb

voltage / V				
-------------	--	--	--	--



	current / A				
	(ii) eureka wire				
	voltage / V				
	current / A				
	(iii) copper wire				
	voltage / V				
	current / A				
	(iv) nichrome wire				
	voltage / V				
	current / A				
	<p>(b) Draw the graphs of current (I) in vertical axis against voltage (V) in the horizontal axis from the values in part (a).</p> <p>2. From your graphs, describe the relationship between current and voltage for the:</p> <p>(a) bulb;</p> <p>(b) eureka wire;</p> <p>(c) copper wire; and</p> <p>(d) nichrome wire.</p> <p>3. (a) Which of the four in question 2 is a non-ohmic conductor? Explain your answer.</p> <p>(b) Describe how you can use the values from your graph to find the resistance of the ohmic conductor.</p>				

Now try working through the following self-mark activity.

Self-Mark Activity



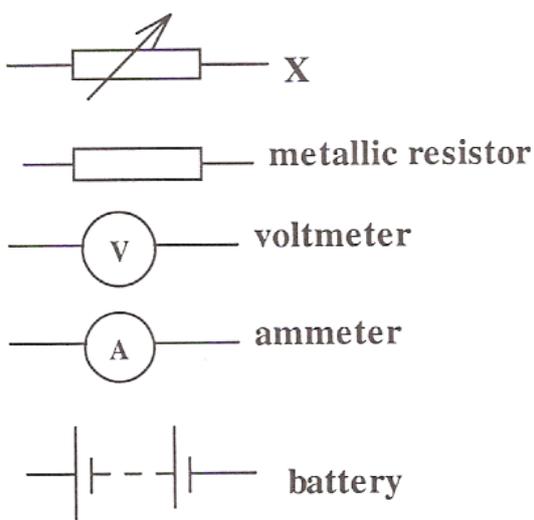
Self-Mark Activity

Self-Mark Activity

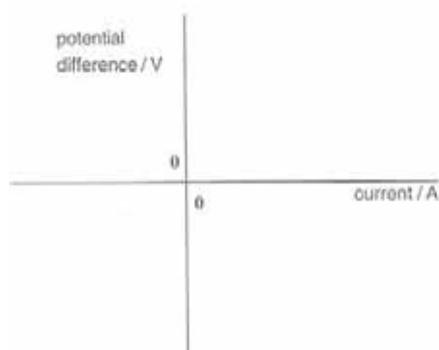
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. A student carries out an experiment to investigate the variation of current through a metallic resistor with potential difference applied across it. He is given the apparatus shown in the diagram.
 - (a) Label the component indicated as X
 - (b) Draw a circuit diagram to show how the apparatus should be set up.

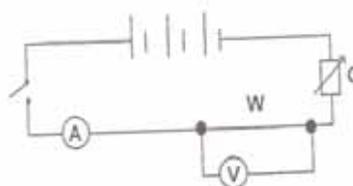


- (c) On the axes below, draw the graph you would expect to obtain from the experiment.



(d) A light bulb was used instead of a metallic conductor. On the same axes, draw the graph you would expect to obtain from the experiment and label it *bulb*.

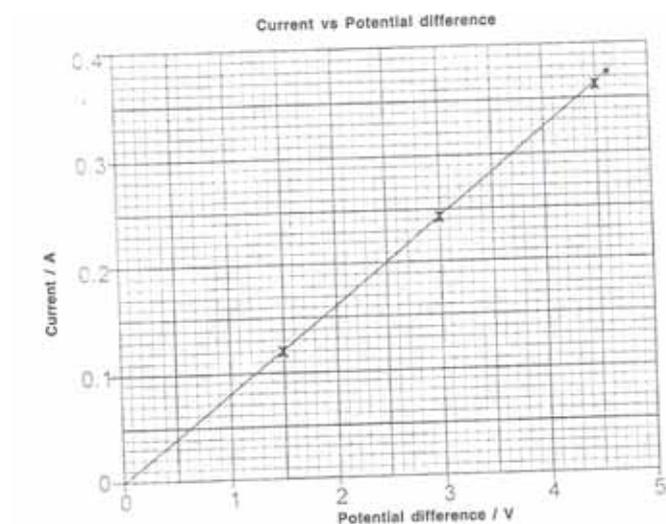
2. The drawing shows a circuit diagram to investigate the relationship between the potential difference and the current through wire **W**.



[Source: JSC 2005]

- (a) State the name of the apparatus used to measure the:
- (i) potential difference across **W**;
 - (ii) current flowing through **W**.

The graph shows the results of the investigation.



(iii) Describe the shape of the graph and the relationship between potential difference and current.

(iv) Use the graph to calculate the resistance of the wire W.

(b) The table shows how the resistance of various light bulbs change when they are switched on.

Description of bulb	Type of bulb / watt	Resistance when cold / Ω	Resistance when hot / Ω
Household bulb	25	157	1940
Bright household bulb	100	37	490
Soccer field lights	1000	2.8	48

(i) Discuss how resistance changes with change in temperature.

(ii) State the condition for Ohm's Law to be true.

(iii) Draw graphs of current against potential difference for any of the bulbs.



Section 6: Electrical Power

Introduction

 <p>Basic Competence</p>	<p>Upon completion of this section, you will be able to:</p> <ul style="list-style-type: none"> state power (P) as the rate of doing work and unit of power as watt (W); explain how electrical power (P) can be calculated by the product of the voltage (V) and the current (I); <i>investigate</i> the voltage across and the current through terminals of different appliances in order to calculate their electrical power output and use the formula $P = VI$ to calculate electrical power; <i>interpret</i> the watt value of bulbs and other electrical appliances and calculate the cost of operating them for a specified time.
 <p>Time</p>	<p>This section will take you about five hours to complete. Make sure that you read and understand everything in order to achieve all of the basic competencies.</p>

Electrical power

In Section 5, you learnt that power is the rate of doing work or the rate at which energy is transferred. In electricity, power is defined in the same way. What we need to know here is what type of energy is involved and what it is converted into. Electrical power is therefore, the rate at which electrical energy is converted into other forms of energy such as light, heat, motion and so on. This depends on what you use the electrical energy for. If you connect a radio to electricity, electrical energy is converted to sound and heat energy. Although the unit of electrical power is still watt (W), the formula for electrical power is different:

Electrical power = voltage x current

$$P = V \times I$$

$$P = VI$$

Let me give you a simple example of how to use this formula. If an electric kettle draws a current of 10 A when connected to a 250 V mains, its power can be determined by:

$$P = VI$$

$$= 250 \text{ V} \times 10 \text{ A}$$

$$= 2,500 \text{ W}$$

What does the power of 2,500 W mean? Well, it means that the electric kettle can convert 2,500 J of electrical energy into heat energy per second. Remember that one Watt is equivalent to one Joule/second (J/s), i.e., $1\text{W} = 1 \text{ J/s}$.

Can you recall that Power = $\frac{\text{energy}}{\text{time}}$?

Therefore, to find energy, we can change the formula to:

$$\text{energy} = \text{power} \times \text{time}$$

$$= VI \times t$$

$$= VIt$$

The unit for electrical energy is kilowatt-hour (kWh). To get kilowatts, you simply divide the power in watts by 1,000.

Look at this example:

A bulb is rated 40 W, and kept on for two hours. Can you find the energy in kilowatt-hours?

Firstly, you convert the power in watts, to kilowatts:

$$\frac{40\text{W}}{1,000}$$

$$= 0.04 \text{ kW.}$$

Secondly, you multiply the kilowatts by time in hours:

$$0.04 \times 2 \text{ hours} = 0.08 \text{ kWh}$$

therefore, the energy is 0.08 kWh.

Electrical energy is charged per kilowatt-hour, which is the unit of electrical energy consumed.

Now that you know how to find energy in kilowatt-hours, let us move on to calculating the cost of electrical energy.

I will use the example of an electric kettle with a of power 2,500 W. If the kettle is left on for four minutes and the cost of electrical energy is 61 cents per kWh, how much would you pay?

Convert power in watts to kilowatts:

$$\frac{2,500\text{W}}{1,000} = 2.5\text{kW}$$

Convert the time in minutes to hours:

$$\frac{4 \text{ min}}{60} = 0.067 \text{ hours}$$

$$\text{Energy} = P \times t$$



$$= 2.5 \text{ kW} \times 0.067 \text{ s}$$

$$= 0.17 \text{ kWh}$$

1 kilowatt-hour costs 61 cents. How much will 0.17 kWh cost?

$$\text{Cost} = 61 \times 0.17$$

$$= 10.37 \text{ cents}$$



Practical Activity

Practical Activity 1

Problem:

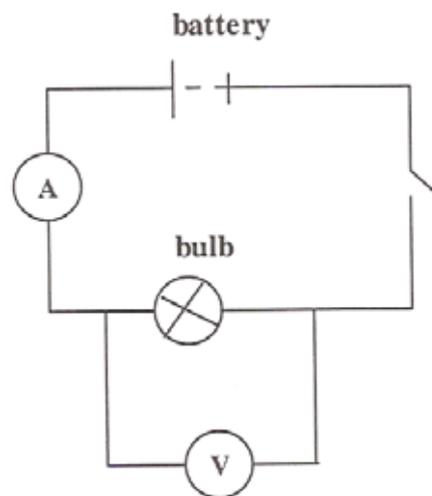
To calculate electrical power.

What you need:

- a battery;
- an ammeter;
- a voltmeter;
- connectors;
- a switch;
- a bulb.

What to do:

1. Connect the components as shown in the diagram.



2. When the switch is closed, take the ammeter and voltmeter readings.
3. Use the formula: Power = voltage x current.

	<p>4. The bulb can be replaced by any electrical appliance.</p> <p>Caution: Do not use mains electricity for this experiment; rather use electricity from a battery.</p> <p>Results: From the voltmeter and ammeter readings, calculate the power of the bulb.</p>
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Now try doing the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. An electric motor uses a 240 V power source and carries a current of 4 amperes.
 - (a) Calculate the power of the motor.
 - (b) The motor runs for 10 minutes. Calculate the electrical energy consumed in kWh.

2. An electric bulb rated 100 watt is left on for 5 hours.
 - (a) Calculate the electrical energy consumed in kilowatt-hours.
 - (b) If the cost of electrical energy is 61 cents per kilowatt-hour, calculate the cost of leaving the bulb on for 5 hours.

Section 7: Electricity in the Home

Introduction

Electricity is used in many households in Namibia on a daily basis. In this section you will learn more about the usage of electricity.



 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>distinguish</i> between mains electricity and electricity from batteries; • <i>describe</i> the uses of electrical energy; • <i>discuss</i> how and why electrical energy should be conserved; • <i>outline</i> the dangers of electricity caused by damaged insulation, overheating, overloading and damp conditions; • <i>suggest</i> ways in which the use of electricity can be made safer using fuses, circuit breakers and earthing wire; • <i>discuss</i> the importance of earthing wire.
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 Time	<p>This section will take you about nine hours to complete. Make sure that you read and understand everything in order to achieve all of the basic competencies.</p>
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Electricity in the home

There are two types of electricity. One type comes from power stations through cables to houses. The other one from batteries or cells. Electricity from a power station is called **mains** electricity.

Let us look at the differences between mains electricity and electricity from batteries.

1. Mains electricity is of much higher voltage than the voltage from batteries. In Namibia, mains electricity is 220 V. The voltage of a torch cell is 1.5 volts while a car battery is 12 volts when fully charged.
2. Current that comes from a cell or battery always flows in one direction. This type of current is called direct current (d.c.). It flows from the positive terminal of the cell through the circuit to the negative terminal of the cell.

The current coming from a power station reverses direction many times in a second. This is called alternating current (a.c.). Instead of having positive and negative terminals, mains have live and neutral wires.

Uses of Electrical Energy

Electricity in the home is used for many things. If you stay in a house with electricity, or you know the uses of electricity, try to list some of them. You can think of the energy conversions taking place when appliances are used. These might include lighting bulbs, charging cellphones, operating your stove and refrigerator and so on.

Since electrical energy is a very important form of energy, it is necessary that we know why and how to conserve it. Why should we conserve electrical energy?

Remember that electrical energy is not supplied for free. The consumer has to pay for it. Therefore if not conserved, it does not only put pressure on the supply stations but also on the consumer. How then can we conserve electrical energy? There are many ways, but I will list just a few. You should be able to list others.

Electrical energy can be conserved by:

- switching off lights in your room when you are not there;
- boiling just enough water for the number of cups, if you want to make tea;
- switching off the television, radio or computer when they are not in use;
- switching off lights outside the house early in the morning;
- switch the geyser on only when it is necessary.

Dangers of electricity

Although electricity is very useful in the home, it can be very dangerous if it is not handled carefully. Here are some dangers of electricity:

1. Damaged insulation

When the plastic that covers wires is damaged, electricity can shock you when you touch a wire. A wire without plastic insulation is said to be a naked wire.

2. Overloading

When you overload sockets by putting too many plugs into a socket, it leads to overheating. Multiple plugs in one socket can cause a fire.

3. Damp conditions

When water contains dissolved salts, it becomes a conductor of electricity. So, when a naked wire touches a wet surface, current can be conducted. This can cause an electric shock if you are in contact with the wet surface.

How to make electricity safer

Electricity can be made safer by using the following technologies:

1. Fuses

A fuse is a short wire in a casing connected in a circuit. When a current becomes too high, the fuse melts, thereby breaking the circuit. This protects appliances from damage.



A fuse

2. Circuit breakers

Circuit breakers are special types of switches. When a current becomes too high or if there is a fault, the switch breaks the circuit. However, it can be reset again when the fault is rectified.



Circuit breakers

3. Earthing

The mains plug has three pin wires; neutral, live and the third called the earth wire.

The earth wire is usually tied to a metal fixed to the ground or to a metal water pipe, which runs underground. It protects the user from an electric shock. How does the earth wire protect the user from an electric shock? When a naked wire touches the casing of an appliance, a short circuit is created. This makes current to run through the user back to earth. In other words, he or she might experience an electric shock. With earth wire, the current runs through the earth wire instead of the person through to the ground.

Work through the following practical activities to reinforce your understanding of this section.



Practical Activity

Practical Activity 1

Problem:

How to make electricity safer in school

What to do:

Survey the school area and record any problems that could be dangerous, for example, damaged earth wires, insulation and so forth.

Report these problems to the person in charge of the school.



Practical Activity

Practical Activity 2

Problem:

How to wire a three-point pin plug.

What you need:

a three-point pin plug;

a three-wire cable with different colours.

What to do:

Read the colour conventions of the cables and match with the pins.

What colour conventions are used for:

(a) earth wire?

(b) live wire?

(c) neutral wire?

Now try doing the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

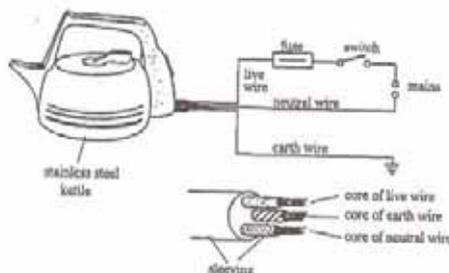
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. The diagram shows a circuit formed when an electric kettle is plugged



into the mains.



[Source: JSC 1996]

- (a) Suggest the suitable material for:
 - (i) the core of the wire;
 - (ii) the sleeving.
- (b) Discuss what the purpose of the earth wire is.
- (c) Fuses and circuit breakers are used to make electricity safer. Explain how each one works.
 - (i) fuse;
 - (ii) circuit breaker.
- (d) The electric kettle takes 4 A.
 - (i) Select which fuse would be suitable in the circuit.
1 A; 2 A; 3A; 5 A; 13 A.
 - (ii) Explain your answer.

2. Complete the table indicating two differences between mains electricity and electricity from a battery.

mains electricity	electricity from a battery

- 3. (a) Electrical energy is very useful in our daily activities.
Describe two uses of electricity.
- (b) Discuss one way in which electrical energy can be conserved.

Section 8: Magnetism

Introduction

In Section 7, we discussed electricity in the home. In this section, we will discuss magnetism.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>distinguish</i> between ferrous and non-ferrous materials; • <i>state</i> the properties of magnets; • <i>account</i> for induced magnetism in terms of alignment of magnet units and explain the magnetic lines of force around a magnet; • <i>investigate</i> and <i>draw</i> the pattern of field lines around a bar magnet and horse shoe magnet; • <i>recognise</i> that the earth has bar magnet like properties; • <i>investigate</i> what happens when a magnet is freely suspended in terms of its alignment with the earth's magnetic field.
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 Time	<p>This section will take you about nine hours to complete. Make sure that you read and understand everything in order to achieve all of the basic competencies.</p>
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Magnetism

Have you ever used a magnet? I am sure you have. What is a magnet?

A magnet is a piece of metal that can attract a number of other metals. Permanent magnets are made of steel. This means that a magnet can only attract certain metals. What type of materials can be attracted to a magnet?

Well, a magnet can attract only materials that contain iron, cobalt or nickel. Such materials are called ferrous materials. Examples of ferrous materials are steel and iron itself.

Those materials that cannot be attracted by a magnet are called non-ferrous materials. These include all other materials such as copper, lead, plastic, wood and so on.

Look at the diagram of a magnet.





A magnet has two ends called poles. It has a north pole and a south pole. What happens when like poles of magnets are brought together? By like poles, I mean; north and north or south and south.

When like poles of different magnets are brought together they will push each other away. We say that they repel each other. This process is called repulsion.



Repel

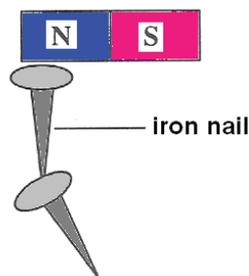
What if you bring unlike poles close together? In this case, they attract each other. This process is called attraction.



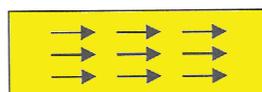
Attract

When an iron nail is attached to a magnet, it can also attract other iron nails. When you remove the magnet, we find that the iron nail stops attracting other iron nails. What happened?

The iron received magnetism from the magnet and became a temporary magnet. When the magnet is removed, it lost its magnetism. This type of magnetism is called **induced magnetism**. Iron becomes a magnet only when it is in a magnetic field.



Let us see how temporary magnetism is induced into an iron nail. There is a theory that in a permanent magnet, there are tiny magnets pointing in the same direction. In soft iron, these tiny magnets are randomly arranged. When magnetism is induced in iron, these tiny magnets align themselves like in a permanent magnet. This makes the iron nail to behave like a magnet. When the magnet is removed, the tiny magnets in the iron go back to their random arrangement and the magnetism is lost.



The tiny magnets in a magnet aligned in same direction



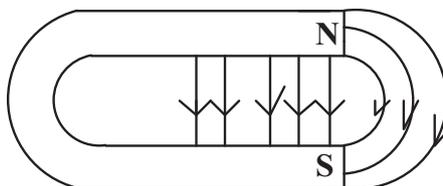
The tiny magnets in unmagnetised iron randomly arranged

In Section 1, we saw that magnetism is a force. Where can this force be experienced?

This force can be experienced around a magnet. The space around a magnet where the force of the magnet can be experienced is called its **magnetic field**.

We are now going to investigate and draw the pattern of field lines around a bar magnet and a horseshoe magnet. The pattern of magnetic field lines around a bar magnet or horseshoe magnet can be demonstrated by using iron filings. So, this is what you should do:

1. Put a magnet under a sheet of paper and sprinkle some iron filings on top.
2. To make the patterns more defined, tap the paper gently with your finger. This will give you the general pattern of the field lines.
3. To show the direction of field lines, you use a compass. When you place it at the North Pole, the compass' needle point moves away from the North Pole.
4. The direction of field lines is from north to south.



horseshoe magnet

How can we show the direction of field lines around a bar magnet? You can show the direction in the following way:

1. Place a bar magnet on a sheet of plane paper and draw its outline with a pencil.
2. Then, place a plotting compass near the north pole of the magnet and put a mark on the paper in front of the compass needle.
3. Move it in such a way that the tail of the compass is on the mark you made.
4. Put another mark in front of the compass needle.

You can refer to the practical activities at the end of this section.



Remember that in Section 1, we said that the earth acts like a big magnet that attracts objects towards its centre. In fact, it behaves like a bar magnet. To prove this, tie a bar magnet in the middle with a string and let it hang freely. It should come to rest.

What do you observe? In which directions does it come to rest? Which pole of the magnet points to the North Pole of the earth? When a bar magnet is suspended freely, it will come to rest in a north-south direction. The pole of the magnet that will point to the North Pole of the earth is called the north-seeking pole or simply north pole. The pole pointing to the South Pole of the earth is called the south-seeking pole or simply south pole. Do you realise the contradiction on the naming of the poles?

Work through the following practical activities to reinforce your understanding of this section.



Practical Activity

Practical Activity 1

Problem:

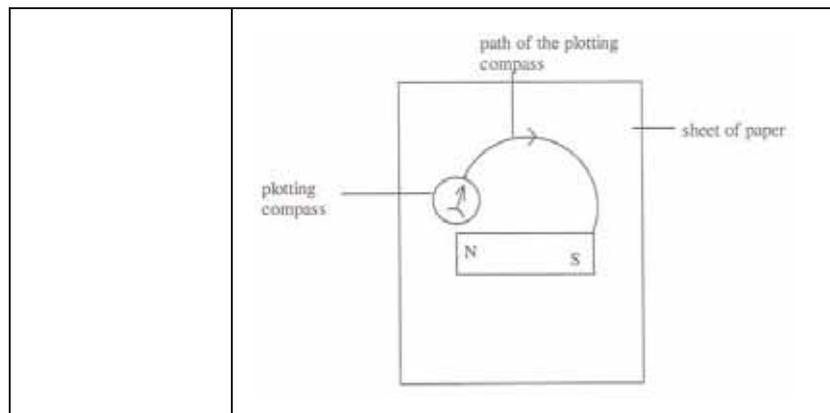
To investigate and draw the magnetic field lines around a bar magnet.

What you need:

a sheet of paper;
a bar magnet;
a plotting compass;
a pencil.

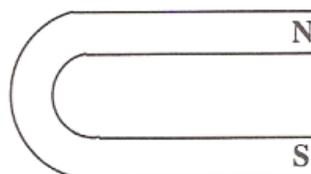
What to do:

1. Place a bar magnet on a sheet of paper.
2. Draw the outline of the magnet.
3. Place the plotting compass near the north pole of the magnet.
4. Mark a dot on the paper in front of the compass needle.
5. Move the compass in such a way that the tail of the needle is on the dot you marked.
6. Mark the new position of the compass needle.
7. Join all the positions.
8. Repeat steps 1-7 for various positions of the magnet.



**Practical Activity****Practical Activity 2****Problem:**

To investigate and draw the magnetic field lines around a horseshoe magnet.



horseshoe magnet

What you need:

a sheet of paper;
a horseshoe magnet;
a plotting compass.

What to do:

1. Place a horseshoe magnet on a sheet of paper.
2. Draw the outline of the magnet.
3. Place a compass needle near the north pole of the magnet and mark the positions of the pointer as in Practical Activity 1.
4. Draw lines to represent the path of the compass needle.

**Practical Activity****Practical Activity 3****Problem:**

To investigate and draw the pattern of the magnetic field lines around a bar magnet.

What you need:

a sheet of paper;
a bar magnet;
iron filings.

What to do:

1. Place a bar magnet under a sheet of paper.
2. Sprinkle some iron filings on the paper.

- | | |
|--|--|
| | 3. Tap the paper gently and watch the pattern of the magnetic field. |
|--|--|

**Practical Activity****Practical Activity 4****Problem:**

To investigate and draw the pattern of the magnetic field lines around a horseshoe magnet.

What you need:

sheet of paper;
horseshoe magnet;
iron filings.

What to do:

1. Place a horseshoe magnet under a sheet of paper.
2. Sprinkle some iron filings on the paper.
3. Tap the paper gently and watch the pattern of the magnetic field.

Now try working through the following self-mark activity.

Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Self-Mark Activity**Answer the following questions:**

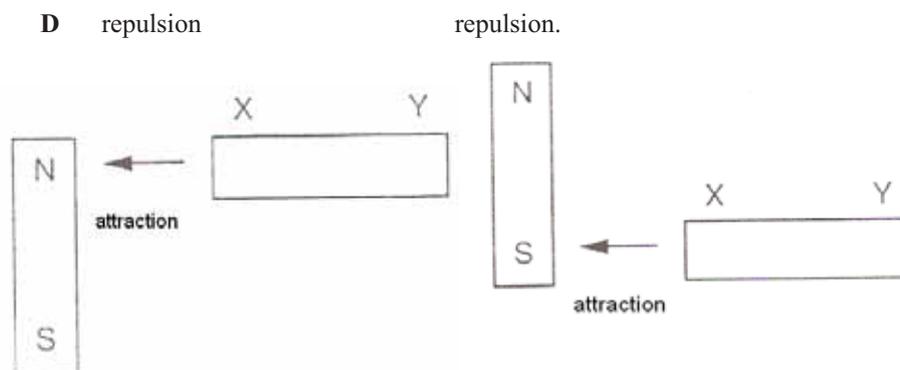
1. A metal rod **XY** is placed near a magnet. End **X** is attracted when it is placed near the north pole of the magnet and also when it is placed near the South Pole. Choose the correct option below:

XY near North Pole

- A** attraction
B attraction
C repulsion

XY near South Pole

- attraction;
repulsion;
attraction;



2. Discuss what happens when:
 - (a) Like poles of magnets are brought close together.
 - (b) Unlike poles of magnets are brought close together.

3. Describe how you can use a marked magnet to identify the poles of an unmarked one.

4. For each of the following materials, say what they are and give one example of each.
 - (a) ferrous materials;
 - (b) non-ferrous materials.

Section 9: Magnetic Effect of an Electric Current

Introduction

In Section 8, we learned about magnetism. In this section, we will learn how magnetism influences electric current.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>investigate</i> the magnetic effect of an electric current in a straight conductor; • <i>investigate, sketch and compare</i> the magnetic field around a bar magnet and a current-carrying solenoid; • <i>describe</i> how to build an electromagnet and outline its uses; • <i>investigate and explain</i> the difference between
--	--

	<p>the electromagnetic properties of iron and steel;</p> <ul style="list-style-type: none"> • <i>predict</i> the difference between a temporary and a permanent magnet; • <i>investigate</i> the movement of a magnet into and out of a coil which produces an electric current; • <i>investigate</i> different appliances to identify the magnets and current carrying conductors and to explain how they work; • <i>discuss</i> the generation of electricity using a simple generator or dynamo; • <i>explain</i> how to make a simple electric motor and convert it into a generator; • <i>study</i> how electricity is generated and transmitted in Namibia and how this process requires the use of transformers.
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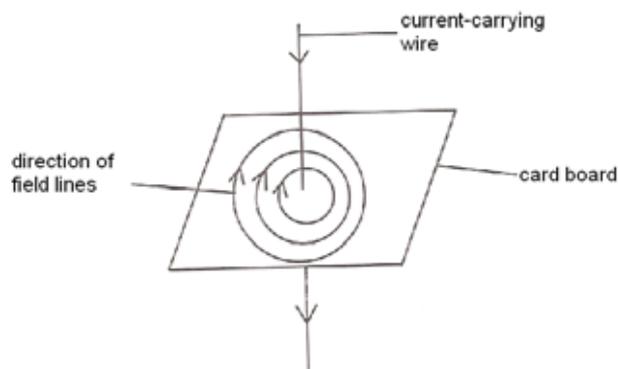


Time

This section will take you about nine hours to complete. Make sure that you read and understand everything in order to achieve all of the basic competencies.

The magnetic effect of an electric current

When current flows through a conductor, magnetism is created around it. An electric current moving through a straight conductor has a magnetic effect around the conductor.



To understand how this works in practical terms, let us perform a small experiment:

1. Connect the two ends of a wire to a d.c. (direct current) source, a battery. Don't use current from the mains. This is dangerous!



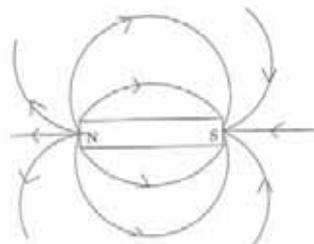
2. If the current flows in the direction of the arrows as shown in the diagram, you can use the **right-hand grip rule** to determine the direction of the magnetic field.
3. Hold the wire with your fingers curled around the conductor and your thumb pointing forward in the direction of current. The curled fingers represent the direction of the magnetic field around the wire.
4. If you place a few compasses around the wire, they will point in the direction of the field.
5. You can also use iron filings. Sprinkle some iron filings around the wire on the cardboard and tap the cardboard a bit. The iron filings will arrange themselves into circular patterns.

This method, however, does not show the direction of the field like the compass needles.

Magnetic field around a bar magnet

We are now going to investigate the patterns of the magnetic field around a bar magnet. In Section 8, you drew the patterns of the magnetic field around a bar magnet.

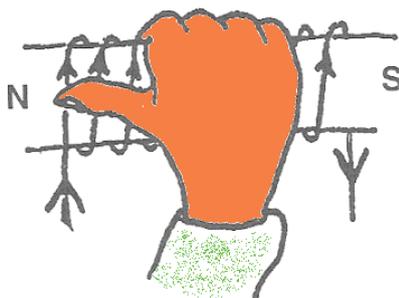
When drawing the field lines, make sure that the arrows on the lines come out of the North Pole and enter the South Pole.



Magnetic field around a solenoid

A solenoid is a coil of wire that becomes magnetic when an electric current is passed through it. The field lines around a current-carrying solenoid is like that of the bar magnet. The only problem is how you identify the poles. To identify the poles, you use the **right-hand grip rule**.

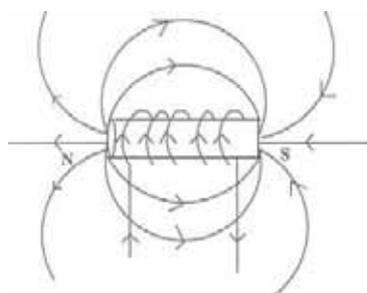
Firstly, identify the direction of the current by looking at the poles of the battery. Remember, conventional current flows from the positive terminal of the battery or cell through the circuit and back to the negative terminal. In this case, the direction of current is already shown. You use the right-hand grip rule as you did with the current-carrying wire, but now it's a solenoid.



right-hand grip rule

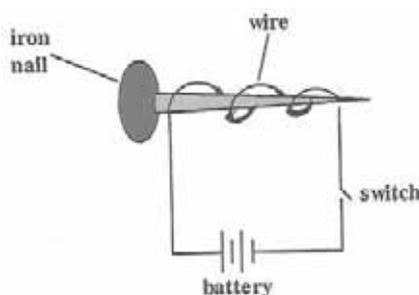
Right-hand grip rule

Hold the solenoid in such a way that your fingers are curled in the direction of the current and the thumb pointing as shown in the diagram. Your thumb then points to the north pole of the coil. Thereafter, continue drawing the field lines like for the bar magnet. The right hand grip rule needs a bit of practice, so try different situations.



How to build an electromagnet

What is an electromagnet? It is a temporary magnet because it only works as a magnet when current flows. The basic design of an electromagnet consists of an insulated copper wire wound around a soft iron core. In the diagram below, only a few turns are shown. However to make it work well, you should use many turns. The two ends of the wires are then connected to a source of current. When the switch is closed, current flows through the coil. Since a current-carrying wire has a magnetic field around it, it magnetises the iron nail.



Uses of electromagnets

1. Scrap yards

Electromagnets are used in scrap yards to separate ferrous metals (iron and steel) from non-ferrous materials. When the electromagnet is switched on, it attracts ferrous metals and leaves non-ferrous metals.

2. Loudspeakers



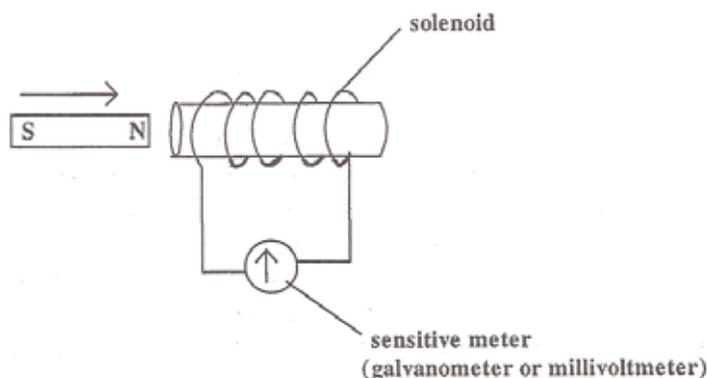
Just like in electric motors, loudspeakers consist of a permanent magnet and a coil of wire with current flowing through it. When the magnetic field of the permanent magnet and that of the current-carrying coil interact, they create a turning effect. This causes the coil to move. This in turn moves the cone causing it to vibrate back and forth.

3. Electric motors

Appliances such as fans, drills, hair driers, vacuum cleaners and so on have electric motors that have electromagnets. You will read more about electric motors later in this section.

Production of an electric current

You have seen that a current-carrying wire has a magnetic effect around it. The production of an electric current is very simple. When a wire or coil cuts the magnetic field, current is produced. This process is called **electromagnetic induction**. You can generate your own electricity by making a coil of insulated wire and connecting the ends to a sensitive meter like a millivoltmeter or a galvanometer as shown in the diagram below.

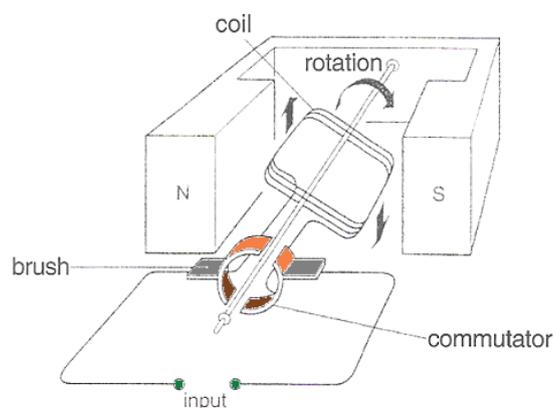


When you push a magnet in and out of the coil, the needle of the sensitive meter you use will move. This shows that an electric current is produced. If you leave the magnet stationary inside the coil, the needle does not move. In short, you need motion, wire or coil and a magnet to produce electricity.

Simple d.c. generator (dynamo)

A simple d.c generator is called a dynamo. The basic design of a dynamo is the same as that of an electric motor. Let us look at how a dynamo and electric motor work.

A dynamo produces electricity. This means it needs motion, a magnetic field and a coil to produce current. A motor on the other hand produces motion. This means it needs current, a coil and a magnetic field in order to produce motion.



A simple d.c.generator (dynamo)

A simple d.c. generator works on the principle of electromagnetic induction. When the coil is rotated between the magnets, it cuts the magnetic field. By cutting the magnetic field, current is induced into the coil.

Simple electric motor

An electric motor converts electrical energy into movement energy. When current flows through the coil, a magnetic field is produced. This magnetic field and the magnetic field due to the permanent magnets cause the coil to rotate. Refer to Practical Activity 6 to gain a more practical understanding of this.

How to convert an electric motor into a generator

An electric motor is the reverse of a generator. To convert a motor into a generator:

1. remove the battery;
2. connect a consumer like a bulb, or an instrument that can measure current like a milliammeter or galvanometer to show whether current is produced;
3. mechanically, rotate the axle so that the coil can cut the magnetic field. In this way, current will be induced in the coil. This is the principle of electromagnetic induction discussed earlier.

If you put the motor at the edge of a table and coil a wire several times on the axle with a load hanging and let the load fall, the motion can produce current.

Generation of electricity

In Namibia, electricity is generated from hydroelectric power stations and thermal power stations. In hydroelectric power stations, water is used to drive the turbines. In thermal power stations on the other hand, coal is burnt to produce heat. The heat turns water into steam. The steam then



turns the turbines. In both cases, the turbines turn the generators and electricity is produced. The electricity produced is at a lower voltage.

At a lower voltage, the current is higher. If transmitted like this, a lot of energy will be lost due to the heat in the cables. To reduce energy loss, transformers are used.

There are two types of transformers; step-up and step-down transformers. Step-up transformers increase voltage while step-down transformers decrease voltage.

A step-up transformer is used to increase the voltage when electricity is transmitted.

When it reaches towns, step-down transformers are used to decrease the voltage so that it is safe to use in homes and industries.

Now, work through the following practical activities to reinforce your understanding of this section.



Practical Activity

Practical Activity 1

Problem:

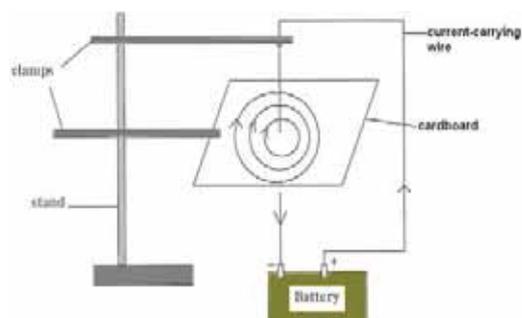
To investigate the magnetic effect of an electric current in a straight conductor.

What you need:

a cardboard;
 a stand;
 a plotting compass;
 a battery (6 – 9 V);
 an insulated copper wire (about 1.5 m).

What to do:

1. Clamp the cardboard.
2. Pass the wire through the cardboard as shown in the diagram.
3. Connect one end of the wire to the battery.
4. Place the plotting compass on the cardboard around the wire.
5. Watch the directions of the compass needles.
6. Connect the other end of the wire to the battery and watch the compass needles.
7. Reverse the poles of the battery and compare the directions of the compass needles.



**Practical Activity****Practical Activity 2****Problem:**

To investigate the magnetic field lines around a bar magnet.

What you need:

a sheet of blank paper;
a bar magnet;
a plotting compass.

What to do:

1. Place a bar magnet on a sheet of paper.
2. Draw the outline of the magnet. Do not remove the magnet.
3. Place the plotting compass near the north pole of the magnet.
4. Mark a dot on the paper in front of the compass needle.
5. Move the compass in such a way that the tail of the needle is on the dot you marked.
6. Mark the new position of the compass needle.
7. Join all of the positions with a smooth line (it should be a curved line).
8. Repeat steps 1 to 7 for various positions of the magnet.

**Practical Activity****Practical Activity 3****Problem:**

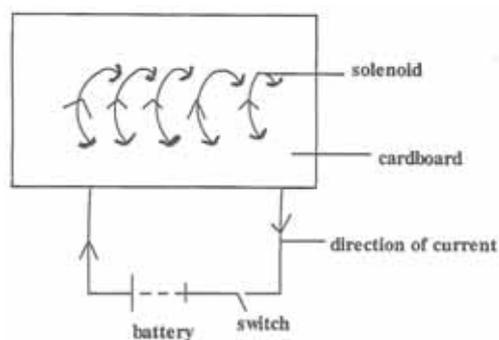
To investigate the magnetic field around a current-carrying solenoid.

What you need:

a cardboard;
an insulated copper wire;
a battery;
plotting compasses.

What to do:

1. Pass an insulated copper wire through the cardboard as shown in the diagram below.
2. Connect the ends to a battery.
3. Close the switch, place compasses at different positions and plot the direction of the field lines on the cardboard as in Practical Activity 2.





Practical Activity

Practical Activity 4

Problem:

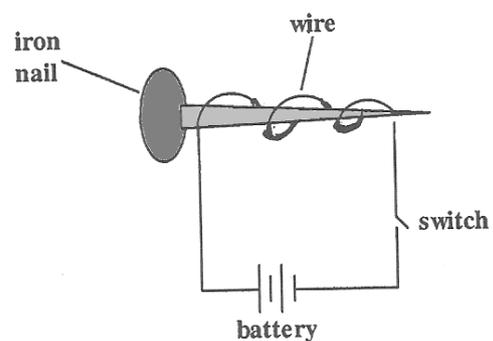
To build an electromagnet.

What you need:

insulated copper wire of about 4 m;
 an iron nail;
 a battery;
 iron filings.

What to do:

1. Wind the insulated copper wire around the iron nail as shown in the diagram below.
2. Connect the two ends of the wire to a battery.



Practical Activity

Practical Activity 5

Problem:

To investigate magnetic properties of steel and iron.

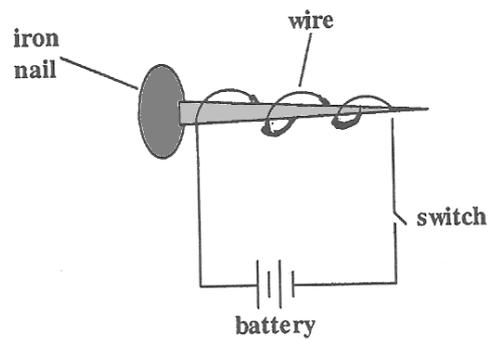
What you need:

a steel pin;
 an iron nail;
 insulated copper wire of about 4 m;
 a battery;
 iron filings.

What to do:

1. Wind the insulated copper wire around the iron nail as shown in the diagram.

2. Close the switch and try to pick up some iron filings.
3. Open the switch and watch what happens to the iron filings.
4. Repeat steps 1 to 3 using a steel needle.



You will find that when the iron nail is used, it will attract the iron filings only when current flows.

When using the steel pin, it will attract the iron filings even if no current flows.



Practical Activity

Practical Activity 6

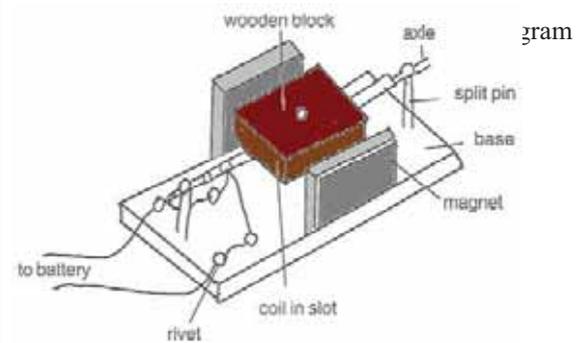
Problem:

How to make an electric motor.

What you need:

an insulated copper wire;
 two permanent magnets;
 a wooden block or matchbox with a hole inside;
 a wooden block base;
 a battery;
 a U-shaped metal plate;
 pins;
 rubber rings;
 cellotape.

What to do:



The parts shown in the diagram are found in an electromagnetic kit. You may improvise some of the parts if you cannot find them easily.

Now try working through the following self-mark activity.

Self-Mark Activity



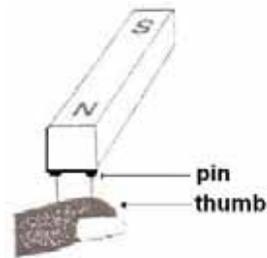
Self-Mark Activity

Self-Mark Activity

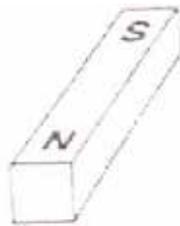
This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- Ndapanda is interested in magnets and the way they behave. She holds two pins on the magnet as shown.



- Complete the diagram below to show what you would expect to happen to the pins when she removes her thumb.



Briefly explain why this would happen.

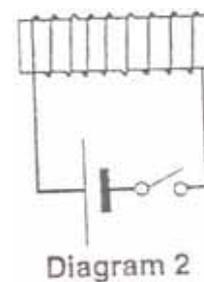
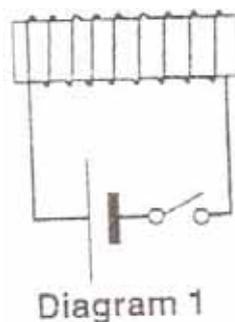
- She then placed the pins as shown below.





Explain why they remain where they are.

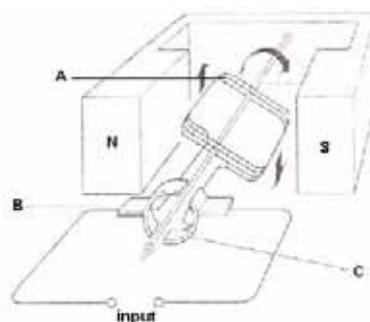
- (b) Ndapanda now finds a soft iron rod and a steel rod. She checks that they are not magnetised. Then she wraps a coil of wire around each one and connects each coil to a battery and a switch.



Describe what you would expect to happen in each of the following cases:

- (i) She closes the switch in **diagram 1** and brings an iron nail up to the soft iron.
- (ii) She then opens the switch.
- (iii) She closes the switch in **diagram 2** and brings an iron nail up to the steel.
- (iv) Finally she opens the switch in this circuit.

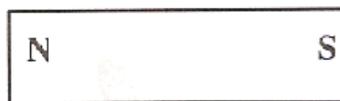
2. The diagram shows a simple electric motor.



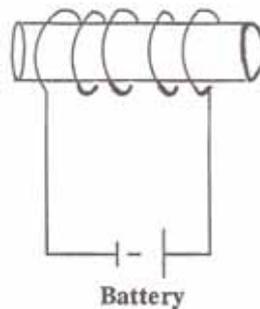
- (a) Name the labelled parts **A**, **B** and **C**.
- (b) Describe two modifications you would make to the electric motor to convert it into a generator.

3. The diagrams show a bar magnet and a solenoid.

- (a) Draw field lines around the bar magnet and indicate their direction.



- (b)(i) On the diagram below, indicate the poles on the solenoid.
- (ii) Draw field lines around the solenoid and indicate their direction.



4. Outline how electricity is generated and transmitted in Namibia and how this process requires the use of transformers.

We have come to the end of this unit. To ensure that you have understood the material, spend a few hours reviewing what we have covered in this unit.



Summary

In this unit you learned:

- from earlier work, the properties of magnets and the nature of magnetic forces and fields;
- from earlier work, charge and static electricity;
- about the imbalance of electrons and protons, that electric current is determined by the flow of charges and is measured in amperes using an ammeter;
- that current (I) can be calculated as the number of charges (Q) per time (t) and that the current can be measured at any point in an electrical circuit using an ammeter;
- about the difference between electrons and conventional currents;
- about the difference between direct and alternating currents;
- to relate electric potential to the ability to drive charge around a complete circuit and explain that potential difference:
 - is measured in volts;
 - is measured across an electrical component in a circuit using a voltmeter;
 - can be calculated by the energy (E) per charge (Q);
 - is the same as voltage, both are measured in volts (V) and that both share the abbreviation “V”.
- that current is made to flow round a circuit by the difference in electrical potential between the poles of a cell;
- to recognise that increasing the number of cells in series in a circuit increases the current flowing round the circuit
- to recognise that increasing the number of cells in a circuit increases the potential difference across components in the circuit;
- to measure the potential difference across individual components in a circuit;

	<ul style="list-style-type: none">• to measure potential difference across the whole circuit;• that resistance is the opposition of a conductor to the flow of charges and is measured in ohms;• about an experiment to determine resistance using a voltmeter and an ammeter;• to relate qualitatively the:<ul style="list-style-type: none">proportionality between resistance and length of a wire;inverse proportionality between resistance and cross-sectional area of a wire;relationship between resistance and temperature of a wire;calculation of the total resistance for a combination of resistors in a circuit.• how to set up, from circuit diagrams, electric circuits involving cells and bulbs and/or resistors in series and in parallel and also how to measure or calculate resistance between any two points;• to recall, interpret and analyse the relationship between current, resistance and voltage in electrical conductors and circuit diagrams involving cells and bulbs or resistors in series and in parallel;• to draw circuit diagrams involving cells and bulbs or resistors in series and in parallel and be able to measure and calculate the:<ul style="list-style-type: none">current at any point in the circuits;potential difference between any two points;resistance between any two points.• about the relationship between current and potential difference across various conductors (nichrome, copper, eureka wires and light bulbs);
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	<ul style="list-style-type: none">• to interpret graphically and by calculation, the relationship between current and voltage in an electrical conductor;• the difference between ohmic and non-ohmic conductors and sketch the V/I characteristic graphs for:<ul style="list-style-type: none">ohmic conductors;non-ohmic conductors such as bulbs;• about power (P) as the rate of doing work, unit of power, and watt (W), and explain that electrical power (P) can be calculated by the product of the voltage (V) and the current (I);• about the voltage across and the current through terminals of different appliances in order to calculate their electrical power output;• how to use the formula $P = VI$ to calculate electrical power;• about the watt value of bulbs and other electrical appliances, and how calculate the cost of operating them for a specified time;• about the difference between mains electricity and electricity from batteries;• about the uses of electrical energy and discuss how and why electrical energy should be conserved;• about the dangers of electricity caused by damaged insulation, overheating and/or overloading and damp conditions;• how to suggest ways in which the use of electricity can be made safer using fuses, circuit breakers and earthing;• the importance of earthing wire;• the difference between ferrous and non-ferrous materials;• about the properties of magnets, give an account of induced magnetism in terms of
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	<p>alignment of magnet units and explain the magnetic lines of force around a magnet;</p> <ul style="list-style-type: none">• how to investigate and draw the pattern of field lines around a bar magnet and horse shoe magnet;• that the earth has bar magnet-like properties and investigate that a magnet freely suspended will align itself with the earth's magnetic field;• about the magnetic effect of an electric current in a straight conductor;• how to investigate, sketch and compare the magnetic field around a bar magnet and a current-carrying solenoid;• how to build an electromagnet and outline its uses;• how to investigate and explain the difference between the electromagnetic properties of iron and steel and predict the difference between a temporary and a permanent magnet;• how to investigate the movement of a magnet into and out of a coil which produces an electric current; investigate different appliances to identify the magnets and current carrying conductors and to explain how they work;• about the generation of electricity using a simple generator or dynamo;• how to make a simple electric motor and suggest how to convert an electric motor into a generator;• how electricity is generated and transmitted in Namibia and how this process requires the use of transformers.
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Answers to Self-Mark Activities

Section 1: Revision of Earlier Work on Magnets and Charges

Self-Mark Activity

1. A magnet is a metal with 2 poles namely north and south. Like poles repel and unlike poles attract.
2. The area around a magnet is called its magnetic field.
3. Static electricity refers to charges that do not move.

Section 2: Current

Self-Mark Activity

1. positive and negative
- 2(a) negative
(b) positive
- 3(a) negative charges (electrons)
(b) ammeter
- 4(a) $I = Q/t$
 $= 200 \text{ C}/60 \text{ s}$
 $= 3.3 \text{ A}$
(b) $Q = It$
 $= 10 \text{ A} \times 120 \text{ s}$
 $= 1,200 \text{ C}$

Section 3: Voltage**Self-Mark Activity**

1. C

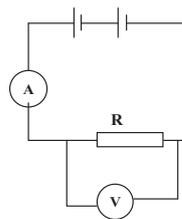
2. B

3. C

Section 4: Resistance**Self-Mark Activity**

1. C

2(a)

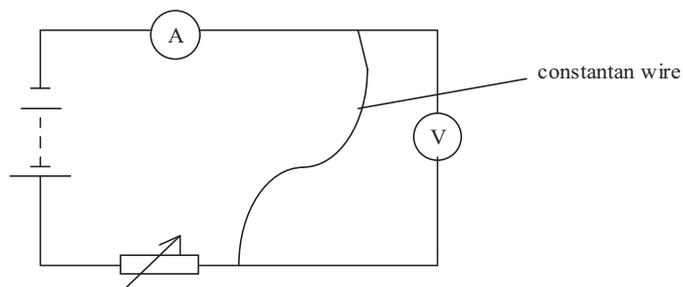
(b) $R = V/I$

(c) It is 4.5 V because the total voltage across components equals that of the source.

3 (a) They are directly proportional.

(b) increase or $100\ \Omega$ $2\text{m} : 20\ \Omega$
 $10\text{m} : 100$

4(a) Any reasonable diagram is acceptable.



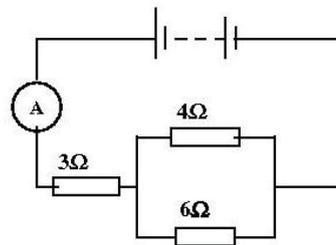


$$\begin{aligned}
 \text{(b) } R &= V/I \\
 &= 6.0 \text{ V}/1.5 \text{ A} \\
 &= 4 \Omega
 \end{aligned}$$

(c) By reducing the current you should increase the resistance of the wire:

1. Increase the length of the constantan wire; the longer the wire the higher the resistance i.e., low current.
2. Decrease the thickness (cross sectional area) of the wire. The thinner the wire, the higher the resistance, therefore low current.

5(a) Calculate the total resistance for the resistors in parallel then add the series.



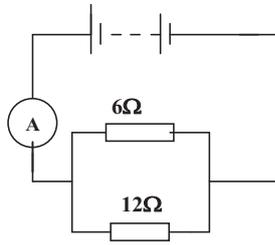
First calculate the total resistance for the parallel.

$$\begin{aligned}
 R_T &= \frac{4 \times 6}{4 + 6} \\
 &= \frac{24}{10} \\
 &= 2.4 \Omega
 \end{aligned}$$

Then you have the 3 Ω resistor in series with the 2.4 Ω resistor

$$\begin{aligned}
 \text{therefore, } R_T &= 3 + 2.4 \\
 &= 5.4 \Omega
 \end{aligned}$$

(b)

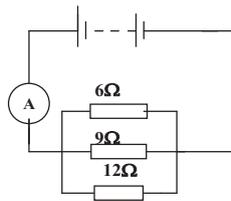


$$= \frac{6 \times 12}{6 + 12}$$

$$= \frac{72}{18}$$

$$= 4\Omega$$

(c)



$$R_T = \frac{6 \times 9 \times 12}{(6 \times 9) + (6 \times 12) + (9 \times 12)}$$

$$= \frac{648}{54 + 72 + 108}$$

$$= \frac{648}{234}$$

$$= 2.769\Omega$$

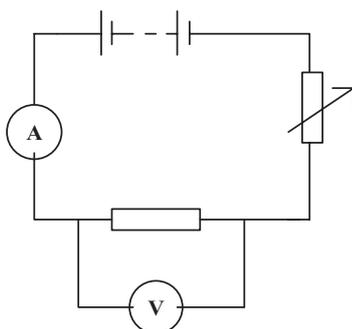
$$= 2.8\Omega$$

Section 5: Relationships Between Current and Voltage in an Electrical Conductor (Ohm's Law)

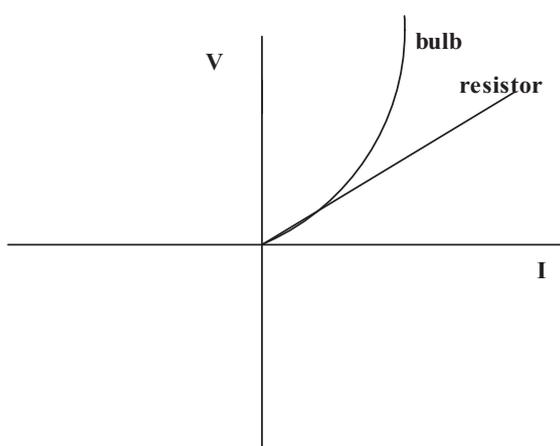
Self-Mark Activity

1(a) X is a variable resistor or rheostat.

(b)



(c) and (d)



2(a)(i) voltmeter

(ii) ammeter

(iii) There is a straight line through the origin. Potential difference is directly proportional to current.

(iv) Take any value of V and divide it with its corresponding value of I, e.g.,

$$R = V/I$$

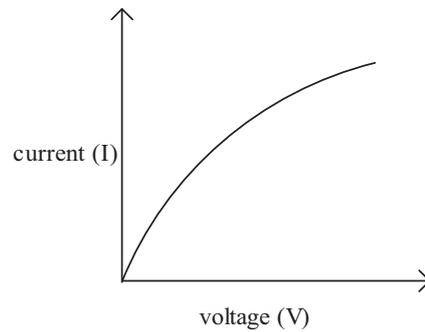
$$= 2 \text{ V}/0.16 \text{ A}$$

$$= 12.5 \Omega \text{ (or an approximate value approximately)}$$

(b)(i) Resistance increases with increase in temperature.

(ii) The temperature should remain constant.

(iii) Take note that swapping the axes reverses the curve, but it is still correct.



Section 6: Electrical Power

Self-Mark Activity

$$\begin{aligned}
 \mathbf{1(a)} \quad P &= V \times I \\
 &= 240 \text{ V} \times 4 \text{ A} \\
 &= 960 \text{ W}
 \end{aligned}$$

(b) Change minutes to hours:

$$10 \text{ minutes} = 10/60 = 0.17 \text{ hours}$$

Change watts to kilowatts:

$$960 \text{ W} = 960/1,000 = 0.96 \text{ kW}$$

$$\begin{aligned}
 E &= P \times t \\
 &= 0.96 \times 0.17 \\
 &= 0.16 \text{ kWh}
 \end{aligned}$$

2(a) Change watts to kilowatts

$$\begin{aligned}
 100 \text{ W} &= 100/1,000 \\
 &= 0.1 \text{ kW}
 \end{aligned}$$

$$\begin{aligned}
 E &= P \times t \\
 &= 0.1 \text{ kW} \times 5 \text{ h} \\
 &= 0.5 \text{ kWh}
 \end{aligned}$$

(b) 1kWh costs 61 c

$$\begin{aligned}
 0.5 \text{ kWh} &\text{ will cost } 0.5 \times 61 \\
 &= 30.5 \text{ c} \\
 &= 31 \text{ c}
 \end{aligned}$$



Section 7: Electricity in the Home

Self-Mark Activity

1(a)(i) copper wire

(ii) plastic

(b) The earth wire lets current to flow into the ground instead of through the person who touches the live wire. This protects the user from electric shock.

(c)(i) A fuse melts when the amount of current flowing is too high.

This breaks the circuit.

(ii) A circuit breaker trips when there is a fault.

(d)(i) 5 A fuse

(ii) It prevents a very high current from flowing.

2.

	mains electricity	electricity from the battery
1.	very high voltage e.g., 220 V	low voltage e.g., 1.5 V for touch cell and 12 V for car battery when fully charged
2.	alternating current (a.c.)	direct current (d.c)

3(a) for cooking , lighting, etc;

(b) switching off appliance when not needed, etc.

Section 8: Magnetism

Self-Mark Activity

1. A

2(a) repel

(b) attract

3. Bring one end of the unmarked magnet close to the poles of the marked one. Where there is repulsion, the poles are the same. NB. Use repulsion to confirm the poles.

4(a) ferrous materials contain iron, therefore can be attracted by a magnet, e.g., steel and iron itself.

(b) Non-ferrous materials don't contain iron, therefore cannot be attracted by a magnet, e.g., copper, zinc.

Section 9: Magnetic Effect of an Electric Current

Self-Mark Activity

1(a)(i) The pins will still be attached to the magnet with their tips repelling each other.

(ii) This is because they have induced magnetism.

(b)(i) The iron nail will be attracted.

(ii) The iron nail falls off.

(iii) The iron nail is attracted.

(iv) The iron nail is still attached to the steel.

2(a) A – coil

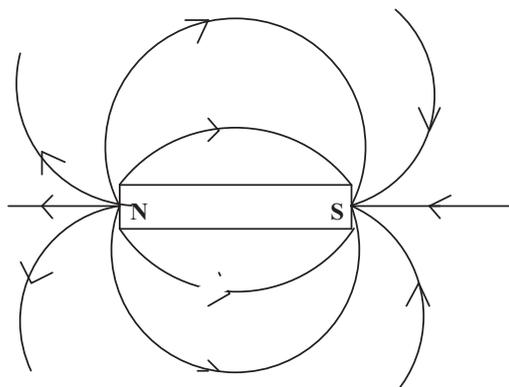
B – carbon brushes

C – split ring commutator

(b)(i) mechanically rotate the coil

(ii) remove the electricity source and connect a consumer, e.g. bulb or instrument like an ammeter.

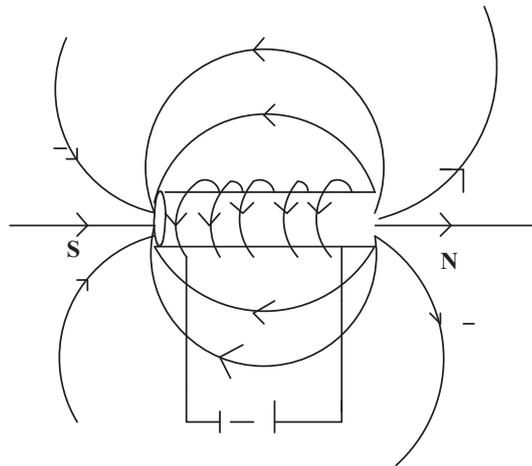
3(a)



(b)(i) From the arrangement of the battery, you should see that current flows from the positive terminal of the battery,



through the solenoid and back to the negative terminal. Then, apply the right-hand grip rule to determine the poles and then proceed as usual to draw the field lines.



4. In Namibia, electricity is generated from hydroelectric power stations and thermal power stations. In hydroelectric power stations, water is used to drive the turbines while in thermal power stations, coal is burnt to produce heat. The heat turns the water into steam. The steam turns the turbines. In both cases, the turbines turn the generators and electricity is produced. The electricity produced is at a lower voltage.

To reduce energy loss, transformers are used. A step-up transformer is used to increase the voltage when electricity is transmitted.

When it reaches towns, step-down transformers are used to decrease the voltage so that it is safe to use in homes and industries.

Unit 7

Waves, Sound and Light

Introduction

In Unit 6, we discussed electricity.

This unit consists of the following sections:

Section	Study Hours
1. General Wave Properties	9
2. Sound	9
3. Light, the Basic Concepts	5
4. Transmission and Absorption	4
5. Reflection by Mirrors	9
6. Refraction of Light	18
Review	2
Total	56



Outcomes

On successful completion of this unit, you will be able to:

- *describe* general wave properties;
- *describe* the production and properties of sound by vibrating sources;
- *describe* the relation between frequency and the pitch of sound, and between the amplitude and the loudness of sound;
- *explain* how light travels in straight lines leads to the formation of shadows, the appearance of an image and eclipses of the sun and moon;
- *explain* the properties of light when using different apparatus and when light falls on different objects that are translucent, transparent and opaque;



	<ul style="list-style-type: none"> ▪ <i>describe</i> reflection in plane mirrors, and by using ray boxes or pins, determine the position, nature and size of an image; ▪ <i>describe</i> how to build an application of plane mirrors such as a periscope or a kaleidoscope and explain how these work; ▪ <i>explain</i> refraction of light and applications and consequences of refraction; ▪ <i>explain</i> that an image is an optical appearance of an object produced by a mirror or a lens; ▪ <i>describe</i> that the dispersion of white light forms a spectrum, that white light is composed of the colours of the spectrum and the formation of rainbows.
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 Terminology	Wave	The regular periodic disturbance in a medium or space.
	Transverse waves	Particles in a medium vibrating at right angles to the direction of the wave motion.
	Longitudinal waves	Particles in a medium vibrating parallel to the direction of the wave motion.
	Medium	The material through which waves travel.
	Frequency	The number of vibrations per second.
	Amplitude	The maximum displacement of a particle from a rest position.
	Wavelength	The distance between neighbouring crests or troughs.
	Echo	Reflected sound.

Section 1: General Wave Properties

Introduction

Have you ever experienced dropping a rock in the middle of a still pond and watched the waves emanating out from the centre. That is what we call water waves. Work through this section and you will realise that waves are always around us.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>explain</i> pulse in terms of a single disturbance and the regular repetition of pulse in terms of waves which transfer energy from one place to another; • <i>describe</i> wave motion using examples such as the vibrations in ropes, springs and water; • <i>distinguish</i> between longitudinal and transverse waves by means of simple diagrams; • <i>describe</i> the propagation of waves through different media such as solids, liquids, gases and vacuum; • <i>compare</i> the speed of light and sound in different media; • <i>outline</i> practical consequences of the difference in the speed of sound and light in air using examples such as the observation that thunder always follows lightning; • <i>recall</i> and <i>state</i> frequency of a wave is the number of vibrations and hertz is its unit of measurement; • <i>describe</i> the wavelength and amplitude in terms of their quality as properties of waves.
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 <p>Time</p>	<p>This section will take you about nine hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Origin of a wave

What is a wave? It is a disturbance in a rope, spring or water surface. A wave is a regular periodic disturbance in a medium or space. When you fix a rope at one end and shake the other end, disturbances travel from your hand to the fixed end. A single disturbance is called a pulse. A pulse is simply a bump. When these pulses repeat in a regular pattern, they produce a wave. Waves carry energy from one place to another, but not matter. Tying a string to one part on a spring or rope can show this. Does the string move to the other end with the waves? No. This means that matter is not transferred. The size of the pulse is proportional to the amount of energy the wave carries. A bigger pulse or bump indicates greater energy.

Wave motion

Water waves and waves on a string or slinky spring are examples of wave motion. How are water waves formed? Hitting the surface of water with an object produce water waves. If you drop a stone into a pool of water, circular waves will be generated. These waves move outwards and are called transverse waves.

The shape of waves produced depends on the shape of the object that hits the water. How can you make straight (parallel) waves? You can use a straight object like a stick.

How can you produce waves in a rope or slinky spring? Place the rope or slinky spring on a table or floor with one fixed end. Your friend can hold one end. Quickly shake the other end of the rope or slinky spring from side to side. Pulses will be generated which travel to the fixed end. These waves are called transverse waves.

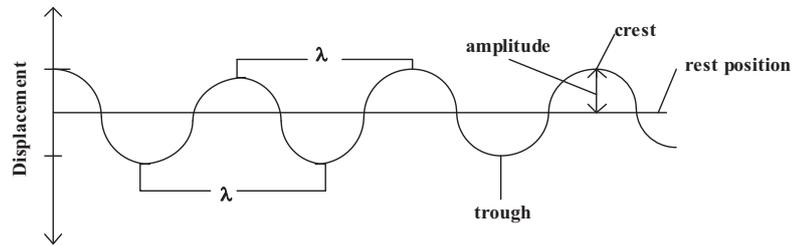
A slinky spring can also be used to produce longitudinal waves. With the spring on a floor and fixed at one end, stretch it slightly, and quickly shake it back and forth in the direction of the spring. Waves will be seen moving from your hand to the other end. These waves consist of compressions and rarefactions. Rarefactions are areas of low pressure.

I have mentioned two types of waves: longitudinal and transverse waves. Let us look at these two types of waves.

Transverse waves

In transverse waves, particles in a medium vibrate at right angles to the direction of the wave motion. Examples of transverse waves include water waves, electromagnetic (light) waves and waves produced by shaking a rope or a slinky spring that is fixed at one end. If you put an object that floats on water and hit the surface of the water near it, the waves generated will cause the object to move up and down in the same place. This shows that waves carry energy from one place to another but

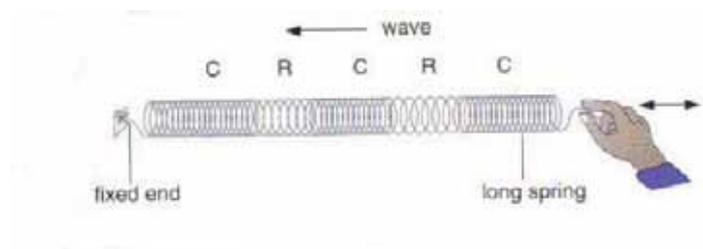
not matter.



λ - is a Greek letter, lambda. It represents wavelength.

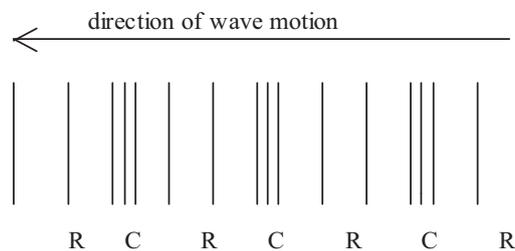
Longitudinal waves

In longitudinal waves, particles in a medium vibrate parallel to the direction of the wave motion. Particles vibrate back and forth in the direction of the wave motion. An example of a longitudinal wave is a sound wave. We can show longitudinal waves using a slinky spring as shown in the diagram. In this case, you shake by compressing at one end of the spring. This movement creates a series of compressions and rarefactions that travel to one end of the spring.



Slinky spring

A diagram consisting of straight lines also show the arrangement of particles. Dots could be used to represent particles in a medium but it is time consuming to draw them. The lines represent particles in the medium for example, air particles.



R - represents rarefactions (low pressure)
C - represents compressions (high pressure)



Wave propagation (how waves travel)

Waves can travel through different types of materials. The material through which waves travel is called a medium.

Sound travels through all three states of matter that is, solid, liquid and gas. However, it cannot travel through a vacuum. This means that sound waves need particles (medium) in order to travel. Sound waves travel fastest in solids and slowest in gases. Can you explain why? To answer this question, think about the arrangement of particles in the three states of matter. Sound travels from one point to another by the vibration of particles. These particles do not necessarily move from one point to another, rather they just transfer energy to neighbouring particles. How quickly this energy is transferred depends on the distance between the particles. As expected, sound waves will be transferred quickest in solids because the particles are tightly fitting together and slowest in gases because the particles are very far apart.

Light can travel through transparent and translucent materials. It can also travel through a vacuum. Unlike sound waves, light waves do not need a medium in order to travel because in a vacuum there are no particles.

When we compare the speed of sound and light, we find that the speed of light is many times higher than that of sound as shown in the table below. This is because light travels by means of electromagnetic waves, which are extremely fast.

Medium	Speed of light m/s	Speed of sound m/s
air	300 000 000 (3×10^8)	330
water	225 000 000 ($2,25 \times 10^8$)	1400
glass	200 000 000 (2×10^8)	3000

What are the consequences of this big difference in the speed of light and sound in air?

1. During a thunderstorm, we often see lightning first and hear thunder later. Did you know that thunder and lightning occur at the same time? It is just like striking a match, sound and light occur at the same time. Lightning is seen first, because light travels much faster than sound. Light is about 900,000 times faster than sound!

2. If you observe someone chopping wood far away from you, sound is heard when the person lifts the axe from the wood. This is because light

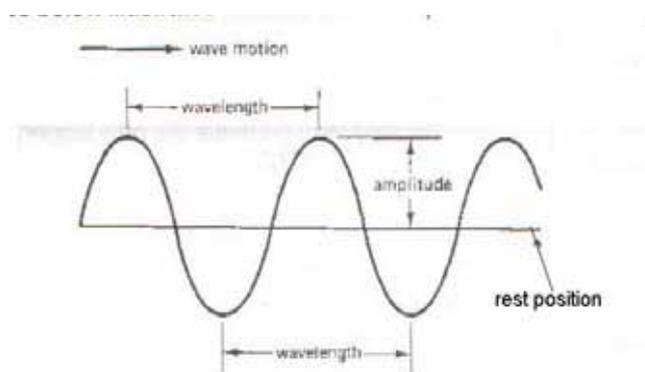
from the person reaches you earlier than sound. Therefore, you see the chopping of wood before hearing it.

Frequency

What is frequency? In general, it is the number of times that something happens in a given time. Frequency of a wave is the number of vibrations per second. The unit of frequency is hertz (Hz). If a source produces 500 vibrations in 2 seconds, its frequency is therefore 250 Hz. This means that the faster an object vibrates, the higher the frequency.

Properties of waves

Amplitude and wavelength are two properties of waves. Use the diagram below to help you understand these two properties.



1. Amplitude

Amplitude is the maximum displacement of a particle from its rest position. Displacement is the distance that a particle moves from its rest position. In the diagram, the rest position is the straight horizontal line. You can also say that amplitude is the height of a crest or depth of a trough. Since amplitude is distance, the units of distance are used such as metre, centimetre or millimetre.

2. Wavelength

Wavelength is the distance between neighbouring crests or troughs. Wavelength can be described in terms of particle movement. In this case, wavelength is the distance between successive points in a medium that are in phase (in step). This is a general description. Just like amplitude, the units of length are used for wavelength. Please note that wavelength can be described in more than one way. So you are welcome to use any explanation as long as it is scientifically correct.

Work through the following practical activities to reinforce your understanding of this section.

**Practical Activity****Practical Activity 1****Problem:**

To demonstrate the production and propagation of waves.

What you need:

- rope;
- slinky spring;
- water.

What to do:

Part 1: Using a rope or slinky spring:

1. Place the rope or slinky spring on a floor of a long bench.
2. Fix it at one end. Your friend can hold it in a fixed position.
3. While on the floor, shake the spring or rope from side to side.

Part 2: Using water:

1. Fill a large basin with water.
2. Place an object that floats on the water, e.g., dry leaf, cork, etc.
3. Repeatedly tap (hit) the water surface near the object.

Results and observations:**Part 1:**

1. Sketch the waveform you have generated.
2. Name the type of wave generated.

Part 2:

1. Sketch the waveforms generated.
2. (a) Name the type of waves generated.
(b)(i) Describe the movement of the floating object as waves pass.
(ii) Describe the movement of the water molecules as waves pass.

**Practical Activity****Practical Activity 2****Problem:**

To show that waves transfer energy from one place to another.

What you need:

- slinky spring;
- bottle (plastic or glass).

What to do:

1. Place a slinky spring straight on a floor with one end fixed.
2. Place the bottle next to the spring near the fixed end or in the middle.
3. Shake the spring from side to side to generate waves.

Results and observations:

1. What happens to the bottle as the wave reaches it?
2. What evidence exists that waves transfer energy from one place to another?

Now, its time to work through the self-mark activity.

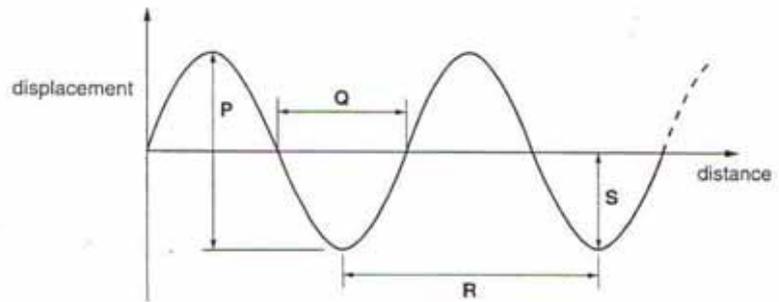
Self-Mark Activity

**Self-Mark Activity****Self-Mark Activity**

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

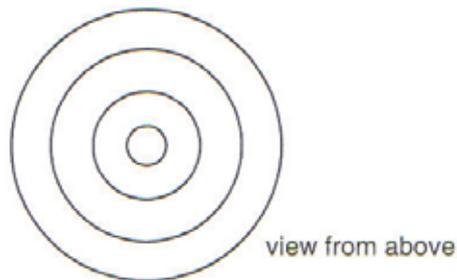
1. The diagram represents a wave.



Choose the letter that correctly identifies the amplitude and the wavelength of the wave?

	amplitude	wavelength
A	P	Q
B	P	R
C	S	Q
D	S	R

2. A drop of water from a tap falls onto the surface of some water of constant depth.

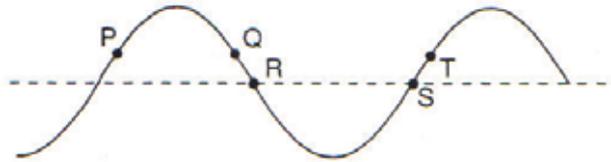


Water waves spread out on the surface of the water.

Which statement is true?

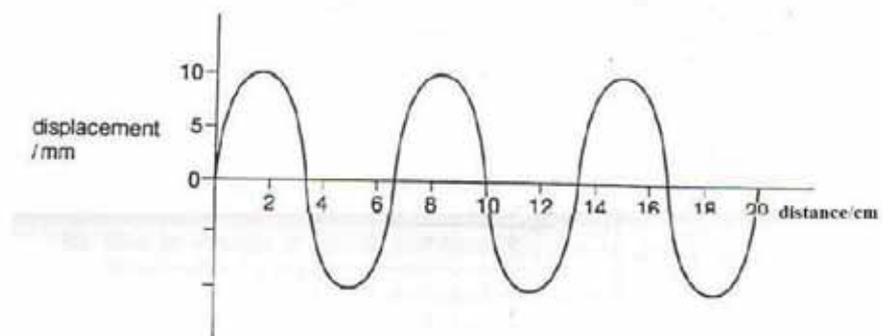
- A** the waves are longitudinal and energy moves in all directions;
- B** the waves are longitudinal and water molecules move in all directions;
- C** the waves are transverse and energy moves in all directions;
- D** the waves are transverse and water molecules move in all directions.

3. The diagram shows a wave on the surface of some water.



At which points are the molecules moving in the same vertical direction at the same time?

- A P and Q;
 - B P and T;
 - C Q and T;
 - D R and S.
4. A guitar string vibrates at 600 vibrations per minute. What is its frequency?
- A 10 Hz;
 - B 60 Hz;
 - C 600 Hz;
 - D 36,000 Hz.
5. The diagram shows a section through some water ripples at one instant.



- (a) Determine the wavelength as accurately as possible, making it clear on the diagram what readings you have taken.
- (b) (i) On the diagram mark and label the amplitude.
- (ii) What is the value of the amplitude?



6. Sound travels faster in liquids than in gases.
- (a) Write down what type of waves are sound waves.
- (b) Explain why sound waves travel faster in liquids than in gases.
7. During a thunderstorm, lightning is seen before thunder is heard.
Explain this observation.

I hope the self-mark activity was not too difficult, you can now move on to Section 2.

Section 2: Sound

Introduction

You can see a picture of a sound wave on the screen of a device called an oscilloscope. Sound is an interesting topic which will be discussed in this section.

<p>?</p> <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none">• <i>describe</i> the production of sound by vibrating sources;• <i>outline</i> the approximate range of audible frequencies;• <i>discuss</i> the frequency of vibration in relation to the pitch of sound;• <i>discuss</i> the amplitude of vibration in relation to the loudness of sound;• <i>describe</i> displayed waveforms on a cathode-ray oscilloscope (c.r.o.) screen;• <i>state</i> that a medium (solid, liquid and gas) is required in order to transmit sound waves;• <i>study</i> the speed of sound by using echoes;• <i>state</i> the unit of sound as decibels;• <i>discuss</i> the effect of noise on human hearing.
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Time

This section will take you about nine hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.



Sound is measured in the unit called, decibel.

Production of sound

Vibrating sources produce sound. When an object vibrates, it causes air particles close to it to vibrate, thereby producing sound. Can you produce sound? There are many ways to produce sound. For example, when you are talking, whistling, clapping, plucking a guitar string, beating a drum or hitting a tuning fork.

Movement of sound

When a person hits a drum, sound energy spreads out in all directions. Only a small amount of the total sound energy reaches your ears. This sound energy causes the eardrum, a thin membrane in the ear, to vibrate. This membrane vibrates at the same frequency as the drum that has been hit. These vibrations are translated into nerve impulses (messages) in your ear. The brain will interpret these impulses, whether the sound is loud or soft, or a high or low frequency. You will learn more about the amplitude and frequency of sound later.

Audible frequencies for the human ear

Audible frequencies are frequencies that can be heard by the human ear. The human ear can normally only hear sounds with a frequency from 16 hertz to 20,000 hertz (or 20 kHz). Above 20 kHz, only animals, like dogs, can hear these frequencies. If this is the case, it is amazing that we might complain about a place being so quiet. Yet, there are a lot of sounds around that we don't hear because they are not within our audible range!

Noise levels

Very loud noise can damage the eardrum. This includes loud music or machines that produce very loud noise. Gun sounds can also damage the ears. These days, those dealing with very loud sounds like explosions, are often provided with earguards.

Frequency of vibrations and pitch

To investigate differences in sound, you can use a microphone connected to an oscilloscope. The microphone turns the sound waves into an alternating voltage which is displayed on the screen of an oscilloscope.

Sound waves can have a low or a high pitch. What do we mean by the term pitch? This is how high or low the tone of sound is. We know that most males have low-pitched voices, while most females have high-pitched voices. The pitch of sound depends on the frequency of the vibration. Faster vibrations result in high frequency sound.

If the frequency is high, the pitch will also be high. This also means that if the frequency is low, the pitch will be low. You should take note that in the diagram, the amplitude is the same regardless of frequency or pitch.



Amplitude and loudness

The loudness of sound depends on the amplitude of the vibrations. Sound with a large amplitude will be loud while the one with a small amplitude will be soft. The diagram below shows the relationship between amplitude and loudness. You should note that in the diagram, the frequency (number of waves in the given space) is the same.



Sound needs a medium to travel through. It cannot travel through a vacuum. In Section 1 under wave propagation, sound wave travelling was discussed.

Echoes

What is an echo? It is reflected sound. When sound hits a hard object and bounces back, an echo is produced. Have you noticed that when you shout loudly near a mountain, tall building, cliff or riverbank, you can hear your voice again? This is an echo. Echoes are very important to both humans and animals.

How do humans use echoes? They use echoes to estimate how far an object is from them. If, for example, you shout in the direction of a mountain and you hear the echo three seconds later, it means the sound has taken 1.5 seconds to get to the mountain and another 1.5 seconds to get back. We know that sound travels at 330 m/s in air. From this we can calculate how far the mountain is:

$$\begin{aligned} \text{Distance} &= \text{speed} \times \text{time} \\ &= 330 \text{ m/s} \times 1.5 \text{ s} \\ &= 495 \text{ m} \end{aligned}$$

This means that the mountain is 495 m away.

Underwater echoes are used by fishing boats to measure the depth of the sea and to find shoals of fish. This is called echo sounding or **SONAR**. Sonar stands for **Sound Navigation Ranging**.

Animals, like bats, are thought to have poor vision, but they are active at night. They depend on echoes to locate their food (insects) and guide them during flight. How do they do this? Bats produce very high-pitched sound of about 80 kHz which bounces off hard objects including insects. The time it takes for sound to get back to a bat gives it an estimation of how far an object is.

Work through the following practical activities to reinforce your understanding of



this section.

 <p>Practical Activity</p>	<p>Practical Activity 1</p> <p>Problem:</p> <p>To demonstrate the propagation of sound through solids.</p> <p>What you need:</p> <p>Long bench or long metal.</p> <p>What to do:</p> <p>Place your ear on the bench or long metal while someone hits the other end softly with a pen or finger. If you stay near a railway line you could use the metal rails.</p> <p>Observations and results:</p> <p>1(a) Are you able to hear the sound when you have not placed your ear on the bench? Explain your answer.</p>
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 <p>Practical Activity</p>	<p>Practical Activity 2</p> <p>Problem:</p> <p>To demonstrate the propagation of sound in liquids.</p> <p>What you need:</p> <p>Water (enough to completely submerge you) e.g., bath tub.</p> <p>What to do:</p> <ol style="list-style-type: none">1. Listen to your heartbeat before you get into the water.2. Lie on your back in the water so that only your ears are completely under the water and listen to your heartbeat again. You may close your nose as a precaution. <p>Observation and results:</p> <ol style="list-style-type: none">1. In which situation is your heartbeat heard louder? Explain your answer.
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 <p>Practical Activity</p>	<p>Practical Activity 3</p> <p>Problem:</p> <p>To demonstrate the difference in the speed of sound and light.</p> <p>What you need:</p>
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a pistol (used in athletics);

a friend;

axe or hammer.

What to do:

Part 1: Athletics pistol:

1. Your friend with the pistol should be at a distance of about 150m.
2. Watch her carefully as she shoots the pistol (watch the smoke).



Part 2: Observe your friend chopping a tree or striking a hammer on a metal

Observations and results:

Part 1:

1. Is there a time difference between seeing the smoke and hearing the sound? Explain your answer.
2. Suppose you were a timekeeper. Would you start the timer upon seeing the smoke or hearing the sound? Explain your answer.

Part 2:

Is there a time difference between seeing the person striking the hammer on the piece of metal and hearing the sound? Explain your answer.



Practical Activity

Practical Activity 4

Problem:

To investigate and compare sound waves of different frequencies, wavelengths and amplitudes.

What you need:

signal generator;

speakers;

cathode ray oscilloscope (CRO).



	<p>What to do:</p> <ol style="list-style-type: none"> 1. Connect the signal generator to speakers and to a CRO. 2. Adjust the signal generator and CRO until a wave appears on the screen. 3. Change the frequency and loudness at the signal generator, one at a time and note the difference in sound waves produced on the CRO. Remember that frequency relates to pitch; amplitude relates to loudness. (For you to be able to do this experiment, you should know how to use the CRO and the signal generator.) <p>Observations and results:</p> <ol style="list-style-type: none"> 1. What happens to the wavelength when the frequency is increased? 2. What happens to the amplitude when the loudness is decreased?
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Now its time to work through the self-mark activity.

Self-Mark Activity



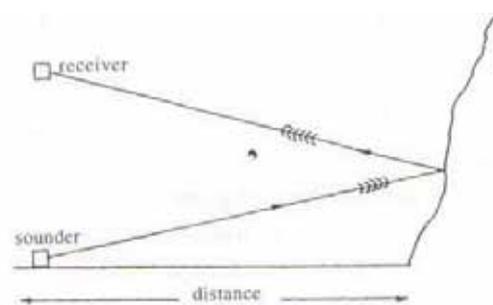
Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. An echo sounder produced a pulse of sound, the echo of which was received after 3 seconds.

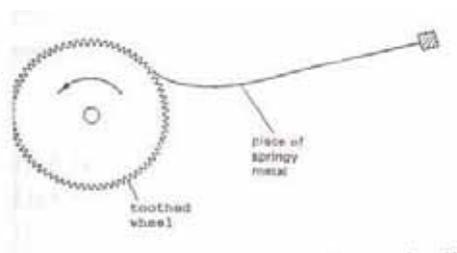


If the speed of sound in air is 330 m/s, what is the distance from the

sounder to the cliff?

- A 495 m;
- B 990 m;
- C 110 m;
- D 220 m.

2. The diagram shows a method of producing sound.



When the toothed wheel is rotates as shown by the arrow, the piece of springy metal vibrates and produces a musical sound.

Lets say you increase the rotation of the wheel. What changes will take place in terms of:

- (a) frequency;
- (b) pitch?

3(a) Peter investigated the speed of sound travelling 2 metres through air and through metal. The table below shows the results obtained.

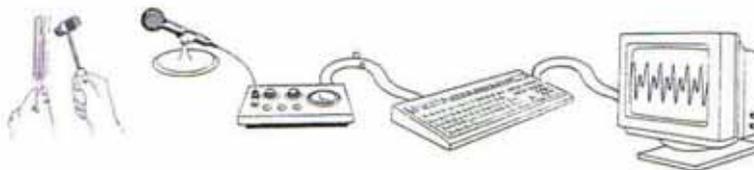
[Source: JSC 2005]

Medium of sound	Time (seconds)	Speed of sound (m/s)
Air	0.006	333
Metal	0.0004	v

- (i) Use the formula: speed = distance \div time, to calculate the value of v.
 - (ii) State how the value of v compares to the speed of sound in air.
 - (iii) Explain why sound travels at different speeds in air and in metal.
- (b) The picture shows a set-up to generate and illustrate sound



waves.



The following images of sound waves are obtained when two different tuning forks, F1 and F2, are hit in front of the microphone:

Tuning Fork	Image of sound wave, first hit	Image of sound wave, second hit
F1		
F2		

- (i) How do the frequencies of sound made by F1 and F2 compare?
- (ii) Choose which tuning fork produces a sound of higher pitch. Give a reason.
- (iii) State what property of the sound wave changed when F1 was hit for the second time.

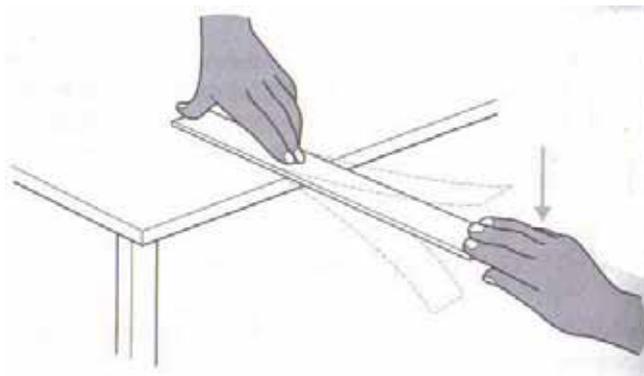
4. The table gives the approximate audible frequency ranges in air as well as the approximate ranges of sounds produced by different species.

species	audible range in air (Hz)	range of sounds made (Hz)
bat		10,000 – 120,000
human	X - Y	85 – 1,100

- (a) State the range of audible frequencies **X - Y** for the human ear.
- (b) Why can humans not hear the noise made by bats?

(c) Explain how a bat uses the sound it makes to catch its prey or find its way during flying.

5. An experiment was done to find out what happens when you change the frequency and amplitude of vibration of a ruler. Study the diagram and answer the questions that follow. [Source: JSC 1995]



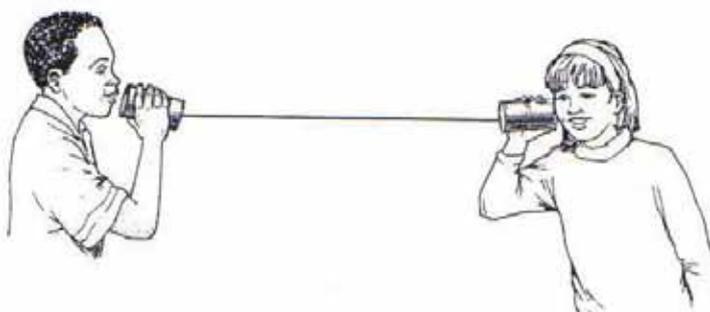
- (a) How can the position of the ruler be changed in order to vibrate faster?
- (b) Describe how the sound produced changes when the ruler is vibrating faster.
- (c) During this experiment, when was the sound produced, the loudest?
- (d) What conclusion (s) can be drawn from the experiment, regarding the loudness and pitch of a sound?

6(a) The table below shows the speed at which sound travels through different materials. [Source: JSC 2004]

<i>Materials</i>	<i>State of materials</i>	<i>Speed of sound (m/s)</i>
granite	solid	5,400
nitrogen	gas	354
oil	liquid	1,460
oxygen	gas	332
steel	solid	5,980
water	liquid	1,510



- (i) Arrange the materials through which sound travels from the fastest to the slowest.
- (ii) Use the information in the table to suggest the speed of sound in a mixture of nitrogen and oxygen.
- (b) Tom and Sharon make a string telephone.
- They use two empty tin cans joined by a piece of string as shown in the diagram.



Tom and Sharon are 5 m apart. Tom talks quietly in one tin can, while Sharon holds the other tin to her ear. When they keep the string tight, the sound of Tom's voice travels along the string.

- (i) State how the sound travels along the string to Sharon.
- (ii) Describe how the sound is transferred from the tin can at Sharon's end to her ear.

Well done, if you could master all the questions. You can start studying Section 3.

Section 3: Light, the Basic Concepts

Introduction

We see things every day, from the moment we get up in the morning until we go to sleep at night. We look at everything around us using light. We rely on mirrors to make ourselves presentable every day.

In this section, we will look at light and how it works.

 <p>Basic Competence</p>	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>describe</i> the difference between luminous and illuminated objects; • <i>state</i> that light travels in straight lines and <i>explain</i> how this leads to the: formation of shadows; appearance of an image (pin-hole camera); eclipse of the sun and moon.
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 <p>Time</p>	<p>This section will take you about five hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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Luminous and illuminated objects

We are going to look at two types of objects namely, luminous and illuminated objects. Luminous objects are those that produce light of their own. Can you list some of these objects? On your list you might have the sun (or stars), a burning candle, burning light bulb and so on.

Illuminated objects, on the other hand, are those that use light from other sources. We see these objects because they reflect light from their surfaces. The section you are reading now does not produce light of its own, but reflects light. There are many objects that we see because they are illuminated such as a cup, desk, pencil and many others. The moon is another good example of an illuminated object. It does not produce light of its own. Instead, it reflects light from the sun.

How light travels

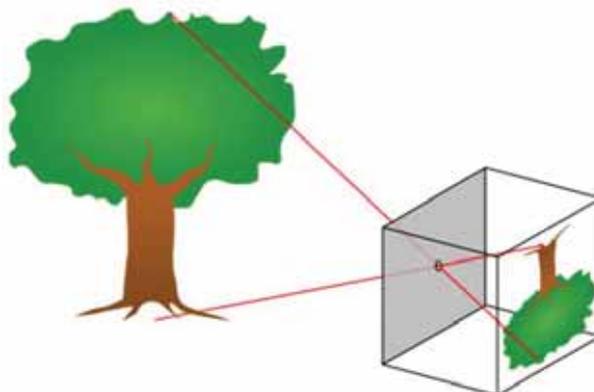
Light travels in straight lines. We will see how the fact that light travels in a straight line leads to the formation of shadows, the solar and lunar eclipse and the appearance of an image in a pin-hole camera.

How shadows are formed

Light travels in straight lines. This means that it cannot bend round objects. How are shadows formed? If light is blocked by an opaque object in its path, a shadow will be formed.

The pin-hole camera

A pinhole camera works on the principle that light travels in straight lines. Light from an object travels in straight lines through the pinhole. The image produced is inverted as shown in the diagram below.



Source: <http://en.wikipedia.org/wiki/File:Pinhole-camera.svg>

Characteristics of images formed by a pin-hole camera:

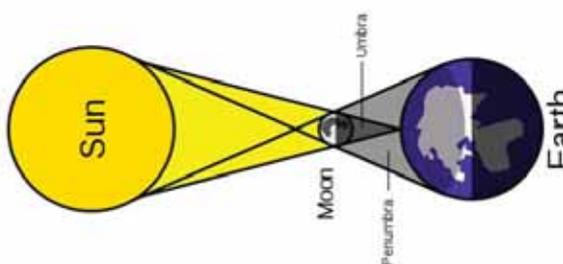
1. The image is inverted (upside down).
2. It is a real image (can be focused on a screen).
3. When the pinhole is made larger, the image becomes brighter but blurred.
4. When the object is moved closer to the pinhole camera, the image becomes larger and less distinct.

Eclipses

What is an eclipse? First of all, the term eclipse means to hide from something. Therefore, an eclipse of the moon means the moon is hidden. Eclipse of the sun means the sun is hidden. For an eclipse to happen, the sun, moon and earth must be in a straight line. Let us look at the two eclipses.

Eclipse of the sun (solar eclipse)

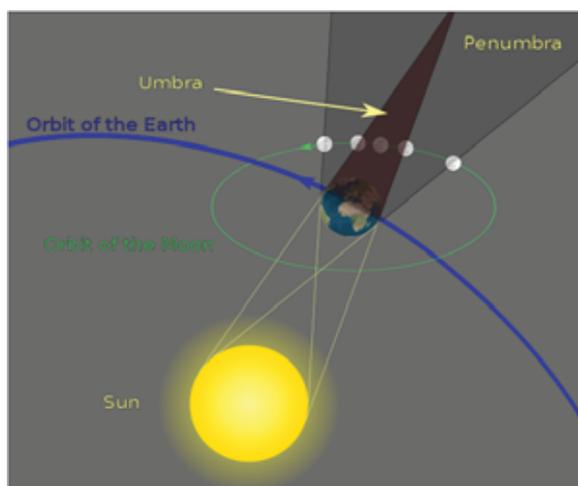
This happens when the moon is between the sun and the earth. The earth is in the shadow of the moon.



Source: http://en.wikipedia.org/wiki/File:Solar_eclipse.svg

Eclipse of the moon (lunar eclipse)

This happens when the earth is between the sun and the moon. The moon is in the shadow of the earth.



Source:

http://en.wikipedia.org/wiki/File:Geometry_of_a_Lunar_Eclipse.svg

Work through the following practical activity to reinforce your understanding of this section.



Practical Activity

Practical Activity 1

Problem:

How to make a pin-hole camera and to explain the image formed.

What you need:

a shoe box;
 cellotape;
 aluminium foil;
 tracing paper;
 pin.

What to do:

1. Cut off one end of the box and seal it with tracing paper.
2. Cut out a small part in front of the box and paste a piece of aluminium foil over the opening.
3. Make a hole in the aluminium foil with a pin.

Observations and results:

1. What happens to the size of the image



	as the object in front of the pin-hole camera is: (a) moved further away from the pin-hole. (b) moved closer to the pin-hole.
--	---

Now it's time to work through the self-mark activity and answer the questions.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- Which of the objects is illuminated?
A burning candle;
B moon;
C star;
D sun.
- Which statement correctly describes a solar eclipse?
A the earth is between the moon and the sun;
B the moon is between the earth and the sun;
C the moon is in the earth's shadow;
D the sun is in the earth's shadow.
- Which characteristic of light leads to the formation of shadows?
A travels as divergent rays;
B travels at very high speed;
C travels faster than sound;
D travels in straight lines.
- Which statement correctly describes the image produced by a pin-hole

camera?

- A erect;
- B inverted;
- C laterally inverted;
- D virtual.

Well done. Now you can move on to Section 4.

Section 4: Transmission and Absorption

Introduction

Light rays makes it possible for us to see objects. In optics we call a narrow beam of light a ray. When we talk about ray on its own we also refer to light ray. We get different types of rays like incident ray, reflected ray or refracted ray. An incident ray is a ray of light that strikes a surface. A reflected ray represents light reflected by a surface. A refracted ray is a bended ray after it hits another material or medium. In this section you will learn more about light rays.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>explain</i> the consequences of light travelling in straight lines in terms of divergent, convergent and parallel rays or beams of light; • <i>explain</i> the use of apparatus such as ray-box, mirror, glass window, Perspex strips, protractor and a rectangular glass block; • <i>investigate</i> what happens when light falls on different objects that are translucent, transparent and opaque.
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 Time	<p>This section will take you about four hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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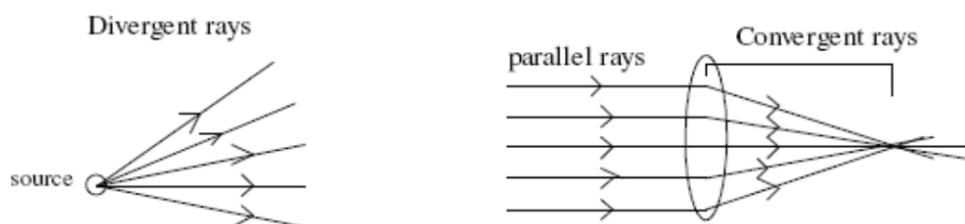


Since light travels in straight lines, rays can converge, diverge or move in parallel form.

Divergent rays move away from each other. Rays from a torch are divergent.

Convergent rays meet at one point. This happens, for example, when light rays pass through a converging lens.

Light rays can be parallel. In this case, they keep the same distance apart. Study the diagrams below and try to understand the differences.



Absorption, reflection and transmission of light

We have already seen that light travels in straight lines. When light hits an object, there are three possibilities regarding what could happen. The light can be:

- absorbed;
- transmitted;
- reflected.

Materials that allow light to pass through are said to be transparent. Clear glass is a good example of a transparent material.

Those materials that only allow part of light to pass through are said to be translucent, such as a paper smeared with oil or frosted glass. Frosted glass is the one usually found on bathroom windows.

Opaque substances are those that do not allow light to pass through at all. They absorb or reflect it. A mirror, brick wall, wood, or a person are examples of opaque objects. While a mirror reflects light, a brick wall, wood or a person absorbs it.

To understand this section work through Practical Activity 1.



Practical Activity 1

Problem:

Practical Activity	<p>To investigate what happens when light falls on an object.</p> <p>What you need: optics (light) kit or ray box; mirror; glass window (in the kit); perspex strips; rectangular block.</p> <p>What to do: Let the light from the ray box hit different objects. Note whether there is absorption, transmission or reflection.</p> <p>Observations and results: 1. Complete the table below by recording your observations.</p> <table border="1"> <thead> <tr> <th>Object</th> <th>What happened to light? (absorbed, reflected or transmitted)</th> </tr> </thead> <tbody> <tr> <td>Mirror</td> <td></td> </tr> <tr> <td>Glass pane</td> <td></td> </tr> <tr> <td>Perspex strips</td> <td></td> </tr> <tr> <td>Protractor</td> <td></td> </tr> <tr> <td>Rectangular glass block</td> <td></td> </tr> </tbody> </table>	Object	What happened to light? (absorbed, reflected or transmitted)	Mirror		Glass pane		Perspex strips		Protractor		Rectangular glass block	
Object	What happened to light? (absorbed, reflected or transmitted)												
Mirror													
Glass pane													
Perspex strips													
Protractor													
Rectangular glass block													

Try to answer the questions in the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

Self-Mark Activity

This self-mark activity will not be submitted but marked by you.
Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

- Describe a simple experiment to show that light travels in straight lines, you may use a diagram.
- Describe each of the following and give one example:



- (a) transparent material;
- (b) translucent material;
- (c) opaque material.

3. Outline how you would obtain the following:

- (a) convergent rays;
- (b) divergent rays.

Well done, now you can start studying Section 5.

Section 5: Reflection by Mirrors

Introduction

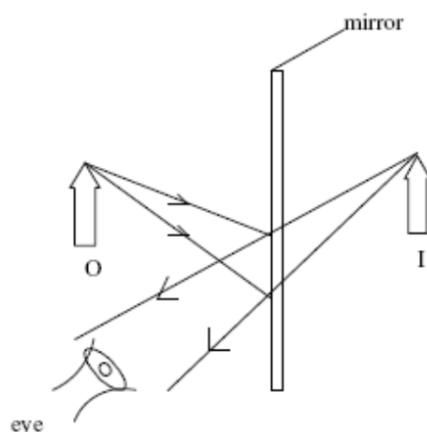
In this section, we will talk about reflection of light by mirrors. What is reflection? Reflection is the bouncing off of light from shiny or polished surfaces like mirrors.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> • <i>investigate</i> reflection by plane mirrors and their applications; • <i>describe</i> and <i>sketch</i> how a plane mirror forms an image; • <i>list</i> the characteristics of an optical image formed by a plane mirror; • <i>explain</i> and <i>measure</i> the angles of incidence and reflection; • <i>distinguish</i> between regular and diffuse reflection; • <i>describe</i> advantages and disadvantages of reflection; • <i>explain</i> everyday applications of reflection such as the use of different kinds of mirrors and the reflecting surfaces behind lights.
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 Time	<p>This section will take you about nine hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.</p>
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How a plane mirror forms an image

An image is formed by a mirror when light from an object hits the mirror and is reflected. Look at the diagram below. From the diagram you should be able to list the characteristics of the image produced by a plane mirror.



Characteristics of an optical image formed by a plane mirror

1. The image is laterally inverted. In other words, the sides are switched. You cannot tell from the diagram above, so let us use a practical example. When you look at yourself in the mirror and close your right eye, it may seem as if you are closing your left eye. The left and the right are switched. This situation is called **lateral inversion**.

2. The object and the image are equidistant from the mirror.

When you stand in front of a mirror, your image appears behind the mirror. When you kiss the mirror, the image behind also kisses the mirror. What happens when you move away from the mirror? The image also moves away. This shows that the distance of the image from the mirror is the same as your distance from the mirror. In other words, you and the image are equidistance from the mirror.

3. The image and the object are of the same size.

Look at your image again. Is it the same size as you?

4. The image is upright (erect).

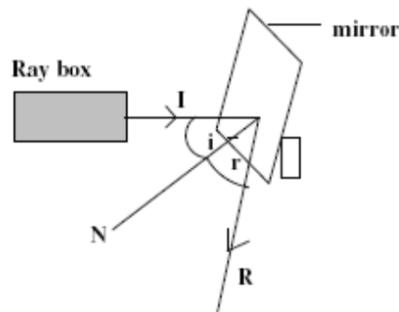
5. The image is virtual.

Can you produce your image on a screen (or wall) like in a cinema? No, you cannot. This is because the image is not real.



The law of reflection

The law of reflection states that the angle of incidence is equal to the angle of reflection. This law makes calculating the missing angles easier when one angle is given.

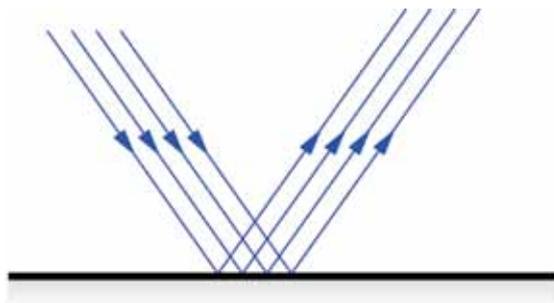


I - incident ray
R- reflected ray
i - angle of incidence
r- angle of reflection
N - normal

Types of reflection

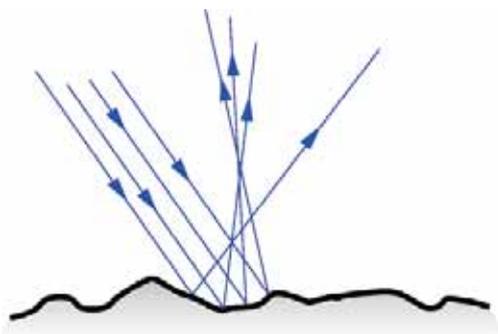
There are two types of reflection namely regular and diffuse reflection. Regular reflection takes place when light rays hit a smooth surface like a plane mirror. When this happens the light rays are reflected uniformly in the same direction. Diffuse reflection takes place on rough surfaces like wood and light rays are reflected in different directions.

REGULAR REFLECTION:



Source: <http://commons.wikimedia.org/wiki/File:Reflexao.png>

DIFFUSE REFLECTION:



Source: <http://commons.wikimedia.org/wiki/File:Difracao.png>

Advantages of reflection

1. We are able to look at ourselves in mirrors.
2. Dentists and doctors use reflection to see some hidden parts of our bodies.
3. Motorists and cyclists use rear view mirrors to see what is behind them.
4. Kaleidoscopes use mirrors to produce many colourful images.
5. Periscopes use reflection to see things above, like in submarines.

Disadvantages of reflection

1. At sunrise and sunset, the reflection of light from a wet road can be dangerous to motorists.
2. Fog and mist are caused by light being reflected in all directions by little water droplets.
3. Light inside a camera can be reflected off the sides and spoil the picture, which is why the inside of a camera is painted black.

Applications of reflection

Although plane mirrors are commonly used, their usefulness is limited. Curved mirrors are more useful for certain purposes. There are two types of curved mirrors: concave and convex. Let me use a spoon to demonstrate these two types of mirrors. A concave mirror is like the inside of a spoon while a convex one is like the outside. Let us look at some applications of these mirrors.

1. Reflectors

Concave mirrors are used as reflectors in car headlamps and torches because they project a parallel reflected beam.

2. Make-up, shaving and dental mirrors

A concave mirror forms a **larger**, erect image of an object inside its focus.

3. Driving mirrors



A convex mirror gives a wider field of view than a plane mirror of the same size. However, it gives a driver a false idea of the distance because the image is smaller.

Work through the following practical activities to reinforce your understanding of this section.



Practical Activity

Practical Activity 1

Problem:

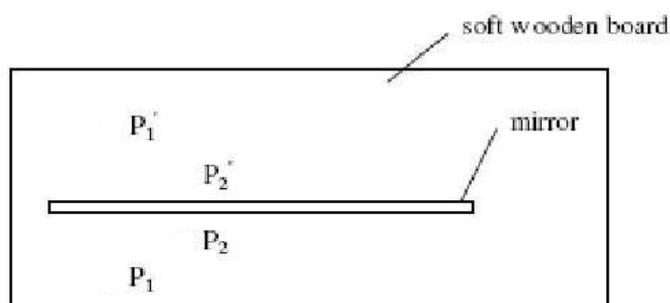
To investigate reflection in plane mirrors

What you need:

4 pins;
a plane mirror.

What to do:

1. Place a mirror vertically on soft wood.
2. Fix pins P_1 and P_2 .
3. Look for the pins behind the mirror.
4. Fix pins P_1' and P_2' where the images of P_1 and P_2 appear to be located.
5. Draw straight lines through P_1 and P_2 , and P_1' and P_2' to meet at the mirror line.
6. Extend the line through P_1 and P_2 beyond the mirror line to the eye.
7. Place a white screen behind the mirror to see whether the image appears on it.



Observations and results:

1. Determine the following from the experiment:
 - (a) the position of the image;
 - (b) the size of the image compared to the

object;
(c) the nature of the image.
 Explain your answer.



Practical Activity

Practical Activity 2

Problem:

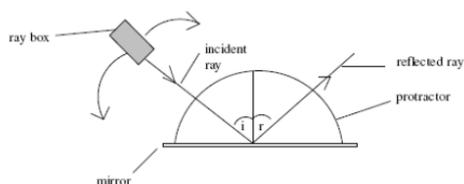
To measure the angles of incidence and reflection.

What you need:

a protractor;
 white paper (one sheet);
 a ray box;
 a mirror.

What to do:

1. Place the protractor and mirror on white paper.
2. Direct the ray onto the mirror as shown in the diagram below.
3. Measure the angle of incidence, i and reflection, r .
4. Move the ray box in the direction of the arrows as shown and repeat step 3.



Observations and results:

1. Describe how the angle of incidence compares with the angle of reflection for different values of the angle of incidence.



Practical Activity 3

Problem:

**Practical Activity**

To build a kaleidoscope.

What you need:

3 plane mirrors;
rubber bands;
cardboard;
tracing or greaseproof paper;
small coloured objects;
scissors.

What to do:

Hold the mirrors with the reflective sides pointing inwards.

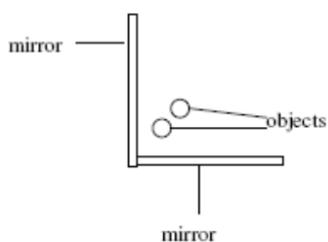
Wrap the mirrors in a cardboard and fix with a rubber band.

Seal one end with tracing or greaseproof paper.

Put some pieces of coloured objects inside the tube and view.

Making a simple kaleidoscope:

1. Place two mirrors at 90° .
2. Put a coloured object or drawing between the mirrors and check how many images are produced.
3. Slowly reduce the angle between the mirrors and check how many images are produced.

**Questions:**

1. Explain how a kaleidoscope works.
2. State the effect of reducing the angle between the mirrors on the number of images produced.
3. Suggest one use of a kaleidoscope.

**Practical Activity****Practical Activity 4****Problem:**

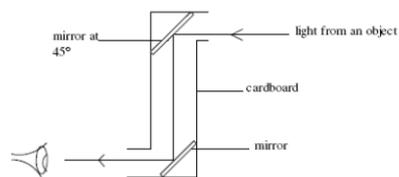
To build a periscope.

What you need:

two plane mirrors;
cardboard or long box;
cellotape;
scissors.

What to do:

1. Build a periscope as shown in the diagram below.

**Questions:**

1. Explain how a periscope works.
2. Suggest two uses of a periscope.

Now answer the questions in the following self-mark activity.



Self-Mark Activity



Self-Mark Activity

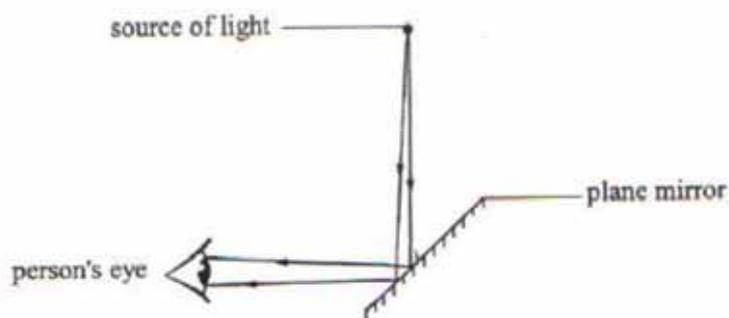
Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. The arrows in the diagram show the path of light from a source.

[Source: JSC 2000]



The light from the source reaches the person's eye by:

- A absorption;
- B dispersion;
- C reflection;
- D refraction.

2. A paper clip is placed in front of a mirror.

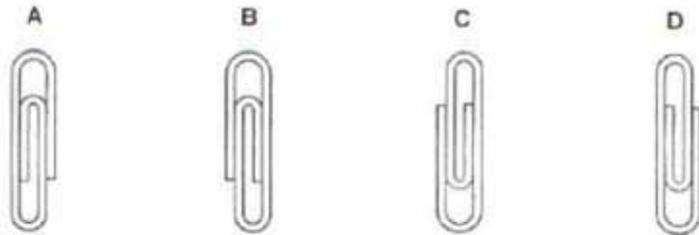


paper-clip

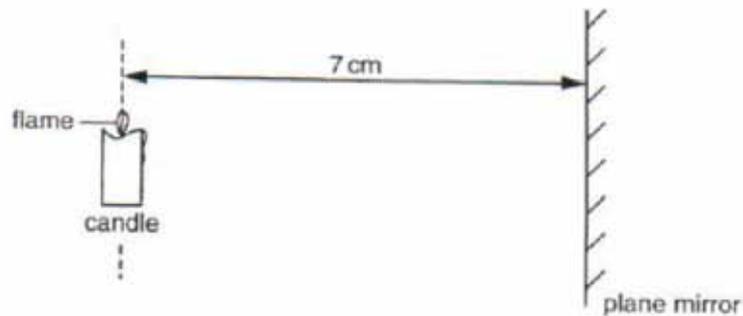


plane mirror

Which diagram shows the image formed behind the mirror?



3. The diagram shows a candle 7 cm in front of a plane mirror.



(a) By accurately drawing the paths of **two** rays from the top of the flame, locate the image of the flame in the mirror.

(b)(i) Write down the distance between the candle and its image.

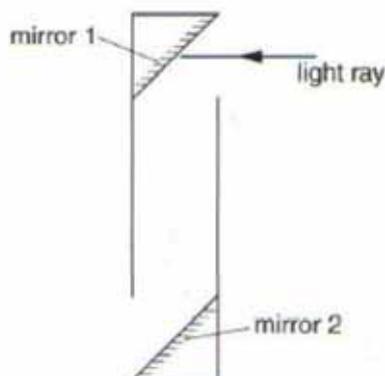
(ii) The candle is moved 2 cm towards the mirror.

Write down the distance between the new position of the candle and its image.

(iii) Calculate the change in distance between the candle and its image when the candle has been moved 2 cm.

(c) List three properties of an image formed by a plane mirror.

4. The diagram shows the design of a periscope.



- Complete the path of the light ray after it strikes mirror 1.
- Draw in the normal to the surface of mirror 1. Mark the angle of incidence and label it i .
- State the relationship between the angle of incidence and the angle of reflection.
- Suggest a possible use for the periscope.

- Distinguish between regular and diffuse reflection.
 - Describe two disadvantages of reflection.
 - Identify two uses of curved mirrors. In your answer, state the name of the curved mirror.

Its now time start studying Section 6.

Section 6: Refraction of Light

Introduction

When light travels through objects, it does not always travel in a straight line. What causes light rays to sometimes bend? As you work through this section and you will get the answers to these type of questions.

 Basic Competence	<p>On successful completion of this section, you will be able to:</p> <ul style="list-style-type: none"> describe the refraction of light through a rectangular block, liquid and triangular prism, and the applications of refraction in everyday life such as lenses used in spectacles, magnifying glasses and other optical instruments;
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	<ul style="list-style-type: none"> • <i>describe</i> the passage of light through a converging lens in terms of refraction and the characteristics of simple images, distinguishing between real and virtual images; • <i>describe</i> how to produce real images using a convex lens; • <i>describe</i> and <i>measure</i> the focal length of a converging lens and explain why the lens is able to focus light; • <i>explain</i> the functioning of a camera within the context of the human eye; • <i>explain</i> how the eye focuses light on its retina and compare the functioning of the human eye with that of a camera; • <i>describe</i> near and far sightedness taking into consideration the use of lenses to correct these defects; • <i>investigate</i> examples of the refraction of light in nature such as a rainbow, size and position of objects under water and mirages; • <i>describe</i> the passage of light through a prism and identify the colours of the spectrum produced from white light; • <i>describe</i> how rainbows can be formed by the internal reflection of light in water; • <i>explain</i> how mirages are formed within the context of optical illusions and the phenomena of reflection and refraction.
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Time

This section will take you about 18 hours to complete. Make sure you read and understand everything in order to achieve all of the basic competencies.

Refraction

Refraction is the bending of light when it passes from one medium to another. This can be from air to glass or from air to water or vice versa. What causes the light to bend? The bending is caused by the change in speed as it travels from one medium to another. Let us look at the refraction of light through a rectangular block and a triangular prism.

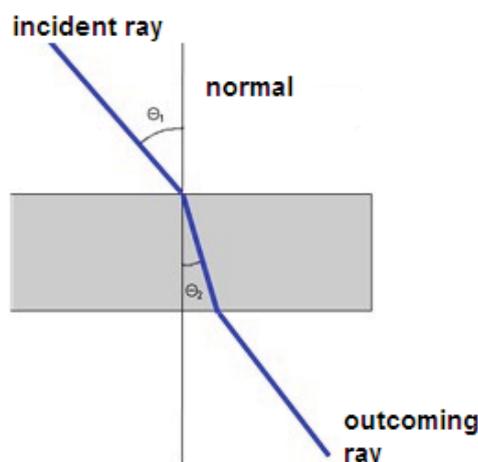
Rule: When light travels from a more dense to less dense medium, it bends away from the normal, e.g., from glass to air or water to air. However, when light travels the other way around, it bends closer to the



normal e.g., from air to glass or from air to water. A normal is a line that is perpendicular to a surface through which a light ray is passing.

1. Rectangular glass block

When light from a ray box is shown through the rectangular glass block, it passes through, but bends at the air-glass boundary as shown in the diagram below.



When a light ray enters the glass block at a right angle, it goes through the glass without bending.

When it enters the block at an angle other than a right angle, it changes direction. In other words, it bends.

The light ray that enters the block is called the **incident ray**.

The light ray that bends within the glass is called the **refracted ray**.

The light ray that leaves the glass block is called the **emergent ray**.

If you take a protractor and measure the angle between the normal and the incident ray, you measure the angle of incidence.

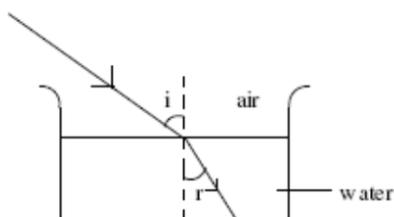
When you take a protractor and measure the angle between the normal and the refracted ray, you measure the **angle of refraction**.

If you use a protractor and measure the angle between the normal and the emergent ray, you measure the **angle of emergence**.

The emergence angle is equal to the angle of incidence.

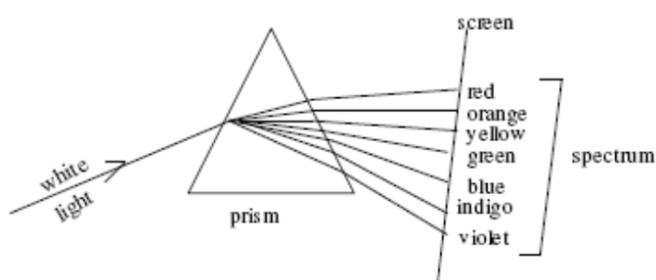
2. Refraction in a liquid

When light travels from air into water, it bends towards the normal. Since the path of light is reversible, you should be able to draw the path of a ray of light from the water to air.



3. Triangular glass prism

When light passes through a glass prism, it undergoes refraction. This causes the light to split into a band of colours called the spectrum. The splitting of white light into a spectrum is called dispersion. The spectrum consists of the colours of the rainbow as shown in the following diagram.



Applications of refraction

Refraction has many important applications in our everyday lives. Lenses are instruments that work on the principle of refraction.

A diverging lens spreads light rays after they pass through the lens.

A converging lens causes light rays to meet at one point after they pass through lens.

These two types of lenses can be used in spectacles to correct eye defects like near and far sightedness. Converging lenses are used in cameras and magnifying glasses. The human eye also uses a converging lens.

The passage of light through a converging lens

When light passes through a converging lens, it undergoes refraction. This means that when rays from an object pass through the lens, they will meet at one point. This point where the rays meet is called the focus — and is where the image will be formed.



What is an image? This is the optical appearance of an object as produced by the lens. The converging lens is capable of producing virtual and real images. When an object is located beyond the focal length of the lens, a real image is produced.

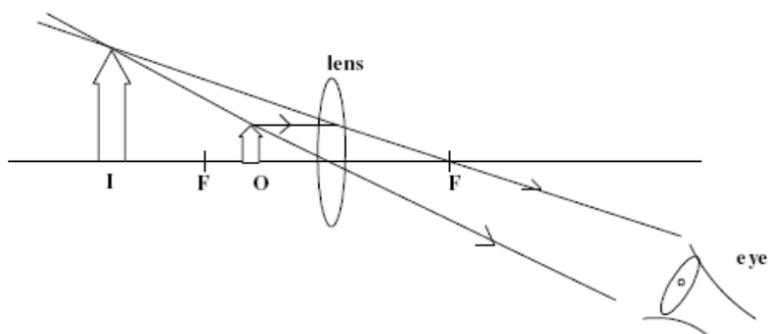
A virtual image is produced when the object is located between the lens and F (see the following diagrams). In diagram 1, a virtual image is produced. The other diagrams (i.e. diagram 2, 3 and 4) produced real images.

What is the difference between a real image and a virtual image? Try to use the following three diagrams to assist you in understanding this difference. Read the notes below the diagrams.

A real image is an image that can be produced on a screen. This would be the same as watching a movie in a cinema.

A virtual image on the other hand cannot be produced on a screen. This means that although you can see it, it cannot appear on a screen.

Diagram 1:

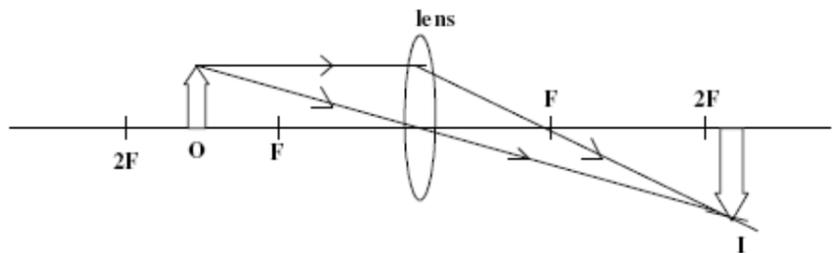


Characteristics of the image:

- it is virtual (not real);
- it is larger than the object (magnified);
- it is upright (erect);
- it is on the same side of the lens as the object.

This is how a magnifying glass produces a virtual image.

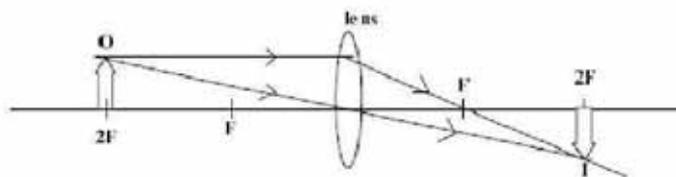
Diagram 2:



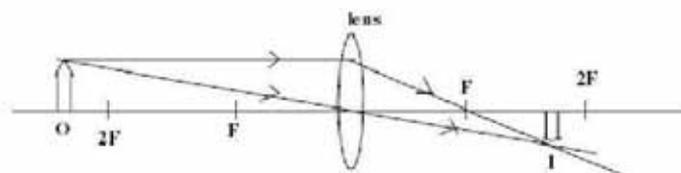
Characteristics of the image:

- it is larger than the object;
- it is inverted (upside-down);
- it is real.

Diagram 3 and 4:



Characteristics of the image:
 It is the same size as the object.
 It is inverted.
 It is real.



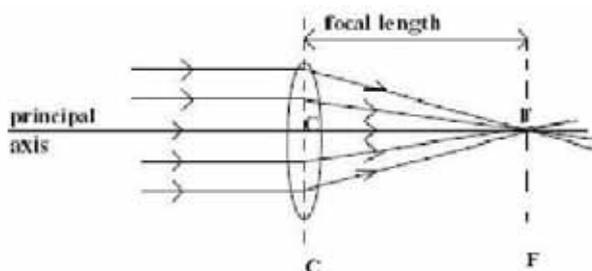
Characteristics of the image:
 It is inverted.
 It is smaller than the object.

It is real.



The focal length of a converging lens

What is the focal length of a converging lens? This is the distance between the centre of the lens, **C** and the focal point, **F** (see following diagram). The lens is able to focus light because it is able to refract light as shown in the diagram below.

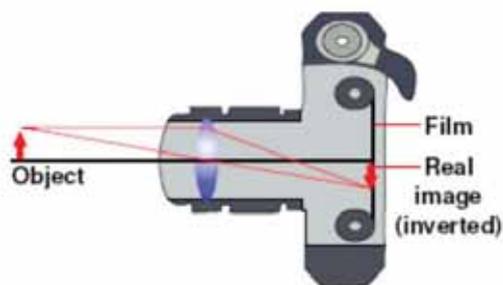


The human eye and a camera

A camera and the human eye have a lot in common. This might sound strange since a camera is made by man while the human eye is made by God. The table below shows you how different parts of a camera are similar, or perform functions similar to those performed by the human eye.

Human eye	Camera	Function
converging lens	converging lens	bends and focuses light
retina	film	where an image is formed
iris	shutter or diaphragm	controls the amount of light

Picture of a camera



How does the human eye function?

When the iris opens, light from an object enters and passes through a converging lens. The converging lens focuses the light on the retina, which acts as a screen where an image is produced. In the eye, the lens does not move back and forth, but simply becomes thinner or thicker. The image produced is real, inverted and smaller than the object.

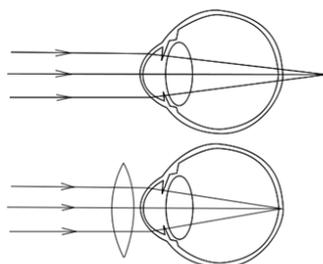
How does a camera function?

When the shutter is opened, light from an object enters and passes through a converging lens. The converging lens focuses the light on the photographic film where an image is produced. In a camera, the lens has a fixed shape and size. It is moved back and forth in order to focus. The image produced is real, inverted and smaller than the object.

Eye defects and how to correct them

Far (long) sightedness

A person who is far-sighted cannot focus on objects that are fairly close to the eye. This is because the lens cannot adjust to become thicker in the middle. This causes the image to be formed beyond the retina. This defect can be corrected by wearing a converging lens in spectacles as shown in the diagram below.

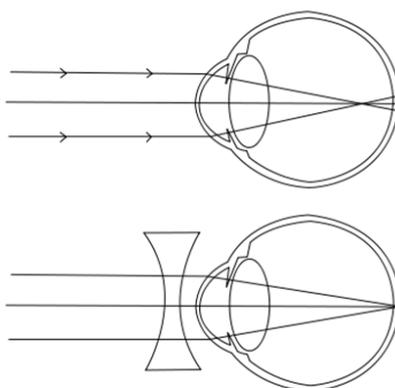


Source: <http://en.wikipedia.org/wiki/File:Hypermetropia.svg>



Near (short) sightedness

A person who is near-sighted cannot see distant objects clearly. This is because the lens cannot adjust to become thinner in the middle. This causes the image to be formed in front of the retina. This defect can be corrected by wearing a diverging lens in spectacles as shown in the following diagram.



Source: <http://en.wikipedia.org/wiki/File:Myopia.svg>

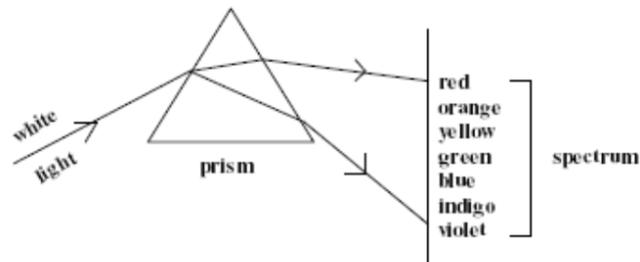
Refraction of light in nature

1. Formation of rainbows

Do you know what a rainbow is? I am sure you do. When there are a few showers with a bit of sunshine, a band of colours can be seen in the sky. If you spray water from a hosepipe at a certain angle to the sun, a band of colours can be seen. In a school laboratory, glass prisms are used to produce a band of colours by viewing sunlight through them. This band of colours is called a rainbow. Now let us see how a rainbow can be produced.

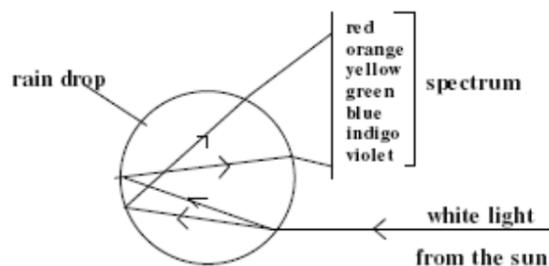
(a) Glass prism

When light passes through a glass prism, it undergoes refraction. This causes the light to split into a band of colours called the spectrum. The splitting of white light into a spectrum is called dispersion.



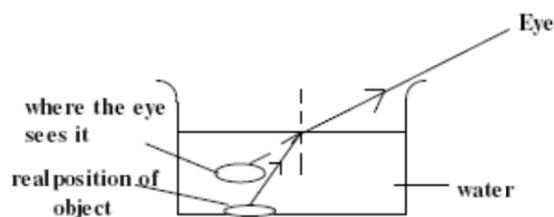
(b) Internal reflection

When light is reflected internally in a raindrop as shown in the diagram below, dispersion takes place. This also involves refraction as you may notice from the diagram. Therefore, a rainbow is formed by refraction and internal reflection of light.



2. The position and size of objects under water

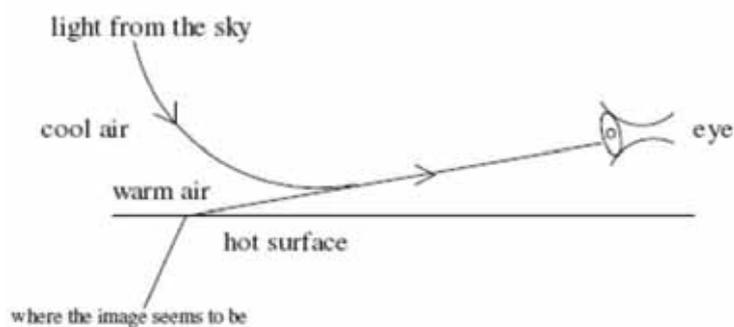
Refraction causes an object to appear above where it is actually positioned. This fact is responsible for swimming pools appearing shallower than they really are. Light from the bottom of a pool bends as it enters the air as shown in the diagram below. This makes the floor of the pool to appear raised. The object in the diagram appears to be raised and larger.



3. Mirages



What is a mirage? A mirage is an optical illusion. On a hot day, there may seem to be a film of water on the road. This is due to refraction of light. The air near the ground becomes hotter and less dense than the air above. This difference in densities causes light rays from the sun to bend. Look at the diagram below that shows how mirages are formed.



An optical illusion that uses reflection and refraction

An optical illusion is something the eye sees but in reality it is not there. Optical illusions can be caused by reflection or refraction. An example of an optical illusion caused by reflection is called Pepper's ghost illusion. In this illusion, a candle appears to be burning in a beaker of water. Another example involves refraction in which a coin appears when water is poured into a beaker. Check Practical Activity 5, Part 2.

Work through the following practical activities to reinforce your understanding of this section.



Practical Activity

Practical Activity 1

Problem:

How to measure the focal length of a converging lens.

What you need:

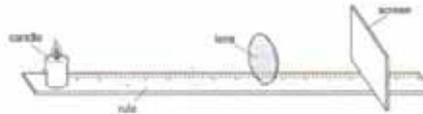
a converging lens;
a metre rule;
a candle;
a screen.

What to do:

1. Arrange the apparatus as shown in the diagram below.
2. Move the lens or screen or candle until a sharp

image appears on the screen.

3. Measure the distance between the screen and the lens. This is the focal length.



Practical Activity

Practical Activity 2

Problem:

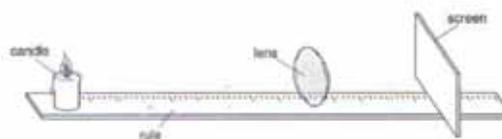
How to produce real images using a convex lens.

What you need:

a convex lens;
a metre rule;
a candle;
a screen.

What to do

1. Arrange the apparatus as shown in the following diagram.
2. Move the candle at various positions. Observe the characteristics of the image that appears on the screen.



Observations and results:

1. State the characteristics of the image produced.



Practical Activity

Practical Activity 3

Problem:

To investigate the refraction of light through a rectangular glass block.



	<p>What you need: a rectangular glass; water; a plastic box; a ray box.</p> <p>What to do:</p> <p>Part 1: Refraction using a rectangular glass block</p> <ol style="list-style-type: none"> 1. Arrange the apparatus with the ray shining onto the glass block. 2. Draw the outline of the glass block. 3. Sketch the path of the ray through the glass block. <p>Part 2: Refraction using water in a plastic box</p> <ol style="list-style-type: none"> 1. Replace the glass block used in Part 1 with a plastic box of water.
--	---



Practical Activity

Practical Activity 4

Problem:

How to produce a spectrum.

What you need:

a ray box or a beam of sunlight;
a triangular glass prism;
a water prism (3 small sheets of glass, adhesive tape, plasticine or candlewax, vaseline).

To construct the water prism:

Stick the three pieces of glass together with tape. Use Vaseline along the joints to make them watertight. Push the prism into a base of plasticine or candle wax so that it is watertight. Fill the prism with water.

What to do:

1. Shine light from the ray box or expose the prisms to sunlight.

Observations and results:

1. Sketch the colours of the spectrum in their order.



Practical Activity

Practical Activity 5

Problem:

To investigate how rainbows are formed by internal reflection of light in water.

What you need:

a hose pipe;
sun light;
water tap.

What to do:

1. Connect the hose pipe to the tap.
2. Slightly close the mouth of the pipe so that there is a spray of water.
3. Adjust your position until a rainbow appears in the spray. It works well when you face away from the sun and the spray is in front of you.

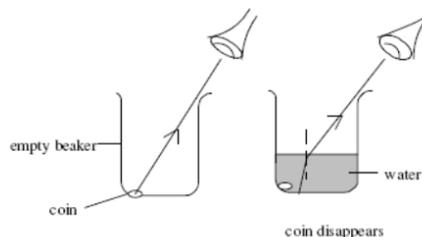
Optical illusion

Appearance of a coin

1. Place a coin in an empty beaker (you should see it when you look into the beaker).
2. While in the same position, let someone fill the beaker with water.

Disappearance of the coin

How can you make the coin to disappear? Try to reverse the process that makes the coin appear. If the coin is directly under the ray in the beaker on the left, would it be possible to see it when filled with water? No, because the ray would bend towards the middle of the beaker. This is how the coin would disappear.





You should now be able to answer the questions in the following self-mark activity.

Self-Mark Activity



Self-Mark Activity

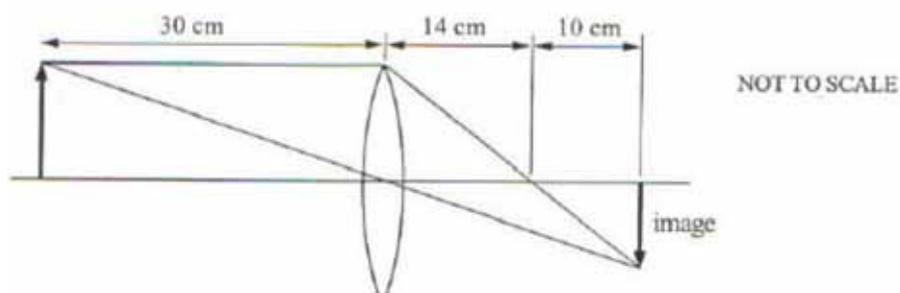
Self-Mark Activity

This self-mark activity will not be submitted but marked by you. Compare your answers with the feedback provided at the end of the unit.

Answer the following questions:

1. The diagram shows how a converging lens forms an image.

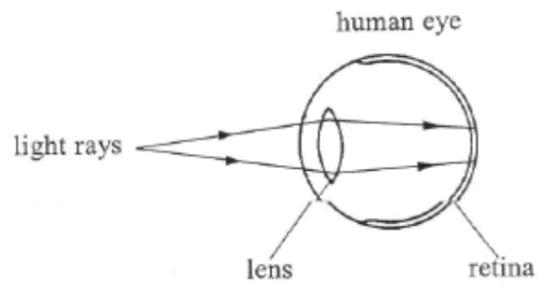
[Source: JSC 2003]



What is the focal length of the lens?

- A 10 cm;
- B 14 cm;
- C 24 cm;
- D 30 cm.

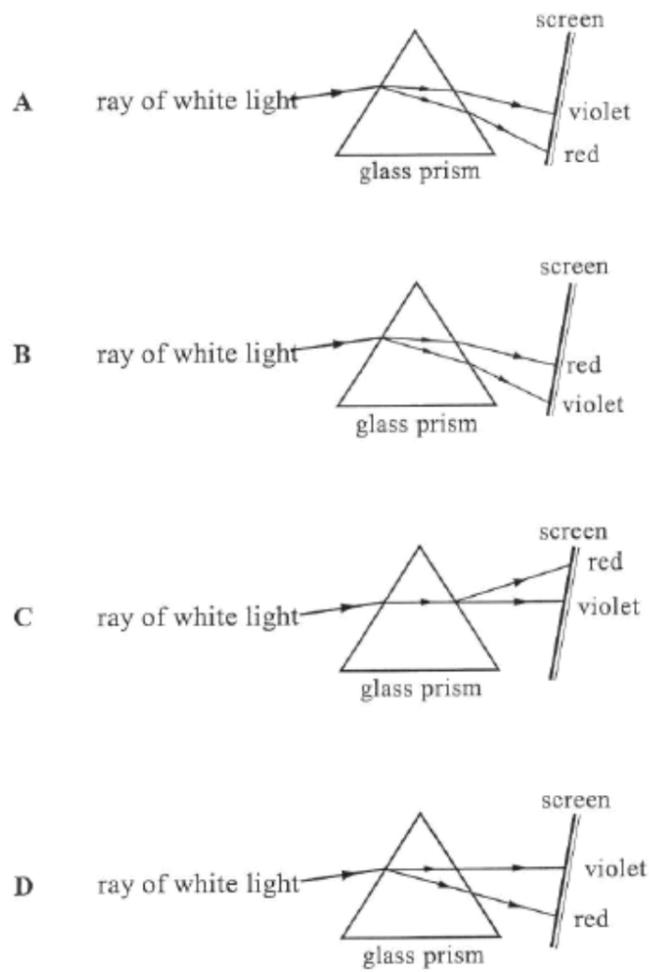
2. The diagram illustrates a human eye defect, which causes light rays from nearby objects to focus behind the retina. [Source: JSC 2004]



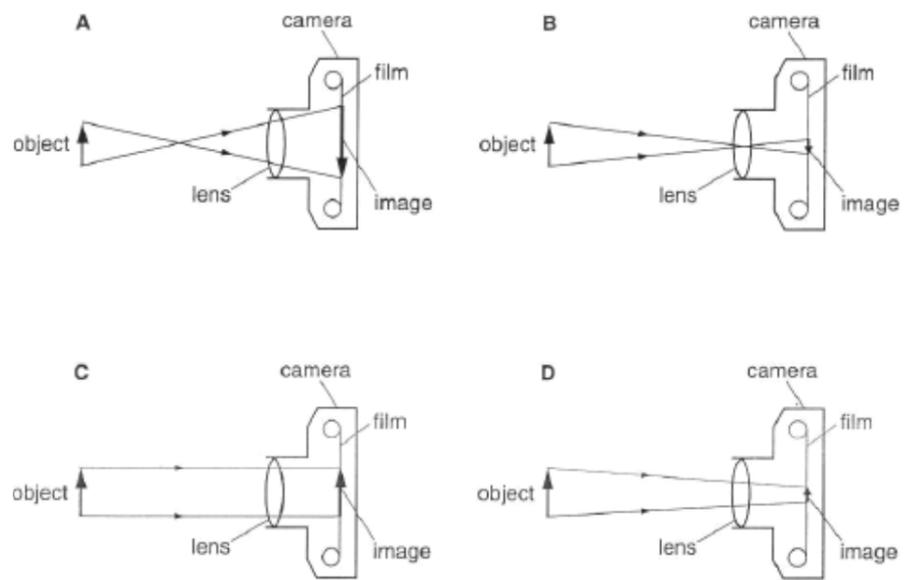
Which type of spectacle lenses can be used to correct this defect?



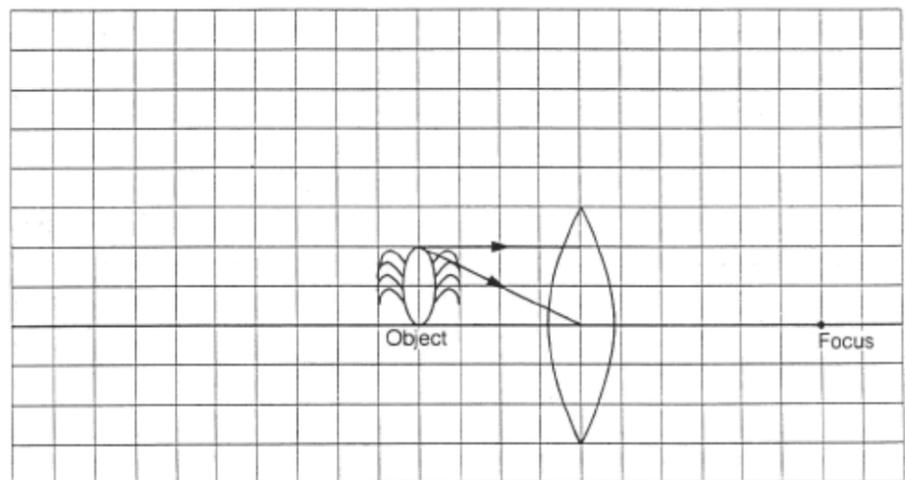
3. Which of the following diagrams correctly shows the refraction and dispersion produced by a triangular glass prism? [Source: JSC 2004]



4. Which of the following diagrams correctly shows rays passing through a camera lens?



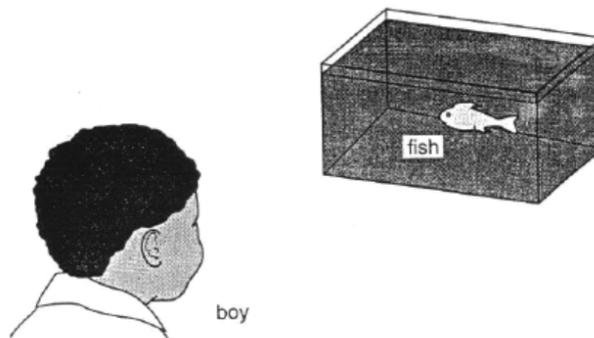
- 5(a)** Draw a labelled diagram to show the action of a thin converging lens on a beam of parallel light rays.
- (b)** The following diagram shows a single lens being used as a magnifying glass.



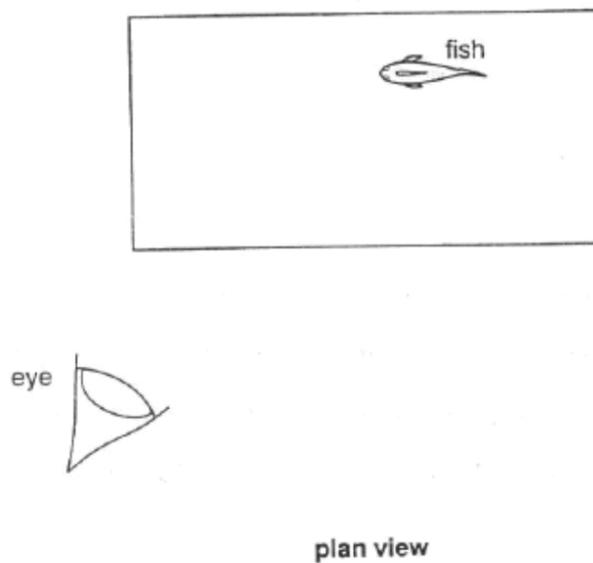


- (i) Complete the ray diagram to locate the image of the object.
Draw in the image.
- (ii) List three properties of the image.

6. A boy looks into a fish tank. He sees the fish displaced from its true position.



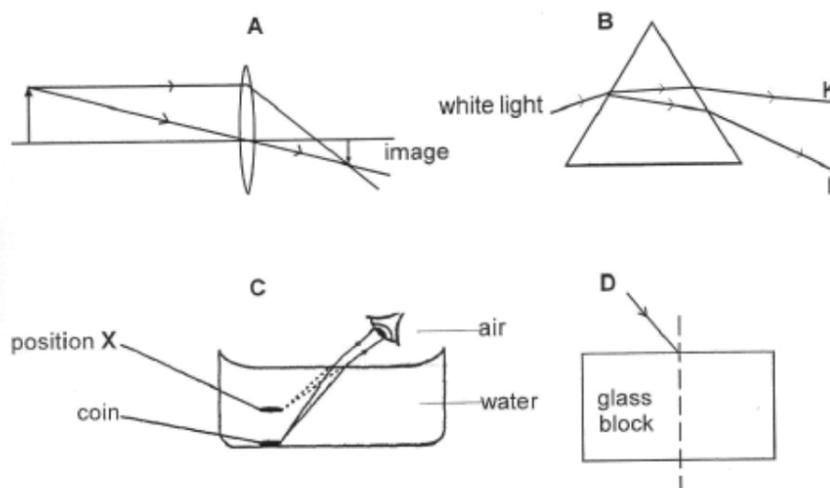
- (a) On the plan view, draw **one** ray of light entering the boy's eye from the fish.



- (b) Add a second ray to the diagram to show where the boy would see the fish.

7. Light is refracted when travelling through different media.

[Source: JSC 2005]



Diagrams **A**, **B**, **C** and **D** show different cases of refraction.

- Describe the properties of the image formed in **A**.
- Identify the colours of light at **K** and **L** in diagram **B**.
- Explain the difference between the image at position **X** and the coin in diagram **C**.
- Copy diagram **D** and complete the path of the ray of light through the glass block.



Reading

If you want to read more on the topic Light, you can visit the following website:

<http://www.openschool.bc.ca/elementary/science4/>

We have come to the end of this unit. To ensure that you have understood the material, spend a few hours reviewing what we have covered in this unit.



In this unit you learned that:

- a wave is a disturbance in a rope, spring or water surface;



Summary	<ul style="list-style-type: none">• in transverse waves, the particles in the medium vibrate at right angles to the direction of the wave motion;• in longitudinal waves, the particles in the medium vibrate parallel to the direction of the wave motion;• the material through which waves travel is called a medium;• the frequency of a wave is the number of vibrations per second;• pitch of sound depends on the frequency of the vibration;• loudness of sound depends on the amplitude of the vibration;• an echo is reflected sound;• light travels in straight lines;• the law of reflection states that the angle of incidence is equal to the angle of reflection;• refraction is the bending of light when it passes from one medium to another.
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Assessment



Assessment

The completed assessment can be submitted to the nearest government/program support centre or can be submitted via electronic form, in scanned pdf format.

Before you complete the assessment, it is best if you spend at least 8 hours revising the material you covered in units 6 and 7.

ASSESSMENT 3

Assessment for units 6 and 7

Revision Study Hours	8 hours
Time dedicated to completing the assessment	6 hours

Answer all questions

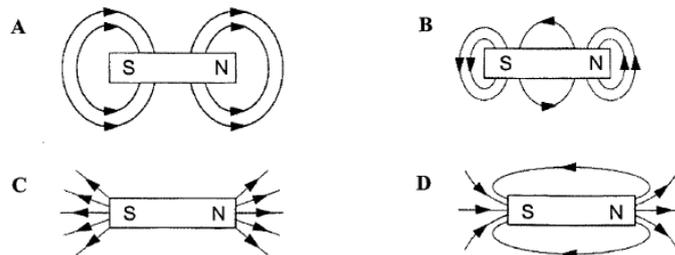
Section A – Multiple Choice Questions

Choose the correct answer from the possible answers given.

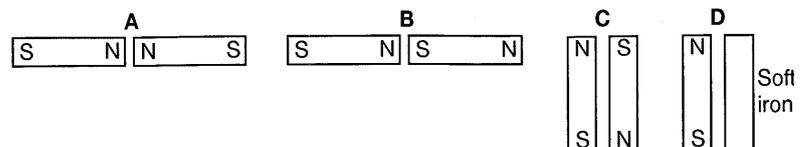
1. Which of the following metals is a magnetic material?

- A aluminium;
- B copper;
- C iron;
- D zinc.

2. Which diagram best show the pattern of field lines around a bar magnet?



3. Which of the following arrangements would produce repulsion?



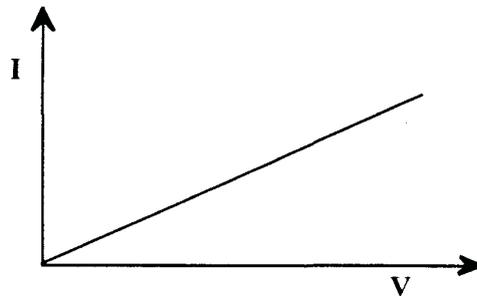
4. An electric current flowing through a wire induces a magnetic field around it. This is called:

- A electromagnetic effect;
- B electromagnetic force; C electromagnetic induction;
- D motor effect force.

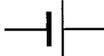
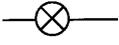


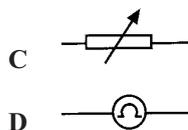
5. What do we call the type of material that allows electricity to pass through it?
- A conductor;
 - B generator;
 - C insulator;
 - D transmitter.
6. The current through a lamp is 5 A. What charge passes in 2 seconds?
- A 0.4 C;
 - B 2.5 C;
 - C 3 C;
 - D 10 C.
7. What does an ammeter measure?
- A current;
 - B power; C resistance; D voltage.
8. Which of the following formulae is used to determine the voltage in a circuit?
- A $V = I \div R$;
 - B $V = R \times I$;
 - C $V = R \div I$;
 - D $V = Q \div I$.
9. A 600 W drill is used for 5 minutes. How much energy is transferred?
- A 0.05 kWh;
 - B 120 kWh;
 - C 605kWh;
 - D 3,000kWh.
10. A lamp is connected to a 12 V supply. The lamp draws a current of 4 A. What is the resistance of the lamp?
- A 3 Ω ;
 - B 8 Ω ;
 - C 16 Ω ;
 - D 48 Ω .

11. The graph shows how the current I changes with voltage V in an experiment to determine the resistance of a sample of material.

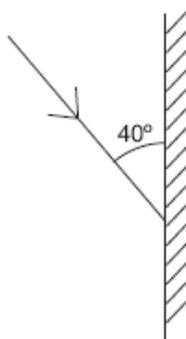


The shape of the graph shows that

- A the current decreases as the voltage increases;
B the resistance of the material decreases as the current increases;
C the resistance of the material increases as the voltage increases.
D the resistance of the material is constant.
12. Why is brass used to make the pins of a plug?
- A brass is a cheap metal;
B brass is a good conductor of electricity;
C brass is a good insulator;
D brass is rust free.
13. What is the colour of the insulation on the live wire inside a plug?
- A blue;
B brown;
C purple;
D yellow/green.
14. Which of the following circuit diagrams represents an ohmmeter?
- A 
- B 



15. An appliance has a power rating of 2,000 watts. It costs 80 cents to use the element when switched on for 1 hour. How much will it cost to use the appliance for $\frac{1}{2}$ hour?
- A 25 cents;
B 40 cents;
C 80 cents;
D 160 cents.
16. What is the current passing through a lamp in a car which is operated from a 12 volts car battery? The power rating of the lamp is 3 W.
- A 0.25 A;
B 4 A;
C 9 A;
D 36 A.
17. A fan **usefully** changes electrical energy into
- A elastic energy;
B heat energy;
C kinetic energy;
D light energy.
18. The diagram shows a single ray of light being directed at a plane mirror.



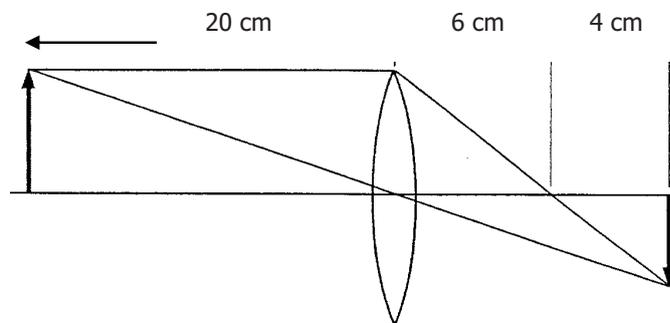
What are the angles of incidence and reflection?

angle of incidence	angle of reflection
A 40°	40°
B 40°	50°
C 50°	40°
D 50°	50°

19. An opaque object does not allow light to travel through. It forms a shadow. What property of light leads to the formation of shadows?

- A** light can be dispersed;
B light can be reflected; **C** light travels in straight lines;
D light travels through a vacuum.

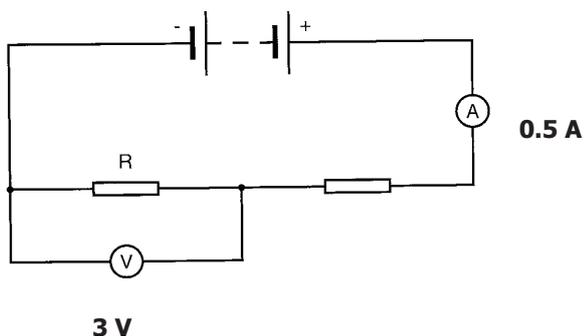
20. The diagram shows how an image is formed by a converging lens.



What is the focal length of the lens?

- A** 4 cm;
B 6 cm;
C 10 cm;
D 30 cm.

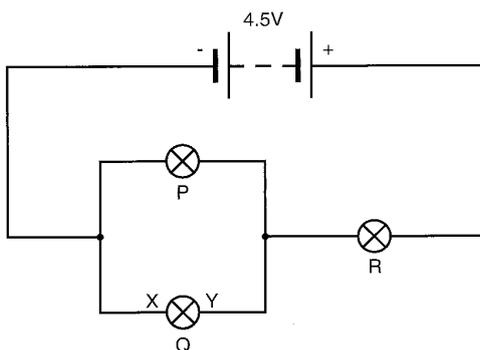
21. A learner set up a circuit as shown below.



What is the amount of current passing through resistor R?

- A 0.16 A;
 B 0.5 A;
 C 1.5 A; D 6 A.

22. Three lamps P, Q and R are connected to a 4.5 volt supply as shown in the diagram below. The voltage across lamp P is 1.5 V.



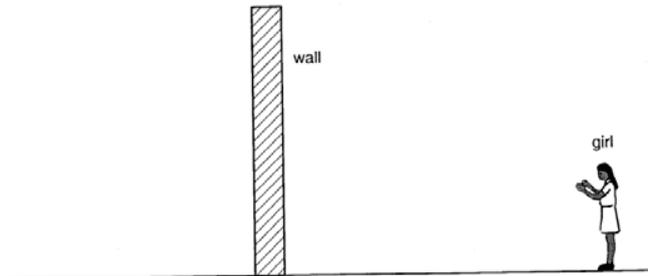
What is the voltage across lamp Q?

- A 1.5 V;
 B 3.0 V;
 C 4.5 V;
 D 6.0 V.

23. When using household appliances, an electric shock can best be prevented by

- A circuit breaker and earthing;
 B circuit breakers and insulation;
 C earthing and insulation;
 D earthing and thick conductors.

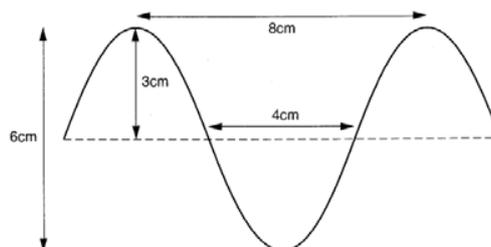
24. A girl stands some distance from a wall. She claps her hands once and a short time later she hears an echo.



When sound waves hits the walls they are

- A absorbed;
 - B conducted;
 - C reflected;
 - D refracted.
25. The speed of sound in air is 330 m/s. How far does sound travel in 2 seconds?
- A 11 m;
 - B 165 m;
 - C 330 m;
 - D 660 m.
26. A violin string vibrates at 600 vibrations per minute. What is its frequency?
- A 10 Hz;
 - B 60 Hz;
 - C 600 Hz;
 - D 36,000 Hz.

27. The diagram shows a wave.

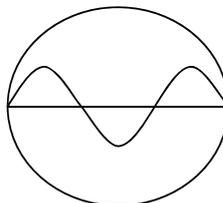




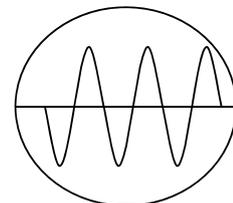
What are the amplitude and the wavelength of this wave?

- | | amplitude | wavelength |
|----------|------------------|-------------------|
| A | 3 cm | 4 cm; |
| B | 3 cm | 8 cm; |
| C | 6 cm | 4 cm; |
| D | 8 cm | 6 cm. |

28. Two sound waves, X and Y, are displayed in an oscilloscope with the same time-base setting for each.



X



Y

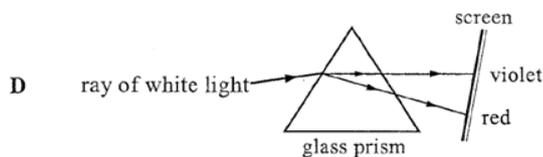
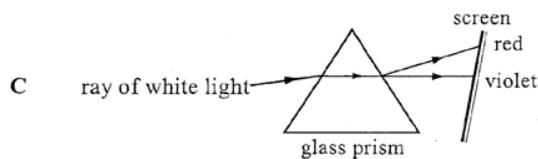
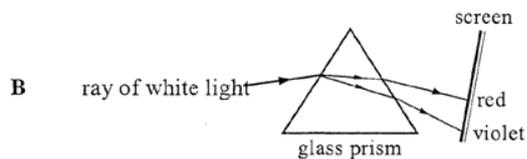
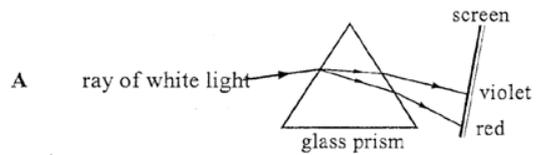
Which statement correctly describes the pitch and loudness of the two sounds?

- A** X has the higher pitch and is louder than Y;
 - B** X has the higher pitch and is quieter than Y;
 - C** X has the lower pitch and is louder than Y;
 - D** X has the lower pitch and is quieter than Y.
29. Which one of the following correctly shows a possible combination of how sound vibrations move?

	fastest		slowest
A	air	water	metal
B	metal	water	air

C	vacuum	metal	air
D	Water	metal	vacuum

30. Which diagram correctly shows the refraction and dispersion produced by a triangular glass prism?

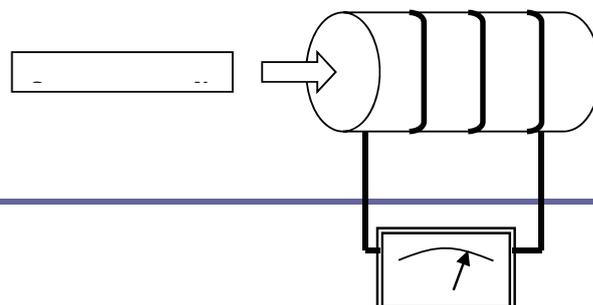


30 marks

Section B – Structured Questions

Answer all questions on the spaces provided.

1(a) A coil of wire is connected to a sensitive ammeter.

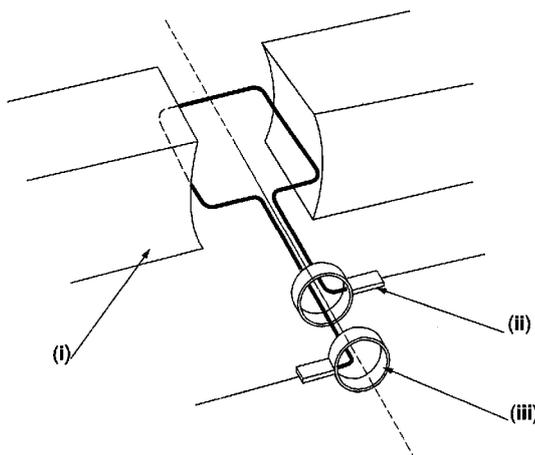




Describe what will be observed if

- (i) the magnet is inserted into the coil;
 -----(1)
- (ii) the magnet was held at rest in the coil;
 -----(1)
- (iii) the magnet is withdrawn more rapidly out of the coil.
 -----(1)

(b) The diagram shows a simple coil generator.



State the names of the parts labelled (i), (ii) and (iii).

- (i)-----
- (ii)-----
- (iii)----- (3)

(c) Name the instrument you would attach to the output of the generator to obtain a trace of the voltage produced.

----- (1)

(d) An electric motor is using a 240 V power source and carries a current of 4 amperes.

(i) Calculate the power of the electric motor.

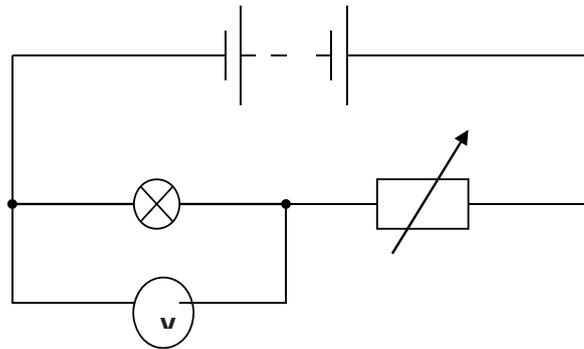
 -----(3)

(ii) The motor runs for 10 minutes. Calculate the energy consumed.

 -----(3)

[13]

2(a) A lamp is connected in series with a variable resistor to a 6 volt supply. A voltmeter is added to measure the voltage across the lamp.



(i) Copy and complete the diagram to show how an ammeter is connected to measure the current in the lamp.

(3)

(ii) The reading on the voltmeter is 4.5 volts. The lamp has a



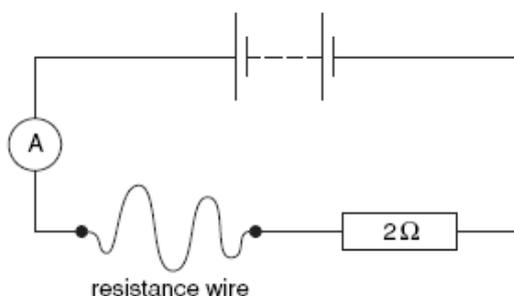
resistance of 9 ohm. Calculate the current through the lamp.

 -----(3)

(iii) The resistance of the variable resistor is decreased. State the effect of decreasing the resistance on the brightness of the lamp. Explain your answer.

 -----(3)

(b) A student set up the circuit below.



Circuit 1

(i) Compare the current in the resistance wire with the current in the 2 Ω resistor.

 -----(1)

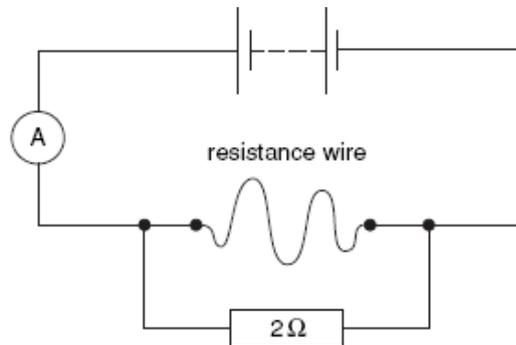
(ii) A voltmeter connected across the resistance wire shows the same reading as a voltmeter connected across the 2 Ω resistor. State the value of the resistance of the resistance wire.

 -----(1)

(iii) Calculate the combined resistance of the wire and the resistor.

 -----(2)

(c) The wire and resistor are disconnected and then reconnected in parallel, as shown in Circuit 2 below.



Circuit 2

(i) Calculate the combined resistance of the wire and resistor in Circuit 2 above.

----- (2)

(ii) The ammeter in **Circuit 1** reads 0.3 A. State whether the ammeter reading in **Circuit 2** is **less than 0.3 A** or **more than 0.3 A**.

----- (1)

[16]

3. The following information appears on an iron.

5 A	50 Hertz	230 V	1100 W
------------	-----------------	--------------	---------------

(a) The iron plugs into the mains supply of ----- (1)

(b) The amount of current the iron draw from the supply is ----- (1)

(c) The frequency of the main supply is ----- (1)

(d) The iron has a power of ----- (1)

[4]

4(a) Differentiate between **transverse** and **longitudinal** waves. Give **one** example of each.

(i) transverse wave:

----- (1)

example: ----- (1)

(ii) longitudinal wave:

----- (1)

example: ----- (1)



(b) A set of 10 regular water waves occupies a distance of 500 cm. The 10 waves take 5 seconds to pass a float.

(i) Calculate the wavelength of the waves.

----- (2)

(ii) Determine the frequency of the waves.

----- (2)

(iii) Use the wave equation, **wave speed = wavelength x frequency**, to calculate the speed of the waves.

----- (2)

5(a)(i) State what causes sound.

----- (1)

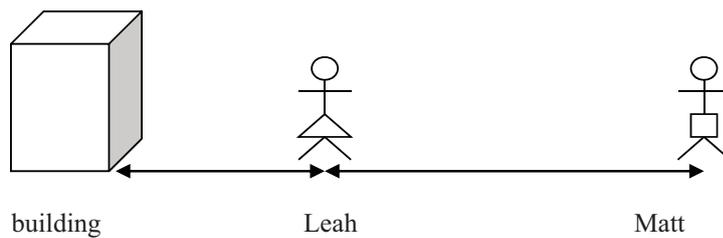
(ii) Write down the range of audible frequencies for the human ear.

----- (1)

(iii) Explain why humans cannot hear the noise made by bats.

----- (2)

(b) Leah, standing in front of a tall building, fires a shot with a starting pistol. Matt, standing behind her, hears two bangs 2 seconds apart.



(i) Explain why Matt hears two bangs of pistol shot.

----- (1)

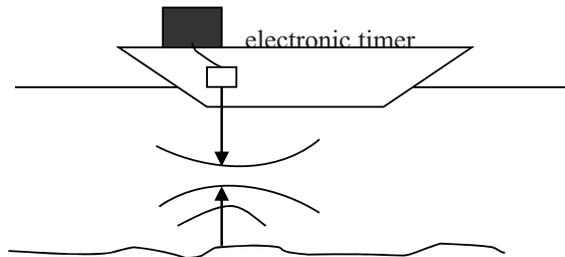
(ii) Given that the speed of sound in air is 330 m/s. Determine the distance travelled by the sound that produced an echo.

----- (2)

(iii) Write down the medical use of echo sound.

------(1)

(c) An underwater transmitter sends out a pulse of sound from the bottom of a boat. An electronic timer measures the time between the pulse being emitted and the echo being received after 3 seconds.



(i) Given the sound travels at 1,500 m/s in water, calculate the depth of the water.

------(3)

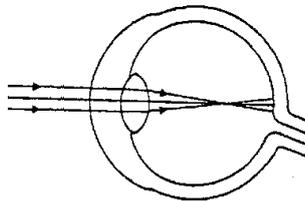
(ii) Explain why the speed of sound in water is higher than the speed of sound in air.

------(2)

[13]

6(a) Anna can see near objects clearly but distant objects are blurred.

The diagram below shows how images are focused in her eye.



(i) State the sight defect she has.

------(1)

(ii) Write down the type of lens that can be used to correct her condition.

------(1)



(iii) Draw a simple sketch of the **lens** used to correct Anna's problem.

(2)

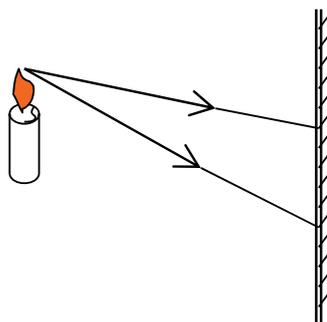
(b) State the type of lens used in a camera.

-----(1)

(c) Write down **two** properties of the image formed in a camera.

 -----(2)

(d)(i) Complete the diagram to show how an image is formed in a plane mirror.

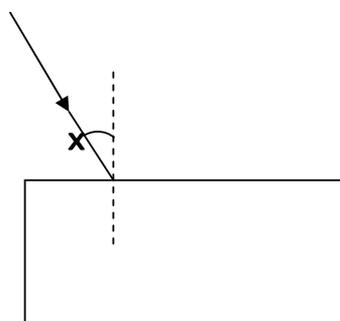


(3)

(ii) Write down **one** property on the image formed in the mirror.

-----(1)

(e) The diagram shows a ray of light striking the surface of a glass block.



(i) Complete the diagram to show the path of the ray through the

glass block and out into the air again. (2)

(ii) Mark another angle on the diagram that is equal to angle X.

Label this angle Y. (1)

[14]

[70]

TOTAL: 100



Answers to Self-Mark Activities

Section 1: General Wave Properties

1. D

2. A

3. B

4. A

5(a) $8\text{ cm} - 2\text{ cm} = 6\text{ cm}$ (crest to crest)

(b)(i) distance from rest position to crest or trough

(ii) 10 mm

6(a) longitudinal

(b) In liquids, particles are closer and therefore transfer sound energy quickly. In gases, particles are far apart and therefore transfer sound energy slowly.

7. Lightning is seen first because light travels faster than sound.

Section 2: Sound

1. A

calculations:

time for a single journey: $3\text{s}/2 = 1.5\text{ s}$



$$\begin{aligned}d &= s \times t \\ &= 330 \text{ m} \times 1.5 \text{ s} \\ &= 495 \text{ m}\end{aligned}$$

2(a) increases

(b) increases

3(a)(i) $v = d/t$

$$= 2 \text{ m}/0.0004 \text{ s}$$

$$= 5,000 \text{ m/s}$$

(ii) v is higher

(iii) In the metal, particles are closer than in air, hence sound is transferred quicker.

(b)(i) F_1 is less than F_2

(ii) F_2 , because the frequency is higher

(iii) amplitude

4(a) 16 Hz to 20,000Hz (20 kHz)

(b) Bats produce sound of which the frequency is higher than the human audible frequencies.

(c) Bats send high-pitched sounds which bounce off objects (including prey). By doing this, bats can estimate how far away an object is.

5(a) make the vibrating end shorter

(b) the pitch increases

(c) when the distance of the ruler from its rest position (amplitude) was greatest

(d) high frequency leads to high pitch
large amplitude leads to loud sound

6(a)(i) steel, granite, water, oil, nitrogen, oxygen

(ii) $(354 + 332)/2$

$$= 343 \text{ m/s}$$

(b)(i) by the vibration of the particles in the string, longitudinally from Tom to Sharon.

(ii) Air particles in the tin vibrate. These vibrations are transferred into the ear.

Section 3: Light, the Basic Concepts

1. B

2. B

3. D

4. B

Section 4: Transmission and Absorption

1. Cut rectangular pieces of cardboard and make holes at the centre.

Align them so that you can see an object at the far end by looking through the holes. Move one of them so that it is not in line any more.

You should not see the object at the far end. You may use a diagram if it helps.

2(a) Material that allows light to pass through — e.g. clear glass.

(b) Material that allows light to partially pass through — e.g. frosted glass/oiled paper/tracing paper

(c) Material that does not allow light to pass through — e.g. person, calculator, etc.

3(a) Pass rays through a converging lens.

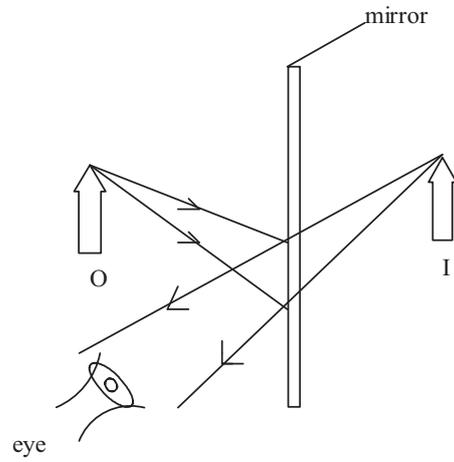
(b) Use light from a torch or pass rays through a diverging lens.

Section 5: Reflection by Mirrors

1. C

2. B

3(a) Draw the diagram similar to this.



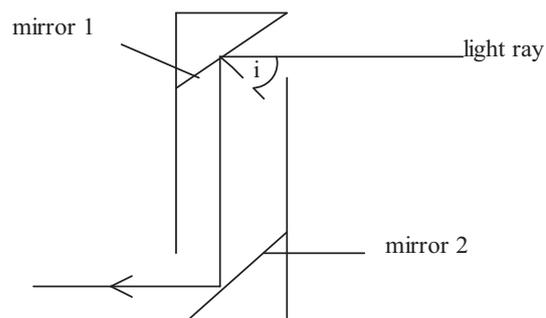
(b)(i) $7 \text{ cm} \times 2 = 14 \text{ cm}$

(ii) $7 \text{ cm} - 2 \text{ cm} = 5 \text{ cm} \times 2 = 10 \text{ cm}$

(iii) $14 \text{ cm} - 10 \text{ cm} = 4 \text{ cm}$

- (c)
1. erect
 2. laterally inverted
 3. same size as object or virtual image

4(a)



(b) see on the diagram.

(c) angle $i =$ angle r

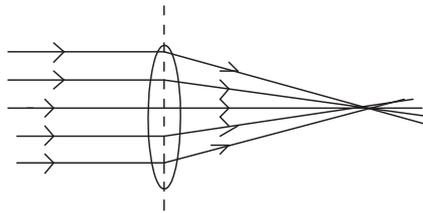
- (d) It is used to:
watch over the heads of people if you are too short;
in submarines to see outside the water.
- 5(a) Regular reflection takes place when light falls on smooth surfaces, e.g., plane mirror.
Diffuse reflection takes place when light falls on rough surfaces, e.g., stone.
- (b) Disadvantages of reflection:
1. at sunrise and sunset, the reflection of light from a wet road can be dangerous;
 2. fog and mist are caused by light being reflected in all directions by little water droplets;
 3. light inside a camera can be reflected off the sides and spoil the picture, which is why the inside of a camera is painted black;
 4. prey can be caught (a lion can easily see a kudu).
- (c) The curved mirror, called a convex mirror, is used by drivers for rear viewing.

Section 6: Refraction of Light

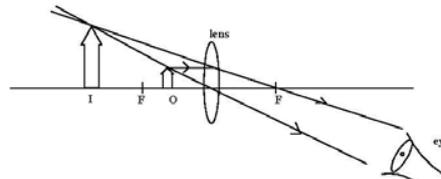
1. C
2. D
3. B
4. B



5(a)



(b)(i) Apply the same principle.

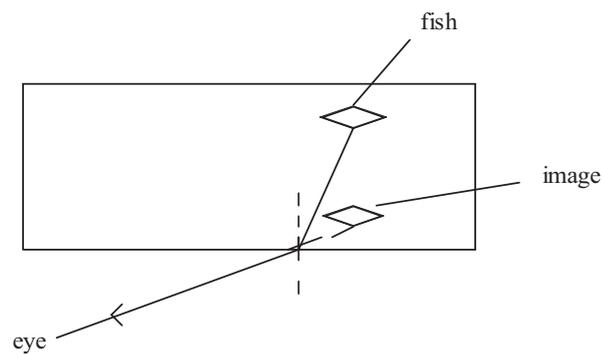


Characteristics of the image:

- it is virtual (not real);
- it is larger than the object (magnified);
- it is upright (erect);
- it is on the same side of the lens as the object.

- (ii)
1. virtual;
 2. erect;
 3. magnified;
 4. same side of lens as the object.

6(a)



(b) on the diagram

7(a) real, inverted, smaller than object

(b) K – red

L – violet

(c) image at X is raised, larger than object

(d)

