Oxford Secondary Science 3

Teaching Guide

Terry Jennings

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Contents

Introduction

Aims and content of the course

Learning science is fundamental to understanding the world in which we all live and work. Science helps people to ask questions, test explanations through measurement or experimentation, and assists people to clarify their ideas. Science is important to everyone—young or old, male or female, city or rural dweller. It is science that has brought our world to where it is today. Science has created the comforts we enjoy and the problems with which we must deal. Used wisely, science can make the world a better place; science used unwisely can lead to global disaster. An added reason for learning science is that we need more scientists, technicians, and engineers to run the complex world of the future.

Science involves mental discipline. As with so many other things, people must be exposed to that mental discipline when they are young. If children do not learn to think in a scientific, systematic way, they grow up blindly accepting all they are told, confusing science and superstition, and depending on hasty judgement rather than considered opinion. We have to learn to recognize that science is not something done to us, for us, or at us, by experts. We must do it. Each individual should be scientifically literate enough to keep abreast of developments throughout their lives. We must also learn to use scientific skills to make intelligent decisions. Life in an advanced technological society is driven by scientific decision-making. Should we build more nuclear power plants? Which diseases should receive research funding? Is it safe to use genetically engineered crops to increase food supplies? What is global warming and how do we deal with it?

Children and teenagers want to know everything about everything. The ***Oxford Secondary Science*** series of books is designed to provide a straightforward approach to the teaching of science in the first three years of secondary education. It develops and extends the learning acquired in the primary school from the use of such courses as ***New Oxford Primary*** Science by Nicholas Horsburgh and ***Science Success*** and ***Simply Science***, both by Terry Jennings.

Oxford Secondary Science covers the requirements of the Pakistani National Curriculum for General Science at Grades VI, VII, and VIII. The course aims to meet the needs of teachers and students by developing and building on the core scientific themes studied in primary school in carefully graded stages, thereby providing a comprehensive introduction to science for students aged 11 to 14 years.

The course is designed to do four main things:

1. To give students a solid body of knowledge in the natural, physical, and Earth and space sciences
2. To develop and extend their knowledge of the nature of scientific enquiry
3. To enable students to explore values and attitudes through science
4. To encourage them to think about how we can use science for the best

These four elements are developed side by side through the books which make up the complete Course. It is hoped that both students and teachers will find ***Oxford Secondary Science*** an exciting and stimulating learning experience. ***Oxford Secondary Science*** is aimed at the average student but is flexible enough to allow use by students of all abilities. It also promotes the development of independent learning by students.

The Course has been written specifically to help the teacher deliver science lessons in a stimulating and engaging way. Its flexibility allows the teacher to tailor the work to meet the known abilities and needs of the students, as well to make best use of what materials and resources are available. In addition, it allows the teacher to use his or her own strengths and to employ strategies that have proved effective in the past. To this end, it is hoped that the course will save the teacher time, money, and preparation.

Using this Teaching Guide

The Student's Books are intended to provide core material on the four broad themes of:

- life and living processes
- materials and their properties
- physical processes
- Earth and space science.

The themes chosen are based firmly on the student's own experience and cover areas affecting their everyday lives.

The overall objectives of the course are that the students should acquire:

A) Knowledge and understanding of science

i. knowledge of some facts and concepts concerning the environment
ii. knowledge of the use of appropriate instruments in scientific experiments
iii. an adequate scientific vocabulary
iv. an ability to communicate using this vocabulary
v. an understanding of some basic concepts in science so that they can be used in familiar situations
vi. an ability to select relevant knowledge and apply it to new situations
vii. an ability to analyze data and draw conclusion
viii. an ability to think and act creatively

The student should acquire:

B) Attitudes

ix. an awareness of the inter-relationship of the different scientific disciplines
x. an awareness of the relationship of science to other areas of the curriculum
xi. an awareness of the contribution of science to the economic and social life of the country
xii. an interest and enjoyment in science
xiii. an ability to become objective in observation and in assessing observations

The student should gain:

C) Practical skills

xiv. some simple science-based skills

xv. some experimental techniques involving several skills

The units within any one Students' Book can be taught in almost any order. If there are two or more teachers with classes of students of the same age, they could each choose different units. The teachers could acquire the materials for their particular unit and then, after the work is completed, they could exchange materials and ideas, and discuss any problems that arise.

Lesson planning

This Teaching Guide does not attempt to specify a rigid strategy for teaching the topics covered in the Students' Book. Schools vary greatly in the time and resources they have available for science work. Instead of detailed lesson plans, notes for possible lessons are included in each chapter. However, it is important to remember that these are just notes and observations which it is hoped will prove helpful in planning lessons and activities. No doubt you will want to develop lessons of your own, hopefully based on the materials in the Students' Book. Some of the suggested activities are spelt out in detail in the form of photocopiable worksheets. It is intended that these worksheets will extend students' knowledge and understanding of the topic, or prove useful when assessing students' basic skills in the laboratory. Some of the other suggested activities are short, fairly simple experiments, while others consist of more open-ended investigations which can be used to assess a student's ability to design scientific investigations and draw conclusions from the results. The use of these will depend upon the apparatus and equipment available and/or the particular characteristics of the teaching group. If equipment and materials are scarce, or if the students cannot be trusted to work without close supervision, then it may be necessary for the teacher to demonstrate some of the experiments rather than allow the students to work on them individually or in small groups.

Science practical work

Most teachers of science see practical work as an essential feature of their everyday teaching, believing that students learn better from doing than simply being told. However although it is in the doing of science that students learn best, this involves more than just practical work. As well as needing to observe, record, predict, measure, look for patterns, classify, ask questions and so on, students need time to discuss their work. Many teachers find that relatively short practical tasks, embedded in a lesson rather than taking up the entire lesson, are more effective in giving the teacher time to introduce students to, and fully discuss, new scientific terms and ideas. In this connection, the experimental worksheets should be discussed both before and after the completion of the activity. This is particularly important with those students who are not fluent readers. Such discussion also helps to clarify the main ideas and will help you to monitor progress and discover what interests the students, with a view to developing their interests in future sessions. Discussion will also reveal any misunderstandings which can then be corrected as soon as possible.

Organization

For practical activities, it may be necessary to divide the students into groups of a size you consider appropriate for each particular activity. The groups should be as small as possible but should have enough students to adequately handle the materials and to keep a record of the results. For most activities, two or three students is probably the optimum number for a group. Many of the activities can be done individually. Certainly the groups should never be so large that some students are merely spectators. In the case of activities which require a great deal of the teacher's attention, it is suggested that the class is divided into two, and while part of the class is engaged in the practical activity, the other part is kept busy with the 'desk-bound' written or other **Things to do** activities in the Students' Book.

Worksheets

The worksheets are designed to be photocopied and used within the purchasing institution. They are designed to allow the students to record their findings on the actual worksheets, but you should also encourage the students to use IT and other methods of recording, as appropriate.

Things to do

Each chapter of the Students' Book contains a number of suggestions for extension work or open-ended investigative work. The suggestions are designed to give students the opportunity to demonstrate creativity in their approach to tackling scientific problems rather than responding to detailed instructions.

There is no definitive answer to many of the tasks set and teachers will need to assess individually the quality of the students' responses. For example, many of the tasks involve the design of experiments, and these can be assessed by looking for examples of good scientific practice. Has the student understood the problem and identified relevant facts? Does the solution offered allow a degree of scientific control? Have appropriate safety factors been taken into account? Does the suggested investigation offer a reasonable chance of success?

Experimental design can be a pen and paper exercise. In many cases lack of resources or the complexity of the problem will make this a necessity. However, wherever possible, the students should be given the opportunity to put their design into practice. For this to be successful, it may be necessary for teachers to define the task much more closely than has been done here and to spell out any constraints which must be taken into account. Finally, it is not recommended that all the suggestions are used with any one group. Many of the open-ended tasks will place great demands on the teacher, so the emphasis placed on these activities is left to the teacher's discretion.

Notes for further investigation and extension work

Each chapter of this Teaching Guide contains a number of suggestions for further investigation and extension work. These are mainly practical or experimental activities and they are offered as suggestions to extend the 'core' practical investigations described in the lesson plans. Depending on the local circumstances and the availability of equipment, the teacher may find that they are more suitable alternatives to the experiments suggested in the outline lesson plans.

Equipment and materials

Essential materials and equipment are listed under 'Materials needed' on each worksheet. Nearly all the items are readily available in a fairly basic school laboratory. It may be necessary from time to time to call upon the school kitchen for access to a refrigerator or deep-freeze. The students themselves may be able to collect some of the materials if they are given sufficient notice.

Safety!

The activities described in this Teaching Guide and in the Students' Books mainly use standard items of equipment, and materials which are perfectly safe if used sensibly. All the activities have been checked for safety as part of the reviewing process. In particular, every attempt has been made to ensure that all recognized hazards have been identified, suitable safety precautions are suggested, and, wherever possible, the procedures are in accordance with commonly-used risk assessments.

However, it is important to be aware that mistakes can be made. Therefore, before beginning any practical activity, you should carry out your own risk assessment in relation to local circumstances. In particular, any local guidelines issued by your employer must be observed, whatever is recommended here. As a general principle if, on safety grounds, you are not completely sure about the ability of your students to carry out an experiment, then demonstrate it to them rather than risk an accident.

General safety precautions

There are a number of general safety rules which you should observe

- If the students taste or handle food, ensure they wash their hands before doing so and that tables and utensils are clean and foods are fresh and uncontaminated. Be sensitive to different dietary requirements.
- Young students have little say or control over what they are given to eat at home. When discussing a healthy or balanced diet, for example, take care to ensure that students do not feel that you disapprove of their dietary habits. Similarly, when comparisons are made between the physical characteristics and intellectual abilities of students, it is important to emphasize that we are all different. Students are built differently, grow at different rates, and have different backgrounds and likes and dislikes and they are particularly sensitive to these differences during the often difficult years of adolescence.
- Visits beyond the school grounds must be carried out in accordance with the guidelines of your school or employing authority.
- Warn students never to look directly at the Sun. It could damage their eyesight or cause blindness. Warn them also of the dangers of inadvertently looking at the Sun through binoculars, telescopes and even microscopes.
- Some students are allergic to certain plants, e.g. some flower bulbs, and pollen (from flowers), and remember that some plants are poisonous. Many students are allergic to certain animals.

- Many seeds bought from garden centres will have been treated with pesticides and are not safe for students to handle unless they wear gloves. Seeds bought from health food shops are usually safe, although it is best to avoid red kidney beans.
- Whenever possible, use transparent plastic containers, rather than glass containers, particularly for collecting living things outside. Particular care is needed not to leave microscope slides or cover slips in sinks and on work surfaces.
- In the absence of Bunsen burners, night-lights and short, stubby candles are difficult to knock over. When using a naked flame always work in a metal tray, such as a baking tray, filled with sand.
- Use soils free from glass, nails, and other sharp objects, and collect soil samples from places that are unlikely to be contaminated with dog or cat faeces. Wash hands after handling soils.
- Wash hands after handling animals.
- Students should not touch ice immediately after it has been taken out of a freezer.
- Take great care with hot water or steam.
- Great care should be taken when using mercury thermometers (recognizable by the silver colour of the liquid inside them), because of the dangers from the toxic metal mercury if they are broken.
- Warn students of the dangers of mains electricity. However, assure them that the batteries they use in class are safe.
- Use plastic mirrors wherever possible. If you have to use glass mirrors, ensure that they do not have sharp edges; bind edges with masking tape or insulating tape.

Assessment

Teachers express considerable concern over assessment. The Students' Book contains questions to support the learning from the units and to build confidence. Many of these questions test factual recall for, without a knowledge of the basics of the topic, it is difficult or impossible for the student to later apply the learning. Answers to these questions are given in this Teaching Guide. In addition, each chapter of the Teaching Guide includes an Assessment section and a list of answers. The multiple choice questions are again primarily included to test the recall of facts, but the structured questions contain more subjective elements, allowing students to reveal a greater depth of understanding. A marking scheme has not been suggested for these assessment items. Again, the aim is to be as flexible as possible. The teacher may wish to set the whole test at the end of the topic, or he or she may want to use the shorter questions for short, sharp tests, or set one or more of the longer questions for homework.

The nervous system

CHAPTER 1

Teaching Objectives

- To introduce the structure and functions of the nervous system
- To use a model to describe the mechanism of the nervous system
- To explain reflex actions and to differentiate between involuntary and voluntary actions

Learning Outcomes

After studying this chapter students should be able to:

- describe the structure and functions of the nervous system
- describe the working of the nervous system through a model
- explain reflex actions with an example
- differentiate between voluntary and involuntary actions they have experienced

Introduction

Even the simplest living thing must adjust to its surroundings to avoid danger, find its food and recognise its own kind. In man this is the function of the nervous system. With the help of the hormones, the nervous system ensures that all our body systems work together and that our sense organs gather information about what is happening all around us. As a result, we can make appropriate adjustments to our behaviour and actions.

Central nervous system

The central part of the nervous system is the brain and the spinal cord. The spinal cord is about 1 cm wide where it leaves the base of the brain, and gradually tapers as it passes down the body through the backbone. Pairs of nerves, from both the brain and spinal cord, run to all parts of the body. Twelve pairs of nerves travel from the brain, mostly going to the head and throat, and another thirty-one pairs of nerves go from the spinal cord to the trunk, arms, and legs. The brain and spinal cord have a small fluid-filled space at their centres, but the nerves themselves are solid.

Voluntary and autonomic nervous systems

The nervous system consists of two parts. The voluntary nervous system lets us send out orders through motor nerves to muscles to carry out actions such as standing, walking, running, and talking, actions which have to be learned after birth. The voluntary nervous system also controls messages received from the skin and sense organs such as the eyes, ears, and taste buds of the tongue, through the sensory nerves. Millions of sensory receptors in the skin are connected to the voluntary nervous system: they are sensitive to touch, pressure, pain, heat, and cold. The autonomic nervous system keeps our body organs working smoothly without our knowing or thinking about it. It automatically controls the heartbeat, the activities of the stomach and intestines, and the production, by glands, of liquids such as sweat and saliva. Part of the autonomic system is controlled by a pair of nerves at the base of the brain, while the rest is supplied by branches from other nerves which combine to form two parallel cords, one running along each side of the backbone.

Although the autonomic and voluntary systems are separate, there are links between them, but it is not always clear which is operating. Most of the functions controlled by the autonomic system cannot, of course, be affected by orders from the brain, but some individuals, for example those practising yoga, seem to be able to exert some control over their rate of breathing, and even over their heartbeat.

Nerves

A nerve may look like a strand of whitish cotton or thickish cord, or it may be too thin to be easily seen. It is made up of a number of nerve fibres, each of which forms part of a nerve cell. The whole nerve is covered by an insulating sheathe. A nerve cell consists of at least one long fibre and a cell body containing the cell nucleus. Sensory cells pick up and pass on messages from the sense organs through receptors; connector cells link the different parts of the central nervous system, and motor cells carry orders to the muscles. The message is sent along the nerve fibre to another through very fine branches which interlock with, but do not touch, those of the adjoining cell. The tiny gap between two nerve cells is called a synapse, and the impulse travels across the synapse by the release of a chemical substance at the nerve endings. The impulse is carried along the fibre as a small electric current. The cell bodies are found only in, or just outside, the brain and spinal cord, mainly in the grey matter in the centre of the cord and in the outer part of the brain. This means that nerve cells are much larger than most other cells—a single fibre may run right up from a toe to the backbone.

Reflex actions

If your hand touches something uncomfortably hot, an impulse in the form of an electric current passes from the sense cell in the hand along nerve fibres to cell bodies just outside the spinal cord. The impulse is carried into the grey matter of the spinal cord, and then transferred to connector nerve fibres which take it to the brain. The brain may decide that the hand is in danger and an impulse will travel along other connector cells to motor cells in the spinal cord grey matter. Fibres from these cells carry the impulse to arm muscle cells which contract to move the hand away. If the danger is very great, the message 'short circuits' in the spinal cord, and the hand is withdrawn before the brain can deal with the problem. This is called a reflex action. Most actions are more complicated. Even deciding to write one's name needs a vast number of sensory and motor impulses. These processes are very rapid. It takes less than one-fiftieth of a second for an itch impulse to travel from your toe to your brain.

The brain

The brain acts as a control for the activities of the body. These include not only conscious activities, such as whether to stand or sit, laugh or cry, but involuntary activities.

The human brain has three main parts. At the top of the backbone, where the nerves bunch together to enter the skull, is the medulla. This controls the unconscious activities of our bodies, which are under the influence of the autonomic nervous system, and include breathing, heartbeat, and digestion. Above the medulla is the cerebellum which controls our sense of balance and assists the coordination of muscular activities. These controls have to be learned, but they are so well learned that they become automatic. Above the cerebellum is the largest part of the brain, the cerebrum, which is divided into two halves (hemispheres) and which makes up 70 per cent of the mass of the whole brain and nervous system. The cerebrum is far more developed in humans than in any other animal. Its surface is a complicated pattern of wrinkles. These give it a very large area into which are packed an enormous number of nerve cells, forming an outer layer called the grey matter. This outer layer of the cerebrum is associated with the capacity for intelligent behaviour, speech, learning, imagination, memory, and decision-making. The grey matter also receives and interprets impulses concerned with conscious activities. Beneath this layer is a thick layer, the white matter, consisting of nerve fibres. The right half of the cerebrum controls the activities and movements of the left side of the body, and vice versa. These are special areas of the brain that control hearing, smell, and sight. A small but very important part of the brain is the pituitary gland at the base of the brain in the medulla. It produces important hormones that control many of the other hormone systems of the body, and is involved in growth, development, and reproduction.

The human brain is larger, in comparison with its body size, than that of any other animal. It grows rapidly at first and then more slowly. When brain cells die or are damaged, they are not replaced by new ones, as are the cells of other organs. The brain is suspended in liquid and well protected by its bony box, the cranium, but any damage to it can seriously affect a person's personality and abilities.

Practical considerations

The work in this chapter develops and extends the material dealt with in Book 1 on senses and sense organs. In this respect, as a preliminary, it may be useful to revise this work and to revisit some of the experiments and activities dealing with senses and sense organs.

Lesson suggestions

1. The control room

Refer to page 2 of the Students' Book

Starter suggestions

Make a list of the different parts of the body that had to work together when you came into the room and sat down.

Watch a short video clip or part of a DVD of a gymnast on asymmetric or parallel bars. Discuss how all his or her movements are coordinated.

Ask the students to list in their notebooks the five main sense organs, or make a list on the board. Ask them to consider how the sense organs make us aware of what is happening around us and how the information received by the sense organs is processed.

Main lesson

Show the class a large poster or PowerPoint slide of the human nervous system.

Briefly discuss the structure of the nervous system and familiarize the class with the idea of a central nervous system and associated nerves. Encourage the students to think of the brain as the body's control room and help them to understand that information is carried to and from the brain in the form of electrical impulses.

Introduce the idea that receptors detect stimuli. Recall some of the receptors in the body, and the stimuli they detect. Describe some of the body's effectors, such as muscles and glands, which can produce a response to a particular situation.

If there are sufficient microscopes, let the students examine prepared slides of nerve cells, or let them examine photographs or diagrams of nerve cells. If time permits, they could carry out the simple activities to examine the nerve endings in the skin and reaction times, described in the **Ideas for investigation and extension work** section of this chapter.

2. Reflex actions

Refer to page 6 of the Students' Book

Starter suggestions

Get the class settled and quiet. Then, unexpectedly, either burst an air-filled balloon or bang a slab of wood hard down against a bench or table. Ask the students to describe their responses, such as increased heart rate, rapid breathing, paler skin, blinking, and other involuntary movements. Ask them to describe which sense organs were involved in their responses.

Main lesson

Ask the students how they would react if they trod on a drawing pin or touched the hot handle of a saucepan. Gather together their ideas and discuss which sense organs are involved in the reaction.

Show the students a large diagram or PowerPoint slide of the reflex pathway. Explain that reflex actions are a rapid, automatic response to a stimulus and that they help to avoid damage to the body. Emphasize that the reflex arc is the pathway taken by a nerve impulse during a reflex action.

Use Worksheet 1 to enable the students to work in pairs to investigate the eyes and reflex action and also some of the smaller activities described in the **Ideas for investigation and extension work** of this chapter.

Discuss the students' results as a whole class, and help them to summarize what they have discovered.

Ideas for investigation and extension work

Looking at nerve cells in the spinal cord

Examine a prepared microscope slide of the spinal cord which has been specially stained to show up the nerve cells. Examine the slide first under the low power. Can you see the grey and white matter? Can you see the nerve cells in the grey matter? Change to high power and focus on a single nerve cell. Draw the nerve cell to show its shape. Compare your drawing with the diagram in the Students' Book.

Nerve endings in the skin

The students should work in pairs for this activity. The subject is blindfolded, and the experimenter touches his or her skin lightly with one or both of the points of a pair of dividers. Each time a touch is given, the subject states whether he or she thinks one or two points of the dividers were used. Start with the points of the dividers wide apart, and gradually bring them closer together as the experiment proceeds. Eventually a stage will be reached where a double touch is reported as one. This shows that the two points are both stimulating the same nerve ending, and the distance between the points gives some indication of the distance between the nerve endings in that part of the body. Begin the investigation on the finger tips and extend it to the back of the hand, the upper arm, and the back of the neck.

What can you conclude from this experiment about the distribution of nerve endings in the skin? Are all parts of the skin equally sensitive to different stimuli?

Reflex action

Again the students should work in pairs for this activity. The subject student sits with his or her legs crossed, so that the lowest part of the uppermost leg is hanging free, with the foot unsupported. The subject relaxes his or her muscles while the experimenter gives a sharp tap with the edge of the hand just below the subject's kneecap. The students should note what happens. What change can the subject feel in the thigh of the uppermost leg if his or her hand is resting on it during the experiment?

Measuring a reflex

Devise a method of measuring how long it takes for a knee jerk to begin from the moment the knee is tapped.

Reflex tests

When a baby is first born, the doctor or midwife will carry out several reflex tests to check that the baby's nervous system is working properly. These tests include the stepping or walking reflex, the clasp reflex, the cuddle reflex, and the suckling reflex. Use the Internet to research these reflex actions and tests. Then explain how the newborn baby begins to learn new responses, for example to recognise familiar faces and voices. Compare this learning with the reflex actions. Present your findings in the form of a leaflet that could be given to expectant mothers.

Some more reflexes

Work in pairs, with one person acting as the subject.

a) ***The ankle jerk*** Kneel on a chair and let your feet hang loosely behind you. Your partner should tap the back of your foot just above the heel. What happens?

b) ***The blink reflex*** Open your eyes and look straight ahead. Your partner should suddenly wave his or her hand in front of your eyes. What happens?

c) Repeat the two reflex actions above, but this time make a conscious effort to prevent them taking place. Do you succeed? What conclusions do you come to?

d) ***The swallowing reflex*** Swallow the saliva in your mouth and then immediately try swallowing again. Is it difficult to swallow the second time? Suggest an explanation. Repeat the experiment, but this time swallow your saliva and then swallow a mouthful of water. What difference does this make? What conclusions can you draw?

Measuring reaction time

There are various ways of measuring reaction time. One simple way is for one student to hold a metre ruler vertically by one end. Find out how far it falls before it is caught by a partner. Alternatively, divide into teams with the same number of people in each team. Stand in a row, one person behind the other, with your arms at your sides. When the teacher says ‘Go’, the person at the back of the row should touch the person in front, and then he touches the person in front of him, and so on. The teacher times how long it takes for this chain reaction to reach the student at the front of the row. Trace the nervous pathway through which the impulses pass in bringing about each person’s response.

WORKSHEET 1

The eye and reflex action

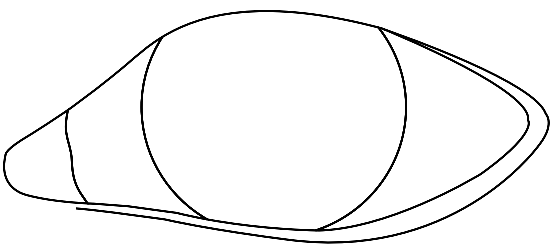
Materials needed: pencil; mirror; lamp

1. Sit in a brightly lit room, ideally with a lamp shining on you.
2. Look into the mirror.
3. Cover one eye with your hand, but do not close your eye.
4. Look into the mirror quickly as you take your hand away from your eye. You may have to do this several times to see exactly what is happening to your eye.

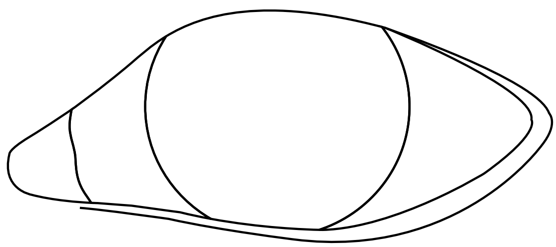
   What happened to the pupil of the eye that was covered up immediately after you took your hand away?

   ____

   ____



i) dark



ii) light

Complete the top diagram to show what the pupil looked like immediately after being in the dark. Complete the second diagram to show what the pupil looked like in the light.

Why is it an advantage to have a pupil that reacts like this? ____

____

Repeat the experiment, but this time watch closely what happens to the pupil of the eye which is not covered as the other one is covered and uncovered. Write down what you see.

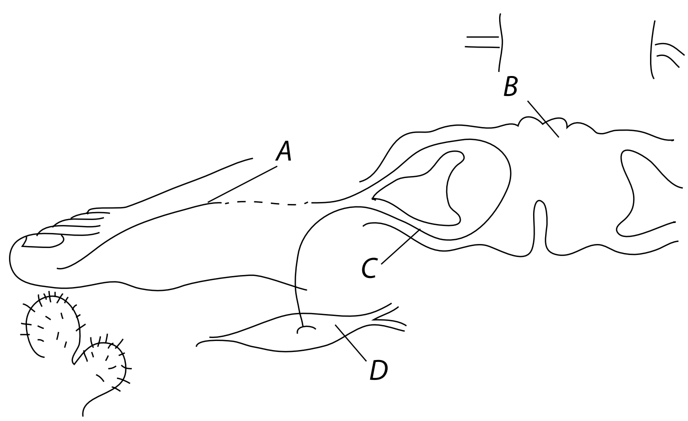
____

Why do you think this happens? ____

____

Answers to questions in the Students' Book

1. A stimulus is a change in the surroundings of a living organism.
2. The action you take as a result of a stimulus is called a response.
3. The five main sense organs are the skin, tongue, nose, eyes, and ears. The skin is sensitive to touch, the tongue is sensitive to taste, the nose is sensitive to smell, the eyes to sight, while the ears are sensitive to hearing and balance.
4. Nerves are bundles of axons or nerve fibres. A nerve cell is one of the cells which make up a nerve. It has a nucleus and cytoplasm and, leading out from the cell, the cytoplasm forms a single long fibre, called the axon. From the axon, nerve impulses travel out to another nerve, or to a muscle or some other cell.
5. Like other cells, neurones have a nucleus, cytoplasm, and a cell membrane.
6. Neurones are adapted to carry out their job or function by having several 'inputs' called dendrites, along which nerve impulses travel into the cell. Heading from the cell, the cytoplasm forms a single long fibre, called the axon, along which impulses travel out to another nerve, or to a muscle or some other cell.
7. The two parts of the central nervous system are the brain and spinal cord.
8. The right side of the cerebrum controls artistic and creative tasks, while the left side controls reading, understanding, and thinking. The cerebellum keeps the body balanced and coordinates the body during walking, running, cycling, and other activities. The medulla oblongata controls the rate of breathing and heart beat, and maintains the pressure of the blood and the body temperature.
9. The spinal cord is protected by the bones of the backbone, the vertebrae.
10. A reflex is an urgent reaction to a stimulus that could harm the body or a part of the body.
11. When dust blows towards your eyes, there is a reflex action of blinking to stop the dust getting in your eyes. Your eyes then produce tears to wash away the dust.
12. It is possible to make a conscious effort to cough, to 'clear your throat'. But coughing because something 'goes the wrong way' when you swallow is a reflex action to prevent you from choking.
13.



A = sensory neurone; B = spinal cord; C = spinal cord; D = muscle

14. A voluntary action is an action your brain can control consciously, such as picking up a book or kicking a ball. An involuntary action is an action your brain does not consciously control, such as digestion, breathing, sweating, and maintaining the heartbeat.
15. The autonomic nervous system consists of the nerves which control involuntary actions.
16. The activities which are voluntary are eating, singing, talking, and some kinds of coughing. The involuntary actions are digesting food, blinking, heart beating, coughing, and sneezing.

Assessment

Question 1

The parts of a nerve cell or neurone include:

(A) nucleus, cell body, cytoplasm
(B) nucleus, cell body, chlorophyll
(C) nucleus, cell body, cell wall
(D) nucleus, cytoplasm, cell wall

Question 2

A nerve consists of a bundle of:

(A) nerve endings
(B) nerve fibres
C) nerve impulses
(D) nerve reactions

Question 3

The gaps between nerve cells or neurones are called:

(A) sinuses
(B) synopses
(C) sinews
(D) synapses

Question 4

The central nervous system is made up of:

(A) the brain only
(B) the spinal cord only
(C) the brain and the spinal cord
(D) every nerve in the body

Question 5

The human brain weighs about:

(A) 0.5 kg
(B) 1.0 kg
(C) 1.5 kg
(D) 2.0 kg

Question 6

The brain contains billions of:

(A) nerves
(B) nerve fibres
(C) nerve endings
(D) nerve cells

Question 7

The largest part of the brain is the:

(A) cerebellum
(B) cerebrum
(C) brain stem
(D) medulla oblongata

Question 8

The body's automatic activities such as breathing and digestion are controlled by the:

(A) cerebellum (B) cerebrum (C) brain stem (D) medulla oblongata

Question 9

A tight-rope walker or gymnast would need to have a well-developed:

(A) cerebellum (B) cerebrum (C) brain stem (D) medulla oblongata

Question 10

Information about your surroundings is collected by:

(A) motor cells (B) sensory cells (C) receptor cells (D) stimuli

Question 11

Special types of action, like sneezing and blinking, which you cannot control are called:

(A) reflux actions (B) reflex actions (C) voluntary actions (D) conscious actions

Question 12

Actions you can control consciously, such as kicking a ball or picking up a book off the floor are called:

(A) reflux actions (B) reflex actions (C) voluntary actions (D) involuntary actions

Question 13

Which of the following is a reflex action?

(A) a girl chooses a book in the library
(B) a boy runs away from a fierce dog
(C) a boy blinks when he gets dust in his eye
(D) a girl writes a letter to a friend

Question 14

Match each word on the left with its correct meaning on the right.

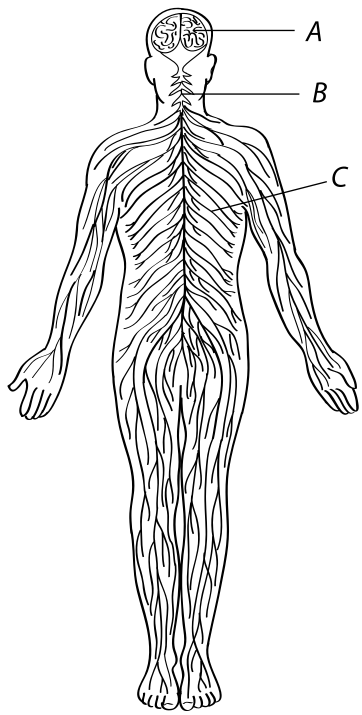
behaviour	a bundle of nerve fibres surrounded by a protective, fatty sheath
nerve	a nerve that carries messages (impulses) from the brain to muscles and other parts of the body
sense organ	a special cell or organ that receives stimuli from outside the body or from other nerve cells inside the body
sense	a pattern of actions carried out by an animal
motor nerve	one of the organs that allows an animal to detect its surroundings
receptor	an action as a result of a nerve impulse, e.g. moving a muscle
response	anything that causes a living organism to do something

stimulus	a nerve that carries stimuli from receptor cells or sense organs
sensory nerve	the ability to be aware of the surroundings by sight, hearing, etc.

Question 15

The nervous system is a complicated network of branching nerves.

Look at this simplified diagram of the nervous system.



a) Name the parts labelled A, B, and C on the diagram.

A ______________ B ______________ C ______________

b) Which TWO parts make up the central nervous system?

____

Abila accidentally stood on a drawing pin and immediate lifted her foot.

c) What was the stimulus in this action?

____

d) A sensory nerve in her foot was responsible for Abila noticing the stimulus. What do these nerves have at one end to 'sense' or detect this?

____

e) Abila did not have time to think about lifting her foot, she just did it without thinking. What is the name given to this type of action?

____

f) What similar kind of action occurs:

i) when dust blows into your eyes? ______________________________

ii) when food accidentally gets into your windpipe? ______________________________

Answers to assessment questions

Question 1 (A) **Question 2** (A) **Question 3** (D) **Question 4** (A) **Question 5** (C)
Question 6 (A) **Question 7** (B) **Question 8** (C) **Question 9** (A) **Question 10** (C)
Question 11 (A) **Question 12** (A) **Question 13** (C)

Question 14

behaviour	a pattern of actions carried out by an animal
nerve	a bundle of nerve fibres surrounded by a protective, fatty sheath
sense organ	one of the organs that allows an animal to detect its surroundings
sense	the ability to be aware of the surroundings by sight, hearing, etc.
motor nerve	a nerve that carries messages (impulses) from the brain to muscles and other parts of the body
receptor	a special cell or organ that receives stimuli from outside the body or from other nerve cells inside the body
response	an action as a result of a nerve impulse, e.g. moving a muscle
stimulus	anything that stimulates or causes a living organism to do something
sensory nerve	a nerve that carries stimuli from receptor cells or sense organs

Question 15

a) A brain B spinal cord C spinal nerves

b) The brain and spinal cord make up the central nervous system.

c) The stimulus to the action was the drawing pin.

d) The nerves have receptors at one end to ‘sense’ or detect the stimulus.

e) This type of action is called a reflex action or innate action.

f) i) When dust blows into your eyes you blink.

ii) When food accidentally gets into your windpipe you cough.

Kidneys and excretion

CHAPTER 2

Teaching Objectives

- To explain excretion and to describe the role of the kidney in the excretion of waste substances
- To examine possible causes of the malfunctioning of the kidneys and to examine treatments and cures

Learning Outcomes

After studying this chapter students should be able to:

- define excretion
- draw and label the human excretory system
- describe the role of the kidney in the excretion of waste
- investigate the possible causes of the malfunctioning of the kidneys
- suggest techniques to cure problems of the kidneys

Introduction

The chemical processes which take place in the body produce waste materials, and the body has to rid itself of these. This is the process of excretion. The kidneys are responsible for filtering off much of the waste chemicals. They also control the amount of water, mineral salts, and other substances in the blood. These substances should be at a certain level and not vary according to how much we eat or drink. All the extra waste chemicals and surplus water are removed through the bladder as urine.

The kidneys

The kidneys look like a pair of very large red bean seeds attached to the back of the body cavity just below the ribs. They are usually embedded in fat which helps to protect them from heavy blows. Blood reaches the kidneys under high pressure from the heart via the dorsal aorta and renal artery, and passes into tiny capillaries in the kidneys. Here much of the water and dissolved substances are forced out of the capillaries and into about a million microscopic blind-ended tubes, kidney tubules or nephrons, in each kidney. As this fluid passes down the kidney tubules, the useful materials and nearly all of the water pass back into the capillaries surrounding the tubules. The rest of the water and the harmful urea, produced from the metabolism of surplus proteins, is the urine. It passes down a thin tube, the ureter, to the bladder where it is stored. The wall of the bladder stretches so that it can hold about a litre of fluid. Once the limit is reached, the bladder wall contracts and the urine is expelled through the urethra.

Medical researchers have developed machines which can take over when the kidneys are seriously damaged or fail to function properly although, of course, kidney transplant is a preferred and permanent alternative to a kidney machine.

Urine

Apart from water, the main content of urine is urea, a waste product produced in the liver from unwanted amino acids. But drugs and other harmful substances are also filtered out of the blood in the kidneys and appear in the urine. That is why tests reveal whether a person has been using illegal substances, as well as other indications of a person's health. Analysis of urine can also reveal diabetes if there is glucose present, or pregnancy when particular hormones appear in the urine.

Urine production

An adult human produces about 1.5 litres of urine a day, but the amount varies widely. For instance, because the kidneys control water in the blood, far more urine is produced when a person has been drinking a lot, or in cold weather when little water is lost in sweating. Some desert animals are very good at saving water, many of them getting all they need from their food alone. Birds and insects do not produce liquid urine. Instead of urea in solution, they produce solid uric acid.

Practical considerations

There are few opportunities for practical work with this topic. If it is decided to dissect a kidney, either as a teacher demonstration or as a class practical exercise, then strict attention to hygiene will be necessary and the students should wear eye protection during the dissection and wash their hands thoroughly afterwards. Students who are sensitive about handling the organs of a dead animal or have religious objections to this should also be treated with compassion and understanding.

Lesson suggestions

1. Excretion

Refer to page 10 of the Students' Book

Starter suggestions

At the beginning of the lesson, ask a student volunteer to sit with an unperforated transparent bag tied loosely around one hand or one bare foot. After a fairly short time, it will be noticed that droplets of condensation have formed on the inside of the plastic bag.

Discuss with the class why it is difficult to survive in a desert.

Main lesson

Emphasize the difference between excretion and defecation.

Refer back to the plastic bag on the student's hand or foot and ask the class what the liquid is that has collected inside the bag. Stress that we sweat all the time, even when we are not aware of it.

Introduce the idea of keeping the body's internal environment constant. Ask the class why, on days when we sweat a lot, do we produce less urine, and vice versa? Emphasize that our body's water intake balances the water leaving the body, and that is a job or function of the excretory system, as well as getting rid of a toxic chemical called urea. Ask the class to recall how the body looses water (in breath from the lungs, in sweat, in urine, in faeces) and how it gains water by drinking and in food.

It may be helpful to compare the way the body balances its water content with the way we balance (or should balance!) our income and expenditure, and the fact that the more money you have, the more you can spend, while the less money you have the less you can spend.

Ask the class to complete Worksheet 1 and then show them a large drawing or PowerPoint slide of the excretory system, internal structure of a kidney and detailed diagram of a kidney tubule. Describe how the kidney tubules filter the blood and stress that the kidneys also control the amount of water and salts in the body and regulate blood sugar levels.

Ideas for investigation and extension work

Urine production

It is said that in summer a person produces less urine than in winter. Devise an experiment which could be carried out to find out if this is true. How would you explain your results?

Kidneys

Taking appropriate hygienic precautions, dissect an animal's kidney, (obtained from a butcher) in front of the class. If possible, select a kidney which still has the blood vessels and ureter attached. Place the kidney flat on a board, and by means of a scalpel or some other sharp blade, cut it into two equal halves by means of a horizontal cut parallel to the board. This is a longitudinal section. Separate the two halves and examine the internal surfaces and the relationship of the tubes to the internal structure. Point out the cortex and medulla. Ask the class to identify the three tubes attached to the kidney. How can they distinguish between them? How would they describe the internal face of the kidney? From what part of the kidney does the ureter directly receive its urine?

WORKSHEET 1

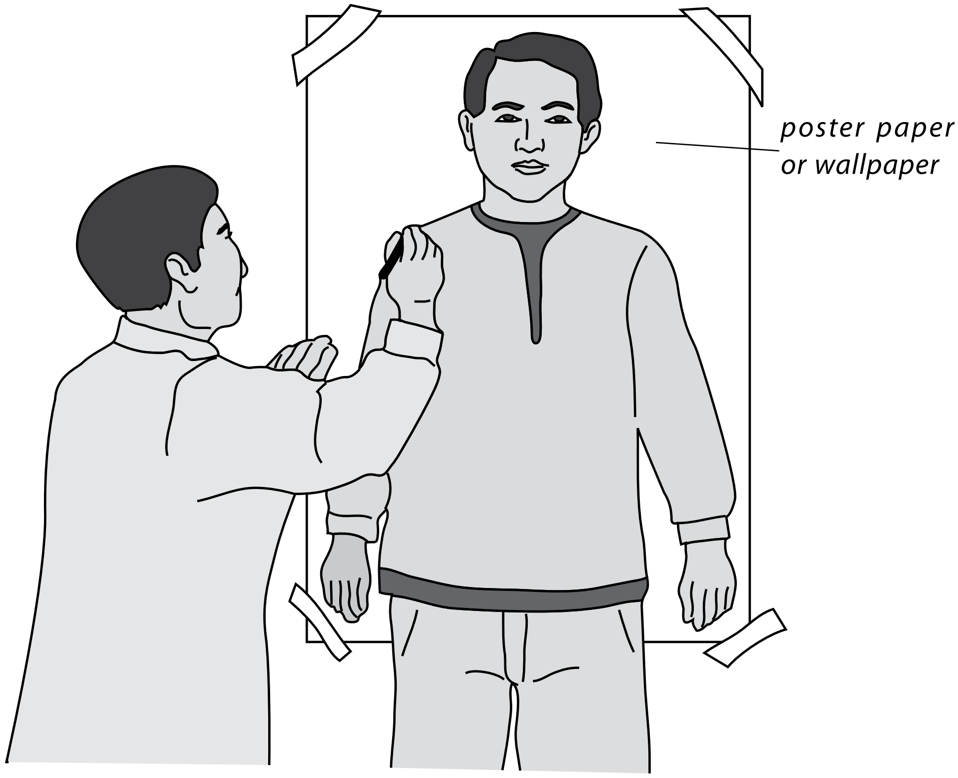
Find your organs

The bodies of mammals are made up of a head, a neck, a thorax, and an abdomen. Many vital organs are found in the thorax and abdomen. They are called 'vital' because they do a life-saving job for the body.

Materials needed: large sheet of poster paper or wallpaper; sticky tape; thick felt-tipped marker pen.

Work with a friend.

1. Lightly tape the large sheet of paper to a wall so that you can stand against it.
2. Ask a friend to draw around your body with a thick felt-tipped marker pen so that you get a good outline of your body.



3. Remove the paper and lay it flat on a desk or bench.
4. Look at this list of vital organs: lungs, stomach, liver, kidneys, bladder, intestines, heart, trachea (windpipe), diaphragm, pancreas

   Draw them on your sheet of paper where you think they are on the body. Think about the size of them as well.
5. Label each organ clearly using a ruler for the arrows.
6. Display your poster when you have finished it. Discuss it with others in your class. Do you all agree where the organs are? If not, check in a textbook to see who is right.

Answers to questions in the Students' Book

1. Excretion is the removal from the body of harmful waste products that were formed *insid*e the body. Defecation is the removal from the body of the solid part of our food which we cannot digest.
2. The lungs are considered to be organs of excretion because they rid the body of carbon dioxide and water which are the waste products of respiration.
3. The skin should be called an excretory organ because it rids the body of some of the urea formed when excess proteins are broken down by the liver.
4. The two functions of the kidneys are to excrete urea and other mineral salts and also to regulate or control the amount of water in the body.
5. Carbon dioxide and water are excreted from the lungs, urea is excreted from the kidneys and, to a lesser extent, from the skin in sweat.
6. The ureter is one of the tubes which carry urine from the kidneys to the bladder, while the urethra carries urine from the bladder to the outside of the body.
7. Each kidney contains over a million funnel-shaped structures called Bowman's capsules. Inside each Bowman's capsule is a ball of blood capillaries called the glomerulus. The blood pressure inside the glomerulus is so high it forces a liquid containing poisonous urea, as well as useful substances such as glucose and amino acids, through the walls of the glomerulus into the Bowman's capsule. The liquid flows down a long coiled kidney tubule or nephron. Here the useful substances are absorbed back into the bloodstream. The liquid that is left is called urine, which consists of urea and unwanted mineral salts dissolved in water. The urine flows down the ureters to the bladder.
8. The blood in the renal arteries contains a high concentration of urea and unwanted mineral salts. The blood in the renal vein has a very low concentration of (or no) urea and unwanted mineral salts.
9. The kidneys regulate the water content of the body. In hot weather you sweat a good deal so less water is passed out of the body as urine. As a result, the urine that is passed from the body contains a high concentration of urea and unwanted mineral salts. In cold weather you sweat very little and so you produce more urine which is a very dilute solution of urea and unwanted mineral salts.

Assessment

Question 1

If there is too much water in the blood, the brain causes a chemical to be released into the blood. Which organ responds to this chemical?

(A) heart (B) liver (C) lung (D) kidney

Question 2

In which of the following is urine stored before it is passed out of the body?

(A) bladder (B) kidney (C) urethra (D) ureter

Question 3

Urea is a by-product of the breakdown in the body of:

(A) fats (B) vitamins (C) proteins (D) carbohydrates

Question 4

Excess amino acids from proteins in the body are broken down to form urea in the:

(A) kidney (B) liver (C) large intestine (D) pancreas

Question 5

Urea is transported by the:

(A) blood plasma (B) blood (C) red blood cells (D) white blood cells

Question 6

The organ that controls the water content of the body is the:

(A) large intestine (B) liver (C) skin (D) kidney

Question 7

Which of the following would not be found in human blood?

(A) carbon dioxide (B) oxygen (C) urea (D) roughage or fibre

Question 8

Which of these parts of the body is NOT used for excreting waste products?

(A) skin (B) lungs (C) kidneys (D) liver

Question 9

What will happen if a person has one kidney removed?

(A) He will survive and remain normal. (B) He will die.

(C) Urea will go on building up in his blood. (D) He will stop urinating.

Question 10

The function of the human kidney is to excrete:

(A) extra salts, urea, and excess water

(B) extra urea, excess water, and excess amino acids

(C) extra urea, extra carbohydrates, and extra water

(D) extra urea, extra salts, and extra sugar

Question 11

If a man eats large amounts of proteins he is likely to excrete more:

(A) urea (B) uric acid (C) sugar (D) carbon dioxide

Question 12

In which part of the kidney does the filtration of dissolved salts occur?

(A) pelvis (B) medulla (C) cortex (D) ureter

Question 13

The name of the part of the excretory system which carries urine from the kidney to the bladder is:

(A) ureter (B) urethra (C) aorta (D) sphincter muscle

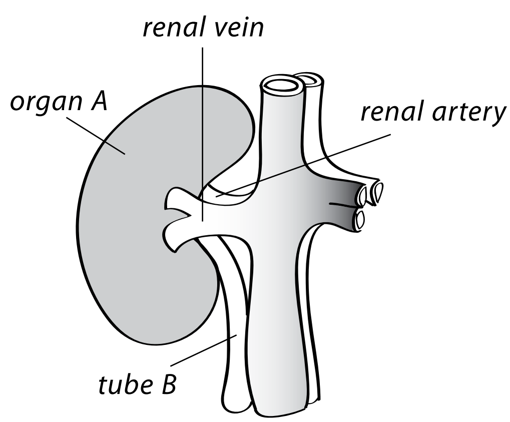
Question 14

The disease which results in glucose being excreted by the kidneys into the urine is called:

(A) anaemia (B) pneumonia (C) bronchitis (D) diabetes

Question 15

The diagram below shows one of the organs in the human body.



a) What is the name of the organ labelled A? ______

b) State ONE function of this organ in the body. ______

c) What is the name of the body system of which this organ is a part?

______

d) The tube labelled B leads to another organ in this system. Name the organ it is connected to.

______

e) This last organ stores a liquid. What is this liquid called? ______

f) Name ONE substance you would expect to find dissolved in this liquid. ______

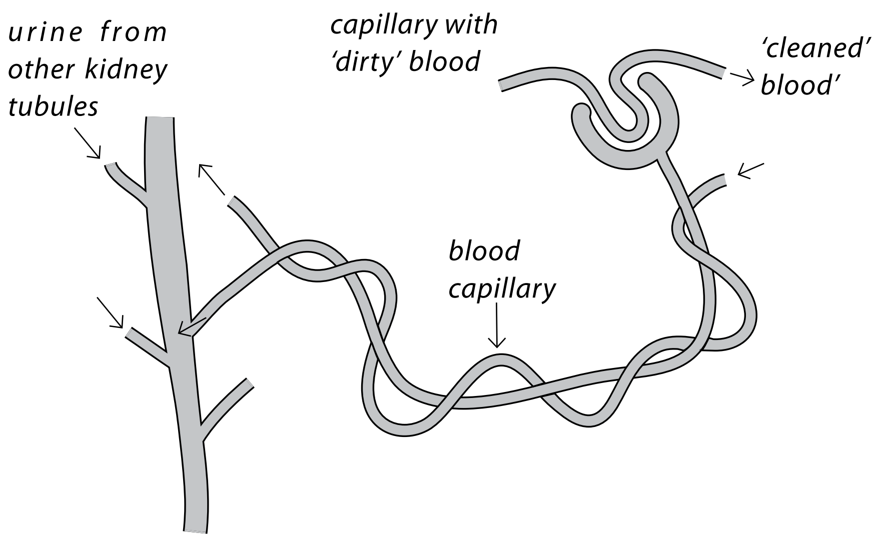
Question 16

a) Complete the following sentences using the words in the box below. You may need to use one or two words more than once.

food	urine	liver	ureter	stored	hormone	tubules	small
reabsorbed	organs	large	urea	proteins	filtering	glucose	

The kidneys are a pair of __________ situated in the lower back of the body. They are involved in controlling the amount of water and salts in the human body and removing toxic __________ from the blood. Water and salts mainly enter the body in __________ and drinks. Urea is a toxic product produced in the __________ by the breakdown of excess __________ (in the form of amino acids) which the body cannot store. All of these substances flow out of each kidney as a liquid called __________. This then passes down a tube called the __________ and into the muscular bladder where it is __________. The control of the amounts of water, salts, and urea in the bloodstream is carried out by millions of tiny structures called kidney __________ which start by __________ out of the blood __________ molecules such as water, glucose, and salts. As the liquid flows down the kidney tubules, all the __________ and much of the water are reabsorbed back into the blood, as are some of the salts, vitamins, and amino acids. None of the urea is __________ because it is poisonous, and it passes through the tubule and eventually out of the kidney. The blood also contains other components, such as __________ and blood cells, but because of their __________ size they remain in the blood at the filtration stage, unlike the smaller molecules mentioned earlier. The amount of water reabsorbed back into the blood is controlled by a __________ called ADH.

b) On the drawing below



i) Write F where filtration takes place.

ii) Write G where glucose is reabsorbed.

iii) Write W where water is reabsorbed.

Answers to assessment questions

Question 1 (D) **Question 2** (A) **Question 3** (C) **Question 4** (A) **Question 5** (A)

Question 6 (D) **Question 7** (D) **Question 8** (D) **Question 9** (A) **Question 10** (A)

Question 11 (A) **Question 1** (C) **Question 13** (A) **Question 14** (D)

Question 15

a) The organ labelled A is the kidney (or right kidney to be precise).

b) There are several ways of expressing the functions of the kidney: removing waste; removing urea; excretion; filtering the blood, OR removing excess ions; taking ions out of the blood, OR controlling the amount of water in the blood or urine; keeping the concentration of the blood constant.

c) This organ is a part of the excretory system.

d) The tube labelled B (the ureter) leads to the bladder.

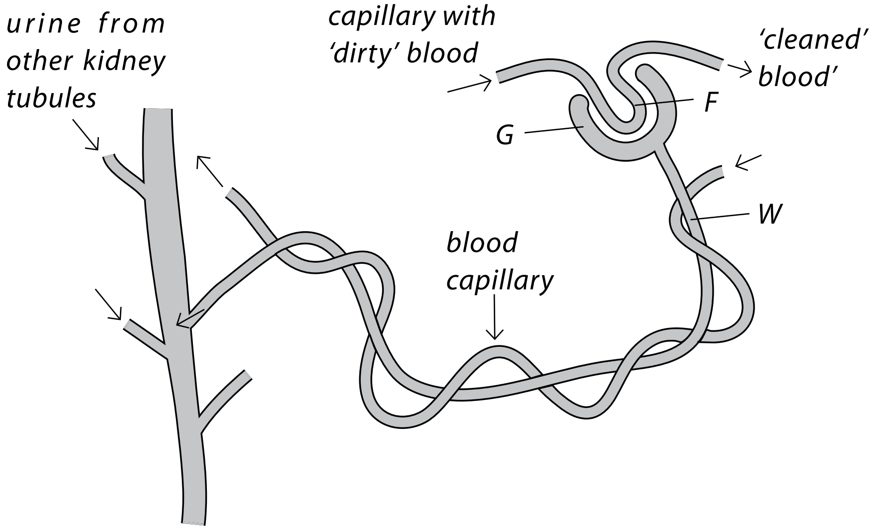
e) The bladder stores urine.

f) The main substance dissolved in the urine is urea. There are also minute quantities of sodium and chloride ions, uric acid, ammonia and creatinine.

Question 16

a) The kidneys are a pair of **organs** situated in the lower back of the body. They are involved in controlling the amount of water and salts in the human body and removing toxic **urea** from the blood. Water and salts mainly enter the body in **food** and drinks. Urea is a toxic product produced in the **liver** by the breakdown of excess **proteins** which the body cannot store. All of these substances flow out of each kidney as a liquid called **urine**. This then passes down a tube called the **ureter** and into the muscular bladder where it is **stored**. The control of the amounts of water, salts, and urea in the bloodstream is carried out by millions of tiny structures called kidney **tubules** which start by **filtering** out of the blood **small** molecules such as water, glucose, and salts. As the liquid flows down the kidney tubules, all the **glucose** and much of the water are reabsorbed back into the blood, as are some of the salts, vitamins, and amino acids. None of the urea is **reabsorbed** because it is poisonous, and it passes through the tubule and eventually out of the kidney. The blood also contains other components, such as **proteins** and blood cells, but because of their **large** size they remain in the blood at the filtration stage, unlike the smaller molecules mentioned earlier. The amount of water reabsorbed back into the blood is controlled by a **hormone** called ADH.

b)



Heredity in living organisms

CHAPTER 3

Teaching Objectives

- To examine the process of cell division and to discuss the importance of mitosis and meiosis
- To explain the process of inheritance in simple terms, and to examine the role of DNA and chromosomes in this process
- To examine inheritance of the external ear structure and eye colour

Learning Outcomes

After studying this chapter students should be able to:

- differentiate between mitosis and meiosis
- identify DNA and chromosomes in the cell diagram
- define heredity and recognise its importance in transferring characteristics from parents to offspring
- compare characteristics related to the ear and eye colour

Introduction

The normal process by which a cell divides into two is called mitosis. Initially the chromosomes become visible in the nucleus, before dividing almost completely longitudinally into a pair of parallel chromatids. The chromosomes shorten and thicken and arrange themselves on a spindle across the equator of the cell nucleus. The chromatids separate so that two sets are formed. One set goes to each end of the spindle of the cell and each forms a new nucleus. A membrane forms down the middle of the cell separating the two nuclei and so creates two new cells, each with a complete set of chromosomes.

Meiosis

A fertilized egg-cell must have a complete set of chromosomes. The egg-cell and sperm cell of which the fertilized egg is made must each have half this number of chromosomes. In order to do this, egg-cells and sperm cells are produced by a special division called meiosis, in which the chromosome number is halved. Thus the egg-cells and sperm cells of humans have twenty-three chromosomes and not forty-six. When the eggs and sperm cells fuse they form a zygote having forty-six chromosomes. During meiosis one chromosome set of the original cell goes into each newly-formed sex cell, but before the two sets separate they exchange genetic material. This means that the offspring from these sex cells will differ in many small characteristics from their parents.

Sex determination

It is a small difference in one pair of chromosomes, the sex chromosomes, that determines whether an organism is male or female. In most female animals and plants the sex chromosomes are similar, and are called XX, but in males they are different and called XY. During meiosis one chromosome of each pair goes into the egg-cells and sperm cells. All the eggs will then contain X chromosomes, but half the sperm cells will have X and the other half Y chromosomes, so that there is an equal chance of male or female offspring being produced.

Variation

People, like all other living organisms, vary in many ways. In fact, no two living things are exactly alike. Even 'identical' twins differ in certain ways. Humans, for example, all have the same general shape and body organs, but characteristics such as height, weight, shape of the face, eye and hair colour, scars, etc. differ from one person to another. These are all examples of variation.

During sexual reproduction, parents pass certain characteristics on to their children. However, not all characteristics can be inherited. A child inherits the shape of its face, ears, and nose and eye coloration from one or other of its parents, but other characteristics, such as skill at football, scars received in an accident, knowledge of science, etc. are not inherited.

Hereditary characteristics

Characteristics which can be inherited from parents are called hereditary characteristics. These characteristics are passed to your body cells on genes from the egg and sperm cells of your parents. They include hair, eye and skin colour, shape of the face, ears, nose and mouth, and all the other characteristics which develop as a baby grows from a fertilized egg. Other aspects of your appearance, such as your height or weight, will be influenced by external or environmental factors, such as the food you eat and the amount of exercise you take. Characteristics such as skills, knowledge, and scars are called acquired characteristics, because people acquire them during their lives.

Some hereditary characteristics show what is called continuous variation. This means that there are many intermediate forms of the characteristic. If you sort a group of people according to height, there is a gradual change from short to tall, with a very few people who are extra short and a very few who are extra tall.

Some other characteristics have few or no intermediate forms. You can either roll your tongue in the middle into a U-shape or you cannot. You are either male or female. Intermediate forms are very rare. Such characteristics display what is called discontinuous variation.

Heredity

The instructions for designing a new baby are contained in the egg-cell or sperm cell of its parents. The chromosomes in the cell nucleus carry these instructions. Every chromosome carries up to 10,000 genes which are made from the chemical called deoxyribonucleic acid (DNA for short). Each gene carries a specific instruction for the 'design' of the baby. Some genes are more dominant than others; they pass on 'stronger' messages. Less strong genes are said to be recessive. The mix of genes you inherit will decide whether you have the potential to be tall or short, are fair or dark, are blue-or brown-eyed, and left- or right-handed.

Practical considerations

There are a large number of simple measurements and other investigations that can be carried out to show how we all differ from each other, even identical twins. However, it is important to be aware of drawing attention to bodily features that some students may be extra sensitive about. When describing variations produced by the environment, for example, it is necessary to be careful about drawing attention to disfiguring scars or overweight students.

Ideally, for the work on cell division, mitosis and meiosis, access to several microscopes is needed. If microscopes are not available, then secondary sources, such as pictures from books, DVDs, or PowerPoint slides will have to do.

Lesson suggestions

1. Variation

Refer to page 21 of the Students' Book

Starter suggestions

Ask the students to recall the two ways in which living things reproduce—asexually and sexually. Ask them if they can remember what the advantages and disadvantages of the two methods of reproduction are as far as plants are concerned.

Let the students work in pairs and draw a table showing how they differ from each other. Ask them to restrict their answers to physical differences.

Main lesson

Go on now to investigate the range of variation within the class. You could perhaps begin with everyone in the class measuring the span of their left hand (the distance from the outstretched little finger to the outstretched thumb). Construct a block graph or histogram of the class results, and show that there is a range of measurements, with a few students having very large or very small hand spans, while the majority of the students have measurements that fall somewhere between the two extremes.

Move on to carry out some of the simple activities described in the **Ideas for investigation and extension work** section of this chapter.

Conclude the lesson or lessons by pointing out that there are two kinds of variation of physical features: continuous variation and discontinuous variation. Continuous variation is where there is a whole range of differences, such as height, weight, finger length, and shoe size. Discontinuous variation is where we can split the population into clear-cut groups, such as hair colour, eye colour, presence or absence of ear lobes, ability to roll the tongue, blood group, etc.

It is important to stress also that variation can come about not only as a result of characteristics inherited from the parents, but also that environmental factors can play a significant role in causing individuals to appear different. Some differences, such as scars, ear piercings, tattoos, and hair styles are due entirely to environmental causes, while many examples of continuous variation can also be affected by the environment. A child might, for example, inherit the tendency to be tall like his parents, but unless he receives a good, balanced diet he may not grow to his full potential.

2. Cells, cell division, and growth

Refer to page 18 of the Students' Book

Starter suggestions

Show the students detailed plans drawn up by an architect of a house, school, or some other building. Explain that normally there are only a few copies of such plans in existence. Point out that a complicated set of chemical plans or instructions is needed to build a human body, and that nearly every cell in your body has these instructions stored in its nucleus (Remember, red blood cells do not have nuclei!).

Main lesson

Ask the students to recall the structures of plant and animal cells and remind them that the nucleus controls the activities of each cell.

Explain that when a cell is not dividing, there is not much detailed structure to be seen in the nucleus, even if it is treated with special dyes called stains. However, just before a cell begins to divide into two, a number of long, thread-like structures appear in the nucleus, and these show up clearly when the nucleus is stained. If sufficient microscopes are available, this is a good point at which the students can carry out the activity described on Worksheet 1. If not, the students can be shown drawings or photographs of the chromosomes in a stained cell.

Explain that each chromosome is made up of a long chain of genes, and that a gene is an instruction for the production of one protein (or occasionally more) which is vital to the development of the cell. For example, one gene may 'instruct' the cell to make the pigment present in the iris of brown eyes, or to make the protease enzyme in the stomach. The chemical which forms genes is called DNA (short for deoxyribonucleic acid).

Complete the lesson by showing how these instructions are passed from cell to cell when a zygote (a single fertilized egg-cell) divides again and again to form a whole organism consisting of thousands or millions of cells. This type of division, which the students need to have explained to them in detail with the aid of clear diagrams, is called mitosis. It is important to point out that it does not take place only in a zygote but also occurs in all living, growing tissues.

If time and equipment permit, you could show the students how yeast cells divide by budding, while if live specimens of amoeba can be found in pond water, they can be placed in a drop of water on a cavity slide and observed with a microscope. The single cell of the amoeba may divide, by the process called binary fission, a process easy for the students to follow.

3. Genes from both parents

Refer to page 22 of the Students' Book

Starter suggestions

Ask the students to work in pairs and to each make a two-column table listing features of themselves which they feel they have inherited from their parents and a second list of things they feel they have not inherited.

Ask the students to make a two-column table comparing sexual and asexual reproduction.

Main lesson

Remind the students that two sex cells fuse together during sexual reproduction. In humans and other animals, one sex cell comes from the mother and one from the father. Each different organism has its own particular number of chromosomes in its body cells, arranged in pairs.

The nuclei of ordinary human body cells each contain forty-six chromosomes in twenty-three pairs.

It is obvious that if a human sperm cell with forty-six chromosomes fused with an ovule or egg-cell with forty-six chromosomes, then the resulting fertilized egg-cell, or zygote, would have ninety-two chromosomes.

In fact, when egg-cells or sperm cells are formed, a reduction division called meiosis occurs, in which the number of chromosomes is halved. When egg-cells or sperm cells are formed, thanks to meiosis, each chromosome 'loses' its partner.

At this point, with the aid of diagrams or a PowerPoint presentation, explain the sequence of events that occur during meiosis.

A knowledge of mitosis and meiosis allows us to understand how variation and heredity occurs. Genes normally work in pairs. One gene in each pair is inherited from each parent. For example, you may have inherited a gene for black hair from your father, and a gene for blond hair from your mother. You do not finish up with striped hair or hair that is halfway between black and blond. This is because only one of these genes can control your hair colour. A black hair gene is dominant over a blond hair gene, so you end up with black hair.

Both of your parents also inherited two genes for each characteristic. However, they only passed on one of the two genes to you. It was a matter of chance which one this was because, unlike other cells, sperm cells and egg-cells only carry one gene from each pair. But when a sperm combines with an egg-cell, they make a new cell with the full set of genes. When an egg-cell is fertilsed, millions of gene combinations are possible. That is partly why people can vary so much, even in the same family.

A good point at which to end the lesson, and one which will help to reinforce the idea of the randomness of heredity, is to give the class an explanation of sex determination in humans. Remind the students that humans have twenty-three pairs of chromosomes. The important point for sex determination is that one of these pairs of chromosomes is called the sex chromosomes—they carry the genes that determine the sex of a person.

Females have two X chromosomes while males have an X and a Y chromosome. As a result of meiosis, all of the egg-cells produced by a woman contain an X chromosome. However, men produce two types of sperm cells. Half of the sperm cells have an X chromosome and half a Y chromosome. If a sperm cell containing an X chromosome fertilizes the egg-cell, the zygote will have two X chromosomes and will develop into a girl. If a sperm cell containing a Y chromosome fertilizes the egg-cell, the zygote will have an X chromosome and a Y chromosome, and will develop into a boy.

Ideas for investigation and extension work

Height variation

Record the heights of all the students in your class. If yours is a mixed school, record the boys and girls separately. Perhaps the students will be able to suggest why when you examine your final results.

Bar graphs, or histograms, are the easiest way of recording the heights. You could make one graph for your class and another for all the students in the year group.

Carefully measure to the nearest 2 cm the height of each member of the class, making sure he or she stands erect and has taken his or her shoes off. Plot height in centimetres on the horizontal or *x* axis of graph, and the number of students on the vertical or *y* axis of the graph. Use a different colour for each class.

You will probably find that in one class the heights may be distributed rather haphazardly, some columns having a number of squares filled in, while others have only one or even none. As the results for other classes are added, the graph should take on a much smoother appearance, with a large number of students in the middle, tailing off on either side to the tallest and shortest students. The more results you obtain, the smoother, and more bell-shaped the histogram will be.

The middle of the histogram will give you an idea of the average height. If the students now look at their individual measurements and at those of the whole class or year group, they can decide whether they are about average height. They could then go on to compare the results of boys and girls of the same age.

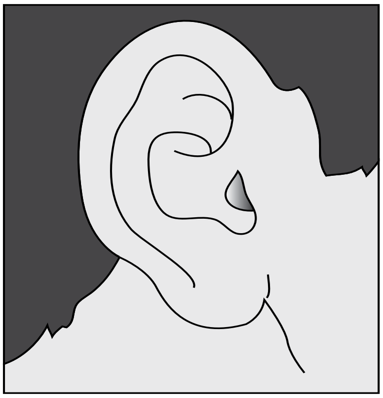
Tongue rollers

This is one example of variation which is absolutely clear-cut. Put out your tongue and try to curl the edges inwards to form a tube. This is called tongue rolling, and either you can do it or you cannot. There are no intermediate stages. Carry out a survey of the members of your class and note the numbers who can and cannot roll their tongues. Compare them with another class and perhaps the whole school (or collect a random sample of results from all the classes in the school). Set out the results in a table like this:

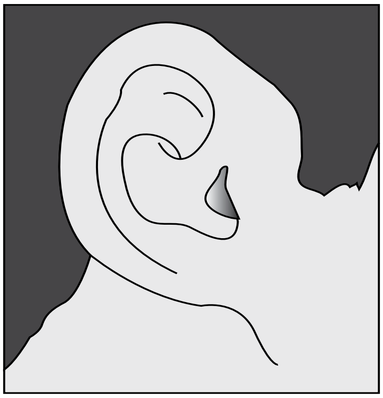
	A Tongue rollers	B Non tongue rollers	Ratio $\frac{A}{B}$
Class			
Class			
Whole school			

Ear lobes

This investigation could be carried out at the same time as the survey of tongue rollers. Some people have a small lump of flesh which hangs down from their ears. This is called a lobe. Other people have no lobes. This is another clear-cut variation—you either have ear lobes or you do not, although the lobes, if present, can vary in size.



Ear with lobe



Ear without lobe

Collect statistics of lobes present or absent, for your class, your year, and if possible the whole school. Tabulate the results, and work out ratios as for the tongue rolling activity.

Hair variation

Hair colour can be any shade from blond to black, with various browns, auburns, and reds in between. Some people have very fine hair, others much coarser hair. These are not clear-cut variations and are thus more difficult to measure.

It is simpler to look at the hair of each individual and note whether it is straight, wavy, or curly. You do, however, have to make sure that the curls are natural ones!

Present you results in a table, like the one below. You can work out the percentages as follows: If, say four students out of a sample of eighty have curly hair, then the percentage is found like this:

$\frac{4}{80} \times \frac{100}{1}$ per cent = 5 per cent

	Straight hair		**Wavy hair**		**Curly hair**	
	No.	**Percentage**	**No.**	**Percentage**	**No.**	**Percentage**
Class						
Class						
Whole school						

Make a class key

Using the information you have already collected on tongue rollers, types of ear lobe, eye colour, and hair type, make a key to identify all the members of the class. You might begin by dividing the class into two groups: those who can roll their tongue and those who cannot. These two groups could then be split into those who have ear lobes and those who do not, and so on.

Body temperature variation

Find out how much the 'normal' body temperature of 37°C varies from person to person. Digital clinical thermometers are easiest to use, but if there are not enough to go round they should be washed in disinfectant before being used again. From the class results, make a bar chart or histogram recording how many in the class have temperatures in each 0.5°C range. How does this compare with the population average? If it varies, can you suggest why?

WORKSHEET 1

Mitosis in onion roots

Materials needed: onion bulb; narrow-topped jar or wide-necked bottle; 2 watch glasses; Bunsen burner; wire gauze; fine scissors or scalpel; acetic orcein stain; dilute hydrochloric acid; dropper; forceps or tweezers; microscope slides; coverslips; filter paper; microscope

Safety: Wear safety spectacles.

1. Completely fill a narrow-topped jar with water. Rest an onion bulb on top so that the base of the onion just touches the water. Stand the jar on a sunny windowsill.
2. After about a week, the onion should have started to send out roots.
3. Use fine scissors or a scalpel to carefully remove the tips of some of the roots (pieces about 5 mm long). Such pieces of root provide excellent material for observing chromosomes during cell division (mitosis).
4. Put a root tip in a watch glass and carefully cover it with nine drops of acetic orcein stain and one drop of dilute hydrochloric acid.
5. Warm (but do NOT boil) the contents of the watch glass over a low Bunsen flame.
6. Add a few more drops of acid and keep on warming. The acid helps to break down the cell walls of the root tip.
7. Turn off the Bunsen burner and cover the watch glass with another watch glass of the same size upside down. Leave it for five to ten minutes to cool.
8. Using forceps or tweezers, carefully transfer the root tip to a clean microscope slide and add one drop of acetic orcein stain before covering it with a coverslip.
9. Lay a piece of filter paper over your slide and squash the root tip by gently tapping with the blunt end of a pencil. Be careful or else you will break the coverslip!
10. Look at the slide under the low power of a microscope and find the very end (rounded) of the root tip. Now go to high power and look closely for cells where chromosomes are visible.

    What do the chromosomes look like?

    ___

    Why did you stain the cells?

    ___

    Onion cells have eight chromosomes. How many chromosomes are there in the cells you have observed?

    ___

    Draw some of the cells and chromosomes in the space below:

Answers to questions in the Student's Book

1. A gene consists of DNA. It is a set of chemical instructions that controls a feature of a human being or some other living organism.
2. Genes instruct our bodies to make proteins.
3. The thread-like structures found in the nucleus are chromosomes.
4. Both chromosomes and genes are made of deoxyribonucleic acid (DNA for short).
5. Human body cells have forty-six chromosomes (twenty-three pairs).
6. A species is one of a group of living things which have important features in common and which can breed with each other.
7. The name given to the differences in characteristics between organisms of the same species is variation.
8. The word 'inherited' describes the one or more characteristic(s) which have been passed to us by one or both of our parents.
9. Characteristics of human beings which are totally unaffected by the environment include fingerprints, eye colour, natural hair colour, blood group, nose and ear shape, whether or not we can roll our tongue, and certain inherited diseases.
10. i) Differences which have an inherited cause include fingerprints, eye colour, blood group, nose and ear shape, ability to roll the tongue, and certain inherited diseases such as haemophilia.
    ii) Differences which have an environmental cause include liking certain foods and colours and liking certain types of clothes, music, or books.
    iii) Differences which have both an inherited and an environmental cause include height, weight, intelligence, musical and artistic ability and, to some extent, skin colour.
11. Because of his outdoor manual work, Robert is likely to be more muscular and have a more darkly tanned skin than his identical twin brother. They will have the same eye colour, hair colour, fingerprints, and blood group.
12. i) The rarest blood group in all the countries is AB.
    ii) The country with the lowest percentage of blood group B is England.
    iii) American people are more closely related to English people than Pakistani people because the original colonists of America came from Britain.
13. The average height of the twins was very similar whether they were brought up together or apart. There was a much bigger difference in the weight of the two groups. Twins brought up apart were much heavier, presumably because they received more or better food. Perhaps this was because they did not have to share the food with a twin.

Assessment

Question 1

Where are chromosomes found?

(A) cell membrane (B) genes (C) nucleus (D) vacuole

Question 2

Where are genes found?

(A) cell membrane (B) vacuole (C) mitochondria (D) chromosomes

Question 3

What substances do genes tell our bodies to make?

(A) proteins (B) carbohydrates (C) fats (D) vitamins

Question 4

Chromosomes and genes are made of:

(A) TPA (B) RNA (C) DNA (D) PVA

Question 5

The division of a cell to form two daughter-cells is called:

(A) meiosis (B) mitosis (C) halitosis (D) hydrolysis

Question 6

The division of a cell which results in each daughter-cell receiving exactly half the number of chromosomes is called:

(A) meiosis (B) mitosis (C) halitosis (D) hydrolysis

Question 7

Whereabouts in a plant or animal does meiosis take place?

(A) in the reproductive organs (B) in all the body cells

(C) in the digestive organs (D) in the heart and lungs

Question 8

How many chromosomes does a human body cell contain?

(A) 46 (B) 23 (C) 27 (D) 47

Question 9

How many chromosomes does a human sperm or egg-cell contain?

(A) 46 (B) 23 (C) 27 (D) 47

Question 10

How many chromosomes does a fertilized human egg-cell contain?

(A) 23 (B) 27 (C) 46 (D) 47

Question 11

What are genes made of?

(A) chromosomes (B) proteins (C) peptides (D) DNA

Question 12

Which of the following is not affected by the environment?

(A) height (B) sex (C) skin colour (D) sight

Question 13

Which of the following words describes the way in which animals or plants of the same species look or behave slightly differently from each other?

(A) deviation (B) revolution (C) variation (D) organization

Question14

Zoya and Hiba are identical twins. They both have brown eyes. Zoya has brown hair but Hiba has red hair.

a) What do you think one of the twins has done to alter her appearance?

____

b) Explain your answer.

____

Adeel and Saim are brothers. Adeel has red hair and Saim has dark brown hair.

c) Does this mean that one boy has changed his natural hair colour?

____

d) Explain your answer.

____

The Khan family has five sons. They all have dark brown hair. Three of them have blue eyes and the other two have brown eyes. Three of them can play the guitar and two are very good swimmers.

e) Which of these characteristics have they inherited from their parents?

____

f) Which of these characteristics are environmental characteristics?

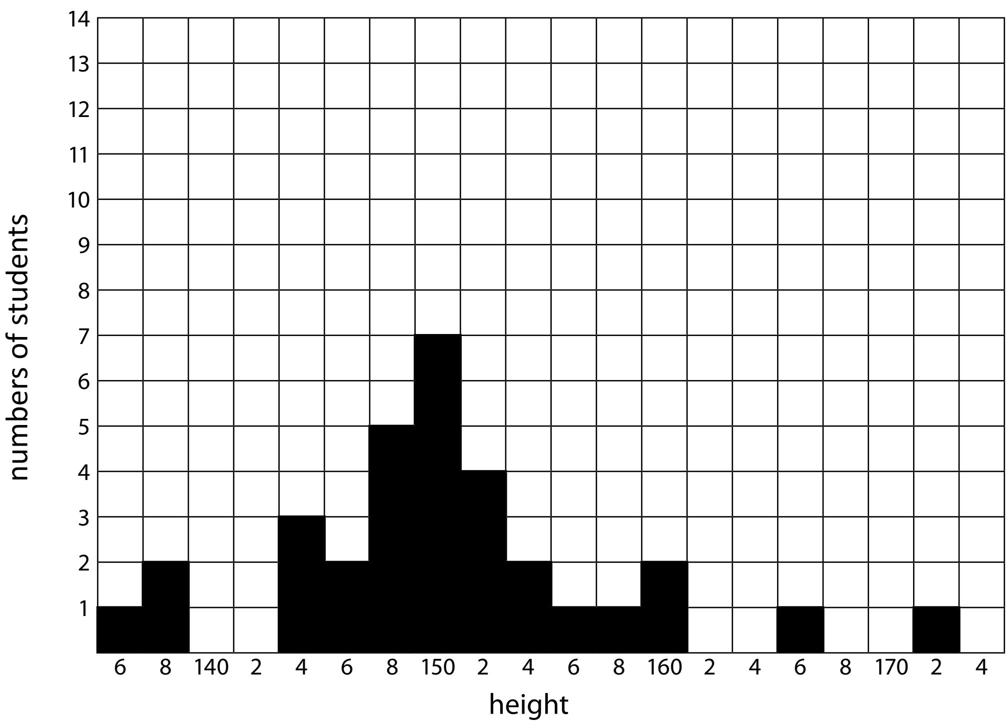
Shafay found a really tall sunflower plant in his grandfather's garden. Shafay took a seed from the sunflower plant and planted it in a pot in the garden. He expected it would grow as big as him, but after two months it was only half his size.

g) What are the FOUR factors that might have affected the growth of Shafay's sunflower?

h) What could Shafay do to make his sunflower plant grow better?

Question 15

Rabia and Sadia measured the heights of the people in their class. They produced the bar chart below.



a) i) What units were used to measure the height of the students? ______

ii) Which height group contained the largest number of students? ______

iii) What was the height of the tallest student in the class? ______

iv) What was the height of the shortest student in the class? ______

v) How many students were in the class? ______

b) If Rabia and Sadia investigated the following characteristics, which would produce a bar chart with a similar shape to the one above?

   i) weight

   ii) eye colour

   iii) intelligence

   iv) hair colour

c) Which of the following statements is TRUE?

   Weight is a characteristic which:

   i) depends totally on inherited factors ☐

   ii) depends totally on environmental factors ☐

   iii) depends on both inherited and environmental factors ☐

Question 16

Differences between members of the same species are called variations or characteristic features. These variations can be inherited or environmental.

a) Look at the three characteristic features below. For each one say if the characteristic feature is inherited, environmental, or a mixture of the two.

   intelligence ____________________

   weight ____________________

   blood group ____________________

   eye colour ____________________

b) Characteristic features are inherited when genes are passed from parents to their children. What structure in every living cell contains the genes? ____________________

c) Very rarely, two human beings have exactly the same genes. Explain how this is possible. __________

   ____

Answers to assessment questions

Question 1 (C) **Question 2** (D) **Question 3** (A) **Question 4** (C) **Question 5** (A)

Question 6 (B) **Question 7** (A) **Question 8** (A) **Question 9** (B) **Question 10** (C)

Question 11 (D) **Question 12** (A) **Question 13** (A)

Question 14

a) One of the twins must have dyed her hair.

b) Natural hair colour is a genetic characteristic, and since the twins are identical they would both have inherited the same gene for hair colour.

c) No, this does not mean that one boy has changed his natural hair colour.

d) Brothers do not necessarily inherit the same hair colour unless they are identical twins.

e) Hair colour and eye colour are the characteristics the sons have inherited from their parents.

f) Swimming and playing the guitar are environmental characteristics.

g) The four factors that might have affected the growth of Abbas' sunflower are temperature, sunlight, water and soil conditions.

h) To make his sunflower plant grow better, Abbas could place it in a warm, sunny place, water it regularly, and 'feed' it with mineral salts in the form of a chemical fertilizer or liquid manure. He could also add compost or humus to the soil in the pot to improve the soil texture and its mineral salt content.

Question 15

a) i) The units used to measure the height of the students were centimetres.

ii) The 150 cm height group contained the largest number of students.

iii) The tallest student in the class measured 172 cm.

iv) The shortest student in the class measured 136 cm.

v) There were 32 students in the class.

b) Weight and intelligence would produce a bar chart with a similar shape to the one in the question.

c) The TRUE statement is that weight is a characteristic which:

iii) depends on both inherited and environmental factors.

Question 16

a) intelligence—mixture

weight—mixture

blood group—inherited

eye colour—inherited

b) The structure in every living cell that contains the genes is the nucleus/chromosomes.

c) Identical twins have exactly the same genes. (Note: the word 'twins' alone is not an adequate answer.)

Biotechnology

CHAPTER 4

Teaching Objectives

- To explain the meaning of biotechnology and to emphasize that the process is not new
- To explain how DNA is made and copied and to describe the relationship between DNA, genes, and chromosomes
- To explain why bacteria and other microbes are used in biotechnology
- To explain in simple terms the process of genetic engineering
- To examine the uses of biotechnology in industry, agriculture, medicine, and human health and nutrition

Learning Outcomes

After studying this chapter students should be able to:

- define biotechnology
- explain how DNA is copied and made
- describe the relationship between DNA, genes, and chromosomes
- define bacterium
- explain how genes are introduced into a bacterium
- list some biotechnological products used in daily life
- explain that genetic modification in different foods can increase the amounts of essential nutrients
- list the general applications of biotechnology in various fields
- explain how biotechnology assists in meeting the nutritional needs of growing populations

Introduction

Biotechnology is the use of living organisms to make or modify products. Microbes such as bacteria and fungi were the first organisms to be harnessed in this way, followed by plants and, most recently, by animals.

'Old' biotechnology

Biotechnology is both an old and a relatively new area of science. 'Old' biotechnology includes well established processes, such as those involved in fermenting drinks, baking bread, making dyes and the explosive cordite, sewage disposal and the production of antibiotics. However, the term has become particularly familiar since the development of genetic engineering during the 1970s.

Fermentation

The first area of biotechnology was fermentation, the breakdown of glucose and other sugars by bacteria or yeasts in the absence of oxygen. The 19th century French chemist Louis Pasteur showed that fermentation was promoted by microbes. Fermentation by yeast has been used for centuries in brewing and baking bread, while bacteria have been used for generations to make cheese. More recently, special fermentations involving other species have been used industrially in the manufacture of propanone (acetone), butanol, glycerol, citric acid, and glutamic acid (monosodium glutamate). Other products include vinegar, oxalic acid, used in printing and dyeing, propenoic acid (acrylic acid) used in the manufacture of plastics, lactic acid used for acidifying foods, and antifreeze.

Genetic engineering

Much of the 'new' biotechnology uses organisms altered to work more effectively than before, or to function in entirely new ways. As their understanding of microbes and the structure of nucleic acids has grown, biotechnologists have been able to increase the output of traditional microorganisms by creating an environment in which they multiply rapidly and can be used for large-scale production. Sometimes, rather than the whole microbe, biotechnologists use part of it, particularly enzymes, that will perform some chemical conversion. Where there is no known enzyme or microbe that manufactures a substance naturally, the techniques of genetic engineering can be used to create new strains. For example, foreign genes can be inserted into bacteria to give them new characteristics and induce them to synthesize particular materials, such as vaccines or human growth hormones or insulin. The biotechnological application of genetic engineering requires four main stages: isolating the required gene; inserting the gene into the bacteria; inducing the bacteria to start synthesising the product; and harvesting that product.

A rapidly developing area of biotechnology is the use of microbes to break down pollutants in the environment, particularly in the soil. Bacteria are also used in many countries to leach metals such as iron, zinc, copper, and uranium out of inaccessible or low-grade ores. A tenth of the copper produced annually in the United States is obtained using this 'microbial mining'.

Plant and animal biotechnology

Plant biotechnology has the same goals as traditional plant breeding: to develop crops and other plants with such features as resistance to pests and drought, and improved palatability and nutrient content. However, genetic engineering gives much more precise and predictable results than traditional plant breeding techniques. Crop plants have also been developed that are not affected by the weedkillers that farmers use to control weeds.

In animals, genes may be introduced into fertilized embryos. For example, the human gene for alpha-1 antitrypsin, which is used to treat the chronic lung condition emphysema, has been incorporated into the DNA of sheep. The sheep then produce alpha-1 antitrypsin in their milk. The same method has been used to direct sheep to produce the blood-clotting factor which is required by people suffering from haemophilia.

An alternative type of biotechnology is the production of cloned animals. The first mammal to be cloned from an adult body cell was Dolly the sheep that was born in Scotland in 1996.

Practical considerations

An understanding of the structure of DNA and its behaviour in cell division, though rather complex, is vital to a proper understanding of biotechnology. Under ideal conditions it would be useful if the students could investigate the tissue culture of plants and also experiment with cultures of bacteria and antibiotics. However, in most schools it will be much easier, and safer, to experiment with yeasts and moulds to give the students some practical experience in the handling of microbes. Because of the nature of the topic, only one worksheet has been included in this chapter. If the teacher feels the need for more, it is suggested that some of the longer assessment items are used as worksheets for the students to research. It would also be very useful to collect newspaper stories and magazine articles about biotechnology and genetic engineering for later discussion with the class.

Lesson suggestions

1. What is biotechnology?

Refer to page 27 of the Students' Book

Starter suggestions

Ask the students what they understand by the word 'biotechnology'. Ask them whether biotechnology is a new branch of science or an old one and why it is so important.

Ask the students how many uses of microbes they can think of. Some of the foods made using microbes include bread, yoghurt, cheese, soy sauce, and Quorn, a meat substitute.

Pass round the class small pieces of bread made with yeast and also small pieces of unleavened bread. Ask the students to compare the two types of bread.

Main lesson

Describe some of the benefits and uses of 'old' biotechnology. Emphasize the importance of fermentation processes and remind the students that fermentation is a type of anaerobic respiration carried out by microorganisms such as yeast.

Examine yeast cells under a microscope as described in the **Ideas for investigation and extension work** section of this chapter, and also grow some moulds, as described there. Carry out the simple experiment described on Worksheet 1 to provide the students with knowledge of the conditions needed by yeast cells if they are to grow and respire.

If time and the facilities are available, bake some bread dough made with and without yeast.

Finally describe the importance of microbes in decomposing organic matter, discuss the growing importance of biogas as a renewable energy source and, if suitable facilities are available, make some biogas, as described in the **Ideas for investigation and extension work** section of this chapter.

2. Understanding genes

Refer to page 33 of the Students' Book

Starter suggestions

If the students have their own dictionaries, ask them to count how many word definitions there are on a typical page and then multiply that number by the number of pages in the dictionary. Compare the students' estimates of the number of words, and then stress that all those words have been made up using just twenty-six letters of the alphabet. And the students' dictionaries are probably quite small. The large Oxford English Dictionary contains more than 600,000 words. Point out that the 'dictionary' which makes us what we are (the genetic code) is based on only four 'letters', but these are arranged in very long strings.

Ask the students to work with a partner and draw up a two-column table containing features about themselves which they think have been, and have not been, inherited from their parents.

Main lesson

Recall why individuals of the same species, in our case the human species, are different from each other, even though they have the same basic structure. Also recall the structure of cells and what is in the nucleus. Remind the class that genes control the development of different characteristics, and that chromosomes are long chains of genes that are made of DNA.

Discuss where our genes come from and relate this to egg-cells and sperm cells and sexual reproduction.

Show the students a model or a large photograph of a model of DNA. Introduce them to the term 'double helix' and compare it to a spiral staircase or twisted ladder, with the rungs made of the four bases that form the genetic code.

Briefly describe the work of Watson and Crick in determining the structure of DNA.

Using the pictures in the Students' Book, or a PowerPoint presentation, show the students how DNA replicates itself.

If time permits, discuss the Human Genome project briefly, and also how we can produce new plants and animals with the characteristics we prefer. You could, at this point, set up the experiment on growing and selecting the characteristics of barley, described in the **Ideas for investigation and extension work** section of this chapter. It is important when carrying out this experiment to stress the length of time it takes and the uncertainty of the results (compared with the results of genetic engineering of organisms).

3. Genetic engineering

Refer to page 36 of the Students' Book

Starter suggestions

Ask the students what they understand by genetic engineering and why it is so much in the news nowadays.

Find a newspaper cutting referring to some controversial aspect of genetic engineering, such as protests at the introduction of genetically modified crops in a western country. Ask the students to make a judgement about the protests—are they right or wrong? Ask them to explain their reasons.

Main lesson

Show the students a microphotograph of a bacterial cell, and a large diagram showing the structure of a bacterial cell and point out that microbes are used in genetic engineering because they are single-celled organisms which reproduce rapidly. Bacteria, in particular, are unusual because they do not have a nucleus. The genetic material floats freely in a ring inside the bacterial cell and because of this it is easier for scientists to alter the genes of bacteria.

Ask the students whether any of them suffers from, or knows someone who suffers from, diabetes. (Diabetes is not uncommon amongst school students.) Ask the students what causes diabetes and what the treatment is. Describe, ideally with a PowerPoint presentation, film clip, or DVD, how genetically modified bacteria are able to produce human insulin. Incidentally, another hormone made in the same way is cortisone. Many students may well have received cortisone to treat skin disorders, inflammation, or allergies.

Discuss what is meant by the word 'clone'. If time and facilities allow, the students could at some time take cuttings of some house plants such as Pelargoniums or Impatiens, or herbs such as mint, or even cuttings from tea plants. They should realize that the cuttings are clones, because they are genetically identical to the parent plant.

Describe to the students the details of how Dolly the sheep was cloned (it is described briefly in one of the assessment questions later in this chapter). Point out that cloning sheep and other domesticated animals allows us to have more animals with a desired feature, such as the ability to produce more meat or better milk.

If time permits, ask the students to discuss the ethics of cloning animals, including humans.

Ideas for investigation and extension work

Growing barley

Plant some barley seeds in a garden plot, or in boxes or seed trays full of soil or compost. The seeds should be planted about 7 cm apart in rows 10 cm apart. If possible, grow some of the seeds in a greenhouse and some outside. Look for variation amongst the plants as they grow. The sort of variations you could look for include the height of the mature plants, the number of branches, the length of the ears, the weight of the grain produced per plant, the colour of the seeds, the structure of the flowers, and any other feature which shows variation. Plot graphs of some of the variations. Ask the students how they would set about producing a new variety of barley with a special feature; for example, a heavier grain production per plant.

Yeast

Yeast is a single-celled fungus that has been used by man for thousands of years. Research and produce a timeline showing how the use of yeast has developed.

Looking at yeast

Prepare some fermenting yeast by adding a teaspoon of sugar to a tube half-filled with water to which some dried or fresh yeast has been added. Leave the mixture to stand for a few hours in a warm place. With a pipette, put a drop of the yeast suspension on a microscope slide. If it is available, add a drop of a stain such as lactophenol. Cover it with a coverslip and examine the slide under a microscope, first under low power and then high power. Yeast cells multiply by a process called budding, whereby a cell sends out a small outgrowth, which gets bigger and eventually separates from the parent cell. Can you see the cells clearly? Are any of them budding?

Making bread

Yeast is used in breadmaking. Dough, from which bread is produced, is a mixture of flour, water, and yeast. The yeast causes slight fermentation, and the bubbles of carbon dioxide gas make the dough swell up. That is why most of the bread you buy is full of tiny holes. Make some bread from dough with and without yeast (the latter is called unleavened bread). Compare the taste and texture of the two types of bread.

Growing moulds

Soak a piece of bread in water and then squeeze it gently to remove the excess water. Use a needle to place on the bread some mould (or a pinch of dust which will almost certainly contain spores of moulds). Seal the bread in a transparent plastic box, plastic jar, or plastic bag and put it to one side in a warm place. Examine the bread, through the container, a few days later. What changes in colour do you observe? Has any change in texture occurred? Continue to observe it for a further two to three weeks. How much solid bread remains? Dispose of the container and decomposed bread safely without opening it.

Antibiotics from the soil

Design and carry out an experiment to find out whether soil fungi produce antibiotics.

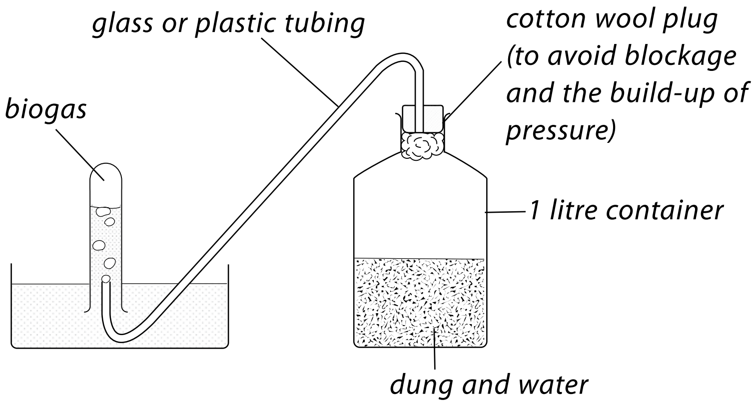
Safety: Do NOT start your experiment until you have discussed it with your teacher.

Gas from rubbish tips

Use the Internet to find out where good use is made of the gas produced from rubbish tips. What is the gas and what is it used for? What part does biotechnology play in the production of this gas?

A model biodigester

The world's supply of fossil fuels will soon be used up and eventually it will be necessary to find new sources of energy. One possibility, which is already being used on a small scale, is to convert waste organic matter into biogas, with the help of microbes. The teacher may like to demonstrate the model biodigester shown in the diagram page 46. The demonstration may be rather smelly, depending on the kinds of waste material available. It works well with fresh dung, such as that of horses, cows, or chickens. It might be interesting to compare different kinds of dung and vegetable wastes and see which produces the most biogas in the shortest time.



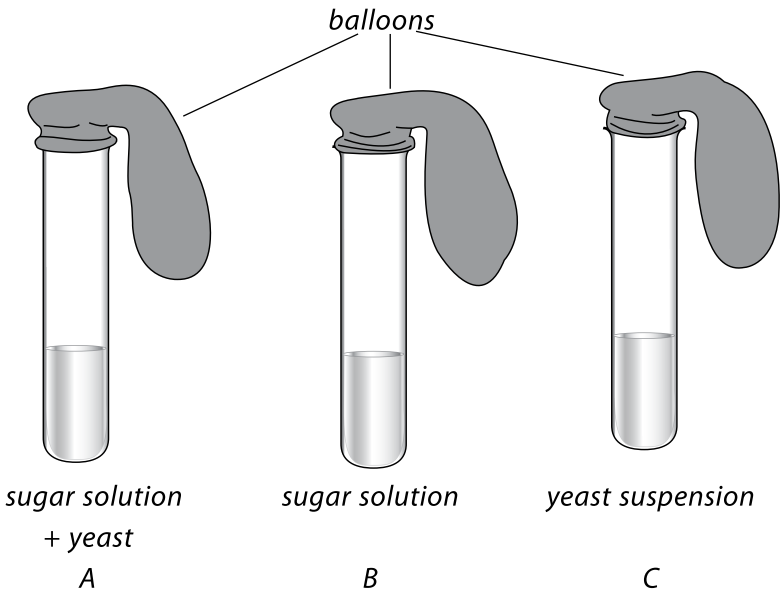
***Safety**:* Strict hygiene conditions will be necessary when handling and disposing of the dung. Biogas is flammable and will need to be handled carefully.

WORKSHEET 1

Growing yeast

Materials needed: four clean test-tubes; yeast (dried or fresh); three balloons; teaspoon or spatula; beaker of warm water; sugar; labels; limewater

1. Half-fill three test-tubes with water.
2. Label the three tubes A, B, and C.
2. Now add a pinch of yeast to tubes A and C.
4. Put a level teaspoon of sugar in tubes A and B.
5. Stretch the neck of a balloon over the top of each of the three tubes. Make sure there is no air in the balloons.
6. Stand all three tubes in a beaker of warm water (at about 30 to 35°C) for 30 minutes.



Draw the tubes as they appear at the end of the experiment.

What happens to the balloon on tube A? ______________________________

____

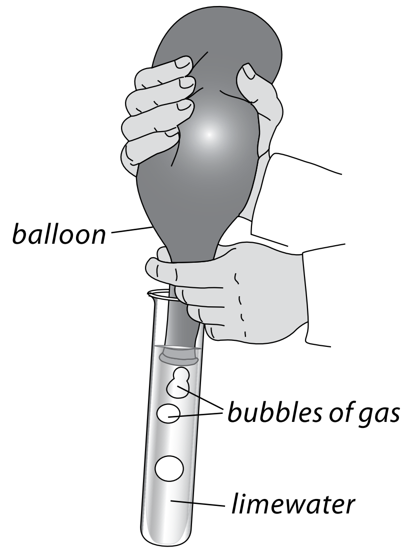
What happens to the balloon on tube B? ______________________________

____

What happens to the balloon on tube C? ______________________________

____

If any of the balloons become filled with gas, squirt the gas into a test-tube of limewater like this:



Write a conclusion for this experiment. ____

____

____

Extend the experiment with two more tubes containing sugar solution and yeast, each covered by a balloon. Place one tube in a warm place and the other in a refrigerator. Leave them for 30 minutes and compare the results. What have you discovered?

Answers to questions in the Students' Book

1. Biotechnology is the use of living things to make products or to do work for human beings.
2. chemical base – gene – chromosome – nucleus – cell
3. Genes make proteins in our cells.
4. The substance found in both chromosomes and genes is deoxyribonucleic acid (DNA for short).
5. The DNA molecule is shaped like a double helix.
6. The four kinds of base which make up the 'rungs' of the DNA molecule are adenine, guanine, thymine, and cytosine.
7. To make an exact copy of itself, a DNA molecule separates down the middle, rather like two halves of a zip fastener coming apart. Spare chemical bases then join up with the matching pairs on the separated strands. As a result, one strand of DNA makes two identical new strands.
8. Fermentation is the use of yeast and other microbes to produce bread, cheese, yoghurt, and ethanol. Fermentation is a type of anaerobic respiration.
9. Yeast is a single-celled fungus.
10. Microbes are used in genetic engineering because they are single-celled organisms which reproduce rapidly. Bacteria, in particular, are unusual because they do not have a nucleus. The genetic material floats freely in a ring inside the bacterial cell and because of this it is easier for scientists to alter the genes of bacteria.
11. If a farmer wanted to produce sheep with finer wool using selective breeding, he would breed only from those sheep which had finer wool.
12. The advantage of genetic engineering over selective breeding is that it is less of a 'hit and miss' affair. Selective breeding involves a number of genes, whereas genetic engineering involves transferring genes in a much more precise and predictable way.
13. Diabetes is a disease which occurs in a person whose pancreas cannot produce the hormone insulin. Insulin controls the amount of glucose in the blood and people with a serious form of the disease have to inject themselves with insulin.
14. The original source of insulin for injection came from the pancreas of cows.
15. In recent years, insulin has come from bacteria which have had the gene that produces human insulin inserted into their genes. The old animal insulin was slow and expensive to purify. Some patients were allergic to animal insulin, while others did not like to inject themselves with a substance that came from dead animals. The insulin produced by bacteria is high-quality, pure, and relatively inexpensive to produce.
16. A digester or biodigester, is a large container in which plant remains, human sewage, animal wastes, leftover food, and other waste materials are decayed or decomposed with the help of bacteria and fungi. The methane they produce is tapped off for use as a fuel. The rotted material can be used as a soil improver, or fertilizer.

17. Materials that could be put into a digester to produce methane include human sewage, animal wastes, leftover food, plant remains, and other organic waste materials.
18. A vaccine is a liquid containing dead or weakened bacteria or viruses of the kinds that produce diseases. The vaccine makes the body produce antibodies in the blood ready to destroy those kinds of bacteria or viruses if they later enter the body. Some vaccines widely used are those against polio, influenza, measles, mumps, and whooping cough.
19. i) Penicillin was discovered in 1928 by a Scottish scientist Alexander Fleming.
    ii) Penicillin is produced by one of the fungi known as moulds.
    iii) Penicillin and other antibiotics attack the bacteria which cause diseases such as cholera, typhoid, and tuberculosis, and also the organisms which cause blood poisoning.

Assessment

Question 1

The use of living organisms for the production of useful substances or in useful processes is called:

(A) biology (B) biochemistry (C) biophysics (D) biotechnology

Question 2

Which of the following is NOT a use of modern biotechnology?

(A) producing more and better food (B) helping the environment
(C) improving our health (D) making the roads safer

Question 3

The ancient process used to produce bread, cheese, and yoghurt is called:

(A) manufacturing (B) fermentation (C) filtration (D) fractionation

Question 4

Fermentation is a type of:

(A) photosynthesis (B) transpiration
(C) aerobic respiration (D) anaerobic respiration

Question 5

Which type of microbe is used for making bread?

(A) bacterium (B) fungus (C) virus (D) virus and fungus

Question 6

Microbes or micro-organisms are NOT required in the manufacture of:

(A) cheese (B) bread (C) jam (D) yoghurt

Question 7

At which temperatures do the enzymes in yeast work best?

(A) 0-10°C (B) 10-15°C (C) 15-25°C (D) 25-30°C

Question 8

Which of the following statements is NOT true?

(A) Cheese results from the growth of microbes in sour milk.

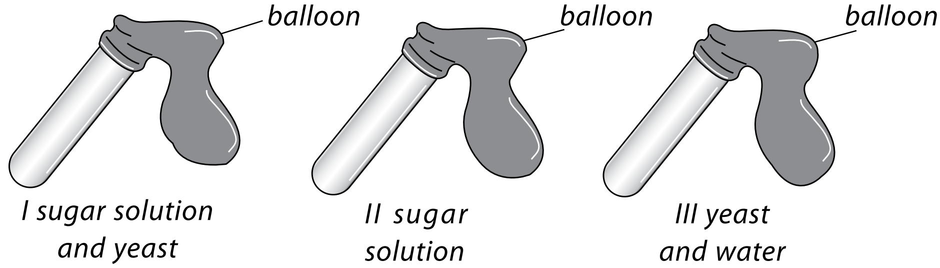
(B) Different kinds of cheese can be made using different types of microbe.

(C) In cheese production, microbes are only needed to give flavour.

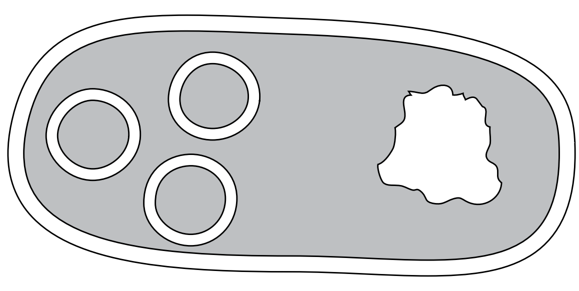
(D) Unleavened (unrisen) bread is made without yeast.

Question 9

The three test-tubes in the diagram below were placed in a water bath at 37°C. After 30 minutes which balloons were filled with gas?



(A) I, II, and III (B) I and II (C) I and III (D) I only



Question 10

The diagram above shows:

(A) an animal cell (B) a plant cell (C) a bacterium (D) a virus

Question 11

Which one of the following scientists discovered penicillin?

(A) Buchner (B) Crick (C) Fleming (D) Pasteur

Question 12

The shape of the DNA molecule is often described as a:

(A) double spiral (B) double ladder (C) double helix (D) double base

Question 13

The 'rungs' of a molecule of DNA are made up of four building blocks called:

(A) acids (B) alkalis (C) salts (D) bases

Question 14

The modification of plant or animal species by choosing parents with desirable (wanted) characteristics is called:

(A) natural selection (B) variation (C) selective breeding (D) inbreeding

Question 15

A clone is :

(A) a collection of genes (B) part of a DNA molecule
(C) one of a group of identical organisms (D) a microbe that divides very quickly

Question 16

The hormone produced by the pancreas which controls the amount of glucose in the blood is called:

(A) amylase (B) insulin (C) diabetes (D) insulation

Question 17

The cells of bacteria are unusual in that they do NOT have:

(A) any DNA (B) a nucleus (C) a cell wall (D) a cell membrane

Question 18

All the genes in a particular living organism are called its:

(A) genetics (B) variation (C) heredity (D) genotype

Question 19

The fuel gas which can be made by some bacteria that are decomposers is:

(A) oxygen (B) carbon monoxide (C) hydrogen (D) methane

Question 20

Every person, apart from identical twins, has a different:

(A) DNA touchpad (B) DNA tissue (C) DNA fingerprint (D) DNA footprint

Question 21

Which of the following fuels is made in a biodigester?

A) hydrogen (B) oxygen (C) methane (D) carbon monoxide

Question 22

a) All species of potato are believed to have originated in southern Peru where potatoes were first domesticated between 4000 and 5000 years ago. Today potatoes are the world's fourth largest food crop (after rice, wheat, and maize) and there are thousands of varieties for all types of cooking.

i) Describe how a grower would try to make plants that have larger potatoes than the original wild plants.

____

____

ii) What is this process called? ______________________________

b) In 1996, a sheep called Dolly was the first animal in the world to be cloned. She was made by replacing the nucleus of an egg-cell from one sheep with the nucleus from a body cell of another sheep.

i) Would Dolly have had the characteristics of the sheep from which the egg-cell came or the sheep from which the body cell came? Give a reason for your answer.

____

____

ii) Dolly died when she was only six years-old. She was suffering from arthritis and lung disease. These diseases don't usually affect sheep until they are more than twice that age. Some people say that the cloning caused her early death. Do you think this is true? Give a reason for your answer.

____

____

c) Biological washing powders contain protease enzymes.

i) Explain how these washing powders can help to remove blood from clothes.

____

____

ii) Many of the enzymes that are used in biological washing powders were obtained from bacteria that live in hot springs at temperatures of up to 80°C. Explain why these enzymes are especially usefully in washing powders.

____

____

iii) When biological washing powders were first introduced, some people found that they affected the skin of their hands. The powders have since been modified. Suggest how the early biological powders could harm people's hands and skin.

____

____

Question 23

Influenza (flu) is a disease caused by a virus. It can make you very ill or even kill you. However, if you have influenza, antibiotics cannot be used to help you get better.

a) Why will a doctor NOT give you antibiotics is you are suffering from influenza?

____

b) People are offered vaccinations (injections) to protect them from some serious kinds of flu. The vaccine may contain dead or weakened viruses, but not the normal living virus.

i) Why is the normal living virus not used in the vaccine?

____

ii) How will the vaccination make the person immune to that particular flu virus?

____

____

iii) A newborn baby can have immunity to viruses for a short time without being vaccinated. Explain why this is.

____

Question 24

Scientists believe that one day they may be able to use biotechnology to recreate extinct animals such as the mammoth. The mammoth has been extinct for 10 000 years, but the bodies of mammoths have been found preserved in the ice in Siberia. The complete genetic code for a mammoth is carried in its DNA, but unfortunately the scientists have not yet succeeded in extracting enough DNA from the dead mammoths.

a) i) What is DNA?

____

ii) Draw a diagram of a small piece of the DNA molecule.

b) Briefly explain how DNA carries the genetic code.

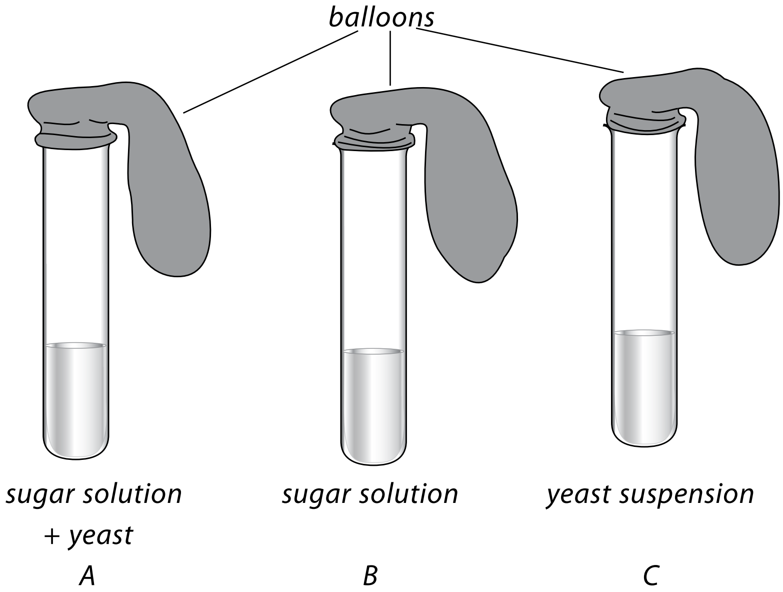
c) Suggest TWO ways in which scientists might obtain mammoth DNA.

d) Suggest how scientists might set about recreating a mammoth if they can obtain enough of its DNA.

e) Suggest how biotechnology could be used to prevent other animals from becoming extinct.

Question 25

Salman has been experimenting with the growth of yeast cells. He set up three tubes, labelled A, B, and C. In tube A he put sugar solution and yeast. In tube B he put just sugar solution and in tube C just yeast suspension. He fitted a balloon over the top of each tube and placed them in a beaker of water at 37°C for half an hour.



i) Why did Salman fix a balloon over the mouth of each tube?

ii) Which were the TWO control tubes?

iii) What would you expect to happen in the other tube?

____

iv) What would you expect to see if any gas formed by the yeast was bubbled into limewater?

____

v) What would Salman find if he put sugar solution and yeast in another tube and left it in the refrigerator for half an hour? Explain your answer.

____

vi) What is the name given to the type of reaction carried out by yeast?

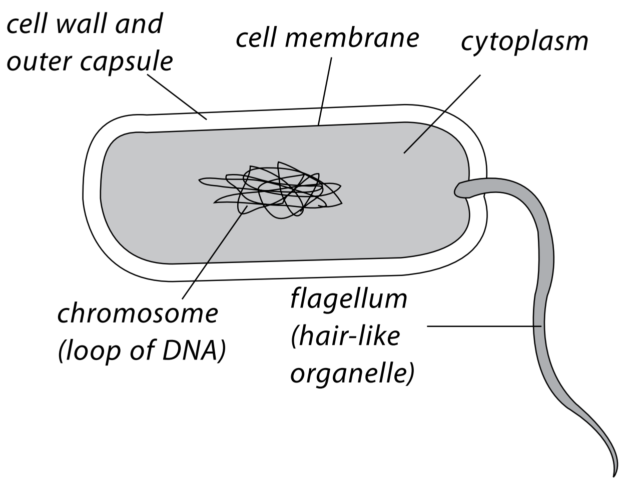
____

vii) What job or function does yeast have in baking bread?

____

Question 26

a) The diagram below shows the cell of a bacterium that can cause disease.



i) Give ONE difference between this bacterial cell and a typical animal cell.

____

ii) Name TWO diseases caused by bacteria.

____

b) Not all bacteria are harmful. Give TWO examples where bacteria are useful to mankind.

____

c) Scientists find it fairly easy to alter the genes of bacteria so that they can carry out useful work. Describe TWO features of bacteria which make them ideal for carrying out such 'genetic engineering' experiments.

____

____

Answers to assessment questions

Question 1 (D) **Question 2** (D) **Question 3** (A) **Question 4** (D) **Question 5** (B)
Question 6 (A) **Question 7** (A) **Question 8** (C) **Question 9** (C) **Question 10** (C)
Question 11 (C) **Question 12** (C) **Question 13** (D) **Question 14** (C) **Question 15** (C)
Question 16 (B) **Question 17** (B) **Question 18** (D) **Question 19** (D) **Question 20** (C)
Question 21 (C)

Question 22

a) i) The grower would select seeds from the original plants that had the largest potato tubers and grow them the following year. He or she would then keep repeating the process. Note: If the grower chose the largest tubers, rather than the seeds, he or she would simply be cloning the original plants.

ii) This process is called selective breeding.

b) i) Dolly would have had the characteristics of the sheep from which the body cell came, because this cell contained the nucleus/genes/DNA, whereas the nucleus of the egg-cell donor had been removed.

ii) Any sensible answer is acceptable, e.g. it was simply a coincidence; the physical handling of the DNA/chromosomes/genes could have damaged these delicate structures; the cloning process may have reduced Dolly's resistance to these diseases.

c) i) Protease enzymes digest proteins. These washing powders can help to remove blood from clothes because the haemoglobin (the red pigment in blood) is a protein. The enzymes turn the haemoglobin into soluble amino acids which can be washed away.

ii) The fact that many of the enzymes that are used in biological washing powders were obtained from bacteria that live in hot springs at temperatures of up to 80°C is useful because clothes are washed cleaner by higher temperatures and these bacteria area adapted to living at these high temperatures. Most enzymes are denatured if they get too hot.

iii) The early biological powders could harm people's hands and skin because hands and skin cells contain proteins, and presumably the enzymes began to digest these.

Question 23

a) A doctor will not give you antibiotics if you are suffering from influenza because influenza is caused by a virus and antibiotics have no effect on viruses—they only kill bacteria.

b) i) The normal living virus is not used in the vaccine because it will give the patient the illness.

ii) Vaccination makes the person immune to that particular virus by making the person produce antibodies which will destroy the virus if it later enters the body.

iii) A newborn baby can have immunity to viruses for a short time without being vaccinated because antibodies are passed from the mother's blood to the developing baby's blood, or later in the mother's milk.

Question 24

a) i) DNA stands for deoxyribonucleic acid, a chemical which carries the genetic information.

ii) At its simplest, the diagram of a small piece of the DNA molecule should show the double helix with a bases acting like the rungs of a ladder.

b) The explanation should mention that it is the bases of the DNA which carry the genetic code, and that these bases can be arranged in different orders.

c) Scientists might obtain mammoth DNA by genetically engineering more of it from a small fragment, or they might be able to obtain more mammoth tissue.

d) If they can obtain enough of mammoth DNA, scientist might be able to recreate it by injecting the DNA into a body cell of a large mammal, such as an elephant, from which the nucleus has been removed.

e) Biotechnology could be used to prevent other animals from becoming extinct by setting up a 'bank' of frozen embryos, or frozen sperms and eggs, of endangered animals.

Question 25

i) Salman fixed a balloon over the mouth of each tube so that he could see whether any gas was formed.

ii) The two control tubes were B and C.

iii) In tube A the yeast would ferment the sugar, producing carbon dioxide which would partially inflate the balloon.

iv) If the gas formed by the yeast was bubbled into limewater, the limewater would go milky, showing the presence of carbon dioxide.

v) Nothing would happen to a tube containing sugar solution and yeast if it was left in the refrigerator for half an hour. This is because yeast cells need warm conditions if they are to grow and multiply.

vi) The name given to the type of reaction carried out by yeast is fermentation (or anaerobic respiration).

vii) The carbon dioxide produced by yeast makes bread rise/become spongy.

Question 26

a) i) The differences between the bacterial cell and a typical animal cell are that the bacterial cell has a cell wall but no nucleus. Typical animal cells also do not have a flagellum.

ii) Diseases caused by bacteria include tetanus, whooping cough, food poisoning, tuberculosis, cholera, diphtheria, dysentery, yaws, and pneumonia.

b) Examples where bacteria are useful to mankind include the production of vinegar, yoghurt, cheese, silage, compost, biogas, and insulin, sewage treatment, and the general decomposition of waste organic matter.

c) Bacteria are ideal for carrying out 'genetic engineering' experiments because the chromosomes are not protected by a nucleus and the bacterial cells grow and reproduce very quickly when given the right food and temperature.

Pollution and the environment

CHAPTER 5

Teaching Objectives

- To examine the sources, properties, and effects of air pollutants both on the environment and on human organ systems
- To explain the importance of the natural greenhouse effect and its role in regulating world temperatures
- To examine the phenomenon of global warming and its implications for world climatic conditions, human welfare, and food supply
- To describe the causes and effects of ozone depletion and acid rain
- To examine the effects of deforestation on the environment
- To explain the importance of local and global conservation measures on natural resources

Learning Outcomes

After studying this chapter students should be able to:

- identify the sources, properties, and harmful effects of air pollutants
- list problems in human organ systems caused by air pollutants
- plan and conduct a campaign that can help to reduce air pollution in their local environment
- explain the greenhouse effect
- describe the causes and effects of ozone depletion
- carry out research to explain global warming and its likely effects on the Earth
- design a model to explain the greenhouse effect
- explain the formation of acid rain and identify its consequences on living and non-living things
- define deforestation
- state the effects of deforestation on the environment
- identify human activities that have long-term adverse consequences on the environment
- explain the importance of local and global conservation of natural resources
- suggest ways in which individuals, organizations, and government can help to make Earth a better place to live

Introduction

In recent years, more and more scientists have produced evidence that the world's climate is becoming warmer. Like the acid rain, photochemical smog and ozone depletion dealt with later in this section, scientists believe this global warming is due largely to pollution of the atmosphere by human activities.

During the twentieth century, the average temperatures at the surface of the Earth have increased by 0.74°C, but the trend has been three times greater since 1976, with some of the largest temperature increases occurring in the high latitudes.

The carbon cycle

Carbon dioxide is one of the gases that make up the air we breathe. Carbon dioxide in the atmosphere is continuously being created and destroyed. It is part of a vast carbon cycle that includes all living organisms, the atmosphere, the oceans, and the Earth's rocks.

In the natural world, carbon is used over and over again in this carbon cycle. Green plants are the only living things that are able to make their own food and they use carbon dioxide and water during photosynthesis. Carbon dioxide is available to plants in the atmosphere and dissolved in surface water, particularly in the oceans. The oceans contain about fifty times more carbon dioxide than the atmosphere and act as a reservoir that helps to keep the amount of carbon dioxide in the air more or less constant, at 0.03 per cent.

The carbon in green plants is transferred to animals when they eat plant materials, or eat other animals that have fed on plants. Animals and plants release carbon back into the air in the form of carbon dioxide when they respire. When animals and plants die they decompose, slowly releasing carbon dioxide back into the atmosphere.

Human disruption of the cycle

Human activity can disrupt the carefully balanced carbon cycle in two main ways. We release carbon dioxide that would otherwise have remained locked up for long periods, for example by burning wood, coal, oil, or natural gas. We also interfere with the removal of carbon from the atmosphere by destroying forests. In 1987, for example, an area of the Amazon rainforest the size of Britain was burnt. This not only added 500 million tonnes of carbon dioxide to the atmosphere, it also removed a vast number of trees that could have absorbed carbon dioxide.

Carbon dioxide makes up only about 0.03 per cent of the atmosphere, but the levels of it are rising rapidly. Every form of burning produces carbon dioxide, and over the last hundred years or so, the amount of carbon dioxide in the atmosphere has increased. This is mainly because of the burning of fossil fuels and the clearance of forests by burning. In an industrialised country such as the United States, over one-third of the carbon dioxide that is released into the atmosphere is from burning fuels to generate electricity. Almost the same amount comes from motor vehicles and jet aircraft, while factories account for about one-quarter of the carbon dioxide. Central heating systems in homes, and domestic fires produce about one-tenth of the carbon dioxide.

The greenhouse effect

Under normal circumstances, heat from the Sun is absorbed by the Earth's surface. Most of this heat is then radiated away from the Earth, some escaping back into space. Carbon dioxide and certain other gases let the Sun's energy pass through to the Earth, but they trap the heat coming back from the surface of the Earth. By doing this, they act in the same way as the glass of a greenhouse in retaining warmth.

The Earth needs this so-called 'greenhouse effect'. If gases like carbon dioxide did not absorb some of the heat radiating from the Earth, the world would be a much colder place. The oceans would freeze over and the average world temperature would be –15°C. Until recently the world's natural levels of carbon dioxide had kept the Earth at a comfortable average temperature of 15°C for thousands of years.

However, since the start of the Industrial Revolution, the Earth's human population has been seriously changing the composition of the atmosphere. We are building up a chemical blanket of carbon dioxide and other polluting gases that act like a greenhouse with extra thick glass, trapping more of the heat that used to escape from the Earth into space. The result is an increase in the global temperature.

Locked-up carbon

Normally the carbon in coal, oil, and natural gas remains locked in rocks for millions of years. But that has all changed since the Industrial Revolution. Each year now we pour around six billion tonnes of carbon dioxide into the atmosphere as a result of burning the fossil fuels coal, oil, and natural gas. Analysis of the gas bubbles in Greenland ice showed that the amount of carbon dioxide in the air during the last Ice Age varied between 170 and 280 parts per million. Today the levels of carbon dioxide in the atmosphere stand at 370 parts per million.

Other greenhouse gases

As well as carbon dioxide, there are more than thirty other so-called greenhouse gases. They include nitrous oxide, given out by fertilizers, motor vehicle exhausts, coal-fired power stations and burning rainforests. This gas can trap around 270 times more heat than the same amount of carbon dioxide.

Another important greenhouse gas is methane. Methane is about thirty times more effective at trapping heat than carbon dioxide, although at the moment there is less methane than carbon dioxide in the upper atmosphere. Methane is produced during coal mining, and oil and natural gas production. Microbes in swamps and rice paddy fields produce methane, as do the digestive systems of cows, sheep, and other plant-eaters, and the decay of animal manure. Methane is also released into the atmosphere when vegetation and fossil fuels are burned and when domestic waste is buried where it can rot. In the last 200 years or so, concentrations of methane in the atmosphere have doubled. This is probably mainly because the numbers of cattle and other domestic animals being kept for human food has increased.

Other greenhouse gases include CFCs and ozone. The latter is produced in the smog over traffic-choked cities.

The effects of global warming

The world average temperature rose by more than 0.74°C during the twentieth century. The year 2010 was the hottest since world records of temperature were first collected in 1850, and the ten hottest years have all occurred since 1998. If the estimates of scientists for the future build-up of carbon dioxide and other greenhouse gases are correct, then the average global temperature could rise by up to 3°C by 2050 and by up to 6.4°C by the end of the century. This may not sound very much, but it is important to remember that the last Ice Age was ended by a rise in temperature of only 3°C or 4°C.

As the temperature rises, most climatologists believe that the world weather will continue to become more extreme. The reason is that, as the Earth's temperature rises, the additional heat will increase the amount of water that evaporates from the oceans and seas. This in turn will create more rain clouds and more storms. There is already evidence that we are suffering more storms, hurricanes, and tornadoes, but at present we cannot be sure whether this is a short-term or a long-term change. As precipitation patterns change and air pressure patterns shift, water may well become scarcer in places where it is already in short supply, while many low-lying parts of the world will suffer from flooding.

Melting ice

At any one time, almost four-fifths of all the fresh water on Earth is frozen solid as ice. Ice exists in several forms, including the Polar ice-sheets, icebergs, mountain glaciers, and the snow and ice on mountaintops. The mass of floating ice over the Arctic is, on average, 5 to 7 metres thick. The vast Antarctic ice sheet has an average thickness of about 2500 metres. In places it may be 4000 to 4500 metres thick.

Since the early twentieth century, most of the world's glaciers have retreated and their meltwater has helped to raise sea levels by several millimetres a year. The Polar ice caps are also contracting. If global warming continues to melt the Polar ice, then sea levels will rise still faster. Even more important, water, like everything else, expands as it heats up. And so, as the Earth becomes warmer, the water in the oceans will expand, raising the sea levels still further. They have already risen by about 15 centimetres since 1880, and are likely to rise another 30 centimetres before the year 2030. This will be enough to flood whole islands and also many of the world's great cities and ports that are on low-lying parts of the coast. Increased rain will add to the problem of flooding.

Flooding

The projected rise in sea levels of 30 centimetres by 2030 would affect about 200 million people worldwide. The United States would need to spend at least an extra $450m a year on flood prevention measures. But for low-lying countries such as Bangladesh, the Netherlands, and many island states in the Indian and Pacific Oceans, it could mean disaster. The danger is not simply from flooding, but from increased coastal erosion, higher storm tides, flooding from backed-up rivers, and increased salinity in freshwater supplies.

Even more worrying is what effect the warming of the oceans will have on the pattern of ocean currents. The top two metres of the world's oceans hold as much heat as the entire atmosphere, and ocean currents play a major part in transporting this heat energy around the world. Another unknown is what will happen to the countless multitudes of tiny plants and animals (phytoplankton and zooplankton) that live near the surface of the oceans and seas.

Global warming and agriculture

Although scientists think that global warming will raise the average temperature of the Earth by up to 3^0C by 2050, they cannot predict in detail what effect this will have on the world's climate. It is believed that the higher temperatures will not be evenly spread. The rise will probably be higher at the Poles than at the Equator, and the major crop growing areas will move away from the Equator towards the Poles. The main grain belt in the United States, for example, will move towards Canada and farmers will have to adapt to these changes. It will not be possible to grow some crop plants where they are grown at present and there will be a drop in crop yields in tropical and sub-tropical regions. Since carbon dioxide encourages plant growth, crop yields may actually be higher in fertile areas.

Global warming, wildlife, and people

Human diseases such as malaria and cholera, and deaths from heat stroke and skin cancer seem certain to increase. Some kinds of plants and animals, which are not able to adapt to the new climatic conditions, will become extinct. Those species particularly at risk are those that are very sensitive to changes in temperature.

One species that seems doomed if the sea ice continues to melt is the polar bear. It is estimated that one-fifth of the Arctic's summer sea ice could have melted by 2050. If that does happen, the polar bear will no longer be able to hunt, and so its numbers will decline drastically. By contrast, it is possible that the populations of pest species, such as rats, flies, mice, and mosquitoes, whose numbers are normally reduced by cold winters, may rocket out of control.

Acid rain

Another result of air pollution is acid rain. Acid rain is a general term used to describe the acidity, not only of rain, but also of other forms of precipitation, including hail, sleet, snow, mist, fog, and dew. In recent years, acid precipitation has had a huge impact on natural and man-made environments across the world.

Fossil fuels and acid rain

Rainfall is always slightly acidic because carbon dioxide gas in the atmosphere dissolves in rainwater to form the weak acid, carbonic acid. However, the burning of fossil fuels produces waste gases, amongst them sulphur dioxide and oxides of nitrogen. When these are combined with moisture in the atmosphere they produce sulphuric and nitric acids and make the rain even more acid.

Acid rain has many harmful effects, including damage to freshwater fisheries, lakes, streams, groundwater, forests, farm crops, buildings, statues, metal structures, and human health. There is the added problem that acid rain is not a local problem. Once the acid gases have reached the atmosphere, the pollution may be carried hundreds or even thousands of kilometres, particularly if the fumes have come from a tall chimney. As a result, acid rain produced by one country or continent can damage the environment of another.

Electricity and acid rain

Most homes in the developed world are now powered mainly by electricity. As a result, it is easy to forget that, when we use electricity, we may still be causing pollution, although indirectly. This is because most of our electricity is produced with the aid of combustion. When coal, oil, or natural gas are burned in a power station, sulphur dioxide and oxides of nitrogen find their way into the air, and these are among the main causes of acid rain.

Large areas of Canada, Scandinavia, and central Europe suffer a lot of damage from acid rain because they are downwind of major industrial areas. However, acid rain is becoming a problem in Venezuela, the east coast of Brazil, parts of West Africa, central India, eastern China, South Korea, Japan, Malaysia, Indonesia, and eastern Australia. In fact, wherever there are large numbers of industries or motor vehicles, there are signs of environmental damage from acid rain.

Acid rain and lakes and rivers

It is in aquatic habitats that the effects of acid rain are most obvious. Acid rain runs off the land and finishes up in lakes, rivers, streams, and marshes. The rain also falls directly on to these. As the acidity of the water increases, the numbers of fish and other aquatic animals begin to decline. Some species of plant and animal are better able to survive the acidic waters than others. Freshwater shrimps, mussels, and water snails are the first to suffer, followed by fish such as salmon, roach, and minnows. The eggs and young of the fish are worst affected, and the acid water can prevent fish eggs from hatching properly, or cause the young fish to be deformed when they are hatched. The acidity of the water also affects plants and animals indirectly because it causes toxic substances such as aluminium to be released into the water from the soil, thus harming fish and other aquatic animals and upsetting the natural balance of species.

Acid rain, forestry, and agriculture

If acid rain falls on alkaline rocks and soils, such as in chalk and limestone areas, the acid is neutralized and there is very little damage to the environment. If acid rain falls where the rocks and soils are already acid, such as in those areas where the underlying rock is granite, the acid is not neutralized and the damage can be severe.

Acid rain reduces crop yields and destroys trees. In both cases this is because it washes essential plant foods from the soil. As a result, sensitive trees and other plants grow more slowly or even die. In addition, the acid rain washes the protective waxy coating off plant leaves, leaving them more vulnerable to drought or attack from pests and diseases.

Many of Europe and North America's great forests have been damaged by acid rain. There has been widespread damage of forests in the north-eastern United States and Canada and as much as 70 per cent of Germany's Black Forest has been damaged.

Acid rain and the built environment

Acid rain also corrodes, or wears away, the outside surfaces of stone buildings, statues, and monuments, as well as paintwork on vehicles and buildings, and metal structures such as steel bridges and railings. Many of the world's great monuments, mosques, churches, cathedrals, and famous statues show signs of damage by acid rain.

Acid rain and human health

Acid rain not only affects wildlife and man-made structures, it also affects human health. Most of the damage is to the respiratory system. Sulphuric and nitric acids in acid rain cause asthma, dry coughs, headaches, and eye, nose, and throat problems. Toxic metals dissolved by the acid rain can enter the human food chain when they are absorbed by fruits and vegetables or are passed on to the animals from which we obtain meat, milk, and eggs. Aluminium, for example, which is leached from the soil by acid rain, causes kidney problems and has been linked to Alzeimer's disease.

Reducing acid rain

In some countries the problem of acid rain is being tackled by adding lime to lakes and streams to neutralize the acid. The treatment works, but it is only temporary. It is also expensive and has to be repeated every three to five years.

Most of the acid gases that produce acid rain probably come from power stations and factories. The exhaust fumes produced by motor vehicles also contain acid gases. Power stations and factory chimneys can be fitted with devices that remove the sulphur dioxide gas, while cars can be fitted with catalytic converters, which reduce the nitrogen oxides in exhaust fumes.

Smoke and smog

Some of the gases that pollute the air, such as CFCs, are invisible. Others, especially exhaust fumes from motor vehicles and smoke from factory chimneys, carry tiny particles. These particles of dust and soot settle on cities, blackening paintwork, masonry, and washing hung out to dry. The smallest particles block the stomata of plants, and slow down transpiration and the exchange of gases with the atmosphere. Dust and smoke are inhaled by people, and if they are present in high concentrations, may cause serious respiratory ailments.

When fog is present in cities and industrial areas, particles of solid matter, especially those from smoke, are trapped in the atmosphere. The resulting mixture of smoke and fog is known as 'smog'. This form of air pollution is a particular problem since it affects human health, buildings, animals, and plants.

Pollution from vehicle exhausts

In the worst kind of smog, visibility is often reduced to four metres or less. The worst kind of smog is produced by motor vehicle exhausts. Under some conditions, the exhaust gases given off by motor vehicles may not be able to escape into the upper atmosphere. Instead they hang around in the air at about 900 metres above ground. They then produce a severe form of air pollution that contains such poisonous chemicals as carbon monoxide, ozone, nitrogen dioxide, benzine, and aldehydes. This cocktail can cause asthma, bronchitis, and eye complaints.

Cities in sunnier parts of the world, where the air is often calm, are at greatest risk. Los Angeles in the United States and Mexico City are famous for their smog, as are Bangkok in Thailand, Jakarta in Indonesia, and many other expanding cities in the developing world. But even relatively small cities, such as Granada in southern Spain, suffer from smog.

Photochemical smog

Mexico City, Los Angeles, and Granada suffer from smog because they are surrounded by hills. They are low rainfall areas and regularly experience the warm, clear, calm conditions that are perfect for the formation of smog. In these cities, as in all towns and cities, fumes rise up from the huge amount of motor traffic, as well as from factories and oil refineries. From time to time, a layer of warm air, often associated with a high-pressure system, then acts like a lid, trapping the cooler, polluted air below. Meanwhile, the sunlight changes the fumes into damaging ozone and choking smog. This remains trapped as a layer, stretching from the ground up to between 150 and 300 metres, sometimes for several days at a time. This type of pollution is called photochemical smog. The situation in Mexico City is so bad that breathing the air there is said to be as harmful to health as smoking forty cigarettes a day.

In recent years a brownish-coloured haze has affected much of India and South-East Asia. Called the Asian Brown Haze, this type of air pollution is caused by fumes from traffic, power stations, and factories, and the smoke from fires used to clear forest areas for farmland. This form of air pollution also leads to a huge increase in the numbers of people with lung infections and breathing problems such as asthma and bronchitis.

As well as causing problems with human health, the toxic gases in smog and pollution haze cause significant damage to plants, including crop plants. In southern California, for example, desert plants that evolved to survive in pure, clean air are now suffering damage as a result of the air pollution from Los Angeles and San Diego.

Alternatives to fossil fuels

Burning fossil fuels is still one of the cheapest ways of producing electricity, so scientists are researching new ways to burn these fuels which do not produce so much pollution. Hydroelectric and nuclear power are alternative ways of producing electricity. They do not produce acid rain, but they do have other serious impacts on the environment. Solar power and wind turbines also produce electricity without pollution, but these are not reliable when it is not windy or sunny. There are also alternative sources of energy for motor vehicles, including battery power, liquid gas, and fuel cells but, as yet, the use of these is not widespread.

CFCs and the ozone layer

Ozone is a toxic and highly reactive form of oxygen that is present in very small amounts in the atmosphere. Normal oxygen makes up about one-fifth of the air we breathe and is essential to us and almost all other forms of life. Ozone can be helpful or harmful to the climate and living things, depending on where it is. As we saw earlier, near the ground, ozone in smog is harmful to humans and other living things. Higher in the atmosphere it is an important greenhouse gas.

Although ozone is found throughout the atmosphere, including at ground level, the highest concentrations are in the stratosphere, about 20 to 25 kilometres above the Earth's surface. Here, ozone is continually formed from oxygen, and it turns back into oxygen when it breaks down. The layer of ozone around the Earth shields the Earth's surface against ultra-violet radiation from the Sun. The ozone layer absorbs the ultra-violet radiation and re-emits its energy as heat.

The 'hole' in the ozone layer

The ozone layer around the Earth had been stable for millions of years. But in 1985 a British scientist discovered that the ozone layer over the Antarctic thins during the southern winter and reaches a minimum thickness between September and November each year, the southern spring. The 'hole' is about the size of the United States and as deep as Mount Everest. A similar, but smaller, 'hole' in the ozone layer was later found over the North Pole, while there is also a general thinning of the ozone layer over the rest of the world. As a result of these changes to the ozone layer, more ultra-violet radiation is reaching the Earth.

CFCs

Scientists studying the 'ozone holes' believe the cause is a group of chemicals known as chlorofluorocarbons, CFCs for short. These chemicals have no smell or colour, they do not burn or react with other chemicals, and they are completely non-toxic. For many years after CFCs were discovered in 1930, they were widely used in aerosol sprays. In aerosol cans, CFCs acted as propellants to force the contents of the cans out as a fine spray. Most aerosols now use other propellants and the cans are labelled 'CFC-free' or 'ozone friendly'. CFCs were also widely used in refrigeration and air-conditioning units, dry cleaning, and the plastic foam used to make hamburger and egg cartons.

CFCs rise from the Earth and gradually accumulate in the stratosphere. There they are broken down by the Sun's ultra-violet light, so releasing chlorine atoms. The chlorine attacks the ozone, and one chlorine atom can destroy 100,000 ozone molecules. When the chlorine from CFCs has destroyed the ozone, more of the sun's ultra-violet rays can then reach the Earth's surface, with harmful effects to human and plant life. Amongst the effects of the increased ultra-violet light reaching the Earth is likely to be an increase in the number of people with skin cancer and eye cataracts. There has already been a noticeable increase in the number of people reported to be suffering from these conditions near the Arctic and Antarctic.

We now know that CFCs are not only the cause of the 'ozone hole', they are also an important factor in global warming. One molecule of the most common type of CFC contributes ten thousand times as much to global warming as one molecule of carbon dioxide. It is only because carbon dioxide is so much more common that it is considered the most important greenhouse gas. In 1987, an international agreement came into force to phase out CFCs, but the damage caused by CFCs to the ozone layer will not be fully repaired until 2050 at the earliest.

One of the most frightening aspects of the 'hole' in the ozone layer is that it was first discovered in Antarctica, the most remote place on Earth with only a small population of scientific workers and a tiny number of visiting tourists. And yet chemicals that were thought to be harmless, and that were used by people living thousands of kilometres away, have damaged this once pristine environment.

Practical considerations

When dealing with this important and urgent topic, it is not possible to avoid the fact that the human population is increasing and making greater demands on resources. These demands have led to a huge increase in the numbers and quantities of polluting substances being released into the environment. The direct effects of these pollutants on air quality are easiest to demonstrate if you live in a town or city, but wherever you live, in town or country, you can witness the results of acid rain and the greenhouse effect. This topic gives students an opportunity to firm up their ideas about pollution and its consequences. Many of them know that pollution is 'bad', but are not always able to say exactly why.

Lesson suggestions

1. Air pollution

Refer to page 44 of the Students' Book

Starter suggestions

Ask the students to work in groups of two or three and to list all the possible ways in which they as individuals pollute their environment.

Alternatively, again working in groups of two or three, the students could list as many things as possible that pollute the air indoors and outside. They should say where each of these pollutants comes from and what, if anything, can be done to reduce them.

Main lesson

Collect and discuss the students' ideas on substances that pollute the air.

Begin by considering in detail what smoke is and where it comes from. Many students will know what smoke is, but not all will realize that it consists of tiny particles.

Discuss the various sources of smoke and point out that the damaging particles in it are tiny particles of unburned fuel.

To emphasize the latter point, using tongs, hold a piece of white ceramic tile either above a candle flame or above a Bunsen flame where the air-hole is closed.

Explain what smog is and how and where it is formed. Go on to describe the health problems caused by smoke and smog.

Use Worksheets 3 and 4 to investigate how polluted the air is in and around the school.

Finish the lesson(s) by discussing what could be done to reduce the production of smoke and smog. Stress the need to reduce our dependence on fossil fuels to power our transport systems and to produce electricity.

By themselves, possibly for homework, the students could research the effect of CFCs on the ozone layer and the effect the 'hole' in the ozone layer could have on human health.

2. Acid rain

Refer to page 45 of the Students' Book

Starter suggestions

Show the students some common substances and ask them whether or not each is an acid. Substances used could include vinegar, lemon juice, battery electrolyte, and the stock laboratory reagents which have acid in their name.

Using, say, vinegar or lemon juice and an indigestion tablet dissolved in distilled water, show the students the effect these substances have on either Universal Indicator or litmus. Then test samples of rainwater collected in the local area with one or other of these indicators.

Main lesson

Ask the students to recall the composition of the air from their earlier work.

Explain that all rain water is weakly acidic because as the rain (or other forms of precipitation) fall, they dissolve some of the carbon dioxide in the air and form the weak acid, carbonic acid.

Go on to explain that in many parts of the world, the rain and other forms of precipitation have become much more acidic because of the acid gases produced when fossil fuels are burned. Environmentally, the worst offender is sulphur dioxide, which is formed when the sulphur that is often present in fossil fuels, and especially in coal, burns and forms sulphur dioxide. High in the clouds, the sulphur dioxide reacts with water and oxygen to form sulphuric acid. Nitrogen oxides are also a problem. Normally nitrogen in the air does not react with oxygen, but it does in the high temperatures and pressures inside an internal combustion engine. The nitrogen reacts with oxygen from the air to form nitric oxide, which can also make acid rain.

This is a good place to carry out the investigation on the effects of acid rain on seedlings, described on Worksheet 1. The worksheet suggests the use of Campden tablets to produce the sulphur dioxide. If these are not available, the experimental seedlings can be watered with very dilute sulphuric acid while the control seedlings are watered with tap water or distilled water.

Discuss the other environmental effects of acid rain—on trees, buildings, statues and monuments, the soil, and on aquatic life. If Worksheet 4 has not been used yet, this would be another good point at which to use it.

If possible, let the students test the acidity of the water in local lakes and ponds, as described in the **Ideas for investigation and extension work** section of this chapter. In addition, if you are able to give the students some pieces of Universal Indicator paper to take home, they could test the pH of the rainwater where they live. The students need to be reminded that the collecting containers must be free from contamination and that Universal Indicator is flammable.

Finish the topic by asking the students to draw a flow chart showing the stages in the formation of acid rain. Let them annotate their charts with suggestions as to how and where the problems of acid rain could be reduced or eliminated. Hopefully they will mention the value of gas scrubbers at power stations and catalytic converters in cars, and the removal of the sulphur from fossil fuels before they are burned. There is also the temporary remedial action of spraying the soil and lakes with lime to neutralize the acid.

3. Global warming

Refer to page 50 of the Students' Book

Starter suggestions

It is said that motor cars cause environmental problems throughout their lives, including during their manufacture, use, and final destruction. Ask the students to work in groups of two or three and discuss whether they think this statement is right or wrong. Ask them to explain their conclusions.

Without prompting them, ask the students to say what they think the greenhouse effect and global warming are, and whether they are good things or bad things. This will enable you to identify any misconceptions they have acquired from the media or elsewhere.

Ask the students to work in pairs and to write down what the differences are between the greenhouse effect and global warming.

Main lesson

Begin by explaining that the greenhouse effect is a natural process. The average temperatures of the world are maintained at a level that allows us to live because carbon dioxide, methane, and water vapour in the atmosphere capture some of the heat that has re-radiated from the Earth’s surface. Without this natural greenhouse effect to trap the Sun’s energy, the average temperature of the whole Earth would be -15°C!

Although they require quite a big leap in imagination, the simple experiments described on Worksheet 2 and in the **Ideas for investigation and extension work** section of this chapter show the effect a greenhouse can have on temperatures and plant growth.

Describe and discuss the effects that increased quantities of carbon dioxide and methane are having on the greenhouse effect and global temperatures. Remember that the extra carbon dioxide comes from burning fossil fuels and the clearance of forests by burning. The extra levels of methane come from cattle, rice fields, and the decomposition of organic matter in landfill sites.

Discuss what effects it is believed that global warming will have on the world climate.

It is important for the students to realize that, although most scientists accept that global warming is a fact, they do not all agree on what its long-term effects will be. Indeed, not all scientists agree that the observed increase in global temperatures is a man-made effect. It may help if you can tell the students how long it took to prove conclusively the link between lung cancer and smoking tobacco. By the time we have conclusive proof that global warming is man-made, it may be too late!

Discuss what can be done to reduce the human contribution to global warming, remembering to stress the important effect that deforestation has on the carbon dioxide levels in the atmosphere.

Conclude the lesson by showing the students some newspaper headlines referring to global warming and then asking them what they think the articles are about.

Ideas for investigation and extension work

Acid rain: gathering evidence

Ask the students to collect samples of water from lakes and ponds over as wide an area as possible. Make sure the samples are labelled and are contained in clean bottles. Carefully transfer 15 cm^3 of each water sample into a test-tube. Measure the pH of the water samples using Universal Indicator paper or solution. Mark on a map where the samples came from. Can the students explain the different pH measurements they obtained? Is there any evidence of acid rain having affected the samples?

How does a greenhouse help plants to grow?

Fill a seed tray to within 1 cm of the top with soil or compost. Sprinkle grass seeds over the surface and then cover the seeds with a thin layer of soil or compost. Water the seed tray so that the soil or compost is moist. Turn a large transparent jar or beaker upside down in the centre of the seed tray. This is the model greenhouse. Stand the seed tray on a sunny windowsill, but do not let the soil or compost dry out. Keep a record of what happens. Compare the growth of the grass seeds inside and outside of the greenhouse. Ask the students to say whether, in the light of this experiment, they think the world's increased greenhouse effect will be a good thing or a bad thing for plants. Ask them to explain their answers.

Recycling

What are the advantages of recycling? Why does it not make sense to drive to a collection point to take only small quantities of cans, bottles, or paper?

Save energy, reduce pollution

One method of reducing the amount of air pollution would be to use less energy. Try to find out how a 'Save it' scheme would reduce the energy used, and pollution created, in: a) heating and lighting homes, b) transport.

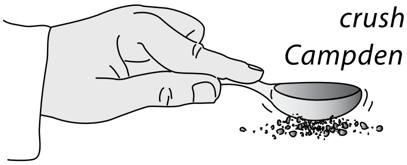
WORKSHEET 1

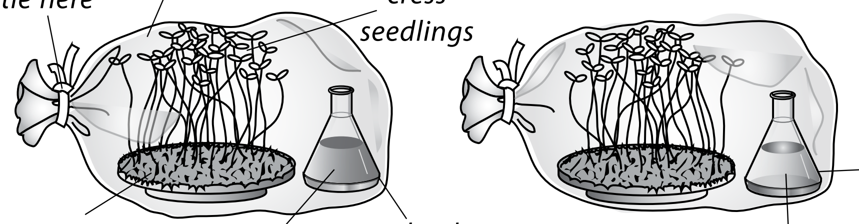
What effect does sulphur dioxide have on plants?

When coal, oil, and some other fuels are burnt, they give off sulphur dioxide in the smoke. Some of the sulphur dioxide eventually comes back to Earth as acid rain. What effect does sulphur dioxide have on plants?

Materials needed: 2 saucers; cotton wool or paper towels; cress seeds; 2 small clean beakers, 100 cm^3; 2 large transparent plastic bags (without holes); 2 bag ties; 1 Campden tablet; lemon juice; teaspoon

1. Put moist cotton wool or paper towels in both saucers. Sprinkle cress seeds on both moist surfaces. Leave the saucers on a sunny windowsill for a few days.
2. When cress seedlings are growing in both saucers, put each saucer in a plastic bag.
3. Crush a Campden tablet with a spoon. Put the crushed tablet into one of the beakers and add two teaspoonfuls of lemon juice. The tablet will fizz and give off sulphur dioxide. Quickly put the beaker into one of the plastic bags and fasten the bag tightly with one of the bag ties.
4. Put two teaspoonfuls of lemon juice into the other beaker. Put it in the second plastic bag and close it with a bag tie.





5. Look at the cress seedlings over the next few days. Write down what you see.

Is sulphur dioxide harmful to cress seedlings? If so, in what way?

____

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Why do you think we used two lots of cress seedlings, two plastic bags, two beakers of lemon juice, but only one Campden tablet?

____

____

Does sulphur dioxide harm other kinds of plants? Carry out some more experiments to find out.

WORKSHEET 2

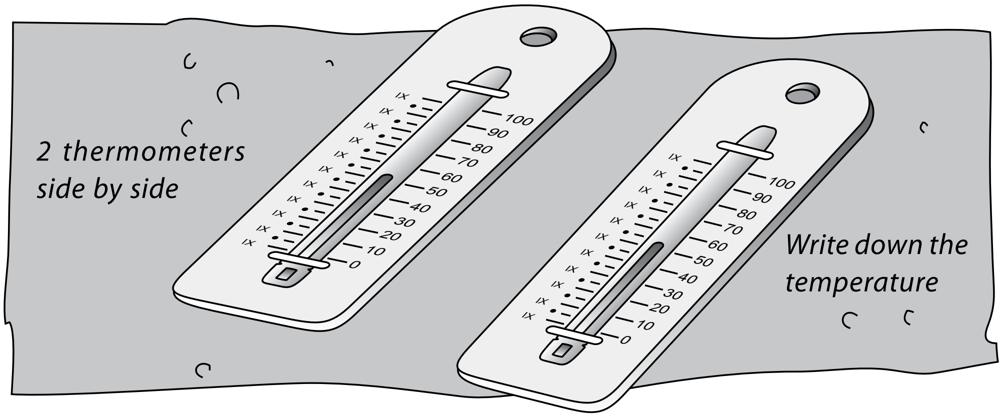
What effect does a greenhouse have on the temperature?

Gases given off by factories, power stations, motor vehicles, and the clearance of forests by burning are collecting high in the sky. They are increasing the Earth's 'greenhouse effect'. What effect does a greenhouse have on the temperature?

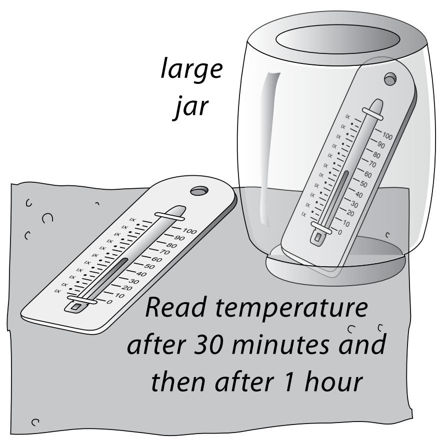
Materials needed: two thermometers; a large clear-glass jar or large beaker

This activity should be done on a sunny day.

1. On a sunny day, lay two thermometers side by side on the same kind of surface outdoors. Write down the temperature shown by each thermometer.



2. Cover one of the thermometers with a large jar or beaker. This is your greenhouse.
3. Read the temperature on the two thermometers after thirty minutes and again after an hour.



Temperature °C			
	At start of experiment	After thirty minutes	After 1 hour
Thermometer 1			
Thermometer 2 (under jar or beaker)			

What happens to the temperature inside a greenhouse?

____

____

What differences do you see between the temperatures shown on the two thermometers?

____

____

WORKSHEET 3

How polluted is the air around your school?

Materials needed: a collection of tree leaves from different places; cotton wool; thick white cardboard; Vaseline; hand lens or magnifying glass

1. Collect one or two tree leaves from each of several different places. If possible, try to collect leaves from all the same kind of trees. Take some leaves from gardens or parks, some from trees growing near busy streets or near factories. Write down where each leaf came from.
2. Look carefully at each leaf. Is the surface dull or shiny? Does the leaf look clean or dirty?
3. Wipe each leaf with a piece of damp cotton wool. How much dirt comes off each leaf? Make a chart to show the differences you discover.
4. Cut squares of white card about 15 cm by 15 cm.
5. Spread a thick layer of Vaseline on one side of each square.
6. Put the squares outside in dry weather. Put them, with the Vaseline facing upwards, in some places where you think the air may be dirty and other places where you think the air is clean.
7. After a few days collect the squares. Make a note of where each one came from. See how much dirt has stuck to the Vaseline. Look at the dirt with a hand lens or magnifying glass. Which squares collected the most dirt?
8. How dirty is the air around your school? Where do you think the dirt comes from? What harm does the dirt do to: a) people and other animals; b) plants? What could you do to make the air cleaner?
9. Carry out traffic surveys. From the results of your surveys, choose a road with light traffic and one which is very busy. Sample tree leaves from near both roads. Which leaves are dirtiest?

Write a report of the results of your experiment and your conclusions.

WORKSHEET 4

Lichens and air pollution

A lichen is a plant-like organism which does not have flowers. It is really two organisms, an alga and a fungus, living together. Lichens are very sensitive to air pollution.

Materials needed: a hand lens or magnifying glass.

Look for lichens on walls, roofs, tree trunks, memorials, and gravestones in the area around your home or school. You can tell how polluted the air is by which kinds of lichens you find growing:

1. **No lichens** Usually this means the air pollution is very bad. The green powdery substance growing on trees is not a lichen but an alga.
2. **Crusty lichens** Grey, green, or white lichens growing on trees or walls. With a hand lens they look like crazy paving. The air pollution is bad.
3. **Orange lichens** Usually in orange scaly patches on walls, roofs, and gravestones, but not on trees. There is quite a lot of air pollution.
4. **Leafy lichens** These lichens are plant-like, grey-green in colour with flat 'leaves'. They occur on walls and trees. Only slight air pollution.
5. **Shrubby lichens** More bush-like, usually branching several times, found on trees. No pollution.
6. **Hairy lichens** Long hairy stems, usually in a tangle hanging from a single point. Very pure air.

How polluted is the air around your home or school?

___

Where are the most polluted places?

___

Where are the least polluted places?

___

Where in Pakistan would you expect to find most air pollution?

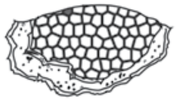
___

Where in Pakistan would you expect to find least air pollution?

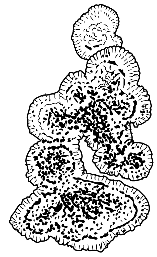
___

shrubby lichens

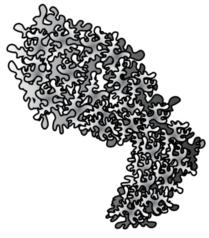
crusty lichens



orange lichens



leafy lichens



hairy lichens

Answers to questions in the Students' Book

1. The main causes of air pollution are the combustion of fossil fuels and wood. The pollutants produced by combustion include nitrogen oxides, sulphur dioxide, carbon monoxide, and hydrocarbon gases, together with large quantities of particulates—tiny particles of solid material, such as soot and dust.
2. Particulates are tiny particles of solid material, such as soot and dust. Inside our bodies they get into our lungs and other parts of the respiratory system and produce diseases such as asthma, bronchitis, and pneumonia.
3. The cause of the thinning of the ozone layer was a group of chemicals called chlorofluorocarbons, or CFCs for short. These chemicals were used in aerosols, refrigerators, freezers, and certain plastics. When their effect was discovered, CFCs were quickly phased out and replaced by other chemicals that could be used safely.
4. Acid rain is produced when gases such as sulphur dioxide and oxides of nitrogen in vehicle exhaust fumes and smoke dissolve in droplets of moisture in the air. Although acid rain looks and feels quite harmless, it can kill trees, and fish and other water animals. It can also eat into stonework and metal and wash certain important mineral salts out of the soil, reducing the amounts of these minerals available to plants.
5. Photochemical smog is a dangerous type of air pollution formed when sunlight acts on car exhaust fumes, producing ozone and other poisonous pollutants. Photochemical smog leads to a great range of illnesses, such as coughs, colds, wheezing and asthma, and lung infections such as bronchitis and pneumonia.
6. The greenhouse effect is a natural process that keeps the temperature on Earth comfortable. Certain gases in the upper atmosphere make it harder for heat energy to escape into space.
7. The Earth is becoming warmer because we are producing more carbon dioxide when fossil fuels and wood (from forest clearances) are burned. We have also increased the levels of other greenhouse gases, including methane and nitrous oxide. All of these gases are increasing the greenhouse effect, so making the Earth warmer.
8. The greenhouse effect is the natural process that keeps the Earth's temperature at a comfortable level. Global warming is the gradual change in the world climate caused by the increased greenhouse effect as a result of air pollution caused by human activities.
9. Acid rain can be reduced by passing the waste gases from factories and power stations through lime to remove the sulphur dioxide. The reason that not all factories and power stations do this is that the cleaning equipment is expensive and would make the goods produced by the factory, or the electricity produced by the power station, more expensive.
10. It is dangerous to run an engine in a closed garage because, when the supply of air is limited, car exhaust fumes contain a large quantity of poisonous carbon monoxide.
11. Some of the types of air pollution which occur indoors include fumes from cooking and heating on open fires or traditional stoves, tobacco smoke, and the fumes and vapours given off by paints, varnishes, glues, polishes and cleaning materials, and insecticides used indoors.

Assessment

Question 1

Which one of the following is a pollutant of the air?

(A) oxygen (B) water vapour (C) carbon monoxide (D) nitrogen

Question 2

Which type of solution is formed when sulphur dioxide dissolves in water?

(A) acid (B) alkaline (C) neutral (D) sulphur chloride

Question 3

Which of these substances can be formed by burning fossil fuels?

(A) sodium chloride (B) carbon dioxide (C) nitrogen (D) oxygen

Question 4

Which of these compounds helps to cause the greenhouse effect?

(A) water (B) sulphur dioxide (C) CFCs (D) carbon dioxide

Question 5

Which of the following pollutants of the air causes the ozone layer to become thinner?

(A) sulphur dioxide (B) CFCs (C) oxides of nitrogen (D) smoke

Question 6

Where was the 'hole' in the ozone layer first noticed?

(A) Africa (B) Antarctica (C) The Arctic (D) South America

Question 7

Which of these elements may occur in fossil fuels?

(A) sulphur (B) nitrogen (C) helium (D) calcium

Question 8

Which one of the following pollutants helps to cause acid rain?

(A) carbon monoxide (B) CFCs (C) sulphur dioxide (D) lead compounds

Question 9

Which one of the following pollutants can spread germs that cause diseases?

(A) farm chemicals (B) leaking oil from oil tankers

(C) untreated human sewage (D) chemical waste from factories

Question 10

What harm will a 'hole' in the Earth's ozone layer cause?

(A) The average temperature of the Earth will increase.

(B) The oxygen content of the atmosphere will increase.

(C) Sea levels will rise as the Polar ice caps melt.

(D) More ultra-violet radiation will reach the Earth.

Question 11

Which of the following does NOT have a major role in the greenhouse effect?

(A) carbon dioxide
(B) methane gas
(C) CFCs
(D) nitrous oxide

Question 12

Which of the following will NOT result from global warming?

(A) rising sea levels
(B) more droughts
(C) more damaging storms
(D) a larger ozone 'hole'

Question 13

Why does deforestation make global warming worse?

(A) Trees absorb moisture from the soil.

(B) Trees take carbon dioxide from the air.

(C) Trees make the landscape look attractive.

(D) There will be a shortage of timber.

Question 14

What is a possible effect of global warming?

(A) acid rain
(B) massive flooding
(C) more earthquakes
(D) damage to statues

Question 15

Which of the following is the BEST description of particulates?

(A) gases that pollute the air
(B) substances that dirty the air
(C) soot from chimneys
(D) tiny particles of solid matter in the air?

Question 16

Which of the following are NOT caused, or made worse, by air pollution?

(A) diabetes (B) asthma (C) bronchitis (D) pneumonia

Question 17

a) Name the gas found in polluted air which causes acid rain.

____

b) How is that gas formed?

____

c) Give one effect of acid rain.

____

d) Name the main gas associated with global warming.

____

e) How is that gas formed?

____

f) Describe ONE possible effect of global warming.

____

g) Where would you find a catalytic converter?

____

h) What does a catalytic converter do?

____

i) A lichen is formed by a fungus and a simple green alga living closely together. If you saw masses of hairy lichens growing on a tree or a wall, what would this tell you about the air quality in the area?

____

____

Question 18

1. Tick the boxes to show which of these environmental problems can be caused by burning fossil fuels.
   a) the damage to the ozone layer ☐
   b) global warming ☐
   c) the cutting down of forests to create space to grow crops ☐
   d) the greenhouse effect ☐
   e) acid rain ☐
   f) the pollution of rivers by pesticides ☐

2. a) What can be done to improve the habitat in a lake that has been affected by acid rain?

   b) What do we call the type of chemical reaction involved?

3. Describe the damage done to the environment by the chemicals called CFCs.

4. What illness in humans may be increasing because of damage to the ozone layer?

Question 19

1. a) Why are coal, oil, and natural gas called fossil fuels?

   b) Are fossil fuels renewable or non-renewable?

   Explain your answer.

2. a) Which gas, released when fossil fuels are burned, is also given off when biomass is burned?

   b) What is the name of the effect caused by this gas in the upper atmosphere?

   c) What effect is this thought to be having on the world's climate?

   d) Suggest TWO things humans can do to help reduce this effect.

   e) Suggest TWO ways in which cutting down large areas of forest can be harmful to the Earth's atmosphere and climate.

Answers to assessment questions

Question 1 (C)
Question 2 (A)
Question 3 (A)
Question 4 (D)
Question 5 (B)
Question 6 (B)
Question 7 (A)
Question 8 (C)
Question 9 (C)
Question 10 (D)
Question 11 (C)
Question 12 (D)
Question 13 (A)
Question 14 (B)
Question 15 (D)
Question 16 (A)

Question 17

a) The gas found in polluted air which causes acid rain is sulphur dioxide.

b) Many fossil fuels, particularly coal and oil, contain a little sulphur. When they are burnt, the sulphur present forms sulphur dioxide.

c) Acid rain damages/kills trees, damages buildings, sculptures, and ironwork, and kills fish and other aquatic plants and animals.

d) The main gas associated with global warming is carbon dioxide.

e) Carbon dioxide is formed by all types of burning or combustion of wood and fossil fuels, and also by the respiration of living things. Methane is formed by the decay of organic waste and also in the digestive systems of cattle and other herbivores.

f) Possible effects of global warming include the melting of Polar ice caps and glaciers, flooding of low-lying areas, disruption of weather patterns, increased droughts, hurricanes, and other forms of severe weather.

g) Catalitic converters are found in the exhaust systems of modern cars.

h) A catalytic converter converts harmful pollutants in the car exhaust fumes, such as carbon monoxide, unburned hydrocarbons and nitrogen oxides, into carbon dioxide, water, and nitrogen.

i) Masses of lichens growing on a tree or building indicate that the air quality is good (i.e. the air is not polluted), as these plant-like organisms are very sensitive to air pollution.

Question 18

1. The boxes that should be ticked are:
   a) the damage to the ozone layer
   b) global warming
   c) the greenhouse effect
   d) acid rain

The only one of these items about which there is any possible argument is the greenhouse effect. This is a natural process which absorbs infrared radiation in the atmosphere and produces temperatures that enable people to live on Earth. The effect is, however, increased by polluting gases, the most important of which is carbon dioxide which is released when fossil fuels are burned.

2. a) The effects of acid rain on the lake can be reduced by spraying the water with lime/quicklime/calcium oxide.
   b) The type of chemical reaction involved is a neutralization.
3. CFCs break down the protective ozone layer in the upper atmosphere.
4. Increased amounts of ultraviolet radiation, as a result of the thinning of the ozone layer, can result in more skin cancer and eye cataracts in humans.

Question 19

1. a) Coal, oil, and natural gas are called fossil fuels because they were formed over millions of years from the remains of prehistoric plants and animals.
   b) Fossil fuels are non-renewable.
   c) It is not possible for us to make any more as they took millions of years to form.
2. a) The gas that is released when both fossil fuels and biomass are burned is carbon dioxide.
   b) The name of the effect caused by carbon dioxide in the upper atmosphere is the greenhouse effect
   c) The greenhouse effect is thought to be making the Earth warmer.
   d) Things humans can do to help reduce the greenhouse effect include burning less fossil fuel, recycling waste, not wasting electricity, and planting more trees to absorb carbon dioxide.
   e) The cutting down of large areas of forest can be harmful to the Earth's atmosphere and climate because, once cut down, the trees can no longer absorb carbon dioxide during photosynthesis. In addition, when the wood from the trees is burned, it releases carbon dioxide into the atmosphere.

Chemical reactions

CHAPTER 6

Teaching Objectives

- Explain, with examples, how different types of chemical reaction occur and how they are due to the rearrangement of atoms and molecules
- Demonstrate that the law of conservation of mass explains the nature of chemical change during reactions where atoms are neither created nor destroyed
- Demonstrate and explain the energy changes in chemical reactions and the importance, in particular, of exothermic reactions in daily life

Learning Outcomes

After studying this chapter students should be able to:

- define *chemical reaction* and give examples
- explain the rearrangement of atoms in chemical reactions
- explain the balancing of a chemical equation
- define the law of conservation of mass
- identify the nature of a chemical change in various reactions
- describe changes in the states of matter in a chemical reaction
- explain the types of chemical reaction with examples
- explain the energy changes in chemical reactions
- explain the importance of exothermic reactions in daily life

Introduction

A chemical reaction is a change by which chemical elements or compounds rearrange their atoms to produce new chemical elements or compounds. The total number of atoms in the reaction remains the same, so that there is no change in the amount of matter. All chemical reactions involve energy changes.

Evidence of chemical change

There are several signs we can look for to show a chemical reaction or chemical change has taken place:

- One or more new substances are formed.

- Mass is not lost when the reactants turn into products. This is an example of the *law of conservation of mass* which states that matter can neither be created nor destroyed in a chemical reaction.
- Energy, usually in the form of heat, is given out or taken in. Reactions which give out heat are called exothermic reactions. Other reactions take in heat and are called endothermic.
- Visible change may occur in the reaction mixture. For example a gas may come off, a solid may be made or a colour change may occur.
- The change is usually difficult or impossible to reverse. For example, several chemical reactions are needed to change iron sulphide back into iron and sulphur.

Speed of reaction

Before substances can react, their moving particles (atoms, molecules, or ions) must meet. The speed of a reaction depends on how quickly this happens. Some of the things that may affect the speed of a reaction are:

- **The size of the pieces** of the solid reactants. A powdered substance reacts more quickly than one with larger pieces. This is because the powder has a much larger surface area, so more reacting particles come into contact. A lump of coal, for example, burns slowly in the air, whereas coal dust can react explosively.
- **Temperature** A chemical reaction takes place faster if the temperature rises. This is because the reacting particles collide with each other more quickly and more often. Increasing the temperature when calcium carbonate and hydrochloric acid react, will not increase the final amount of carbon dioxide produced, but the same amount of gas will be produced in a much shorter time.
- **Concentration** (of a solution) Increasing the strength or concentration of the reactants makes the reaction take place faster. A higher concentration means that more particles are likely to meet and join, or react with each other. If a piece of magnesium ribbon is added to a solution of hydrochloric acid, the mixture fizzes as hydrogen gas is given off. Magnesium chloride is also produced. Using stronger hydrochloric acid will make the reaction occur more quickly but, if the same amount of magnesium ribbon has been used, the same amount of hydrogen and magnesium chloride will be produced, but more quickly.
- **Pressure** (of a gas) Increasing the pressure on a reaction between two gases will increase the rate of the reaction. Increasing the pressure reduces the volume of the gases, moving their particles closer together. If the particles are closer together, there will be more collisions between them.
- **Light** Increasing the light intensity will increase the rate of some reactions, including the rate of photosynthesis. This is also true of photography, where photographic film is coated with chemicals that react to light.
- **Catalysts** A catalyst is any chemical which is added and which makes the reaction faster. However, the catalyst is not used up; it simply helps the other particles to meet and join up or react more quickly. Hydrogen peroxide decomposes slowly at room temperature into water and oxygen. If manganese oxide is added to the mixture, it speeds up the reaction, although the manganese oxide itself remains unchanged.

Types of chemical reaction

Many chemical reactions are useful, although as we will see later, some are less useful or are even harmful. Chemical reactions are useful because we use them to produce a wide range of valuable products, including plastics, medicines, cosmetics, household cleaners, metals, and the cement used to construct buildings.

a) **Combustion reactions**

Combustion is burning. A fuel is a substance which reacts with oxygen as it burns to give heat or light. Common fuels include wood, coal, oil, petrol, and natural gas (methane). Most fuels are hydrocarbons (compounds of hydrogen and carbon). When hydrocarbons burn the main products are carbon dioxide and water plus useful energy.

fuel + oxygen → water + carbon dioxide

It is important to remember that three things are needed for burning or combustion to occur: fuel, heat, and oxygen. Combustion has many uses including heating, cooking, generating electricity and in the working of petrol, diesel, and jet engines.

b) **Oxidation reactions**

Oxidation reactions are chemical reactions where oxygen is gained by one of the reactants. Combustion reactions are a type of oxidation since the carbon in the fuel combines with oxygen to form carbon dioxide. Another example of an oxidation reaction is where magnesium burns in the air and combines with oxygen to form magnesium oxide.

c) **Thermal decomposition reactions**

These are chemical reactions where substances decompose, or break down, when they are heated. Calcium carbonate (chalk or limestone), for example, decomposes to form calcium oxide and carbon dioxide when it is heated.

d) **Displacement reactions**

These are reactions in which a reactive element displaces a less reactive element. If, for example, a piece of magnesium is dropped into a test-tube containing copper sulphate solution, the magnesium replaces the copper in the copper sulphate. The copper sinks to the bottom of the tube as a brown layer. Similarly, if an iron nail is placed in copper sulphate solution, some of the iron dissolves and displaces the copper in the solution. The copper forms a brown coating on the nail. There is also a displacement reaction whenever a metal reacts with an acid. All acids contain hydrogen, and the metal displaces the hydrogen in the solution.

e) **Neutralization reactions**

These are reactions where an acid reacts with an alkali to form a metal salt and water. Hydrochloric acid and sodium hydroxide are neutralized to form sodium chloride and water.

f) Precipitation

When some solutions are mixed, they react to give a product which does not dissolve—it is insoluble. The product appears as tiny solid particles, called a precipitate. For example, if silver nitrate solution is added to sodium chloride solution, they react. Insoluble silver chloride is produced as a precipitate, while sodium nitrate is left in solution.

g) Reduction reactions

These reactions are very important because they allow metals to be produced from metal oxides. Iron oxide, for example, is dug out of the ground. We call it iron ore. In a blast furnace the iron oxide reacts with carbon monoxide gas to produce iron and carbon dioxide. The carbon monoxide removes the oxygen from the iron oxide, leaving the iron behind. This reaction, which is called a reduction reaction, is the opposite of oxidation, and it can be used to separate most metals from their oxides. When hydrogen is passed over heated copper oxide, for example, the copper oxide loses its oxygen. It is reduced. However, the hydrogen gains oxygen and so is oxidized.

If we put the chemical formulae in the equation we can see what is happening with the atoms:

$$CuO + H_2 \longrightarrow Cu + H_2O$$

copper oxide hydrogen copper water

Reduction and oxidation always go together, which is why sometimes the name redox is used to describe these reactions.

h) Fermentation

Fermentation is the process by which sugars are turned into ethanol by the fungus yeast. Carbon dioxide is produced as a waste product. Fermentation is used for making bread and certain medicines. In some countries, including Brazil, ethanol is made for use as a motor fuel by fermenting sugar cane and other plant materials rich in sugars.

i) Electrolysis

Another method of bringing about chemical decomposition, which is not described in the Students' Book, is electrolysis. This is the process by which an electric current flowing through a liquid containing ions causes the liquid to undergo chemical decomposition. The electric current is carried not by electrons, but by the movement of ions.

Practical considerations

The students will already be familiar with a great number of chemical reactions, possibly without realizing it. They will all have come across chemical reactions such as baking a cake, photosynthesis, respiration, fermentation, or the rusting of iron. This chapter is concerned mainly with the study of chemical reactions and the effects of various conditions on the rate of these reactions. Which of the reactions you demonstrate or allow the students to carry out obviously depends upon the reagents and other equipment available. The experiments suggested in this chapter all use chemicals that are normally quite readily available. They also provide opportunities for the students to write and balance chemical equations. Throughout this work, it is important to stress to the students that they should not carry out experiments of their own unless they have been sanctioned by a responsible adult.

Lesson suggestions

1. Chemical reactions

Refer to page 36 of the Students' Book

Starter suggestions

Ask the students to recall the work they have done earlier in their school careers and to make a table to compare reversible and irreversible reactions.

Ask the students to list the properties of solids, liquids, and gases, with special reference to how the particles are arranged and behave in these three states of matter.

Main lesson

Remind the students that changes to materials can be reversible or irreversible. Hopefully the students will already be familiar with such changes as mixing and heating iron filings and sulphur and burning magnesium ribbon in air or oxygen.

To extend the practical work you could either demonstrate, or let the students carry out the following experiments:

a) Heat a few spatulas of hydrated (blue) copper sulphate crystals in a boiling tube until it goes white (anhydrous copper sulphate). Allow the tube to cool and then add a few drops of water, when the anhydrous copper sulphate will become hydrated again. This reversible reaction can be repeated over and over again.

b) Heat some zinc oxide in a boiling tube, when it will be seen that the chemical changes from white to yellow. Ask the students whether the change is chemical and irreversible or physical and reversible. In fact, when the zinc oxide is cooled, it turns white again. The change is physical and reversible.

b) Heat a few spatulas of blue-green copper carbonate ($CuCO_3$) in a boiling tube until it changes colour as a result of the formation of black copper oxide. Allow the copper oxide to cool and again add water and show that this time nothing happens because an irreversible change has occurred. You can, if you wish, introduce the term *thermal decomposition* to describe this reaction.

Carry out other simple irreversible chemical reactions, including some of those described in the **Ideas for investigation and extension work** section of this chapter and also perhaps Worksheets 2 and 5.

At the end of this lesson or lessons, ask the students what they might observe during a chemical change or chemical reaction. The list could include a colour change, the formation of one or more new substances, the emission of gas, a temperature change, or the emission of light. However, it is important to stress that none of these on its own is a definite proof that a chemical change has occurred.

2. Exothermic and endothermic reactions

Refer to page 58 of the Students' Book

Starter suggestions

Ask the students to think of any chemical reactions they know of which give out heat. Hopefully they will mention the burning of magnesium in air or the various combustion reactions. Can they think of any reactions where heat is absorbed?

Main lesson

Introduce the terms *exothermic* and *endothermic* to describe reactions which emit heat and absorb heat, respectively.

Either demonstrate or let the students carry out the first two reactions described in the **Ideas for investigation and extension work** section of this chapter and also the experiment described on Worksheet 1.

Remind the students of the importance of combustion reactions (which are also oxidation reactions) in our use of hydrocarbon fuels to provide us with energy.

Finally, show the students a photograph of a bonfire and of a car being refuelled. Ask them to describe what is happening in terms of energy.

3. Rusting and corrosion

Refer to page 64 of the Students' Book

Starter suggestions

Show the students some photographs of tarnished silver ornaments or jewellery, tarnished copper coins, and rusting iron and steel. Ask them what all the pictures have in common. The answer is that they all involve a reaction between a metal and air or oxygen.

Main lesson

Discuss what is meant by the terms *corrosion*, and *rusting*. Basically, corrosion is a chemical reaction between a metal and the gases in the air. Typically the metal reacts with oxygen to form an oxide layer on its surface (a type of oxidation). Rusting is the term reserved for the corrosion of iron and steel. If the students carry out the experiment called 'Do-it-yourself green copper' in the **Ideas for investigation and extension work** section of this chapter, they can see how quickly tarnishing or corrosion of metals can occur.

Carry out the experiment described on Worksheet 3 so that the students learn that, for rusting to occur, both oxygen and water must be present. The reaction is, in fact, an oxidation-reduction or redox reaction.

Explain to the students that rusting and other forms of corrosion weaken the metal (the exception is aluminium, where the oxide layer forms a protective coat against further corrosion). Because it weakens metals, corrosion shortens the life of machinery, metal bridges, and other structures and is therefore very costly.

Discuss with the students how rusting and other forms of corrosion can be slowed or prevented. Most rusting can be slowed or prevented by reducing the supply of oxygen and water to the metal. Coating metals, such as machine parts and tools, with oil or grease prevents air or oxygen from reaching the metal. Painting metal objects or coating them with plastic or other metals has the same effect and so helps to prevent corrosion.

Galvanising is a method of protecting iron or steel from corrosion by covering it with a thin layer of zinc through dipping or electroplating. Buckets, dustbins, and corrugated roofing sheets are often made of steel that has been galvanized by dipping them in molten zinc.

'Tin' cans for fruit and vegetables are made of thin steel electroplated with a thin layer of tin. The shiny parts of cars and bicycles are often made of steel given a protective layer of chromium by electroplating. The students can see how electroplating works if they carry out the experiment on Worksheet 4.

4. Chemical equations

Refer to chapter 6 of the Students' Book

Starter suggestions

Ask the students how many word equations they can think of, reminding them that they should already know the word equations for photosynthesis and respiration, and probably the equation for the combustion of hydrocarbon fuels.

Ask the students to work in pairs and make a list of all the elements and their symbols they can think of.

Main lesson

Explain that, as the students already know, a chemical reaction can be summarized by an equation. The simplest equation is a word equation.

For example, when sodium hydroxide and hydrochloric acid react together, sodium chloride and water are formed.

sodium hydroxide + hydrochloric acid $\longrightarrow$ sodium chloride and water

The substances on the left-hand side (sodium hydroxide and hydrochloric acid) are called the reactants. The substances produced (sodium chloride and water) are called products.

Although word equations may be useful, they do not give us a full picture of what is happening.

Reactions can be summarized using chemical symbols. This is a system which is used and understood throughout the world.

The equation for the reaction between sodium hydroxide and hydrochloric acid is written as:

$NaOH + HCl \longrightarrow NaCl + H_2O$

This equation is correctly <u>balanced</u>. This is because there are the same numbers of each type of atom on each side of the equation. (1 sodium atom, 1 oxygen atom, 2 hydrogen atoms, and 1 chlorine atom)

To take another simple example, hydrogen burns in oxygen to form water. The word equation is:

hydrogen + oxygen $\longrightarrow$ water

The formula for each reactant and each product is then given:

$H_2 + O_2 \longrightarrow H_2O$

This equation is not balanced because there are four atoms of the reactants and only three atoms of the products. It is an important law, called the law of conservation of mass, that atoms cannot be made or destroyed in a chemical reaction, just rearranged. You cannot write:

$H_2 + O_2 \longrightarrow H_2O_2$

This would mean altering the formula of water and you cannot do that. Instead you have to change the proportions of the substances by placing large whole numbers in front of the reactants and products, where necessary.

The equation above is balanced by using the simplest multiples of the formulae. In this case the simplest whole number is two:

$2H_2 + O_2 \longrightarrow 2H_2O$

The above equation is now balanced because there are four atoms of hydrogen and two atoms of oxygen on each side of the equation.

Obviously the students need a great deal of practice at writing and balancing equations. However, at some appropriate stage they can be told that we can also use equations to show whether the substances are solids, liquids, or gases, or whether they are in solution. The symbols used are :

(s) solid

(l) liquid

(g) gas

(aq) in aqueous solution (where water is the solvent)

An example of an equation with these symbols showing the state of the reactants and products is that for the reaction between sodium metal and water:

$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$

Ideas for investigation and extension work

Reaction race

Here is a simple reaction the students can carry out, either at home or at school, to see the effects of temperature on the rate of a reaction. Take two glasses (or beakers) and put cold water from the refrigerator in one and an equal volume of hand-hot water in the other. At the same moment, put a soluble indigestion tablet into each glass. Watch what happens over the next fifteen minutes or so. The students will find that the reaction between the tablet and the water needs a little heat to start it. The tablets in the cold water will not start to fizz until the water warms up to room temperature. By contrast, the hot water starts the reaction almost immediately. This reaction is also exothermic, so when the reactants do start to fizz, they make the water even hotter. A thermometer can be used to show this.

Endothermic reactions

Here are two examples of endothermic reactions that are easy to demonstrate to the students.

a) Take the temperature of about 25 cm^3 of dilute hydrochloric acid in a small beaker. Add to this about four spatula measures of potassium hydrogencarbonate. Observe what happens to the temperature as shown by the thermometer.

b) Mix together roughly equal amounts of sodium hydrogencarbonate (bicarbonate of soda) and citric acid crystals (the acid contained in citrus fruits). Find the temperature of about 25 cm^3 of distilled water in a small beaker. Then add the solid mixture to the water and notice the temperature change.

Do-it-yourself green copper

This is another simple reaction the students can carry out, either at school or at home. Leave two copper coins in a saucer of vinegar to which a little salt has been added, until the coins are clean and shiny. Rinse one of the coins in clean water and then leave both coins on a windowsill to dry. To avoid discolouring the windowsill lay the coins on a piece of paper. After a few hours the unrinsed coin will start to turn green, while the other coin will stay shiny much longer. What happens is that the unrinsed coin reacts with the vinegar and salt solution to form a layer of green copper acetate. The rinsed coin reacts with air to form a layer of green copper oxide, although this reaction normally takes much longer.

Rates of reaction

Marble chips (calcium carbonate) will react with dilute hydrochloric acid to produce carbon dioxide gas and calcium chloride. Design experiments to find out whether the rate of this reaction depends on: a) the temperature of the acid; b) the size of the marble chips. Students may draw diagrams of the apparatus they would use, and carry out their experiments.

Zinc and acid

Granules of zinc will react with cold, dilute sulphuric acid to produce hydrogen gas and zinc sulphate. Design and carry out an experiment to show that a small quantity of copper (II) sulphate solution acts as a catalyst for this reaction.

Mixing an element and a compound

This simple displacement reaction is between iron and copper sulphate solution.

Pour dilute copper sulphate solution into a test-tube to a depth of about 3 cm^3. Ask the students to note the colour of the copper sulphate solution. Add a spatulaful of iron filings to the test-tube of dilute copper sulphate solution. Allow the contents of the test-tube to stand for about two minutes. Observe what happens to the iron filings. Observe what happens to the colour of the copper sulphate solution. Ask a volunteer to feel the test-tube. Is it warm? Do the students think a chemical reaction has taken place? Why? Ask them to write a word and balanced symbol equation for the reaction.

Mixing compounds

This is a precipitation reaction between copper sulphate solution and sodium hydroxide solution. Fill a test-tube with dilute copper sulphate solution to a depth of 1 cm. Fill another test-tube with dilute sodium hydroxide solution to a depth of about 1 cm. Pour the dilute sodium hydroxide solution into the tube of dilute copper sulphate solution. What happens? Do the students think a chemical reaction has taken place? Why? Ask them to write a word and balanced symbol equation for the reaction.

The reaction between sodium and water

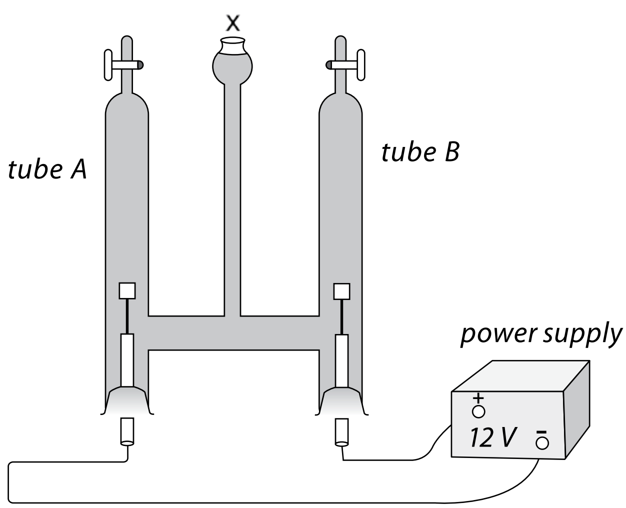
This teacher demonstration is of the reaction between sodium (an element) and water (a compound).

Safety: Carry out the experiment behind a Perspex safety screen while wearing safety spectacles.

Half-fill a plastic or glass trough with water. Add a few drops of Universal Indicator or red litmus solution to the water. Does the water change colour? Cut a very small piece of sodium, slightly larger than a rice grain. Ask the students to observe and record the appearance of the freshly-cut sodium. Using tongs, put the small piece of sodium into the trough of water. The students should observe and record what happens. Do the students think a gas is given off? How do they know? Do they think a chemical reaction has taken place? Why? Ask them to write a word and balanced symbol equation for the reaction.

The effect of electricity on water

If Hoffman's apparatus is available, use it to demonstrate the electrolysis of water acidified with some bench sulphuric acid. Set up the apparatus as shown in the diagram below:



Fill the apparatus with acidified water through the thistle funnel labelled X. Pass electricity through the acidified water for about ten minutes. Notice what happens to the water levels in tubes A and B. Point out to the students that this is an indication that gases are being formed. Place an inverted test-tube over the top of tube A, open the tap and collect the gas. Bring a burning splint to the mouth of the tube to test for hydrogen. Place another inverted test-tube over the top of tube B and open the tap to collect the gas. Test it with a glowing splint to show the presence of oxygen. Do the students think a chemical reaction has taken place? Why? Ask them to write a word and balanced symbol equation for the reaction.

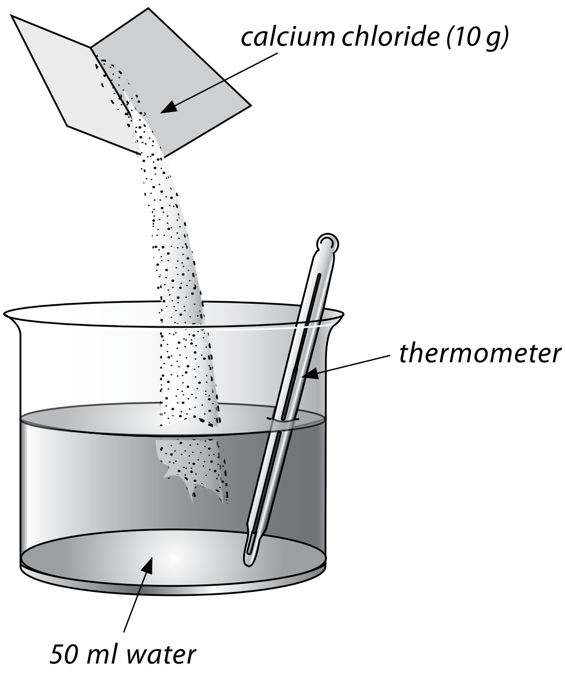
WORKSHEET 1

Observing exothermic and endothermic reactions

Materials needed: calcium chloride; sodium chloride; ammonium chloride; thermometer; beaker, 100 cm^3; beaker, 1000 cm^3; clean plastic bucket; measuring cylinder; stirring rods

Safety: Wear safety spectacles.

1. Measure 10 g of calcium chloride onto a small piece of paper.
2. Half-fill the large beaker or plastic bucket with water at about 25°C.
3. Measure out 50 cm^3 of this water and pour it into the small beaker. Feel the beaker.
4. Take the temperature of the water.
5. Add the calcium chloride to the water and stir thoroughly.
6. Take the temperature of the calcium chloride solution.
7. Cup your hand around the beaker. Does it feel warmer or cooler than when you started?
8. Repeat steps 1 to 7 twice more, first using sodium chloride, and then ammonium chloride.



Record your results in this table:

Solute	**a) Initial water temperature**	**b) Temperature of final solution**	**Difference between a) and b)**	**Warmer or cooler?**
calcium chloride				
sodium chloride				
ammonium chloride				

Conclusion

On the basis of your observations, which reactions were exothermic and which were endothermic?

Exothermic ____________________

Endothermic ____________________

WORKSHEET 2

Gas production in a bottle

Materials needed: a small glass bottle; a cork that fits tightly into the top of the bottle; measuring cylinder, 100 cm^3; dropper or teat pipette; metal teaspoon; baking soda (sodium bicarbonate); vinegar (dilute ethanoic acid)

1. Put three heaped teaspoons of baking soda (sodium bicarbonate) into the bottle.
2. Use the dropper or teat pipette to wet the cork with water.
3. Using the measuring cylinder, pour in 50 cm^3 of vinegar. Stopper the bottle with the cork immediately.

What do you observe?

____

____

What do you think caused this change?

____

____

In the space below, draw a labelled diagram showing what you did and what happened.

How is this type of reaction useful when making a cake?

____

____

____

Baking soda is sodium bicarbonate ($NaHCO_3$). Write a word equation to show what happened in this reaction. You may need to revise your work on acids to find out what element is present in every acid and what gas is produced when acids react with carbonates and bicarbonates.

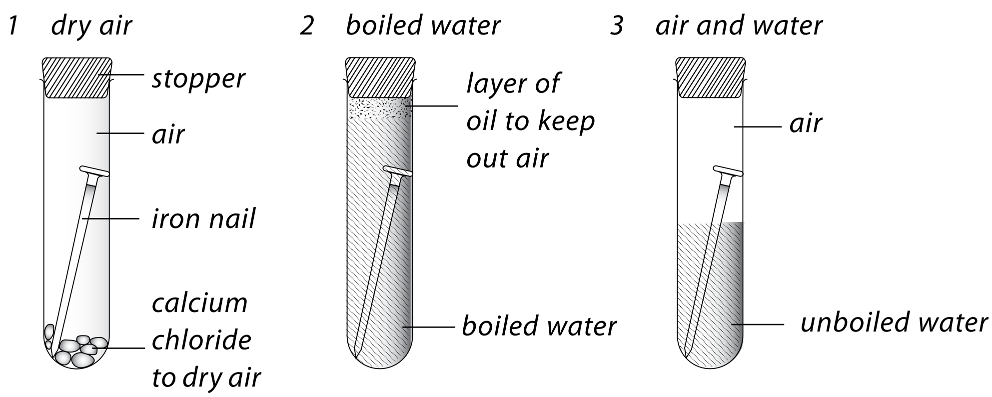
____

WORKSHEET 3

What makes iron rust?

Materials needed: three test-tubes with solid rubber stoppers to fit; three clean and shiny iron nails; calcium chloride; spatula; small quantity of vegetable or mineral oil; boiled tap water which has been allowed to cool

1. Place an iron nail in each of the three tubes.
2. Add a spatula of calcium chloride to the first tube and push the stopper in firmly. Calcium chloride absorbs water and so will keep the air in the tube dry.
3. Put water which has been boiled and then allowed to cool in the second tube, leaving a small gap at the top of the tube. Add a thin layer of oil here to keep out air and then put the stopper in the tube.
4. Half-fill the third tube with water which has not been boiled and put the stopper in.



5. Leave the three tubes for several days, but each day examine the nails through the glass for signs of rust.

In which of the three tubes does the nail go rusty?

___

What was the reason for boiling and then cooling the water in the second tube?

___

Why was a layer of oil added to the second tube?

___

What conditions have to be present if rust is to form on iron?

___

List THREE ways in which we can prevent iron from rusting.

___

___

___

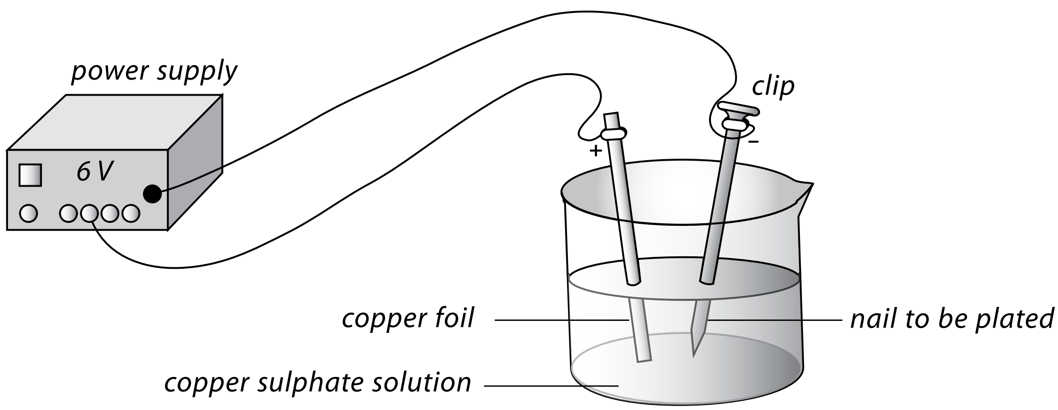
WORKSHEET 4

Copper plating

This experiment is best carried out as a teacher demonstration of a displacement reaction.

Materials needed: 6 V DC power supply or four 1.5 V cells; connecting wires with clips; beaker, 250 cm^3; copper foil; copper sulphate solution; object to be copper plated, such as a coin, key, or iron nail

1. Set up the apparatus as shown in the diagram below, with a strip of copper foil as the anode and an iron nail or some other object to be plated, as the cathode.



2. What happens to the object when electricity is passed through the solution?

____

____

3. Has a chemical reaction occurred? Explain your answer.

____

____

4. The coating of a metal on the surface of another substances using electricity is called electroplating. Name some examples of electroplated objects around you. What metals are they plated with?

____

____

WORKSHEET 5

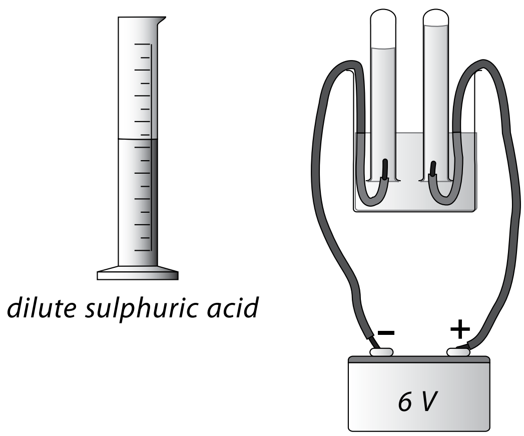
Decomposing water using electrolysis

This experiment is best carried out as a teacher demonstration of an electrolysis reaction.

Materials needed: beaker, 250 cm^3 or larger; insulated copper wire (about 1 m); dilute sulphuric acid; 6V battery (or four 1.5V cells); matches and wooden splints; measuring cylinder; two test-tubes; paper towels. You may need a retort stand and two clamps to hold the test-tubes

Safety: Do not get any sulphuric acid on your skin or clothes. If this does happen, wash with plenty of water.

1. Cut the wire in half and remove about 4 cm of insulation from each end of both pieces.
2. Half-fill the beaker with water. Then fill the two test-tubes completely with water and invert them into the beaker, as shown in the diagram below.
3. Bend one end of each wire and insert the bent end in each tube.
4. Connect the wires to the battery. Then slowly add about 15 cm^3 of dilute sulphuric acid to the water.



5. Disconnect the battery as soon as one of the test-tubes is nearly full of gas. Compare the amounts of gas you have collected in the two tubes.
6. Without removing the test-tubes, slip the wires out of the beaker.
7. Remove the test-tube which is filled with gas and quickly, while holding the tube upside down, put a *lighted* splint into it. If the gas is hydrogen you will hear a 'pop'.
8. Test the gas in the half-filled tube. Have a *glowing* splint ready and quickly insert the splint into the gas while holding the tube upside down. If the gas is oxygen, the glowing splint will burst into flame.
   a) Record what happened in stage 4:

   ____

   b) Record what happened in stage 7:

   ____

c) Record what happened in stage 8:

d) What two elements does water consist of?

e) Write a balanced equation for the electrolysis reaction:

Answers to questions in the Students' Book

1. During a chemical reaction one or more new substances is formed. There is no overall loss of mass; energy in the form of heat is either lost or gained; and the reaction is difficult to reverse.
2. The reaction between calcium carbonate and dilute hydrochloric acid would speed up if, i) the temperature of the reacting mixture was increased, or iii) the calcium carbonate was in the form of a powder. The reaction would slow up if, ii) the acid was diluted with water.
3. The factors that affect the rate of a chemical reaction are the size of the reacting particles, their concentration, the temperature, and whether or not a catalyst is present.
4. A catalyst is a substance which increases the rate of a chemical reaction but which is not itself used up during the reaction.
5. To see which of four black powders is the best catalyst, it would be necessary to divide the 100 cm^3 of hydrogen peroxide equally between four tubes. Then an equal weight of one of the black powders would be added to each tube and the amount of oxygen given off would be measured. The best catalyst would be the one which caused most oxygen to be produced in the shortest time.
6. If an element burns in oxygen, an oxide of that element is produced.
7. If a fuel such as methane (a hydrocarbon) is burned in air, carbon dioxide and water, plus heat energy will be produced.
8. Another name for combustion is burning.
9. For combustion to occur, a fuel, heat, and air or oxygen are needed.
10. Fermentation is the conversion of sugars into ethanol and carbon dioxide gas by the action of microorganisms such as yeast, in the absence of air.
11. When a sugar such as glucose is fermented, ethanol and carbon dioxide gas are produced.
12. When copper oxide is reduced with hydrogen, copper metal and water are produced.
13. Some chemical reactions which are definitely not useful include the rusting of iron, the spoiling of food by microbes, making it 'go off', and the pollution of the atmosphere , including global warming and the formation of acid rain, as a result of combustion reactions.
14. Oxygen and water must be present if iron is to rust.
15. Global warming is the gradual change in the world climate caused by atmospheric pollution which increases the greenhouse effect.
16. Global warming is a problem because it is thought it may cause changes in the world's weather patterns, producing more droughts and storms. It may lead to the melting of the polar ice caps to bring about severe flooding.
17. Acid rain is rainwater which has a pH of less than 5 due to dissolved gases such as sulphur dioxide and oxides of nitrogen. These gases are produced mainly by burning fossil fuels.
18. Acid rain damages plant leaves, kills trees, washes essential nutrients out of the soil, and kills fish and other aquatic life in lakes and rivers.

19. Some chemical reactions that occur naturally in everyday life include photosynthesis, respiration, the decomposition of organic matter, the burning of vegetation in forest fires and wild fires, and the digestion of food by enzymes in the digestive systems of animals.

Assessment

Question 1

Which one of the following is a chemical reaction?

(A) burning a piece of paper
(B) heating a piece of iron in a Bunsen burner
(C) boiling water
(D) adding salt to water

Question 2

Which of the following is a chemical reaction?

(A) the removal of grease from clothing using carbon tetrachloride
(B) the use of neon lighting for advertisements
(C) the bleaching of fabric using hypochlorite
(D) the removal of nail varnish using acetone

Question 3

The smallest number of elements which can form a compound is:

(A) 1 (B) 2 (C) 3 (D) 4

Question 4

Sulphur is an example of:

(A) an element (B) a compound (C) a metal (D) a mixture

Question 5

The rusting of iron is classed as a chemical change because:

(A) no heat is given out in the process
(B) the rust has very different properties from those of iron
(C) the rust cannot be converted back to iron
(D) the rust only forms when water and air are present

Question 6

Which of these substances will NOT stop iron from rusting?

(A) water (B) plastic coating (C) chromium plating (D) paint

Question 7

Which of the following NEVER occurs during a chemical reaction?

(A) Molecules are changed to different molecules.

(B) Atoms are changed to different atoms.

(C) Atoms are combined to form molecules.

(D) Molecules are decomposed to atoms.

Question 8

What is the name of the compound formed when magnesium burns in air or oxygen?

(A) magnesium carbonate (B) magnesium dioxide

(C) oxide magnesium (D) magnesium oxide

Question 9

A compound containing sulphur, sodium, and oxygen could have the formula:

(A) N_2SO_4 (B) N_2SiO_4 (C) Na_2SO_4 (D) Na_2SiO_4

Question 10

A catalyst is a substance that changes the:

(A) speed of a chemical reaction (B) total amount of chemicals formed

(C) temperature of a chemical reaction (D) volume of gas given off in a chemical reaction

Question 11

When 50 cm^3 of dilute hydrochloric acid was added to 2 g of calcium carbonate (chalk or limestone), a gas was given off. After about twenty minutes there was no more gas, although some calcium carbonate was left. The reason for this was:

(A) The temperature of the reaction was too low.

(B) All the acid had been used up.

(C) The calcium carbonate had become coated with impurities.

(D) The calcium carbonate had all been used up.

Question 12

During a chemical reaction a gas was given off which turned limewater milky. This showed that the gas was:

(A) nitrogen (B) water vapour (C) carbon dioxide (D) oxygen

Question 13

Which one of the following will burn in air to produce water?

(A) nitrogen (B) oxygen (C) carbon dioxide (D) hydrogen

Question 14

A gas lights with a 'pop' and burns with a blue flame. It is likely to be:

(A) oxygen (B) hydrogen (C) nitrogen (D) carbon dioxide

Question 15

Which chemical elements do all hydrocarbons contain?

(A) hydrogen and carbon
(B) hydrogen and oxygen
(C) carbon and oxygen
(D) hydrogen and sulphur

Question 16

A mixture of iron filings and sulphur was heated over a Bunsen flame for two or three minutes. After removing the Bunsen, the solid remained red-hot for several minutes. Which of the following statements is true?

(A) The reaction was endothermic (absorbed heat).
(B) The iron dissolved in hot liquid sulphur.
(C) A compound of iron and sulphur was produced.
(D) No reaction occurred.

Question 17

Complete the following sentences using the words in the box below.

boiling	bubbles	colour	compound	condensation
elements	equation	gases	heat	products
reactants	chemical	reversed		

a) Hydrogen and carbon dioxide are ______. If they are formed in a chemical reaction you will see ______. This can be a sign that a ______ reaction has occurred.

b) Other signs of a chemical reaction might be an increase in temperature if ______ is released, or a change in ______.

c) Physical changes like ______ do not make new materials and are easily ______, for instance by cooling which causes ______.

d) The substances you start with are called ______, and after the chemical change the substances that are formed are called the ______.

e) Zinc and carbon consist of only one type of atom and so are called ______.

f) Carbon dioxide consists of atoms of carbon and oxygen combined together, and is known as a ______.

g) A shorthand way of showing a chemical change is to use a word ______.

Question 18

Read the following statements about chemical reactions. For each one, say whether you think it is TRUE or FALSE.

i) There is a loss of mass when the reactants turn into products. ______

ii) A word equation shows what is happening in a reaction. ______

iii) Chemical reactions involve temporary changes. ________

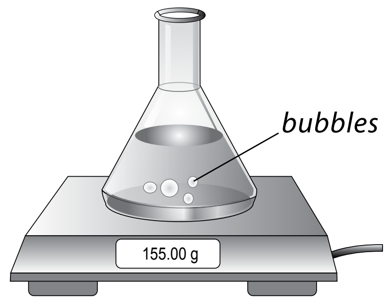
iv) Reactions always either take in or give out energy. ________

v) Usually the temperature in a reaction goes up. ________

vi) There are often visible changes in a reaction. ________

Question 19

Bashir placed a conical flask on an electronic balance. The flask weighed 50 g. He then added 100 g of dilute hydrochloric acid and 5 g of powdered calcium carbonate. The total mass of the flask, the acid, and the calcium carbonate was now 155 g.



a) How could Bashir tell, just by looking, that a chemical reaction was taking place?

____

____

b) What would you expect to have happened to the total mass shown on the balance by the end of the reaction?

____

____

c) Explain why you think this would have happened.

____

____

d) What other change may have occurred in the flask?

____

____

e) Write out the word equation for the reaction. It has been started for you.

calcium carbonate + hydrochloric acid ⟶ ________ + ________ + ________

f) Name a naturally-occurring substance which consists mainly of calcium carbonate.

____

Question 20

Six very useful types of chemical reaction are listed below. For each one say why it is so useful.

a) **Combustion** is useful because ____

____

b) **Fermentation** is useful because ______________________________

____

c) **Reduction** is useful because ______________________________

____

d) **Neutralization** is useful because ______________________________

____

e) **Electrolysis** is useful because ______________________________

____

f) **Thermal decomposition** is useful because ______________________________

____

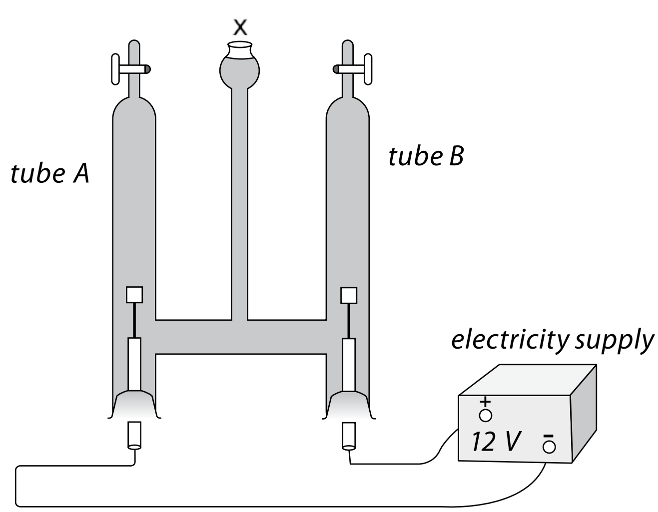
Question 21

This question is about electrolysis.

a) Draw a straight line to match each word on the left with its correct meaning on the right.

Word	**Meaning**
anion	liquid that conducts electricity
cathode	negative ion
anode	negative electrode
cation	positive electrode
electrolyte	positive ion

b) Look at the diagram below. It shows the apparatus used to see the effect of electricity on water.



i) Why was a little sulphuric acid added to the water used in the apparatus?

____

ii) When electricity is passed through the acidified water, what happens to the water levels in tubes A and B?

____

iii) Does the water level change by the same amount in both tubes?

____

iv) A gas is given off in both tubes A and B. How would you collect samples of these gases?

____

v) How would you test the two gases and what results would you expect?

Tube A ______________________________

Tube B ______________________________

vi) Water is not an element. It can be split into two elements by electricity. Name these two elements.

____

Answers to assessment questions

Question 1 (A) **Question 2** (C) **Question 3** (B) **Question 4** (A)

Question 5 (B) **Question 6** (A) **Question 7** (B) **Question 8** (D)

Question 9 (C) **Question 10** (A) **Question 11** (B) **Question 12** (C)

Question 13 (D) **Question 14** (B) **Question 15** (A) **Question 16** (C)

Question 17

a) Hydrogen and carbon dioxide are **gases**. If they are formed in a chemical reaction you will see **bubbles**. This can be a sign that a **chemical** reaction has occurred.

b) Other signs of a chemical reaction might be an increase in temperature if **heat** is released, or a change in **colour.**

c) Physical changes like **boiling** do not make new materials and are easily **reversed**, for instance by cooling which causes **condensation**.

d) The substances you start with are called **reactants**, and after the chemical change the substances that are formed are called the **products**.

e) Zinc and carbon consist of only one type of atom and so are called **elements**.

f) Carbon dioxide consists of atoms of carbon and oxygen combined together, and is known as a **compound**.

g) A shorthand way of showing a chemical change is to use a word **equation**.

Question 18

a) i) There is a loss of mass when the reactants turn into products. FALSE

ii) A word equation shows what is happening in a reaction. TRUE

iii) Chemical reactions involve temporary changes. FALSE

iv) Reactions always either take in or give out energy. TRUE

v) The temperature in a reaction always goes up. FALSE

vi) There are often visible changes in a reaction. TRUE

Question 19

a) Bashir could tell, just by looking, that a chemical reaction was taking place because fizzing was occurring/bubbles of gas could be seen.

b) The total mass shown on the balance would have decreased by the end of the reaction.

c) The gas would have dispersed into the air.

d) The other change that may have occurred in the flask is that the temperature increased.

e) The word equation for the reaction is:

calcium carbonate + hydrochloric acid $\longrightarrow$ calcium chloride + carbon dioxide + water

f) Naturally occurring substances which consist mainly of calcium carbonate are chalk, limestone, marble, and coral.

Question 20

a) **Combustion** is burning. It is useful because it gives out energy, as for example when a fuel burns. Combustion is used in heating and generating electricity.

b) **Fermentation** is useful because it produces ethanol, which can be used as a fuel. It is also used in the production of bread and medicines (antibiotics).

c) **Reduction** is useful because it can be used to extract metals such as iron and zinc from their ores.

d) **Neutralization** is useful because it can be used to remove alkalis or acids, e.g. putting lime on acid soils or using weak alkalis to counter acid indigestion.

e) **Electrolysis** is useful for splitting compounds using electricity, e.g. silver-plating jewellery, purifying copper, or extracting reactive metals, such as aluminium and sodium, from their ores.

f) **Thermal decomposition** is useful because it is a way of producing new compounds, e.g. calcium oxide (quicklime) can be made by heating calcium carbonate (chalk or limestone).

Question 21

a)

Word	Meaning
anion	negative ion
electrolyte	liquid that conducts electricity
cathode	negative electrode
anode	positive electrode
cation	positive ion

b) i) A little sulphuric acid was added to the water used in the apparatus because pure water only conducts electricity very slightly, whereas dilute sulphuric acid is a good conductor of electricity. The acid is needed because it readily forms ions which can be separated by the electricity passing through the electrodes.

ii) When electricity is passed through the acidified water, the water levels in both tubes A and B fall.

iii) The water level falls by roughly twice as much in tube A as it does in tube B.

iv) You could collect samples of the gases by inverting a test-tube over the little tap at the top of each of tubes A and B and then opening the tap to allow the gas to enter the test-tube.

v) The gas from tube A would make a 'popping' sound when a lighted splint is put near it, showing that it is hydrogen.

The gas from tube B would relight a glowing splint, showing that it is oxygen.

vi) Water is a compound which can be split into the two elements hydrogen and oxygen by electricity.

Acids, alkalis, and salts

CHAPTER 7

Teaching Objectives

- Explain the meanings of the terms *acid*, *alkali*, and *salt*
- Examine some common acids, alkalis, and salts and their properties and uses in everyday life
- Examine the effects of solutions of different pH on Universal Indicator, litmus, and other pH indicators

Learning Outcomes

After studying this chapter students should be able to:

- define the terms *acid*, *alkali*, and *salt*
- describe the properties of acids, alkalis, and salts
- explain the uses of acids, alkalis, and salts in daily life
- define indicators
- use indicators to identify acids, alkalis, and neutral substances

Introduction

One of the most important methods used in science is to classify materials with similar properties. For example, the many substances found to be corrosive and with a bitter taste were called acids by the early chemists. Other substances, which could neutralize the effects of these acids, were named alkalis. These group names have been retained today, but now they have much more precise meanings.

Acids and hydrogen

Most acids react with metals, giving off hydrogen gas, but all acids form hydrogen ions (H^+) when dissolved in water. Acids are, in fact, electrovalent compounds of hydrogen and other atoms or groups of atoms called radicals. The three common mineral acids are: sulphuric acid, H_2SO_4, which in solution in water consists of $2H^+ + SO^{2-}_4$; hydrochloric acid, HCl ($H^+ + Cl^-$); and nitric acid, HNO_3 ($H^+ + NO_3^-$). The SO^{2-}_4 group of atoms is the sulphate radical—a covalent group of one sulphur atom and four oxygen atoms with two extra electrons to give it the two negative charges. Similarly the NO_3^- group is called the nitrate radical.

Alkalis and salts

A commonly occurring radical is OH^- (the hydroxyl group), a covalent group of one oxygen atom and one hydrogen atom. This will readily combine electrovalently with a metal, or sometimes with other groups of atoms, to form an alkali. When dissolved in water, alkalis produce hydroxyl ions, OH^-. For example, sodium hydroxide (caustic soda), NaOH, in solution consists of $Na^+ + OH^-$, while ammonium hydroxide, NH_4OH, becomes $NH_4^+ + OH^-$. A base is a chemical compound that will react with an acid to form a salt and water. Simple bases are oxides and hydroxides of metals. If a base dissolves in water it is then called an alkali.

The result of neutralizing an acid with an alkali is always to form a salt and water. The hydrogen ions of the acid and the hydroxyl ions of the alkali, combine covalently to form water.

Electrolytes

Since acids, alkalis, and salts are all electrovalent compounds, they all produce ions when dissolved in water and these charged particles enable them to conduct electricity. Acids, alkalis, and salts are all called electrolytes.

Indicators

Some dyes, known as indicators, change colour in the presence of acid or alkali. The colour depends on the concentration of hydrogen ions or hydroxyl ions in the solution. The most common indicator is litmus which turns red with acids and blue with alkalis. Universal Indicator is a mixture of several indicators and it turns a range of colours corresponding to different pH values.

Practical considerations

The students should already be very familiar with the term *acid* at this stage, but it is important for them to be aware of the extensive range of uses and reactions of both acids and bases. Throughout the whole of this topic there are a great many opportunities for experimental work. However, at all times, the safety aspects of using acids and bases in the laboratory must be emphasized. If the students are allowed to taste tiny quantities of the 'food acids' such as ethanoic acid or vinegar, citric acid, and tartaric acid, ideally on the tip of a cotton bud, they should be warned of the serious danger of tasting other types of acid.

Lesson suggestions

1. Acids

Refer to page 68 of the Students' Book

Starter suggestions

Ask the students to say what they think an acid is and what it is like.

Challenge the students to think of as many sentences as they can which contain the words 'acid' or 'acidic'.

Main lesson

Ask the students to name as many acids as they can. If they do not know already, tell them about some of the naturally occurring acids, as well as the mineral acids to be found in most laboratories. Emphasize that all acids contain the element hydrogen.

Explain the terms 'dilute' and 'concentrated', saying that acids dissolved in a lot of water are called dilute acids. The more concentrated an acid is, the less acid is dissolved in the water. Make sure that the students are also aware of the difference between strong and weak acids. Compile lists of strong and weak acids on the board.

Show the students a bottle of acid with the 'Corrosive' warning sign on it. Ask the students to say what it means. Explain to them that all acids are corrosive to some extent. For example, the weak acid called carbonic acid present in rainwater will slowly dissolve chalk and limestone. However, strong acids will damage flesh, clothing and other materials, and can 'eat' them away.

If you have a fume cupboard, or can take the class outdoors, you can demonstrate the difference in properties between a dilute and a concentrated acid. Wearing eye protection and chemical-resistant gloves, put 20 g of white sugar in each of two 100 cm^3 beakers. First pour 25 cm^3 of dilute sulphuric acid onto the sugar and show that very little happens. Then pour 25 cm^3 of concentrated sulphuric acid onto the sugar in the other beaker. The sugar will rapidly turn black and froth up vigorously as acid-rich steam and carbon are formed. Whether you carry out this demonstration in a fume cupboard or outside, it is essential that the teacher and students keep well back and that the bench or ground is protected from damage.

Round off the lesson by compiling a list of the properties of acids, and a table of the uses of acids. If you have the time and equipment, you could demonstrate the electrolysis of water acidified with dilute sulphuric acid, to show that acids conduct electricity (this is described in detail in Chapter 6 of this book).

2. Alkalis

Refer to page 71 of the Students' Book

Starter suggestions

Ask the students if they know what an alkali is. Can they remember where they have heard of an alkali being used to help get rid of the harmful effects of an acid? (They may recall that sometimes lakes are sprayed with lime to reduce the harmful effects of acid rain, while calamine lotion is used to sooth an acidic bee or nettle sting, and indigestion mixture is used to treat excess acid in the stomach.)

Arrange a display of pictures or, better, the actual items of vinegar, lemon juice, a laboratory acid, and either a bar of soap or an indigestion mixture or tablet. Ask the students which is the odd one out and why.

Main lesson

Wet a bar of soap and ask the students to touch it and describe how it feels. Explain that soap is made from an alkali, which is the chemical opposite of an acid. Ask them to touch a very dilute but warm solution of washing soda (sodium carbonate). They will notice that it also feels soapy, like the bar of soap.

Tell the students that, like acids, there are strong and weak alkalis and give them the names of some of each. Explain that strong alkalis, such as sodium hydroxide and potassium hydroxide are corrosive, while ammonium hydroxide is also harmful.

Demonstrate that alkalis can also bring about chemical reactions by adding bench sodium hydroxide solution to copper sulphate solution in a test-tube. A blue precipitate of copper hydroxide is produced (a double decomposition reaction). Ask the students whether it is a chemical change or a physical change and, having ascertained that it is a chemical change, help the students to write word and symbol equations of the reaction.

Round off the lesson by compiling a list of the properties of alkalis, and a table of the uses of alkalis. You could also ask the students to research the difference between an alkali and a base. They should discover that alkalis are simply bases which are soluble in water.

3. Indicators and pH

Refer to page 71 of the Students' Book

Starter suggestions

Discuss with the students why we need a simple method of distinguishing acids from alkalis, and also why we need to know how strong or weak acids and alkalis are.

Ask the students what they understand by the word ‘indicator’. How many ways in which we use the word ‘indicator’ can they think of?

Main lesson

Explain to the students that special dyes, or mixtures of dyes, called indicators can be used to help us work out whether a chemical is an acid or alkali.

Indicators are either weak acids or weak bases (alkalis) and the chemistry of how they work is too complicated to explain at this level.

However, if the students are not familiar with litmus paper or solutions, this is probably a good point at which to show, by demonstration or class experiment, how this indicator changes in the presence of an acid (it turns red), or an alkali (it turns blue).

Introduce the term pH and the pH scale (there is no need to explain that pH is a logarithmic scale and that pH stands for hydrogen ion concentration at this level). You could, however, remind the students that when water breaks down it forms hydrogen ions (H+) and hydroxide ions (OH-). Solutions are called acidic or basic depending on what kinds of ions they release. Acidic solutions have lots of hydrogen ions present, while alkalis or basic solutions have lots of hydroxide ions present.

At this point, allow the students, wearing eye protection, to carry out the experiment on Worksheet 1.

As a follow up, the students could go on to make and test their own indicators, as described in Worksheet 2. If possible, make and test indicators from a variety of plant materials, including grass as well as flower petals, fruits, and brightly-coloured vegetables.

To finish this lesson or lessons, ask the students what they think would happen if an acid with a pH of 1 was added to an alkali with a pH of 14. Introduce the terms ‘neutralize’ and ‘neutralization’ and help the students to compile a list of occasions when we carry out neutralization reactions.

4. Acid reactions

Refer to page 72 of the Students' Book

Starter suggestions

Ask the students what they understand by the word 'salt'. How many salts do they know?

Ask the students if they can remember what a neutralization reaction is, and also what is meant by a neutral substance. Remind them that neutralization is the reaction of an acid with a base, or alkali, to form a salt and water only. A neutral substance is neither acidic nor alkaline.

Main lesson

Demonstrate the neutralization reaction between sodium hydroxide solution and dilute hydrochloric acid, using a few drops of Universal Indicator to show when neutralization has occurred. If possible, evaporate the resulting solution to dryness to show the presence of sodium chloride, or common salt.

Explain that there are many kinds of salt, not just sodium chloride. There are four ways of preparing soluble salts:

metal hydroxide + acid $\longrightarrow$ salt + water (the type of reaction they have just seen)

metal + acid $\longrightarrow$ salt + hydrogen

metal oxide + acid $\longrightarrow$ salt + water

metal carbonate + acid $\longrightarrow$ salt + water + carbon dioxide

Carry out as many of these methods of producing salts as possible, either as demonstration experiments or as class practical exercises. There are some suggestions for suitable experiments in the **Ideas for investigation and extension work** section of this chapter. These experiments also provide good opportunities for the students to gain practice in writing word and symbol equations.

Round off the topic by telling the students how salts are named. Salts formed from sulphuric acid are *sulphates*; salts formed from hydrochloric acid are *chlorides*; and salts formed from nitric acid are *nitrates*. The students will notice that the acid part of a salt's name sometimes ends in *–ide* and sometimes in *–ate*. The *–ide* ending tells you that there is only one element in the acid part of the salt. For example, sodium chloride is made of the elements sodium and chlorine only. But the *–ate* ending means that the salt also contains oxygen. For example, sodium sulphate is made of the elements sodium, sulphur, and oxygen.

Ideas for investigation and extension work

Acids, alkalis, and salts

There is a large number of small experiments on this topic which can either be demonstrated by the teacher, with the assistance of students, or carried out by small groups of students, depending on the calibre of the students and the availability of equipment and materials.

Safety: The students should wear safety spectacles and any spills on skin or clothing should be dealt with immediately.

a) ***The effect of acids on litmus papers***

Half fill a clean test-tube with water. Using a dropper, add two drops of ethanoic acid (vinegar) to the water. Close the mouth of the tube with your thumb and shake. Now pour a little of the ethanoic acid onto both pieces of red and blue litmus papers. Observe and record the changes in colour of the litmus papers. Now treat other acids in the same way, including citric acid, dilute hydrochloric acid, dilute sulphuric acid, and dilute nitric acid.

b) ***The action of dilute acids on some metals***

Pour dilute hydrochloric acid into a clean test-tube to a depth of 2 cm. Drop a small piece of magnesium ribbon into the test-tube. Quickly close the mouth of the test-tube with your thumb for a few minutes. Observe what happens and whether the reaction is fast or slow. Light a wooden splint and hold it at the mouth of the test-tube. Observe what happens.

Repeat this experiment with iron filings and dilute hydrochloric acid, and zinc powder and copper turnings with dilute sulphuric acid. If the reaction is too slow, warm the test-tube in a beaker of hot water. Make a table of the results.

Write word equations and balanced symbol equations for the reactions you have observed.

c) ***The action of dilute acids on carbonates***

Place a spatula of calcium carbonate in a clean, dry test-tube. Pour dilute hydrochloric acid into the test-tube to a depth of 2 cm. Observe and record what happens. Close the mouth of the test-tube with a stopper that has a delivery tube attached. Dip the delivery tube into limewater and bubble the gas through the limewater. Observe and record what happens.

Repeat the experiment using sodium carbonate with dilute nitric acid and potassium carbonate with dilute sulphuric acid.

Write word equations and balanced symbol equations for the reactions you have observed.

d) ***The action of dilute acids on metal oxides***

Warm a few cm^3 of dilute hydrochloric acid in a boiling tube. Take care not to boil the solution and do not point the open end of the tube towards yourself or anyone else. Then add a spatula of black copper oxide to the warm acid. Stir the mixture with a glass rod. Observe and record what happens. Repeat the experiment with dilute nitric acid and dilute sulphuric acid, and again observe and record what happens. Now try the experiment using magnesium oxide instead of copper oxide.

Write word equations and balanced symbol equations for the reactions you have observed.

e) ***The action of alkalis on some ammonium salts***

Pour dilute sodium hydroxide into a clean test-tube to a depth of 2 cm. Add a spatula of ammonium chloride to the alkali in the test-tube. Warm the mixture gently over a Bunsen flame. Observe the colour and smell of the gas given off. Hold a piece of damp red litmus paper and damp blue litmus paper over the mouth of the test-tube. Observe the colour changes of the litmus papers. Record your observations.

Repeat this experiment using ammonium sulphate with potassium hydroxide and ammonium nitrate with calcium hydroxide. Record your observations.

Write word equations and balanced symbol equations for the reactions you have observed.

f) ***The action of acids on alkalis***

Using a measuring cylinder, pour 10 cm^3 of dilute hydrochloric acid into an evaporating basin. Dip a piece of red litmus paper into the acid by the side of the basin. Using a dropper, add about 10 cm^3 of dilute sodium hydroxide solution drop by drop to the acid in the dish. Stir the mixture with a glass rod as you add the sodium hydroxide. Keep adding the sodium hydroxide, a drop at a time, until the red litmus paper just changes from red to blue. Remove the litmus paper. Heat the mixture over a Bunsen flame until all the liquid has evaporated. Allow the evaporating basin to cool. Observe the colour (and the taste if the experiment has been carried out under hygienic conditions) of the solid left in the basin. What happens when an acid and alkali are mixed?

Write a word equation, and balanced symbol equation for the reaction you have observed.

Cleaning products

Many household cleaners are alkaline. Test the pH value of a selection of detergents, washing powders, and floor cleaners. Compare your results with those products designed for use on the skin, such as soaps, shampoos and conditioners, and cleansing lotions.

Soil and calcium carbonate

Add dilute hydrochloric acid to a small quantity of soil in a test-tube. If calcium carbonate is present, carbon dioxide will be given off as bubbles. How would you test that it was carbon dioxide being produced? Test another sample of the soil with pH paper or Universal Indicator. Soils that contain calcium carbonate are usually alkaline. Is this true of your soil sample?

Antacid tablets

Investigate how the size of the pieces of antacid tablet affects the time it takes to neutralize dilute hydrochloric acid. Put 10 cm^3 of dilute hydrochloric acid and a few drops of Universal Indicator solution into three clean boiling tubes. Put one whole tablet in one tube, break a second tablet into pieces in another tube, and crush a third tablet into a third tube. Time how long it takes for the antacid to neutralize the hydrochloric acid. If possible, carry out the experiment at 37°C, to imitate the conditions in the stomach.

WORKSHEET 1

Universal Indicator and acids and alkalis

Materials needed: measuring cylinder, 50 cm^3; 2 beakers, 100 cm^3; beaker, 50 cm^3; glass rod; Universal Indicator; pH chart; distilled water; dilute ethanoic acid (vinegar); dilute sulphuric acid or dilute hydrochloric acid; dilute ammonia solution

Safety: Wear safety spectacles. If you get the chemicals on your skin or clothes, wash with plenty of water immediately.

1. Pour about 50 cm^3 of distilled water into a clean beaker.
2. Add a few drops of Universal Indicator and stir with a clean glass rod. (Keep this mixture for a later part of this experiment). What colour is the mixture?
3. Compare the colour of the mixture with the pH chart given. Note the approximate pH of the mixture.
4. Add a few drops of dilute ethanoic acid (vinegar) to the distilled water and Universal Indicator from part 2 above. Observe the colour of the mixture.
5. With the help of the pH chart, record the approximate pH of the mixture.
6. Continue adding acid, drop by drop, until another colour change is seen. Record the colour change and the approximate pH of the mixture.
7. Repeat stages 1 to 6, but this time use dilute sulphuric or dilute hydrochloric acid instead of ethanoic acid.
8. Repeat stages 1 to 6, but this time use an alkali, dilute ammonia solution, instead of one of the acids. Again, record the colour changes and approximate pH of the mixture.

Record all your results on the chart below:

Substance tested	**Colour**	**pH**
distilled water		
ethanoic acid (vinegar)		
dilute sulphuric/hydrochloric acid		
ammonia solution		

WORKSHEET 2

Make your own indicator

Materials needed: red cabbage; knife; boiling water; filter paper; funnel; large glass beaker, 1000 cm^3 or another heat-proof glass container; six beakers, 250 cm^3; selection of common acids and alkalis (such as baking soda, washing soda, lemon juice, vinegar, cream of tartar, lemonade, and antacid or indigestion tablets

Safety: Take care when pouring the boiling water and the acids and alkalis.

Wear safety spectacles and gloves.

1. Cut the cabbage into small pieces until you have about 2 cups of chopped pieces.
2. Place the cabbage in the large beaker and add enough boiling water to cover the cabbage.
3. Allow the mixture to stand for at least ten minutes for the colour to leach out of the cabbage.
4. Filter out the plant material to obtain a purple or bluish liquid. This liquid is at about pH 7. (The exact colour will depend on the pH of the water you use.)
5. Pour about 50 to 100 cm^3 of your red cabbage indicator into each 250 cm^3 beaker. Begin by adding a little of one of the weak acids, such as vinegar or lemon juice, until the colour changes. What colour does the indicator become?
6. Now add a little of one of the weak alkalis, such as a solution of one of the indigestion tablets, to the indicator in another beaker. What colour is produced?
7. Now try other acids and alkalis, including dilute sulphuric acid and dilute sodium hydroxide solution, if your teacher agrees. Record the colour of the indicator in each case.

These are the usual colours produced by red cabbage indicator:

pH	2	4	6	8	10	12
Colour	red	purple	violet	blue	blue-green	greenish-yellow

Does your indicator produce the same colours? Record your results here:

You can make your own pH indicator paper if you take a filter paper and soak it in a concentrated red cabbage juice solution for a few hours. Remove the paper and hang it up to dry. Cut the paper into strips and use them to test the pH of various solutions.

Make and test indicators made from other fruits and vegetables, including beetroot, purple onion skins, red spinach stems, blackberries, black currants, plums, apple peelings, and grapes. Try also to make indicators from brightly-coloured flower petals such as those of poppies, morning glory, hibiscus, balsam, and rose.

Answers to questions in the Students' Book

1. The element found in all acids is hydrogen.
2. A concentrated acid contains a large amount of the acid dissolved in water. A dilute acid is one dissolved in a lot of water.
3. A strong acid is very corrosive. It can release lots of hydrogen and dissolves metals quickly. A weak acid is one which is not very corrosive and which releases hydrogen slowly.
4. The main strong acids are hydrochloric, sulphuric, and nitric acids. Weak acids include ethanoic or acetic acid, citric acid, tartaric acid, and carbonic acid.
5. Uses of acids include flavouring and preserving food, health salts and cooking, cleaning metals, helping digestion, producing fertilizers, explosives, plastics and artificial fibres, and in car batteries.
6. The pH of pure water is 7.
7. Neutralization is the chemical reaction between a base and an acid (or an alkali and an acid) to form a salt and water.
8. Some everyday examples of neutralization include taking an indigestion tablet to correct excess acid in the stomach, using toothpaste to neutralize the acids which decay teeth, and adding lime to acid soils. Wasp stings, which are alkaline, can be neutralized with a weak acid such as vinegar. Bee stings contain an acid and can be neutralized with an alkali such as calamine lotion.
9. Vinegar, with a pH of 3 is a weak acid.
10. A piece of wet soap, with a pH of 8, is a weak alkali.
11. When an acid is added to a base or an alkali, a salt and water are produced.
12. The gas given off when a piece of zinc is dropped into sulphuric acid is hydrogen. Zinc sulphate is formed in the tube.
13. Common alkalis include sodium hydroxide, potassium hydroxide, calcium hydroxide, and ammonium hydroxide.
14. Acids are chemical compounds which contain hydrogen. They turn moist litmus paper from blue to red, and they have a pH of less than 7. They also conduct electricity (they are electrolytes). Acids react with metals like zinc and iron to form a salt and hydrogen gas, and they react with metal carbonates to form a salt, water, and carbon dioxide gas. Acids also neutralize bases and alkalis to form a salt and water. A base is a chemical compound that reacts with acids to form a salt and water.

    Simple bases are oxides and hydroxides of metals. Water soluble bases are known as alkalis.
15. Alkalis feel soapy, they turn litmus blue, they have a pH greater than 7, and they conduct electricity when in solution (they are electrolytes).
16. Uses of some common alkalis include making soaps, drain cleaners, and washing powder (sodium hydroxide); making paint and varnish removers and dyeing cloth (potassium hydroxide), making mortar and reducing the acidity of soil (calcium hydroxide).
17. i) You can use vinegar (a weak acid) to treat a wasp sting because the wasp sting is alkaline.

    ii) You can use ammonia solution (an alkali) to treat a bee sting because a bee sting is acidic.

18 Universal Indicator, a mixture of dyes, turns a range of colours corresponding to different pH values, i.e. it is used to measure pH.

19. A salt is a chemical compound formed when the hydrogen of an acid is partially or wholly replaced by a metal or some other positive ion.

20. Some uses of salts include in batteries and washing powder (ammonium chloride); plaster of Paris and wall plaster (calcium sulphate); as a drying agent in chemical reactions (calcium chloride); for flavouring and preserving food, dyeing and printing fibres (sodium chloride); for making explosives, matches, and fertilizers (potassium nitrate).

Assessment

Question 1

What is the pH of a strong acid?

(A) 6 (B) 7 (C) 1 (D) 14

Question 2

Dilute acids are substances which:

(A) have a pH of more than 7
(B) turn red litmus blue
(C) react with magnesium producing hydrogen
(D) do not conduct electricity

Question 3

If a soil is too acidic, what should a farmer add to it?

(A) compost (B) water (C) lime (D) manure

Question 4

What is formed when an acid reacts with an alkali?

(A) salt plus hydrogen (B) salt plus water (C) salt only (D) sodium chloride

Question 5

Which of these chemicals is a strong acid?

(A) sodium hydroxide
(B) calcium hydroxide
(C) potassium hydroxide
(D) sulphuric acid

Question 6

The pH of a neutral solution is:

(A) 1 (B) 5 (C) 7 (D) 10

Question 7

What is the pH of a weak acid?

(A) 1 (B) 6 (C) 7 (D) 14

Question 8

Which of these chemicals can be found in indigestion tablets?

(A) hydrochloric acid (B) calcium carbonate

(C) sodium hydroxide (D) sulphuric acid

Question 9

Name the gas produced when an acid reacts with a metal:

(A) hydrogen (B) oxygen (C) helium (D) carbon dioxide

Question 10

Which of these chemicals is a base?

(A) lemon juice (B) sulphuric acid

(C) hydrochloric acid (D) calcium oxide

Question 11

Which of the following products are formed when calcium carbonate reacts with sulphuric acid?

(A) calcium sulphate + carbon dioxide + water

(B) calcium nitrate + carbon dioxide + water

(C) calcium sulphate +hydrogen

(D) calcium sulphate + water

Question 12

Which of the following will be shown to be an acid when touched with dry litmus paper?

(A) washing-up liquid (B) vinegar

(C) milk (D) sodium bicarbonate solution

Question 13

A boy playing with a chemistry set spills some acid on the carpet. The best remedy would be to treat it with:

(A) water (B) lemon juice

(C) vinegar (D) sodium bicarbonate

Question 14

The soil in a garden was found to be very acidic. To cure this, the gardener would add:

(A) water (B) salt (C) lime (D) fertilizer

Question 15

A wasp sting is alkaline and so could be soothed by dabbing with a solution of:

(A) soap (B) washing soda (C) ammonia (D) vinegar

Question 16

Universal Indicator solution can be used to test the pH of soil. If you tested some soil and found that it had a pH of 6, what colour would the indicator turn?

(A) red (B) orange/yellow (C) green (D) blue

Question 17

When vinegar (an acid) was added to some baking powder (sodium hydrogencarbonate or sodium bicarbonate), a gas was given off. This gas was:

Question 18

An alkali:

(A) turns litmus red (B) reacts with magnesium and produces hydrogen

(C) is a soluble base (D) turns various colours when acids are added

Question 19

What colour is litmus in an acid solution?

(A) red (B) blue (C) green (D) orange

Question 20

Titration is a technique used to:

(A) find out how much alkali neutralizes an acid (B) separate a mixture of two solutions

(C) test the strength of an acid (D) tell whether or not a solution is acidic

Question 21

a) Which of these substances would turn litmus paper blue and which would turn it red?

Substance	**Colour of litmus**
lemon juice	
toothpaste	
vinegar	
cola drink	
soap	
bleach	

b) Bee stings are acidic, while wasp stings are alkaline. Which of the substances in the above table could be used to treat:

i) a wasp sting

____

ii) a bee sting

____

iii) Give reasons for your suggestions.

____

____

Question 22

Finish the passage below using words and numbers from the list. You may need to use the words and numbers more than once.

1	alkalis	purple	8	orange	Indicator	7	strongly
acids	yellow	pH	6	neutral	corrosive	spectacles	

Acids are substances that have a _______ of less than 7. Acids react with alkalis to form _______ solutions. The strongest acids have a pH of_______, while the weakest acids have a pH of _______ .The strongest _______ have a pH of 14, while the weakest alkalis have a pH of _______. Distilled water, which is neutral, has a pH of _______.

Universal _______ is a particularly useful mixture of dyes. It not only shows you whether a solution is acidic or alkaline, but it also shows how _______ acidic or alkaline the solution is. The strongest _______ turn Universal Indicator red. Weaker acids, like rainwater which has a pH of about 5, turn Universal Indicator_______. The weakest acids turn Universal Indicator _______. Weak _______ turn Universal Indicator blue, while stronger alkalis turn it _______.

Both strong _______ and strong alkalis are very _______. You should always wear safety _______ when using either of these two types of chemical and handle their containers with extreme care.

Question 23

The table below shows the pH of five different soaps.

Soap	pH
Easyclean	5.8
Lifeguard	6.9
Cleaneze	7.3
Healthy Clean	7.6
Supersoap	9.7

a) Which soap is the strongest acid? _______________

b) Which soap is the weakest alkali? ______________________________

c) Tick ONE of the boxes below to show which you think gives the best description of the soap called Lifeguard.

strongly acidic ☐

weakly acidic ☐

neutral ☐

weakly alkaline ☐

strongly alkaline ☐

The table below shows the colour of Universal Indicator in different types of solution.

Description of solution	**Strong acid**	**Weak acid**	**Neutral**	**Weak alkali**	**Strong alkali**
Colour of Universal Indicator	red	orange	green	blue	purple

d) What colour will the soap Easyclean turn Universal Indicator? ______________

e) What colour will the soap Healthy Clean turn Universal Indicator? ___________

Question 24

This is the pH scale, a scale showing the strength of an acid or alkali.

1	2	3	4	5	6	7	8	9	10	11	12	13	14

a) Where on this diagram would you expect to find:

i) lemon juice? ______________

ii) distilled water? ______________

iii) hair shampoo? ______________

b) When an acid reacts with an alkali, a certain type of compound is formed.

Complete the word equation for this type of reaction:

acid + alkali ⟶ ______________ + ______________

c) The name of the reaction between an acid and an alkali is:

i) combustion ii) neutralization iii) oxidation iv) reduction

____

d) Now complete these examples of this type of reaction:

hydrochloric acid + sodium hydroxide ⟶ ______________ + ______________

sulphuric acid + potassium hydroxide ⟶ ______________ + ______________

nitric acid + calcium hydroxide ⟶ ______________ + ______________

e) Write the word equation for when an acid reacts with a metal.

acid + metal ⟶ ____________ + ____________

f) How would you test for the gas given off in this reaction?

____

g) What kind of salt is always formed in reactions with sulphuric acid?

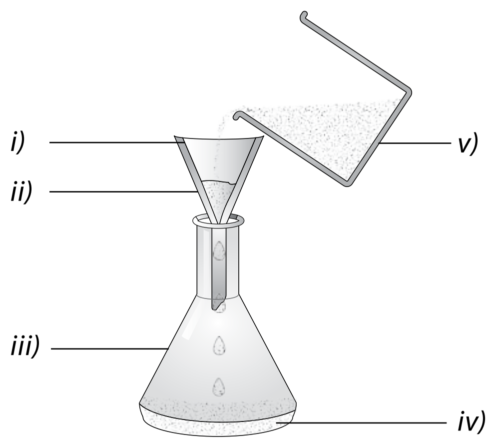
____

Question 25

Rahim used red cabbage to make an indicator. He cut up the red cabbage into small pieces. He then placed it in a test-tube of water and heated it up.

After a few minutes the water changed colour. Rahim then removed the pieces of red cabbage to leave the cabbage water indicator.

The diagram shows the pieces of equipment Rahim used.



a) Label the pieces of equipment:

i) ____________ ii) ____________

iii) ____________ iv) ____________

v) ____________

b) What is the name of the method Rahim used to separate the cabbage water indicator from the pieces of cabbage. Put a tick in the box next to the correct method:

A solidifying ☐ B distillation ☐

C chromatography ☐ D filtration ☐

c) In Rahim's experiment, what was the filtrate and what was the residue?

filtrate ____________

residue ____________

Question 26

A farmer wanted to find out the pH of the soil in three of his fields. He placed a sample of soil from each field in a beaker and added distilled water. He filtered the mixture and then added Universal Indicator to it. He recorded the colour of the Universal Indicator in the table below.

a)

Soil sample	**Colour with Universal Indicator**
Field A	green
Field B	yellow
Field C	blue

a) Draw a line to connect the name of the field to the type of soil.

Field A acidic

Field B neutral

Field C alkaline

b) Decide in which field (A, B, or C) the farmer should grow the crops, based on the information below.

i) Wheat grows best in soils that have a pH of 7.0. ____________________

ii) Cabbages grow best in soils that have a pH of 8.0. ____________________

iii) Potatoes grow best in soils that have a pH of 5.5. ____________________

Answers to assessment questions

Question 1 (C) **Question 2** (C) **Question 3** (C) **Question 4** (B) **Question 5** (D)

Question 6 (C) **Question 7** (B) **Question 8** (B) **Question 9** (A) **Question 10** (D)

Question 11 (A) **Question 12** (B) **Question 13** (D) **Question 14** (C) **Question 15** (D)

Question 16 (B) **Question 17** (D) **Question 18** (C) **Question 19** (A) **Question 20** (A)

Question 21

a)

Substance	**Colour of litmus**
lemon juice	red
toothpaste	blue
vinegar	red
cola drink	red
soap	blue
bleach	blue

b) i) a wasp sting—use lemon juice or vinegar or cola drink.

ii) a bee sting—use soap or toothpaste, NOT bleach which is harmful to the skin.

iii) A wasp sting needs something acidic to neutralize the alkali. A bee sting needs something alkaline to neutralize the acid.

Question 22

Acids are substances that have a **pH** of less than 7. Acids react with alkalis to form **neutral** solutions. The strongest acids have a pH of **1**, while the weakest acids have a pH of **6.** The strongest **alkalis** have a pH of 14, while the weakest alkalis have a pH of **8**. Distilled water, which is neutral, has a pH of **7**.

Universal **Indicator** is a particularly useful mixture of dyes. It not only shows you whether a solution is acidic or alkaline, but it also shows how **strongly** acidic or alkaline the solution is. The strongest **acids** turn Universal Indicator red. Weaker acids, like rainwater which has a pH of about 5, turn Universal Indicator **orange**. The weakest acids turn Universal Indicator **yellow**. Weak **alkalis** turn Universal Indicator blue, while stronger alkalis turn it **purple**.

Both strong **acids** and strong alkalis are very **corrosive**. You should always wear safety **spectacles** when using either of these two types of chemical and handle their containers with extreme care.

Question 23

a) Easyclean soap is the strongest acid with a pH or 5.8.

b) Cleaneze soap is the weakest alkali with a pH of 7.3.

c) The soap called Lifeguard is very slightly acidic (pH 6.9)

d) Easyclean soap would turn Universal Indicator orange as it is a weak acid.

e) Healthy Clean soap would turn Universal Indicator blue as it is a weak alkali.

Question 24

a) i) lemon juice = weak acid, about pH 3

ii) distilled water = neutral, pH 7

iii) hair shampoo = slightly alkaline, about pH8

b) When an acid reacts with an alkali, a salt and water are formed.

Complete the word equation for this type of reaction:

acid + alkali ⟶ **salt** + **water**

c) The name of the reaction between an acid and an alkali is:

ii) neutralization

hydrochloric acid + sodium hydroxide ⟶ **sodium chloride** + **water**

sulphuric acid + potassium hydroxide ⟶ **potassium sulphate** + **water**

nitric acid + calcium hydroxide ⟶ **calcium nitrate** + **water**

d) acid + metal ⟶ **salt** + **hydrogen**

e) The test for the hydrogen given off in this reaction is to place a lighted splint in the mouth of the test-tube, when the hydrogen will 'pop'.

f) A **sulphate** is always formed in reactions with sulphuric acid.

Question 25

a) The pieces of equipment:

- i) filter paper
- ii) filter funnel, or funnel
- iii) conical flask, or flask
- iv) cabbage water indicator, or filtrate
- v) chopped red cabbage and water, or beaker

b) D Filtration [✓]

c) In Rahim's experiment, the filtrate was the red cabbage indicator in the beaker, and the residue was the pieces of red cabbage in the filter paper.

Question 26

a)

Field A	neutral
Field B	acidic
Field C	alkaline

b)
- i) Wheat grows best in soils that have a pH of 7.0 – **Field A**
- ii) Cabbages grow best in soils that have a pH of 8.0 – **Field C**
- iii) Potatoes grow best in soils that have a pH of 5.5 – **Field B**

Pressure

CHAPTER 8

Teaching Objectives

- To explain the term pressure and to relate pressure to force and area using appropriate examples
- To explain and demonstrate simple examples of hydraulic systems
- To describe and explain the behaviour of gases under pressure and to identify uses of high and low pressure in gases
- To explain the significance of changes in atmospheric pressure

Learning Outcomes

After studying this chapter students should be able to:

- define the term pressure
- identify the units of pressure
- explain hydraulics and hydraulic systems by giving examples
- explain how gases behave under pressure
- describe the causes of gas pressure in a container
- explain the working of aerosols
- identify the application of gas pressure
- describe the term atmospheric pressure

Introduction

Air is all around us. We cannot see it but are conscious of it every time we take a deep breath, and we feel it when the wind blows. Although invisible, air has substance and consists of atoms and molecules in the same way as liquids and solids. However, air is about one thousand times less dense than water and one cubic metre of it weighs about 1.25 kg. This means that the air in an average-sized single bedroom weighs about as much as a six-year old child sleeping in it. As air has weight, it exerts a pressure on all the surfaces with which it is in contact. At sea level this pressure is equivalent to about one kilogram on every square centimetre.

Early barometers

It was in 1644 that an Italian, Evangelista Torricelli, devised an experiment to show that air exerts pressure. He sealed a glass tube at one end and filled it with mercury, and then he turned the tube upside down and placed the open end in a dish of mercury. The mercury in the tube fell slightly, but did not all run out. The pressure of the air upon the mercury in the dish supplied the force required to support the 76-cm column of mercury in the tube. The height of the column does not depend on the diameter of the tube but only on the pressure of the air on the mercury in the dish. This became the basis for the mercury barometer. As the pressure of the air varies slightly from time to time, it causes a rise or fall in the level of the mercury. Such changes are useful in forecasting weather: usually, high atmospheric pressure means fair weather and when the barometer falls rain may be expected. Other scientists discovered that the barometer can also estimate height. Since the higher you go, the less air is above you, the pressure is weaker and the mercury falls. For every 100-metre increase in height above sea level, the mercury falls about 1 cm. In 1648 the French scientist, Blaise Pascal, took a barometer up a mountain to demonstrate that at heights above sea level atmospheric pressure falls. Over a hundred years later the first balloonists carried barometers to estimate their altitude. Aircraft altimeters are a special form of barometer (aneroid) to measure height above sea level. An aneroid barometer consists of a metal capsule from which most of the air has been removed. As the air pressure outside the capsule increases the surface of the capsule is forced inwards, causing the attached levers to move a pointer.

Atoms, molecules, and pressure

All matter consists of atoms or molecules, which are small groups of atoms. The behaviour of atoms and molecules is simpler in gases than it is in liquids or solids. In the nineteenth century, scientists put forward the kinetic theory of gases to explain their behaviour. The theory assumes that all gases are made of atoms or molecules which are in constant and rapid motion. The atoms or molecules are continually bombarding the walls of the vessel which contains them and in doing so they exert a pressure on the walls. This pressure is entirely due to the momentum of the moving atoms or molecules.

The more heat a gas contains, the faster the molecules move. The faster they move, the more frequent and powerful are their collisions with the walls. This is why heating a gas increases its pressure. The heat of a gas is equal to the total of the energy of motion (kinetic energy) of all its molecules. Therefore the more gas molecules there are in a vessel the greater the quantity of heat it contains. Temperature, on the other hand, is a measure of the average kinetic energy of the molecules, so the temperature of a gas does not depend on the number of molecules present. The kinetic theory, therefore, makes a very clear distinction between heat and temperature.

Compression

Once the ideas of kinetic theory were accepted, all kinds of observations about the behaviour of gases could be explained including why, when a gas is compressed, it becomes hotter. Notice how warm a bicycle pump becomes when you are pumping up the tyres. The pressure of a gas is due to the molecules bombarding and bouncing off the walls of the container. If one of the walls itself is moving inwards, in this case the piston of the bicycle pump, the molecules bounce off this wall with a greater speed than the speed with which they approached it. The energy of the moving wall is added to the energies of the molecules. Their kinetic energy is increased and so the temperature of the gas rises. In a diesel engine, the rise in temperature when the piston compresses the gas is enough to explode the mixture of air and oil in the combustion chamber of the engine. In a petrol engine, a sparking plug is necessary to make the mixture explode because the compression ratio is lower than that in a diesel engine. The higher compression means that diesel engines must be considerably stronger and therefore heavier than petrol engines.

Practical considerations

This is quite a straightforward topic which lends itself to some simple yet dramatic experiments and activities. Throughout the topic, however, it is important to make sure that the students understand the difference between a force and the pressure it exerts on a surface. Many students seem to think that the two terms are interchangeable and that pressure is just another type of force, like friction or magnetism.

Lesson suggestions

1. Pressure

Refer to page 78 of the Students' Book

Starter suggestions

Ask the students to give their definitions of the words 'pressure' and 'force'. Discuss the range of definitions of the two words and what the true scientific meaning of the two words is. The students should understand that a force is a pushing or pulling action which can change the shape of an object, or make a stationary object move or a moving object change its speed or direction. A force produces pressure when it acts over an area. The size of the pressure is equal to the force divided by the area it acts over.

Show the students real examples, or photographs, of shoes with stiletto heels, flat shoes, and snow shoes. Ask the students to imagine they had a new floor made of smooth polished wood, and visitors came wearing each of these types of shoe. Who would cause the most damage to the floor, and why?

Main lesson

Explain that a large force acting on a small area gives a high pressure. A small force acting on a large area gives a low pressure.

Illustrate this last point by taking a wooden block and a drawing pin. Push the drawing pin into the block of wood. Ask the students to observe that the point of the drawing pin goes into the wood quite easily, while the flat surface of the drawing pin does not push into the flesh of your thumb, even though the force is the same in both cases.

Explain that pressure is equal to force divided by area. The point of the drawing pin has an area of about 1 mm^2, while the area of the top of the drawing pin is about 1 cm^2 (or 100 mm^2). This means that the pressure on the point of the pin is about 100 times greater than the pressure under your thumb.

Ask the students to compile a table consisting of two columns: forces spread over a large area and forces spread over a small area. Forces concentrated over a small area include bee stings, sharks' teeth, pins, needles and drawing pins, stiletto heels, ice skates, knives, chisels, cheese wire (used for cutting blocks of cheese), and arrowheads.

Forces spread over a large area include snow shoes, duck's feet, camel's feet, skis, caterpillar tracks on vehicles, tractor tyres, workmen using boards to walk on a weak roof, and the wide straps on a rucksack.

Let the students measure the pressure exerted by a range of objects by measuring their mass and then the area of the object which is in contact with the ground or bench top. Decide whether you want them to use the unit 'pascal' or its equivalent, which is N/m^2.

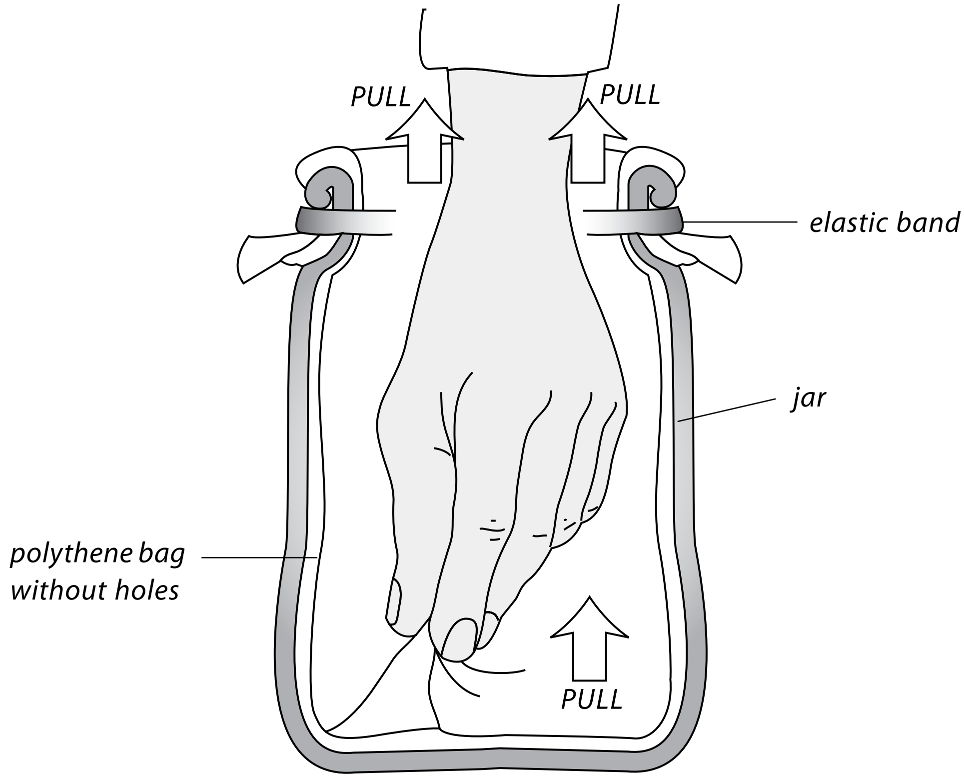
If you have access to a car or motor cycle, let the students measure the area of contact of the tyres and the ground and the pressure they exert, as described in the **Ideas for investigation and extension work** section of this chapter. If possible, round off this part of the topic by carrying out the experiment described on Worksheet 1.

2. Pressure in liquids and gases

Refer to pages 81 and 85 of the Students' Book

Starter suggestions

Have a plastic jar large enough to put your hand in. Seal part of a plastic bag (without any holes in it) inside the jar, using an elastic band. Now ask a volunteer student to pinch the bottom of the bag and try to pull the bag out of the jar. What does the volunteer notice? Can the students explain what they have observed?



Show the students a balloon. Ask a volunteer to try to blow up the balloon. Then inflate the balloon with a pump. Ask the students what is happening to the air inside the balloon and why the balloon inflates. Release the neck of the balloon and let the balloon go. Ask the students why the balloon is pushed along as the air rushes out of it.

Main lesson

Ask the students why it is that the atmosphere has pressure. Explain that atmospheric pressure is caused by the gravitational attraction of the air to the Earth. Furthermore, atmospheric pressure acts equally in all directions and decreases with altitude.

Explain that at sea level there is about 1 kg of air pressing down on every square centimetre. Using this figure, let them calculate the pressure on their textbook and their table or bench.

If possible at this point, demonstrate the collapsing can experiment described in the **Ideas for investigation and extension work** section of this chapter. The activity should be demonstrated from behind a safety screen. In addition, or instead, the egg in the bottle experiment and the inverted glass experiment are also good ways of demonstrating the effects of unequal air pressure.

Worksheets 2 and 3 will enable the students to see how air pressure varies from time to time. Ideally these two activities should be combined with an examination of a real aneroid or mercury barometer.

Move on to study pressure in liquids. Show the students a picture of a submarine or a deep-sea submersible vehicle. Ask why it is that the deeper the submarine or submersible has to dive, the stronger it has to be. Show the class another picture, this time of a dam and reservoir, viewed from the side of the dam. Again, ask the students why the dam wall is much thicker at the bottom than at the top. Let the students carry out the activity described on Worksheet 4 to reinforce their ideas on pressure and depth.

Finish the lesson by explaining that liquids can be used to transmit forces because, unlike gases, they cannot be compressed. Use two syringes half-filled with water and connected by a short length of rubber tubing to demonstrate this fact. If possible, either using diagrams or the real thing, go on to examine the hydraulic brakes of a car or a construction machine that uses hydraulics, such as an excavator or backhoe.

Ideas for investigation and extension work

The collapsing can experiment

The collapsing can experiment makes a dramatic demonstration of the effects of air pressure. You need a clean 5 litre oil can with a screw top which is in good condition. The can and screw top must be made of metal. Pour a cupful of water into the can and place it over a heat source. Allow the water to boil for a short time until the can is full of steam. Quickly and carefully remove the can from the heat. Screw the top on very tightly and let the can stand and cool. What happens? Can the students explain what happens by thinking about the air pressure inside and outside of the can? What is the reason for letting the can cool?

The egg in the bottle experiment

Here is another interesting demonstration of the effects of differences in air pressure. You need a hard-boiled egg and a wide-necked glass bottle. You also need a piece of scrap paper and some matches.

Remove the shell from the egg and check to see that its diameter is slightly larger than the mouth of the bottle. Light the piece of scrap paper and drop it into the bottle. Quickly place the egg, sharp end down, on the mouth of the bottle and watch what happens. Can the students explain what they have seen by thinking about differences in air pressure?

Drinking through a straw

Ask the students to provide a wax or plastic drinking straw and a glass of their favourite drink for this experiment, which they can easily carry out at home. Tell them to put the straw in the drink and then remove some of the air from inside the straw. This is best done by gentle sucking. When the pressure inside the straw has been lowered, the drink rises up the straw. This happens simply because the air pressure outside of the straw is now greater than the air pressure inside the straw.

The inverted glass experiment

Demonstrate this trick over a sink. Fill a glass to the top with water. Place a fresh sheet of paper, or a piece of thin card about the size of a postcard, on top of the glass. With one hand holding the glass and the other firmly pressing on the paper or card, turn the glass upside down. Pull away the hand that is holding the paper or card. Air pressure will hold the water in place.

Contact between tyres and the ground

You will need the help of someone who owns a car or motor cycle. With a ruler and calculator, measure the area of contact the tyres have with the ground. Find the average area of contact. Ask the owner for the tyre pressures, or obtain them from the Internet or a local garage. It may be that the front and rear tyres have different pressures, if so find the average value.

Use the fact that pressure = $\frac{\text{force}}{\text{area}}$, so force = pressure x area to calculate the force pressing down under one tyre.

What is the total force of the car or motor cycle pressing down on the ground? How could you modify this experiment to provide a more accurate result, bearing in mind that tyres have treads?

Compressing materials

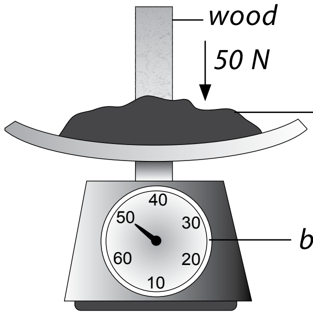
Obtain three large disposable syringes (without the needles). Make sure the syringes are clean. Half-fill one syringe with fine dry sand and one with water. The third syringe should contain only air. Try to compress each of the substances in turn—air, water, and sand—by pressing down on the plunger. Which of the substances can be compressed? Ask the students to explain their observations in terms of the particles they are made of.

WORKSHEET 1

How do area and force affect pressure?

Materials needed: compression spring balance or electronic top-pan balance; metre ruler; lump of clay or Plasticine; piece of wood 20 cm x 0.5 cm x 0.5 cm; piece of wood 20 cm x 3 cm x 3 cm; pencil

1. Place the lump of clay or Plasticine on the scale pan of a balance as shown in the diagram below.



2. Take the piece of wood of cross-section 0.5 cm x 0.5 cm and push it down into the clay or Plasticine until the scale reads 50 N. Make a pencil mark on the wood to show how deep it has gone into the clay or Plasticine. Then remove the piece of wood.
3. Measure how high the pencil mark is from the end of the piece of wood. This will tell you the depth of the dent in the clay or Plasticine.
4. Repeat stages 2 and 3 above, but this time using the piece of wood of cross-section 3 cm x 3 cm. Push it down into a new area of the clay or Plasticine.
5. Record your measurements in the table below:

Cross-section of wood	Depth of the dent (cm)	force, F (N)	area, A (cm^2)	pressure, P(Pa) = $\frac{\text{force}}{\text{area}}$ (N/cm^2)
0.5 cm x 0.5 cm				
3 cm x 3 cm				

Which piece of wood makes the deeper dent?

____

From your calculation, which piece of wood exerts the greater pressure?

____

Explain why the same force exerts a different pressure on the clay or Plasticine.

____

If the two pieces of wood were the heels of shoes, which would cause the most damage to a floor?

____

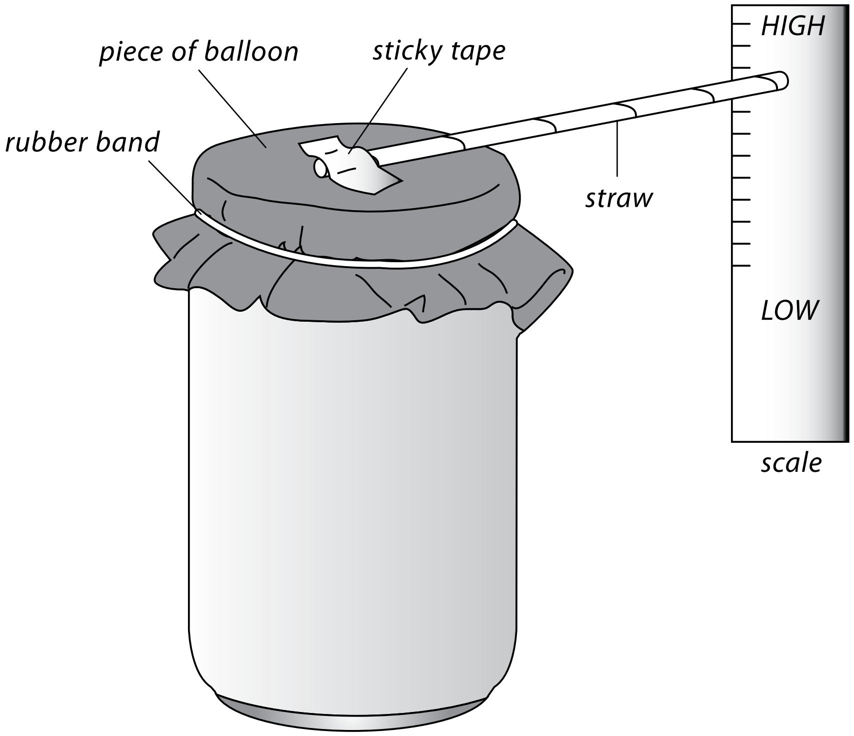
WORKSHEET 2

A jam jar barometer

This model barometer is an anaeroid (no liquid) one.

Materials needed: empty jam jar; balloon; drinking straw; strong rubber band; sticky tape; thin card; scissors; pen

1. Cut the neck off the balloon and then stretch the rest of it over the mouth of the jam jar.
2. Keep the balloon in place with the elastic band.
3. Place one end of the drinking straw in the middle of the stretched balloon. Hold the straw in place with a piece of sticky tape.
4. Make a scale with the pen and thin card, as shown in the diagram below.



5. Over the next week or so, collect information about the changes in air pressure shown by your barometer.
6. Decide on a suitable scale and draw a graph of your results.

Can you explain how the barometer works? Why are the 'high pressure' values at the top of the scale and why are the 'low pressure' values at the bottom?

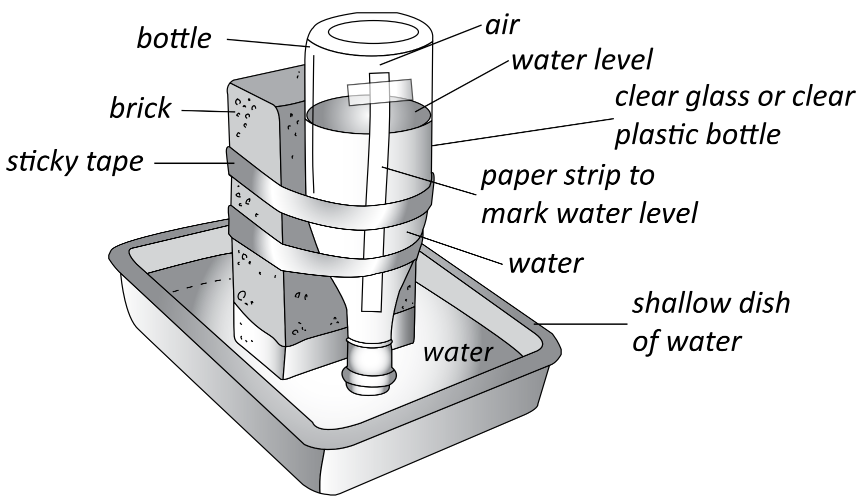
WORKSHEET 3

A simple model barometer

This model barometer relies on the changing air pressure altering the height of a column of water.

Materials needed: a long, narrow clear-glass or clear-plastic bottle; a paper strip to mark the water level; a brick or block of wood; sticky tape; a shallow dish; water

1. Fill the bottle with water.
2. Hold the dish over the top of the bottle, and turn the bottle upside down quickly but carefully. Some of the water will spill so do this part over the sink.
3. Put the bottle on a shelf where it can be left undisturbed. The bottle should be about one-third filled with air. If necessary, tilt the bottle slightly to let some more air in.
4. Tape the bottle to a brick or block of wood so that it will not fall over. Stick a strip of paper on the bottle and mark the level of the water at the start of your work.



5. Look at the barometer at the same time every day for a month. Each day write down the date, time, the weather, and whether the water level in the barometer is going up or going down (compared to the previous day). Remember, when the air pressure increases, the level of the water in the bottle will rise. When the air pressure falls, the level of the water in the bottle will fall.

At the end of the month, look at your results. Say what you think will happen to the weather when the air pressure is:

a) going up ______________________________

b) very high ______________________________

c) going down ______________________________

d) very low ______________________________

e) staying the same ______________________________

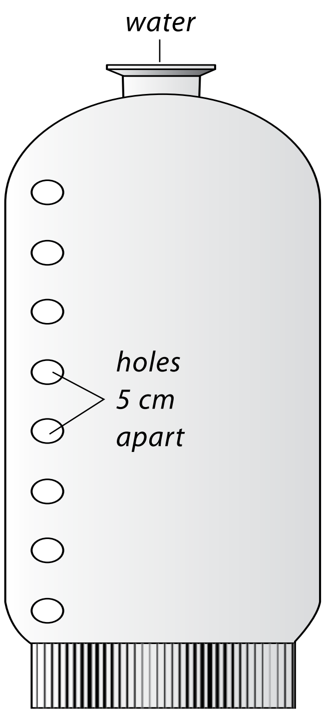
WORKSHEET 4

Pressure and the depth of water

Materials needed: empty plastic lemonade bottle, or similar; compasses; clay or Plasticine; ruler; measuring cylinder; stopwatch

1. Use a compass point, or some other sharp object, to make a line of holes up the side of the bottle. Make the first hole 5 cm from the base of the bottle and then continue every 5 cm to the top.
2. Hold the bottle over the sink and fill it with water.
3. Observe the series of 'water fountains' that appear from the holes in the bottle.

Is there any difference between the fountains at the top of the bottle and those at the bottom?



4. Use some clay or Plasticine to fill up the holes in the side of the bottle, leaving only one open at a time. Measure the length of the water fountains coming from each of the holes. Record your results in the space below.

5. Repeat the experiment, again blocking up the holes in the side of the bottle, leaving just one open at a time. Let the fountain from each hole flow into the measuring cylinder over a set time (say 30 seconds or 1 minute, depending on the volume of the bottle and the size of the holes). You can then compare the flow rates from each of the holes.

Record your results in the space below.

What have you discovered about the pressure of the water at different depths?

Answers to questions in the Students' Book

1. pressure = $\frac{\text{force}}{\text{area}}$
2. pressure = $\frac{\text{force}}{\text{area}} = \frac{800\text{N}}{4\text{m}^2}$ = 200 Pa
3. A sharp knife cuts better than a blunt knife because the force exerted by the user of the sharp knife is spread over a much smaller area.
4. A bulldozer has wide caterpillar tracks to spread its weight over a large area so that it does not sink into soft ground.
5. A human body does not collapse under the weight of air pressing down on it because the body is designed to cope with that pressure. In addition the body fluids and the air in the lungs are at pressure too, and they push back with the same force.
6. If the air is removed from a sealed metal can, the can collapses because the external air pressure no longer has to push against the pressure of the air inside the can.
7. When the air pressure is reduced the height of a column of mercury supported by it will be reduced.
8. If you inverted a tube of mercury 1.5 metres long in a dish of mercury, the level of the mercury would fall until it stood approximately 76 cm high. The vacuum space above the mercury would be approximately 150 – 76 = 74 cm long.
9. A device which measures air pressure (a barometer) can also measure altitude or height (an altimeter) because the air pressure decreases uniformly as you rise above the Earth's surface, or sea level.
10. The air pressure outside an aircraft flying at, say 10,000 m, is very low and at these low pressures the passengers would not be able to breathe. In addition, at that altitude the temperature outside the aircraft is about -60^{0}C. The cabin is, therefore pressurised by high-pressure air from the jet engines. This keeps the passengers warm and comfortable and enables them to breathe without difficulty.
11. pressure = $\frac{\text{force}}{\text{area}} = \frac{40{,}000\text{ N}}{500\text{ m}^2} = \frac{40{,}000\text{ N}}{0.05\text{ m}^3}$ = 800,000 Pa
12. pressure = $\frac{\text{force}}{\text{area}} = \frac{500\text{ N}}{0.5\text{ cm}^2} = \frac{500\text{ N}}{0.000005\text{ m}^3}$ 10,000,000 Pa

    It would be better to be stepped on by an elephant (800,000 Pa) than by a stiletto heel (10 million Pa) since the former would cause less damage or injury.
13. With their large surface area, snowshoes spread out the user's weight, so that he or she exerts less pressure and does not sink into the snow.
14. Lemonade and other fizzy drinks contain carbon dioxide gas dissolved in the liquid under pressure. As soon as the pressure is decreased by opening the can or bottle, the gas comes out of solution and bubbles of it rise towards the surface of the liquid. The bubbles collapse on the way to the surface because the liquid has a higher density than the bubbles and 'squashes' them.
15. An aerosol consists of very small particles of a substance suspended and dispersed in air or some other gas. An aerosol can contains paint, polish, air-freshener, or some other substance held, under pressure, in a liquid known as the propellant. When the nozzle on the can is pressed, the propellant turns to a gas and forces tiny particles of the substance through the hole in the nozzle. It thus creates an artificial

aerosol of the substance.

16. Gravity acting on a liquid causes pressure to be exerted on the walls of its container. This, like air pressure, acts equally in all directions but does not depend on the shape of the container. It does, however, depend on the density of the liquid and it increases with depth.

    The pressure at a point in a liquid is

    = height of liquid at a point x density of liquid x gravitational constant

    = 100 x 1,1150 x 10 (in round figures)

    = 1,1150,000 Pa (ignoring air pressure)

17. The weight of the block of metal in, i) air is 10 N. ii) Its weight, half-submerged in water is 8 N. iii) Its weight fully submerged in water is 6 N and iv) fully submerged in strong salt solution is 5 N.

18. i) When the piston is pushed in so that the air enclosed now occupies a quarter of the length of the cylinder it occupied originally, the volume of the air is now a quarter of what it was originally.

    ii) The pressure of the air has increased by a factor of about 4.

    iii) The number of molecules of air is unchanged.

19. The tyre pressures were lower in the evening because, as the temperature fell, the movement of the particles of air became slower and slower. The particles of air collided with the sides of the tyre at a lower speed, and so the pressure fell.

Assessment

Question 1

The unit for force is the:

(A) kilogram (B) metre (C) joule (D) newton

Question 2

The force of gravity pulling on an object is called its:

(A) height (B) mass (C) weight (D) temperature

Question 3

Which of these statements is NOT true?

(A) Gases are easy to compress because there is a lot of space between the particles.

(B) The higher the pressure, the less gas will dissolve in a liquid.

(C) Liquids are difficult to compress because there is little space between the particles.

(D) Solids are almost impossible to compress because there is almost no space between the particles.

Question 4

Which of the following will create the greatest pressure on a surface?

(A) snowshoes (B) drawing pin (C) skis (D) the feet of a camel

Question 5

Which word describes a device that works off pressure transmitted through liquid in a pipe or cylinder?

(A) incompressible (B) compressible (C) hydraulic (D) pneumatic

Question 6

The pressure of a liquid:

(A) is the same everywhere (B) increases with depth

(C) is caused by air pressure (D) is greatest from above

Question 7

Which one of the following is an example of a force creating a low pressure?

(A) pushing in a drawing pin (B) using a sharp knife

(C) wearing stiletto heels (D) wearing snowshoes

Question 8

What units do we use to measure pressure?

(A) newtons (B) metres (C) pascals (D) newtonmetres

Question 9

Which of these equations do we use to calculate pressure?

(A) pressure = force x area (B) pressure = force/area

(C) pressure = area/force (D) pressure = force/volume

Question 10

What pressure is created when a force of 64 N is applied over an area of 4 m^2?

(A) 256 Pa (B) 16 Pa (C) 16 m^2 (D) 256 m^2

Question 11

What pressure is created when a force of 500 N is applied over an area of 25 m^2?

(A) 20 Pa (B) 20 Nm (C) 2500 Pa (D) 12,500 Nm

Question 12

High-heeled shoes are banned from certain types of floor because:

(A) they are not fashionable
(B) the wearer can easily fall over
(C) they may damage the floor
(D) it is not easy to dance in them

Question 13

The cause of gas pressure is:

(A) the force of the gas particles colliding with the walls of the container
(B) temperature changes
(C) diffusion
(D) expansion of the gas particles

Question 14

If a balloon containing air is heated, the gas pressure inside the balloon:

(A) decreases
(B) stays the same
(C) increases
(D) increases and decreases

Question 15

Complete the following sentences using the words in the box below. You may need to use one or two words more than once.

area	increased	camel	reduce	knife	heels	floor
damage	increasing	force	sinking	small	pressure	

If a ________ is spread over a larger area, the ________ is less. If a force is concentrated on a smaller ________ the pressure is greater.

Pressure can be ________ by decreasing the area over which a force acts. Stiletto ________ on shoes increase the pressure because only a ________ area is in contact with the ________. As a result, such shoes can do a great deal of ________. A ________ has a sharp edge with a very small area, allowing it to cut easily.

Pressure can be decreased by ________ the area over which a ________ acts. Snowshoes have a large area to ________ the pressure, preventing the wearer from ________ into the snow. Similarly, the feet of a ________ have a large area that decreases the pressure, preventing them from ________ into the sand.

Question 16

Which of these statements are TRUE and which are FALSE?

a) Sharp knives create greater pressure than blunt knives. ________

b) Snowshoes spread forces over a large area. They create low pressure enabling us to walk over soft snow without sinking in. ________

c) A table with very narrow legs will do less damage to a wooden floor than the same size table with wide legs. ________

d) The pressure created on a nail when it is hit by a hammer is greatest on the head of the nail. ________

e) The area underneath the blade of an ice skate is one of low pressure. ________

f) Excavators have special wheels called caterpillar tracks to spread their weight when they move over soft ground. ________

g) Pressure is defined as the force acting on a unit area. ________

h) The SI unit for pressure is the square metre. ________

Question 17

a) Name a unit of pressure.

____

b) Why are high-heeled shoes banned in some public buildings?

____

c) Write down the formula for calculating pressure.

____

d) Why is it an advantage for a camel to have big feet when it walks across desert sand?

____

e) Calculate the pressure exerted on the ground by each foot of a camel if it weighs 7000 N and each foot has an area of 600 cm^2.

____

f) Calculate the pressure exerted on the ground by each foot of a horse if it weighs 5000 N and each foot has an area of 125 cm^2.

____

g) Which animal would make the deepest footprints in sand, the horse or the camel?

____

Question 18

Khalid needed to pump up his football. He used a bicycle pump for this.

a) i) Where was the energy stored before it was changed in pumping up the football?

____

ii) In what form was the energy stored? ________________________

b) i) Khalid noticed that the bicycle pump became hot as he was pumping up the ball. Why was this?

____

ii) What effect would this increase in temperature have on the movement of the air particles (molecules) inside the ball?

____

iii) What effect would an increase in temperature have on the pressure of the air inside the ball?

____

iv) Why would the presence of more air molecules inside the ball increase the pressure inside the ball?

____

c) If Khalid places the ball in a fridge, the air inside the ball will become colder and the pressure inside the ball will change.

i) Explain what happens to the pressure inside the ball as the air particles (molecules) get colder.

____

ii) Explain why the change in pressure occurs when the ball is cooled, in terms of air particles.

____

Question 19

Adeel stands on the bathroom scales. The scales read 50 kg.

a. What is Adeel's mass? ______________________

b. What is Adeel's weight? ______________________

When Adeel stands, the area of his feet in contact with the ground is $200cm^2$.

c. What pressure does Adeel exert on the ground? ______________________

d. When Adeel stands on one foot, what effect does this have on the pressure he exerts on the ground?

____

Answers to assessment questions start new page

Question 1 (D) **Question 2** (C) **Question 3** (B) **Question 4** (B) **Question 5** (C)

Question 6 (B) **Question 7** (D) **Question 8** (C) **Question 9** (B) **Question 10** (B)

Question 11 (A) **Question 12** (C) **Question 13** (A) **Question 14** (C)

Question 15

If a **force** is spread over a larger area, the **pressure** is less. If a force is concentrated on a smaller **area**, the pressure is greater.

Pressure can be **increased** by decreasing the area over which a force acts. Stiletto **heels** on shoes increase the pressure because only a **small** area is in contact with the **floor**. As a result, such shoes can do a great deal of **damage**. A **knife** has a sharp edge with a very small area, allowing it to cut easily.

Pressure can be decreased by **increasing** the area over which a **force** acts. Snowshoes have a large area to **reduce** the pressure, preventing the wearer from **sinking** into the snow. Similarly, the feet of a **camel** have a large area that decreases the pressure, preventing them from **sinking** into the sand.

Question 16

Which of these statements are TRUE and which are FALSE?

a) Sharp knives create higher pressure than blunt knives. TRUE

b) Snowshoes spread forces over a large area. They create low pressures enabling us to walk over soft snow without sinking in. TRUE

c) A table with very narrow legs will do less damage to a wooden floor than the same size table with wide legs. FALSE

d) The pressure created on a nail when it is hit by a hammer is greatest on the head of the nail. FALSE

e) The area underneath the blade of an ice skate is one of low pressure. FALSE

f) Excavators have special wheels called caterpillar tracks to spread their weight when they move over soft ground. TRUE

g) Pressure is defined as the force acting on a unit area. TRUE

h) The SI unit for pressure is the square metre. FALSE

Question 17

a) Units of pressure are N/mm^2 OR N/cm^2 OR N/m^2 OR the Pascal (Pa). 1 Pa = $1Nm^{2.}$

b) High-heeled shoes are banned in some public buildings because the small size (or small surface area) of the heel creates a large pressure which can dent wood and other soft flooring materials.

c) The formula for pressure is: pressure = $\frac{\text{force}}{\text{area}}$

d) The large feet of the camel reduces the pressure the animal exerts on the sand. It is therefore less likely to sink in.

e) Each foot has an area of 600 cm^2.

Therefore 4 feet = 4 × 600 = 2,400 cm^2

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{7\,000}{2\,400} = \frac{2.9\text{ N}}{\text{cm}^2}$$

f) Each hoof has an area of 125 cm^2.

Therefore 4 hooves = 4 × 125 = 500 cm^2

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{5\,000}{500} = \frac{10\text{ N}}{\text{cm}^2}$$

g) Because the horse exerts the greatest pressure, it would make the deepest footprints or hoofprints in the sand.

Question 18

a) i) Before it was changed in pumping up the football, the energy was stored in Khalid's muscles.

ii) The energy stored was stored in the form of glucose in Khalid's muscles.

b) i) The bicycle pump became hot as Khalid was pumping up the ball because of the friction of the moving parts.

ii) This increase in temperature would make the air particles (molecules) inside the ball move faster.

iii) The increase in temperature would increase the pressure of the air inside the ball.

iv) The presence of more air molecules inside the ball would increase the pressure inside the ball because there would be more collisions between the air particles and the inside surfaces of the ball.

c) i) If Khalid places the ball in a fridge, the pressure inside the ball will get less/decrease as the air particles (molecules) get colder and move around more slowly.

ii) The reduction in pressure occurs when the ball is cooled because the air particles have less energy and move more slowly. As a result, they collide with the walls of the football less often and with less energy, so the pressure decreases.

Question 19

a. Adeel's mass is 50 kg (or 50 000 g).

b. Adeel's weight is 50 x 10 = 500 N.

c. The pressure that Adeel exerts on the ground:

$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{500}{200} = \frac{2.5\text{ N}}{\text{cm}^2}$

d. When Adeel stands on one foot, the pressure he exerts on the ground doubles (or increases).

Scientists must measure

CHAPTER 9

Teaching Objectives

- To explain the importance of accurate measurement in scientific investigation and the desirability of using SI units
- To explain the meaning of physical quantities, and the importance of appropriate measuring instruments and units of measurement
- To demonstrate methods of measuring regular and irregular solids and the volume of liquids

Learning Outcomes

After studying this chapter students should be able to:

- define a physical quantity with examples
- apply the prefixes milli-, kilo-, centi-, and interpret the units
- interconvert smaller units and bigger units
- select and use measuring instruments
- interpret SI units in daily life
- investigate why it is desirable for scientists to use the SI units in their work
- measure the volume of a liquid by reading the meniscus correctly

Introduction

Who needs to measure? The answer is simple—it is not just scientists, it is everyone. We use a measuring jug or scales when cooking, a clock or watch to measure the passage of time, a thermometer to show us the temperature, a ruler or tape measure for lengths and distances in sewing and carpentry. Those are just a few examples. You can probably think of many other uses of measurement in sports, business, travel, and shopping.

Qualitative descriptions and quantitative measurements

Descriptions of size may be either qualitative or quantitative. When we use terms such as *long* and *short*, *light* and *heavy*, or *hot* and *cold* we are referring to measurements of length, mass, and temperature, but only in a general way. They are qualitative measurements. When we use descriptions such as *3.4 m long*, *a mass of 4.5 kg*, or *a temperature of 30^{o}C*, we are giving precise information. These are quantitative measurements.

Qualitative descriptions are used frequently for comparing things in ordinary conversation. Scientists have to be precise, so they usually use quantitative measurements.

Practical considerations

Young students will not get very far in their work in science without being familiar with the whole range of modernized metric units, or SI units. Most of the time they will be using these units as an incidental, although vital, part of their work on other aspects of science. It is probable that only the measurement of the volumes of liquids and irregular solids and the measurements of speed and density will need extra study at this stage.

Lesson suggestions

1. Measuring volumes

Refer to page 99 of the Students' Book

Starter suggestions

Ask the students to use hand spans and/or cubits (the distance from the elbow to the tip of the middle finger) to measure the furniture and other items in the classroom. Compare results and discuss why we need a system of standard measurements.

Check that the students all know how to measure the length, area, and volume of regular solids. Perhaps they could carry out some of the activities on estimating and then measuring which are described in the **Ideas for investigation and extension work** section of this chapter.

Main lesson

Let the students use a variety of equipment to measure the volume of water or some other liquid. Equipment they could use includes measuring cylinders, measuring flasks, pipettes, and burettes. Explain and demonstrate the problems caused by parallax error when viewing the meniscus from different angles.

The students could then move on to measure the volume of some everyday objects, such as glasses, bottles and jars, using the equipment you have provided.

Finally allow the students to measure the volume of a variety of small irregular solids using the two methods described on Worksheet 1.

2. Measuring density

Refer to page 103 of the Students' Book

Starter suggestions

Cut a block of expanded polystyrene so that it is the same shape and size as a house brick. Paint the polystyrene so it looks like a brick. Put the ‘brick’ by the side of an identical unpainted block of polystyrene and ask the class which of the two is heaviest. Drop the ‘brick’ on the floor or the table and ask the class why it did not do any damage.

Show the class a small block of a dense metal and a beaker containing the equivalent mass of water. Ask the class which of the two is heaviest.

Main lesson

Ask the students if they have ever been in a crowded cinema, sports ground, or shopping centre. Tell them that if they have, then they already have an idea of what is meant by density.

Now ask them to picture the room they are in with only five students in it. Now imagine the same room with fifty students in it. Which situation has the higher density? The answer, of course, is that the room with fifty students in it has the higher population density.

Explain that in science, density is a physical property of matter. Density depends on both mass and volume. Density is how heavy something is for its size. It is calculated using this formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The mass is usually measured in grams and the volume in cm^3.

Now let the students use Worksheet 2 to measure the density of, say, a stone and some cooking oil.

Round off the lesson by explaining that the density of a substance determines whether that substance will sink or float in water. Water has a density of 1.00 g/cm^3. Substances that are less dense than water will float on its surface. Substances that are denser than water will sink in it. Ask the students to use this information to explain why it is that even a small block of steel will sink in water, and yet an enormous steel ship will float.

3. What are rate and speed?

Refer to page 107 of the Students' Book

Starter suggestions

Ask the students to write down as many uses as they can of the word 'rate'. Hopefully they will remember earlier lessons about pulse rate, heart rate, and the rate of chemical reactions.

Ask each student to come to the lesson with information on people or machines that have broken speed records. When discussing these, stress the two important components of speed: time and distance.

Main lesson

Explain to the students that a rate is a ratio or comparison between two measurements, often with different units. Rates usually compare something with time. You might, for example, measure your heartbeat after you have been running and come up with the answer that your heart was beating at a rate of 118 beats a minute.

To give the students experience in measuring rates, let them carry out the activity described on Worksheet 3.

Speed is a term based on rates. The speed of something is the distance it moves in one unit of time. For example, if a car travels seventy kilometres in one hour, its speed is 70 kilometres an hour, or 70 km/h.

To give the students experience in measuring speed, let them carry out the activity described on Worksheet 4. Experience of using more accurate measurements can be gained if the students set up a long adjustable slope and time how long it takes for a toy car or dynamics trolley to travel down the slope when the slope is arranged at different angles. For experience with slower speeds, and smaller units of distance, ask the students to measure the speed of a slug, snail, or some other invertebrate animal.

Ideas for investigation and extension work

Estimate and measure small distances

Ask the students to estimate and then measure, using a ruler or tape measure, small distances such as the diameter of a small coin, the length of a finger nail, the diameter of a drawing pin, etc. Make a table of the results like this:

Object	Estimate of length	Measured length	Difference

Estimate and measure larger distances

Using a metre ruler, a tape measure, and a trundle wheel, estimate and measure larger distances, such as the length of the classroom, length of a corridor, width of the school building, etc. Present the results in a table like that above.

Measure small and large areas

Measure small and large areas, such as the area of a textbook, the classroom and the school playground. Include also the areas of circular objects such as coins and plates.

Measuring mass

Estimate and then measure the masses of large and small objects, including a button, a stick of chalk, an orange, a book, a pencil, and a ruler. Make a table of the results.

Measure volume

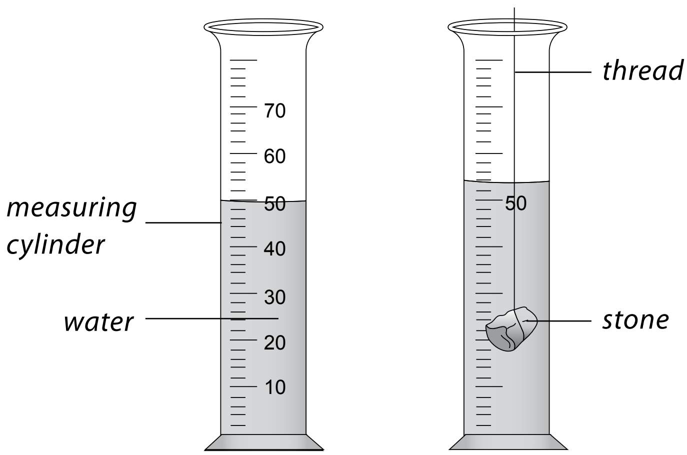
Measure the volume of everyday objects such as boxes, drinking glasses, bottles, yoghurt pots, etc. Let the students choose what they consider to be the most appropriate method for measuring each of the objects they are presented with.

WORKSHEET 1

Measuring the volume of irregular solids

Materials needed: measuring cylinder; 2 beakers 250 cm^3; 2 stones or other irregular solids; length of strong thread; displacement (or Eureka) can; tripod stand

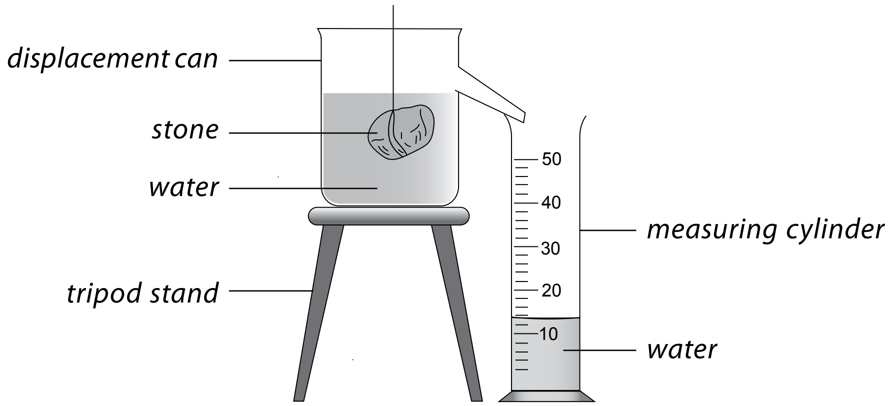
1. Tie a length of thread to a stone.
2. Pour water into the measuring cylinder to a suitable level. Record this volume of water in the table below.
3. Lower the stone slowly and carefully into the measuring cylinder. Take care not to splash any water out of the measuring cylinder. Record the new volume of water.
4. Complete the table to find the volume of the stone.



volume of water	cm^3
volume of water + volume of stone	cm^3
volume of stone	cm^3

1. Place the displacement can on the tripod stand. Put a beaker under the spout of the displacement can.
2. Fill the displacement can with water until it overflows into the beaker.
3. Remove the beaker.
4. Place a clean, dry measuring cylinder underneath the spout of the displacement can.
5. Tie a length of thread to the second stone.
6. Carefully lower the stone into the displacement can until it is completely submerged and rests on the bottom.

7. Read the volume of water collected in the measuring cylinder, which is the same as the volume of the stone.



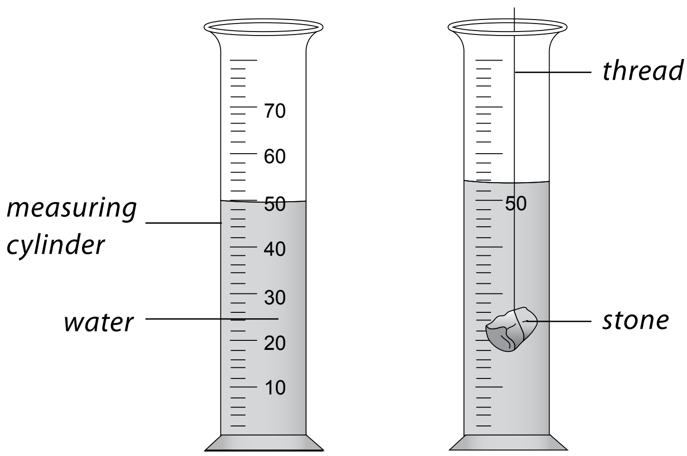
volume of stone = __________ cm^3

WORKSHEET 2

Measuring density

Materials needed: measuring cylinder 100 cm^3; beaker, 100 cm^3; small stone; cooking oil; strong thread; beam balance or top-pan balance

1. Density of a stone
   a) Find the mass of the stone by using the balance. Record this mass below.
   b) Tie a thread to the stone.
   c) Put a known volume of water in the measuring cylinder and then carefully lower the stone into it. Record the new volume as shown by the measuring cylinder. The difference in volumes is the volume of the stone.



mass of stone = __________ g

volume of stone = __________ cm^3

Calculate the density of the stone.

density of stone = $\frac{\text{mass}}{\text{volume}}$ = __________ = __________ g/cm^3

2. Density of water
   a) Find the mass of the empty beaker by using the balance.
   b) With the measuring cylinder, measure 50 cm^3 of water and carefully pour it into the beaker.
   c) Find the combined mass of the beaker and water.
   d) Calculate the mass of the water.
   e) Calculate the density of water.

mass of empty beaker = ______________ g

mass of beaker + water = ______________ g

mass of water = ______________ g

volume of water = ______________ cm^3

density of water = $\frac{\text{mass}}{\text{volume}}$ = ______________ = ______________ g/cm^3

3. Density of cooking oil.

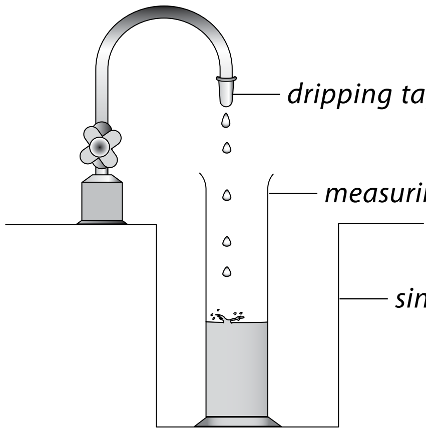
   Find the density of cooking oil. Write down the steps you used in the space below. Show your calculations.

WORKSHEET 3

Measuring rate

Materials needed: measuring cylinder, 100 cm^3; stopwatch or stop clock

Work with a partner.



1. Slowly turn on a tap until the drops of water flow out at a regular rate.
2. At an agreed moment, put the measuring cylinder under the tap while your partner starts the stopwatch or stop clock.
3. When the volume of water in the measuring cylinder reaches 100 cm^3 stop the watch or clock.
4. Record the volume and time in the table below.
5. Empty and dry the measuring cylinder.
6. Increase the rate of flow of the water slightly and repeat steps 2 to 5 above. Do this again for a third, even faster, rate of flow.

Volume of water cm^3	Time in seconds s	Rate of flow cm^3/s

How would you change the experiment to measure an even faster rate of flow?

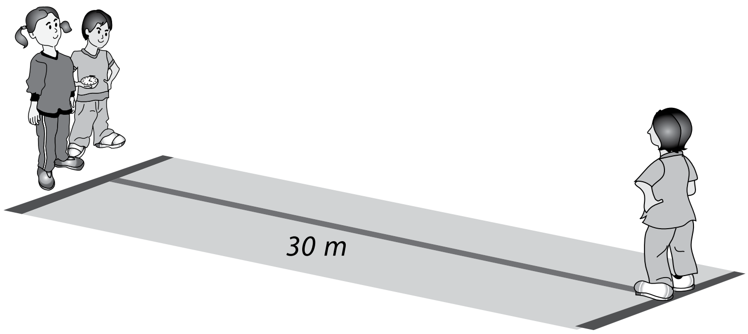
WORKSHEET 4

Measuring speed

Materials needed: stopwatch or stop clock; measuring tape; roll of masking tape, stick of chalk or two small sticks

Work with a partner.

1. Do this activity in an empty space like the school field, playground, or school hall.
2. With the measuring tape, measure 30 m on the floor or ground. If you are indoors mark the two points with masking tape, on the playground use chalk, while on the playing field use the two small sticks.



3. Ask your partner to stand at the finishing line and to measure the time you take to walk the 30 m.
4. Record the time you take to the nearest second.
5. Calculate your walking speed, remembering that speed = $\frac{\text{distance}}{\text{time}}$
6. Repeat stages 3, 4, and 5 above to find your running and hopping speeds.
7. Record your results in the table below.

Type of movement	Distance (m)	Time (s)	Speed (m/s)
walking			
running			
hopping			

a. For the 30 m distance travelled, how will your speed be affected if:

i) a longer time is taken?

____

ii) a shorter time is taken?

____

b. If you could use any one of the three types of movement in a 100-metre race, which one would you choose? Explain your answer in terms of speed.

____

____

Answers to questions in the Students' Book

1. There are i) 10 millimetres in 1 cm; ii) 40 mm in 4 cm; iii) 5 mm in 0.5 cm,

   67 mm in 6.7 cm, and 1000 mm in 1 m.

2. i) area of field = 100 x 100 m = 10,000 m^2 = 1 ha

   ii) area of 2 ha field = 20 000 m^2

   number of cows = $\frac{20\,000\ m^2}{20\ m^2} = 1000$

3. volume of box = 10 × 10 × 10 cm = 1000 cm^3 or 1 litre

   The box will hold 1 litre of milk.

4. area of circle = π x $radius^2$ = 3.142 × 14 × 14 = 615.83 cm^2

5. volume of water in box = 6 × 6 × 7 cm = 252 cm^3

   Stone causes water to rise by 2 cm.

   volume of stone = 6 × 6 × 2 cm = 72 cm^3

6. Density is the mass per unit volume, or density = $\frac{mass}{volume}$

7. density = $\frac{mass}{volume}$ and mass = density × volume

   mass of i) 1 cm^3 = 0.5 × 1 cm = $\frac{0.5g}{cm^3}$

   ii) 2 cm^3 = 0.5 × 2 cm = $\frac{1.0g}{cm^3}$

   iii) 10 cm^3 = 0.5 × 10 cm = $\frac{5.0g}{cm^3}$

8. density = $\frac{mass}{volume} = \frac{96}{12} = \frac{8.0g}{cm^3}$ or $\frac{8000\ kg}{m^3}$

9. Substances that would sink in water but float in mercury include aluminium, steel, stainless steel, iron, copper, and lead.

   It would be extremely painful as well as dangerous to jump into a swimming pool full of mercury.

10. The volume of water in the box is 10 × 10 × 10 cm = 1000 cm^3

    The rock displaces 10 × 10 × 2 cm = 200 cm^3 of water

    The volume of the rock is 200 cm^3

    The density of the rock is $\frac{500}{200} = \frac{2.5g}{cm^3}$

11. Cork has a density of $\frac{0.25g}{cm^3}$

    mass of cork = 10 g

    density = $\frac{mass}{volume}$ volume = $\frac{mass}{density} = \frac{10}{0.25}$ = 40 cm^3

12. A piece of a material with a density higher than that of water will sink when it is placed in water. A piece of a material with a density less than that of water will float in water.

13. The family's rate of water use is $\frac{180\ m^3}{7}$ = 25.71 m^3 in a day.

14. The car's rate of petrol consumption is $\frac{150}{10} = \frac{15\ km}{l}$.

Assessment

Question 1

What are the international units for scientific work called?

(A) CM units (B) TP units (C) SI units (D) RG units

Question 2

What is the correct order, in increasing size, for measurements of length?

(A) kilometre, centimetre, metre, millimetre

(B) metre, centimetre, millimetre, kilometre

(C) millimetre, centimetre, metre, kilometre

(D) millimetre, metre, centimetre, kilometre

Question 3

What word do we use to describe the amount of matter in an object?

(A) weight (B) force (C) gravity (D) mass

Question 4

The force of gravity pulling on an object is called its:

(A) distance (B) height (C) mass (D) weight

Question 5

The unit for force is the:

(A) kilogram (B) metre (C) joule (D) newton

Question 6

What do we call the curved surface of a liquid in a narrow container?

(A) meninges (B) meniscus (C) membrane (D) manometer

Question 7

Which instrument would you use to measure the external diameter of a golf ball?

(A) micrometer (B) metre rule (C) pressure gauge (D) callipers

Question 8

What is the name given to the error caused by the apparent change in position of one of the marks on a ruler or some other scale when it is looked at from different positions?

(A) parallelogram error (B) parallel error (C) parallax error (D) positional error

Question 9

As well as a measuring cylinder, what else would you use to measure the volume of a small piece of rock?

(A) callipers (B) displacement can (C) ruler (D) micrometer

Question 10

The density of water at 4°C is 1000 kg/m^2. What is the density of ice?

(A) 250 kg/m^2 (B) 920 kg/m^2 (C) 1100 kg/m^2 (D) 2700 kg/m^2

Question 11

Which is heavier, a kilogram of lead or a kilogram of polystyrene beads?

(A) the lead (B) the polystyrene

(C) both weigh the same (D) it depends on the temperature

Question 12

Which of the following is NOT an SI unit of time?

(A) second (B) minute (C) day (D) week

Question 13

A piece of steel has a volume of 12 cm^3 and a mass of 96 g. What is its density?

(A) 6 g/cm^3 (B) 8 g/cm^3 (C) 10 g/cm^3 (D) 12 g/cm^3

Question 14

A thermometer measures:

(A) heat (B) temperature (C) weather (D) expansion

Question 15

A cyclist covers 300 metres in 10 seconds. What is his speed?

(A) 10 m/s (B) 20 m/s (C) 30 m/s (D) 40 m/s

Question 16

What is the speed of a train that travels 240 km in 3 hours?

(A) 720 km/h (B) 720 m/s (C) 80 km/h (D) 80 m/s

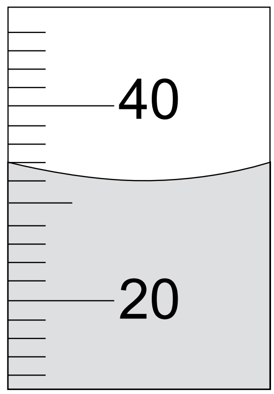
Question 17

How far will a bus travel in five hours if its average speed is 60 km/h?

(A) 12 km (B) 24 km (C) 300 km (D) 120 km

Question 18

What is the reading on this measuring cylinder?



(A) 26 cm (B) 27 cm^3 (C) 31 cm^3 (D) 32 cm^3

Question 19

a) What is meant by the term *SI unit*?

____

b) Why is it important to have SI units?

____

c) What are the SI units of:

i) time ______________

ii) distance ______________

d) Choose the instrument you would use to measure each of the following distances:

30 cm ruler tape measure metre ruler car milometer

i) the distance between Karachi and Lahore ______________

ii) the length of one of the school corridors ______________

iii) the size of your textbook ______________

iv) the size of your science workbench or table ______________

Question 20

The table below shows some of the quantities that you need to know. They are listed with their symbol. Complete the table using the correct SI units contained in the box.

degrees Celsius	volts	ohms	amperes	pascals	newtons
kg per m^3	kilograms	metres^3	newtons	metres^2	metres
joules	newton-metres	metres/second	seconds		

Quantity	Symbol	Standard units
distance	d or r	
area	A	
volume	V	
mass	m	
density	D	
force	F	
pressure	P	
time	t	
speed	s	
weight (a force)	W	
moment	M	
energy	E	
current	I	
resistance	R	
potential difference (voltage)	V	
temperature	T	

Question 21

Fatima has been asked to measure the density of some modelling clay.

She has been provided with:

- some modelling clay
- some thin thread
- a measuring cylinder
- some water
- a top-pan balance

a) Fatima will use the thin thread to lower a piece of the clay into the measuring cylinder of water. How will the thread improve the experiment?

______

______

b) Describe what Fatima will do to measure the volume of the clay using the water and the measuring cylinder.

______

______

c) List three precautions that Fatima should take to reduce the errors when using this method.

______

______

d) Fatima carries out the experiment three times and finds that the clay has an average volume of 4.0 cm^3. She uses the top-pan balance and finds that the clay has a mass of 6.8 g. Calculate the density of the clay, remembering to show your working.

______

______

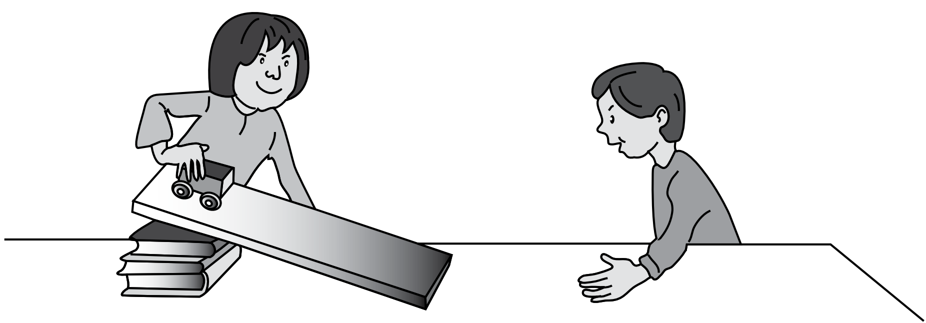
e) Would you expect the density of the clay to be greater or less than the density of water? Explain your answer.

______

______

Question 22

Ikram and Safia are carrying out an experiment to find the average speed of a trolley as it travels down a slope.



a) What pieces of apparatus, not shown in the diagram above, will the two students need to carry out this investigation?

______

b) Suggest TWO variables Ikram and Seeta need to control in order to make sure that their test is fair?

____

c) What effect do you think increasing the angle of the slope will have on the average speed of the trolley?

____

Answers to assessment questions

Question 1 (C) **Question 2** (C) **Question 3** (D) **Question 4** (D) **Question 5** (D)

Question 6 (B) **Question 7** (D) **Question 8** (C) **Question 9** (B) **Question 10** (B)

Question 11 (C) **Question 12** (D) **Question 13** (B) **Question 14** (B) **Question 15** (C)

Question 16 (C) **Question 17** (C) **Question 18** (D)

Question 19

a) SI units (Systeme International d'Unites) are the international system of units recommended for all scientific work.

b) It is important to have SI units so that scientists everywhere use the same units in their work and are able to understand (and if necessary repeat) the measurements and experiments of other scientists.

c) i) The SI unit of time is the second (s).

ii) The SI unit of distance is the metre.

d) To measure the following distances:

i) The distance between Karachi and Lahore – **car milometer**

ii) The length of one of the school corridors – **tape measure**

iii) The size of your textbook – **30 cm ruler**

iv) The size of your science workbench or table– **metre ruler**

Question 20

Quantity	**Symbol**	**Standard Units**
distance	d or r	metres, m
area	A	metres^2, m^2
volume	V	metres^3, m^3
mass	m	kilograms, kg
density	D	kg per m^3, kg/m^3
force	F	newtons, N
pressure	P	pascals, Pa (n/m^2)
time	t	seconds, s

speed	s	metres/second, m/s
weight (a force)	W	newtons, N
moment	M	newton-metres, Nm
energy	E	joules, J
current	I	amperes, A
resistance	R	ohms, Ω
potential difference (voltage)	V	volts, V
temperature	T	degrees Celsius, °C

Question 21

a) The thread will avoid any water being lost by splashing, which would be the case if the clay was simply dropped into the water. The thread will also make it easier to remove the clay from the water.

b) Fatima will need to put some water in the measuring cylinder and note the volume. She will then lower the clay into the water and record the new volume shown by the measuring cylinder. The difference is the volume of the clay.

c) In order to reduce the errors when using this method, Fatima must place the measuring cylinder on a flat surface, read the volume measurements at eye level, to avoid parallax error, and she must read the volume measurement from the bottom of the meniscus.

d) density = $\frac{\text{mass}}{\text{volume}} = \frac{6.8}{4.0} = 1.7\ \text{g/cm}^3$ approximately

e) The density of the clay is greater than the density of water because the clay sinks when placed in water.

Question 22

a) The apparatus not shown in the diagram that the students will need to carry out the investigation are a metre ruler (or tape measure) and a stopwatch or stop clock.

b) The variables Ikram and Safia need to control in order to make sure that their test is fair include the angle of the slope, the distance over which the speed of the trolley is to be measured, the place from which the trolley is released, and how it is to be released.

c) The greater the angle of the slope, the greater will be the average speed of the trolley.

Heat and its effects

CHAPTER 10

Teaching Objectives

- To describe the sources and effects of heat on solids, liquids, and gases
- To examine the behaviour of water and other liquids, solids, and gases during expansion and contraction
- To examine some effects and applications of expansion and contraction
- To examine the adverse effects of expansion and contraction and how they are overcome
- To investigate how thermometers of different kinds can be used to measure temperature

Learning Outcomes

After studying this chapter students should be able to:

- describe the sources and effects of heat
- explain the thermal expansion of solids, liquids, and gases
- explore the effects and applications of expansion and contraction of solids
- describe the uses of expansion and contraction of liquids
- explain the peculiar behaviour of water during contraction and expansion
- investigate the processes making use of the thermal expansion of a substance
- identify damage caused by expansion and contraction in their surroundings and suggest ways to reduce this damage
- investigate the means used by scientists and engineers to overcome the problems of expansion and contraction in everyday life
- describe the workings of a thermometer

Introduction

A red-hot tack is much hotter than a bowl of warm water. But the warm water contains more heat than the tack. This highlights the distinction between heat and temperature: the red-hot tack is at a higher temperature than the warm water. Temperature is a measure of the degree of hotness of a material and can be read on a thermometer. Heat is a form of energy. When a body is hot, its atoms and molecules vibrate more vigorously than when it is cold. The heat of a body is a measure of the total of all the energy of motion of all its atoms and molecules. There are more molecules in the bowl of water than there are in the red-hot tack (the water weighs much more than the tack). The water therefore contains more energy in its moving molecules than the tack. But the tack is at a higher temperature because the average energy of its molecules is greater than that of the water.

Temperature

Temperature is measured in degrees. On a Celsius thermometer, which was devised by the Swede, Anders Celsius, in 1742, the temperature of melting ice was originally taken as 100° and the temperature of boiling water as 0°. This scale was later inverted so that on the modern Celsius scale (Centigrade) water freezes at 0°C and boils at 100°C. The scale between these two 'fixed points' is divided into 100 degrees. On one of the earliest thermometer scales, devised in Germany by Gabriel Fahrenheit in about 1724, the temperature of melting ice was marked as 32°F and the temperature of steam as 212°F. This rather odd scale came about because Fahrenheit used a mixture of ice, salt, and water to get the lowest possible temperature and then called it zero. His higher temperature was the temperature of the human body, which he mistakenly thought was 100° on this scale. (In fact it is 98.4°F.)

Useful heat

A low-temperature body may contain a considerable amount of useful heat—if its mass is large enough. In many rivers in industrial areas, the water is very slightly warmer than the surroundings because of the waste heat from the factories along its banks. As there are millions of tonnes of water in the river, this low-temperature heat is worth removing and this can be done by a heat pump.

Expansion

One of the effects of heat is that it causes substances to increase in size (expand). For example, the liquid in a thermometer expands. All solids, liquids, and gases expand when they are heated. When heat is added to a solid, its atoms and molecules vibrate more energetically and can therefore take up a little more space. The molecules of liquids and gases move much faster and further when hot than when they are cold. For the same rise in temperature, gases expand about a hundred times more than liquids, and liquids about ten times more than solids.

Because different substances expand by different amounts, scientists can compare the expansion of substances by measuring a quantity called the coefficient of expansion. This is the amount by which unit quantity (length, area, or volume) of the material will expand when heated through one degree Celsius. A bar of steel expands by 0.000012 of its length when heated through one degree Celsius. This is an important fact for engineers. The Forth Railway Bridge in Scotland is about one metre longer on a hot summer's day than in the cold of winter: if no allowance was made for this variation, the bridge would be seriously buckled on a hot day. The twisted steel girders of a building after a fire show the enormous forces that are exerted by expansion.

Invar, an alloy of steel and 36 per cent nickel, has a very low coefficient of expansion and is used in instruments where a variation in length with temperature would make the instrument inaccurate. If the pendulum of a clock expands, the clock will go more slowly because the swing of a pendulum depends on its length—it is actually proportional to the square root of the length. For this reason, pendulums and the balance wheels of watches are made of Invar. Expansion has useful applications in the measurement of temperature and also in devices called thermostats.

Contraction

When substances are cooled, they contract. But there is one exception to this rule: when water is cooled from 4°C to 0°C it expands slightly. It expands further as it turns into ice. This is why water pipes burst when water freezes. It is also why ice floats on water—as it expands it becomes less dense, and the less-dense ice floats on the denser water. If ice did not float on water, all the fish in a lake or pond would be killed when the temperature falls in winter; because it does float, they are able to survive.

Practical considerations

There are a number of interesting demonstrations and class experiments that can be carried out to increase the students' knowledge and understanding of this topic. However, of necessity, some of the activities involve heating metals and other substances. The students should be warned to be careful not to touch these hot objects. Safety spectacles should be worn at all times when there is the slightest risk of danger, and the demonstrations should be carried out behind a safety screen.

Lesson suggestions

1. Expanding and contracting solids

Refer to page 113 of the Students' Book

Starter suggestions

Discuss with the students the difference between heat and temperature, perhaps by asking them which is hotter, a red-hot tack or a bath of warm water. Then ask the follow up question, *Which of the two has the most heat?*

Ask the students to say what they already know about the particulate make-up of solids, liquids, and gases, and how the particles behave when they are heated and cooled in all three states of matter.

Tell the students that Mazhar tried to open a jar, but its metal lid would not budge. He ran hot water over the lid, and the lid came off easily. Ask the students to explain this.

Main lesson

To help develop the students' understanding of what happens to the particles in solids when they are heated and cooled, demonstrate some of the pieces of apparatus described in the **Ideas for investigation and extension work** section of this chapter.

Although it needs to be set up and tested in advance of the lesson, the experiment described on Worksheet 1 also provides a good illustration of the expansion and contraction of metals.

End the lesson by describing some of the problems caused by thermal expansion on railway lines, roads, bridges, and pipelines, and the uses of expansion and contraction in riveting, the fitting of metal tyres, and the making of metal-rimmed wooden barrels.

If a bimetallic strip is available, demonstrate what happens when it is heated and cooled, and describe its uses in thermostats.

2. The expansion of liquids and gases

Refer to page 117 of the Students' Book

Starter suggestions

Put an empty plastic bottle, with its stopper on tightly, in the freezer for an hour or two. The sides of the bottle collapse. When the bottle is placed under the hot tap for a few moments, it returns to its original shape. Can the students explain what has happened?

Tell the students that they have already seen that solids expand when they are heated because their particles vibrate faster, and so become slightly further apart. Ask them what they think will happen to the particles of liquids and gases if they are heated. Can they think of any evidence to support their statements?

Main lesson

If you have not already carried out the activity with the 'empty' bottle placed in the freezer and then under a hot tap, open the lesson with it to show that a gas, in this case air, also contracts when it is cooled and expands when it is heated.

The experiments described on Worksheets 4 and 5 show the expansion and contraction of air on a larger scale. These can either be demonstrated or used as a class experiment. These worksheets will also help the students to understand how convection currents are formed and also how a hot-air balloon works.

Now move on to consider the expansion and contraction of a liquid, in this case water, when it is heated and cooled. Worksheet 2 can be used to demonstrate what happens when water freezes. It will help the students to understand why alternate freezing and thawing cracks rocks and road surfaces, and also why ponds and lakes freeze from the top, so protecting the fish and other aquatic life deeper down in the water.

Worksheet 3 demonstrates how water expands when it is heated and contracts when it is cooled. It will go some way to helping the students understand how a thermometer works when they investigate this in the next lesson.

Conclude the lesson by explaining to the students that they have now seen evidence that, like solids, liquids, and gases also expand when they get hotter because their particles vibrate faster and move further apart. The particles of liquids and gases contract when they are cooled because their particles slow down and move closer together. But the difference is that when heated by the same amount, liquids expand about ten times more than solids, and gases expand about a thousand times more than liquids.

3. Thermometers

Refer to page 119 of the Students' Book

Starter suggestions

If you have not done so in an earlier lesson, discuss with the students the difference between heat and temperature, perhaps by asking them which is hotter, a red-hot tack or a bath of warm water. Then ask the follow up question, *Which of the two has the most heat?*

Ask the students what they consider to be the three most important temperatures that every scientist should know: the temperature of pure melting ice (0^0C), the temperature of steam from pure boiling water under standard atmospheric pressure (100^0C), and the temperature of a healthy human body (37^0C)).

Main lesson

Remind the students that some things are hot and some things are cold, and the temperature of an object indicates how hot or cold it is. If the students have not done so before, let them carry out the simple activity on estimating temperature described in the **Ideas for investigation and extension** section of this chapter. Hopefully they will appreciate why, because of the unreliability of the human sense of temperature, we use a thermometer to measure temperature. Remind them of the Celsius scale and of the two fixed points.

Show the students as many different kinds of thermometer, or if need be, pictures of thermometers, as you can. The collection could include a room thermometer, a clinical thermometer (ideally, mercury-filled rather than digital), a soil thermometer, a maximum and minimum thermometer, and a thermometer for measuring high temperatures. The students should compare the different thermometers and determine their range and sensitivity.

Safety: Great care will be needed if the students handle thermometers containing mercury because of the highly toxic nature of this metal.

Remind the students of the experiment they saw (or carried out) when they observed the expansion of water when it is heated and its contraction when it is cooled. Explain that a typical thermometer contains either mercury or ethanol. Unlike water, these liquids expand and contract at a steady rate and do not freeze easily.

If possible the students should compare the accuracy of the different types of thermometer, perhaps with hot water from the tap and distilled water containing ice cubes.

Round off the lesson by asking the students to investigate some temperature records, such as the highest and lowest temperatures ever recorded in Pakistan and other parts of the world. How do these temperatures compare with the temperatures that ovens and kilns work at? Alternatively the students could investigate the origins and uses of the Celsius, Fahrenheit, and Kelvin scales of temperature.

Ideas for investigation and extension work

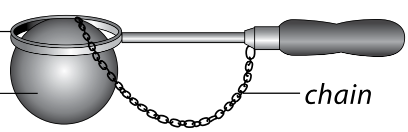
Estimating temperature

Demonstrate the difficulties involved in estimating temperature. Fill three basins with warm water, cold tap water, and ice-cold water respectively. Ask a volunteer student to put a finger from his or her left hand into the warm water and a finger from the right hand into the ice-cold water. After about a minute, the student should put both fingers in the centre basin containing cold tap water. Ask how the student's fingers feel. The usual response is that the left finger feels cold, but the right finger feels warm!

Observing the expansion of solids

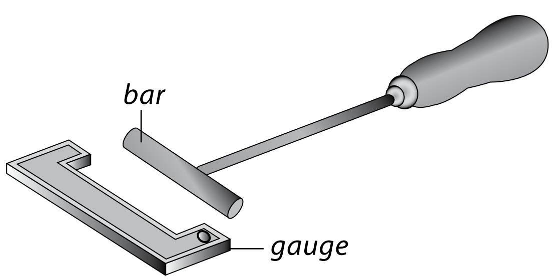
If the ball and ring apparatus, bar and gauge apparatus, and bar-breaker apparatus are available, or can be borrowed from another school, then these simple demonstrations of the effects of heat on the expansion of solids can either be demonstrated by the teacher, or the students can carry them out themselves as part of a 'circus' of experiments set up around the classroom or laboratory. Of course, strict attention to safety will be necessary if the students carry out these experiments for themselves. They need to wear safety spectacles all the time. The bar-breaker experiment needs particular care since, if a cast-iron rod is used, it may shatter when the apparatus is left to cool.

a) *Ball and ring experiment* Without heating the apparatus, try to get the ball through the ring. Does the ball pass through the ring easily?



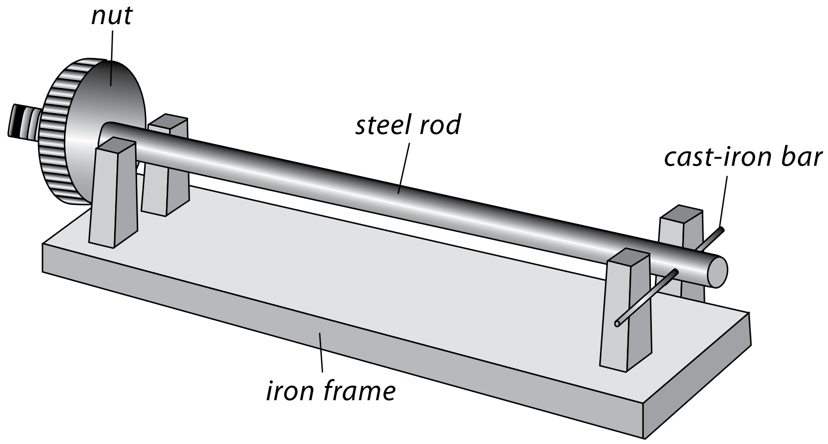
Now hold the chain using crucible tongs and heat the ball in a Bunsen flame for about half a minute. Remove the ball from the flame and, while holding the chain with the crucible tongs, try to get the ball to go through the ring. Ask the students to explain their observations.

b) *Bar and gauge experiment* Without heating the apparatus, try to fit the bar in the gauge. Does the bar fit into the gauge easily?



Now heat the bar by moving it back and forth in a Bunsen flame for about a minute. Remove the bar from the flame and try to fit it into the gauge. Does the bar fit into the gauge? Allow the bar to cool and try to fit it into the gauge again. Does the bar fit into the gauge this time? Ask the students to explain their observations.

c) *Bar-breaker experiment* Set up the apparatus as shown in the diagram below. A cast-iron bar is preferable, but if it is not available, an old iron nail will usually work perfectly well.



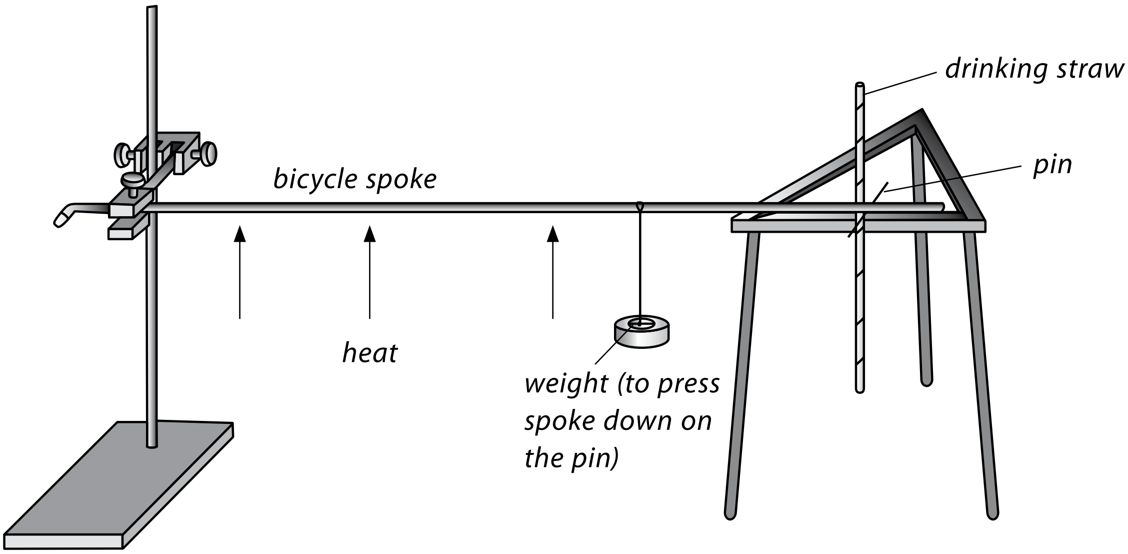
Begin by tightening the nut as much as possible and then heat the steel rod with a Bunsen flame. Tighten the nut again as the steel rod expands. Continue heating and tightening the nut until the steel rod will not expand any further. Allow the steel rod to cool and observe what happens to the cast-iron bar or nail. Ask the students to explain their observations. What can they conclude about the size of the forces arising from expansion?

WORKSHEET 1

Observing the expansion of a metal

Materials needed: retort stand and clamp; tripod stand; bicycle spoke or steel knitting needle; weight with thin wire loop (50 to 100 g mass); long pin; drinking straw; Bunsen burner

1. Push a pin through the middle of the drinking straw.
2. Set up the apparatus as shown in the diagram. Note that the bicycle spoke or knitting needle must rest on the pin. The weight is needed to pull the spoke down onto the pin.



3. Adjust the drinking straw so that it is approximately vertical.
4. Move the Bunsen burner flame left and right so that it heats most of the bicycle spoke or knitting needle. Observe what happens to the drinking straw.
5. Stop heating when the drinking straw stops moving.
6. On the diagram draw the drinking straw in its new position. Show with an arrow the direction in which the drinking straw moved, a) when the bicycle spoke or knitting needle was heated and, b) when the spoke or needle later cooled down again.

Explain what happened during the experiment:

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____

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WORKSHEET 2

What happens when water freezes?

Materials needed: small plastic bottle with a cork; clean yoghurt pot; bowl; use of refrigerator or freezer

1. Completely fill the small bottle with water. Put the cork loosely on top.
2. Put the small bottle in the freezer or the freezing compartment of a refrigerator.
3. Look at the bottle next morning. Observe and record what has happened.
4. Fill the yoghurt pot with water and put it in the freezer until the water turns to ice.
5. Remove the ice from the pot and put the ice in a bowl of water. Observe what happens to the ice.
6. Leave the ice to stand in the water for a few hours.

Draw what happened to the bottle and the water inside it.

Draw what happened to the ice in the bowl of water. Did it float or did it sink?

Explain what happened. ______________________________

____

____

Why does very cold weather sometimes lead to leaking water pipes? ______________________________

____

____

Extend the experiment by soaking a small piece of brick or porous rock in water overnight. Place it in a small plastic bag and leave it in the freezer overnight. What happens to the brick or rock? ______________

____

Why? ____

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____

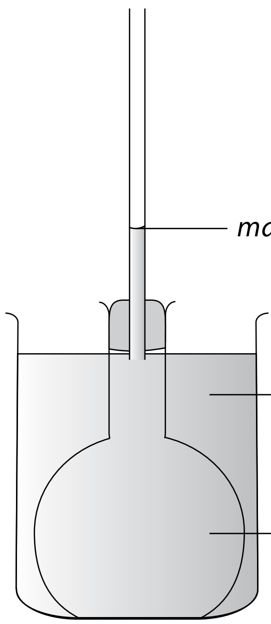
WORKSHEET 3

Observing the expansion of water

Materials needed: flat-bottomed flask, 250 cm^3; rubber bung with glass tube, about 30 cm long; beaker, 1000 cm^3; water coloured with potassium permanganate or food colouring; hot water; marker pen

1. Fill the flat-bottom flask to the brim with the coloured water.
2. Carefully fit the stopper with glass tube attached into the flask. Make sure there are no air bubbles in the flask or the glass tube.
3. Mark the level of the coloured water in the glass tube with a marker pen.
4. Half fill the beaker with hot water.

Put the flask into the beaker and observe the water level in the glass tube.



What do you notice about the water level in the glass tube at the beginning of the experiment?

____

Explain what you observed.

____

Why did the water level rise in the glass tube later on?

____

What instrument makes use of the fact that a liquid expands when it is heated and contracts when it is cooled?

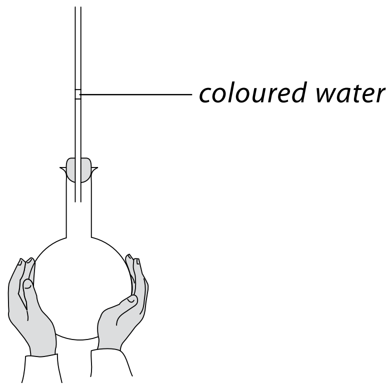
____

WORKSHEET 4

Observing the expansion of air

Materials needed: round-bottomed flask, 250 cm^3; rubber bung with glass tube, about 30 cm long; beaker, 250 cm^3 or larger; water coloured with potassium permanganate or food colouring

1. Dip the glass tube into the coloured water so that a bubble of water about 0.5 cm goes into the glass tube. This bubble of water should be near the rubber bung.
2. Put the stopper and glass tube in the flask. As you do so, the coloured water will move up the glass tube. Adjust the rubber bung so that the bubble is about half-way up the glass tube.
3. Warm the air in the flask by holding the flask with your hands.



4. Observe the coloured water in the glass tube and record what happens to it.

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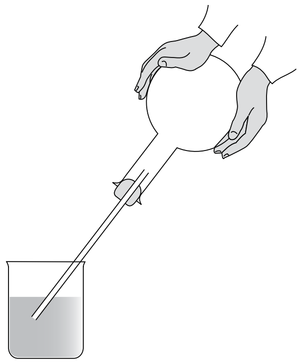
5. Remove the length of coloured water from the glass tube. You may have to remove the rubber bung and glass tube to do this.
6. Dip the glass tube into the beaker of coloured water and warm the flask with your hands, as shown in the diagram here.



7. Record your observations.

____

What have you learned about what happens when air is heated?

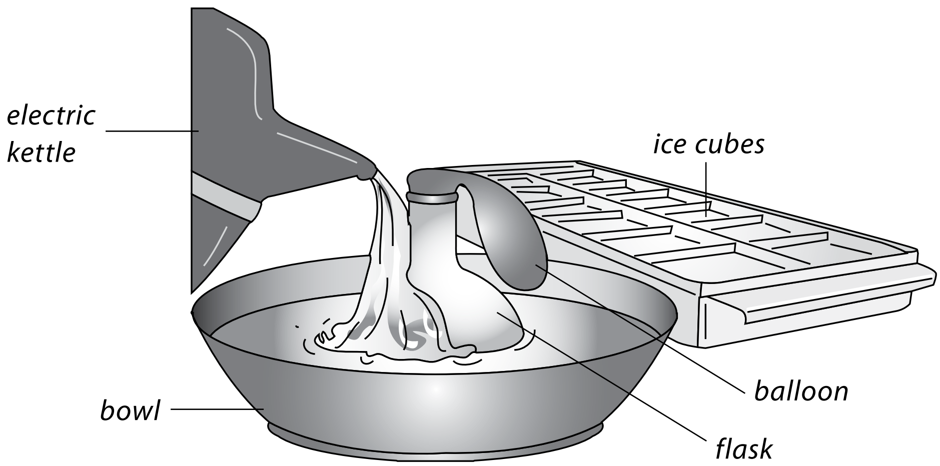
____

WORKSHEET 5

Observing the expansion of air

Materials needed: flask, 250 cm^3; balloon; basin or bowl; electric kettle; ice cubes

1. Fit the balloon over the open end of the flask.
2. Place the flask in the basin or bowl. Carefully pour some hot water from the kettle over the flask. Observe what happens.
3. Replace the hot water in the bowl or basin with cold water. Put several ice cubes in the water and then put the flask and balloon in this very cold water. Observe what happens.



In the boxes below, draw diagrams to show the appearance of the balloon a) before heating; b) after heating, and c) after cooling.

Before heating	After heating	After cooling

What happens to air when it is heated?

___

What happens to air when it is cooled?

___

Why do cakes shrink after they have been taken out of the oven?

___

Answers to questions in the Students' Book

1. i) The metal lid of the jar expands more than the glass in hot water.
   ii) Furniture often creaks at night after a hot day because it has expanded slightly during the day and then contracts when it cools down at night.
   iii) Concrete roads have tarmac or rubber strips between the sections to allow for expansion in hot weather and contraction in cold weather.
2. Sections of railway lines either have gaps left between them to allow for expansion or the joints overlap slightly.

   Bridges are often built on rollers to allow them to expand on hot days and to contract on cold days.

   Oil pipelines are laid in a series of zig-zags to allow them to expand during the heat of the day and to contract at night.
3. The metal rivets used in construction work are red hot when they are hammered into place. When they cool, they contract, pulling the two pieces of metal tightly together.
4. A blacksmith heats the iron rim for a wooden wheel so that it expands slightly and fits easily over the wheel. When the rim cools it contracts, pulling the sections of the wheel tightly together.
5. Many large structures are built from concrete and steel. It is fortunate that both concrete and steel expand by almost the same amount, otherwise buildings and other structures would crack or split open when the temperature changed.
6. The temperature of the layer of ice is 0^0C. The water just underneath the ice is also at 0^0C. The water near the bottom of the pond is a 4^0C.

   Ice is a poor conductor of heat so the water underneath it in the pond cools at a much slower rate. Fish and plants can live quite comfortably in the water at 4^0C under the ice.
7. Ice floats in water because when water cools from 4^0C to 0^0C, it expands and becomes slightly less dense than it was at 4^0C.
8. If an inflated balloon is left in a warm place, the air inside expands and its pressure on the walls of the balloon increases. Eventually the balloon will burst.
9. The bore of a thermometer is made very narrow so that when the mercury or ethanol in the bulb of the thermometer expands or contracts it makes the liquid in the tube rise or fall quite a large distance.
10. Water would not be a good liquid to use in a thermometer because it does not expand at a steady rate and it also freezes easily.
11. Thermometers are useful in today's society for recording weather conditions, for monitoring the temperature of the human body, and for measuring vital temperatures in industrial processes, such as the fractional distillation of petroleum.
12. Three important temperatures to remember are the temperature of pure melting ice (0^0C), the temperature of steam from pure boiling water under standard atmospheric pressure (100^0C), and the temperature of a healthy human body (37^0C).

13. A thermostat is a device used to maintain a steady temperature in air-conditioned or centrally-heated rooms and buildings, in freezers and refrigerators and in ovens, engines, and electric irons.
14. i) In a restricted supply of air, hydrocarbon fuels burn to form carbon (soot) and poisonous carbon monoxide gas. In a plentiful supply of air, hydrocarbon fuels burn completely to form carbon dioxide and water.
    ii) The two unwanted products are carbon (soot) and carbon monoxide.
    iii) The carbon (soot) can dirty buildings and contaminate plants. It can also damage the respiratory system of humans and other mammals. Carbon monoxide is poisonous, particularly in a confined space, while carbon dioxide contributes to global warming.
    iv) The product which is already present in the air is carbon dioxide.

Assessment

Question 1: A thermometer measures

(A) heat (B) temperature (C) weather (D) expansion

Question 2: Which two liquids are most commonly used in thermometers?

(A) water or oil B) mercury or oil C) mercury or ethanol D) ethanol or water

Question 3: In which direction is heat transferred?

(A) from a hot object to a cooler object (B) from a cool object to a hotter object

(C) from a hot object to an equally hot object (D) from a cool object to an equally cool object

Question 4: How does the heat from the Sun reach the Earth?

(A) conduction (B) convection (C) radiation (D) combustion

Question 5: Which of the following is NOT a fuel?

(A) coal (B) oil (C) natural gas (D) electricity

Question 6: Which of the following is NOT a fossil fuel?

(A) coal (B) oil (C) natural gas (D) wood

Question 7: The particles in a liquid gradually vibrate faster and move further apart. What has been done to the liquid?

(A) It has been cooled. (B) Acid has been added to it.

(C) It has been heated. (D) It has been put under pressure.

Question 8: What name is given to a device which automatically controls the temperature of an appliance such as an oven or refrigerator?

(A) thermometer (B) thermostat (C) transistor (D) thermocline

Question 9: Which of the following does NOT use expansion?

(A) riveting metal (B) welding (C) making wooden barrels (D) thermometers

Question 10: The particles in a piece of metal start vibrating more slowly and move closer together. What has happened to the metal?

(A) It has been heated. (B) It has been cooled.

(C) A magnet has been moved near it. (D) It has been bent.

Question 11: I put my finger over the end of a bicycle pump. When the pump is filled with air I can push the handle down a long way. When the pump is filled with water I cannot push the handle down at all. This suggests:

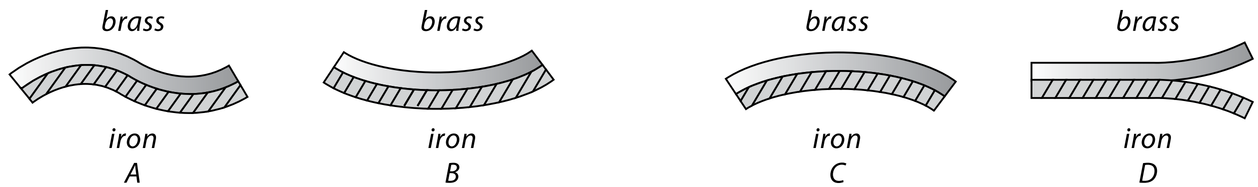
(A) Water molecules are continually on the move.

(B) The spaces between air particles are larger than the spaces between water particles.

(C) The spaces between air particles are smaller than the spaces between water particles.

(D) There are no spaces between air particles.

Question 12: Which of the diagrams below, A, B, C, or D, correctly shows what happens to a flat, bimetallic strip when it is heated?



Question 13: Read the following statements about solids, liquids, and gases. For each one, say whether you think it is TRUE or FALSE.

a) The particles in a solid are packed close together. ☐

b) The particles in a gas are far apart. ☐

c) Liquids are easy to compress. ☐

d) Gases have a low density. ☐

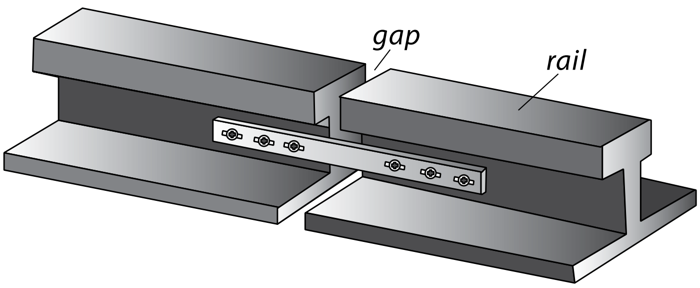
e) Gases are difficult to compress. ☐

f) Liquids and gases can flow. ☐

g) The particles in a solid vibrate. ☐

h) The particles in a gas move very slowly.
i) Solids are easy to compress.
j) There are weak forces of attraction between the particles in a solid.
k) Solids expand more than liquids when they are heated.
l) When water cools from 4° to 0°C it contracts.
m) Gases expand about a thousand times more than liquids when they are heated.
n) Unlike liquids and solids, all gases expand at the same rate.

Question 14: Many railway lines have gaps between neighbouring lengths of track. These gaps are about 1 cm wide.



a) What happens to the size of objects as they get hotter?

b) What happens to the size of objects as they get colder?

c) As the railway lines get hotter, what happens to the gaps in the track?

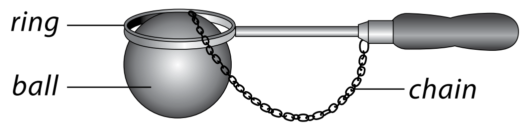
d) What would happen in hot weather if there were no gaps in the track?

e) In countries where there is very hot and very cold weather, should the gaps between the lengths of track be wider or narrower?

f) What difference would you see between telephone wires on a hot day and a cold day?

g) How are metal bridges built to cope with changes of temperature?

Question 15: Noman is carrying out an experiment using a ball and ring. At the start of the experiment Khalid finds that the ball will pass through the ring.



a) Describe how the particles inside the ball are moving at the start of the experiment.

b) Noman then heats the ball in a Bunsen burner flame. He finds that the ball will no longer pass through the ring. Explain, in terms of the particles, why the ball will not pass through the ring.

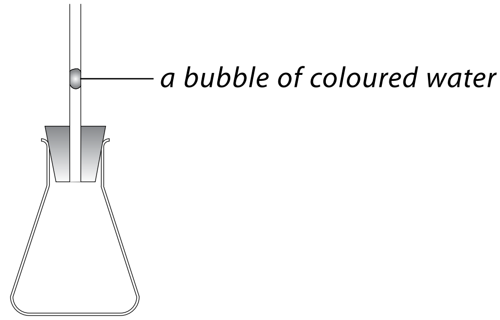
c) Explain why most trains make a 'clackety-clack' sound as they travel along the rails.

d) Why does a car engine click after it has been switched off?

e) How can you easily loosen the metal lid of a glass jam-jar? Why does this work? Explain in as much detail as possible.

f) Why do you think a glass bottle might crack when you pour hot water into it?

Question 16: Saira set up the experiment shown in the diagram here. The conical flask was empty, apart from the air in it, and the rubber bung and tubing fitted tightly. Saira put a bubble of coloured water in the tube.



a) Saira heated the flask by dipping it in a bowl of hot water. What do you think would happen to the air in the flask?

b) What is the bubble there for?

c) Next Saira cooled the flask by putting it in a refrigerator for a few minutes. What happened to the air in the flask?

d) What happened to the bubble of coloured water?

Saira then filled the whole flask with coloured water. He arranged it so that the water went a little way up the tubing when the bung was replaced.

e) Saira cooled the flask by putting it in cold water. What happened to the water in the flask?

f) What happened to the level of the water in the tube?

g) Saira then heated the flask by immersing it in hot water. What happened to the water in the flask?

h) What happened to the level of the water in the tube?

i) What does this experiment tell you about the behaviour of gases and liquids as they are heated?

j) Why would it be very dangerous to heat tins of food, such as soup, in a fire without opening them first?

Answers to assessment questions

Question 1 (B) **Question 2** (C) **Question 3** (A) **Question 4** (C) **Question 5** (D)
Question 6 (D) **Question 7** (C) **Question 8** (B) **Question 9** (B) **Question 10** (B)
Question 11 (B) **Question 12** (C)

Question 13

a) The particles in a solid are packed close together. TRUE
b) The particles in a gas are far apart. TRUE
c) Liquids are easy to compress. FALSE
d) Gases have a low density. TRUE
e) Gases are difficult to compress. FALSE
f) Liquids and gases can flow. TRUE
g) The particles in a solid vibrate. TRUE
h) The particles in a gas move very slowly. FALSE
i) Solids are easy to compress. FALSE
j) There are weak forces of attraction between the particles in a solid. FALSE
k) Solids expand more than liquids when they are heated. FALSE
l) When water cools from 4^{o} to $0^{o}C$ it contracts. FALSE
m) Gases expand about a thousand times more than liquids when they are heated. TRUE
n) Unlike liquids and solids, all gases expand at the same rate. TRUE

Question 14

a) Objects expand (or get bigger) as they get hotter.
b) Objects contract (or get smaller) as they get colder.
c) As the railway lines get hotter, the gaps in the track decrease or get smaller.
d) In hot weather if there were no gaps in the track, the track would buckle.
e) In countries where there is very hot and very cold weather, the gaps between the lengths of track should be wider.
f) On a hot day telephone wires tend to sag or hang down because of expansion. On a cold day they are much tauter.
g) Many metal bridges are built on rollers to cope with expansion and contraction due to changes of temperature.

Question 15

a) The particles inside the ball are vibrating slowly at the start of the experiment.
b) After the ball has been heated, the particles are vibrating more vigorously, so the ball expands and will no longer pass through the ring.
c) Most trains make a 'clackety-clack' sound as they travel along the rails. This sound is repeated each time the metal wheels pass over one of the expansion gaps between the rails. Trains which are running on continuous rails do not make these sounds.

d) When a car engine is running it gets very hot and the metal parts expand. The clicking sounds made after the engine has been switched off are where the parts of the engine are contracting again.

e) If the top of a glass jam-jar with a metal lid is turned upside down in hot water for a few moments, the metal lid expands more than the glass rim of the jar. The lid can then be unscrewed easily.

f) If hot water is suddenly poured into a glass bottle, the glass expands and, since the bottle is cylindrical in shape, it is put under stress and the bottle cracks or breaks.

Question 16

a) When the flask was heated by dipping it in a bowl of hot water, the air in the flask expanded and the bubble rose up the tube.

b) The bubble acts as a marker, moving up the tube when the air in the flask expands, and moving down the tube when the air contracts.

c) When the flask was cooled by putting it in a refrigerator for a few minutes, the air in the flask contracted.

d) The bubble of coloured water moved down the tube.

e) When the flask was cooled by putting it in cold water, the water in the flask contracted.

f) The level of the water in the tube dropped/fell.

g) When the flask was heated by immersing it in hot water, the water in the flask expanded.

h) The level of the water in the tube rose.

i) This experiment shows us that both gases and liquids expand when they are heated and contract when they are cooled.

j) It would be very dangerous to heat tins of food, such as soup, in a fire without opening them first because the liquid inside the tin would expand rapidly and with such force that the can would probably explode.

Lenses

CHAPTER 11

Teaching Objectives

- To examine lenses of different kinds and their roles in refracting light
- To demonstrate image formation by lenses with the aid of ray diagrams
- To compare and contrast the working of the human eye with a camera
- To explain how the converging lens in the human eye forms an image on the retina in varying light conditions
- To explain how lenses are used to correct short-sightedness and long-sightedness
- To examine the uses of lenses in optical instruments and for other purposes in daily life

Learning Outcomes

After studying this chapter students should be able to:

- define lenses
- differentiate between the different types of lenses
- explain the image formation using a lens by a ray diagram
- compare and contrast the working of a human eye with the lens camera
- explain how eyes get used to darkness after some time
- explain how lenses are used to correct short sightedness and long sightedness
- identify the types of lenses used for various purposes in daily life

Introduction

No matter what its source, light always travels through a vacuum at a speed of about three hundred million metres per second. It also travels at very nearly the same speed in air, but when it encounters another medium, such as glass or water, it slows down. Different transparent substances slow light down by a different amount. The ratio of the speed of light in a vacuum to its speed in a particular medium is called the refractive index of that medium. The refractive index of glass is about 1.5, which means that light travels in glass at two-thirds of its speed in a vacuum.

Refraction

When light passes from one medium to another, the change of speed alters its wavelength, making the light bend slightly (refraction). White light is split up into its separate colours on being refracted by a prism because each colour is refracted by a different amount. Refraction is also important in lenses. When a ray of light passes through a lens it is bent, and this enables the lens to produce an image of a distant object. The first lenses were made for spectacles about seven hundred years ago but it was not until about 1600 that scientists discovered that by looking through two lenses in line, small objects could be greatly magnified and distant objects made to seem close. This led to the development of the microscope and the telescope.

Convex and concave lenses

A convex lens, which curves outwards and is thicker at the centre than at the edges, causes light beams to converge when they pass through it. A concave lens, which is thinner at the centre, spreads out the beam. Objects viewed through a concave lens always appear smaller. A simple magnifying glass is a double convex lens which causes a beam of light to converge to a focus (the point at which all the rays meet). When an object is fairly close to the lens, an upright magnified image is seen.

Aberrations

Objects seen through cheap lenses show a fringe of colours around the object, which blurs the outline because the lens acts as a prism to split the light into a spectrum. This defect, called chromatic aberration, can be corrected by constructing the lens of special types of glass. The outer part of a cheap lens also bends light more than the central portion, and gives the image a fuzzy look (spherical aberration). This effect is avoided in a camera by the use of a stop which lets light enter only through the centre of the lens.

The eye

In some ways an eye is like a complicated camera. A camera has a lens which focuses the light onto a sensitive film or digital sensor in a dark box. The amount of light entering is adjusted by altering the size of the hole (aperture) through which the light enters. The 'box' of the eye is the more or less spherical coat, or sclerotic, part of which is the white of the eye. This tough layer is protected by a bony socket, to which it is attached by three pairs of muscles that move the eye around. The eye is further protected by fat, by the eyelids which wipe the front clean, and by tears which are secreted from ducts behind the top eyelid to wash away dust particles and kill bacteria. Tears are produced all the time, but they usually drain away so we do not notice them. When the eye is irritated, more tears are produced and the excess drains down a channel into the nose. When we cry, tears are produced at a faster rate than they can drain away.

Inside the sclerotic layer is a dark layer called the choroid, which prevents blurring when light is reflected within the eye, and also contains blood vessels that supply the inner part of the eye. Beneath the choroid is the retina, the light-sensitive layer of the eye, which is several cells deep. It contains two types of light-sensitive cells: the rods, which give black and white vision and are sensitive even in poor light, and the cones which give colour vision and function best in bright light. The most sensitive spot on the retina is the yellow spot (fovea) which contains many cones.

The transparent bulging front of the eye is the cornea, and it helps to bend the light rays so that they fall onto the retina. Fine focusing is carried out by the lens. A camera is focused by moving the lens backwards or forwards, but in the eye the lens focuses the light by varying its shape, by means of the contraction and relaxation of the muscles to which it is attached. In front of the lens is the iris, which we can see as the coloured part of the eye. It controls the size of the central hole (pupil) through which the light passes (the weaker the light the wider the pupil). The black colour of the pupil is due to the choroid, which can be seen in the pupil. The inner part of the eye is filled with a clear liquid, which is rather watery in front of the lens but more jelly-like behind it.

Stereoscopic vision

Man and other primates have two eyes set at the front of the head, each giving a slightly different view of the same object. These two views are turned into a three-dimensional (stereoscopic) view, to allow us to judge distances accurately. Stereoscopic vision is most developed in hunting and tree-dwelling primates. Because man's ancestors were probably tree-dwellers who had to land accurately when jumping, this may be why he has such good stereoscopic vision. If one eye is closed it is much harder to judge distances. In hoofed animals such as deer and antelope, the eyes are set on each side of the head so that they cover a wider field but give a much less detailed view.

Colour vision

Man and monkeys, among the mammals, are able to see different colours. Some of the cones in the retina are sensitive to red light, some to green, others to blue. A number of men, but only a very few women, are at least partly colour blind, which means they cannot distinguish one colour from another. The most common form of colour blindness is the inability to tell red from green.

Cones are more sensitive than rods to colour and to minute differences in detail. At one point at the back of the retina, immediately opposite the lens, is the yellow spot (fovea), an area that contains only cones and is not covered by blood vessels and nerve fibres. This is the area of clearest vision, but it means that in poor light, when the cones do not operate, a better view of an object may be obtained by looking slightly to one side so that the rays do not fall on the rods. It is because the cones do not operate in poor light that we see mainly in shades of black and white under these conditions.

Defects of vision

When vision is imperfect it may be because of long sight, when nearby objects are focused behind the retina, or it may be short sight, when distant objects are focused in front of the retina. Both conditions can be corrected by artificial lenses, which were first invented in Europe in the thirteenth century. Long sight needs convex lenses which bend the light towards the centre of the cornea. Short sight needs concave lenses which bend the light away. As people age, their lenses and the surrounding muscles gradually lose their elasticity, so they cannot adjust to different distances. This condition is called presbyopia and can be corrected by bifocal or varifocal lenses. The lower part of bifocal lenses is used for reading, the upper part for looking at distant objects. Varifocal lenses are really three lenses in one. For distant views the upper part of the lens is used; arm's length vision uses the middle part of the lens, while for close-up vision the lower part of the lens is used.

Practical considerations

Refraction is an important property of light, and lenses work on this principle. Without refraction, not only would optical instruments fail to work, but our eyes would be unable to use lenses to help us see. It is important for students to realize that we see because rays of light are reflected off objects into our eyes, rather than, as many students think, rays of light come from our eyes and bounce off objects.

When dealing with the functioning of the eyes and particularly with defects of vision, it is important to be sensitive to the feelings of students who may have imperfect vision.

Lesson suggestions

1. Lenses

Refer to page 124 of the Students' Book

Starter suggestions

Ask the students what they can remember about refraction and how and why rays of light are refracted.

Give each student a piece of newspaper or the page from a magazine, a small piece of cling-film or other transparent plastic wrap, an eyedropper, and a beaker of water. Ask them to lay their piece of newspaper on the desktop and then cover part of it with the cling-film or plastic wrap. Using an eyedropper, they then place one drop of water on the cling-film or plastic wrap. What does the water drop do to the newspaper or magazine print? Can your students explain what happens?

Main lesson

Discuss the term 'refraction' (the bending of light when it moves from one substance to another). Explain how a lens is used to refract light (a lens is a piece of curved plastic or glass which light is able to pass through).

Explain that there are two types of lenses—concave and convex lenses. Show the class examples of each.

Demonstrate, or let the students carry out, the activities described on Worksheets 1 and 2. Ask the students to notice how a convex lens refracts parallel rays of light so that the rays come together at a single point. Explain that the light rays are said to converge and, for this reason, a convex lens is often called a converging lens. Explain that the point that light focuses on is known as the focal point, and the distance from the centre of the lens to the focal point is called the focal length. The thicker a convex lens is in the middle, the shorter the focal length will be.

Let the students experiment with holding a convex lens at arm's length to look at whatever scene is in front of them and to slowly bring the lens closer towards them, as described in the **Ideas for investigation and extension work** section of this chapter.

Describe concave lenses and how they cause light rays to converge.

Ask the students to draw up a table to compare the shape and properties of convex and concave lenses.

Ask the students if they can name some practical uses of lenses. Examples might include magnifying glasses (convex); cameras (convex); spectacles and contact lenses (concave and convex); telescopes (at least two convex lenses); microscopes (at least two convex lenses).

Round off the lesson by reminding the students of the 'water lens' they made at the beginning of the lesson (or let them make the 'water lens' now). Ask whether the lens was convex or concave (answer: convex).

2. The eye

Refer to page 126 of the Students' Book

Starter suggestions

Ask the students what they remember about the earlier work they did on the structure of the eye. Ask them to make a table to compare the eye with a camera.

Ask the question *Why do we have two eyes?* Divide the class into groups of three. If the students are working indoors, have them toss a ping-pong ball to each other, first with both eyes open, and then with one eye blindfolded or patched. If the students are working outdoors, then they could use a tennis ball, although there are obvious safety issues to be considered here. Is it easier to catch the ball with one eye or two?

Main lesson

Use a large picture of the eye or a model of the eye to explain its structure and the functions of the parts.

The important points to bear in mind during your explanation are:

i) When light from an object enters the eye it is refracted by the cornea and lens. It forms an image on the retina.
ii) The convex lens of the eye can change shape. It becomes thinner to allow light from distant objects to be refracted to form a clear image on the retina. It becomes fatter so that light from near objects is refracted to form a clear image on the retina.
iii) By altering the size of the pupil, the iris controls the amount of light entering the eye.
iv) The retina consists of roughly 130 million tiny, light-sensitive cells, called rods and cones.
v) Rods are sensitive to dim light, cones are sensitive to bright light and colour.
vi) The image formed on the retina is inverted, it is our brain which turns images the right way up.

If possible, and subject to the students' sensitivities, obtain an eye from a butcher's shop and show the students its exterior and interior structures.

Carry out some of the simple activities described in the **Ideas for investigation and extension work** section of this chapter to reinforce the students' understanding of the eye.

Complete the topic by discussing the common defects of vision and how they are corrected.

Ideas for investigation and extension work

Lenses at home

Look around your home. How many different uses of lenses can you find? Make a list of them.

Lenses in the shopping centre

Next time you are in a shopping centre, look around the insides of the shops and department stores. How many different uses of lenses can you see? Make a list of them.

Image formation

Hold a convex lens at arm's length and look through it at whatever scene is in front of you. Record the details of the image you can see—whether it is upright/upside down, smaller/larger, etc. Slowly bring the lens towards you. Are there any changes to the image?

The Sun's image

Use a convex lens to project an image of the Sun onto a sheet of white paper or tissue paper. **Be careful** because you may find it is still too bright to look at without hurting your eyes. Does this experiment suggest to you why convex lenses are sometimes called converging lenses?

An aid to drawing

Stand at the back of an unlit room facing a window. Hold a sheet of white paper against the wall behind you. Use a convex lens to project an image of the window and whatever is beyond it onto the paper. How would you use this technique to draw the outside scene? How would you further modify this technique to allow you to draw portraits or, for that matter, any object you choose?

What happens when light rays pass through a convex lens?

For this experiment you need a clean, dry, glass bottle and a convex lens which is approximately the size of the bottom of the bottle. You also need a torch and an incense stick (sometimes called a joss stick) or a short piece of thick string.

Use sticky tape to fix the lens to the bottom of the bottle. Lay the bottle on its side. Light the incense stick or piece of string. Blow out the flame to leave it smouldering. Place this inside the bottle so that the inside of the bottle becomes very smoky. Turn any lights out and darken the room. Shine the torch beam through the lens into the bottle. You may have to move the torch backwards and forwards to obtain the best effect, but you should see a cone of light inside the bottle. This shows how the convex lens makes the rays of light converge to a point (the principal focus of the lens).

How could you modify this experiment to allow you to see what a concave lens does to rays of light?

Looking at the eye

Look at one of your eyes in a mirror. Which structures in the diagrams on page 127 of the students'book can you see? Examine an animal's eye which has been obtained from a butcher. Name the structures you can see on the outside of the eye. With scissors, cut a hole in the side of the eyeball. What comes out of the hole? What effect does making the hole have on the shape of the eyeball? Find the lens and the retina. What other structures can you see? Carefully cut the lens out of the eye. What does the lens feel like?

Why do we have two eyes?

Hold a pencil at arm's length so that it points upwards. Look at the pencil using one eye. Now, without moving the pencil, look at it using the other eye. You will see that the pencil seems to change position.

Hold a pencil in each hand, at arm's length, so that the pencils point towards one another. Close one eye and then move the pencils closer together to make their points touch. Repeat the experiment with both eyes. Which is easier?

Finding the blind spot

Look at the picture below: hold it about 10 cm from your eyes. Close your left eye and look directly at the circle with your right eye. Slowly move the picture away from your eyes, keeping your right eye focused on the circle all the time. What happens to the star as you move the picture away from you? How would you explain this?

Repeat the experiment with both eyes open. What happens this time? How would you explain the difference?

Eye defects

Carry out a survey to find out how many people suffer from sight defects. Your survey should include details of the age, sex, and occupation of the people, the type of sight defect, and method of correction. Can you draw any conclusions?

Long-sight

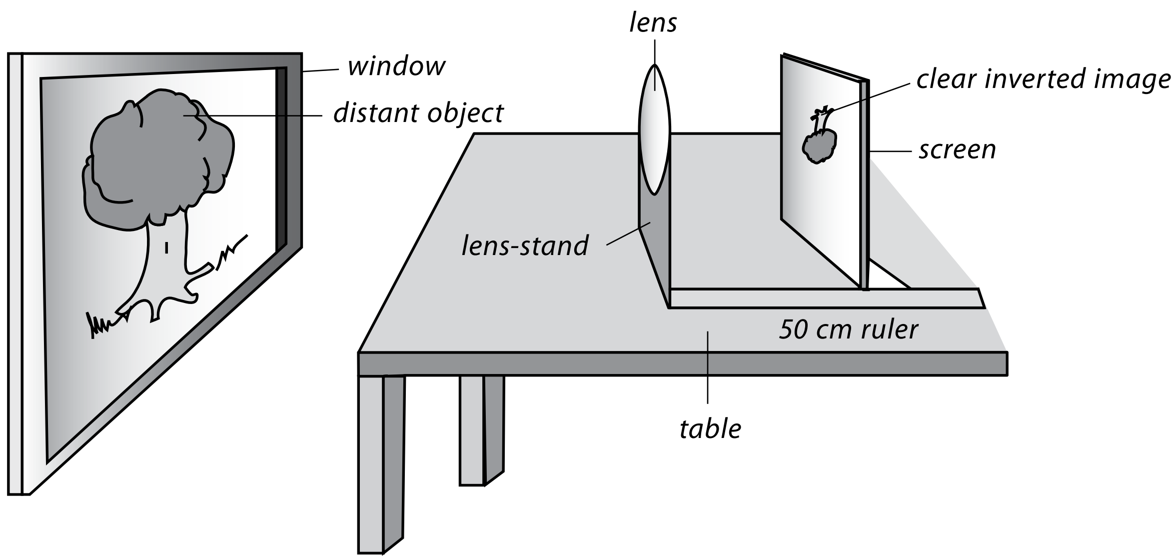
Prove by experiment that long-sighted people have converging lenses prescribed for their glasses.

WORKSHEET

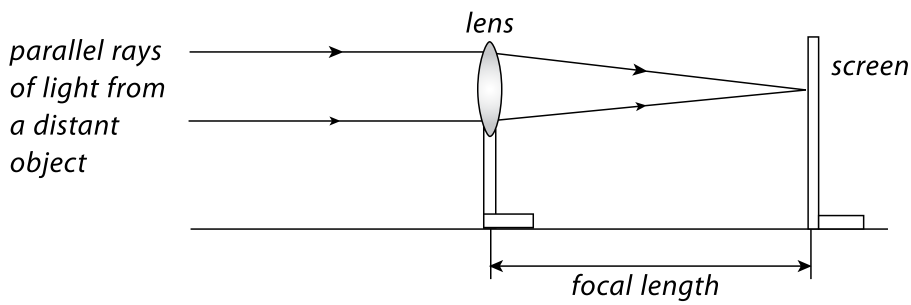
Find the focal length of convex lenses

Materials needed: 2 convex or converging lenses of different thicknesses (marked A and B); lens-stand; white screen; 50 cm ruler

1. Place lens A on the lens stand. Handle the lens with care and only hold it by the edges, using your thumb and index finger.
2. Arrange the lens so that it is facing a distant object, such as a tree outside the window, as shown in the diagram.



3. Slowly and carefully move the screen backwards and forwards until you find a point where a very clear inverted image of the tree or other object is formed on the screen.
4. Measure the distance between the image and the centre of the lens as shown in the diagram below. This distance is the focal length, *f*, of the lens. Record this distance in the table below.



5. Repeat steps 2, 3, and 4 with the same lens to get another value of the focal length of that lens.
6. Repeat steps 1 to 4 for lens B.

7. Examine lenses A and B and decide which lens is the thicker of the two.

The thicker lens is lens ___________ .

Lens	Focal length in centimetres		
	First measurement	Second measurement	Average
lens A			
lens B			

Conclusion

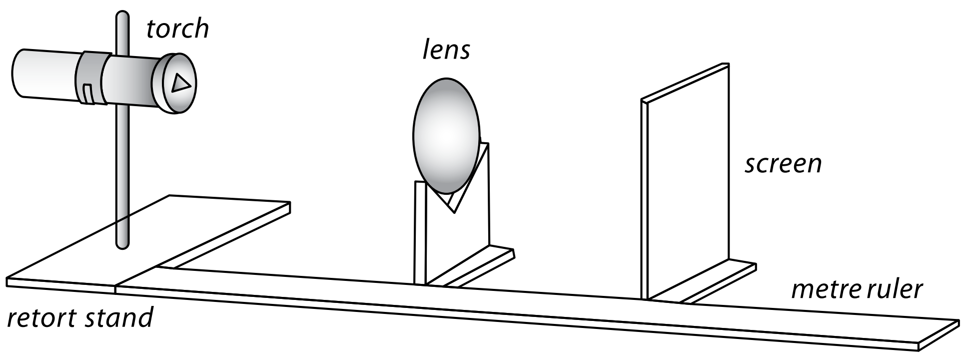
A thicker lens has a (longer/shorter) focal length than a thinner one.

WORKSHEET 2

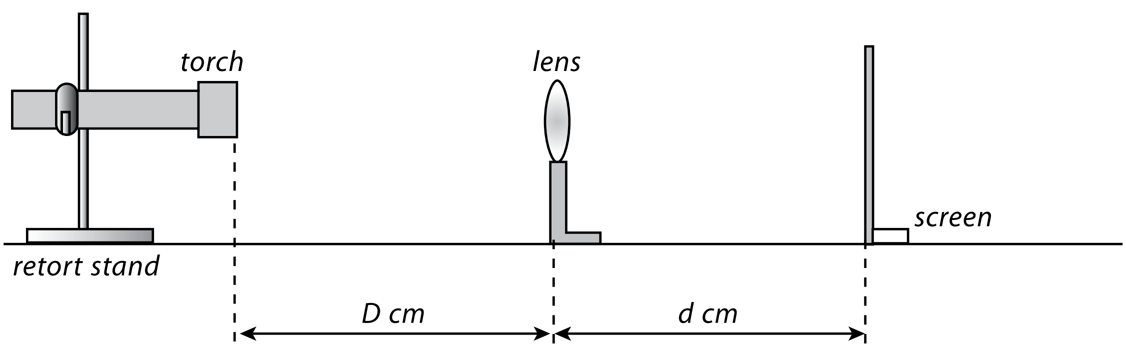
Object distance and image size

Materials needed: convex lens; lens stand; torch; black paper; metre ruler; retort stand and clamp; white screen; scissors

1. Cut a circle of black paper to fit over the lens of the torch. In the centre of the black circle, cut out a triangle about 1 cm high.
2. Holding the lens only by the edges, put it on the lens-stand.
3. Place the white screen behind the lens.
4. Clamp the torch on the retort stand and adjust its height until the triangle on the torch is in line with the centre of the lens, as shown in the diagram below.



5. Move the torch until the triangle is 20 cm from the centre of the lens. This is the object distance, *D*. Switch on the torch. Move the screen slowly and carefully until a clear image of the triangle is formed on the screen.
6. Measure the distance between the screen and the centre of the lens. This is the image distance, *d* . Record this distance on the table below.



7. Measure the height of the triangle on the torch. This is the size of the object. Then measure the height of the triangle on the screen. This is the size of the image. Compare the two and state in the table whether the image is bigger than the object, smaller than it, or the same size.

8. Repeat stages 5 to 7 for distances *D* of 18 cm, 25 cm, 36 cm, and 60 cm.

Object distance, *D* in cm	**Image distance, *d* in cm**	**Size of image (larger, smaller, or the same)**

Conclusion

When the object distance from the lens increases, the image distance (increases/decreases).

When the object is moved away from the lens, the size of the image (increases/decreases).

Answers to questions in the Student's Book

1. Instruments which rely on lenses to make them work include telescopes, binoculars, projectors, microscopes, camcorders, and cameras.
2. Another name for a convex lens is a converging lens.
3. Another name for a concave lens is a diverging lens
4. Reflection is the change in direction of a light ray after it hits a surface and bounces off. Refraction is the change in direction of a light ray as a result of the change in speed or velocity when it passes from one transparent substance or material to another.
5. i), ii), and iii): A camera, magnifying glass, and the human eye have convex lenses.

    iv) A concave lens is used to correct short sight.

    v) A convex lens is used to correct long sight.
6. The lens in the human eye focuses by changing its shape. This change in shape is brought about by the ciliary muscles.
7. The iris of the eye controls the amount of light entering the eye by varying the size of the pupil, the black hole in the centre of the eye.
8. The blind spot is the point where the optic nerve is connected to the retina. Unlike the rest of the retina, the blind spot has no light-sensitive cells.
9. The two types of cells that form the retina are called rods and cones. Rods are sensitive to quite dim light but not to colours. Cones are sensitive to bright light and give colour vision.
10. The rods of the retina cannot detect colours and they cannot work in bright light. When you suddenly go into a dim or dark place, or go outside at night, it takes about seven to ten minutes for the rods to adapt to the dark.
11. The yellow spot is the most sensitive part of the retina where the receptor cells (all cones) are packed most closely together.
12. Long-sightnedness is a defect of vision whereby people can see distant objects clearly, but near objects are blurred. The image is formed behind the retina. It is corrected by placing a convex lens in front of the eye.
13. Short-sightedness is a defect of vision in which the affected person can see near things clearly but distant objects are blurred. The image is formed in front of the retina. Short-sightedness is corrected by placing a concave lens in front of the eye.

14.

Human eye	**Camera**
convex lens	convex lens
focuses by changing the shape of the lens	focuses by moving the lens backwards and forwards
image formed on a sensitive screen called the retina	image formed on a film or digital sensor
amount of light entering is controlled by the iris	amount of light entering is controlled by an iris/ diaphragm
image inverted	image inverted

15. The camera lens moves backwards and forwards (nearer or further away from the film or sensor) to focus on near or distant objects. The lens is mounted on a screw thread so that it can be moved in and out.

Assessment

Question 1

The bending of a ray of light when it passes from one transparent substance to another is called:

(A) reflection (B) refraction (C) dispersion (D) deviation

Question 2

A convex lens is called a:

(A) converging lens (B) diverging lens
(C) refracting lens (D) converging and diverging lens

Question 3

A concave lens is called a:

(A) converging lens (B) diverging lens
(C) refracting lens (D) converging and diverging lens

Question 4

The image produced by a concave lens is:

(A) always virtual and enlarged (B) always real
(C) always virtual and reduced in size (D) sometimes real, sometimes virtual

Question 5

The image produced when an object is placed in front of a concave lens:

(A) is always erect (B) may be erect or inverted
(C) is always inverted (D) is always real

Question 6

Which of the following is true? The amount of light entering the eye is controlled by the:

(A) iris (B) lens (C) cornea (D) retina

Question 7

The cornea of the eye is the transparent part of the:

(A) iris (B) lens (C) sclerotic (D) retina

Question 8

A cricketer loses the sight of one eye in a car crash. The other eye is not affected. When he plays cricket again, the effect will be:

(A) He can see the ball only half the time.
(B) He cannot focus on the ball.
(C) He cannot judge how far away the ball is.
(D) The ball looks smaller.

Question 9

The human eye can recognize different colours because of the presence of the:

(A) yellow spot (B) blind spot (C) rods (D) cones

Question 10

The rod-shaped cells in the retina of the eye respond to:

(A) the colour of light
(B) the intensity of light
(C) the intensity and colour of light
(D) neither the intensity nor the colour of light

Question 11

The part of the eye which focuses light is the:

(A) retina (B) iris (C) pupil (D) lens

Question 12

When light enters the eye and falls on the retina it produces chemical changes in the retina. The result of this is that:

(A) the pupil of the eye gets larger
(B) electrical signals are sent to the brain
(C) the iris changes colour
(D) the lens becomes more curved

Question 13

Rahim is colour-blind. This means that:

(A) he cannot see coloured objects
(B) he sees everything in black and white
(C) all colours look the same
(D) he confuses some colours

Question 14

A girl walks through a grassy field looking for some flowers. She finds none until she bends down to tie her shoelace and discovers that there are hundreds around her. She picks a bunch of blue flowers but misses the similar red ones growing around them. This shows that she is:

(A) long-sighted
(B) short-sighted
(C) long-sighted and colour blind
(D) short-sighted and colour blind

Question 15

In the eyes of a long-sighted person, light rays coming from a nearby object are brought to focus behind the retina. Long-sightedness can be corrected by a:

(A) concave lens
(B) convex lens
(C) circular lens
(D) telephoto lens

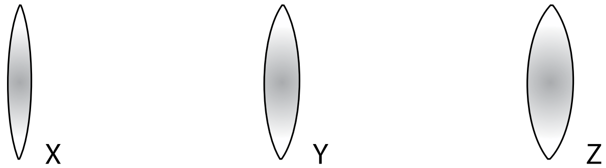
Question 16

In the eyes of a short-sighted person, light rays coming from a distant object are brought to focus in front of the retina. Short-sightedness can be corrected by a:

(A) concave lens
(B) convex lens
(C) circular lens
(D) telephoto lens

Question 17

The diagrams below show the shape of the lens in a woman's eye. She holds a needle close to her eye to thread it, then looks at the sewing on her lap, and then at the television set across the room. Which is the correct sequence for the shape of the lens during these activities?



(A) XYZ
(B) XZY
(C) YXZ
(D) ZYX

Question 18

Complete the following sentences using the words in the box below. You may need to use one or two words more than once.

focus	diverges	convex	converging	thinner	sensor
concave	transparent	focal	thicker	lens	far

A lens is made of ________ material with a curved, spherical surface. A convex or ________ lens is thicker in the middle than at the edges. A diverging or ________ lens is thinner in the middle than at the edges. A convex lens will converge a parallel beam of light to a point, called the principal ________. The distance between the principal focus and the centre of the lens is called the ________ length. A concave lens ________ a beam of light. This means that the beam of light spreads out more after passing through the lens.

The lens in the eye is a ________ lens. To focus the image in a human eye, the shape of the convex lens is changed by becoming ________ when the object is far away and ________ when the object is nearby. In a camera, the shape of the ________ does not change. To focus the image in the camera, the image distance is changed by moving the lens towards the film or sensor when the object is ________ away, and away from the film or ________ when the object is nearby.

Lenses are used to correct the defects of vision. Short-sightedness can be corrected by using ________ lenses, while long-sightedness can be corrected by using ________ lenses.

Question 19

a) Which of the following statements about light are TRUE? Tick three correct options.

(A) Light is a form of radiation. ☐

(B) Light is a form of energy. ☐

(C) Light rays reflect off your eyes onto objects. ☐

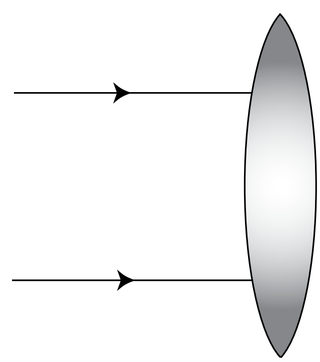
(D) Light rays reflect off objects into your eyes. ☐

b) The diagram below shows a lens.

i) What type of lens is shown? ____________________

Two parallel rays of light are shown striking the lens.

ii) Complete the diagram to show the effect the lens has on the rays of light.



iii) Mark on the diagram the focal length of the lens.

iv) What would the image formed by this lens be like if a **distant** object was viewed through it? Choose TWO words for your answer from the following:

upright   inverted (upside down)   small   large (magnified)

____

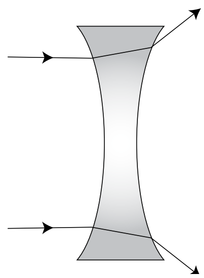
v) What would the image formed by this lens be like if a **close** object was viewed through it? Choose TWO words for your answer from the following:

upright   inverted (upside down)   small   large (magnified)

____

vi) The diagram below shows another lens. What kind of lens is this?

____

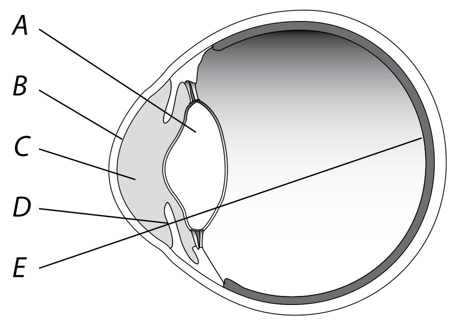


vii) What kind of vision defect would you correct with this lens?

____

Question 20

The diagram below shows a cross-section through an eye.



a) Name the parts of the eye labelled A to E:

A ________ B ________ C ________

D ________ E ________

b) Which part of the eye that sends impulses to the brain is not shown on the diagram?

____

c) Why is it important for the cornea of the eye to be transparent?

____

d) Name the two kinds of sensitive cell which are found in the retina.

____

e) The size of the pupil can be varied by the iris. What is the purpose of this?

____

f) If someone moves something quickly towards your eyes (like a fist!), what do you do, without thinking, in order to protect your eyes?

____

g) If some dust actually gets in your eye, your eye begins to water a lot. How does this help?

____

Answers to assessment questions

Question 1 (B)	**Question 2** (A)	**Question 3** (B)	**Question 4** (C)	**Question 5** (A)
Question 6 (A)	**Question 7** (C)	**Question 8** (C)	**Question 9** (D)	**Question 10** (B)
Question 11 (D)	**Question 12** (B)	**Question 13** (D)	**Question 14** (D)	**Question 15** (B)
Question 16 (A)	**Question 17** (D)			

Question 18

A lens is made of **transparent** material with a curved, spherical surface. A convex or **converging** lens is thicker in the middle than at the edges. A diverging or **concave** lens is thinner in the middle than at the edges. A convex lens will converge a parallel beam of light to a point, called the principal **focus**. The distance between the principal focus and the centre of the lens is called the **focal** length. A concave lens **diverges** a beam of light. This means that the beam of light spreads out more after passing through the lens.

The lens in the eye is a **convex** lens. To focus the image in a human eye, the shape of the convex lens is changed by becoming **thinner** when the object is far away and **thicker** when the object is nearby. In a camera, the shape of the **lens** does not change. To focus the image in the camera, the image distance is changed by moving the lens towards the film or sensor when the object is **far** away, and away from the film or **sensor** when the object is nearby.

Lenses are used to correct the defects of vision. Short-sightedness can be corrected by using **concave** lenses, while long-sightedness can be corrected by using **convex** lenses.

Question 19

a) (A) Light is a form of radiation. TRUE

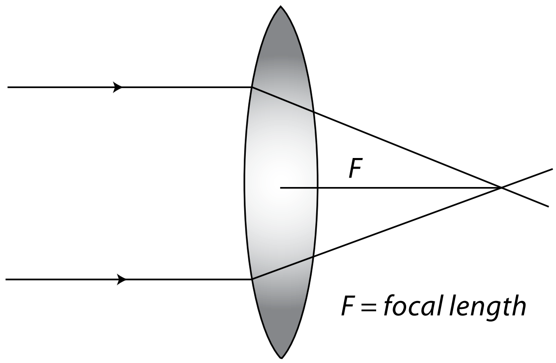
(B) Light is a form of energy. TRUE

(C) Light rays reflect off your eyes onto objects. FALSE

(D) Light rays reflect off objects into your eyes. TRUE

b) i) The lens shown is a **convex lens** or **converging lens**.

ii) The effect the lens has on the rays of light is:



iii) The focal length of the lens is represented by the line labelled F.

iv) If a **distant** object was viewed through the lens, the image formed would be **small** and **inverted** (upside down).

v) If a **close** object was viewed through the lens, the image formed would be **upright** and **large** (magnified).

vi) The lens is a **concave** or **diverging lens**.

vii) Concave lenses are used to correct **short-sighted** eyes.

Question 20

a) The parts of the eye are:

(A) lens (B) cornea (C) pupil (D) iris (E) retina

b) The part of the eye which sends impulses to the brain and which is not shown on the diagram is the optic nerve.

c) It is important for the cornea of the eye to be transparent to allow light to pass through the lens and reach the retina.

d) The two kinds of sensitive cell which are found in the retina are rods and cones.

e) The size of the pupil can be varied by the iris so that more light enters the eye in dim conditions and less light when it is bright.

f) If someone moves something quickly towards your eyes (like a fist!), you blink (a reflex action).

g) If some dust actually gets in your eye, your eye begins to water a lot in an attempt to wash away the dust.

Electricity in action

CHAPTER 12

Teaching Objectives

- To demonstrate the differences and similarities between a simple dynamo and a modern power station generator
- To develop an appreciation of the need for a reliable supply of electricity
- To explain the need for a National Grid and to investigate the problems involved in the transmission of electricity
- To investigate the basic components of an electronic system
- To investigate how alternating current is turned into direct current in a variety of everyday appliances

Learning Outcomes

After studying this chapter students should be able to:

- design an experiment to generate electricity
- explain the working of the model generator
- identify the simple devices that generate electricity in daily life
- design and demonstrate the working of a power station
- list the types of energy being used in power stations
- identify problems involved in generating electricity
- describe the basic components of an electronic system
- list components that would be needed to turn A.C. to D.C
- state how output component in various devices could be used in their schools and surroundings

Introduction

Most mains electricity is generated in thermal power stations, which turn heat into electrical energy. In many power stations heat is provided by burning fossil fuels. Other power stations use the heat that is given off during a nuclear reaction to generate electricity. In all these cases, the National Grid is used to transmit electricity to consumers.

Fossil fuels

Fossil fuels include coal, oil, and natural gas. These are all compounds of carbon and hydrogen. Most power stations that use fossil fuels burn vast quantities of them to produce steam from water. The steam then drives turbines, which in turn provide the mechanical power for generators. Gas-turbine power stations are different.

They use the hot gases from burning natural gas or fuel oil to drive turbines without making steam. Fossil fuels are used in the vast majority of power stations around the world, but they do have serious drawbacks. The gases formed by burning fossil fuels include carbon dioxide, which causes global warming, and also gases that form acid rain. An added problem is that fossil fuels are non-renewable and they will not last forever.

Nuclear power

Nuclear power stations use nuclear fission to release huge quantities of heat from small amounts of fuel. The nuclei of radioactive elements, such as uranium and plutonium, are split, and the energy released is used to create the steam to drive a steam turbine, as in a coal-fired power station. Nuclear power stations do not produce greenhouse gases, so they do not contribute to global warming. There are, however, environmental hazards, due to the accidental release of radioactive materials. In addition, nuclear power stations produce dangerously radioactive waste that can be active for thousands of years.

Renewable sources of energy

With the exception of biomass, which is burned to produce steam from water, and solar energy which is changed directly by photovoltaic cells into electricity, other renewable energy resources are used directly to turn the turbines. These include the use of wind power, tidal and wave energy, the production of hydro-electricity, and the use of geothermal energy.

Dynamos and generators

When a conductor moves through a magnetic field or is placed in a changing magnetic field, it causes a voltage to be produced. This voltage is called an induced voltage and the phenomenon is known as electromagnetic induction. A voltage can be induced in a conductor either by moving the conductor at right angles to a magnetic field, or moving a magnet inside a coil of wire, or switching a nearby electromagnet on and off.

A bicycle dynamo uses a rotating permanent magnet inside a coil of wire to produce electrical energy in the form of a direct current. As the bicycle speeds up, the magnet rotates faster, increasing the size of the induced voltage so that the lights become brighter. It also increases the frequency of the induced voltage, since one cycle is generated for each revolution of the magnet.

Power station generators use a rotating electromagnet to produce a changing magnetic field. A voltage is induced in thick copper bars around the electromagnet. The electromagnet rotates at 3000 revolutions each minute to induce a voltage with a frequency of 50 Hz. A generator produces electricity as an alternating current.

Direct current and alternating current

In a wire carrying a direct current (produced, for instance, by a cell or battery) there is a constant stream of electrons in one direction at regular intervals. By contrast, in a wire carrying an alternating current, the electrons surge rhythmically backwards and forwards. One complete forward and backward movement is a cycle and the number of cycles per second is the frequency of the alternating current. This is measured in hertz (one hertz = one cycle per second). The frequency supplied to our homes is usually 50 Hz.

An alternating current operates lights, heaters, and motors just as well as a direct current but it has the great advantage that the voltage of the supply can easily be changed up or down by using a transformer. A transformer consists essentially of two separate coils of wire wound onto the same soft iron core. Depending on the relative number of turns on the primary (input) and secondary (output) coils, the voltage can be either stepped up or stepped down. If there are 100 turns on the primary coil and 200 turns on the secondary coil, the voltage will be doubled. But the power remains the same, apart from heat losses, so the secondary current will, in this case be half of the primary. As a current is only induced in a secondary coil when the field around the primary coil is changing, a transformer will not work on direct current.

Transmitting power

Whenever an electric current passes along a wire, the resistance of the wire causes some energy loss due to heat. These energy losses can be minimized by using wires with very low resistance, but these are expensive to install. The problem is solved by using transformers. Large transformers are used in the grid system which links all the power stations in Pakistan, so that current from one station can be supplied to another region in the case of a breakdown or a greater demand for current than usual.

A typical power station generator produces electricity at a voltage of 25,000 V. However it is cheaper to transmit a low current at a high voltage, rather than a high current at a low voltage. This is because the power loss is proportional to the square of the current, but only directly proportional to the voltage. Also a thinner (and therefore cheaper) cable can be used at low currents. As a result, the 25,000 V produced by the power station generators is stepped up by a transformer so that it passes into the National Grid at 400,000 V. The high voltage electricity is stepped down in stages before it reaches consumers such as factories, transport systems, and homes. Transformers provide an efficient way of changing the voltage of an alternating current. There is no equivalent way of changing the voltage of a direct current, which is why alternating current is used for mains electricity.

Practical considerations

This is a large but fairly straightforward topic which could take up a considerable amount of time. However, it is important to remind the students of the dangers of the misuse of mains electricity and of approaching too closely to pylons, transformers, and other electrical installations.

Lesson suggestions

1. Generating electricity

Refer to page 138 of the Students' Book

Starter suggestions

Ask the students to write down as many sources of electricity as they can. For each one, ask them to state what energy changes took place to produce the electricity.

Ask the students to make a list showing as many different ways as possible in which electrical energy is changed to other usable forms of energy.

Main lesson

If the students have not seen or carried out this type of experiment before, let them see or carry out the activity described on Worksheet 1, which shows how a lemon and two different metals can act as a primary cell and produce electricity.

If possible, bring a bicycle fitted with a dynamo into the classroom. Show the students how it is turned by the cycle wheel and how the brightness of the light produced varies with the speed at which the wheel is turned.

With the aid of a diagram or, better still, a cycle dynamo which has been dismantled, explain to the students how it works, stressing the importance of the permanent magnet and the coil. Point out that a dynamo works as an 'electric motor in reverse' because it changes kinetic energy into electrical energy. (You could, if you wish, carry out the activity on Worksheet 3 at this point.)

Go on to describe the work of Michael Faraday, who discovered that a moving magnetic field causes an electric current to flow in a wire. Explain that most of the electricity generated throughout the world today is based upon his discovery. The experiment described on Worksheet 2 examines the scientific principle that makes this possible.

Explain how the generators in a power station are constructed and cooled.

Complete the lesson by showing the students a film, DVD, video clip, or pictures of the generators inside a power station.

2. Power stations

Refer to page 140 of the Students' Book

Starter suggestions

Discuss the power stations that students have seen, where they are located, and what they look like.

Each student writes out a question he or she would like to ask a power station manager. The teacher collects in the questions and reads them out anonymously. How many of the questions can the students answer between them? This will help the teacher to assess the students' prior knowledge of the topic.

Main lesson

Ideally with the help of video clips, television programmes or DVDs, the teacher should explain the use of fossil fuels and nuclear fuels in power stations.

The important facts to bear in mind are that fossil fuels include coal, oil, and natural gas. These are all compounds of carbon and hydrogen.

Most power stations that use fossil fuels burn vast quantities of them to produce steam from water. The steam then drives turbines, which in turn provide the mechanical power for generators. Gas-turbine power stations are different. They use the hot gases from burning natural gas or fuel oil to drive turbines without making steam.

Although fossil fuels are used in the vast majority of power stations around the world, they do have serious drawbacks. The gases formed by burning fossil fuels include carbon dioxide, which causes global warming, and also gases that form acid rain. An added problem is that fossil fuels are non-renewable and they will not last forever.

Nuclear power stations use nuclear fission to release huge quantities of heat from small amounts of fuel. The nuclei of radioactive elements, such as uranium and plutonium, are split, and the energy released is used to create the steam to drive a steam turbine, as in a coal-fired power station. Nuclear power stations do not produce greenhouse gases, so they do not contribute to global warming.

Round off the topic by asking the students to draw a flow diagram to show the energy changes at each stage in a fossil fuel-burning power station. Show the types of energy that are lost or wasted at each stage of the energy transformations.

3. The National Grid

Refer to page 145 of the Students' Book

Starter suggestions

Ask the students to list all the places around their home neighbourhood or school where they have seen evidence of the electricity supply to homes, schools, offices, shops, and factories.

Ask the students to write down everything they know about the production and use of mains electricity. Where have the students seen signs warning of the dangers of high voltages? This will help the teacher to assess the students' prior knowledge of the topic.

Main lesson

Recall that mains electricity is produced in power stations.

Discuss with the class the features of the National Grid, including what it is and why it is necessary.

Explain why high voltages allow electrical energy to be transferred by the National Grid using smaller currents and thinner wires than would otherwise be necessary. Explain also that high voltages reduce the heating losses from wire, making the movement of the electricity cheaper and more efficient.

Describe the structure and function of transformers. Use Worksheet 4 to help the students' understanding of transformers.

Ask the students to discuss the advantages and disadvantages of using overhead power cables and underground power cables.

Finish the lesson by asking the students to use secondary sources to research one type of fossil fuel power station or, even better, their local power station if there is one nearby. Questions for them to research include:

- How big is the power station?
- What type of fuel does it use?
- Where does the fuel come from and how does it reach the power station?
- How much electrical energy does it supply?
- How many homes and businesses does it supply?

- How many people work at the power station?
- What types of job do the people do and what kind of qualifications do they have?

4. Renewable energy

Refer to page 142 of the Students' Book

Starter suggestions

In order to assess their existing knowledge, ask the students to make two lists, one of non-renewable energy resources and the other of renewable energy resources.

Ask the students to work in pairs and discuss whether they already use any forms of renewable energy at home or at school.

Main lesson

Discuss the advantages and disadvantages of the main forms of renewable energy.

Point out that power stations can burn alternatives to fossil fuels, including biomass, animal dung, and household waste.

Remind the students that with the exception of biomass, which is burned to produce steam from water, and solar energy which is changed directly by photovoltaic cells into electricity, other renewable energy resources are used directly to turn the turbines. These include the use of wind power, tidal and wave energy, the production of hydro-electricity, and the use of geothermal energy. Point out also that we can trace the energy in biomass, wind, water, wave, or tidal power back to the Sun or Moon.

Ask the students to prepare a table comparing the advantages and disadvantages of the main renewable energy resources.

Finally, ask the students to work in groups of two or three to research one kind of renewable energy resource. Ask them to find out about the advantages and disadvantages of this energy resource and how much of this energy resource is used in the different countries of the world. The students should elect a spokesperson to report their findings to the rest of the class.

5. An introduction to electronics

Refer to page 147 of the Students' Book

Starter suggestions

Ask the students to write down what they understand by electronics and what changes developments in electronics have produced in the past sixty years or so.

Show the students a collection of photographs of radios, television sets, telephones, record players, tape recorders, and other communications equipment dating from about the 1950s. Ask them to compare the devices in the photographs with the equivalent objects they use today. What differences do they notice?

Hopefully one of the main differences they will see is the great reduction in size brought about by the use of modern electronics.

Main lesson

Ask the students to work in pairs and for each pair to bring an electronic device to school. Let them work together to list the special features of their chosen electronic device and then report their findings to the rest of the class.

Explain the importance of diodes in electronic circuits. Explain that they have very low resistance in one direction and very high resistance in the other, so that they can be used as a one-way switch. They can be used to change alternating current to direct current.

If you can obtain a diode, find the printed band on it that tells you which way round it is. Set up a simple circuit consisting of a 6V electricity supply, a bulb in a holder and a diode. Connect the diode into the circuit, first of all with the band facing one way in the circuit and then reverse its direction. Notice when the bulb lights and when it does not.

Show the students examples of a light-emitting diode in use in a calculator, watch, digital clock, digital thermometer, or hi-fi equipment. Explain that it is a semiconducting diode that has a higher resistance than normal and produces light instead of heat.

Finally show the students a transistor and explain that this is an electronic device that is commonly used as a switch or amplifier. It is a fundamental building block of modern electronics and is found almost everywhere in electronic equipment. Following its general release in the early 1950s, the transistor revolutionized electronics and made it possible to have smaller and cheaper radios, calculators, computers, telephones, and other electronic equipment. If possible, obtain an unwanted transistor radio, or some other unwanted electronic device, and take it apart so that the students can see the transistors and other electronic components.

Ideas for investigation and extension work

Cycle dynamos

Design and carry out an experiment to find out how the output power of a bicycle dynamo varies with the speed of the bicycle.

Cycle lights

Compare the cost of buying and using battery-powered cycle lights with the cost of buying and using a dynamo set.

The National Grid

Carry out a survey in your local area to identify important parts of the National Grid. Look for overhead power cables and pylons, substations and transformers, and for underground cables being repaired. If possible record your findings on a map and take photographs of the different parts of the Grid.

Safety: Never climb pylons or enter substations or touch transformers. Never ignore the warning signs.

Nuclear power

Nuclear power stations do not produce polluting gases. However, they do cause other problems. What are these problems?

Research what happens in a nuclear power plant. What replaces the furnace? Why is global warming not a problem when electricity is produced by a nuclear power station? It is an expensive and lengthy process to de-commission a nuclear power station. What is de-commissioning?

Michael Faraday

Use the Internet or reference books to find out about the life and scientific discoveries of Michael Faraday. Find out in particular about his work on electric motors, dynamos, and transformers. Write a small illustrated biography of Michael Faraday.

James Watt

The unit for electrical power is named after James Watt, the Scottish engineer who also invented the high-pressure steam engine. Find out more about James Watt and his contributions to science. Present your findings in the form of a diary or scrap book.

Biomass

What advantage does using biomass have over using fossil fuels? What are likely to be the main impacts on the environment from using energy from biomass?

Light-emitting diodes

Make an exhibition of devices (or pictures of devices) that contain light-emitting diodes (LEDs). These could include calculators, watches, hi-fi equipment, and certain types of light switch. Examine the devices and discuss why LEDs are used under those particular circumstances.

First Aid

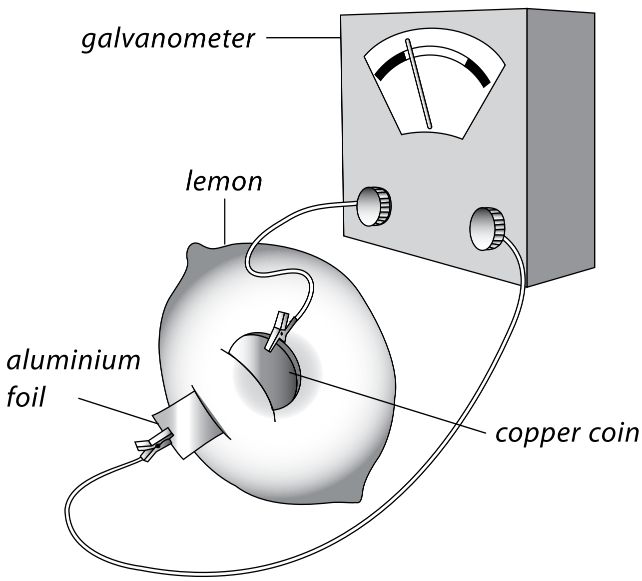
Find out more about what to do in the case of an electric shock. Design a poster giving simple instructions on how to give first aid for electric shock.

WORKSHEET 1

Make a lemon cell!

Materials needed: lemon (or lime); copper coin (or strip of copper); aluminium foil; sandpaper; connecting wires; crocodile clips or paper clips; galvanometer

1. Clean both sides of the copper coin (or the strip of copper) with sandpaper.
2. Make two cuts in the lemon about 2 cm apart.
3. Insert a small piece of aluminium foil in one cut and the clean copper coin or strip in the other cut.
4. A galvanometer can detect very small electric currents. Use wires and clips to connect your lemon cell to a galvanometer.
5. What happens to the galvanometer needle when you connect it to the lemon cell?



6. Try using an iron nail in place of the aluminium foil. Check the galvanometer to see whether an electric current is produced.
7. Repeat the experiment, using an apple, an orange, or a potato instead of the lemon. Do any of these produce an electric current?

Record what you observed with the galvanometer.

____

____

Which combination of metals worked best in your cell?

____

A lemon cell contains citric acid and two different metals. Ask your teacher to show you a dry cell which has been sawn in half with a hacksaw. In what ways is a lemon cell like a dry cell?

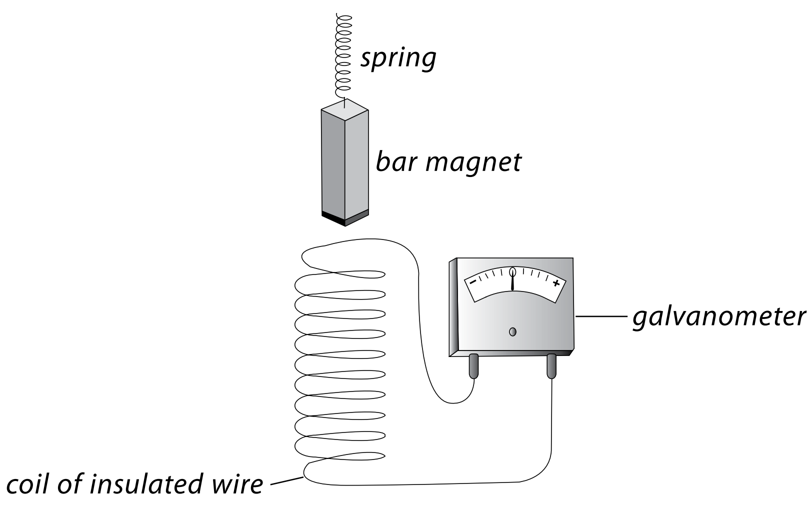
WORKSHEET 2

Generating an electric current with a magnet

Michael Faraday discovered that a moving magnetic field causes an electric current to flow in a wire. Most of the electricity generated throughout the world today is based upon his discovery. This experiment looks at the scientific principle that makes this possible.

Materials needed: bar magnet; thin insulated wire (the wire with a clear or coloured enamel coat works well); a galvanometer; a strong coiled spring

1. Wrap the insulated wire neatly and evenly around a broom handle. Start with perhaps 30 turns of the wire. Carefully remove the broom handle.
2. Connect the two ends of the wire to the positive and negative terminals of the galvanometer.
3. Predict what you think will happen if you place the magnet inside the coil. Try it and see what happens to the galvanometer.
4. Move the magnet back and forth in the coil. What happens to the galvanometer needle?
5. Move the magnet back and forth outside the coil. What effect does this have?
6. What happens if you move the coil but keep the magnet still?
7. What happens if you move the magnet inside the coil very fast? You could hang the magnet from a spring to do this.
8. What happens if you add more turns of wire to the coil?



Write down here what you have learned about using a magnet to generate an electric current.

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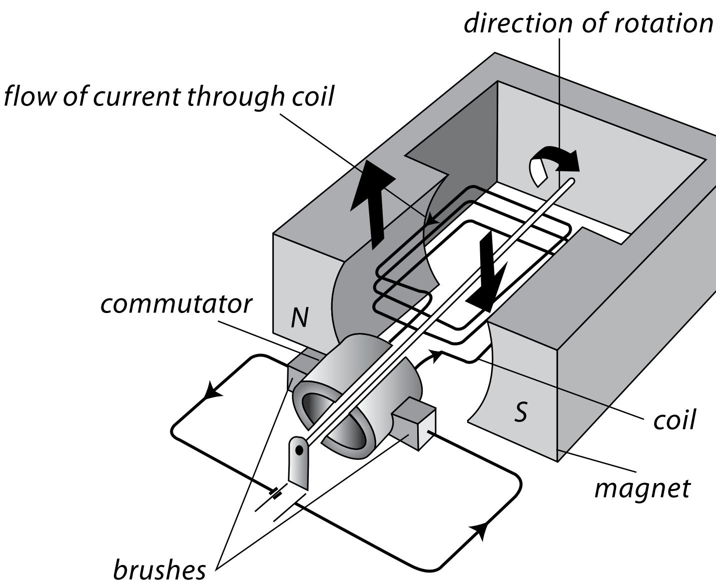
WORKSHEET 3

Examining a simple electric motor

For this activity, a simple battery-operated electric motor is needed; one of the motors which comes with a construction kit such as Lego or Meccano is ideal.

Materials needed: a simple, battery-operated electric motor; cells or batteries for the motor, connecting wires

1. Connect the motor to the cells or batteries and get it running.
2. Observe the direction and speed of rotation of the drive shaft.
3. If possible, carefully dismantle the motor. How many of the parts in the diagram below can you see?
4. What do you notice about the way the commutator is constructed?
5. The two small devices which rub against the commutator are called brushes. What do they do?

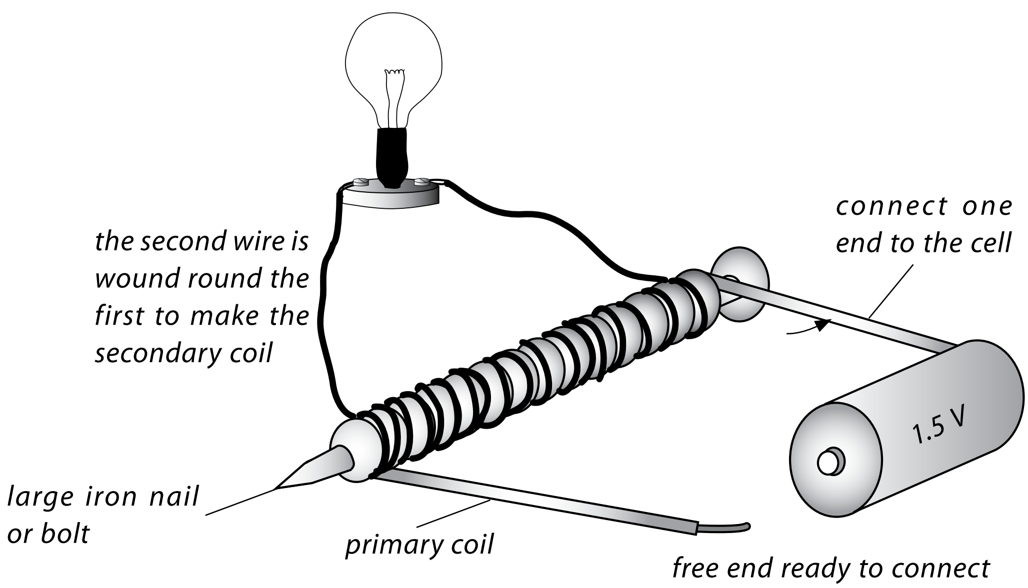


WORKSHEET 4

Making a simple transformer

Materials needed: about 1.5 m of thin single core insulated wire; a very large iron nail or bolt; a 1.5 V cell; sticky tape; 2.5 V bulb in a holder; small screwdriver

1. Cut the wire into two pieces (approximately 0.5 m and 1.0 m in length).
2. Bare the four ends of the wires.
3. Wind the shorter of the two wires around the nail fifty times, leaving the bared ends free (see diagram below). This is your primary coil.
4. Attach one end of the primary coil to the cell with some sticky tape.
5. Now wrap the second wire around the nail (over the top of the first wire) fifty times. This is the secondary coil.
6. Attach the two ends of the secondary coil to the bulb holder.
7. Touch (on and off rapidly) the remaining free wire of the primary coil to the free terminal of the cell. What happens?
8. Try again, but use seventy-five turns in the secondary coil.
9. Now try other combinations, as shown in the table.



Turns in the primary coil	Turns in the secondary coil	Noticeable effect
50	50	
50	75	
50	100	
25	50	
25	75	
25	100	
10	25	
10	50	
10	100	

Write a conclusion to your experiment here:

____

____

____

If you have a willing friend, this experiment is much more effective if the friend holds the two free ends of the secondary coil in his or her fingers. In this case, only touch the free end of the primary coil against the free terminal of the cell for the briefest of moments!

Answers to questions in the Student's Book

1. Michael Faraday invented the first electric motor. He also discovered that when a magnet is pushed in and out of a coil of wire it generates an electric current.
2. A turbine is a huge fan or propeller which is turned by the wind, steam, hot gases, flowing water, or the tides. It turns the generators which produce electricity.
3. A generator (or dynamo) is a device which produces electrical energy from mechanical energy. In it, a coil of conducting wire is rotated in a magnetic field.
4. A bicycle dynamo consists of a spinning permanent magnet inside a coil of wire. The power station generator also has a magnet spinning inside a coil of wire. But as well as being much bigger, the power station generator has a spinning electromagnet instead of a permanent magnet. This magnet also spins at a steady rate (unlike the bicycle dynamo) and it produces a very large electric current. Unlike the cycle dynamo, the power station generator's electromagnet does not spin in air, which would slow it down. Instead the electromagnet spins in hydrogen.
5. Because the power station generator produces such large electric currents, it also produces large amounts of heat inside the coils. This could damage the coils and electromagnet, and so the generator has to be cooled, either by circulating water or, less often, by circulating hydrogen gas.
6. The National Grid is a network of overhead cables on pylons, and underground cables, for transmitting electricity around the country. It enables electric current from one station to be supplied to another region in the case of a breakdown or a greater demand for current than usual.
7. The cables on pylons are made of aluminium because this metal is a good conductor of electricity and also is light in weight.
8. The voltage in the National Grid is highest after the current leaves the first transformer it meets after leaving the power station. A power station usually produces electricity at 25,000 volts. Transformers then increase this voltage to 400,000 V.
9. Electricity is transmitted at a high voltage across the National Grid so that the currents which flow are small and only a small amount of the energy is wasted as heat.
10. A transformer is a device for changing the voltage of an alternating current without changing its frequency. A step-up transformer is one in which the number of turns on the secondary coil is greater than the primary coil, so the secondary voltage is greater than the primary voltage. A step-down transformer has fewer turns in the secondary coil than in the primary coil, so the secondary voltage is less than the primary voltage.
11. Ways of generating electricity without burning a fuel, and in which the energy is renewable, include the use of wind power, hydro-electric power, wave and tidal power, solar power, and geothermal power.
12. Modern devices that use electronics include computers, computer games, calculators, radios, televisions, digital cameras, camcorders, mobile telephones, i-Pods, i-Pads. The controls of washing machines, motor vehicles, aircraft, and spacecraft also use electronics.

13. The binary code is a number code based on the digits 0 and 1, with 1 being represented by a pulse of electricity and 0 by the absence of a pulse. This code is used in computers, digital cameras, computer printers, and many other digital electronic devices.
14. A transistor is an electronic device which is commonly used as a switch or an amplifier.
15. Transistors and most other electronic devices are made from pure silicon. Silicon is a type of material called a semiconductor.
16. A diode is an electronic device made from a semiconductor material such as silicon which can be used as a one-way switch. A capacitor is an electrical device designed to store small quantities of electric charge.
17. A device called a rectifier is used to change an alternating current to a direct current. A convertor can convert alternating current to direct current, or vice versa.

Assessment

Question 1

We measure the current flowing through a wire using:

(A) an ammeter (B) a voltmeter (C) a joulemeter (D) a pedometer

Question 2

The scientist who discovered how to generate electricity with a magnet and a coil of wire was:

(A) Alexander Fleming (B) Michael Faraday

(C) Isaac Newton (D) Alessandro Volta

Question 3

As electrical charges move around a circuit they give up:

(A) charge (B) current (C) energy (D) resistance

Question 4

Which part of a bicycle dynamo spins in order to generate electricity?

(A) the coil (B) a magnet (C) the tyre (D) a galvanometer

Question 5

The machine which turns in a power station to produce electricity is called a:

(A) dynamo (B) permanent magnet (C) generator (D) cyclone

Question 6

The electricity from a cell or battery is called:

(A) low current
(B) indirect current
(C) alternating current
(D) direct current

Question 7

The electricity we use in our homes and schools is called:

(A) low current
(B) indirect current
(C) alternating current
(D) direct current

Question 8

What are the huge fans called which turn the generators in a power station?

(A) tureens
(B) turbines
(C) turbots
(D) tubers

Question 9

The device used to change the voltage of an alternating current is called a:

(A) meter
(B) galvanometer
(C) transformer
(D) transmitter

Question 10

What is the core of a transformer made of?

(A) solid iron
(B) solid steel
(C) thin sheets of iron fixed together
(D) thin sheets of copper fixed together

Question 11

During the night, when few people are using electricity, extra electricity is used to pump water back up to the top reservoir at a hydro-electric power station in Wales. Choose which you think is the BEST explanation for this.

(A) It prevents the generators wearing out.
(B) It stores up energy for use during the day.
(C) Water is a good conductor of electricity.
(D) It keeps the pipes full of water.

Question 12

Which of the following is NOT a fossil fuel?

(A) wood
(B) oil
(C) coal
(D) natural gas

Question 13

An energy source which cannot be replaced once it has all been used up is called a:

(A) renewable energy source (B) non-renewable energy source
(C) fossil fuel (D) replenishable energy source

Question 14

Which of the following is NOT a renewable energy source?

(A) wind power (B) geothermal energy (C) tidal power (D) natural gas

Question 15

Which of the following does not use water as its source of energy?

(A) tidal energy (B) biomass (C) hydroelectricity (D) wave energy

Question 16

The network of cables which carries electricity around the country is called the:

(A) National Power (B) National Trust (C) Natural Grid (D) National Grid

Question 17

Which is the voltage at which power stations usually produce electricity?

(A) 230 V (B) 15,000 V (C) 25,000 V (D) 400,000 V

Question 18

The electronic device which is often used as a switch or amplifier is called a:

(A) transformer (B) transistor (C) thermistor (D) thermostat

Question 19

A microchip is often called:

(A) an asbestos chip (B) a silicon chip (C) a crystal chip (D) an electro-chip

Question 20

Silicon is a type of:

(A) conductor (B) insulator (C) semi-conductor (D) semi-insulator

Question 21

Natural gas is an important fossil fuel used in many power stations and in many homes across the world.

a) Name TWO other fossil fuels. ______________________________

b) Natural gas is often described as a 'non-renewable energy resource'. Explain what this term means.

____

____

c) What is a renewable energy resource?

____

d) Give TWO examples of renewable energy resources.

____

e) Explain why it is important to use more renewable energy resources.

____

____

f) Fossil fuels like coal are often burnt in power stations to generate electricity. The stages involved in producing electricity are given below, but they are in the wrong order. Write the letters of the stages in the boxes provided.

(A) The steam turns the turbines.

(B) The electricity is generated and fed to the National Grid.

(C) Fuel is burnt and heats the tanks of water.

(D) The turbines turn the generators.

(E) The water changes to high pressure steam.

☐ ☐ ☐ ☐ ☐

g) Copy the sentences below and fill in the gaps to show the energy changes that have taken place.

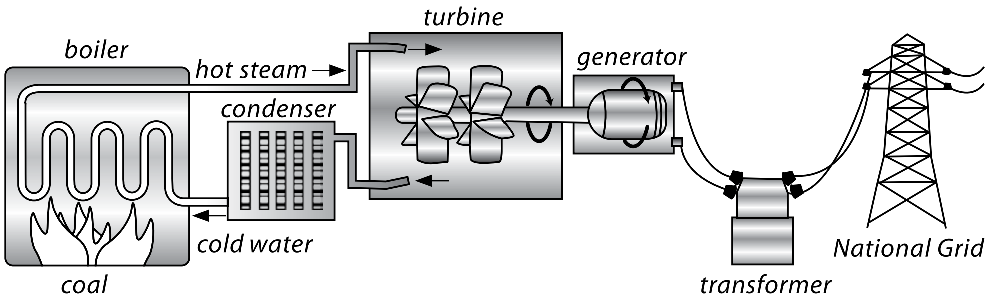
i) When a wind turbine spins and produces electricity, it changes ________ energy to ________ energy.

ii) When coal is burnt in a power station it changes ________ energy to ________ energy.

iii) In a hydroelectric power station the ________ energy of running water is changed to ________ energy.

Question 22

The diagram below shows the energy changes that take place in a power station that uses coal for its fuel.



a) What kind of energy is stored in coal?

b) How is the energy stored in coal released?

c) What is the energy released from the coal used for in a power station?

d) What energy transfer takes place when the steam enters the turbine?

e) What energy transfer takes place when the turbine turns the generator?

f) Coal is a fossil fuel. Name TWO other fossil fuels.

g) How were fossil fuels formed?

h) Why are fossil fuels called non-renewable sources of energy?

i) Name TWO environmental problems that may arise because of the use of fossil fuels in power stations.

j) Suggest TWO ways in which we could make fossil fuels last longer.

Question 23

a) Explain what is meant by the term *National Grid*.

b) Explain briefly why we need a National Grid.

c) Give ONE advantage of using very high voltages in the National Grid.

d) Give ONE disadvantage of using very high voltages in the National Grid.

e) Explain why overhead power lines are used rural areas rather than underground cables.

f) Give ONE situation where underground cables would be better in rural areas.

Question 24

a) The use of wind turbines to generate electricity is on the increase.

i) Complete the boxes below naming the main energy changes taking place in a wind turbine.

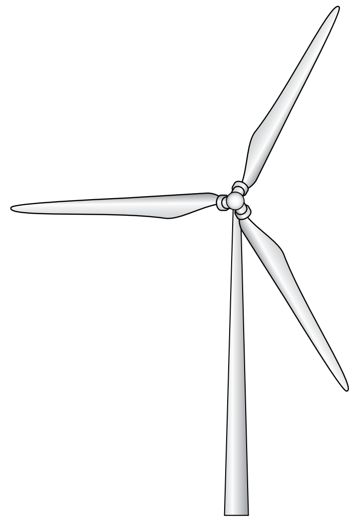
Energy in the wind

↓

Energy in the moving rotor blades

↓

Output energy from the turbine



ii) Name TWO unwanted forms of energy that result from wind turbines.

iii) What are TWO advantages of wind turbines?

iv) What are TWO disadvantages of wind turbines?

v) Explain why wind is a renewable energy source.

b) i) Nuclear power is seen by some people as a solution to the problem of global warming. Explain briefly why this is.

ii) Why is the waste from a nuclear power station considered to be dangerous?

iii) What element is used as a fuel in nuclear power stations?

iv) Nuclear power is a non-renewable source of energy. Explain why it is described in this way.

Question 25

Below are nine different energy resources.

biomass	coal	natural gas	geothermal	hydroelectric
nuclear	wind	oil	wave	

a. Classify these energy resources by writing the name of each in the correct column in the table below.

Renewable and dependent on energy from the Sun	**Renewable and independent of energy from the Sun**	**Non-renewable**

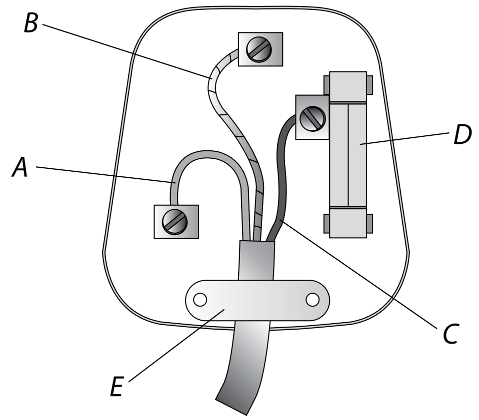
b. There is increasing interest in the use of biofuels for energy. Biofuels frequently come from sugar cane and the seeds of crops like oilseed, e.g. rape and maize. What form of energy is stored in biofuels?

c. Explain why biofuels can be thought of as renewable sources of energy.

d. What greenhouse gas is given off when biofuels are burned?

Question 26

a) The diagram below shows a fused 13 A plug. Five parts are labelled A, B,C, D, and E.



i) Complete the table to identify the wires connected to the three pins of the plug.

Wire connected to:	**Live pin**	**Neutral pin**	**Earth pin**
Letter (A, B, or C)			

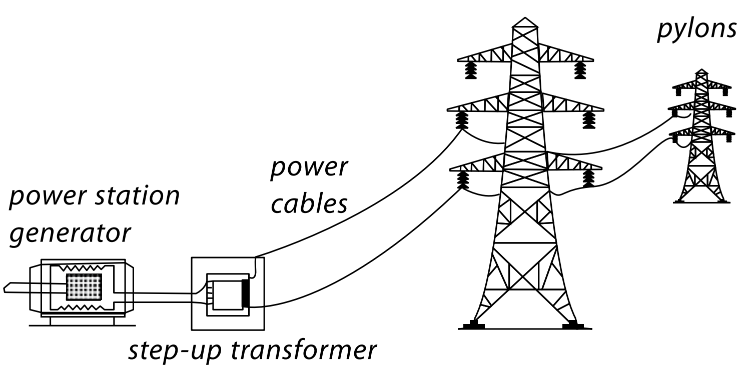
ii) What name is given to the part of the plug labelled D?

iii) What is the purpose or function of the part of the plug labelled E?

b) A washing machine has a metal frame. A fault occurs so that the live wire connected to the motor becomes loose and touches the metal frame. Explain fully how the fuse and the earth wire in the plug on page 230 work together to prevent someone touching the washing machine from being electrocuted.

Question 27

a) The cables from a power station generator are connected to a step-up transformer. The transformer is connected to the power lines or cables.



i) What is the work or function of the step-up transformer?

___

ii) What is the advantage of using a step-up transformer to send electricity along the power cables?

___

iii) Since this is a step-up transformer, which of its two coils, the primary coil or the secondary coil, will have the largest number of turns of wire?

___

b) The resistance of a piece of wire depends on several factors.

i) Does the resistance of a piece of copper wire increase, decrease, or stay the same when its length increases?

increase ☐ decrease ☐ stay the same ☐

ii) Does the resistance of a piece of copper wire increase, decrease, or stay the same when its diameter increases?

increase ☐ decrease ☐ stay the same ☐

c) A piece of thread and a copper wire have the same length and diameter. Will the copper wire's resistance be bigger, smaller, or about the same as that of the cotton thread?

bigger ☐ smaller ☐ about the same ☐

Answers to assessment questions

Question 1 (A)	Question 2 (B)	Question 3 (C)	Question 4 (B)	Question 5 (C)
Question 6 (D)	Question 7 (C)	Question 8 (B)	Question 9 (C)	Question 10 (C)
Question 11 (B)	Question 12 (A)	Question 13 (B)	Question 14 (D)	Question 15 (B)
Question 16 (D)	Question 17 (C)	Question 18 (B)	Question 19 (B)	Question 20 (C)

Question 21

a) Two other fossil fuels are natural gas and oil (or petroleum).

b) A 'non-renewable energy resource' is a source of energy that is being used up much faster than it can be replaced naturally. It will, therefore, eventually run out.

c) A renewable energy resource is an energy source than can easily be renewed or replaced as it is used up.

d) Examples of renewable energy resources include wood, solar power, wind power, wave power, tidal power, biofuel, biogas, hydroelectric power, and geothermal power.

e) It is important to use more renewable energy resources to make the non-renewable energy resources last longer and to have alternatives available when all the non-renewable energy resources are used up.

f) The correct stages involved in producing electricity are:
   (C) Fuel is burnt and heats the tanks of water.
   (E) The water changes to high pressure steam.
   (A) The steam turns the turbines.
   (D) The turbines turn the generators.
   (B) The electricity is generated and fed to the National Grid.

g) i) When a wind turbine spins and produces electricity, it changes **kinetic** energy to **electrical** energy.
   ii) When coal is burnt in a power station it changes **chemical** energy to **heat** energy.
   iii) In a hydroelectric power station the **kinetic** energy of running water is changed to **electrical** energy.

Question 22

a) The energy stored in coal is chemical energy.
b) The energy stored in coal is released by burning.
c) In the power station the energy released from the coal is used to heat water and turn it into steam.
d) The energy transfer that takes place when the steam enters the turbine is that heat or thermal energy is changed into kinetic energy.
e) The energy transfer that takes place when the turbine turns the generator is that kinetic energy is changed into electrical energy.
f) Two other fossil fuels are oil and natural gas.
g) Fossil fuels are composed of the fossilized remains of dead plants and animals.
h) Fossil fuels are called non-renewable sources of energy because once they have been used up they cannot be replaced.
i) Global warming/the greenhouse effect and the formation of acid rain are two environmental problems that may arise because of the use of fossil fuels in power stations.
j) Ways in which we could make fossil fuels last longer include insulating homes, driving smaller cars, developing smaller cars or electric cars; using public transport more; walking or cycling rather than travelling by motor car, reusing or recycling materials.

Question 23

a) The 'National Grid' is a network of cables, transformers, and sub-stations across the country.
b) We need a National Grid to distribute electrical power from the power station to users in all parts of the country. The electricity from the power stations within the National Grid can also be used to meet fluctuating demand.
c) The advantage of using very high voltages in the National Grid is that little energy or power is lost.
d) The disadvantages of using very high voltages in the National Grid are the dangers to the public and the need for transformers in every part of the network.

e) Overhead power lines rather than underground cables are used in rural areas because it is cheaper, they are easier to erect, and it is quicker and easier to repair them.

f) Underground cables would be better in attractive rural areas, near schools and children's play areas, in areas where flocks of birds migrate, and near places such as rivers and canals where anglers use long fishing rods.

Question 24

a) i) Energy in the wind **kinetic**

Energy in the moving rotor blades **kinetic**

Output energy from the turbine **electrical**

ii) Two unwanted forms of energy that result from wind turbines are sound and heat.

iii) Advantages of wind turbines include they do not produce carbon dioxide/air pollution/greenhouse gases; they are relatively inexpensive to build; the electricity is produced at low cost.

iv) Disadvantages of wind turbines are that some people consider them to be unsightly; they are noisy; they can be a hazard to flying birds; they produce electricity only when the wind is blowing.

v) Wind is a renewable energy source because, unlike coal, oil, and natural gas, it will never run out/ or cease to blow for any length of time.

b) i) Nuclear power is seen by some people as a solution to the problem of global warming because it does not produce carbon dioxide.

ii) The waste from a nuclear power station is considered to be dangerous because it is radioactive.

iii) The element used as a fuel in nuclear power stations is uranium or plutonium.

iv) Nuclear power is a non-renewable source of energy because there are limited supplies of uranium, or it cannot be replaced in a human lifetime.

Question 25

a.

Renewable and dependent on energy from the Sun	Renewable and independent of energy from the Sun	Non-renewable
biomass hydroelectric wind wave	geothermal	coal oil natural gas nuclear

b. Chemical energy is stored in biofuels.

c. Biofuels can be thought of as renewable sources of energy because when supplies are used up, more of the crops they are produced from can be grown.

d. The greenhouse gas given off when biofuels are burned is carbon dioxide.

Question 26

a) i)

Wire connected to:	**Live pin**	**Neutral pin**	**Earth pin**
Letter (A, B, or C)	C	A	B

ii) The part of the plug labelled D is the fuse, or cartridge fuse.

iii) The purpose or function of the part of the plug labelled E is to clamp the cable in place.

b) The fuse and the earth wire in the plug work together to prevent someone touching the washing machine from being electrocuted in the following ways:

The current flows to the earth.

The earth wire has a low resistance.

The current is greater than the fuse rating.

The fuse wire melts/blows/breaks.

The fuse disconnects/breaks the circuit.

Note: Award full marks for any four of the above correct answers.

Question 27

a) i) The work or function of the step-up transformer is to **increase** the voltage.

ii) The advantage of using a step-up transformer to send electricity along the power cables is that less energy is lost as heat in the cables (or it saves power/energy).

iii) Since this is a step-up transformer, the **secondary coil** will have the largest number of turns of wire.

b) i) The resistance of a piece of copper wire **increases** when its length increases.

ii) The resistance of a piece of copper wire **decreases** when its diameter increases.

c) The copper wire's resistance will be **smaller** than that of the cotton thread.

Exploring space

CHAPTER 13

Teaching Objectives

- To investigate and evaluate the tools and technologies used in space exploration
- To examine the survival strategies used by astronauts in space and to review the research they carry out there
- To examine the benefits to the lives of people on Earth of space exploration and the new technologies developed

Learning Outcomes

After studying this chapter students should be able to:

- describe the development of tools and technologies used in space exploration
- analyze the benefits generated by the technology of the space exploration
- explain how astronauts survive and carry out research in space
- suggest ways to solve the problems that have resulted from space exploration
- identify the technological tools used in space exploration
- identify new technologies used on Earth that have developed as a result of the development of space technology
- design a spacecraft and explain the key features of its design to show its suitability as a spacecraft

Introduction

The thousands of planets, stars, and galaxies that are visible from Earth are some of the countless billions of objects that make up the universe.

The Universe

Stars and planets have been studied since the first humans looked up at the night sky. They made sense of the bright dots they saw by grouping them into constellations. They followed the movements of the Moon and planets, and developed a simple model of the Universe. More recently, scientists have studied what stars are made of and how they form, evolve, and die. Most scientists now believe the Universe was born in a 'Big Bang'—

an instant when all matter was created and time began. We now know that the Universe consists of everything in space, and space itself. It is unimaginably large, constantly changing and getting larger all the time.

Space exploration

Almost all the objects in the universe are too far away for missions from Earth to visit. Astronomers use telescopes on Earth and in orbit to gather information from the light, X-rays, radio, and infrared radiation given out by such distant objects. Unmanned space probes have visited some of the planets, comets, and asteroids, and twelve men have walked on the surface of the Moon. Each year, astronomers and space scientists discover more objects in space and learn new details about those objects they have known about for some time. In the course of their investigations, they also invent new materials, instruments and other equipment that can be used for the benefit of ordinary people living on Earth.

Practical considerations

This is such a fast-moving area of science and technology that it is very difficult to be prescriptive about possible lesson topics. The best lessons are those which are based on current developments, particularly if recordings can be made of news items or items from the NASA and other space exploration websites.

Lesson suggestions

1. Space shuttles and space suits

Refer to page 165 of the Students' Book

Starter suggestions

Ask the students to recall how many important stages in space exploration they can think of. Which astronauts and cosmonauts made notable ‘firsts’ in space exploration?

Make a large space exploration time-line, as described in the **Ideas for investigation and extension work** section of this chapter**.** Display it on the classroom or laboratory wall so that the students can refer to it from time to time.

Main lesson

Show the students a large photograph of the space shuttle.

Tell the students that space shuttles were the world’s first reusable spacecraft. They are launched by rocket but land like a conventional aircraft. The shuttles are operated by the US National Aeronautics and Space Administration (NASA) for human spaceflight.

The first shuttle to fly in space—*Columbia*—was launched on 12th April 1981. The shuttles are due to be retired from service in 2011, but presumably future space flights will involve similar craft.

When the shuttle re-enters the Earth’s atmosphere it hits air particles at a speed of about

28,000 km/h. Without special measures, the huge friction force would heat the shuttle to a temperature of about 1650°C.

To prevent the astronauts being incinerated, the outside of the shuttle is coated with special insulating tiles which, although they are made of silica, are 93 per cent air. Discuss the advantages of having lots of air bubbles in the material. After the first shuttle flight, sixteen of the heat-resistant tiles fell off and 148 were damaged. As a result, a special glue had to be developed which would resist high temperatures.

Ask the students to research the successful, and two unsuccessful, space shuttle flights and the new materials that scientists and engineers have had to develop for the space shuttle. In particular find out which of these materials have important uses or applications on Earth.

The NASA website is an important source of information and illustrative material on the space shuttle. Go to: www.nasa.gov/mission_pages/shuttle/main/index/html

Go on to discuss and investigate the development of spacesuits. Worksheet 1 will act as a starting point. A lot of information and many photographs can be found on the NASA website at: www.nasa.gov/audience/spacesuits

2. Telescopes and space exploration

Refer to page 153 of the Students' Book

Starter suggestions

Ask the students to recall what they remember about the structure of refractive and reflective telescopes and their use in observing planets and stars.

Main lesson

Start with a brief history of the telescope and the fact that the Italian scientist Galileo Galilei first developed a telescope in about the year 1600.

As you develop the history of the telescope, emphasize the limiting factors inherent in optical telescopes. Refractive telescopes, for example, were limited by the diameter of the objective lens and the amount of light that could enter the optical system. It is also important to stress the problems of observing distant objects through the Earth's atmosphere because of diffraction and lack of clarity, so that images are not clear. In more recent years, light pollution has become a serious problem, hence the need to reduce as much as possible the amount of atmosphere the telescope has to penetrate. First of all telescopes were constructed on top of mountains and later installed in space itself.

Working in pairs, give the students two convex lenses and some cardboard tubing and see whether they can make their own working refractive telescope.

Briefly describe the structure and uses of radio telescopes and stress that they can detect electromagnetic waves that our eyes cannot see, including radio, infra-red rays, and X-rays.

Let the students go on to research the construction, launch, and discoveries and achievements of the Hubble Space Telescope which was launched in 1990. It has been sending pictures and data back to Earth ever since. There is a wealth of information and spectacular images and video clips of Hubble on the website at: http://hubblesite.org

More recently, the Kepler Space Telescope was launched in March 2009. It has a planned mission lifetime of at least three to five years and is designed to search for Earth-like planets in outer space. In February 2011, the Kepler team announced that they had found fifty-four planets thought to be suitable for life because they lie within the habitable zones of stars. Five of these newly-discovered planets are Earth-sized. As with the Hubble telescope, there is up-to-date information and a wealth of photographs and video clips on the website: http://kepler.nasa.gov

Ideas for investigation and extension work

The International Space Station

The International Space Station (ISS) can be viewed from Earth if you know where to look. Since it has little or no light of its own, you can see it only when the ISS is in sunlight and it is dark on the ground where you are. The best viewing times are just before or after sunrise and sunset while the station is passing overhead. The ISS appears as a bright, fast-moving star. Normally you have only about two minutes to see it—four minutes at most. Telescopes are no help because of the speed at which the ISS is travelling. Binoculars may let you see some details of the station as long as you know exactly where to look, but most times naked eyes are best. Details of when the ISS and other spacecraft are passing over where you live can be found on the National Aeronautics and Space Administration's website at: www.spaceflight.nasa.gov/realdata/sightings

A map of the night sky

Every month certain foreign newspapers publish notes and maps of the night sky. If you have access to any of these, cut out one of these maps and mount it on a sheet of card. Hold the chart in front of you and make sure that 'north' on the chart is pointing towards the north. Use a compass if you are not sure which direction is north. Use the chart to help you identify the positions of the stars and planets.

Keep a 'Space Diary'

Keep a 'Space Diary'. In the diary, place newspaper and magazine reports and photographs of important space discoveries as they occur. Write against each article and picture the date when it was published.

Website research

Visit the NASA website to find out more about such subjects as the International Space Station, the Space Shuttle, space probes, details of rockets and space suits used in space research, and information on future missions into space.

Deepest space

Decide on what you think is the furthest place that humans could reasonably reach. Describe the plans that you would need to make for such a voyage.

Would-be astronauts

Design an application form that could be used by would-be astronauts. Base the form on ten facts that you have researched about the Solar System and space. Make sure the form includes questions about the challenges and problems involved in surviving in space and carrying out exploration there.

Science fiction

Think of some of the travels which popular science fiction characters make. Try to explain why their exploits are, in fact, impossible.

A space time-line

Make a large illustrated time-line to show the history of space exploration. Display it on the classroom or laboratory walls.

A planetarium

If there is a planetarium near where you live or go to school, see if a visit can be arranged, or may be someone from the planetarium can come and give a talk at your school.

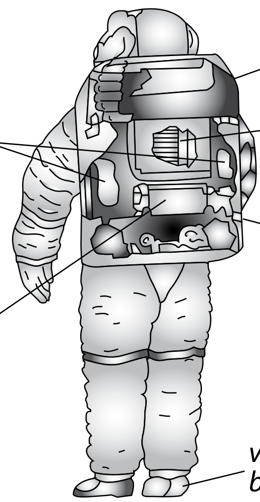
WORKSHEET 1

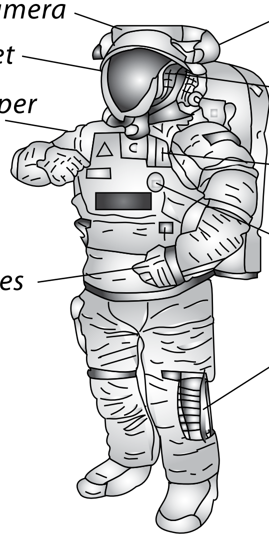
Out of this world!

Our bodies are designed for life on Earth. We are adapted to breathe its atmosphere, to move under atmospheric pressure, to resist the downward pull of gravity, and to live in warm, light surroundings. Life in space is very different and humans cannot survive there without protection.

Materials needed: **pen or pencil**

Look carefully at these pictures of an astronaut in his space suit. Then answer the questions below.





1. Which part of the space suit protects an astronaut's face from flying dust and pieces of rock?

   ____

2. How does the astronaut keep cool inside the space suit?

   ____

3. How does the astronaut breathe in space?

   ____

4. What do you think the portable life-support system does?

   ____

5. Why do you think there are lights attached to the astronaut's helmet?

   ____

6. Why do you think an astronaut wears a camera that sends pictures to the spacecraft and Mission Control?

   ____

7. Why do you think the astronaut's boots are very heavy?

8. If you could add one feature to the space suit, what would it be? Explain your answer.

Answers to questions in the Students' Book

1. The telescope was invented by the Italian scientist Galileo Galilei in about the year 1600.
2. A reflecting telescope uses mirrors to produce magnified images of distant objects, while a refracting telescope uses lenses.
3. The size of a refracting telescope is limited by the size of the lenses in it. It is difficult and expensive to make really large lenses because imperfections such as air bubbles often form in the glass when it is in a molten state. In addition, large lenses have to be thick and this reduces the amount of light that passes through them. Finally, a lens can only be supported by its thin edge and large lenses are heavy and often bend in the middle.
4. It is important to site large telescopes on high mountains or in remote areas to avoid light pollution and pollution of the air from factories, power stations, and motor vehicles. In addition, the air on high mountains is thin enough for the twinkling effect caused by air movements to be reduced.
5. The spectrum produced by stars can tell scientists which chemical elements they are made from and also their temperature. The spectrum can also show whether a star is moving away from or towards the observer.
6. Radio telescopes have the advantage over refracting and reflecting telescopes in that they can be used during the day as well as at night, and in cloudy or even stormy weather. Radio telescopes are also not affected by the Earth's atmosphere.
7. A typical radio telescope consists of a huge concave reflector, called a dish, which looks rather like an enormous satellite television aerial. The radio receiver of the telescope is positioned at the focal point of the dish where the radio waves can be collected.
8. A space telescope has the advantage over land-based telescopes in that it is away from the adverse effects of the Earth's atmosphere and artificial light pollution and it can see much further into space. Its view is not blocked by clouds and it does not have to wait for night-time.
9. The world's first artificial satellite was Sputnik 1 which was launched by the Soviet Union on October 4, 1957.
10. The first human to travel in space was the Russian Yuri Gagarin, on 12th April 1961.
11. An astronaut is the American name for a space explorer, while the Russian name is cosmonaut.
12. The first person to walk on the Moon was the American Neil Armstrong in 1969.
13. A space station is a spacecraft that moves in a fixed orbit in space and has compartments where scientists can live and work for months or even years at a time.
14. A space shuttle is a reusable spacecraft.
15. A space probe is an unmanned spacecraft that can travel to other planets or journey deep into space to collect scientific information.
16. Some of the benefits of space exploration include greater knowledge about space and other planets, the development of new electronic equipment such as hearing aids and a camera small enough to photograph inside someone's stomach. The kidney dialysis machine resulted from space research, as

did the artificial heart. Other benefits include fire-resistant materials, more accurate watches, new insulating materials, stronger fibreglass for storage tanks, and special 'jaws' to rescue victims from crashed motor vehicles.

Assessment

Question 1

Which Italian scientist invented the first telescope?

(A) Alessandro Volta
(B) Galileo Galilei
(C) Amadeo Avogadro
(D) Louis Pasteur

Question 2

Telescopes which use lenses are called:

(A) refracting telescopes
(B) reflecting telescopes
(C) lens telescopes
(D) radio telescopes

Question 3

Telescopes which use mirrors are called:

(A) refracting telescopes
(B) reflecting telescopes
(C) lens telescopes
(D) radio telescopes

Question 4

The world's first reflecting telescope was made by:

(A) Galileo Galilei
(B) William Harvey
(C) Edward Jenner
(D) Isaac Newton

Question 5

Which instrument helps scientists to find out what stars are made of?

(A) light meter
(B) spectroscope
(C) chromatogram
(D) pH meter

Question 6

A large telescope in Puerto Rico has a concave reflector 305 metres in diameter. What kinds of waves does this reflector collect?

(A) light waves
(B) sound waves
(C) heat waves
(D) radio waves

Question 7

What type of telescope is carried by the Hubble Space Telescope?

(A) reflecting telescope
(B) refracting telescope
(C) radio telescope
(D) electronic telescope

Question 8

What was the name of the first person to walk on the Moon?

(A) Alan Shepard (B) Neil Armstrong (C) John Glenn (D) Yuri Gagarin

Question 9

Which of these statements about space probes is NOT true?

(A) They are launched by rockets.
(B) They are controlled from Earth by radio.
(C) They carry scientific equipment.
(D) They have a crew of two.

Question 10

What was unusual about the Space Shuttle?

(A) It carried people and scientific equipment.
(B) It was powered by rocket engines
(C) It was reusable.
(D) It was American.

Question 11

Read the following statements about chemical reactions. For each one, say whether you think it is TRUE or FALSE.

a) A refracting telescope uses lenses to make distant objects seem nearer. ☐
b) The world's first refracting telescope was invented by Isaac Newton. ☐
c) Air movements and city lights make it easier to see stars through a telescope. ☐
d) A spectroscope can tell scientists how old stars are and what elements they are made of. ☐
e) Radio telescopes use huge convex reflectors to capture radio waves. ☐
f) The Hubble Space Telescope is a reflecting telescope. ☐
g) The first object to be sent into space was the American satellite Sputnik 1. ☐
h) The first human to travel in space was the Russian cosmonaut Yuri Gagarin. ☐
i) A Space Station is a large unmanned spacecraft. ☐
j) The American Space Shuttle was the world's first reusable spacecraft. ☐
k) Space probes are unmanned spacecraft that orbit the Earth. ☐
l) The first person to walk on the Moon was the American Neil Armstrong in 1969. ☐

Question 12

a) Telescopes are often used to study the night sky.

i) Explain why a reflecting telescope produces better images than a simple optical or refracting telescope.

____

____

ii) The world's largest radio telescope is at the Arecibo Radio Observatory in Puerto Rico. Explain what is meant by a radio telescope.

____

____

iii) Describe ONE advantage that a radio telescope has over telescopes that use lenses or mirrors.

____

____

iv) The Hubble telescope is a space telescope. Explain what is meant by a space telescope.

____

____

v) Describe TWO advantages of having a telescope in orbit.

____

____

Question 13

Complete the following sentences using the words in the box below. You may need to use one or two words more than once.

Moon	oxygen	instruments	food	exercise
weight	packaged	weightless	crumbs	astronauts
drink	spacesuits	fit	water	

Living in space is not easy, but life for modern ________ is much more comfortable than it was on the early space missions.

While they are walking in space or walking on the surface of the ________, astronauts wear bulky ________. But inside a spacecraft, the cabins are filled with ________ so that they can dress more comfortably.

Astronauts normally take all their ________ with them. Nowadays they have quite a choice of foods. They also have hot ________ and usually an oven too. Many foods are dried to reduce their ________, and need to have ________ added. Other foods, such as biscuits, nuts, and cereal bars, can be stored as they are. Everything has to be carefully ________.

Eating and drinking while you are ________ is not easy. A big problem is ________, as they float around and get into delicate ________. Astronauts ________ out of closed containers using a straw.

On long space flights, it is very important for ________ to keep ________ and healthy. They have a carefully planned, nutritious diet, and they have to take plenty of ________.

Answers to assessment questions

Question 1 (B) **Question 2** (A) **Question 3** (B) **Question 4** (D) **Question 5** (B)
Question 6 (D) **Question 7** (A) **Question 8** (B) **Question 9** (D) **Question 10** (C)

Question 11

a)	A refracting telescope uses lenses to make distant objects seem nearer.	TRUE
b)	The world's first refracting telescope was invented by Isaac Newton.	FALSE
c)	Air movements and city lights make it easier to see stars through a telescope.	FALSE
d)	A spectroscope can tell scientists how old stars are and what elements they are made of.	TRUE
e)	Radio telescopes use huge convex reflectors to capture radio waves.	FALSE
f)	The Hubble Space Telescope is a reflecting telescope.	TRUE
g)	The first object to be sent into space was the American satellite Sputnik 1.	FALSE
h)	The first human to travel in space was the Russian cosmonaut Yuri Gagarin.	TRUE
i)	A Space Station is a large unmanned spacecraft.	FALSE
j)	The American Space Shuttle was the world's first reusable spacecraft.	TRUE
k)	Space probes are unmanned spacecraft that orbit the Earth.	FALSE
l)	The first person to walk on the Moon was the American Neil Armstrong in 1969.	TRUE

Question 12

i) A reflecting telescope produces better images than a simple optical or refracting telescope because very large mirrors are cheaper and easier to make than large lenses. The large mirror can collect much more light than a large lens.

ii) A radio telescope collects radio waves that bounce off a large concave reflector, or dish, and are collected by a radio receiver.

iii) The advantage that radio telescopes have over telescopes that use lenses or mirrors is that they can be used by night and day and in all weathers, even when it is cloudy. In addition, many objects in space which are not visible to telescopes using mirrors and lenses, including comets, pulsars, black holes and distant planets, give out radio waves which can be detected by a radio telescope.

iv) A space telescope is one which is in orbit in space and which transmits images back to Earth.

v) The advantages of having a telescope in orbit include better quality images; no interference from the atmosphere or light pollution, as on Earth; it can collect data by night and day; it can collect very faint images of distance objects.

Question 13

Life in space

Living in space is not easy, but life for modern **astronauts** is much more comfortable than it was on the early space missions.

While they are walking in space or walking on the surface of the **Moon**, astronauts wear bulky **spacesuits**. But inside a spacecraft, the cabins are filled with **oxygen,** so that they can dress more comfortably.

Astronauts normally take all their **food** with them. Nowadays they have quite a choice of foods. They also have hot **water** and usually an oven too. Many foods are dried to reduce their **weight**, and need to have **water** added. Other foods, such as biscuits, nuts and cereal bars, can be stored as they are. Everything has to be carefully **packaged**.

Eating and drinking while you are **weightless** is not easy. A big problem is **crumbs**, as they float around and get into delicate **instruments**. Astronauts **drink** out of closed containers using a straw.

On long space flights, it is very important for **astronauts** to keep **fit** and healthy. They have a carefully planned, nutritious diet, and they have to take plenty of **exercise**.