Natural Science

Grade 8

Learner's Book

The content of this textbook was formatted to combine the two original workbook volumes into a single textbook.

Natural Sciences Grade 8 Learner's Book

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Contents

Strand

Life and Living

1 Photosynthesis and respiration

Key questions

- What drives life on Earth and in ecosystems?
- How do green plants photosynthesise when no other organism can make its own food?
- What do plants do with the food that they produce?
- Why do we need to eat food? What does it provide us with?
- We know respiration is one of the seven life processes, but what happens during respiration in organisms?

Keywords

- chemical potential energy
- chlorophyll
- chloroplast
- glucose
- photosynthesis
- radiant energy
- respiration
- starch
- soluble
- insoluble
- pigment

Energy is needed to sustain life and without it nothing would be able to live on Earth. Our most important source of energy is the Sun. In this unit we are going to investigate the processes involved in transferring the Sun's energy to our bodies to allow us to read this text. These two important processes are photosynthesis and respiration.

1.1 Photosynthesis

Energy sustains life

All life on Earth depends on energy to sustain the seven life processes.

ACTIVITY: The seven life processes

1. Do you remember what the seven life processes are? Do you remember using the letters from MRS GREN to help you remember these?
2. Write down the seven life processes in your exercise books.

M ____

R____

S ____

G ____

R ____

E ____

N ____

The form of energy that the Sun produces is called radiant energy. Although the Sun provides us with both light and warmth, plants use the light energy from the Sun only to photosynthesise.

Most organisms cannot directly use the energy from the sun to

Figure 1.1 The Sun provides us with energy in the form of light and heat.

Did you know?

All the New words listed in the boxes in the margin are defined in the glossary at the end of this strand.

perform the seven life processes. For example, a reptile can lie in the Sun to warm up from the heat energy, but this does not provide the necessary energy for that animal to move, reproduce or excrete waste.

Except for a few sea slugs, plants are the only organisms on Earth that can absorb the Sun's radiant energy and convert it into food for themselves and for other living organisms.

Radiant energy to chemical potential energy

What is potential energy? Do you remember that we spoke about energy for movement (kinetic energy) and energy that is stored (potential energy) in Energy and Change in Grades 6 and 7? What are some things that have kinetic energy and some that have potential energy? Remember to take down some notes in the margins of your workbook as you discuss things in class.

All living organisms can use energy in the form of chemical potential energy for the life processes. This is the energy that is stored in the food that organisms eat. Plants are able to capture the radiant energy from the Sun and transfer it to chemical potential (stored) energy for other organisms to use. They do this through the process of photosynthesis. All organisms release the stored potential energy from the food that they eat to support their life processes. This process is called respiration.

Did you know?

Chloroplasts are present only in plants. However, some sea slugs have learnt to absorb the chloroplasts from the green algae that they eat into their bodies and can actually photosynthesise themselves!

Photosynthesis is the process in which chlorophyll molecules absorb the radiant energy from the sun and transfers it into chemical potential energy. The only function of chlorophyll is to trap the sunlight energy; chlorophyll is not produced or used up during photosynthesis.

Figure 1.2 Elysia chlorotica, a sea slug, has evolved to absorb the chloroplasts from the green algae it eats and use them to photosynthesise! This animal can produce its own food and is green.

Photosynthesis has other requirements besides light energy from the Sun. What are these? Look at the following diagram which summarises the process of photosynthesis.

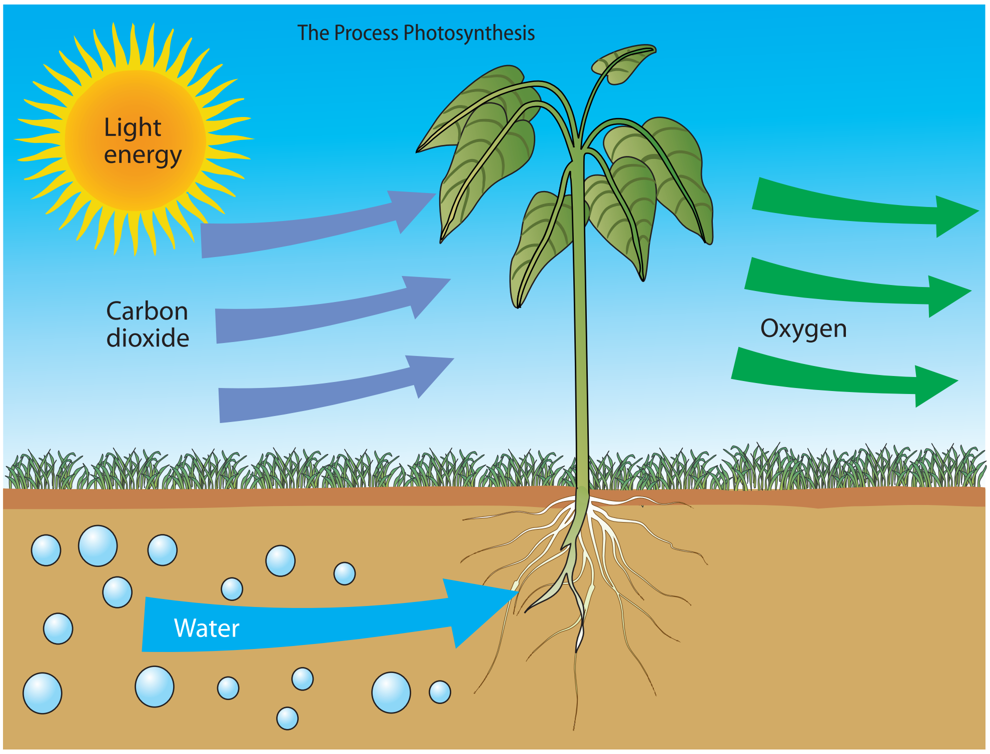
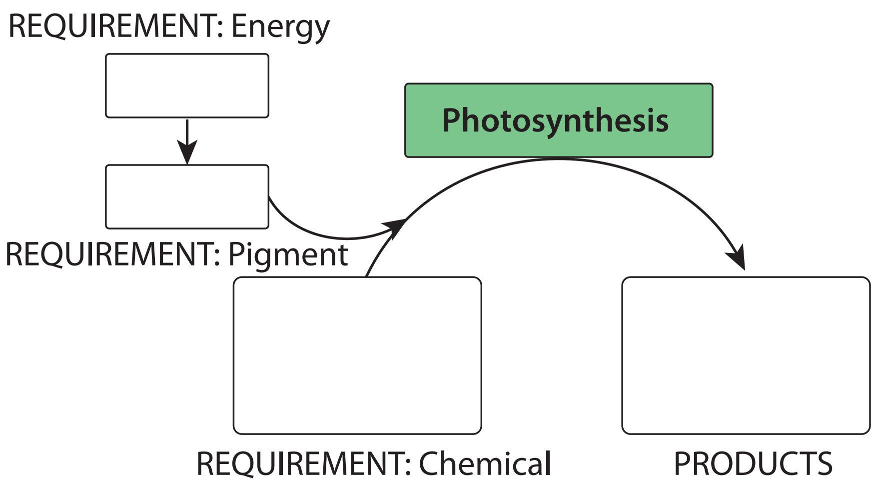


Figure 1.3 Plants use radiant energy from the Sun in a series of chemical reactions to change carbon dioxide from the air and water from the soil into glucose. The process releases oxygen.

ACTIVITY: Requirements and products of photosynthesis

Instructions

1. Copy the diagram below in your exercise books and summarise what you have learnt about photosynthesis.
2. Fill in the requirements of photosynthesis in the block on the left and fill in what type of energy is needed and the name of the pigment that absorbs the energy.
3. Fill in the products of photosynthesis in the block on the right.



The process of photosynthesis can be presented in the form of an equation:

carbon dioxide + water $\xrightarrow{\text{chlorophyll and sunlight}}$ glucose + oxygen

What happens to the glucose that plants produce during photosynthesis?

Glucose storage and use

The glucose that a plant produces when it photosynthesises is the food for the plant. The plant can use this glucose directly, and release the energy during its own respiration or it can store the glucose or convert it into other chemical compounds.

Glucose is soluble in water. As we learnt in Matter and Materials in Grade 6, this means that glucose can dissolve in water. This is useful to the plant as it means it can transport the glucose in water to where it is needed elsewhere in the plant. However, in order to store large amounts of glucose, plants need to convert it into compounds which are insoluble in water. Therefore the plant converts glucose into starch, which is insoluble in water. Why do you think the plant might need to store some glucose?

In addition to starch, plants also convert glucose into cellulose. Cellulose is used to support and strengthen plants. Animals do not have cellulose for support.

Instead animals have something else to provide support and protect the body.

Do you remember what this is?

Glucose is also converted into other chemical compounds that enable processes in the plant such as reproduction and growth.

We have now learnt about how plants produce glucose and store it as starch, but how do we know for sure? As young scientists we also need to question whether this explanation of photosynthesis is accurate. Is there an investigation we can do to test for the presence of these compounds? Let's find out!

We have learnt that plants produces glucose during photosynthesis and store this in the form of starch. Therefore, to see if a plant photosynthesises, we can test to see if the plant produced starch.

Study the following properties of starch and glucose with your class. Think of possible tests that can be done to determine whether a plant has produced either starch or glucose. Record some of your discussion points.

Glucose tastes sweet but starch does not taste sweet at all.

Glucose will dissolve in water, while starch will not dissolve in water.

Take note

The Visit boxes in the margins contain links to interesting websites and videos. Simply type the link exactly as it is into the address bar in your browser.

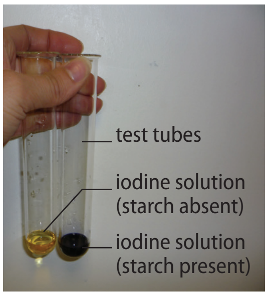


Figure 1.4 The left tube contains only diluted iodine solution and the right tube contains diluted iodine solution with starch.

Iodine changes from brownish-orange to dark blue-black when it comes into contact with starch. Have a look at the photo alongside that illustrates this.

Now that we know that plants produce glucose and change this into starch, we can find out if all leaves produce the same amount of starch through photosynthesis.

Investigation Which leaves photosynthesise?

There are two parts to this investigation. First, we want to find out which leaves are able to photosynthesise. We will place some pot plants in the light for a day, and some other pot plants in a dark cupboard for a day, and then perform the investigation on the leaves of plants from both groups. In the second part of the investigation, we will use what we have learnt to investigate which parts of variegated leaves photosynthesise.

Part 1: Leaves in light and dark

Aim

What do you wish to establish by conducting this investigation?

Hypothesis

What do you think or predict will happen when you conduct this investigation?

Materials and apparatus

- gloves
- a range of pot plants that can be easily moved around
- 100 ml beaker or glass jar in a saucepan with water
- bunsen burner, spirit lamp or a stove
- tweezers
- ethyl alcohol (or methylated spirits)
- glass petri dishes, white saucer or white tile
- stopwatch or timer
- glass pipette or dropper
- iodine solution

Method

1. Work in groups of three or four.
2. Place half of the plants in the dark for at least 24 – 48 hours and the others in a well-lit area of the class that is exposed to lots of natural sunlight.
3. After 24 hours, pour 50 ml of the ethyl alcohol into the beaker and place it in the saucepan with water. Heat the saucepan over the bunsen burner or the stove. The water in the saucepan will distribute the heat evenly to warm the ethyl alcohol evenly.
4. Remove one healthy-looking leaf from the pot plants that were in the well-lit area exposed to direct sunlight.

5. Using the tweezers, dip a leaf into the boiling water for 1 – 2 minutes. This helps to remove the waxy cuticle that covers the leaf and breaks down the cell walls.
6. After this, place the leaf into the beaker with the ethyl alcohol.
7. Leave the leaf in the alcohol until all the chlorophyll has been removed from the leaf and the alcohol turns green.
8. Place the leaf into warm water to soften it.
9. Remove the leaf from the warm water and place it on a white saucer or tile or a petri dish on top of a white surface.
10. Use the pipette or dropper to drop two or three drops of iodine solution carefully on the leaf in the petri dish and record your observations.
11. Repeat this process for two more leaves that were in the well-lit area.
12. Remove the plants that were in the dark for at least 24 hours. Use the test above to determine whether there is starch present in the leaves from the plants that were kept in the dark.
13. Record your observations.

Results and observations

Keep a record of your observations. Draw a table to record and compare your results.

Conclusion

What did you learn from doing this investigation?

Questions

1. Why were some plants placed in a well-lit area with direct sunlight and others in the dark?
2. Explain what the results of the iodine test indicate.

Part 2: Which parts of variegated leaves photosynthesise?

Have a look at the following photos of different plants. What do you notice about the leaves?

Figure 1.5 Ivy leaves

Figure 1.6 Geranium leaves

We call these leaves variegated as they have green and white sections. We want to find out which parts of these leaves photosynthesise in this part of the Investigation.

Instructions

1. You need to design this investigation yourself.
2. First decide what question you are trying to answer and the aim of your investigation.
3. Make a hypothesis for your investigation.
4. You then need to think back to Part 1 and design the method for your investigation.
5. After conducting the investigation, you need to write up an experimental report on your findings.
6. In your report, you must have the following headings:
   a) Aim
   b) Hypothesis
   c) Materials and apparatus
   d) Method
   e) Results
   f) Discussion
   g) Conclusion
7. In your results section you need to record your observations in a scientific way. You can do this using a table, diagrams, or a combination of both. Think carefully about what information you need to record in order to come to conclusions at the end of your experiment.
8. In your discussion, you need to explain your results and what they mean. You also need to evaluate your investigation and explain if there were any unusual results, and suggest ways that you could have improved your investigation for future researchers who might want to repeat what you have done.
9. Present your report on a clean sheet of paper.

Leaves are not the only parts of plants that store starch. Starch is also stored in the stems, roots and fruit. Have you ever wondered why fruit becomes sweeter as it ripens? Think of an unripe green banana and a ripe yellow banana. Which one is sweeter? Let's find out why.

Investigation: Why do bananas become sweeter as they ripen?

In this investigation we will taste the bananas to determine if they have more glucose or more starch. We will also conduct a starch test on the ripe and unripe bananas to see which contain more starch.

Figure 1.7 Ripe yellow bananas and unripe green bananas.

Aim

What do you wish to establish by conducting this investigation?

Hypothesis

What do you think or predict will happen when you conduct this investigation?

Materials and apparatus

- ripe and unripe bananas cut into discs
- petri dish or saucer
- iodine solution
- dropper

Method

1. Work in groups of three or four. Take a piece of the ripe banana and a piece of the unripe banana and compare the tastes and textures of each. Record your observations in a table. Which banana do you think contains the most starch and the least glucose (a sugar), based on the taste test?
2. Use the iodine starch test to identify which banana, the ripe or the unripe one, contains the most starch. Record your observations in the table.
3. Compare this test to the results from your taste and texture test to identify which banana contained the most starch.

Observations

Draw a table to record your observations from the taste and iodine test for starch.

Questions

1. Compare your observations of ripe and unripe bananas with those of the other learners in the class. Did you all make the same observations?
2. What do you conclude from these results? Which method of testing is better to use and why do you say so?
3. Explain what you think happens to the starch as the bananas ripen.

Now that we have looked at how green plants produce their own food, let's find out how all living things release the energy stored in food in order to perform the life processes.

1.2 Respiration

We have now seen how plants produce food during photosynthesis. The energy from this food needs to be used by plants and by all the animals who eat those plants. In fact, all organisms need to break down food in order to release its chemical potential energy for life processes. So how does this happen? Let's find out.

Keywords

- limewater
- respiration

Energy from food

Our bodies need energy to move and do work. Where do we get our energy from? The energy is obtained from the food that we and all other organisms eat.

If you think back to the work you did on fuel and energy in previous grades in Energy and Change, you will remember that fuels, such as wood, coal, and oil, contain chemical potential energy. When this fuel is burned in the presence of oxygen, the chemical potential energy is transferred into light and heat energy. In the same way, the glucose from the food that you eat is combined with oxygen in a series of chemical reactions to release the energy. The glucose is broken down and the energy is released. This energy is then used to drive all the other processes in your body. This process is called respiration. We can define respiration in all living organisms as the process by which energy is released from glucose in a series of chemical reactions.

Respiration takes place in all organisms, even plants. However, plants do not need to eat any food as they make their own food during photosynthesis.

Take note

We will learn more about chemical reactions next term in Matter and Materials. You will also learn more about respiration in later grades.

Products of respiration

Do you remember how we represented photosynthesis as an equation to show what goes in and what comes out? We can represent respiration as an equation in the same way as we did for photosynthesis.

We know what is required for respiration to take place in all organisms. List the two ingredients for respiration.

However, respiration does not only produce energy. It also produces water and carbon dioxide as by-products. We can write an equation for respiration as follows:

glucose + oxygen → carbon dioxide + water + energy

Take note

A by-product is also sometimes referred to as a waste product.

During photosynthesis in plants, oxygen is produced as a by-product. We call it a by-product as it is not the main product that is wanted from the process. In photosynthesis, the main product that is required from the process is glucose.

What are the by-products of respiration?

The carbon dioxide that is produced in the body of an organism during respiration needs to be removed. In humans, we do this by breathing out carbon dioxide-rich air. We will learn more about the whole respiratory system next year in Grade 9, and how breathing, our blood circulation system, and respiration all work together as one system within our bodies.

We can test for the products of respiration using our own breath. So how do we test that our breath contains carbon dioxide? It is a colourless gas, so we cannot see it directly.

There is a very well-known test for detecting carbon dioxide using clear limewater. To test if a gas contains carbon dioxide, simply bubble the gas through limewater. If the clear limewater turns milky, then the gas contains carbon dioxide. Next term in Matter and Materials, we will look at this again and find out about the chemical reaction taking place in the test. For now, let's use this test to show that our breath contains carbon dioxide.

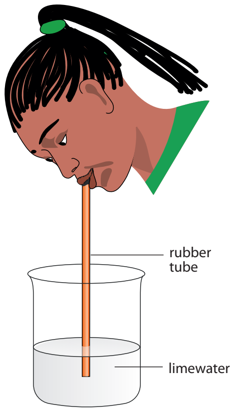
ACTIVITY: Does our breath contain carbon dioxide?

Materials

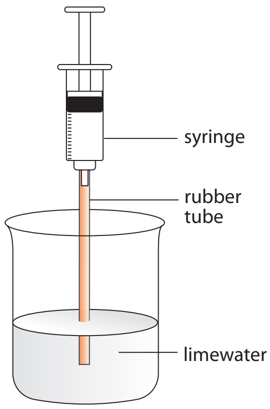
- small beakers (or test tubes)
- rubber tubes or drinking straws
- limewater
- 20 ml syringe (or larger if available)

Instructions

1. Work in groups of three.
2. Mark one beaker AIR and the other BREATH.
3. Pour clear limewater into each beaker until they are half full.
4. Blow bubbles through the rubber tube into the beaker marked BREATH, as shown in the diagram. Do this for at least 1 minute. Notice what happens to the clear limewater.



5. Attach a rubber tube to the front of a syringe. Draw air into the syringe from the atmosphere.
6. Place this rubber tube into the beaker marked AIR and push the air inside the syringe out slowly and carefully into the limewater as shown in the diagram. Notice what happens to the clear limewater.



Take note

Do not confuse breathing with respiration! Breathing is the act of inhaling and exhaling air into and out of the lungs. Respiration is the metabolic process that uses oxygen to release energy, and releases carbon dioxide as a by-product.

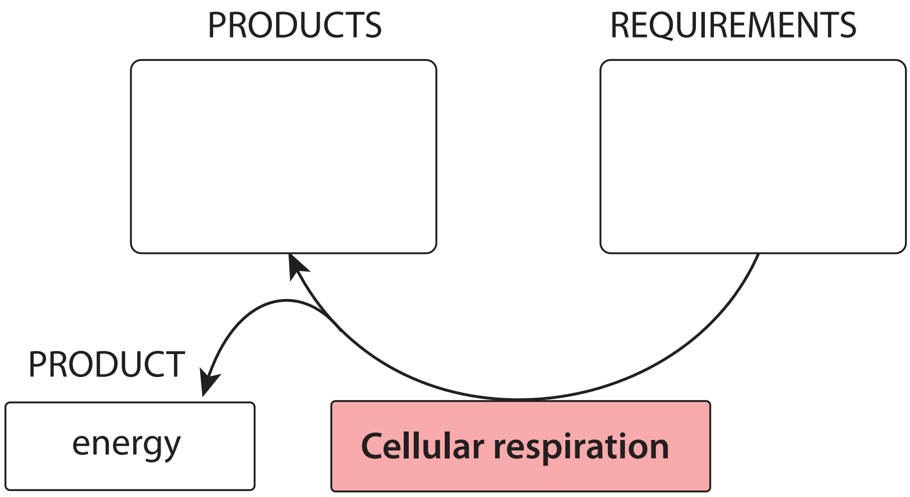
Questions

1. Describe what you observed when you blew air from your lungs through the limewater. What does this mean?
2. Describe what you observed when you used the syringe to bubble air from the atmosphere through clear limewater.
3. A very small percentage of atmospheric air is carbon dioxide gas (0.03%). Why do you think you observed the result you did when you pushed air from the atmosphere through the limewater?
4. Think about respiration.
   a) What are the requirements for respiration?
   b) What are the products of respiration?

ACTIVITY: Requirements and products of respiration

Instructions

1. Copy the diagram below in your exercise books and summarise what you have learnt about respiration.
2. Fill in the requirements of respiration in the block on the right.
3. Fill in the products of respiration in the block on the left.
4.



Summary

In the summary, we first have the 'Key concepts' for this unit. This is a written summary where the information from this unit is summarised using words. We can also create a concept map of this unit. This is a map of how all the concepts (ideas and topics) in this unit fit together and are linked to each other. A concept map gives us a more visual way of summarising information.

Different people like to learn and study in different ways; some people like to make written summaries, while others find drawing their own concept maps when studying and learning very useful, especially in higher grades and after school.

Others like to make things even more visual, using pictures and diagrams to form their summaries. Figuring out the study method that works best for you, and developing these skills is.

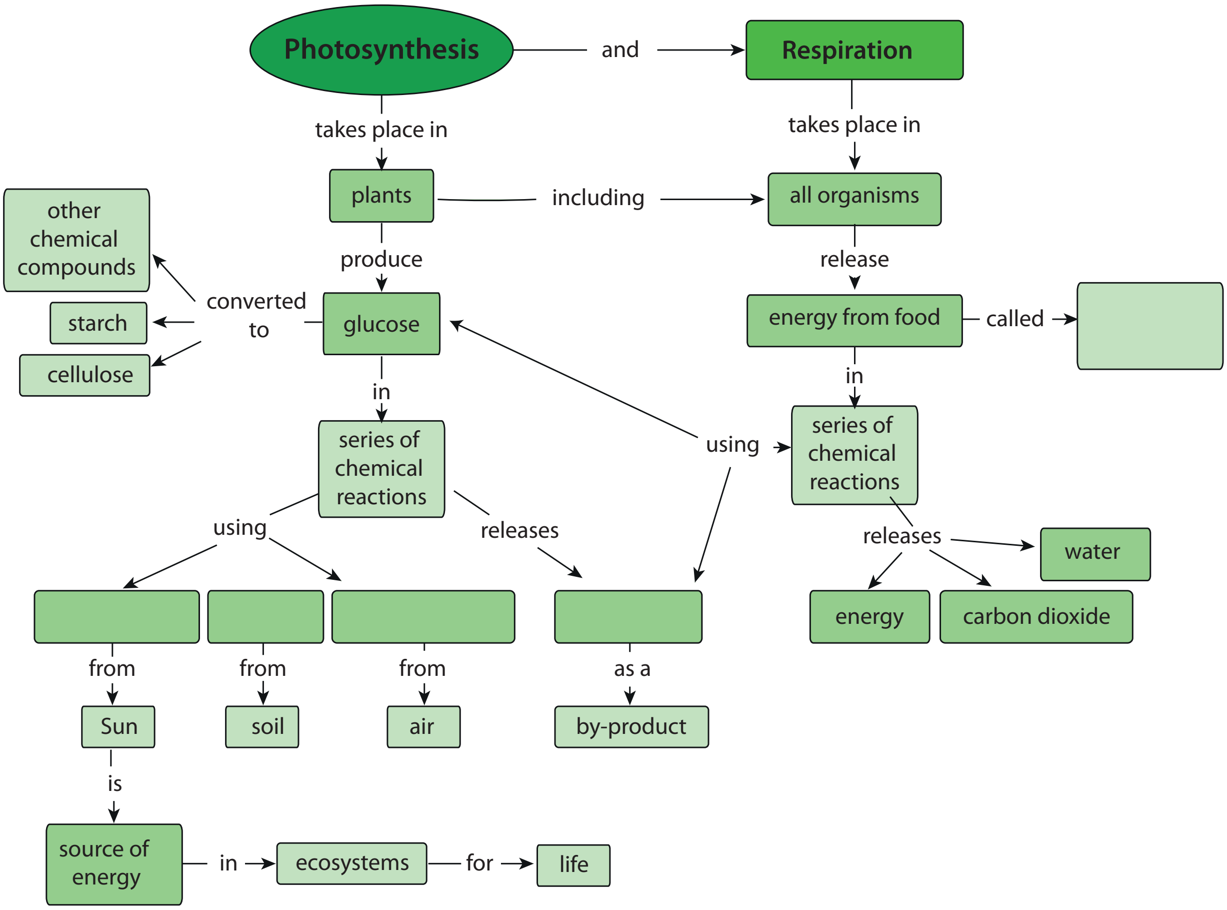
Key concepts

- Energy is needed to sustain life on earth.
- The need for energy drives the interactions and interdependence in an ecosystem.
- The Sun provides energy to the Earth in the form of radiant (light) energy and heat energy.
- Photosynthesis is the process whereby green plants use carbon dioxide from the air, water from the soil, and radiant energy from the Sun in a series of chemical reactions to produce glucose (food) and oxygen.
- Plants are able to photosynthesise because they contain chlorophyll, a green pigment that can capture light energy from the Sun.
- Plants change the glucose that they produce into starch that can be stored more easily.
- Plants also produce cellulose fibres that give plants strength and support and are important to our digestive systems as roughage.
- The food that a plant produces is used by animals when they eat the plant and by other animals that eat them.
- This food contains chemical potential energy that needs to be released.
- Respiration is the process in all living organisms by which energy is released from glucose in a series of chemical reactions.
- Respiration uses oxygen, while carbon dioxide and water are given off as by-products.
- Equations for photosynthesis and respiration

Concept map

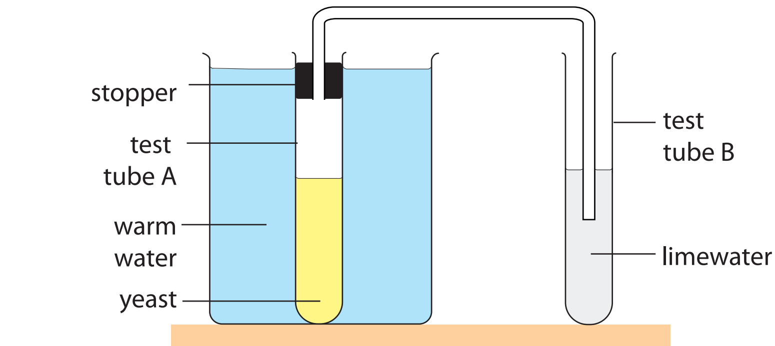
Have a look at the concept map for 'Photosynthesis and Respiration'. Do you see that there are some empty spaces? You need to complete the concept map by filling these in. To do this you need to read the map from top to bottom and have a look at the concepts which come before. For example, read the concept map as follows: 'Respiration takes place in all organisms.

All organisms release energy from food, called … ' What type of energy does food contain? Remember, food is the fuel for our bodies. You also need to fill in the three things that plants use to photosynthesise. You need to look at what concepts link from these in order to know where to put each one. Finally, what does photosynthesis release as a by-product? You also need to fill this in.

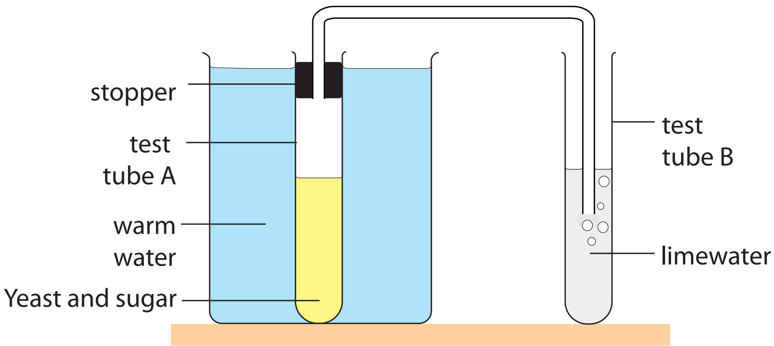


Revision

1. A Grade 4 learner wanted to grow some beans and carefully planted them in a yoghurt tub and watered them. He was scared that his little brother would knock his tub over, so he hid the tub in his cupboard.
   a) Explain what he would have noticed a few days after planting the beans. [2]
   b) Predict what would have happened after another few days with the beans hidden in his cupboard. [2]
   c) Explain why you predicted this outcome for his beans. [2]
   d) What should he have done to make his bean plants grow tall and strong? [2]
2. What are the requirements for photosynthesis to occur? [3]
3. A farmer is growing some tomatoes. He heard from his daughter that plants produce glucose during photosynthesis, so he decided to see for himself. However, when he tested the leaves, he did not find much glucose, but he did find a lot of starch present.
   a) Why did the farmer see this result? [2]
   b) Describe the test that the farmer conducted to show that the leaf contained starch. [5]
4. Do plants undergo photosynthesis and respiration all day and all night? Give reasons for your answer. [4]
5. A group of Grade 7 learners wanted to show that carbon dioxide is released when yeast is mixed with sugar in a test tube and the content is dipped a warm water bath. They set up the following two experiments. The gas that they collected from each test tube was run through limewater.



Setup 1



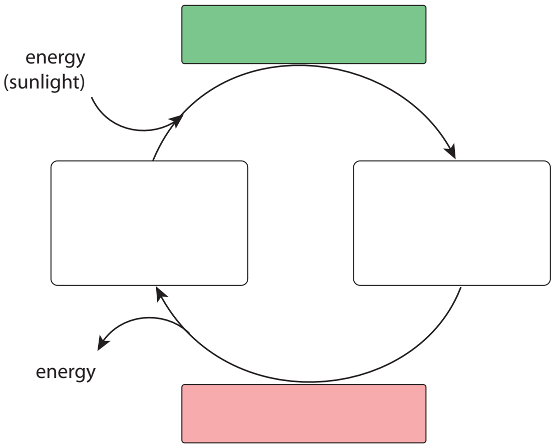
Setup 2

   a) Why did they run the rubber tube from Test Tube A to Test Tube B? [3]
   b) Explain why they pushed a stopper into the top of Test Tube A. [1]

c) One of the test tubes shown below is from setup 2 after the experiment. Which test tube is this? Give a reason for your answer. [2]

d) Why do you think the yeast solution in Setup 1 did not produce carbon dioxide? [2]

6. Study the following diagram and fill in the missing information. [6]



7. Draw a table in your exercise book to show the differences between the processes of photosynthesis and respiration. Your table should highlight the differences in requirements, the differences in the products, which organisms the processes takes place in, and when. [8]

Total [44 marks]

2 Interactions and interdependence within the environment

Key questions

- What is ecology?
- We talk about the population of people in South Africa, but do other animals live in populations?
- What makes up an ecosystem? Are we part of an ecosystem?
- How are organisms linked by their feeding relationship to make food webs?
- Why do we need many more producers and fewer carnivores in a food web?
- How does an ecosystem remain balanced so that it can support all of the organisms that live there?
- We know that natural disasters can have a huge impact on ecosystems, but what are we as humans doing that upsets the fine balance in ecosystems?
- What does it mean if an organism is adapted to its environment?
- Why have some organisms become extinct?
- During the course of Earth's history, many organisms have become extinct, so what is different and worrying about the decreasing numbers of rhinos and elephants?
- How can we make a difference to conserve our own environments?

2.1 What is ecology?

Every living organism on earth depends on and interacts with other living and non-living things to stay alive. Organisms depend on other organisms for food for example, and also depend on their environment for protection and a place to stay. The particular branch of Science that studies how organisms interact with other organisms and their environment is called ecology. Someone who studies these relationships and interactions is called an ecologist.

Keywords

- biosphere
- community
- ecologist
- ecology
- ecosystem
- interact
- population
- population
- ecology
- species

Ecological interactions

The ecological interactions that take place within a specific area are generally classified into four levels: populations, communities, ecosystems, and the biosphere.

Individuals live together in populations. Different populations together make up a community. Communities together with the non-living things in their surroundings make up an ecosystem. All the ecosystems on Earth make up the biosphere.

Look at the following illustration which shows the levels of organisation.

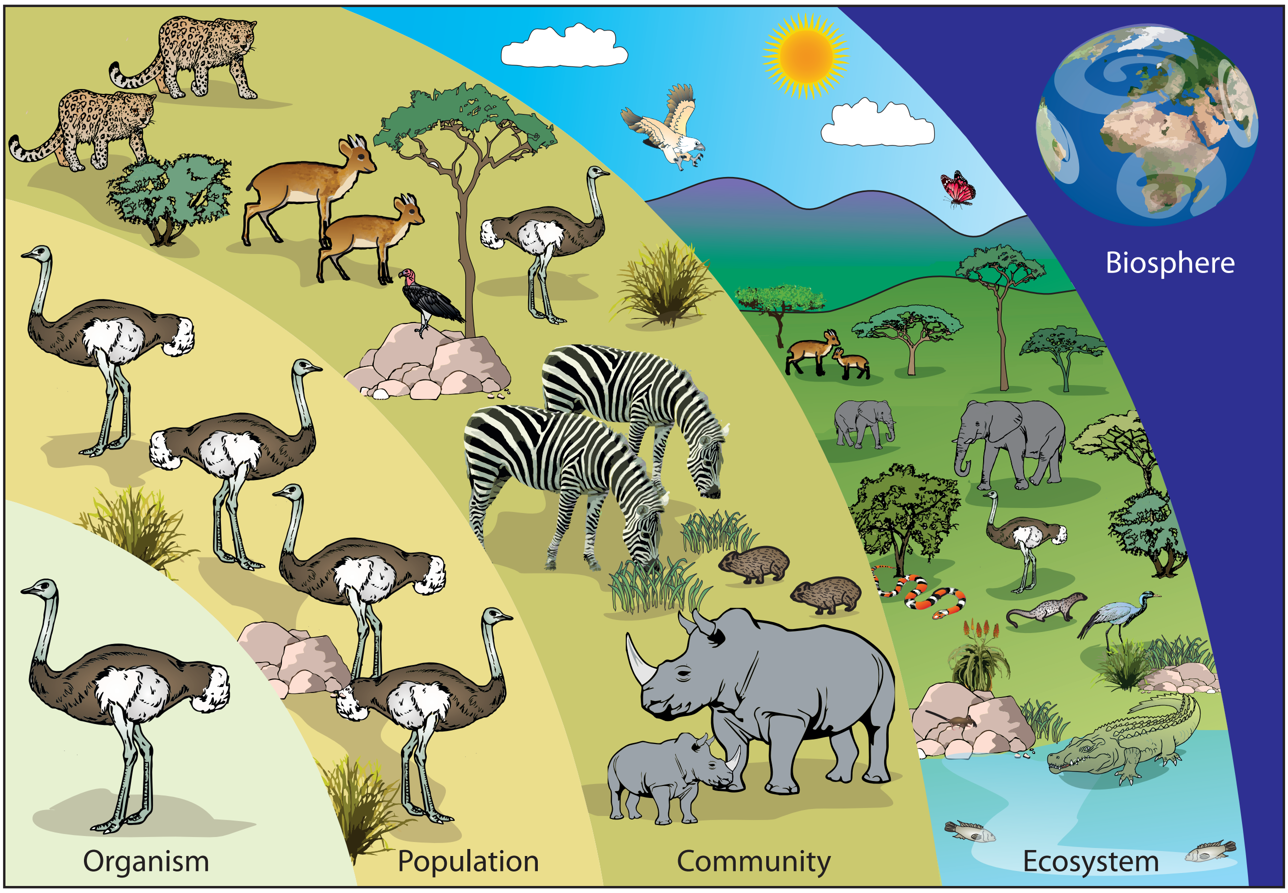


Figure 2.1 Level of organisations

Take note

If you want to check the definition of a **New word**, check the Glossary at the end of this strand.

You may have heard of terms such as the biosphere and ecosystems in previous grades. What about populations and communities? You may have also heard about the population of people in South Africa, or when someone talks about your local community at home. What do we mean when we use these terms in ecology? Let's take a closer look.

Population

In the previous illustration, we can see that the individual impalas make up a population in the game reserve. On a large scale, we can also say that the 50 million people in South Africa make up our country's population.

Community

In ecology, a community refers to all the populations of organisms that interact in a certain area. Community ecology is the study of how they interact. For example, what feeding relationships occur in the area? What types of grasses do specific herbivores eat and what eats the herbivores? Turn back to the illustration of the wildlife in the game reserve. Which animals make up the community?

ACTIVITY: What is a population?

Instructions

1. Look at the following examples of populations.
2. Answer the questions which follow.

Figure 2.1 A population of hippos in the St Lucia estuary (river mouth) in KwaZulu-Natal.

Figure 2.2 A population of zebra in Kruger National Park.

Figure 2.3 A population of seals on Seal Island in False Bay.

Figure 2.4 A population of penguins at Boulders Beach.

Questions

1. What do you notice about all the animals that make up a population?
2. In each of the photos, the populations of animals are found in a specific area. Do you think the zebra in Kruger National Park and the zebra in Hluhluwe-Umfolozi game reserve in Zululand are from the same population? Why do you say so?
3. How big is a population?
4. Do you think the seals that lived on Seal Island 100 years ago are part of the same population as the seals that live there now in the photo? Why do you say so?
5. What do you think would happen to the population of hippos in the estuary at St Lucia if the river dried up? Explain your answer.
6. A group of scientists is studying a population of zebra in the Kruger National Park. They notice that over the last 4 years, the population has grown quite rapidly. Why do you think this might be the case? What are some possible reasons for this? Discuss this with your class.

Ecosystems

Turn back to the illustration of the wildlife in a game reserve. The different populations interact with each other to form a community. When we look at how the communities interact with the non-living things in their environment, we are looking at ecology at the ecosystem level.

Think of the different populations of organisms making up a community in

Figure 2.5 An ecosystem in the game reserve consist of the living and non-living things interacting with each other.

Kruger National Park, such as the zebra, elephant, lions, springbok, different trees, and grasses. Now look at the photo of some of these populations at a watering hole. In this photo we are studying how the living things interact with the non-living things. For example, the zebra and springbok are drinking water, whilst the elephant is splashing mud over itself to cool down. This is an ecosystem.

Biosphere

All the ecosystems on Earth combined make up the biosphere. At the biosphere level, we can study how the living and non-living things interact on a much larger scale. This includes climate changes, how the Earth has changed over history, and even how the movement of planet Earth affects different ecosystems, wind patterns as well as rock and soil formation.

Figure 2.6 All the ecosystems on Earth make up the biosphere.

ACTIVITY: Check your understanding

Write your own definitions and explanations for the following terms.

1. Ecology:
2. Interaction:
3. Organism:
4. Population:
5. Community:
6. Ecosystem:
7. Biosphere:

Let's now take a closer look at ecosystems.

2.2 Ecosystems

Keywords

- abiotic
- biotic
- habitat
- migrate
- predator

The living organisms on Earth live and interact in different ecosystems around the planet. Together all these ecosystems make up the Earth's biosphere. An ecosystem consists of the abiotic (non-living) environment and the biotic (living) organisms.

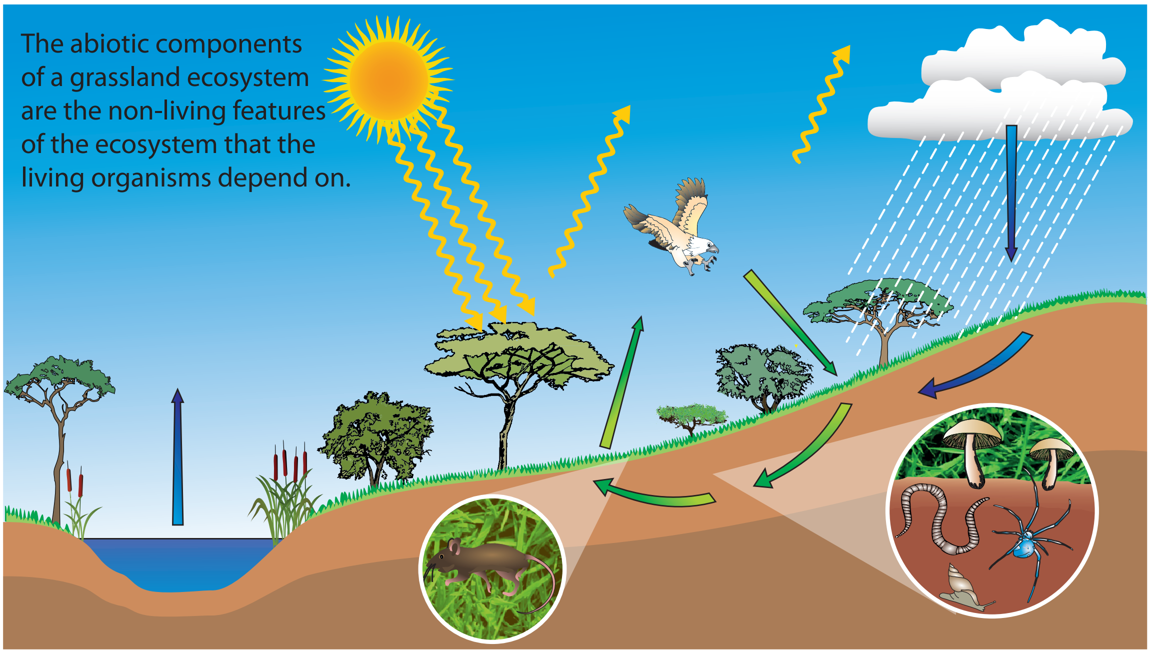
Biotic and abiotic components in an ecosystem

We have looked a lot at the living organisms in different ecosystems in the last section, but what are some of the abiotic things in ecosystems? And how do the biotic things interact with the abiotic environment in a system?

ACTIVITY: Abiotic components in a grassland ecosystem

Instructions

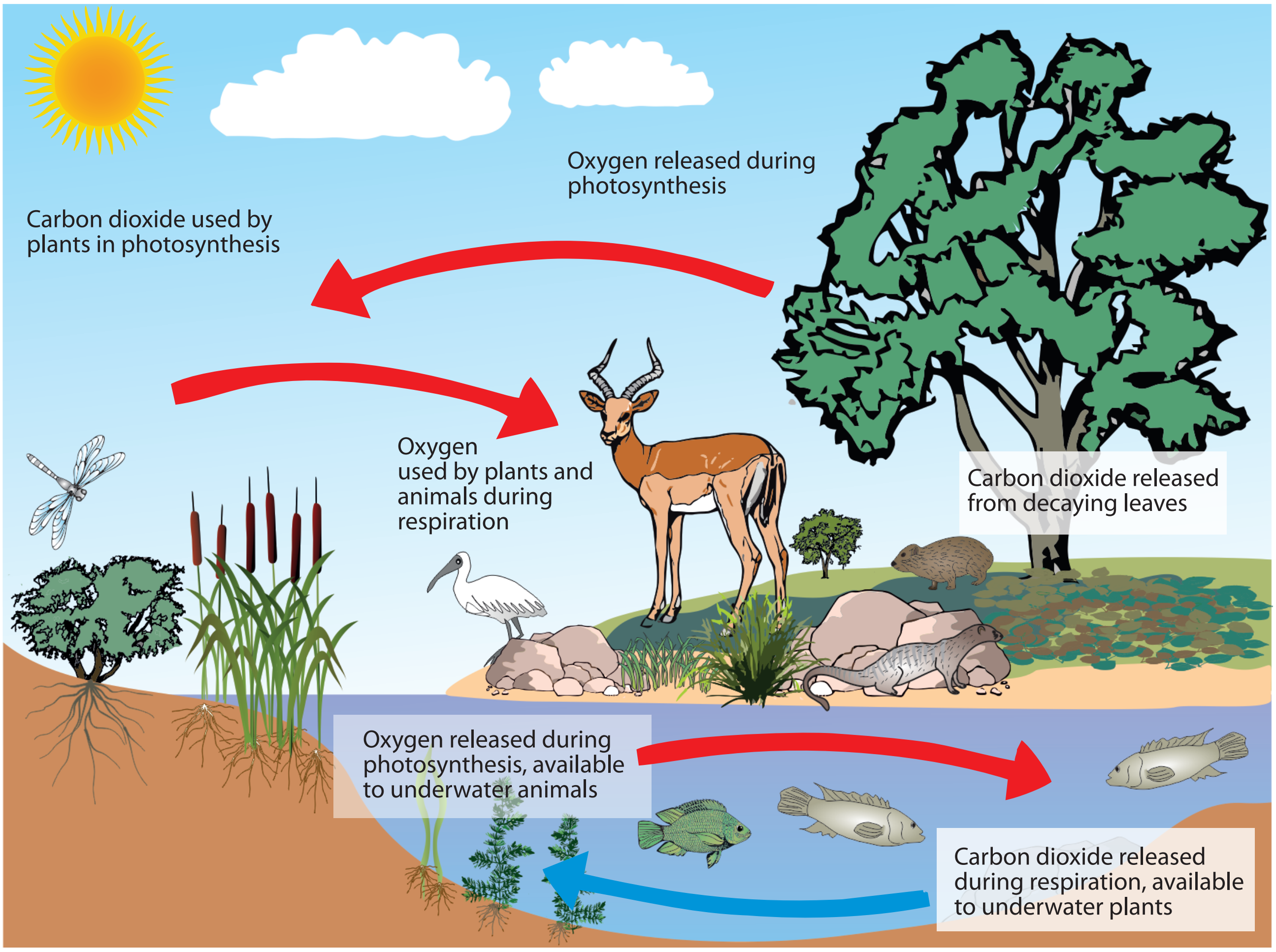
1. Look at the following image of a grassland ecosystem.
2. Answer the questions that follow.



Questions

1. List some of the abiotic things in the grassland ecosystem shown in the image.
2. For each of the animals, discuss how you think the organisms below are interacting with the abiotic environment.
   a) The eagle
   b) The trees and grass
   c) The mouse
   d) The worm and the insect
3. In the picture, the blue arrows show the movement of water through the ecosystem. What do we call this movement of water?
4. Temperature is an abiotic factor in an ecosystem. What can affect the temperature in the grassland ecosystem?
5. Another abiotic factor which affects ecosystems is the slope of the land. For example, is it flat or are there hills or mountains? How would you describe the land in the grassland ecosystem? How do you think this contour affects the ecosystem?

Apart from recycling water, biotic and abiotic factors also interact to recycle carbon dioxide and oxygen in ecosystems. Photosynthesis in plants uses carbon dioxide to produce glucose. The plants and animals then break down the sugars and release carbon dioxide again during respiration. Photosynthesis releases oxygen, while plants and animals take it in for



Take note

You can find out lots more online by visiting the links provided in the Visit boxes. Be curious and discover the possibilities!

respiration. Look at the following illustration above which shows how the gases are cycled through a pond ecosystem.

Now that we know a bit more about the different biotic and abiotic factors in an ecosystem and how they interact, let's study an ecosystem!

ACTIVITY: Studying an ecosystem

Materials:

- 60 m long string
- pegs or stakes
- measuring tape (10 m long)
- old fabric for flags on pegs
- thermometer
- rulers
- trowel
- sieve
- insect nets
- large plastic Ziploc bags
- marking pens
- forceps
- gloves
- hand lens
- clipboard, paper and pens or pencils
- camera (if possible)

Instructions

1. Work in groups of five. Your teachers will help you to select a site to study.

2. Stake out a square measuring 10 m × 10 m. Use the 10 m measuring tape and knock the stakes or pegs into the ground to mark the corners of the square. Tie a flag to the stake to make it more visible. (You will use this square to study different things in the next few weeks, so make sure that you choose an appropriate site that does not overlap with another group's site.)

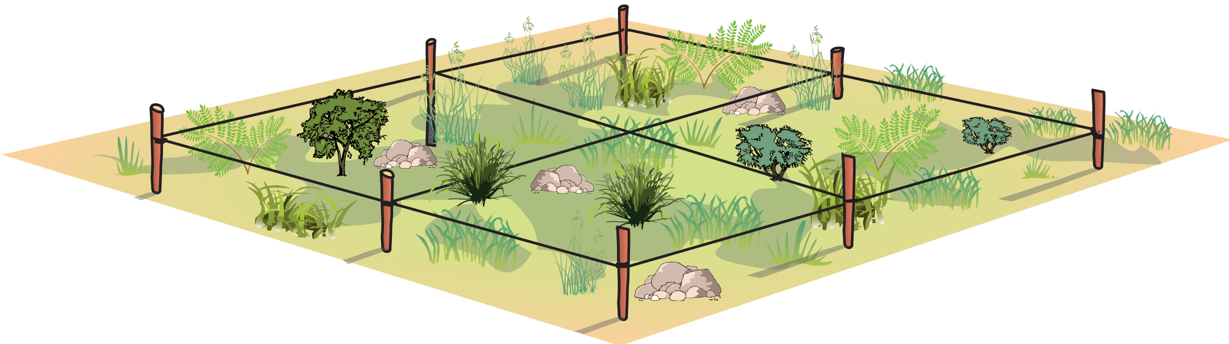


Figure 2.7 An example of a square with four quadrants.

3. Try to identify as many plants as possible. Record your findings about the plants. You can even draw some illustrations.
4. Use the net to capture a few small invertebrates. Try to identify them (ask for help if you need it), then release them unharmed. Record your observations. You can use illustrations.
5. Look for evidence of bigger animals. Are there any droppings, tracks, or birds in the trees? Record what you find.
6. Measure the temperature.
   a) Measure the air temperature in your square.
   b) Measure the temperature of the soil about 5 cm below the surface.
7. Take a soil sample by putting one scoop of soil into a plastic bag. Determine whether it is sand, loam or clay soil. Compare your sample with those of other groups. The following illustrations give an idea of the different types of soil.

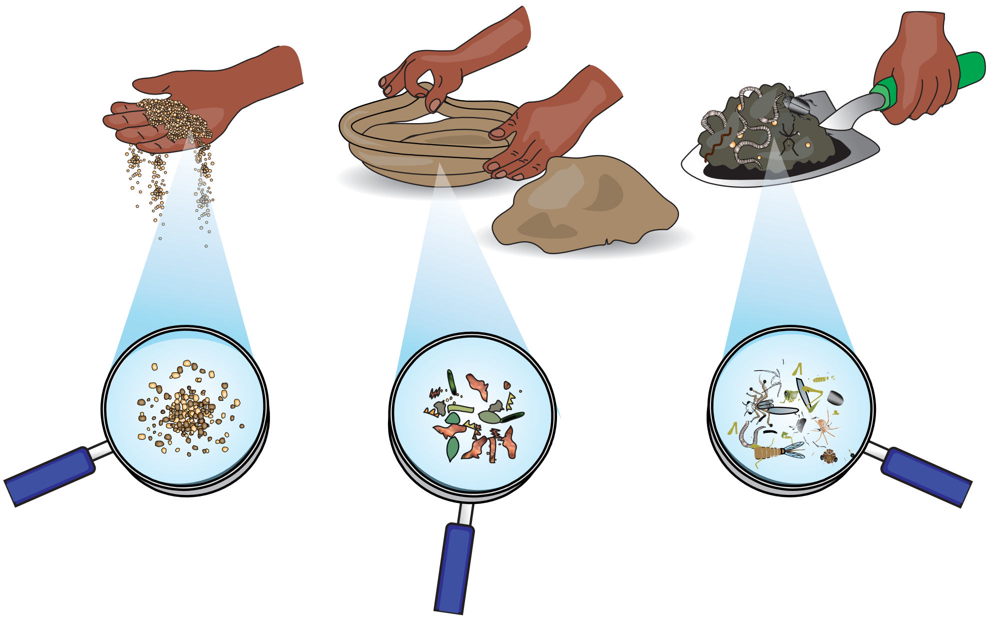


Figure 2.8 Different soil types

Use the hand lens to see if you can find any plant or animal remains in the soil.

8. Write about your observations and draw images. (Optional: Measure the rainfall and wind speed. Measure the rainfall over the next few weeks.)

Questions

1. Describe the different habitats in your ecosystem.
2. Explain how you think the abiotic factors of the ecosystem you studied affect the plants and animals in your ecosystem.
3. What relationships did you notice between the plants and animals in the area you studied?
4. In the area that you studied, was there any evidence of human interference? For example, rubbish or a pathway? How did this impact on the living organisms and also the abiotic factors in your square? What suggestions can you make to prevent this kind of interference?
5. Do you think that your presence while you made your observations had an influence on the animals or plants in the quadrant that you observed?

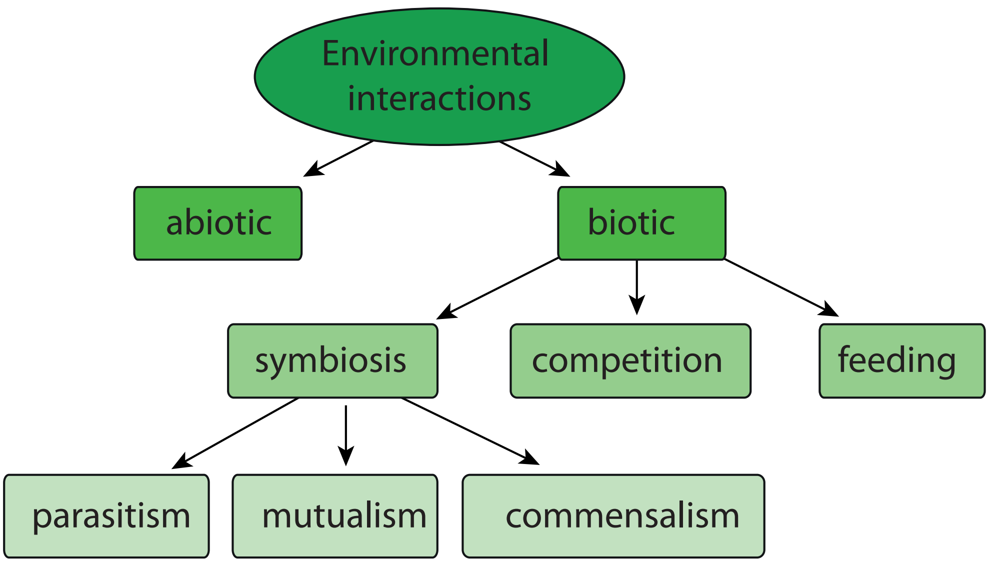
We studied relatively small ecosystems. How big can an ecosystem be? Does size in an ecosystem matter?

Ecosystem size

The size of a real ecosystem is not defined in terms of area, but rather by the interactions that occur inside it. It can be as small as a river bank or as large as the Kruger National Park.

Types of interactions

Within an ecosystem the species living in a particular area can interact in different ways with each other. We can classify the interactions between organisms as follows:



Competition

When two species in an ecosystem need to share a valuable and often limited resource such as food or water, they are in competition with each other. The two different species compete with each other for the same resources, especially food.

Feeding

Different species in an ecosystem are related and interact when one species can use the other species as a food source. For example, in predator-prey relationships, the one species (predator) will hunt another species (prey).

Figure 2.9 Hyenas and vultures are both scavengers and compete for the same food.

Figure 2.10 Lions and zebras have a predator-prey relationship.

2.3 Feeding relationships

In the last section we saw how organisms from different species interact within an ecosystem. Let's now take a closer look at how organisms interact through their feeding relationships.

Take note

The term 'autotroph' comes from the Greek words autos meaning 'self' and "trophe' meaning 'nourishing'. So autotroph means 'self-feeding'.

Key words

- carnivore
- consumer
- decomposers
- herbivore
- insectivore
- omnivore

Feeding types

Living organisms need to feed to be able to perform the other life processes.

Some organisms can produce their own food, such as plants, while other organisms cannot do this and need to feed on other organisms to obtain their energy.

We can therefore identify different feeding types in an ecosystem, based on how the organism obtains (gets) its food. There are producers and consumers.

Producers

Producers are organisms that are able to produce their own organic food. They do not need to eat other organisms to do this. Producers are also called autotrophs. Which organisms have you come across that can make their own food?

Plants are producers because they make their own food during photosynthesis.

What do plants need in order to photosynthesise?

Consumers

Organisms which cannot produce their own food need to eat other organisms to get food. These organisms are called consumers. All animals are consumers as they cannot produce their own food. Consumers are also called heterotrophs.

There are many types of consumers and we can classify them into specific groups depending on the food that they consume. These are:

- herbivores
- carnivores
- omnivores
- decomposers

ACTIVITY: Different types of consumers

Instructions

1. The illustration on the next page shows a variety of different animals found in South Africa.
2. Study the illustration and then answer the questions that follow.

Questions

1. What is a herbivore? Write down a definition in your exercise books and then give four examples of animals from the images that are herbivores.
2. What is a carnivore? Write down a definition in your exercise books and then give four examples of animals from the images that are carnivores.
3. There are different types of carnivores. Some carnivores hunt other animals. They are called predators. The animals that they hunt are called prey. A lion is an example of a predator. Give three examples from the images of animals that are prey of the lion.
4. Other types of carnivores are called scavengers as they eat dead meat, for example a hyena. There are three other scavengers in the images. Identify them and write the names in your exercise books.
5. The following animals are also all carnivores. They all have a similar diet. Do you know what they all eat? Find out what these animals eat. Discuss this with your class.

Figure 2.11 A chameleon.

Figure 2.12 A bat.

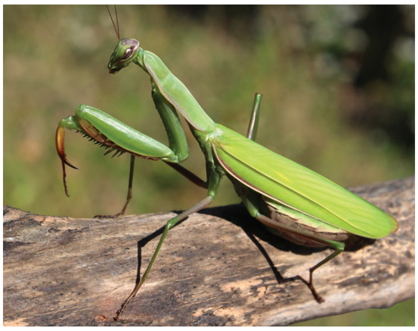


Figure 2.13 A praying mantis.

Figure 2.14 A swallow.

6. Write down what these animals all eat and what we call this type of carnivore.
7. What do we call animals that eat both plants and other animals? Give one example from the pictures.
8. What would you classify humans as?
9. The last group of animals that we can discuss from this image are the decomposers. Decomposers break down the remains of dead plants and animals. Give an example of a decomposer from the image.
10. Refer to the study of an ecosystem in or near your school that you are busy with.
    a) List the producers in your ecosystem. Explain how you know they are producers.

Keywords

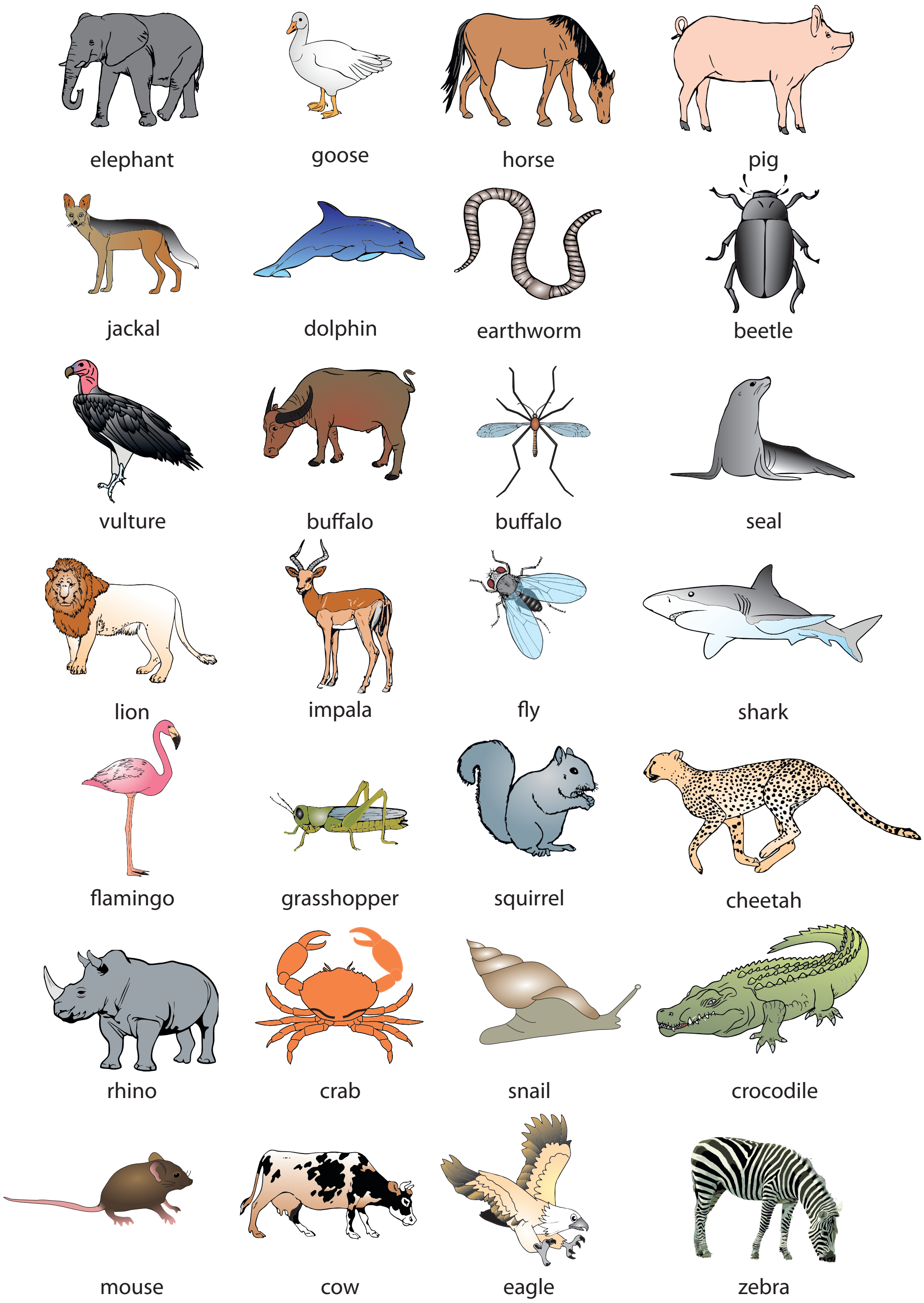
- producer

Did you know?

In 2011, deep-sea researchers discovered mussels living in symbiosis with bacteria that use hydrogen as a fuel source in chemosynthesis. These are the first organisms discovered to do so!

Take note

The term 'heterotroph' comes from the Greek words 'heteros' meaning 'different' and 'trophe' meaning 'nourishing'. So 'heterotroph' means 'different-feeding' or feeding on different things.



b) List the herbivores that you found in your ecosystem. Explain how you know they are herbivores.

c) Did you find evidence of or find examples of carnivores in your ecosystem? List them in your exercise books.

d) Study the soil again. Use the hand lens to see if there are any decomposers that you can see or see evidence of in your ecosystem. Describe any decomposers that you found.

In the last activity, we looked at different consumers. The examples that we studied were all different types of animals. But what about the other kingdoms, such as fungi?

You may remember learning about fungi in previous grades. Fungi are not plants. Fungi cannot photosynthesise as they do not have chlorophyll. So where do fungi get their food from?

ACTIVITY: Different decomposers

Instructions

1. Look at the following photographs of different fungi.
2. Answer the questions that follow.




Questions

1. What kingdom do the above organisms belong to?
2. What do you notice about where these mushrooms are growing? What are they mostly growing on? Is it dead or alive?
3. The mushrooms get their nutrients from what they are growing on. At the same time, they are breaking down this dead matter. What can we therefore call fungi?
4. When fungi, and other decomposers, break down dead material, they help to return nutrients to the soil. Write a few sentences where you explain why you think decomposers are important in an ecosystem and how they help an ecosystem to function.

We now know that the different organisms in an ecosystem are related by how they feed. There are producers and consumers. We have seen that organisms from one species eat other organisms from another species. How can we link these feeding relationships together to describe how the energy is transferred in an ecosystem from the producers to the consumers?

2.4 Energy flow: Food chains and food webs

The flow of energy from the sun to different organisms in an ecosystem is very important as it supports all the life process of living organisms. In this section we will look more closely at the way in which energy flows from the sun to different organisms in order to support and sustain life on Earth.

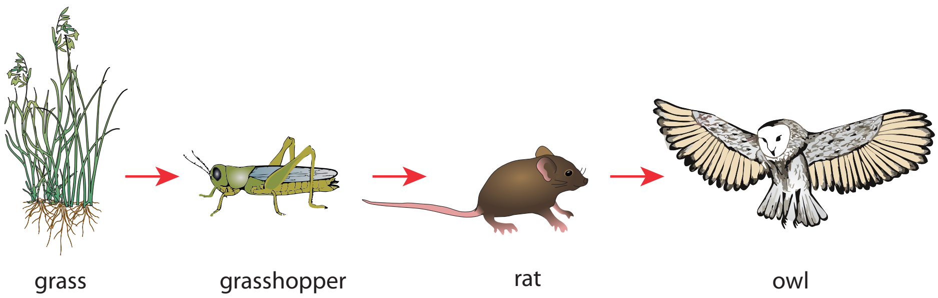
Energy transfer

Energy is vital for organisms to carry out their life processes. All energy in food webs comes from the sun. Plants trap sunlight energy during photosynthesis and convert it to chemical potential energy in food compounds, which are available to animals. Herbivores get energy directly from plants, but carnivores and omnivores eat animals for energy. This energy transfer is shown by food chains.

ACTIVITY: Energy transfer in an ecosystem

Instructions

1. Study the following diagram which describes the feeding relationships between different organisms in an ecosystem.
2. Answer the questions which follow.



Questions

1. What can we call this diagram?
2. Which organism is the producer?
3. Which organisms are the consumers?
4. Out of the consumers, identify the herbivore and the carnivores.
5. The rat also actually eats seeds and other plants. Therefore, what do we call the rat? Give a reason for your answer.
6. What do the arrows show us?
7. Do you think it makes a difference which way the arrows are pointing? Explain your answer.
8. Draw three more food chains. Use organisms from the ecosystem that you are studying at or near your school in at least two of the food chains you draw.
9. Where would you place decomposers in a food chain? Why do you say so?

Can you see how the above food chain describes how the energy is passed along from the producer to the consumers? But there are three different consumers in this food chain. How can we distinguish between the different consumers?

- Animals that eat plants are primary consumers. (Primary means *first*.)
- Animals that eat primary consumers are called secondary consumers.
- Animals that eat secondary consumers (mostly predators) are tertiary consumers.

Identify the different levels of consumers in the food chain in the activity.

Each of these levels in the food chain is called a trophic level. The organism uses up to 90% of its food energy itself for its life processes. Only about 10% of the energy goes into new body cells and is available to the next animal when it gets eaten. This loss of energy at each trophic level can be shown by an energy pyramid. But why do we show it in the shape of a pyramid? Let's find out.

Keywords

- energy pyramid
- food chain
- food web
- primary consumer
- secondary consumer
- tertiary consumer
- trophic level

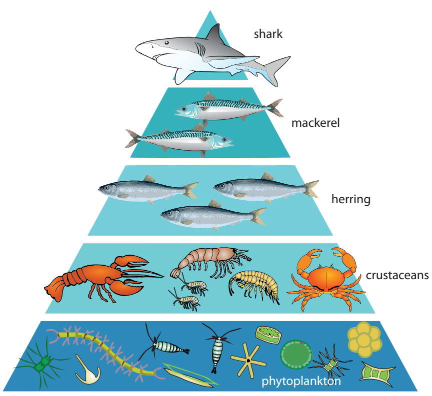
ACTIVITY: Studying energy pyramids

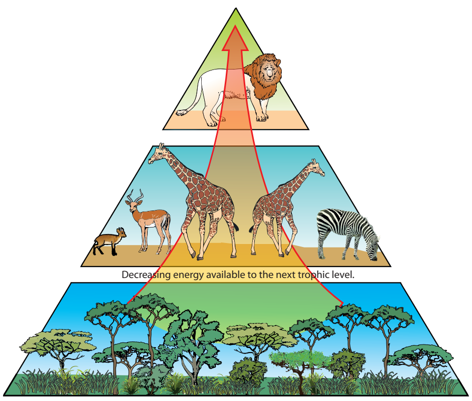
Materials

- cardboard
- scissors
- glue
- coloured pens and pencils

Instructions

1. Have a look at the following energy pyramid for a marine and a savanna ecosystem. Pay careful attention to the number of organisms in each level.
2. Answer the questions that follow.
3. At the end, you can make your own energy pyramid.



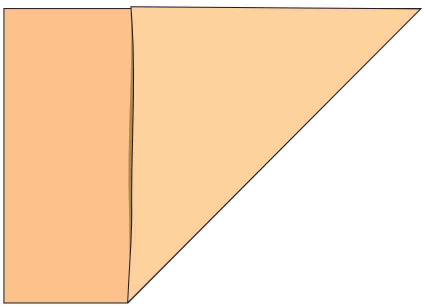


Questions

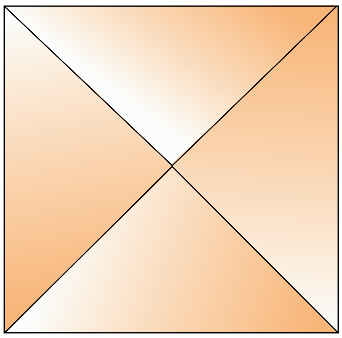
1. Which organisms are the producers in the marine ecosystem and in the savanna ecosystem?
2. Which organisms are the primary consumers in the marine ecosystem and in the savanna ecosystem?
3. 90% of the energy is lost and only 10% is made available to the next trophic level. Why do you think this happens? Discuss this in your class and write your answer down.
4. Give possible reasons why you think there need to be so many producers in these ecosystems.
5. How many trophic levels are there in each of the ecosystems?
6. Compare the number of producers with the number of secondary consumers. Why does there seem to be such a large difference in numbers?
7. Read the following quote and draw an energy pyramid with five trophic levels in your exercise books:

   'Three hundred fish are needed to support one man for a year. The trout, in turn, must consume 90 000 frogs, which must consume 27 million grasshoppers that live off 1 000 tons of grass.'

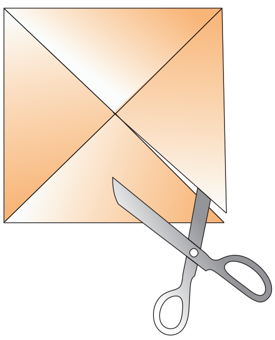
Now let's make our own energy pyramids. Follow the steps:



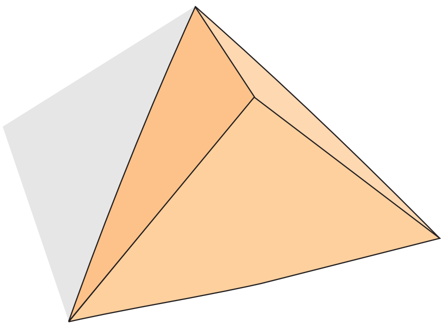
1. Use an A4 sheet of cardboard and cut out a square. Do this by folding one corner to the opposite side and cutting off the rectangle sticking out.



2. Next, fold the square in half the other way so that you have two folds diagonally across the square.

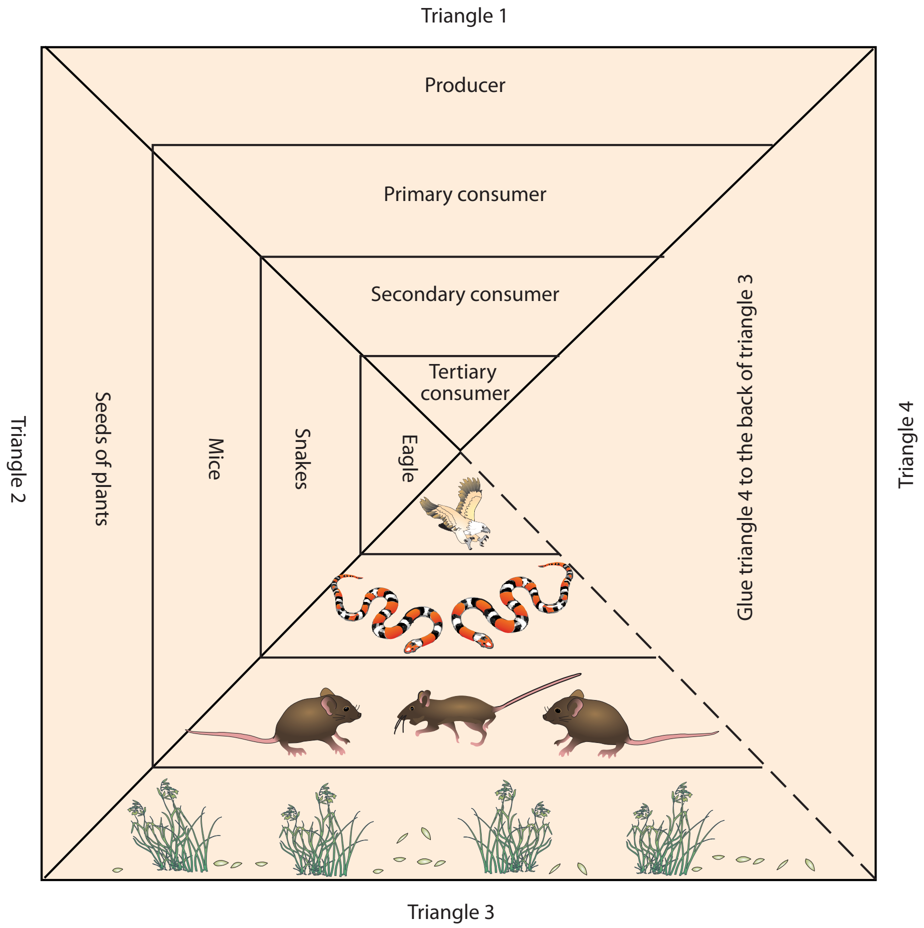


3. Cut along one fold to the centre.



4. Fold one of the triangle sides underneath the one next to it to make a pyramid.

5. Before gluing the two sides together, draw three lines to divide the sides into 4 layers.
6. Now you need to design your energy pyramid. Decide on the organisms that will go into each level. You will need producers, primary consumers, secondary consumers and a tertiary consumer.
   a) In one of the triangles, draw images of each of the organisms in the different levels.
   b) In another triangle write the names of the organisms.
   c) In the last triangle, write whether the organism is the producer or which type of consumer.
   d) Now glue the triangle together.
   e) Have a look at the following example. You must come up with different organisms!



Food webs

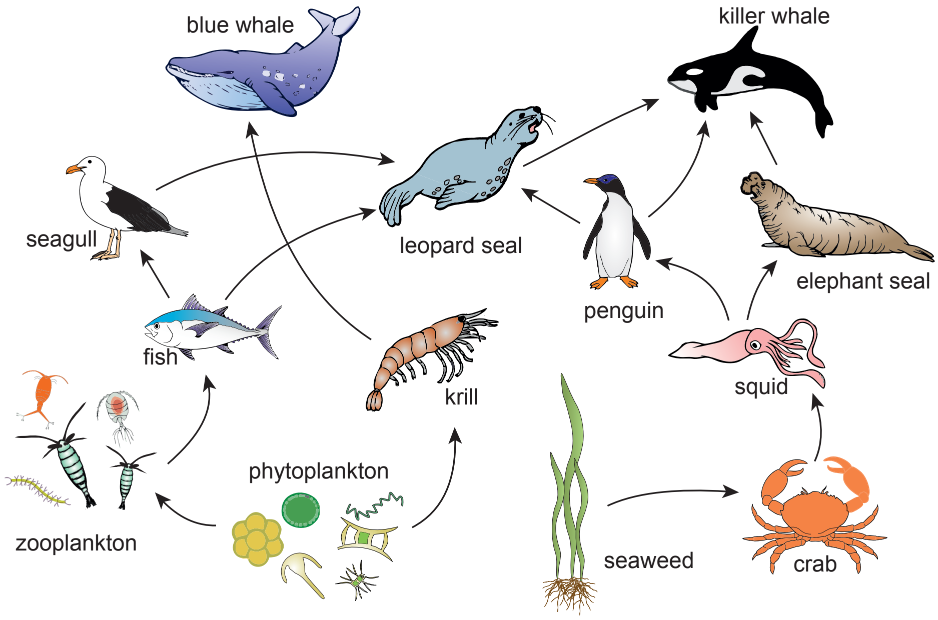
Consumers have different sources of food in an ecosystem and do not rely on only one species for their food. If we put all the food chains within an ecosystem together, we end up with many interconnected food chains.

Interconnected food chains is called food web. A food web is very useful to show the many different feeding relationships between different species within an ecosystem

ACTIVITY: Identifying food chains and food webs

Instructions

1. Study the food web below.
2. Answer the questions that follow.



Questions

1. What sort of ecosystem does this food web describe?
2. Write down 4 different food chains from this food web.
3. What does a food web show?
4. Name the producer in this food web.
5. List the herbivores in this food web.
6. Name two species in this food web that are top carnivores.

Refer to the ecosystem that you are currently studying. See if you can identify the food web that is applicable in your marked off ecosystem. Draw it in your books.

What do you think would happen to the marine ecosystem in the last activity if we removed the phytoplankton? This brings us to the next section.

ACTIVITY: Balance in an ecosystem

Keywords

- endangered
- extinct
- limit

Any area can support only a limited number of animals. Look at the ecosystem on the next page and decide which resources the organisms depend on. Remember to take some notes.

If all the grass and trees died, what would happen to the zebra and elephants?

What would later happen to the cheetah and hyena? Why is this?

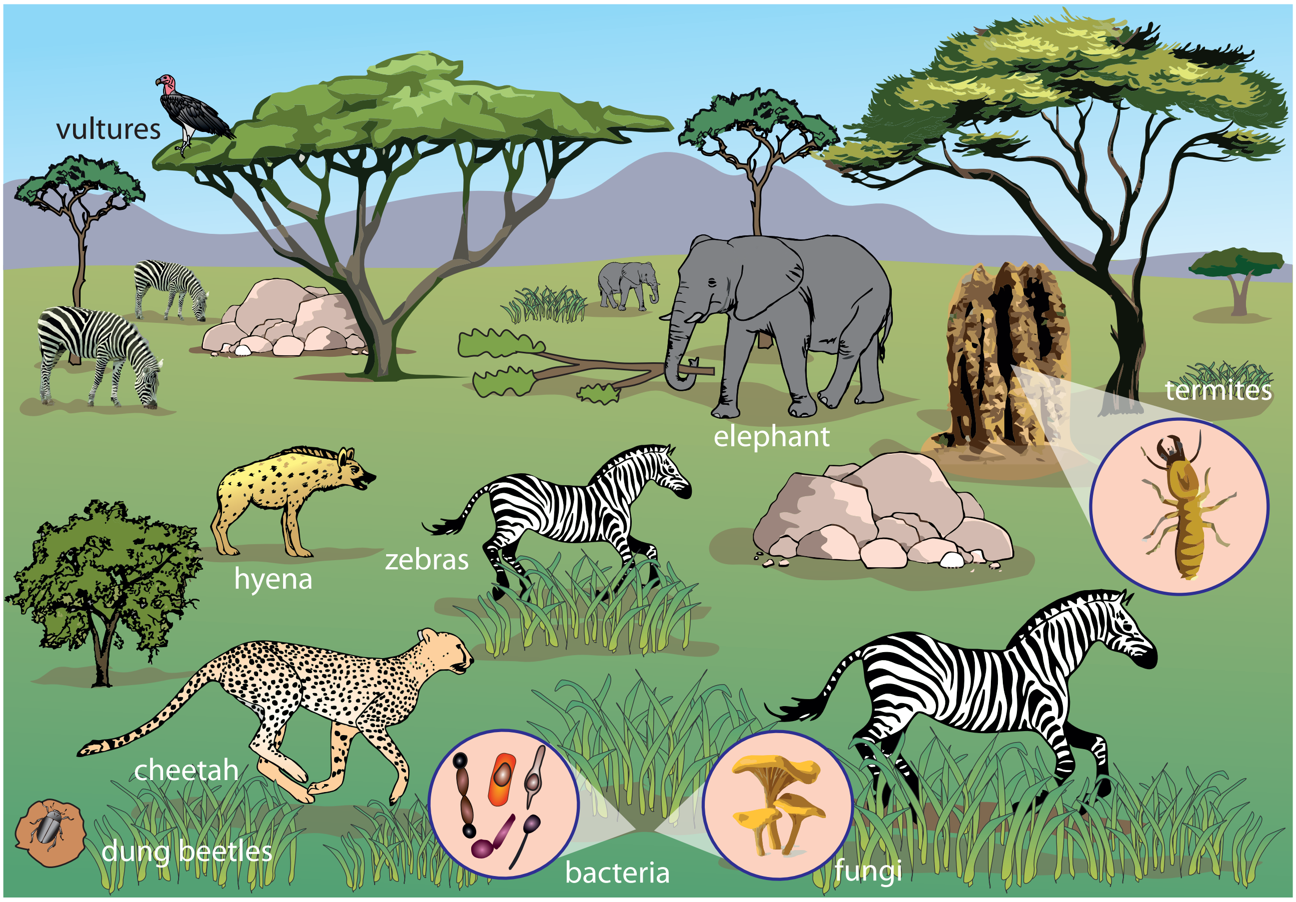


Figure 2.15 A balanced savanna ecosystem

One of the factors that we can look at within an ecosystem to see if it is balanced is the population growth of different species over time.

Population growth

Over time ecological populations interact and change within a community. All populations change over time and grow. The population growth of a species in the wild is kept in balance by a number of different factors.

Human intervention can sometimes cause serious damage to an animal population, such as the critically endangered Riverine Rabbit. There are fewer than 200 individuals left in South Africa. It eats only from a few plant types, so its habitat is restricted to where these plants are found, such as small areas of the Karoo. During the day, it hides under bushes on the river banks, but many of its home areas have been invaded by humans or destroyed.

ACTIVITY: The critically endangered Riverine Rabbit

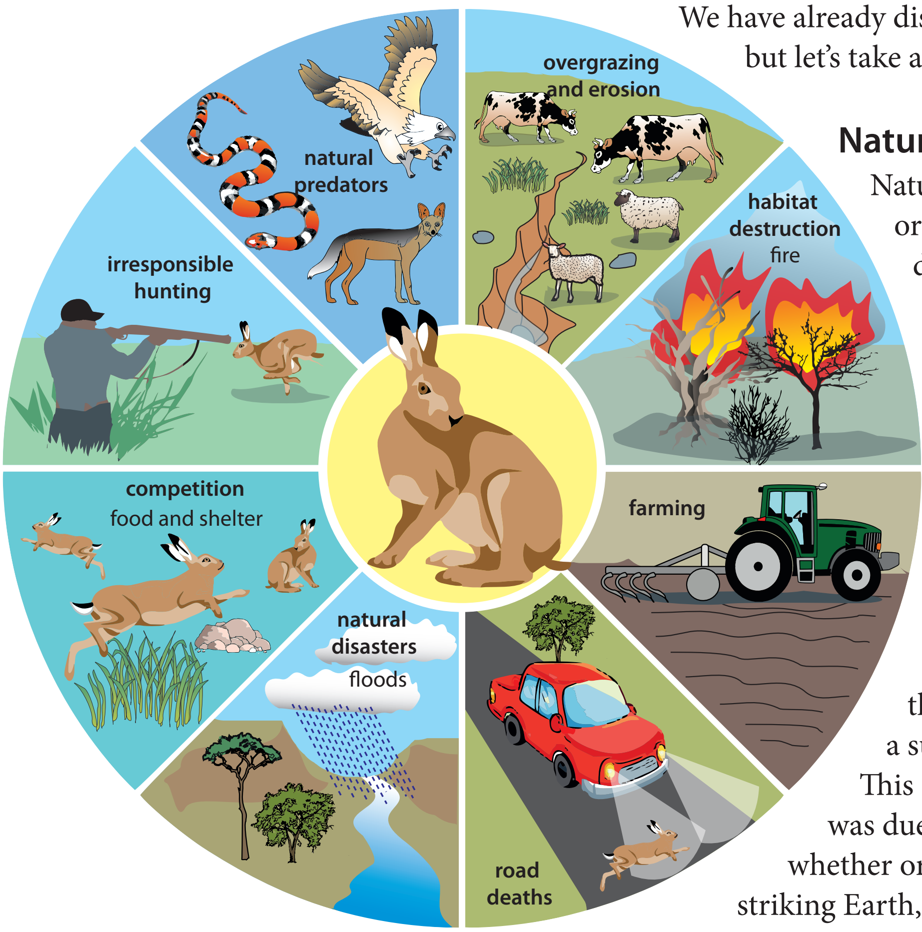
Instructions

1. Study the diagram that shows the threats to the Riverine Rabbit.
2. Explain the different limiting factors on the population growth of the Riverine Rabbit using the information in the diagram.

Factors that disrupt a balanced ecosystem

We can group these factors as:

1. natural factors; and
2. human factors.



We have already discussed this in some detail, but let's take a closer look.

Natural factors

Natural disasters such as floods or hurricanes can cause severe disruptions to ecosystems, but the ecosystems recover eventually. If the change occurs over long periods, such as climate change and global warming, the damage may not be reversible. There are many different theories about why the dinosaurs became extinct. One of the main theories is that there was a sudden change in climate. This sudden change, whether it was due to a meteor striking earth whether or not it was due to a meteor striking Earth, disrupted the balance in the ecosystems to such an extent that all the dinosaurs died out.

ACTIVITY: Assessing the impacts of a natural disaster

In the 1980s a devastating drought and famine raged in Ethiopia and caused the death of 400 000 people. Many animals, plants and microorganisms also died and species that depend on water for their reproductive cycle, such as amphibians, were particularly badly affected.

Figure 2.16 A sudden natural disaster, such as flooding, can disrupt an ecosystem.

Questions

1. What is a drought?
2. What is a famine?
3. How do you think a drought and famine in a particular area are linked?
4. A famine is often accompanied by the spread of diseases among animals and humans. Why do you think this is so?
5. Do you think the effects of a drought and famine on an ecosystem are reversible or irreversible? Give a reason for your answer.

Human factors

Many years ago, people like the San had little impact on their environment, as they lived in harmony with the land and only took what food they could carry.

Modern man has, however, had a huge effect on nature. We clear land to build cities, roads and farms, we pollute the environment, and we produce waste and litter. Humans also poach endangered animals and over-harvest marine animals, causing lasting damage to ecosystems.

ACTIVITY: Poaching in Southern Africa

Instructions

1. Read the following newspaper article.

Hunting and bush meat – the road to extinction

19 October 2012

Illegal hunting (poaching) of animals and the killing of wild animals for 'bush meat' in many parts of Southern Africa is of serious concern to environmentalists and is driving some species close to extinction. Poor communities often rely on small wild animals they can trap for food, but removing too many of the smaller animals could force the carnivores (such as lions, leopards and wild dogs) that eat them to turn to domestic animals such as sheep or cattle for food. For this reason, farmers may go out and shoot even more of them. The carnivores themselves sometimes get caught in the traps. Although hunting and finding bush meat have been traditional ways of getting food for many generations, the current 'over-hunting' is causing concern. Dr Rene Czudec of FAO commented: 'There is an urgent need to look for solutions to ensure the sustainable use of SA's wildlife, while still helping to develop poor communities'.

Questions

1. After reading this article, explain what you think bush meat is.
2. How did the hunting of the San differ from today's removal of bush meat?
3. Why do you think there is a market for bush meat (people who buy the bush meat)?
4. Some people from local communities that live on the edge of protected reserves sneak into the reserves and illegally kill wildlife for food. Do you think this is justified? Discuss this with your class. What do you think some solutions to the problem could be?
5. What is poaching?
6. Why do you think poaching causes an imbalance in an ecosystem?
7. In the article, wildlife is poached for the meat to be sold as food. What two other animals are poached in southern African game reserves, and why are they poached?
8. Abalone (perlemoen) are edible sea snails sold as a delicacy in Asia. Although they are farmed, many are removed illegally by divers, causing a serious decrease in their numbers.

Figure 2.17 A perlemoen straight out of the ocean.

Figure 2.18 Perlemoen served as a delicacy.

How do you think the illegal poaching of perlemoen is affecting our marine ecosystems?

9. In the Northern provinces in South Africa, Mopani worms are a traditional source of high protein seasonal food found in the area. But they have also become a favourite of tourists and visitors of the area. Each year, more and more are being eaten so that they are now hard to find. We say they are becoming locally extinct.

   Describe the impact that this could have on the rest of the food chain or food web.

Pollution

Another way in which humans have a huge impact on the environment and cause disruption to ecosystems is through pollution. There are many different types of pollution. Are you aware of the ways in which you are contributing to pollution?

ACTIVITY: Assess your impact on the environment

Questions

1. There are different types of pollution, as listed below. For each one, discuss it with your partner and write a short description of the type of pollution, and where it can come from.
   a) Water pollution.
   b) Air pollution.
   b) Land pollution and refills.
2. Assess your own life. Where have you perhaps contributed to the types of pollution mentioned above?
3. Brainstorm ways in which you can reduce each of these types of pollution.
4. Study the following posters made by a Grade 8 class. What do you think they are trying to encourage us to do? What is the message of the posters?

2.6 Adaptations

Organisms in ecosystems face competition, predation, parasitism and human influence, all of which could affect them negatively, forcing them to adapt, move away or die. It is well known that SA has undergone big climatic changes in the past. For example, the dry Karoo was once swampy and the Cango Caves in Oudtshoorn were once under water.

When Southern Africa rose out of the sea millions of years ago, organisms that could not adapt to the new, drier terrestrial environment became extinct, but individuals that could adapt, survived and formed new populations. These adaptations could be changes in the organism's structure, function or behaviour over very long time periods. Only populations of organisms that happen to have suitable characteristics are able to survive in

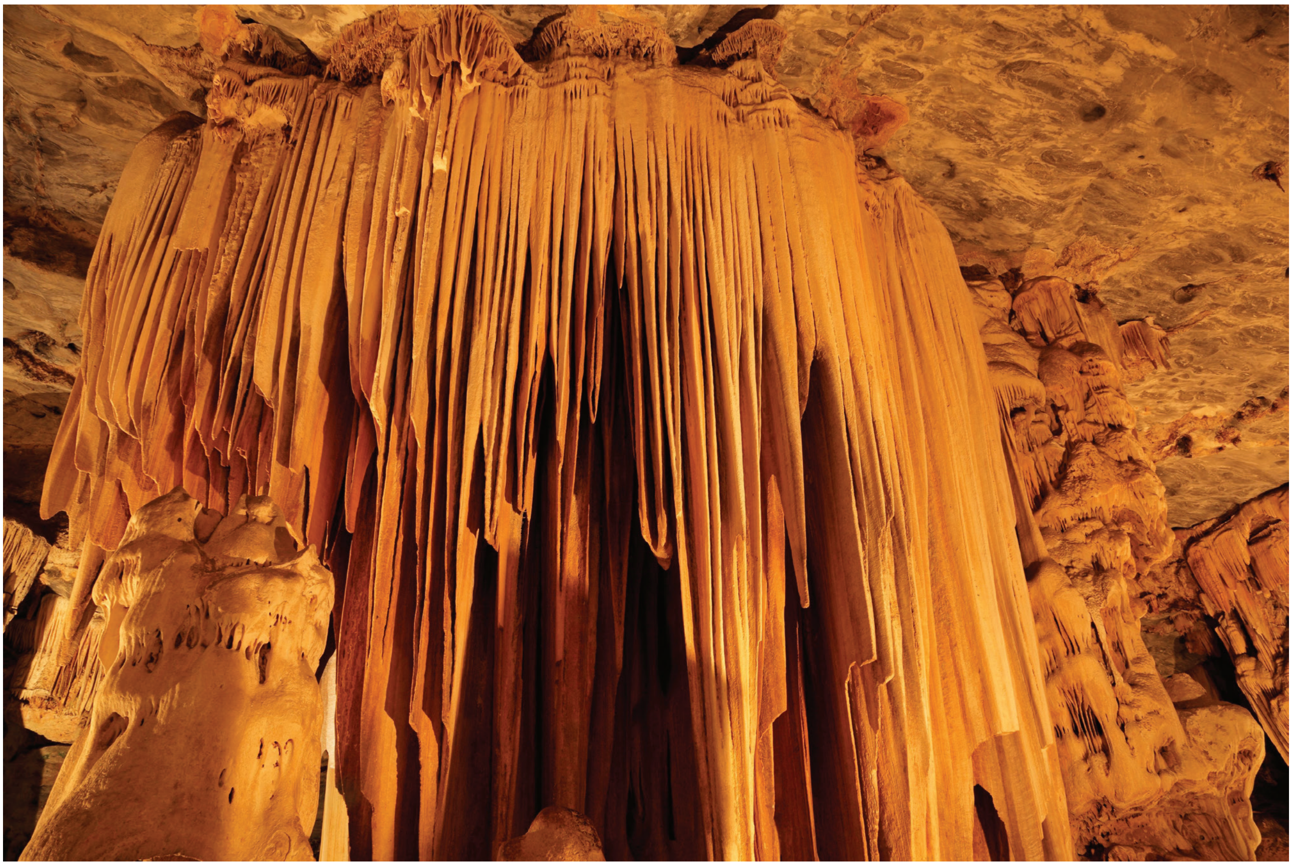


Figure 2.1 Rock formations inside the Cango Caves show that they were once under water.

Keywords

- adapt
- camouflage
- hibernation
- instinct
- migration
- mimicry
- terrestrial environment

Did you know?

Cango is a KhoiSan word and means 'Place of deep water'.

changing conditions within an environment. They are 'selected by nature' to survive. Those species that do not adapt will die out and become extinct.

Adaptation in species can occur in three main ways:

1. Structural: the physical characteristics of a species such as having long legs and strong muscles.
2. Functional: a species may have a special way of carrying out its life processes, such as being able to produce eggs with a hard shell, so that the embryos can grow and hatch even if the climate changes.
3. Behavioural: the species can have special behaviours that are instinctive (which they know by instinct) or can be learned, such as making safe nests for protecting their babies

These changes take place over a long time period within a species and must be passed on from generation to generation. Over time and over many generations, these adaptations in the individual organisms will allow the species to evolve and adapt to its changing environment. Let's have a look at some of the adaptations of plants and animals.

Adaptations in animals

Animals have different adaptations which have enabled different species to live and function in different areas. Let's look at some of the animals that live in our country and how they have adapted to live in their environments.

ACTIVITY: Distinguish between types of adaptations

Instructions

1. We will work through different adaptations in South African animals that have enabled them to survive in the environment they live in.
2. In each of the examples, say whether you think it is a structural, functional or behavioural adaptation and give a reason for your choice.

Questions

Record your work in in your exercise book for each set of animals.

1. Aardvark: It has a flexible, tubular tongue up to 30 cm long as well as thick skin and short, powerful legs with strong claws for digging into termite mounds, its favourite food. These ants are then collected by the tongue – up to 50 000 in one night! It hides underground in daytime to escape heat and predators.

Figure 2.19 An aardvark

How is the species adapted to life in its habitat?	
What type(s) of adaptation is this?	

2. Desert beetles: They have ridges on their backs for collecting mist in the Namib Desert at night. Long back legs tilt the body, so mist is collected, condenses and runs via channels and grooves into their mouths.

Figure 2.20 A desert beetle

How is the species adapted to life in its habitat?	
What type(s) of adaptation is this?	

3. Gemsbok: This striking antelope from the Kalahari Desert prefers grass and shrubs, but will dig for roots and tubers if it needs water. They save water by not sweating and sleep in the shade during the day. If they cannot find shade, they turn the body's lightest side to the sun.

Figure 2.21 Gemsbok in the Kalahari

How is the species adapted to life in its habitat?	
What type(s) of adaptation is this?	

4. Ostrich: These are the biggest and heaviest birds, but they can't fly. To avoid predators, they fight with strong clawed toes or run away, up to 70 km/hr! Ostriches swallow small stones to help digest any food they find.

Figure 2.22 A female ostrich

Figure 2.23 A male ostrich

Male ostriches get red beaks in the mating season. The female lays eggs and she sits on them during the day, while the male incubates them at night – examine their colour differences to see why.

How is the species adapted to life in its habitat?	
What type(s) of adaptation is this?	

5. Stick and leaf insect: These insects look like leaves or sticks to avoid predators – this is called mimicry. They are nocturnal insects, because they feed on plant materials at night and move very slowly to avoid being seen. Female stick insects can reproduce without mating.

Figure 2.24 A stick insect

How is the species adapted to life in its habitat?	
What type(s) of adaptation is this?	

Other behavioural adaptations

Many species of animals display an interesting behavioural adaptation called migration. This occurs when an animal or a group of animals move between different areas at different times or periods.

Did you know?

Frogs have a special chemical in their bodies that prevents their blood from freezing completely – a kind of natural antifreeze!

ACTIVITY: Why do animals migrate?

Instructions

1. Have a look at the following animals.
2. Think of reasons why they would want to migrate from their present habitat.

Animals	Description	Reason to migrate
 Wildebeest migrating in the Masai Mara.	Wildebeest migrate long distances each year which coincides with the pattern of rainfall and grass growth.	
 The sardine run as sardines migrate along the South African coastline.	The sardine run occurs along the African coast during May to July each year when billions of sardines migrate to the north east coast of South Africa.	

Animals that don't migrate sometimes go into an inactive state called hibernation in winter. Some of them sleep through a whole winter, while some frogs hibernate by burrowing into the mud when the pond dries up, until the rains return.


Figure 2.25 An umbrella thorn acacia.

Adaptations in plants

Several local plants are also adapted to their environment. The umbrella thorn in the African savannah can survive temperatures ranging from 50 °C to below freezing. Its deep roots reach ground water easily and the small leaves prevent dehydration, while still being well exposed to light due to the umbrella shape of the tree. Why does it need light?


Figure 2.26 A baobab tree.

The Baobab tree survives in dry areas, since it stores water in the thick trunk and spongy wood. The smooth bark reflects heat, making it cooler, but also helps protect the fruits from monkeys. How can it do this?

The flowers smell like rotting meat to attract bats, flies and moths at night. Why do you think the baobab tree needs to attract these animals and insects to its flowers?

Figure 2.27 This baobab is over 3 000 years old! Take note of its width and the reflective bark.

Figure 2.28 A baobab flower, which smells like rotting meat.

We are now going to look at some very unique plants, which are found only in South Africa.

Take note

The name 'Lithops' comes from two Ancient Greek words 'lithos' meaning 'stone' and 'ops' meaning 'face'. So, Lithops means 'stone-faced'!

ACTIVITY: Living stones

Instructions

1. Study the following photographs. They show different types of plants. These plants actually look like pebbles. They are from the genus *Lithops* and they are succulent plants, meaning they have parts that can store water.
2. Answer the questions which follow.

Figure 2.29 Lithops plants growing in dry rocky ground.

Figure 2.30 Different-patterned Lithops plants.

Figure 2.31 A flowering Lithops.

Figure 2.32 Lithops plants use their surroundings to camouflage themselves. These lithops plants blend in well with their surroundings.

Questions

1. Why do you think these plants are commonly referred to as 'living stones' or 'pebble plants'?
2. Why do you think the plants have such different patterns on their surfaces?
   How does this help them to survive in their environment?
3. Lithops plants are classified as succulents. What does this mean? What type of environment are succulents adapted to live in?
4. Lithops leaves are fleshy and mainly underground, and the stem is short. Flowers grow between the leaves, which shrink to below ground level during drought. How does this help the plant survive?
5. If the leaves are reddish-brown and mainly underground, where is the chlorophyll? Examine these dug-up stone plants.

Figure 2.34 The upper surfaces of Lithops plants.

Figure 2.35 The underneath surfaces of the Lithops plants.

   Where is most of the green part of the plant located?
6. This is a thin section of a stone plant under a hand lens. Draw a diagram of it and label the top of the leaves, the split between the leaves and the stem. Indicate where the soil level would be. What is stored in the clear area of the leaves?
7. The upper patterned surface acts as a window. Can you see the clear, fleshy middle parts of the leaves? Do you think light can travel through this? How does this allow the plant to photosynthesise?

Figure 2.33 A cross section of a Lithops plant viewed under a microscope.

2.7 Conservation of the ecosystem

Our country is one of the most naturally diverse in the world. This means that we have many different species and habitats and ecosystems here, more than most other places in the world.

Our country's natural beauty and diversity attract thousands of tourists each year, but it is under severe threat from poaching, pollution, and other human influence. Ecosystems are able to recycle materials like water, carbon dioxide and other gases and the remains of organisms naturally, if they are left alone. But ecosystems cannot do this effectively if we interfere. These human interferences include:

- Habitat destruction such as deforestation and burning
- Pollution causing global warming
- Alien invasive plants taking over ecosystems
- Hunting, poaching and other killing of wildlife

These pressures have caused great loss in biodiversity. Some ecosystems are under strain and others have already collapsed. There are many reasons why it is important for humans to care about the environment. As we have learnt, everything in an ecosystem is connected. Therefore, harming one component of the ecosystem will have a ripple effect that can damage all the other systems.

ACTIVITY: Finding solutions to environmental problems

Instructions

1. The following table is a list of environmental issues.
2. Do some research on air pollution, water pollution, landfills and climate change.
3. Copy the table below in your exercise books and write down the effect (consequence) of each issue on the ecosystem (or on humans). Write down a possible solution or a simple action that you can take to help.

Environmental Issue	Consequence	Action
Inappropriate waste disposal: Air pollution		
Inappropriate waste disposal: Water pollution		
Inappropriate waste disposal: Landfills and littering		
Carbon emissions and climate change		

Some people and organisations such as Greenpeace fight for environmental conservation. There may be groups in your local area that also promote environmental conservation – do not think that you cannot make a difference if you are just one person!

Figure 2.36 The Greenpeace ship, Arctic Sunrise, which is used for environmental awareness campaigns and research.

These are all ordinary people who feel passionate about saving the only world we have. It takes the combined work of many concerned people to maintain healthy ecosystems – you can also make a difference!

ACTIVITY: Why should we care?

Instructions

1. Divide the class into two teams. One group supports environmental conservation and the other believes we should use all Earth's resources as we like.
2. Both groups must research their topics beforehand and gather relevant points.
3. The teacher can lead the debate and ensure it proceeds in an orderly way.

Questions

After the debate, write down three points about each viewpoint that you can remember.

ACTIVITY: Individuals who make a difference

Instructions

1. Various individuals who have contributed to environmental conservation and awareness in some way include *Sir David Attenborough*, *Jane Goodall*, *Jacques Cousteau*, *Al Gore.*
2. Research what each individual has done.
3. Then choose one whom you find most inspiring and write about them, identifying what is you admire.
4. You do not have to use only the people who have been identified here. You can write about someone else whom you have identified.
5. Lastly, reflect on how you can make a difference in your own life and what you could do to conserve your own local environment. Write about this too.

Some other people to research include:

- Wangari Mathai
- Lawrence Anthony
- Steve Irwin
- Diane Wilson
- Dian Fossey
- Ian Player

Summary

Key concepts

Ecosystems

- Ecology is the study of interactions of organisms with one another and with the physical and chemical environment.
- The study of ecological interactions is conducted at four levels:
  - populations
  - communities
  - ecosystems
  - biosphere(s)
- All ecosystems combined make up the biosphere.
- An ecosystem consists of a community that includes all living organisms (biotic) such as plants and animals, together with the non-living (abiotic) environment and climatic conditions such as temperature, air and wind, and water, interacting as a system.
- An ecosystem can refer to a specific area on Earth or the entire biosphere can be regarded as one large ecosystem.
- Individuals are suited to the environmental conditions at the time. As conditions do change over time, only those better suited to the changed environment will be able to continue the species. And so over time species adapt.
- The survival of populations and species depends on whether enough plants and some algae play a very important role in the ecosystem, because they capture the radiant energy from the Sun and use it in the process of photosynthesis to produce glucose that the plant and other animals can use to gain energy.
- This energy is passed along a food chain from producers to consumers; decomposers are the last link in this transfer of energy. They release energy as heat to the environment.
- Each stage of a food chain is called a *trophic level*.
- Energy transfer and energy loss occur at each trophic level.
- Interlinked food chains together form food webs.

Feeding relationships

- Plants are *producers*. They make their own food.
- Animals are *consumers*. They obtain food from plants either directly (such as herbivores) or indirectly (such as carnivores).
- *Herbivores* feed on plants.
- *Carnivores* feed on other animals (living or dead). This group includes:
  - *Predators,* for example lions and leopards, hunt other animals, their *prey*.
  - *Scavengers*, for example hyenas and vultures, that eat dead animals.
  - *Insectivores,* such as worms, that eat insects and other small invertebrates
- *Omnivores* feed on plants and animals. Humans are generally omnivores.
- *Decomposers* break down (decompose) the remains of dead plants and animals. They recycle important nutrients in the environment.

Energy flow: food chains and food webs

- Plants and some algae play a very important role in the ecosystem because they capture the radiant energy from the Sun and use it in the process of photosynthesis to produce glucose that the plant and other animals can use to gain energy.

Balance in an ecosystem

- An ecosystem can accommodate only as many organisms as its resources (food, water and shelter) can carry.
- The balance can be disturbed by natural or human factors:
  - natural factors include extreme changes in patterns of weather and climate, such as floods, drought, and extreme and sudden changes in temperature.
  - human factors include removing organisms from the ecosystem (such as poaching), and human-induced pollution.
- These factors can contribute to an imbalance in an ecosystem, seriously impacting on its components and altering its nature.

Adaptations

- Adaptation is the change in the structural, functional or behavioural characteristics of a species over many generations.
- Adaptation allows the species to survive as it adapts to changing conditions within the environment.
- Species and populations of organisms that are unable to adapt to changes in the environment will die out and become extinct.

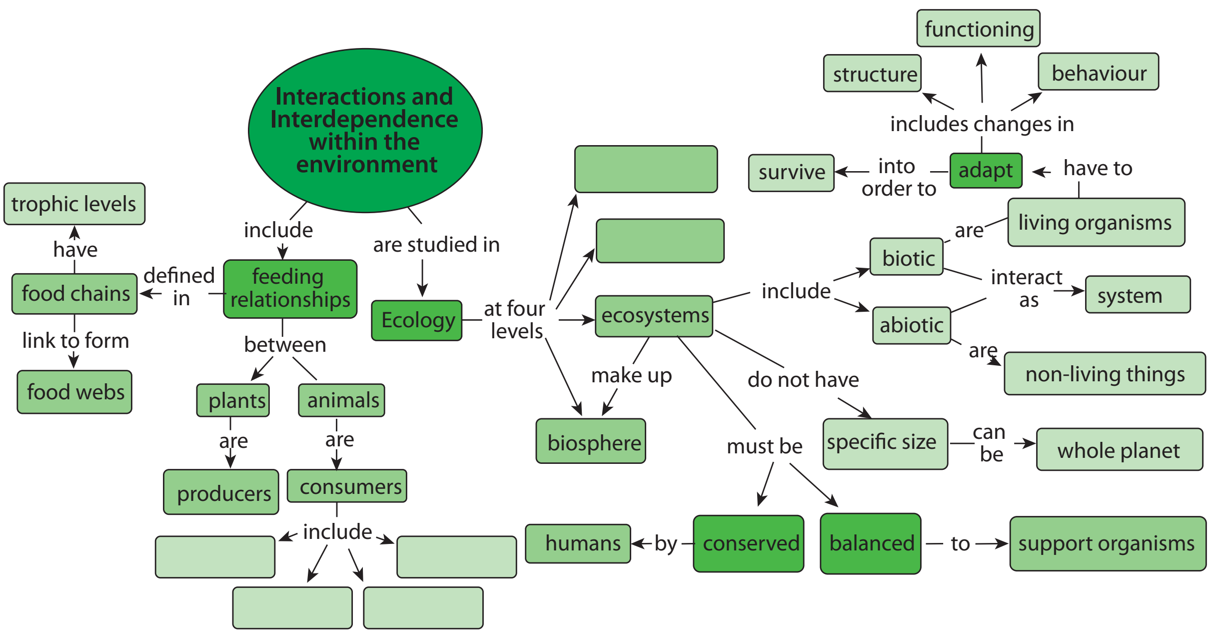
Conservations of ecosystems

- People can work towards managing and sustaining natural ecosystems.
- Individuals can contribute to conservation in various ways such as appropriate waste disposal (including recycling and reusing).

Concept map

This concept map shows how the concepts in this unit on the 'Interactions and interdependence within the environment' link together. Complete the concept map by filling in the two levels which are missing for the study of ecology. Also, fill in the four types of consumers that you have learned about in this unit.

Can you see how the arrows show the direction in which you must 'read' the concept map?

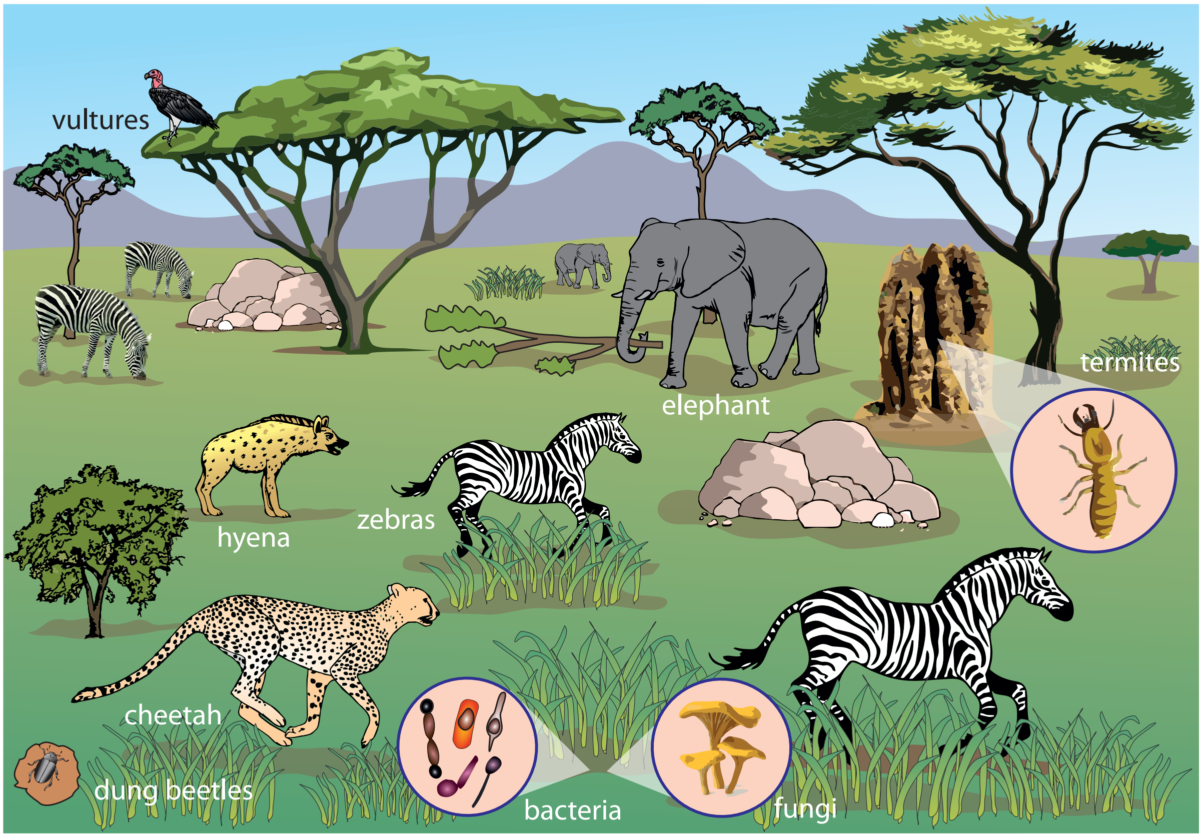


Revision

1. Match the columns in the following table to link the description to the term. [9]

1. Producer	A. Organisms that eat other organisms to obtain food
2. Carnivore	B. Feeds on plants and animals
3. Consumer	C. Organisms that make their own food.
4. Omnivore	D. Organisms that eat only plant material
5. Predator	E. A carnivore that eats dead animals
6. Decomposer	F. An organism which feeds on other animals (living or dead)
7. Insectivore	G. An organism that breaks down the remains of dead plants and animals
8. Scavenger	H. A carnivore that hunts other animals
9. Herbivore	I. A carnivore that eats mainly insects and other small invertebrates

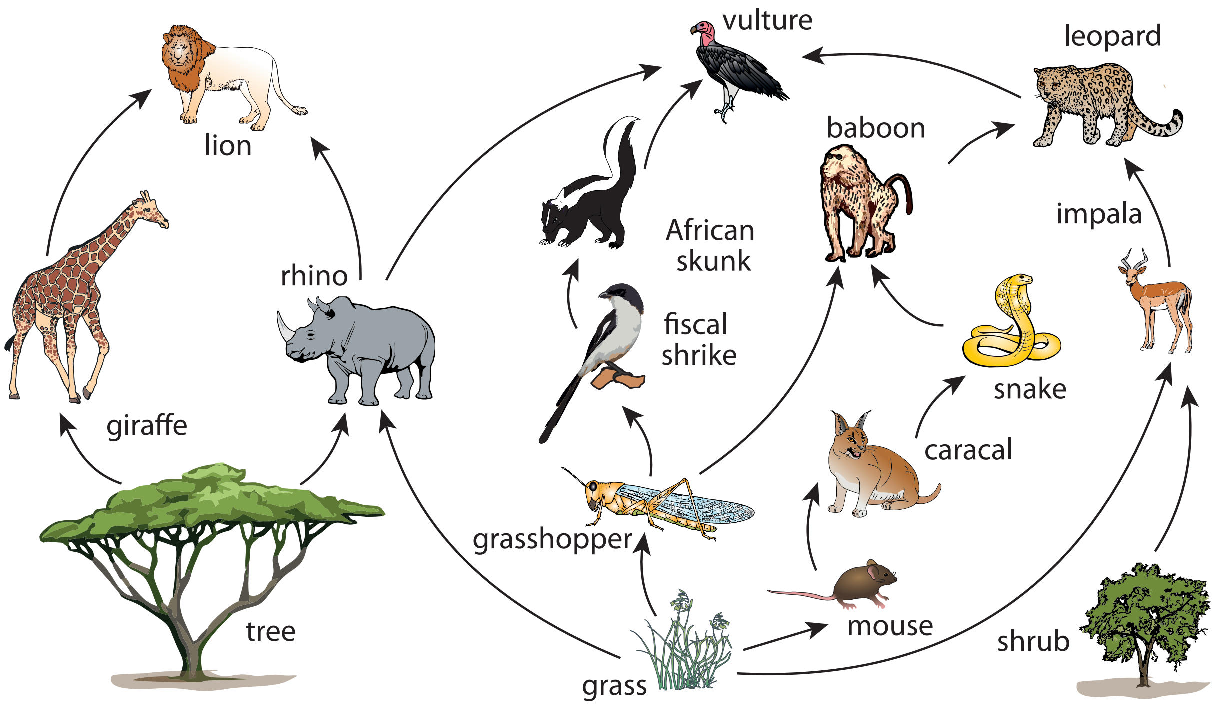
2. Distinguish between abiotic and biotic factors in the environment. [4]
3. There are different levels of ecological organisation between an individual organism and the biosphere of the Earth. List and describe the levels in between the two mentioned here. [6]
4. Discuss the different types of interaction that exists between species. [9]
5. Explain what the different trophic levels represent in an ecosystem and why we can represent the levels as a pyramid with the bottom layer being the largest. [8]
6. Evaluate this statement: '*An insectivore is a carnivore.*' [2]
7. Identify the following in the ecosystem shown. [7]



a) Producers:

a) Primary consumers:
b) Secondary consumers:
c) Scavengers:
d) Decomposers:

8. There are more zebra than cheetah in this balanced ecosystem. Explain why this is so. [3]
9. Describe the work of the producers in this ecosystem. [2]
10. Based on this picture, evaluate how active the decomposers are in this environment. [2]
11. What do you think would happen to this ecosystem if all the zebra got a disease and died? [2]
12. What do you think would happen to this ecosystem in the short term and in the long term if a big fire came through and burned most of the grass and some of the trees? [2]
13. The following food web shows the feeding relationships between organisms in another savanna ecosystem. Use this food web to write down three food chains. [6]



14. Copy the table below in your exercise books and describe how the different organisms in the table are adapted to live in their specific environments. [4 × 3 = 12]

Organism	Adaptations
 A leopard.	

Organism	Adaptations
 A whale.	
 A Venus Flytrap.	
 A dung beetle.	

15. Read this paragraph about the Quiver tree of the Kalahari and Namib desert.

The Quiver tree lives in the Namib and Kalahari deserts, where the heat and lack of water makes it extremely difficult for plants to grow and survive. It stores its water inside green succulent leaves and bloated branches. The San used to hollow out the branches and use them for their quivers, which is where the tree gets its name from. The branches are covered with a white powder that reflects the heat and the leaves have very few pores to minimise water loss through evaporation. During extremely harsh weather conditions, the tree can amputate (remove) its own branches and reduce the leaves to minimise water loss even further. When the conditions improve, it sends out new shoots and grows a rich leafy top again.

How is this species adapted to life in its habitat? [4]

16. A group of poachers recently made the following statement when they were arrested: 'Why is it so important to conserve the biodiversity and the environment? Surely there are enough wild animals and plants that it doesn't matter if some of them die and become extinct?' Write 3 – 4 sentences to explain to them why we need to care about the biodiversity in our country. [6]

Total [84 marks]

3 Micro-organisms

Key questions

- What are micro-organisms?
- Why do we need micro-organisms on Earth?
- Are there micro-organisms living in my body?
- How do we study micro-organisms?
- What causes your body to get sick?
- Are micro-organisms of any use to us?

Micro-organisms have been on Earth for billions of years and have adapted to live in extreme conditions. They are found in almost all areas of the Earth's biosphere and new micro-organisms are still being discovered all the time. Some can be harmful, causing disease and illnesses, while others are useful to us and are a vital part of ecosystems. Let's take a closer look!

Keywords

- bacteria
- disease
- fungi
- infect
- protist
- virus

3.1 Types of micro-organisms

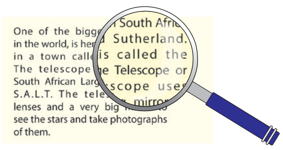
Micro-organisms are extremely small living organisms. People did not even know they existed until the invention of microscopes in the 1600s! We say that we cannot see micro-organisms with the 'naked eye' because they are too tiny to view without the aid of magnification. We have to view them under a microscope.

Figure 3.1 Antonie van Leeuwenhoek is considered to be the first microbiologist.

ACTIVITY: What does 'microscopic' mean?

Materials

- hand lens or magnifying glass
- newspaper print
- other small objects with detail



Instructions

Your teacher will provide you with a range of different objects to view.

1. First observe the objects with your naked eye.
2. Then use the hand lens to view the objects again.
3. Take note of the differences in the detail you can observe.

Questions

1. What do we mean by the term 'naked eye'?
2. Describe some of the differences when you viewed the objects using just your eyes and when you used a hand lens.
3. The following images show different views of the same object. One image shows what we would see with our naked eye. We call this the

Take note

Someone who studies micro-organisms is a microbiologist.

> **Take note**
>
> The prefix 'micro' comes from the Greek word 'mikros' meaning small. How many words can you think of which contain the prefix 'micro'? What do they all have in common?

> **Did you know?**
>
> Antonie van Leeuwenhoek designed and built his own microscopes. In 1674 he became the first person to see and describe microscopic organisms like bacteria, yeast and many other micro-organisms.

Figure 3.1 A basic light microscope

macroscopic view. The other photo shows what we would see if we viewed the object under a microscope. This is called the microscopic view.

For each object, identify which is the microscopic view and which is the macroscopic view.

a) Beetle

b) White bread

c) Onion skin

d) Cotton

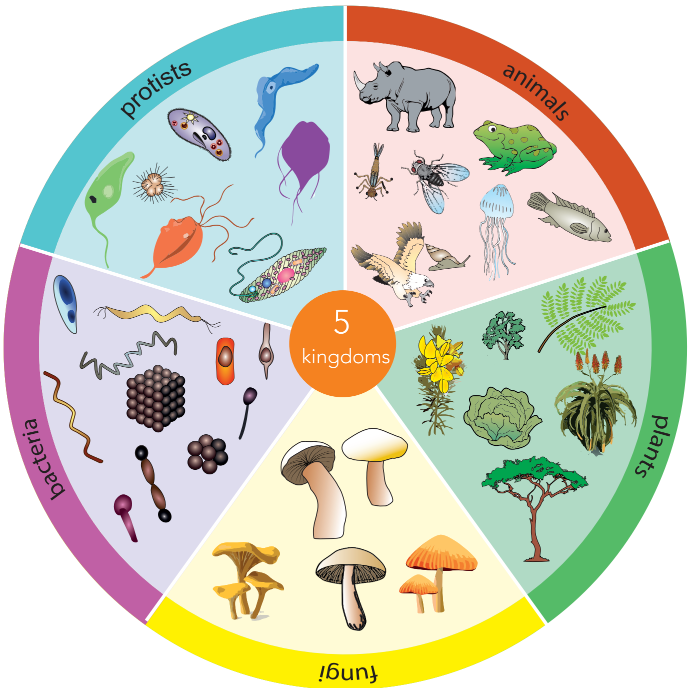
In the last activity we saw that you can view objects under a microscope, allowing you to see much more detail than if you just viewed them with your naked eyes. There are many organisms on Earth, however, which we cannot see at all with our naked eye. We can see them only when we look under a microscope. These are micro-organisms.

ACTIVITY: Classifying organisms

The living organisms on Earth can be grouped in many ways. You have learnt about classification before. Let's revise our classification system for all organisms on Earth.

Instructions

1. Study the following diagram showing how we classify organisms on Earth.



2. Answer the questions that follow.

Questions

1. Do you see that the organisms in the diagram are divided into five groups? What do we call these five groups?
2. Which groups do you think contain organisms which can be classified as micro-organisms?
3. Do you think micro-organisms are living or non-living? Give a reason for your answer.

Micro-organisms include **viruses, bacteria, protists, and some types of fungi** (although many fungi can be seen without the use of a microscope). Let's have a closer look at the different types of micro-organisms, before looking at how they can impact on our lives in a positive or negative way.

Bacteria are a large kingdom of micro-organisms. Many bacteria are responsible for causing diseases in humans. However, some are also useful, as we will see later. Viruses are also tiny organisms, much smaller than bacteria even. They can infect all types of organisms, such as plants, animals and also bacteria.Viruses need to infect other organisms in order to replicate (reproduce).

Take note

Bacterium is singular and bacteria is plural.

Did you know?

There is much debate amongst scientists about whether or not we can classify viruses as living!

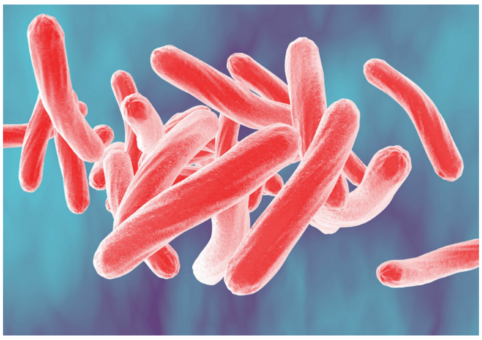


Figure 3.2 *Mycobacterium tuberculosis* bacteria which cause tuberculosis (TB) in people.

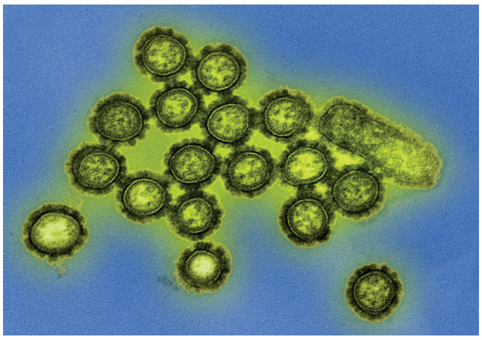


Figure 3.3 H1N1 influenza virus particles which cause flu symptoms in people.

Fungi are also one of the five kingdoms of organisms. Many different varieties of fungi exist. Some are large enough for us to see without the help of a microscope, like mushrooms and bread mould. They are macroscopic. There are others which are microscopic and can be seen only under a microscope, for example yeast.

Figure 3.4 Not all fungi are microscopic, such as mushrooms.

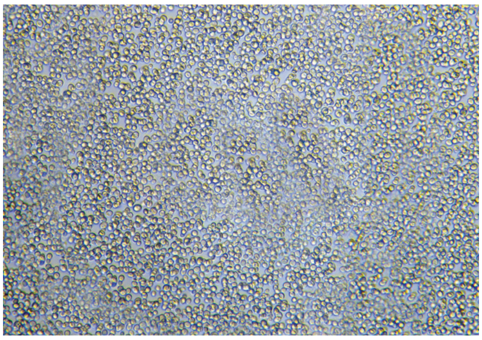


Figure 3.5 Millions of yeast cells viewed under the microscope.

Protists are a very diverse group of micro-organisms. The organisms in this kingdom do not fit easily into any of the other four kingdoms, namely animals, plants, fungi or bacteria. However, some protists are plant-like and others are animal-like. Most protists are microscopic and live in water. The only macroscopic members are the algae or seaweeds.

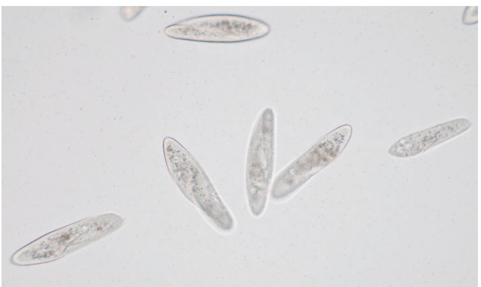


Figure 3.6 A protist living in fresh water.

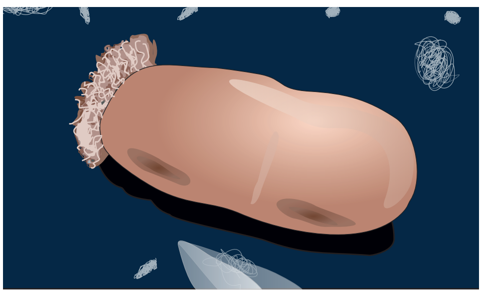


Figure 3.7 A protist found in the gut of many animals.

As you might have noticed from some of the micro-organisms mentioned here, some of them can be harmful to humans and other organisms as they cause diseases and illnesses.

ACTIVITY: Calculating the size of an organism using a scale bar

How do you know the size of a microorganism? You will notice that many pictures of micro-organisms have a scale bar. A scale bar is a very useful tool that allows us to calculate the actual size of objects. Follow the instructions below to figure out the length of this *Oxytricha trifallax* protist.

Instructions

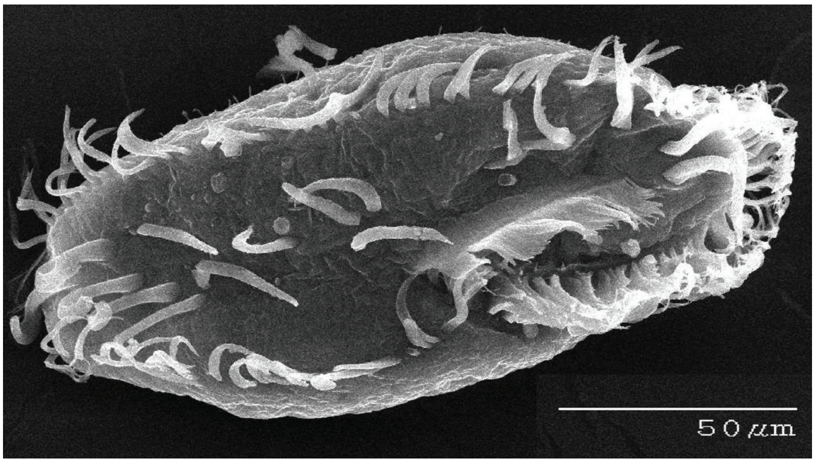


Figure 3.8 A micrograph of *Oxytricha trifallax*.

1. Measure the length of *Oxytricha trifallax* using your ruler. (Express your answer in mm.)
2. Measure the length of the scale bar with your ruler. (Express your answer in mm.)
3. Divide the size of the object (in mm) by the size of the scale bar (in mm) and round off. Your answer will be a ratio and will not have units, since you divided mm by mm.
4. To find the actual size of the organisms, take your answer and multiply it by the number on the scale bar. The units on the scale bar are in µm and so your answer must be in µm. How big is *Oxytricha trifallax?*
5. How many μm are there in a mm?
6. How many *Oxytricha trifallax* could lie end to end in 1 mm?
7. Using the same method you practised before, calculate the size of the following organisms:

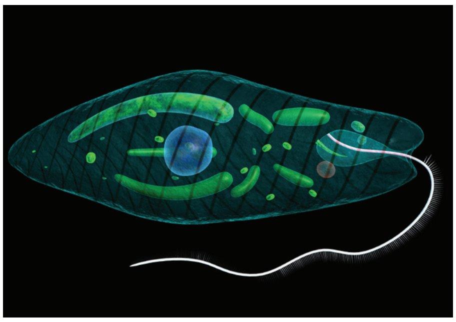


Figure 3.9 A Euglena


Figure 3.10 A fossilised diatom.

Take note

Scientists know what size to make the scale bar because they know what magnification they are using on their microscopes. You will learn about magnification, field of view and how to create your own scale bar if you continue with Life Sciences in Grade 10.

3.2 Harmful micro-organisms

Take note

These diseases are called infectious diseases as they can be passed from one organism to another.

Some micro-organisms cause diseases which may result in death.

Micro-organisms that cause diseases are called pathogens. These pathogens infect other organisms and cause various signs and symptoms in the organism.

ACTIVITY: Where are pathogens found?

We can come into contact with various dangerous micro-organisms each and every day. This activity will help you identify some common places where harmful pathogens are found.

Instructions

1. Discuss the question asked in the title of this activity with your group or class.
2. Use the following photos in your discussion.

Figure 3.13 A handrail.

Figure 3.12 Public payphones.

Figure 3.11 A basin and toilet.

Figure 3.16 Drains and pipes.

Figure 3.15 Rubbish

Figure 3.14 An ATM keypad.

Questions

1. What can you conclude about where disease-causing micro-organisms are found?
2. How do you think diseases spread from one person to the next?
3. Find out what it means to 'sterilise' an object, and write your own definition.

Keywords

- contaminate
- fever
- immune system
- pathogen
- transmitted
- sterilize

Transmission of infectious diseases

We can come into contact with various dangerous micro-organisms each and every day, whether it is when you open the door handle of a toilet or use a trolley at the shopping centre. Pathogens can spread between humans and other organisms in many different ways, for example:

1. In droplets from the air that we breathe: When an infected person sneezes or coughs, the pathogen travels in the drops of spit or mucus to another person.
2. In untreated and contaminated water: The pathogen is transmitted in contaminated water, especially if it has been in contact with human sewage. These diseases are called waterborne diseases, such as cholera and typhoid, and cause diarrhoea.
3. In contaminated food: Sometimes people prepare food without washing and disinfecting their hands properly and the food can become contaminated.
4. Through cuts or wounds: Many pathogens enter our bodies via cuts or wounds. For example, tetanus bacteria live in the soil and when someone hurts themselves on a piece of rusty metal, this pathogen can infect the person.
5. Through bites from animals: Some pathogens can spread via bites from infected animals. For example, the rabies virus from infected animals and malaria is transmitted to humans through mosquitoes.

One of the best ways to prevent the spread of harmful pathogens is by washing your hands regularly with soap and warm water.

ACTIVITY: How easily do viruses spread?

We are going to have a look at how some viruses spread by acting out what happens.

Materials

- paper cups or beakers (one per learner)
- white vinegar (diluted)
- water
- dropper
- liquid indicator

Instructions

1. Your teacher will divide your class into three groups: A, B and C.
2. Each group will be given specific instructions. You must obey the instruction that your teacher gives to your group for the activity.
3. After the activity, answer the questions.

Questions

1. Which group had the most cups with red liquid? What does this mean?
2. The activity that you just acted out can be used to describe the spread of one of the most devastating viruses in the world today, especially Southern Africa. Which virus is this?
3. How does this virus spread? What action did you do in the activity to represent this?
4. How can you prevent the spread of this virus? Discuss this with your class.

Viral Infection

The Human Immunodeficiency Virus (HIV) is one of the most devastating viruses in our world today. The HI virus causes Acquired Immunodeficiency Syndrome (AIDS) in humans. It is a condition where the immune system starts to fail and is ultimately life-threatening. HIV infects white blood cells in the human immune system.

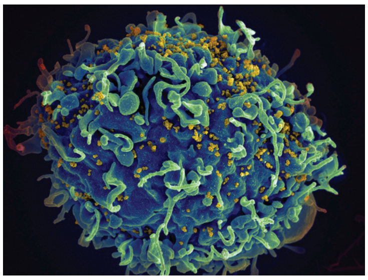


Figure 3.17 White blood cell (stained blue) infected with tiny HI viruses (stained yellow).

Did you know?

South Africa is one of the world leaders in the treatment of HIV/AIDS and better ways of living with the syndrome are being developed all the time. You must continue to do your own reading about the latest developments.

ACTIVITY: HIV Research

Instructions

1. Below is a list of questions about HIV. You will be allocated a question to research.
2. Write your findings in your exercise book and then you will report back to the class in a discussion.

Questions

1. What organism causes HIV/AIDS?
2. What are the symptoms of the disease?
3. What are the dangers of having many sexual partners and unprotected sex?
4. How can the spread of the virus be prevented/minimised?
5. What is the current treatment for this condition?
6. How is mother-to-child infection prevented?
7. Why are pre- and post-natal treatment and monitoring important for pregnant mothers?

Did you know?

The Anopheles mosquitoes that cause malaria have their abdomens pointing up, whereas normal mosquitoes have their abdomens pointing down.

As we saw, the spread of HIV can be prevented by abstinence and having protected sex. HIV can also spread if one uses an infected needle, for example.

This is why it is very important that doctors always use sterilised needles and equipment in their practices. Other diseases spread in different ways.

ACTIVITY: Preventing the spread of diseases

Malaria is a disease caused by a protist. The protist enters the human body via the bloodstream when an infected female Anopheles mosquito bites a person.

The protist travels to the liver of the person and starts to reproduce. Malaria causes high fever and severe headaches, and can lead to coma and death.

Figure 3.18 The Anopheles mosquito which spreads the protist that causes malaria in humans.

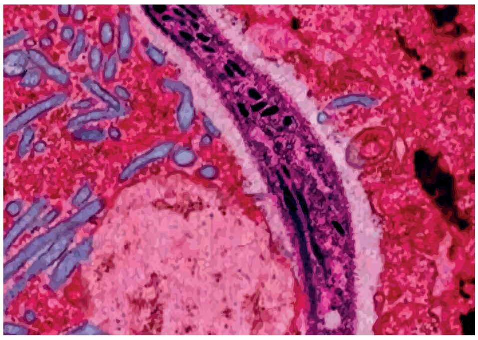


Figure 3.19 The protist (purple) that causes malaria is moving through the gut of the mosquito in this image.

Questions

1. Find out how the spread of malaria can be prevented. Write about this in your exercise books.
2. What you should do if you are travelling to an area where there is a high risk of malaria.
3. Airborne diseases such as tuberculosis (TB) caused by a bacterium, and influenza (flu) caused by a virus, can spread very easily. How do these diseases spread
4. How can we reduce the transmission of these diseases?

Bacterial Infection

ACTIVITY: Typhoid Mary

Typhoid is a disease caused by a bacterial infection. Some people can have these bacteria inside their bodies without realising it, and without ever getting ill from them. These people are called 'carriers'. This was the case with Mary Mallon, or Typhoid Mary, who was a carrier of the disease.

Instructions

1. Research about typhoid. Find out what causes the disease and what its symptoms are, and find out about treatment.
2. Share your research with the class.

3. Read Mary's story below and then answer the questions that follow.

Typhoid Mary

Mary Mallon emigrated from Ireland to America at the age of 15. When she arrived she became a servant, and soon discovered a talent for cooking. Since the cook in households earned a higher salary, she was happy to change from a simple servant to this role. She worked in 8 households from 1900-1907 as the cook, leaving a trail of 51 people seriously ill with typhoid, one of whom, a small girl, died of the disease.


Figure 3.20 Mary Mallon. also known as 'Typhoid Mary', was a carrier of typhoid without knowing it.

When she was eventually identified as the cause of the many illnesses, authorities at first tried to persuade her to volunteer samples of her faeces, blood and urine to be tested.

She refused, although she did admit that she seldom washed her hands when working with food. She didn't think it was necessary.

Eventually, after putting up a tremendous fight, she was taken, with the help of five policemen, to the nearby hospital where the samples were removed. These proved that she was in fact infected with typhoid although she was not sick at all. The authorities sent her to a small island near the city where she was kept away from others for fear of infecting them too. Apart from a short 'parole period', she remained on this island, in full health, until her death.

Questions

1. Why do you think the newspaper article from more than 100 years ago shows Mary breaking skulls into a frying pan?
2. Explain how you think the disease was most probably spread from Mary to the people in the home where she worked? Tip: We know that handwashing was not a common practice at this time.
3. Do you think Mary believed the accusations against her? What could have been her reasons for this?
4. Imagine being Mary and refusing to give authorities samples of your faeces, urine and blood. Why would you not want to give these?
5. Do you think authorities acted against Mary's basic human rights? Explain your answer.
6. If you were the doctor in charge of the investigation against Mary, how would you have acted in the same situation? Explain why you would have done this.
7. Discuss with your class possible alternative courses of action that we, as a society, can take when faced with such a dangerous microorganism that can potentially kill millions of people.

Many micro-organisms can be harmful and cause dangerous diseases around the world.

Scientists are contineously doing research to find and develop cures or vaccinations for infectious diseases, as well as ways to prevent the spread and transmission of diseases.

One of the most important scientists in medical microbiology was Louis Pasteur. He was a French chemist and microbiologist. He discovered a way to reduce the death rate in many diseases and also created the first vaccines for rabies and anthrax. Would you like to make a difference to the lives of people in the world? Perhaps you also want to contribute to the research going on to find cures for some of the devastating infectious diseases, such as HIV/AIDS? Or develop a vaccine against a certain strain of influenza? If so, find out what subjects you need to do in Gr. 10 and what and where you can study after school! Be curious and discover the possibilities!

Figure 3.21 Louis Pasteur (1822 – 1895), a famous French microbiologist

ACTIVITY: Research an infectious disease

Instructions

1. Your teacher will assign the following viral, bacterial, protist or fungal diseases to different learners in the class.
2. Use sources from the library, the internet and interviews with a healthcare professional, to find out more about the diseases. Remember to list your sources in a bibliography.
3. Write a report, prepare a poster, or prepare an oral report, depending on your teacher's instruction on the disease.
4. You must include information on:
   a) The causes of the disease
   b) Symptoms of the disease
   c) Treatment of the disease
   d) How communities react to people with the disease

Diseases or illnesses caused by viruses	Diseases or illnesses caused by bacteria	Diseases or illness caused by fungi and/or protists
chicken pox or shingles colds genital herpes infectious hepatitis influenza (flu) measles meningitis mumps pneumonia rabies rubella (German measles) smallpox yellow fever Marburg Virus Disease (MVD) Poliomyelitis	anthrax bubonic plague cholera diphtheria some strains of dysentery gonorrhea leprosy mastitis meningitis pneumonia syphilis tetanus tuberculosis typhoid fever whooping cough	malaria African sleeping sickness giardiasis amoebic dysentery diarrhoea candidiasis ringworm athlete's foot

3.3 Useful micro-organisms

Keywords
- antibiotic
- fermentation
- fixed
- legumes
- nitrogen

In Unit 2 we looked at the interactions and interdependence of organisms within an ecosystem. Do you remember discussing food chains and decomposers? What was the role of decomposers in the environment? Many decomposers are micro-organisms. These micro-organisms play a very important role in ecosystems as they break down dead plant and animal matter.

They help to return the nutrients to the soil so that they are recycled. Some bacteria remove nitrogen (N_2) from the air and convert it to nitrogen compounds that animals and plants can use. In plants such as legumes, the roots actually contain nodules with bacteria inside them.

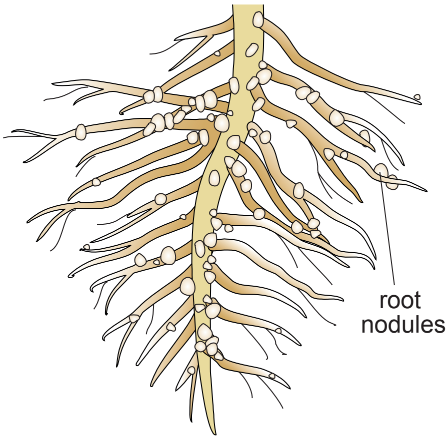


Figure 3.22 Nitrogen-fixing bacteria form root nodules in some plants, such as legumes.

Figure 3.23 Can you see the white root nodules on these roots, which contain *Rhizobia* bacteria?

These nitrogen-fixing bacteria, called *Rhizobia*, cannot live independently and need a plant host. The bacteria get glucose from the plant and the plant benefits by getting the nitrogen compounds which the bacteria fixed from the soil. What is this kind of symbiotic relationship called?

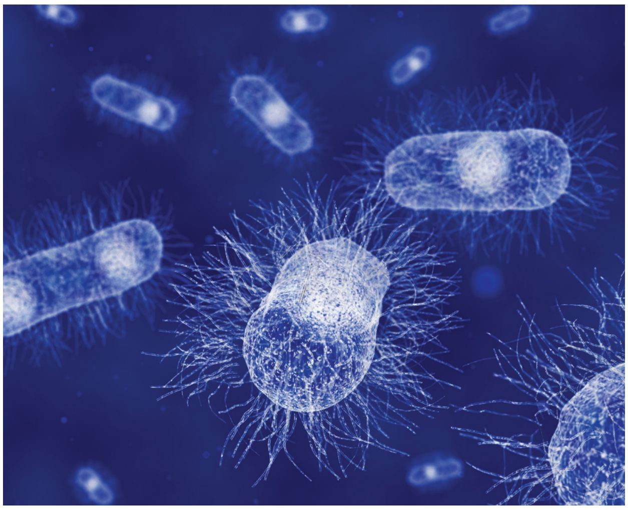


Figure 3.24 *Escherichia coli* bacteria found in the gut of many warm-blooded animals.

We also have bacteria which live inside of us and help the functioning of our bodies! *Escherichia coli* is found in the lower intestine of many warm-blooded animals. They are part of the natural flora of the gut. They can actually help the animal by producing vitamin K2 and also help prevent other harmful bacteria from growing in the gut.

Humans have also found ways to use micro-organisms to do things for us. This dates back throughout our history. Let's find out!

Micro-organisms used by people

You might be surprised at how many of our day-to-day experiences are somehow due to micro-organisms.

Have you ever seen the side of a yoghurt container which says it contains 'live cultures'? This refers to the bacteria inside the yoghurt. People use micro-organisms for processing foods, such as when brewing beer, making wine, baking bread and pickling food. Micro-organisms are also used in the fermentation process when producing dairy products, such as yoghurt and cheese.

Yeast is one of the micro-organisms humans have used for food-processing. The most common uses of yeast are in producing alcoholic beverages, such as beer and wine, and in baking, as yeast is used to make dough rise.

Yeast grows under specific conditions. As it grows it uses sugar for energy and converts it into carbon dioxide and alcohol. This process is called fermentation.

We can measure the amount of carbon dioxide that is produced to see how well the process works.

What are the best conditions for this to take place? Is there an optimal amount of sugar. What about the best temperature? These are all questions which curious people have asked over time. Let's do an investigation to find out.

Take note

We will look more at fermentation next term in Matter and Materials when we do chemical reactions.

Investigation: Investigating the growth of yeast

The first will measure what sugar concentrations are necessary for yeast to grow best. You will receive some guidance and help with this part.

The second part will require you to set up your own investigation to determine at what temperature the yeast will grow best. You will be required to plan, conduct and collect data from the investigation on your own.

Part 1: Yeast growth in different sugar concentrations

Write an experimental report, using the headings Aim, Investigative Question and Hypothesis

Materials and apparatus

- six balloons
- 14 grams (two packets) of dry yeast
- white sugar
- mass scale
- funnel

- six × 50 cm string
- two × 50 ml graduated cylinders
- 600 ml beaker
- overflow pan
- permanent markers
- ice packs

Method

1. Work in groups of four.
2. Use the permanent marker to label each balloon A, B, C, D, E and F.
3. Each balloon will need to be filled with 2 g of yeast and a different quantity of sugar. Balloon A will need to get 2 g of sugar, B will get 3 g of sugar, C will get 4 g of sugar and so on. (See the table below.) Use a plastic spoon or spatula to place the yeast and sugar into the balloon.
4. Use a funnel and pour 50 ml lukewarm tap water into each balloon.
5. One person should hold the balloon and funnel while the other pours in the water.
6. As soon as the balloon has been filled, take a piece of string and tie off the balloon as close as possible to the level of the water without trapping any air.
7. Knot the balloon's rubber neck to ensure that no air can get in or water can get out.
8. Place each prepared balloon on ice to prevent the fermentation process from starting.
9. Before you allow the fermentation process to start, you need to determine the starting mass and volume of each balloon.
10. MASS: Determine the mass of the tied balloon to the nearest two decimal places. Return it to the ice.
11. VOLUME: Use the water displacement method to determine the volume of the balloon.
    a) Place water in a large jug level with the top of the jug.
    b) Completely submerge the balloon under the water in the jug: push the balloon and allow the water to flow over the sides into the overflow pan. You should stop when your fingers touch the water.
    c) The water in the overflow plan is therefore the volume of water that the balloon displaced.
    d) Carefully measure the water in the overflow pan. Record your measurements.
    e) Return the balloon to the ice as soon as possible.
12. PREPARE FOAM COOLER BOX: You are going to place the balloons inside a foam cooler box with warm water in (the box should keep the water warm). Pour 40 °C water into the cooler box (as it normally cools down quite quickly).
13. FERMENTATION INCUBATION: You are now ready to start the process of incubating the yeast.
    a) Place each balloon in the warm water.

b) Record which balloons sink and which float.

Take note

There are different kinds of yeasts. The one we are using breaks down sugar in dough. Others break down wood and corn stalks and produce ethanol (alcohol), while another breaks down the sugar in fruits, nectar, molasses or sorghum.

c) Leave the balloons in the warm water for 20 – 30 minutes, during which time the yeast will ferment the sugar.
   d) Record the exact time that you used for incubation.

14. AFTER INCUBATION: Use a paper towel to dry the balloons.
    a) Determine the volume of each balloon.
    b) Determine the mass of each balloon.

Tip: It is really important that you work fast and accurately at this point. Your team should really consider letting one pair determine the mass and the other the volume of each balloon.

15. Calculate what changes (if any) occurred during incubation to the mass and volume of each balloon.
16. Hang your balloon on a clothesline or hanger in the class to dry.
17. Clean up your work area and wash, dry and pack away all equipment that you used.
18 THREE DAYS LATER: remove your balloons from the clothes line/ hanger. Record all observations that you can make – remember to use ALL your senses.
19. Use the same methods to determine the mass and volume of each balloon and record this in the table.
20. AFTER measuring the mass and volume of each balloon, carefully cut it open. Make careful notes to describe your observations of the contents of each balloon.
21. Use your table of measurements to draw a graph.

Did you know?

The first records of using of yeast to make bread date back to Ancient Egypt.

Results and observations

Copy and complete the table below in your exercise books with the correct information obtained from your work.

Balloon	Yeast (g)	Sugar (g)	Balloon mass before fermentation (g)	Balloon volume before fermentation (g)	Sink/ Float	Balloon volume after fermentation (g)	Balloon mass after fermentation (g)
A	2	2					
B	2	3					
C	2	4					
D	2						
E	2						
F	2						

Analysis

Present the data you collected on a graph.

Questions

1. Describe the changes that you observed happening in your balloons from the start to the end of the incubation period.
2. Were the changes the same in each balloon?
3. Explain why you think these changes occurred differently in the contents of each of your balloons.
4. How did you expect the balloons to react after 3 days?
5. Describe how each of the balloons actually looked after the 3 days.
6. Provide a possible explanation for your observations. Think for instance of what could possibly have been lost from the balloons.
7. At the start you added yeast, sugar granules and water. Describe how the contents of each of the balloons looked at the end of the investigation.

Conclusion

1. What did you learn from doing this investigation?

Part 2: Yeast growth at different temperatures

Conduct this investigation again, but this time you need to find out the best temperature for yeast growth. A suggestion is to use 10 ml of sugar for each of the balloons and 7 g of instant yeast (or 2 teaspoons of sugar and 1 teaspoon of yeast). Why do you need to add the same amount of yeast and sugar to all containers? You will need to change the temperature of the water, however, to measure the optimum temperature for yeast to ferment.

Write an experimental report, using the headings of aim, hypothesis, materials, method, results and observations, discussion, and conclusion.

Figure 3.25 Sir Alexander Fleming, who discovered penicillin in 1928.

Remember to evaluate your results and discuss any difficulties you might have had or ways to improve your experimental design. In your discussion, you will also need to do some extra research about the applications of this process and include this information. Do not forget to reference your sources in a bibliography at the end.

Apart from the use of micro-organisms in food and food-making processes, there are also other processes for which we use micro-organisms. Specific micro-organisms are used in water treatment, such as when treating sewage on a large scale. In biotechnology research, micro-organisms are being used to produce alternative, renewable energy, for example, biogas and biofuels.

Micro-organisms are used in the development of various medicines, for example, antibiotics. Penicillin is a group of antibiotics which come from *Penicillium* fungi. The discovery of penicillin and its uses to treat certain bacterial infections happened by chance. This was due to the curiosity of a scientist, Alexander Fleming, and this led to the discovery and development of many more antibiotics.

Micro-organisms are also used in many fields of science and medical research. Scientists use yeast to learn more about many other types of organisms. The use of viruses is also currently being explored in many universities and research institutions around the world to actually help with cures for various conditions, even cancer. The possibilities for discovery are endless.

ACTIVITY: Careers as a natural scientist

Instructions

1. Examine the list of careers below and select one career that interests you.

Agronomist	Farmer	Botanist	Zoologist	Food Scientist
Ecologist	Veterinarian	Microbiologist	Gameranger	Nature conservationist
Doctor	Nurse	Entomologist	Geneticist	Environmental scientist

2. Do some research about the career you have selected.
3. Pretend it is 14 years in the future and you are about to attend your 10-year high school reunion.
4. Break into groups and have a discussion as 28 – 30 year-olds.
5. Use the questions below to guide your discussions.

Questions

1. What subjects did you take in Grade 10?
2. Which university did you go to? What did you study?
3. Where do you live?
4. What does your 'typical day' involve?
5. What is the best part of your career?
6. What is the worst part of your career?

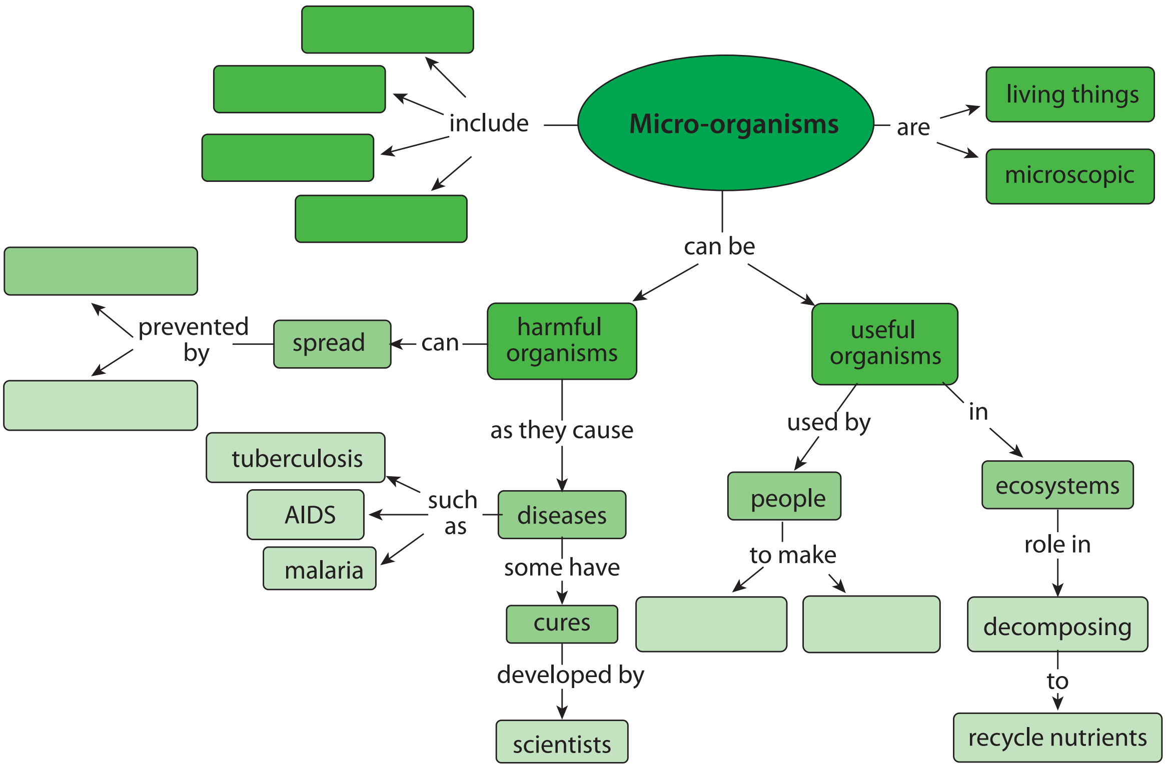
Summary

Key concepts

- Micro-organisms are living things.
- They are too small to see with the naked eye and can be seen only under a microscope.
- There is a variety of micro-organisms, including viruses, bacteria, protists and fungi.
- Micro-organisms can be harmful or useful.
- Harmful micro-organisms:
  - Harmful micro-organisms causes disease such as TB, HIV, malaria and food poisoning.
  - Disease-causing organisms are found almost everywhere – ATMs, handrails, toilets, and so on.
  - Waterborne diseases such as cholera and dysentery cause diarrhoea, resulting in many childhood deaths.
- Effective methods of preventing the spread of diseases caused by micro-organisms include washing hands and sterilising equipment and utensils.
- Modern scientists such as Louis Pasteur played an important role in identifying and developing cures for some diseases.
- Useful micro-organisms:
  - Some micro-organisms play an essential role in ecosystems, such as decomposing dead plant and animal matter, thereby recycling nutrients in the soil.
  - Some micro-organisms are used by people for making certain foods (such as yoghurt and bread) and medicines (such as penicillin)

Concept map

This concept map shows all that we have learnt about Micro-organisms in this unit. What types of micro-organisms are there? How can we prevent the spread of harmful micro-organisms? Fill in 2 of these actions in the spaces provided. In this unit we learnt about useful micro-organisms – what are two products we make using micro-organisms? Fill these in.



Revision

1. Explain in your own words why a microorganism is said to be 'microscopic'. [2]
2. Which groups of organisms are always microscopic? [3]
3. Which kingdom contains organisms which can be microscopic or macroscopic? [1]
4. Name three foods that are made using micro-organisms. [3]
5. Draw a cartoon to show how someone in a shopping centre could possibly be contaminated by a virus or bacteria. [5]
6. More people seem to catch colds and the flu in winter than in summer. Explain a possible reason(s) for this. (Hint: think of the different ways in which people behave in winter.) [2]
7. Describe how someone would typically contract a waterborne virus. [2]
8. Why do you think certain diseases such as malaria, typhoid and cholera are more serious and cause more deaths in third-world countries in Africa, especially in children, compared to first-world countries? [4]
9. List three important ways that we can prevent the spread of diseases. [3]
10. Describe the optimal conditions necessary for yeast to grow. [2]

Total [27 marks]

GLOSSARY: Life and Living

abiotic: non-living; devoid of life

adapt: to change, become adjusted to new conditions

antibiotic: a compound, often produced by micro-organisms, which kills or slows down the growth of bacteria

bacteria: microscopic organisms, lacking a nucleus; they can inhabit many different environments (air, water, soil, the bodies of other organisms etc.)

biosphere: the regions of the surface and atmosphere of the Earth where different organisms live

biotic: relating to living organisms

camouflage: an adaptation in which an animal can hide by blending in with its surroundings

carnivore: an animal that feeds on other animals

chemical potential energy: stored energy in the form of chemical compounds

chlorophyll: a green pigment found in green plants (and certain bacteria) that absorbs radiant energy from the Sun to provide energy for photosynthesis

chloroplast: a part inside the plant cell of green plants that contains chlorophyll, where photosynthesis occurs

community: all the animals, plants or micro-organisms that live together and interact in a certain area at a specific time

consumer: an organism that cannot produce its own food and therefore has to eat other organisms; also called a heterotroph; e.g. all animals, fungi

contaminate: unwanted or waste material enters a place where it does not belong e.g. sewage entering a river, bacteria entering a wound

decomposers: organisms that decompose (break down) organic material, including the remains of dead plant and animal material; usually bacteria or fungi

disease: an abnormal condition (or sickness) of an organism that interrupts the normal functioning; often includes pain, weakness and other symptoms

ecologist: a scientist who studies the interactions of organisms with each other and with their environment

ecology: the branch of biology that deals with the interactions of organisms with one another and with the physical and chemical environment

ecosystem: a biological community of interacting organisms and their physical environment

endangered: organisms that are seriously at risk of extinction

energy pyramid: a triangular picture of a food chain with producers at the bottom and consumers higher up

extinct: an organism that no longer exists; the death of an entire species

fermentation: the chemical breakdown of a substance (by micro-organisms such as bacteria or yeast) in the absence of oxygen, producing simpler compounds and energy

fever: dangerously high body temperature

fixed (fix, fixation): the process in nitrogen or carbon in their elemental forms are assimilated into biological molecules, eg nitrogen fixation by bacteria, carbon fixation during photosynthesis

food chain: a series of organisms linked together to show which one eats what; arrows show the flow of energy through it

food web: many food chains interlinked in an area form a food web, so organisms have many different food sources

fungi: a kingdom of organisms which includes moulds, yeasts and mushrooms, that do not contain chlorophyll, produce spores to reproduce and feed on other matter

glucose: a type of sugar, produced by plants during photosynthesis

habitat: a particular type of environment in which an organism lives

herbivore: an animal that eats only plants

hibernation: an instinctive behaviour in which some animals spend time where conditions are not ideal (e.g. winter; periods of food scarcity) in an inactive (dormant) state

immune system: the system that defends the body against infections, disease and foreign substances

infect: a microorganism enters the body and multiplies, causing illness and damage to the organs

insectivore: animals that feed on insects and other smaller invertebrates such as worms

insoluble: unable to dissolve in a liquid

instinct: a pattern of behaviour that requires no thinking and is biologically driven

interact: to have an effect on somebody/something else or on one another by being or working closely together

legumes: group of plants, including beans, lentils, peas and peanuts, that have edible seeds inside fruit that forms a pod

limewater: a solution of calcium hydroxide in water which turns cloudy white in the presence of carbon dioxide

limit: a restriction on the size or amount of something available or possible

migrate: to move from one region or habitat to another according to the seasons

migration: a seasonal movement of animals move from one place to another and back again

mimicry: an adaptation in which one animal imitates (copies) another in appearance or behaviour

nitrogen: an important element that forms part of proteins in all living organisms

nocturnal: active at night

omnivore: an animal that eats both plant and animal material

pathogen: a microorganism that causes a disease

pigment: is a molecule that absorb certain wavelengths of light and reflect others to produce colours

photosynthesis: the process by which green plants and some bacteria use radiant energy from the Sun to turn carbon dioxide and water into glucose and oxygen

population: a group of organisms from the same species that interbreed and live in the same place at the same time

population ecology: the study of what contributes to the rise and fall of numbers of a species

predator: an animal that naturally preys on other animals for food

primary consumer: an organism that eats plant material

producer: an organism that is able to make its own food; for example, all green plants

protist: member of a diverse group of micro-organisms that are not viruses, bacteria or fungi; can be animal-like e.g. protozoa, plant-like e.g. algae or fungi-like e.g. slime moulds, water moulds

radiant energy: energy contained in light rays or other forms of radiation

respiration: the process by which energy is released from the glucose in food in a series of chemical reactions

secondary consumer: an organisms that eats herbivores and primary consumers

soluble: able to dissolve in a liquid

species: a group of organisms classified by common attributes that can breed and produce fertile offspring

starch: a substance which consists of many glucose molecules joined together; plants store glucose produced by photosynthesis in this complex form

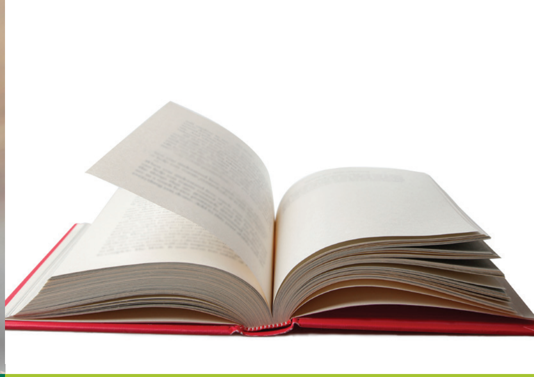
terrestrial environment: an environment on dry land

tertiary consumer: an organism that eats secondary consumers; a carnivore at the highest level in a food chain that feeds on other carnivores

transmitted: to cause something to be passed from one individual to another; for example, disease-causing micro-organisms passed from one person to another

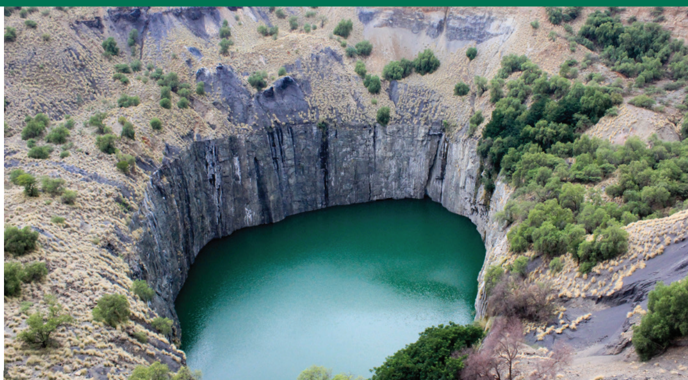
trophic level: a feeding level in a food web, chain or pyramid; all organisms at the same trophic level get their energy in the same way

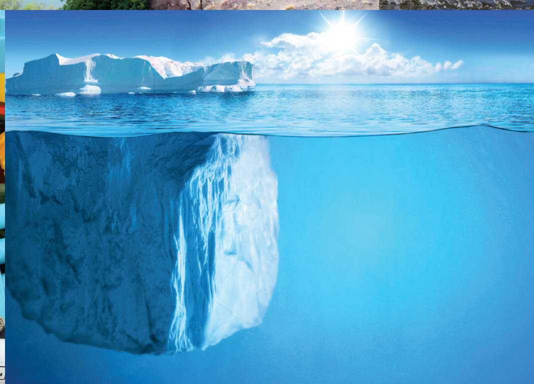
virus: a small infectious agent that typically causes disease

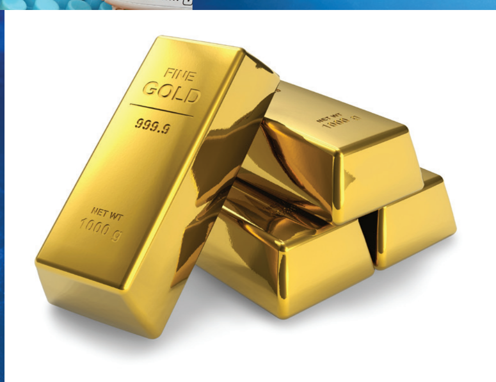

Strand

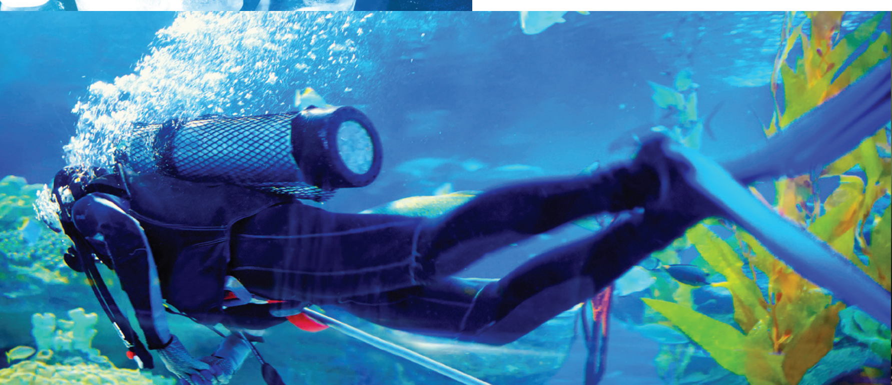
Matter and Materials






4 Atoms

Key questions

- What is matter made up of?
- What do elements look like at an atomic level?
- How are the atoms of one element different from the atoms of another element?
- Which table summarises all the elements known to humankind according to their chemical properties?
- Are atoms the smallest particles making up matter, or are they themselves made up of even smaller particles?
- What do scientists know about the 'inside' of the atom?
- Why do we say atoms are 'neutral'?
- When is a substance 'pure'?
- How is a compound different from an element?
- How is a molecule different from an atom?
- What holds molecules together?
- What happens to atoms and molecules during a chemical reaction?
- How is a mixture of elements different from a compound?

In this unit, we will answer questions about the basic building block of matter, the **atom**.

4.1 The building blocks of matter

What is matter? The definition says matter is anything that has mass and occupies volume (takes up space).

All the different types of matter that exist on Earth are made up of one or more chemical **elements**. You were introduced to some of the elements in Grade 7 Matter and Materials. Before reading further, stop and see how much you can remember about the elements. Write down what you remember or say it out loud.

There are more than 100 known elements and scientists are still looking for more. We also learnt that each element has a unique name, chemical symbol and atomic number that represents it, along with a fixed place on the Periodic Table of Elements.

Keywords

- atoms
- element
- scientific model
- postulate

Periodic Table of Elements

The title of this section is 'The building blocks of matter'. For this reason, we will start our discovery by imagining a wall that has been built of bricks, like the one in the following picture. Can you see how the wall is made of many identical bricks?

Similarly, we can think of most forms of matter as being made up of many, many small particles. These small particles are called **atoms**.

Take note

'Atomos' is a Greek phrase which means 'not cut' or 'that which is indivisible'.

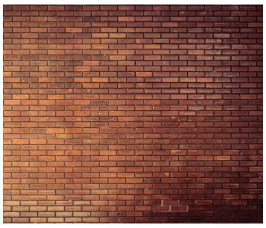


Figure 4.1 A brick wall.

What are atoms?

The early Greek philosophers proposed that all matter is made up of incredibly small but discrete units (like the bricks in our wall example). Democritus (460 – 370 BC) was the first to call these units *atomos*. From this phrase came the term *atom* that we use today.

Democritus first used the term 'atomos' more than 2 000 years ago to describe the smallest particle that matter is made of.

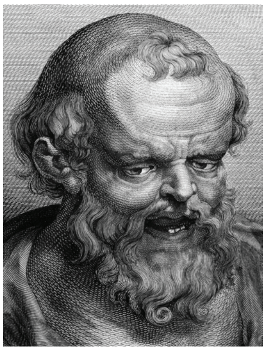


Figure 4.2 Democritus

Did you know?

Atoms are so small that until recently, it was impossible to see them, even using the strongest microscope. Nowadays there are microscopes connected to sophisticated computer software, which make it possible for scientists to actually 'see' atoms.

It took a very long time (more than 2 000 years!) for the ideas of Democritus to be accepted by scientists. Why do you think it took so long? Discuss this in your class.

Can you imagine how difficult it must have been to convince those early scientists that matter consists of really, really small particles that no-one has ever seen?

How small are atoms really? Well, about 5 000 000 000 000 000 000 of them would fit inside the full stop at the end of this sentence. Of course different atoms have different sizes, so this is just an approximate number. Wait... atoms have different sizes? How does that work? In the next section, we will find out.

What are elements?

Democritus's ideas about matter were ignored and forgotten for more than 2000 years, until an Englishman by the name of John Dalton reintroduced them to the scientific world in 1803. Dalton made five claims about atoms that are still largely accepted as the truth today. Three of these claims, or postulates as they are more commonly called, tell us how to understand elements. We will get to the remaining two postulates later. Here is what Dalton taught us about elements:

1. Each element consists of indivisible, minute particles called atoms.
2. All atoms of a given element are identical.
3. Atoms of different elements have different masses.

This ties in with what we learnt about the elements in Grade 7 *Matter and Materials*.

Let's revise what we already know:

- The Periodic Table of Elements was originally made to represent the patterns observed in the chemical properties of the elements.
- Each element has a fixed position on the Periodic Table of Elements.
- The elements are arranged in order of increasing atomic number.

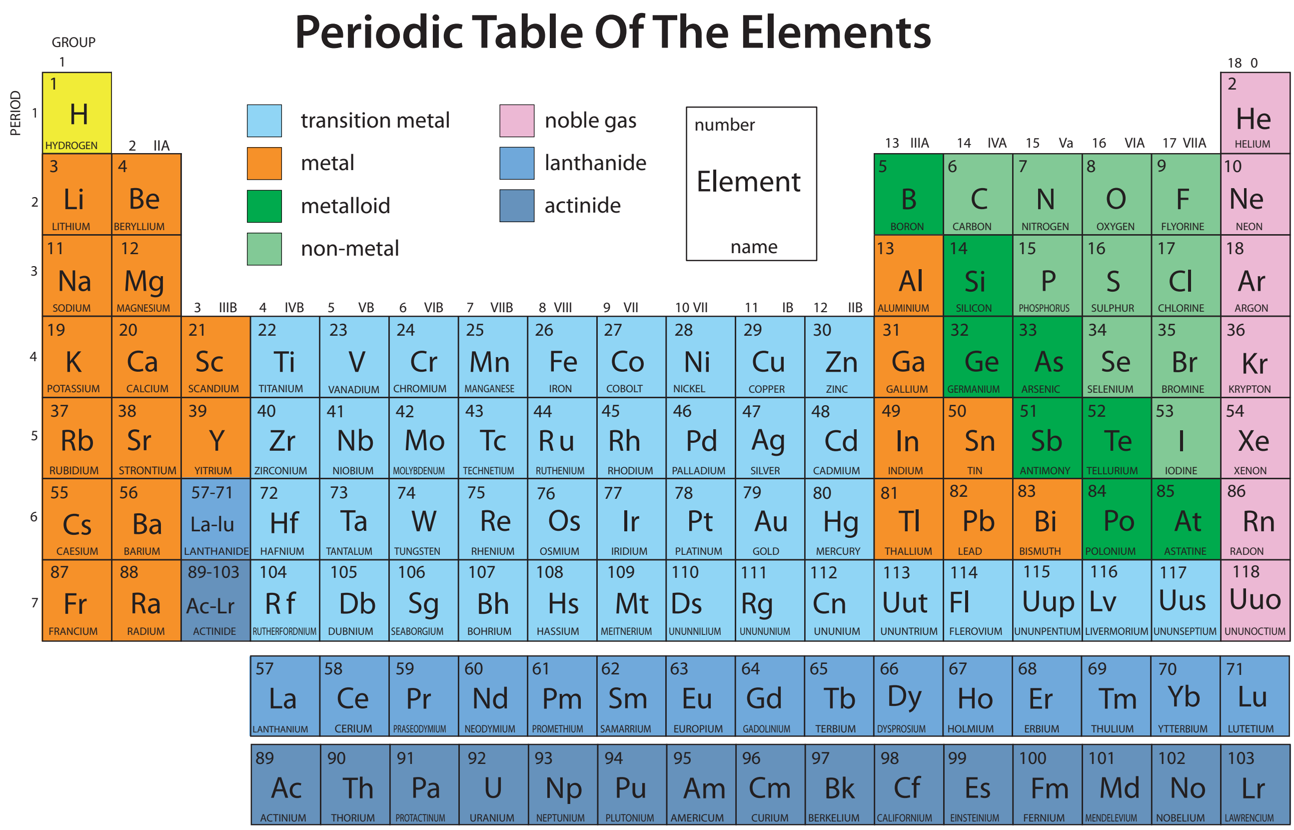


Figure 4.3 The elements are arranged in order of increasing atomic number.

ACTIVITY: A quick revision of the Periodic Table of Elements

Questions

1. In your own words, explain what you think the Periodic Table is.
2. Where do we find metals and where do we find non-metals on the Periodic Table?
3. What is the third class of elements called that we have learned about, and where are they found?
4. Give the symbols of two examples of metals and two examples of non-metals.
5. Complete the following sentence: The elements are arranged in order of increasing ________________
6. What is the atomic number of hydrogen, and what is the atomic number of carbon?
7. In your exercise books copy and complete the following table by supplying either the name or symbol for the elements listed, and whether it is a metal, non-metal, or semi-metal.

Did you know?

The only letter that does not appear on the Periodic Table is the letter 'J'.

Take note

You can find a larger version of the Periodic Table on the inside cover of your book for easy reference.

Name	Symbol	Metal or semi-metals?
Hydrogen		
	Li	
	Na	
Carbon		
	Si	
Magnesium		
	O	
	Cl	
Potassium		
Boron		
	Cu	

Are atoms really the smallest particles? Dalton thought so! He also postulated that:

Atoms can be neither created nor destroyed during chemical reactions

Dalton was correct in saying that atoms cannot be created or destroyed in chemical reactions. Does that mean atoms are the smallest particles of matter? Not exactly. Scientists have since discovered that atoms themselves are made up of even smaller particles. We call these sub-atomic particles.

We will learn about the sub-atomic particles that make up atoms shortly, but first we need to talk briefly about **scientific models**.

Do you know what a model car is? Look at the pictures below.

Figure 4.4 This is a photograph of a real car. It is about 2.5 m long.

Figure 4.5 This is a photograph of a model car. It is about 25 cm long.

Scientists use models to help them understand the real world and how it works.

Scientific models

Have you ever seen a geographical globe? The globe in the next picture on the left is a model of the Earth. What do you think it can be used for? Do you think we could learn more from a globe than from a map of the Earth?

Globes are the best representations we have of our planet, because they are three-dimensional. Can you think of some of the things we can learn about the Earth from a globe?

Figure 4.6 A globe of the world.

Sometimes a model can be an idea or a set of ideas; a simplified representation of difficult concepts or phenomena. A scientific model is a set of ideas that tells a story about something in the world around us, in the same way that the globe tells us a story about Earth.

A model of the atom

Atoms cannot be seen with the naked eye, only with very powerful microscopes. However, scientists have a good idea of how they behave in different situations. Based on these ideas, they have developed a model of what the atom looks like, to help us understand atoms better.

Figure 4.7 A map of the world.

The modern model of the atom teaches us that all atoms are made up of sub-atomic particles. Sub-atomic means 'smaller than the atom'. In the next section, we are going to learn more about these interesting little particles.

4.2 Sub-atomic particles

After many decades of studying atoms, scientists discovered that all atoms are made up of three different kinds of sub-atomic particles. They are called:

- protons
- neutrons
- electrons

The illustration of the atom shows how they all fit together. These three sub-atomic particles form the basis of our modern-day understanding of what atoms look like on the inside. Let's look at what is known about each particle in turn.

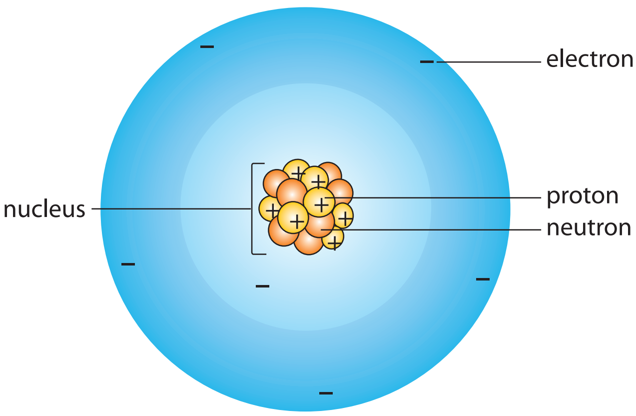


Figure 4.8 Protons, neutrons, and electrons are sub-atomic particles that make up an atom.

Keywords

- atomic nucleus
- sub-atomic particle
- electrons
- neutrons
- protons

> **Did you know?**
>
> If we could enlarge the size of the nucleus to the size of the full stop at the end of this sentence, the outer edges of the electron cloud surrounding it would be between 3 and 5 metres away.

Protons

The protons are deep inside the atom, in a zone called the nucleus. The protons are said to be positively charged. What does this mean?

To answer this question, think about the following phenomena that have been discovered by scientists:

- When two protons get near each other, they push each other away.
- When an electron gets near a proton, they attract each other.
- Two electrons will also push each other away.

What causes this? There must be some property of electrons and protons that make them apply these forces. Scientists use the word 'charge' to represent the property these particles have. We observe that:

- like charges repel (meaning the same charges push each other away)
- opposite charges attract.

Neutrons

Neutrons are particles that are neither positively nor negatively charged. They are neutral. The neutrons together with protons form the tightly packed nucleus at the centre of the atom.

Electrons

Electrons are negatively charged particles. Electrons are the smallest of the three sub-atomic particles. Electrons are about 2000 times smaller than protons and neutrons. The electrons move in a zone around the atomic nucleus at extremely high speeds, forming an electron cloud that is much larger than the nucleus. Have another look at the drawing which shows a model of the atom to see this. These three sub-atomic particles help us understand what atoms look like on the inside.

Do you remember Dalton's three postulates from the beginning of the unit?

They are:

1. Each element consists of minute, indivisible particles called atoms.
2. All atoms of a given element are identical.
3. Atoms of different elements have different masses.

So, each element on the Periodic Table has its own type of atom. The atoms of different elements are different as they have different numbers of protons. The **atomic number** of an element is the number of protons in an atom of that element?

1. So, if we wanted to make a model of a nitrogen atom, how many protons would we need?
2. If we wanted to make a model of a sulfur atom, how many protons would we need? In most atoms of an element, the number of neutrons in the nucleus is the same as the number of protons. The number of electrons can change, but for now we are going to make models of neutral atoms. So, there must be the same number of electrons as protons.

ACTIVITY: Make your own model of an atom

Materials

- glue
- paper plate
- playdough, beads, dried lentils or peas, etc

Instructions

1. After reading the information about atoms, your teacher will give you an element of which you have to build a model.

Questions

1. What is the name of your element?
2. What is the atomic number of your element?
3. How many protons will you need to make for your atom?
4. Now decide what objects you will use to create the subatomic particles in your model.
5. Stick these onto the paper plate and provide labels.
6. After you have built your model, draw a model of your atom.

Did you know?

The nucleus is very dense. That means the protons and neutrons are tightly packed and are very heavy for their size. If the nucleus was scaled up to the size of a full stop, it would weigh as much as a fully loaded minibus taxi, or 2,5 tonnes!

Can you remember learning about mixtures in Grade 7? You may remember that a mixture consists of two or more substances mixed together. The next section is NOT about mixtures. It is about substances that are not mixed with anything and consist of only one type of matter throughout. Such substances are called pure substances. In this sense, 'pure' simply means: not mixed with any other substances.

4.3 Pure substances

There are only two classes of pure substances, namely **elements** and **compounds**. To understand the difference between the two, look at the two diagrams below.

The diagram on the left represents an element. Can you see that all the atoms are of the same kind? An element is a material that is made up of atoms of only one kind.

The diagram on the right represents a compound. It shows two important things about compounds:

1. The compound consists of atoms, but there are more than one kind.
2. The different atoms are combined in little clusters, which are all exactly the same.

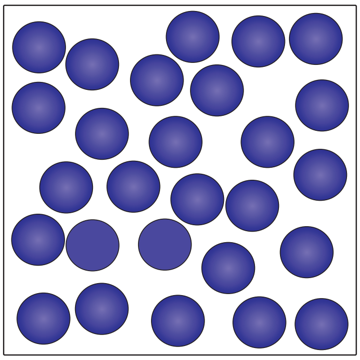


Figure 4.9 An element consists of atoms that are all the same kind.

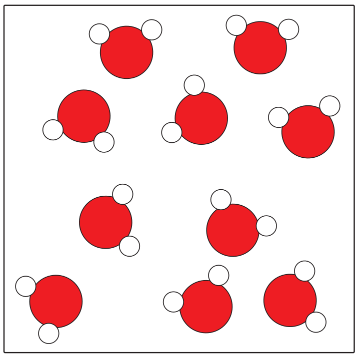


Figure 4.10 A compound consists of two or more kinds of atoms in a fixed ratio.

Keywords

- pure substance
- compound
- chemical bond
- molecule
- chemical formula
- chemical reaction
- decomposition reaction

Take note

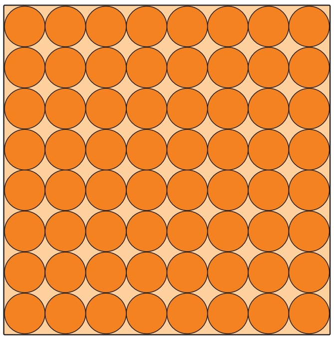
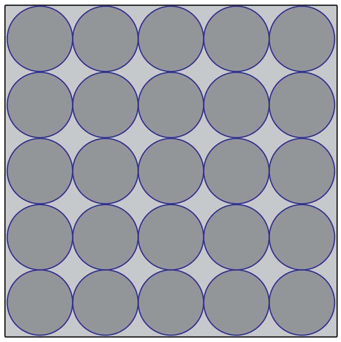
In these diagrams, the different coloured circles represent different atoms.

A compound is a material that is made up of two or more kinds of atoms that are chemically bonded together.

We are now going to explore each of these classes on their own and discuss some examples of each.

Elements

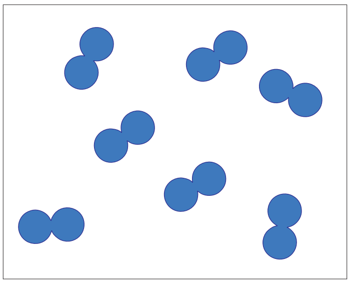
We have just learnt that an element is made up of atoms of the same kind. This means that if we had a piece of the metal copper, it would be made up entirely of copper atoms. Likewise, a piece of silver would be made up entirely of silver atoms. Copper and silver look different and have different properties, because they are made up of different atoms. Have a look at the following table, which illustrates the sub-microscopic image of the atoms, and also a piece of jewellery made from each of the different metals.

Copper	Silver
Sub-microscopic structure of copper  The element copper (Cu) consists of only copper atoms.	Sub-microscopic structure of silver  The element silver (Ag) consists of only silver atoms.
 Bracelets made of copper wire.	 Earrings made of silver.

ACTIVITY: Studying representations of atoms and elements

Questions

1. Why are the silver atoms bigger than the copper atoms in the previous diagrams? Hint: Find the two elements on the Periodic Table and compare their positions.
2. Do you think the substance represented in the diagram alongside is an element? To help you answer the question, go through the questions below the diagram.



   a) First write down what you see in the picture.
   b) Are the clusters tightly packed or far apart?
   c) What does that mean? Do you think the substance is a solid, a liquid or a gas?
   d) Do you think it is a mixture of substances or a pure substance? Why do you think so?
   e) Are the atoms all of the same kind?
   f) What class of substances is made up of only one kind of atom?
   g) Is the substance an element? Why?
   h) Can elements be made up of molecules?

The clusters of atoms in the previous activity are called molecules. **Molecule** is a very important word in chemistry. A molecule is two or more atoms that have chemically bonded with each other.

The atoms in a molecule can be of the same kind (in which case it would be a molecule of an element), or they can be of different kinds (in which case it would be a molecule of a compound).

Not all elements have molecules. The metals on the left-hand side and the middle part of the Periodic Table are solids at room temperature and so they exist as tightly packed arrays of atoms, like the previous examples of silver and copper.

Many of the non-metals on the right-hand side of the Periodic Table are gases at room temperature that exist as molecules made up of two atoms each. These are called **diatomic molecules**.

The picture of the element that we discussed earlier shows what diatomic molecules look like. Oxygen (O_2), nitrogen (N_2), hydrogen (H_2), chlorine (Cl_2) and some other elements from the non-metals all form diatomic molecules.

Take note

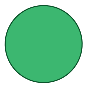
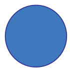
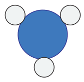
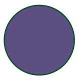
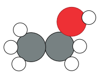
Diatomic refers to a molecule made of two atoms of the same element bonded together, as in oxygen (O_2). 'Di' means two. Triatomic refers to a molecule made up of three of the same atoms bonded together, such as ozone (O_3).

ACTIVITY: Atoms and molecules

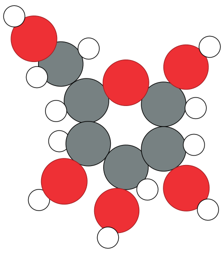
Let's make sure we understand the difference between atoms and molecules.

Questions

1. Look at the following diagrams. Decide whether each represents an atom or a molecule. If it is a molecule, state how many atoms make up the molecule.

Diagram	Atom or molecule?
	
	
	
	
	

2. Look at the following complex molecule.



a) How many atoms make up this molecule?
b) How many different types of atoms make up this molecule?
c) What holds the atoms together in this molecule?

If compounds consist of two or more kinds of atoms, this would mean that compounds are made of two or more different elements that have chemically bonded in a fixed ratio.

Compounds

A compound is a material that consists of atoms of two or more different elements. The elements are not physically mixed, but chemically bonded together at the atomic level.

There are at least 118 elements in our known universe. They can form compounds by bonding in millions of different combinations – far too many

Did you know?

The International Union of Pure and Applied Chemistry (IUPAC) name for water is dihydrogen monoxide.

to discuss here! We will look at a few simple combinations of elements to illustrate the idea.

Since water is such an important compound for organisms living on Earth, we will use that as our first example. Scientists know that a water molecule is made up of one oxygen atom and two hydrogen atoms. If we could see them, all water molecules would look a little bit like this diagram of a water molecule.

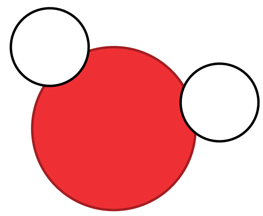


Figure 4.11 A representation of a water molecule.

All water molecules are exactly the same. We say the atoms are bonded in a *fixed ratio*: two hydrogen atoms for every one oxygen atom. The atoms in the molecule are held together by a special force that we call a '**chemical bond**'.

Chemical formulae

Can you remember that each element has its own unique chemical symbol? We can combine these symbols into a chemical formula for water. The **chemical formula** is another very important concept in chemistry.

The chemical formula for water is H_2O. It shows the ratio of hydrogen atoms (two) to oxygen atoms (one) in one molecule of water. What do you think the chemical formula CO_2 tells us?

In the next activity we are going to practise writing and understanding chemical formulae. It is always a good idea to think about a new concept in many different ways. For this reason, we are also going to build models of the molecules we are writing formulae for.

ACTIVITY: Writing and understanding simple chemical formulae

Materials

- play dough or plasticine clay in different colours

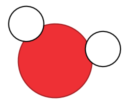
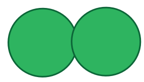
Instructions

1. In the following table, the names of some pure substances are given in the left-hand column. Copy the table in your exercise books and fill in all the empty blocks.
2. Build a model of one molecule of each of the compounds on the table. Your atoms should be roughly pea-sized. It may help you to build the model before drawing the molecule in the right-hand column. When you are done, show your teacher.

To help you do this, here are some guidelines:

- Each row in the table contains enough information for you to fill all the empty blocks.
- The first row has been filled in for you, so that you have an example:
- Column 1 contains the name: water
- Column 2 contains the formula: H_2O

- Column 3: The formula of water (in column 2) contains all the information we need to fill in the block in the 'What is it made of?' column. When we read the formula H_2O, the subscript '2' tells us there are two H atoms. Since O does not have a subscript, it means there is only one O atom.
- Column 4: The model of a water molecule must reflect that there is one O atom and two H atoms. How do we know that O must be in the middle? For now, it is enough to know that the atom that we have the least of, is usually in the middle.

Name of substance	Chemical formula	What it is made of?	What would a molecule of this compound look like (if we could see it)?
Water	H_2O	Two H atoms and one O atom	
Carbon dioxide	CO_2		
Sulfur dioxide			
Dihydrogen sulfide	H_2S		
Ammonia	NH_3		
Oxygen gas		Two O atoms	
Nitrogen gas	N_2		
Chlorine gas			
Hydrogen gas		Two H atoms	

Questions

1. List all the substances from the table that are elements. Write their names and formulae.
2. List all the substances from the table that are compounds. Write their names and formulae.
3. How did you know which of the substances in the table were compounds and not elements?

Water (H_2O), carbon dioxide (CO_2) and salt, or sodium chloride (NaCl), are examples of compounds, while oxygen gas (O_2), hydrogen gas (H_2) and nitrogen gas (N_2) are examples of elements.

The compound with the formula H_2O_2 also consists of hydrogen atoms and oxygen atoms. The formula tells us that one molecule of this substance is made up of two atoms of hydrogen and two atoms of oxygen. Is H_2O_2 the same as H_2O? What do you think?

Do not confuse H_2O_2 with H_2O.

H_2O_2 is a compound called hydrogen peroxide.

Hydrogen peroxide is similar to water in that it is a clear, colourless liquid at room temperature (25 °C) though not as runny, but it is different in many ways.

The following properties of hydrogen peroxide may convince you that it is not the same as water:

- Hydrogen peroxide has a boiling point of 150 °C and it is a very effective bleach for clothes and hair.
- Concentrated hydrogen peroxide is so reactive that it is used as a component in rocket fuel!

1. Hydrogen peroxide is extremely corrosive.
2. We can drink water, but hydrogen peroxide is very hazardous and harmful.

Take note

Corrosive substances are substances that cause damage to metal or other materials through a chemical process. Think of rainwater causing rust that eats away at metal.

If this doesn't convince you, let us compare what the hydrogen peroxide molecule looks like next to water:

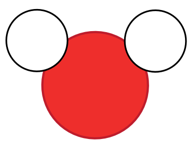


Figure 4.12 Water.

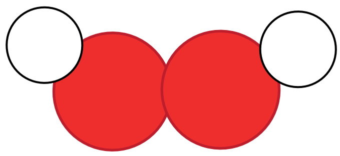


Figure 4.13 Hydrogen peroxide.

Even though they are made up of exactly the same elements, the two compounds are very different and should never be confused with one another.

The purpose of the comparison of hydrogen peroxide and water above was to show you that the atoms in a given compound are always combined in a fixed ratio. In all water molecules in the universe, there will always be one O atom and two H atoms bonded together.

This was the fifth of Dalton's postulates:

Atoms chemically combine in fixed ratios to form compounds.

How do atoms 'combine'? What makes them stick together to form molecules?

Chemical bonds

Look at the photo with the different arrangements of metal balls. These balls are magnetic and this allows you to make different patterns by sticking them together. What makes magnets stick together?

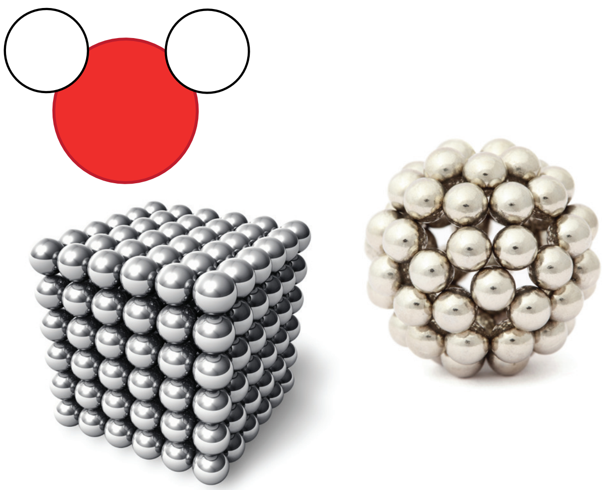
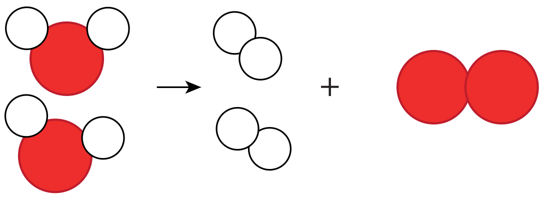


Figure 4.14 These balls are magnetic.

Magnets attract (or repel) each other because of a magnetic force between them (you will learn more about magnets in Grade 9). When atoms combine, they do so because they also experience an attractive force. The force is slightly more complex than the force between magnets, but it works in the same way: the force holds atoms together as if they are stuck together with glue. The forces that hold atoms together are called chemical bonds.

- What would happen if we had enough energy to break those bonds? What would we have if we separated water molecules into their atoms?
- Theoretically, we would have hydrogen and oxygen atoms.
- What actually happens is that the hydrogen atoms immediately combine to form H_2 and the oxygen atoms immediately combine to form O_2.



- When atoms separate from each other and recombine into different combinations of atoms, we say a **chemical reaction** has occurred. In the above chemical reaction, the water has decomposed (broken up) and recombined into smaller molecules. We say that water has undergone a **decomposition reaction** in the example above. Of course, not all chemical reactions are decomposition reactions. There are many different kinds of chemical reactions, and we are going to investigate some examples in the next section.

Chemical reactions

Two important events happen in all chemical reactions:

- Chemical bonds break.
- New chemical bonds form.

This means that, in all chemical reactions, the atoms in the molecules rearrange themselves to form new molecules.

In the next activity, we are going to simulate the decomposition reaction of water using clay or playdough balls to represent the different atoms.

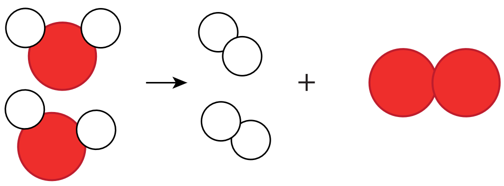
ACTIVITY: Imagining the decomposition of water at the scale of molecules

Materials

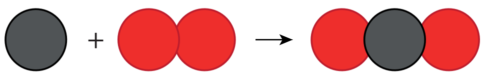
- playdough or plasticine clay in two different colours

Instructions

1. Build two water molecules from the clay or playdough. Look at the previous pictures to remind you what a water molecule looks like. You may use any colour clay to build yours.
2. Now break all the bonds holding the molecules together, separating them into individual atoms.
3. Answer the following questions
   a) How many hydrogen (H) atoms do you have?
   b) How many oxygen (O) atoms do you have?
4. Combine the hydrogen and oxygen atoms into hydrogen molecules (H_2) and oxygen molecules (O_2).
5. Answer the following questions
   a) How many hydrogen molecules could you build from the H atoms?
   b) How many oxygen molecules could you build from the O atoms?
6. Write a chemical equation for the reaction that you have just built with the clay models? Look at the diagram for inspiration:



7. Let us look at another example of a chemical reaction: the reaction when carbon (in coal) reacts with oxygen (in the air) to form carbon dioxide:



   You can use the play dough balls to simulate this reaction.
   a) Try to write a chemical equation for the reaction when carbon and oxygen combine to form carbon dioxide. (Hint: Use the diagram to guide you.)

Next, your teacher will demonstrate two chemical reactions to the class. Watch carefully and write down your observations, which is what you can see happening.

Investigation: The decomposition of copper chloride

Aim

To determine whether it is possible to decompose copper chloride using electrical energy.

Materials and apparatus

- beaker
- cardboard disk large enough to cover the top of the beaker
- two graphite electrodes
- two small pieces of wire
- copper chloride solutions
- 9-volt battery

Make the following observations before starting:

1. What colour is the copper chloride solution?
2. What colour are the graphite electrodes?

Method

1. Pour the copper chloride solution into the beaker.
2. Make two small holes, as shown in the cardboard disk and push the electrodes through the holes, as shown in the following diagram.
3. Place the disk over the beaker, so that the greater part of each electrode is under the surface of the solution.
4. Connect the tops of the electrodes to the ends of the battery using the wire lengths. Have a look at the diagram of the experimental set-up.
5. Allow the reaction to proceed for a few minutes and observe what happens.
6. When the reaction has proceeded for approximately 10 minutes, the wires can be disconnected and the set-up disassembled.

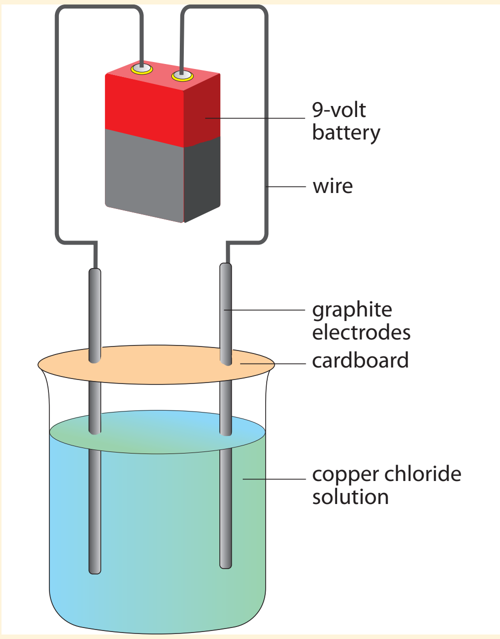


Figure 4.15 The demonstration that your teacher sets up might look something like this.

Observations

1. After the reaction had proceeded for a few minutes, what do you observe on the surface of the two electrodes?
2. At the end of the experiment, what colour was the copper chloride?
3. How did the appearance of the graphite electrodes change?
4. Summarise your experimental observations in the following table.

Take note

The electrode attached to the positive side of the battery is the positive electrode and is called the anode. The electrode attached to the negative side of the battery is the negative electrode and is called the cathode.

	The copper chloride solution	Electrode 1 (called the anode)	Electrode 2 (called the cathode)
Before the experiment			
After the experiment			

Analysis and discussion

1. What gave the copper chloride solution its intense blue colour?
2. Do you think that some of the copper chloride may have changed into something else during the reaction? Explain why you think so.
3. How would you explain the bubbles on the surface of the first electrode? Do you have any idea what they might have been? Hint: What did the electrode smell like afterwards?
4. Do you know what the reddish-brown coating on the second electrode is? Hint: Which metal has that same characteristic reddish-brown colour?
5. How do we know that a chemical reaction has occurred?

Conclusion

Write a conclusion for the investigation. In your conclusion you should rewrite the aim of the investigation into a statement about the findings of your investigation.

Do you think it would have been possible to separate the copper chloride into copper and chlorine by any of the physical separation methods that we learnt about in Grade 7 *Matter and Materials*, such as sieving, filtering, evaporation, distillation or chromatography? Here is a hint: None of those methods are able to break the bonds between atoms in a substance.

The answer is no. Copper and chlorine are chemically bonded in copper chloride. We know this from its chemical formula: $CuCl_2$. Physical separation methods can be used only to separate **mixtures** into the substances they are made up of.

We have learnt about atoms, molecules, elements and compounds so far. These are sometimes confusing concepts because they describe things that are too small to see and sometimes difficult to imagine. In the next section we are going to return to the idea of mixtures and see how everything we have learnt so far can be placed into a scheme for classifying matter and materials.

4.4 Mixtures of elements and compounds

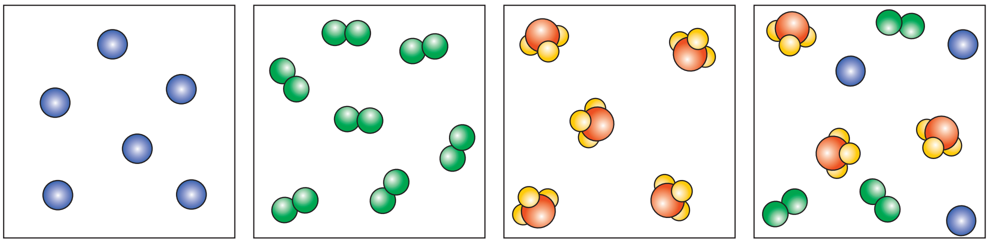
In Grade 7 Matter and Materials we learnt that a mixture is a combination of two or more materials. In this unit we learnt about pure substances. Pure substances always consist of one type of matter throughout. That matter can be an element or a compound and we have learnt how to distinguish between them by looking at the different kinds of atoms they are made up of:

Keywords

- mixture
- distinction

- Elements are made up of just one kind of atom.
- Compounds are made up of more than one kind of atom, but always combined in a fixed ratio.

All material can be classified as either a pure substance (in other words, just one substance throughout), or a mixture of substances. Let's look at some diagrams to help us understand this **distinction** a little better.



a) Atoms of an element
b) Molecules of an element
c) Molecules of a compound
d) Mixture of elements and a compound

Figure 4.16 Diagrams to show the difference between elements, compounds and mixtures.

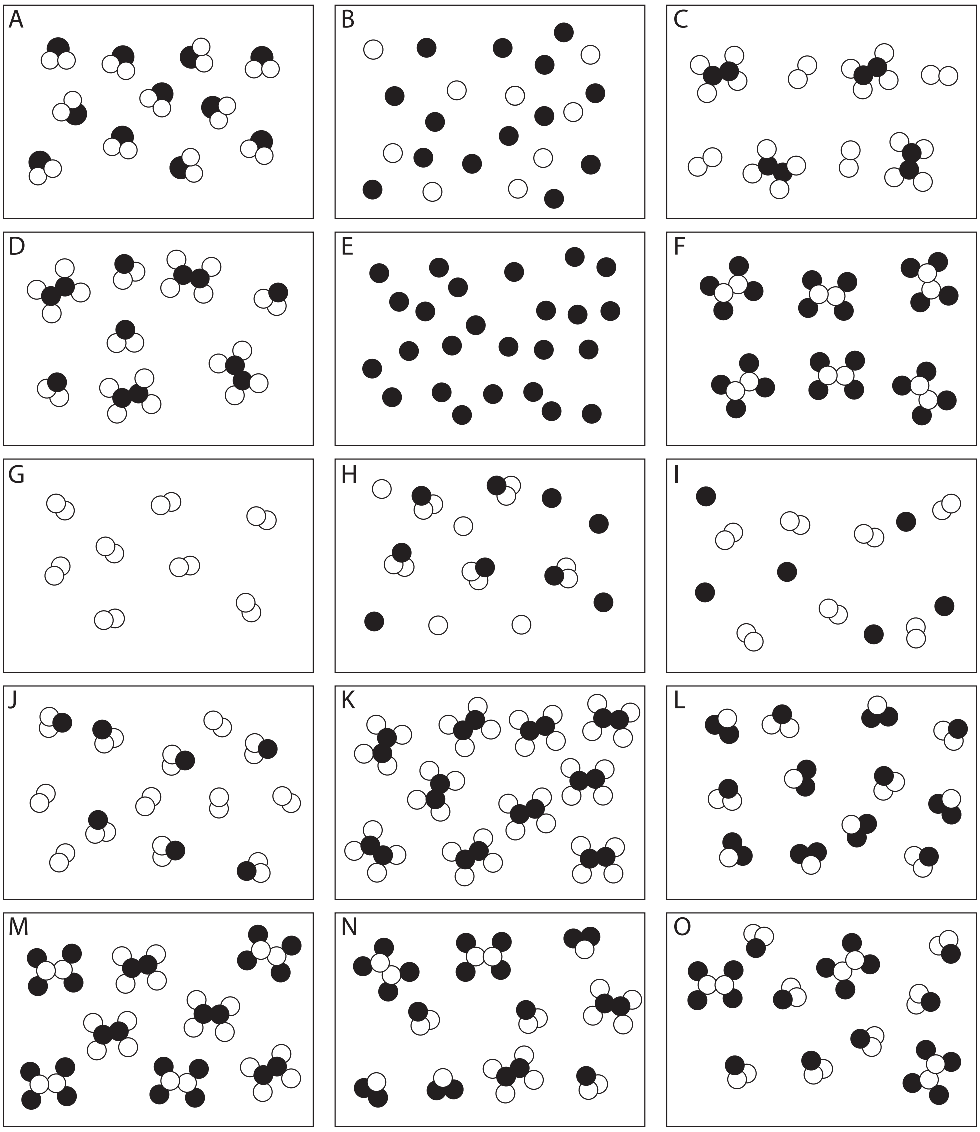
- The two diagrams on the left (a and b) summarise what we know about the particles in elements, namely that an element can consist of atoms or molecules, but that the atoms in a certain element are always of only one kind.
- What special name do we give to the molecules of elements which consist of two atoms bonded together?
- Diagram (c) shows that the molecules of a compound consist of two or more different kinds of atoms, but in a given compound they will always be bonded in the same fixed ratio. Think of the example of water (H_2O) and hydrogen peroxide (H_2O_2) that we saw earlier.
- Diagram (d) shows how elements and compounds are different from mixtures. Elements and compounds are both pure substances (they have the same kinds of particles throughout), while mixtures always have more than one kind of particle. We find mixtures of elements and compounds in many places in the natural world, such as in the air, sea water, rocks, and living organisms.
- In the next activity, let's see if we can apply these principles to distinguish between different possibilities.

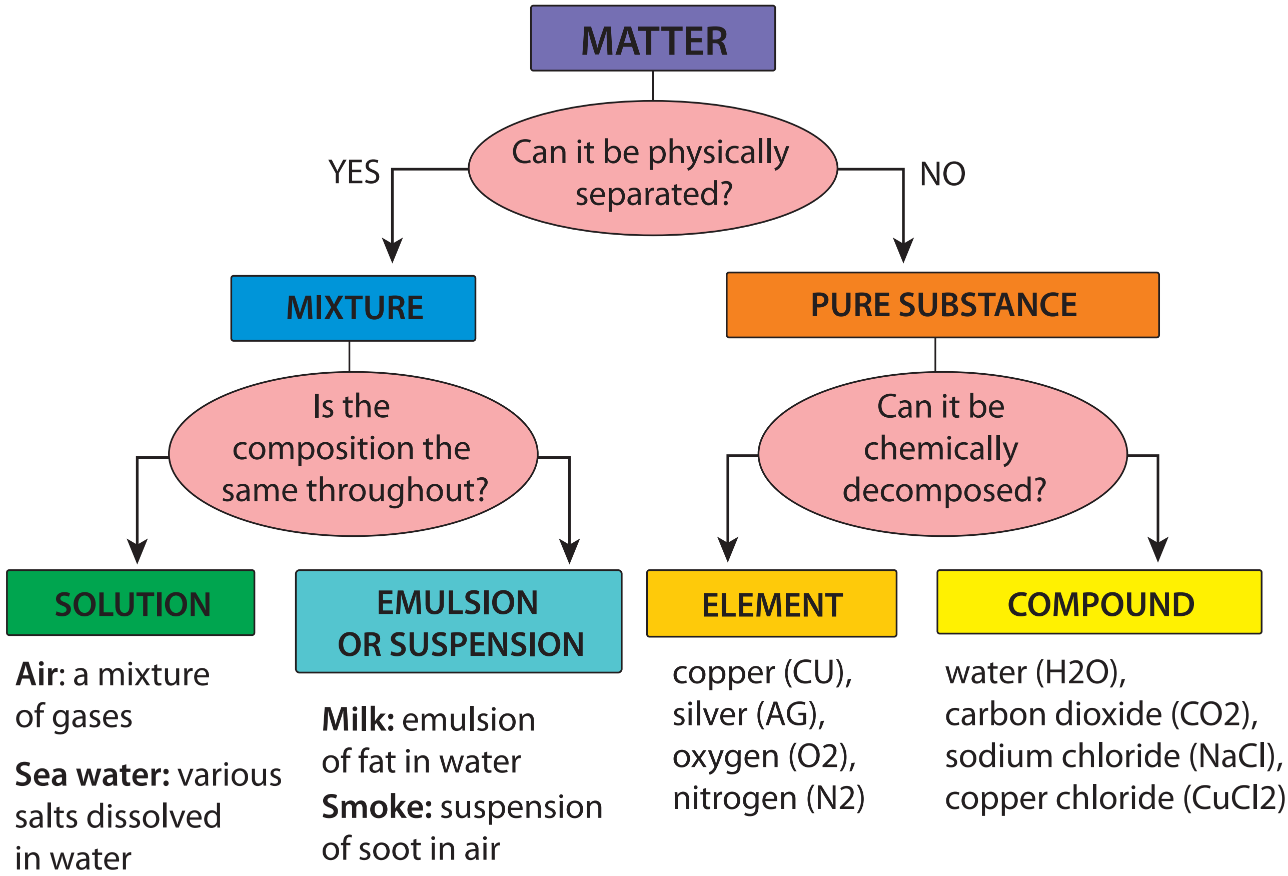
ACTIVITY: Distinguishing between elements, compounds and mixtures

Instructions

1. Each of the 15 blocks contains a diagram representing atoms and molecules of matter.
2. You must classify the matter in each block using only the letters A to E to identify the categories:
   A = element
   B = compound
   C = mixture of elements
   D = mixture of compounds
   E = mixture of elements and compounds

You may find the following chart useful to help you understand how all these concepts fit together.





The flow diagram brings together all the different classes of matter we learnt about in this unit. It puts them all into a scheme that helps us see how the different classes are related to each other.

Summary

Key concepts

Atoms

- All matter is made up of tiny particles called atoms.
- The atoms of each element are unique and essentially identical to each other.
- All the known elements are listed on the Periodic Table.

Sub-atomic particles

- The three main sub-atomic particles that determine the structure of the atom are protons, neutrons and electrons.
- Protons are positively charged and are found in the nucleus, deep in the centre of the atom.
- Neutrons are similar to protons in size and mass, but they do not carry any charge (they are neutral). They are also found in the atomic nucleus.
- Electrons are negatively charged particles, much smaller than protons and neutrons. A cloud of fast-moving electrons surrounds the atomic nucleus.
- In a neutral atom, the number of protons always equals the number of electrons; hence the atom is neutral.

Pure substances

- All matter can be classified as mixtures of substances or pure substances.
- Pure substances can be further classified as elements or compounds.

Elements

- All the atoms in an element are of the same kind. That means that an element cannot be changed into other elements by any physical or chemical process.
- Elements can be built up of individual atoms, or as bonded pairs of atoms called diatomic molecules.
- When atoms of different elements combine, they form compounds.

Compounds

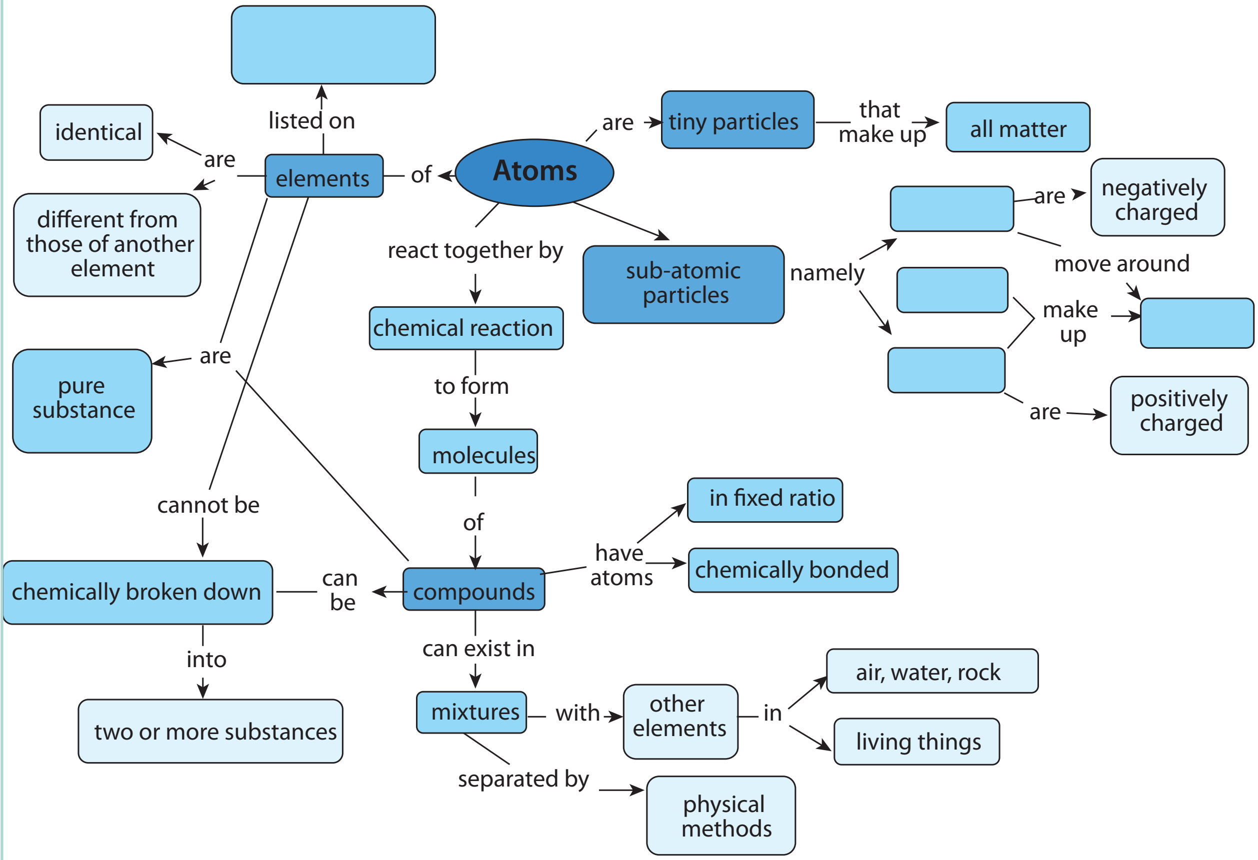
- In a compound, atoms of two or more different kinds are chemically bonded in some fixed ratio.
- The atoms that make up a molecule are held together by special attractions called chemical bonds.
- Compounds can be formed and broken down in chemical reactions.
- A chemical reaction in which a compound is broken down into simpler compounds and even elements, is called a decomposition reaction.
- Compounds cannot be separated by physical processes, but they can be separated into their elements (or simpler compounds) by chemical processes.

Mixtures

- Mixtures are combinations of two or more elements and/or compounds.
- The components in a mixture can be separated by physical separation methods, such as sieving, filtration, evaporation, distillation and chromatography.

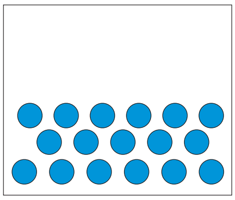
Concept map

The concept map summarises all that we have learnt in this unit about atoms, elements, compounds and mixtures. You need to complete the concept map by filling in the name of the table that lists all the elements, and the names of the three sub-atomic particles. You need to look at the concepts which come afterwards to determine which sub-atomic particle must be placed in which space.



Revision

1. Name the three sub-atomic particles that atoms are made up of. [3]
2. Draw a picture of the atom. Your picture must show all three different types of sub-atomic particles. [4]
3. Read the following statements, and answer the questions that follow:
   a) Some elements consist of molecules.
   b) All compounds consist of molecules.
      (i) Do all elements consist of molecules? Explain your answer briefly. [2]
      (ii) Can you think of at least three examples of elements that do NOT consist of molecules? Write down their names and formulae. [6]
      (iii) Give examples of three elements that exist as molecules. Write down their names and formulae, and draw one molecule of each. [3 × 3 each = 9]
4. Give examples of three compounds. Write down their names and formulae, and draw one molecule of each. [3 × 3 each = 9]
5. How are the molecules of an element different from the molecules of a compound? You may use drawings in your explanation. [4]
6. Each of the nine blocks below (labelled A to I) contain some matter. Use the illustrations to answer the questions that follow. Each question may have more than one answer! [7]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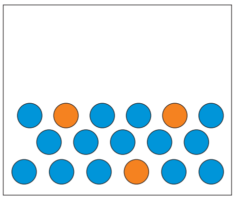
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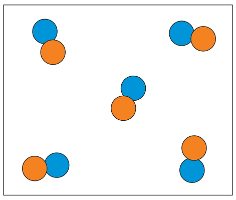
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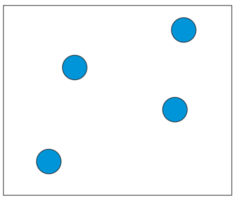
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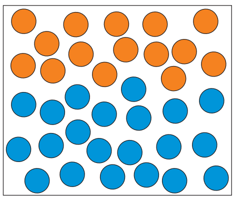
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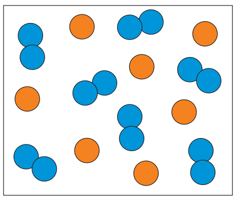
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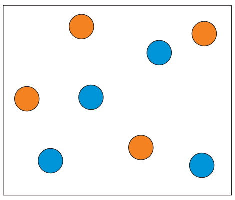
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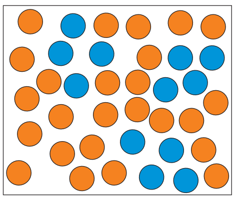
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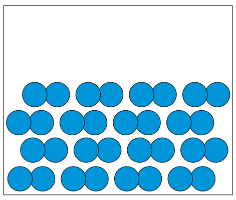

I

   a) Which blocks represent the particles of an element?
   b) Which block represents the particles of a compound?
   c) Which block represents the particles of a mixture?
   d) Which block represents the particles of a pure substance?
   e) Which block represents diatomic molecules of an element?
7. What is the difference between mixtures and compounds in terms of how we can separate them? [2]

Total [46 marks]

5 Particle model of matter

Key questions

- What is the particle model of matter?
- How small are atoms and molecules?
- How does the particle model of matter describe solids, liquids and gases?
- How does the particle model of matter help us understand the process of diffusion?
- How can materials be made to change their state?
- How does the particle model of matter help us to understand changes of state in materials, such as melting, evaporation, condensation and freezing?
- How are density, mass and volume related to each other?
- Which aspects of the particles in a given material influence the density of that material?
- Why does oil float on water? Is this related to density?
- How can the particle model of matter help us to understand expansion and contraction?
- How does a gas exert pressure?
- Is the pressure a gas exerts related to the number of gas particles? If so, how?
- What happens to pressure when we change its volume and temperature?

Keywords

- scientific theory
- phenomenon
- disordered
- uniform
- random
- reverse
- controlled experiment

Can you remember learning that matter can exist in three different states?

What are the three states called?

Can you remember the properties of the different states of matter? Discuss this in your class. Look at the following diagram of the states of matter to help you. Remember to take some notes as you discuss in class.

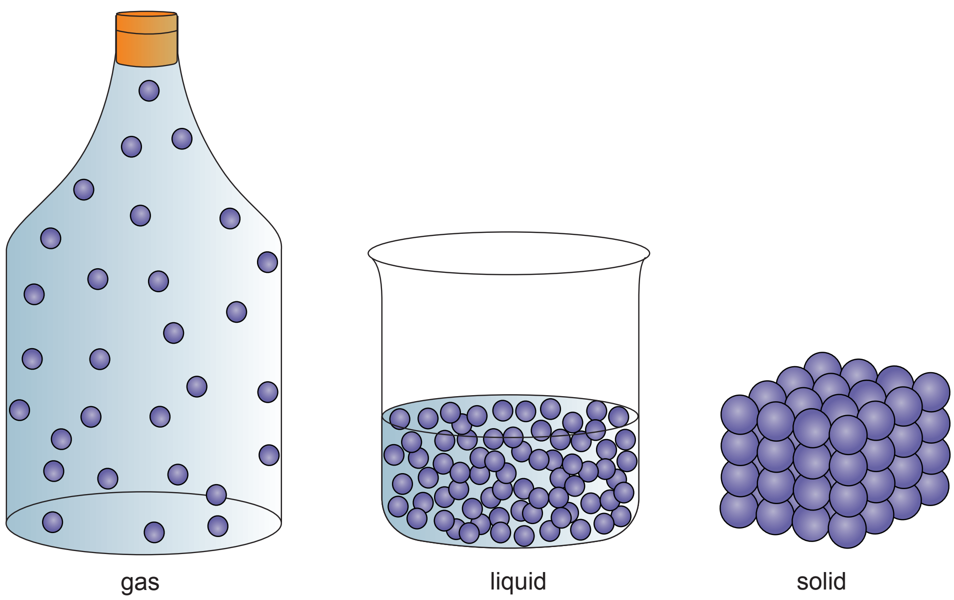


Figure 5.1 Each state of matter behaves differently and the particles in each state behave differently. This diagram compares the particles in a gas, a liquid and a solid.

In this unit we are going to review what we know about solids, liquids and gases. We are going to learn about a scientific model that can be used to describe how the particles in all three states behave. This model is called the particle model of matter and it will help us understand much more about the properties of solids, liquids and gases. Let's get started!

5.1 What is the particle model of matter?

In the previous unit we learnt that scientists use models when they want to describe things that are difficult to understand. We discussed a model of the atom that helped us to imagine what atoms look like.

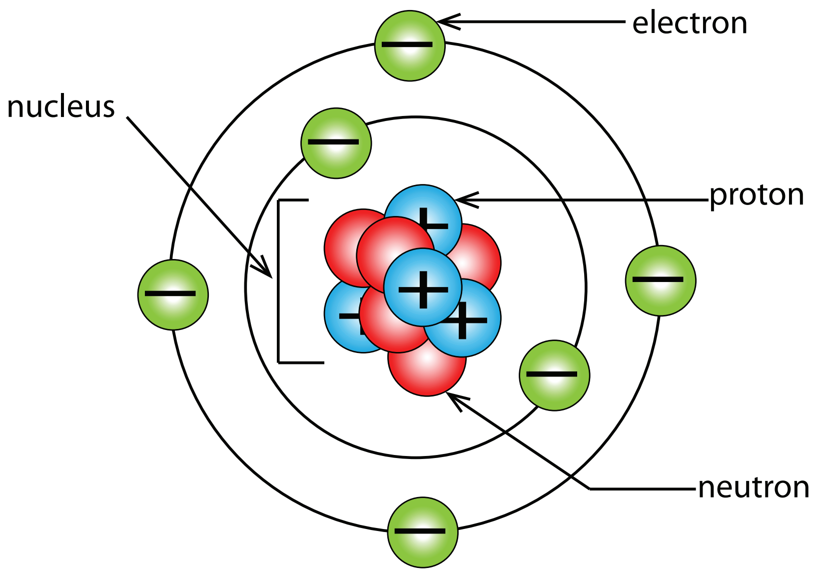


Figure 5.2 This model of the atom shows us where the different sub-atomic particles can be found. The sub-atomic particles shown here are the proton, neutron and electron.

Theories are similar to models. They explain scientific **phenomena** (things and events that can be described and explained in scientific terms) using pictures and words.

What does the particle model of matter teach us?

The particle model describes matter in a very specific way. It describes four important aspects of matter:

- All matter is made up of particles that are incredibly small – much too small to see with the naked eye. The particles can be atoms and combinations of atoms that are bonded.
- There are forces between the particles.
- The particles in matter are always moving. The more energy they have, the faster they move.
- The spaces between the particles in matter are empty. You might assume that the spaces between particles are filled with air, but this is not the case. They contain nothing at all.

Take note

If you need to, turn back to unit 1 to revise the terms atom, element, compound and molecule and how they relate to each other.

Did you know?

Under special circumstances, a solid can change directly into a gas without melting first. This process is known as sublimation and its reverse (when a gas changes directly into a solid without condensing first) is called deposition.

Why is the particle model of matter so useful?

The particle model of matter is one of the most useful scientific models because it describes matter in all three states. Understanding how the particles of matter behave is vital if we hope to understand science!

The model also helps us to understand what happens to the particles when matter changes from one state to another.

The following diagram shows different changes of state, as well as which processes are the **reverse** of each other. Melting and freezing are the reverse processes of each other and so are evaporation (boiling) and condensation.

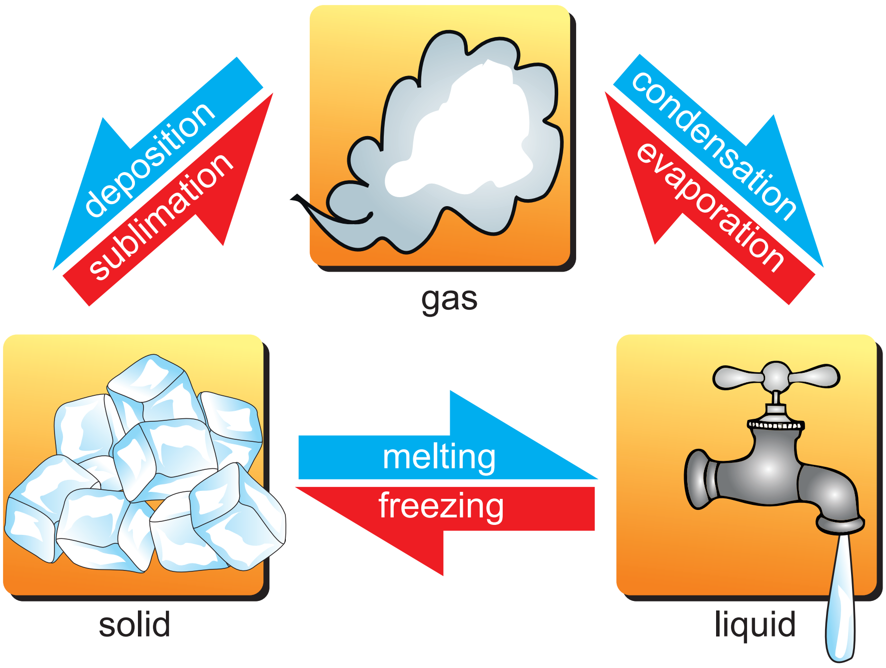


Figure 5.3 The change of states.

ACTIVITY: Changes of state revision

Instructions

1. Refer to the previous diagram.
2. Check that you remember some of the concepts you learnt about in previous grades by going through these quick questions.

Questions

1. What is the name of the process when a solid turns into a liquid?
2. What is the reverse process to melting?
3. What can we do to make ice melt quickly?
4. Explain the steps that a solid must go through to become a gas.
5. What is the reverse process of evaporation?
6. When we heat something, are we adding energy to it, or taking energy away?
7. How do you think the particles in a substance behave when we give them more energy?

We will use the model to look at each of these changes more closely. But first, we will look at how the model describes each state of matter.

5.2 Solids, liquids and gases

We can use the particle model to help us understand the behaviour of each of the states of matter. We are going to look at each state in turn. There is one very important thing to remember when we consider the different states of matter. For any matter, the individual particles of that matter are exactly the same in all three states, solid, liquid and gas. It is the *behaviour* of the particles that changes in each state.

Keywords

- compress
- collide
- diffuse
- rate
- constant motion
- observation
- forces of attraction
- regular arrangement
- vibrate

The solid state

Solids keep their shape and cannot be **compressed**. Let us see if the particle model can help us understand why solids behave in this way. In a solid, the particles are packed close to each other in fixed positions. They are locked into place, and this explains why solids have a fixed shape. Look at the following images of sodium chloride (table salt). Do you remember the formula for sodium chloride?

Macroscopic view of sodium chloride	Submicroscopic view of sodium chloride

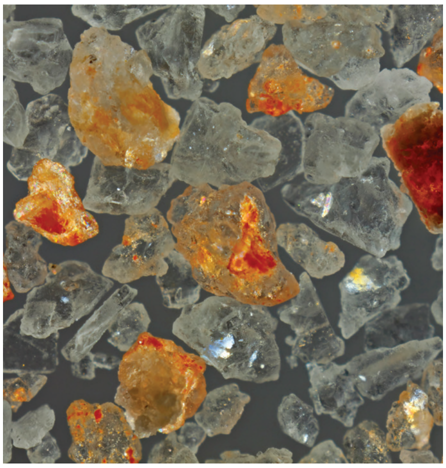
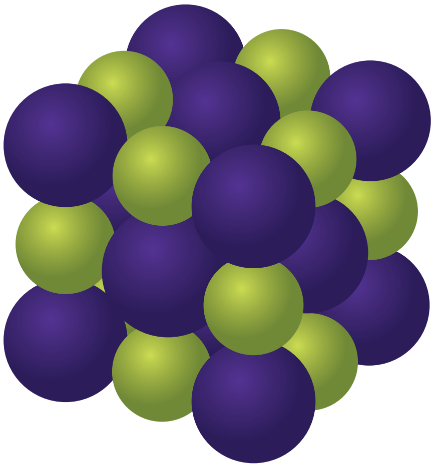

	

Table salt crystals are hard and have a fixed shape.	Can you see how the chloride atoms (purple) alternate with the sodium atoms (yellow) in a fixed arrangement?

Take a good look at the picture of the particles in a solid (table salt) above. You will see that they are packed in a **regular arrangement**. There are very small spaces between the particles in a solid.

Particles are held together by **forces of attraction**. In solids, these forces are strong enough to hold the particles firmly in position.

Does that mean the particles in a solid do not move at all? No. The particles in a solid move a little bit. They **vibrate** in their fixed positions. The more energy the particles have, the faster and more strongly they vibrate.

Do you see how we have used the particle model of matter to explain the properties of solids that we can **observe**? For example, the particles in solids are closely packed and have strong forces between them explains why solids have a fixed shape and you cannot compress them.

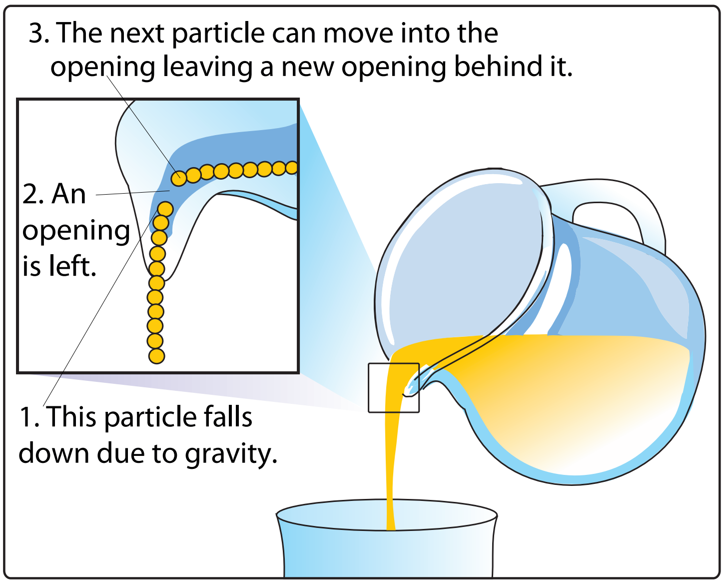
The liquid state

An important characteristic of liquids is that they flow. They fill containers they are poured into. Liquids are also not very compressible. How can these properties be explained? In the liquid state, particles do not have fixed positions. They move about freely, but they stay close together because the forces of attraction between them are quite strong, but not as strong as in solids.

Figure 5.1 Orange juice is a liquid, which can be poured.

Have you noticed how a liquid always takes the shape of the container it is in? Within the liquid, the particles slip and slide past each other. This is why liquid flows. Their particles are free to move around, filling the spaces left by other particles. Look at the image of the juice being poured. Let's zoom in and have a look at what the particles are doing as the juice is poured.

The particles in a liquid have small spaces between them, but not as small as in solids. The particles in a liquid are loosely arranged which means they do not have a fixed shape like solids, but they rather take the shape of the container they are in.



The speed at which the particles move around inside the liquid depends on the energy of the particles. When we heat a liquid, we are giving the particles more energy and speeding them up.

In gases, the particles move at even greater speeds.

The gaseous state

Gases spread out quickly to fill all the space available to them. Think of when you blow up a balloon. The air that you blow into the balloon fills up the whole balloon. A gas will fill the entire space that is available to it. This is because the particles in a gas have no particular arrangement.

Gases do not have a fixed shape. Think about the balloon again: the gas fills the entire space inside the balloon. You can squeeze the balloon, changing the shape.

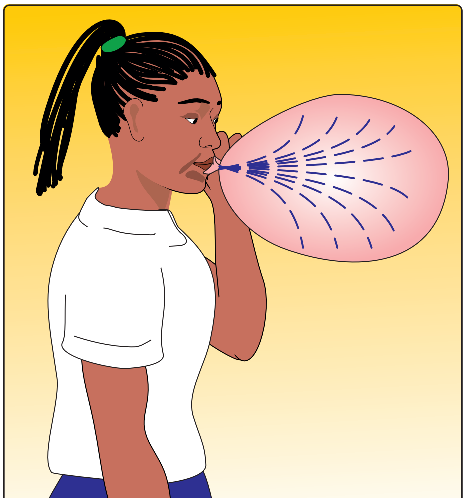


Figure 5.4 Gases fill the space available to them.

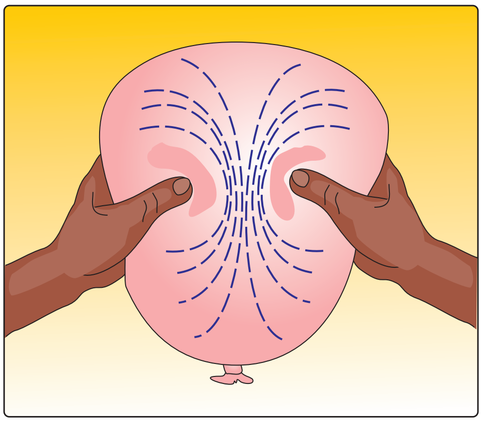
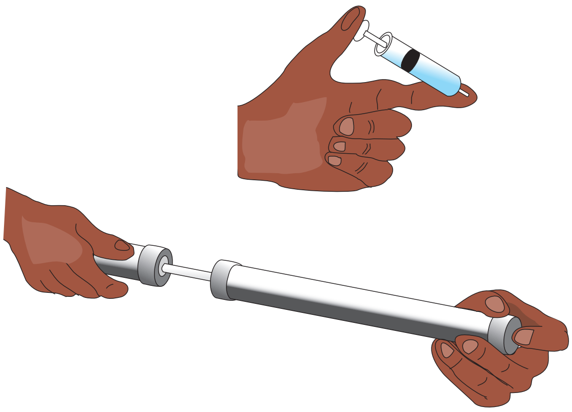


Figure 5.5 Gases do not have a fixed shape.

Gas particles move very fast, much faster than in solids and liquids. The particles in a gas possess a lot of energy.



Have you ever tried to compress the gas in a syringe or in a bicycle pump? Why do you think you can compress the gas?

In gases, the forces between particles are very weak. This explains why the particles in gases are not neatly arranged. They are not held together tightly and there are large spaces between them. These spaces are much larger than in the solid and liquid state.

Gases can be compressed, because their particles can be forced closer together. Look at the photo of a scuba diver underwater. Do you see the tank on his back? He uses this tank to breathe underwater. A scuba diver can stay underwater for almost an hour. How do you think he can get enough air to breathe for a whole hour from a small tank like that? Discuss this with your class.

Figure 5.6 A scuba diver underwater with a tank of air.

ACTIVITY: Comparing solids, liquids and gases

Let's summarise what we have learnt about what the particle model of matter tells us about solids, liquids and gases.

Instructions

1. Use the images of the different states to help you, and revise the text in your books.

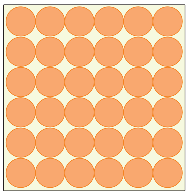
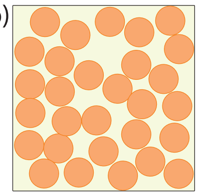
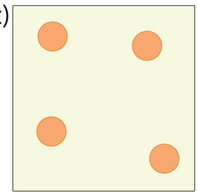
	Solid	Liquid	Gas
Arrangement of particles	a) 	b) 	c) 
Movement of particles			
Forces between particles			
Spaces between particles			

Figure 5.7 Has anyone ever set off a stink bomb near you?!

Questions

1. Use the particle model of matter to explain why solids have a fixed shape, but gases fill the shape of the container they are in.
2. Use the particle model of matter to explain why you can compress a gas easily, but you cannot compress a liquid very easily.
3. Think of a bag of cake flour. You can pour the cake flour out of the bag and into a mixing bowl. Does this mean the flour is a liquid? Explain whether you think the cake flour (and all powders) are solids or liquids.

Diffusion


Figure 5.8 You can often smell garbage bins when you walk past them.

Have you ever noticed how quickly smells travel? Perhaps you have walked past a rubbish bin, and smelled the garbage.

Have you ever smelled a stink bomb? When you smell these things, how do the 'stink bomb' or 'garbage' particles reach your nose?

Most smells travel fast, because their particles mix with air and get into our noses when we breathe. We say that the particles **diffuse** through the air.

In Grade 7 we learnt about different kinds of mixtures. In the next investigation we are going to explore whether particles mix faster when they are in the liquid state or in the gas state. This is called the **rate of diffusion**. What would your prediction be?

investigation: Comparing the diffusion of particles in a gas and in a liquid

Investigative questions

1. Do particles diffuse (mix) faster when they are in the liquid state or in the gaseous state? Which particles will mix more quickly: gases or liquids?

Hypothesis

What are your predictions? Do you expect liquids to mix more quickly than gases, or the other way around? Will stirring influence the speed at which gases mix? Write down your hypothesis.

Identify variables

This is not a controlled experiment as we are not measuring the rates of mixing of the liquids and gases under exactly the same conditions. We will make a simple comparison of the mixing rates, by seeing how long it takes each to mix under two different sets of conditions.

Materials and apparatus

1. large glass beaker or other large clear glass container
2. dropper
3. food colouring or ink
4. tap water
5. vanilla essence
6. shallow dish or saucer

Method

Part 1: How fast do liquids mix?

1. Fill a large, clear container with tap water and place it where everyone can see it.
2. Use a dropper to place one or two drops of the food colouring in the water.
3. Record the time at which the colouring is added to the water.
4. Look carefully at the two liquids mixing, and write your observations in your exercise books. Allow the liquids to mix without any stirring.
5. Record the time when the liquids are fully mixed, in other words, when the colour is uniformly spread throughout the water.

Part 2: How fast do gases mix?

This experiment should be performed with the windows closed.

1. Raise your hand as soon as you can smell vanilla essence.
2. Pour some vanilla essence into the saucer.
3. Record the time when the vanilla essence is poured out.
4. Record the time when the first learner puts up his/her hand to indicate that they can smell the vanilla essence.
5. Record the time when roughly half of the learners in the class have their hands up, to indicate that they can smell the vanilla essence.

Take note

When we talk about a rate, we are measuring how something changes in relation to another factor, such as time. Another example is speed measured in km/h – this is a rate of how distance in kilometres changes over a period of time (hours).

6. Record the time when the learners at the back of the class first smell the vanilla essence.
7. If there is enough time during your next Natural Sciences lesson, repeat steps 1 – 5. You should do everything exactly the same, but this time, you should move your arms and try to 'wave' the air towards the back of the class.

Results and observations

1. What did you observe in the container immediately after the liquids were mixed?
2. How long did it take for the liquids to be fully mixed, until the colour was uniformly spread throughout the water?
3. When you did NOT wave your arms during the experiment:
   a) How long did it take until the first learners smelled the vanilla essence molecules?
   b) How long did it take until the last learners smelled the vanilla essence?
4. When you DID wave your arms during the experiment:
   a) How long did it take until the first learners smelled the vanilla essence molecules?
   b) How long did it take until the last learners smelled the vanilla essence?
5. Draw a table with your results for the vanilla essence experiment. You can choose your own column and row headings. Remember to give your table a heading.

Analysis and evaluation

1. Did anything go wrong during the experiment?
2. Can you think of anything that could have improved this experiment?

Conclusion

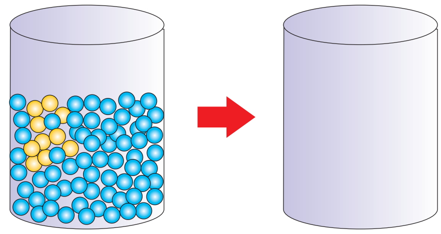
What are your conclusions? (What are your answers to the investigative questions?)

In this investigation we explored the rates at which particles diffuse. What do you think happens at the particle level when two substances mix?

In the photos, we see food colouring added to water. Notice how the liquid swirls and spreads out as the particles mix with the colourless particles of the water. Of course we cannot see the particles, but we can make a macroscopic observation (something we can see with the naked eye) of the process.

What will the mixture look like when the coloured particles are uniformly spread out amongst the water molecules?

What will the mixing process look like on particle level? The following diagram represents one of the glasses pictured above, containing a colourless liquid (represented by the blue circles) to which a yellow liquid (represented by the yellow circles) is added. The glass on the left shows the particles in the mixture directly after the yellow liquid was added to the colourless liquid. The glass on the right is empty. Draw the particles in the mixture after the yellow liquid has spread uniformly throughout the colourless liquid.

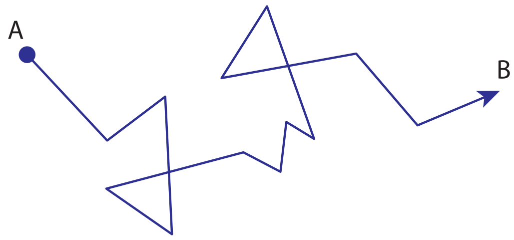


When you were watching the coloured liquid mix with the water in the last investigation, was it possible to predict the direction in which the colour would swirl? What made the two liquids mix?

Random movement of particles

The particles in liquids and gases are constantly moving. Their movements are unpredictable: we say the particles move randomly. It is the random movement of the particles that allow liquid and gaseous substances to diffuse.

This zigzag illustration explains what is meant by 'random' movement.



When a gas particle travels from point A to point B, it will collide with many other gas particles along the way – up to eight billion collisions every second! Only a few of those collisions are shown in the diagram. Each time the particle collides, it will change direction. This means the actual distance travelled by the particle is much further than the direct distance between points A and B.

The process responsible for the mixing and spread of particles in a gas and liquid is called diffusion. Therefore, we can define diffusion as the random movement of liquid or gas particles from the region of higher concentration to the region of lowe concentration (glossary). The following diagram illustrates the idea in a very simple way: it shows the particles in a gas spreading out over time to fill all the space that is available to it.

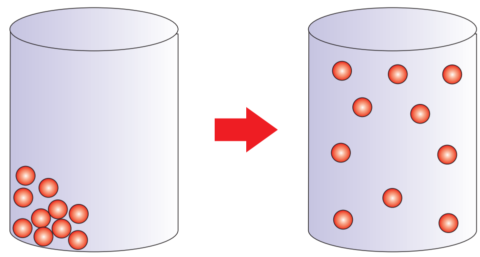


Figure 5.9 In the diagram on the left some particles were placed into an empty container. At first they were close together (at high concentration), but over time they spread out to fill the entire container.

Factors that affect the rate at which particles diffuse

The speed at which particles diffuse depends on several factors, namely:

- The mass of the particles: lighter particles will diffuse faster, because on average they move faster.
- The state of the particles: the particles in a gas are always moving fast; we say their average speed is high. The particles in a liquid travel more slowly.

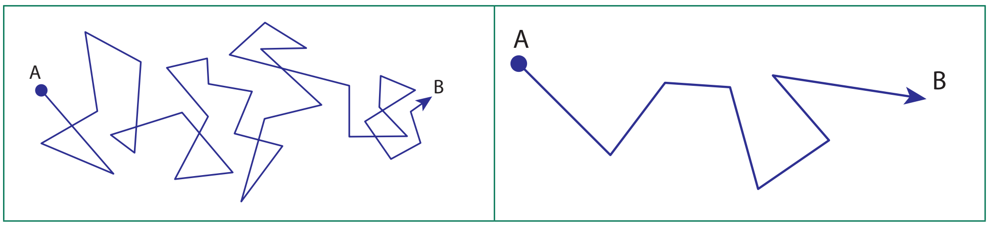
- The temperature of the particles: temperature is a measure of the kinetic energy of the particles. The higher the temperature, the more energy the particles have and the faster they will move and diffuse.
- The size of the spaces between particles: If there are large spaces between the particles of one substance, the particles of another substance can move into those spaces easily.
- Particles diffuse because they are in **constant motion**. We found that gas particles diffused much more quickly than the liquid particles in the last investigation. Can we explain that result using the factors listed above?

Figure 5.10 Imagine walking through this crowd of people. This is similar to diffusion through a liquid.

Think of it in this way: imagine you are trying to move through a crowd of people. The closer they are together, the more often you are going to have to change direction to make it through the crowd and the longer it will take to get to your destination.

A particle in a liquid cannot travel very far before colliding with another particle, because the particles are so close together. That means the liquid particles are constantly colliding and are sent into a new direction with each collision. This means the rate of diffusion is much slower in liquids than in gases, because the particles of a gas are further apart and collide much less. Gas particles can travel further without being sent in a different direction by a collision. This is why gases diffuse more quickly.

The following table shows similar zigzag illustrations as you saw before, but now you can see the difference between the random movement of a particle through a liquid and through a gas. It will take the particle much longer to travel from A to B in the liquid than in the gas.



Now that we have a better idea of the behaviour of particles in the different states of matter, we are ready to look at how particles behave when matter changes its state.

5.3 Changes of state of Matter

In science, a change of state refers to a change in physical state (for example, when a liquid changes to a solid). What is this process is called? It is always a good idea to learn new things in terms of what we already know.

We are going to start this section with a crossword puzzle to revise what we already know about changes of state.

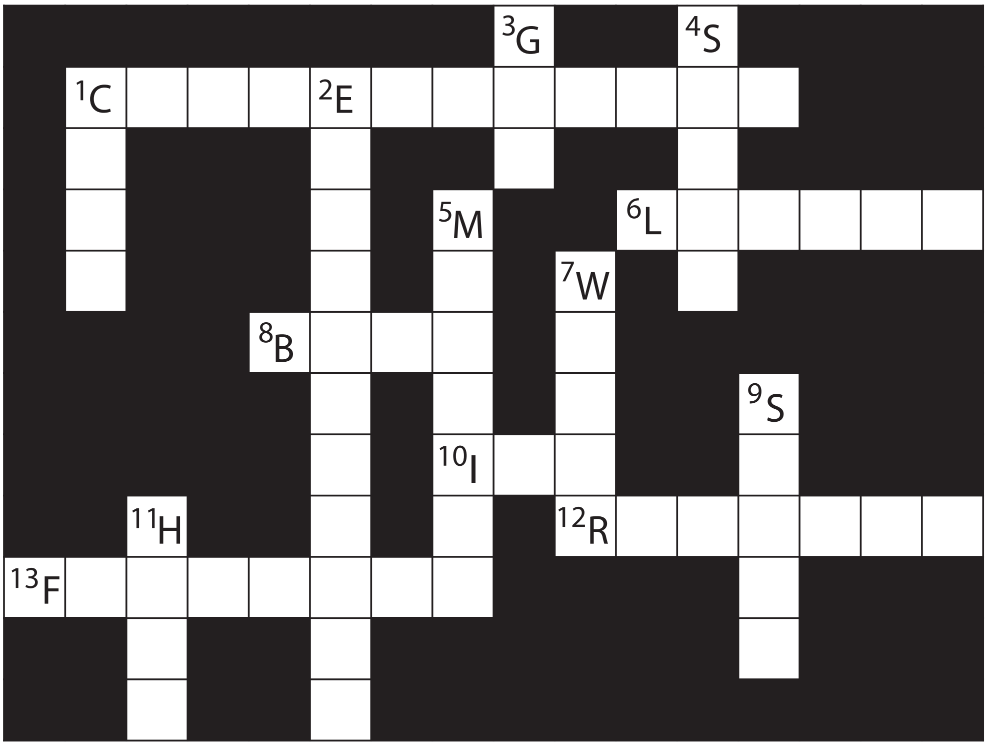
Keywords

- vapour
- vigorous
- energetic
- transformation
- condensation
- evaporation

ACTIVITY: Changes of state of matter

Instructions

1. The crossword puzzle below can be completed by following the clues given below.
2. The 'Down' clues are for the vertical words in the puzzle and the 'Across' clues are for the horizontal words in the puzzle.
3. All the clues have to do with changes of state of materials, and the first letter of every word has been filled in to help you.



Here are the clues:

Down:

1. If we want to turn steam into water we have to __________it. (4 letters)
2. The process of turning a liquid into a gas is called __________. (11 letters)
3. The particles of a __________ have large spaces between them. (3 letters)
4. The particles of a __________ are locked in position by strong forces. (5 letters)
5. A solid will change into the liquid state at its __________ point. (7 letters)
7. The liquid state of ice is called __________. (5 letters)

9. The gaseous state of ice is called _________. (5 letters)
11. If we want to turn water into steam we have to _________it. (4 letters)

Across:

1. The process of turning a gas into a liquid is called _________. (12 letters)
6. The particles of a ________ are close together but they can flow and slide over each other. (6 letters)
8. The boiling point of a liquid is the temperature at which that liquid will start to _________. (4 letters)
10. The solid state of water is called _________. (3 letters)
12. Freezing and melting are the ________ of each other. (7 letters)
13. _________ water turns it into ice. (8 letters)

How can we change a substance from one state to another?

Changes of state involve energy

For matter to change from one state to another, its particles must gain or lose energy. The following diagram shows us that to change the state of a substance, it must either be heated or cooled.

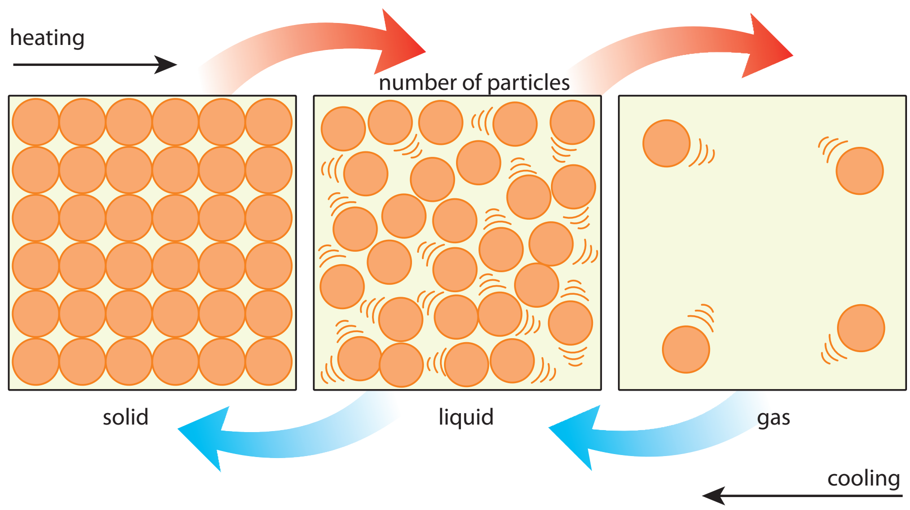


Figure 5.11 Melting and evaporation are processes that require heating; condensation and freezing are processes that require cooling.

First, let us look at what happens to particles when they are heated.

Keywords

- boiling
- melting
- evaporation
- melting point
- boiling point

Figure 5.12 Melting ice cubes.

Melting and evaporation

When a solid is heated to reach its melting point, it will change into a liquid. This is a process that we are all familiar with, because we have seen how ice melts.

For a solid to change into a liquid state, the particles in the solid need to be freed from their fixed positions in the solid state. How could that occur?

Imagine you are holding hands with a group of other learners. Everyone is jumping in place, much like a solid particle vibrating in a fixed position.

The more energetic everyone is and the more randomly they jump, the more difficult it will be for everyone to keep holding hands.

When a substance is heated, the particles are gaining more energy. By giving the vibrating particles in a solid more energy, their vibrations will become more and more **vigorous**, until the solid particles are able to shake themselves loose from their fixed positions. The forces between the particles are no longer able to hold them together tightly, and the solid **melts**.

What will happen if we add even more energy to the particles? The particles (which are now in the liquid state) will whizz around faster and faster as they heat up. particles at surface level that have gained enough energy will escape the liquid. Once they are free from the forces that hold them together in the liquid state, they enter the gas (or gaseous) state. The gaseous state is sometimes called the **vapour** state, which forms when a liquid **evaporates**. This is why the gaseous state of water is sometimes called water vapour.


Figure 5.13 Clothes hanging outside.

The higher the temperature of the liquid, the faster it will evaporate. A puddle of water will evaporate much faster from the hot pavement than it would from a cool kitchen floor! Why do you think we hang washing outside in the sunshine to dry?

Is there a difference between evaporation and boiling?

Evaporation takes place at all temperatures, while boiling occurs at a specific temperature, called the **boiling point**. When a liquid is heated to its boiling point, bubbles form in the liquid and rise up to the surface. When this happens, we say the liquid is boiling. Evaporation occurs only on the surface of the liquid, while boiling occurs throughout the entire liquid.

Keywords

- condensation
- solidifying

What is the boiling point of water at sea level?

Look carefully at the picture of the boiling water. What do you think is inside the bubbles?

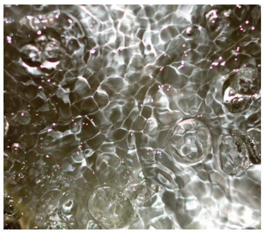


Figure 5.14 Boiling water.

Next, we will look at the changes of state that can happen when we cool a substance.

Condensation and solidifying

When a gas changes to a liquid, the state change is called **condensation.**

Condensation is the opposite of evaporation. Have you noticed the little droplets of water that form on the outside of a cold glass of water? They are formed by condensation.

When the temperature of a gas is lowered, it takes energy away from the gas particles. The movement of gas particles slows down as their energy decreases and they will start to experience attractive forces. These forces cause them to move closer to each other and they eventually return to the liquid state.

What do groups of people, animals, or birds do when they get cold? They huddle together! In the same way gas particles that are cooled down condense and come together to form water droplets.

What would happen if we cooled the liquid even more? By cooling the liquid, we would be removing energy from it. As the liquid particles lose energy, their movement slows down even more. As their movements become slower and slower, the attractive forces between them become stronger. The particles eventually 'lock' into position in the solid state. They can no longer move freely and are able only to vibrate in their fixed positions. We say the liquid has **solidified**.

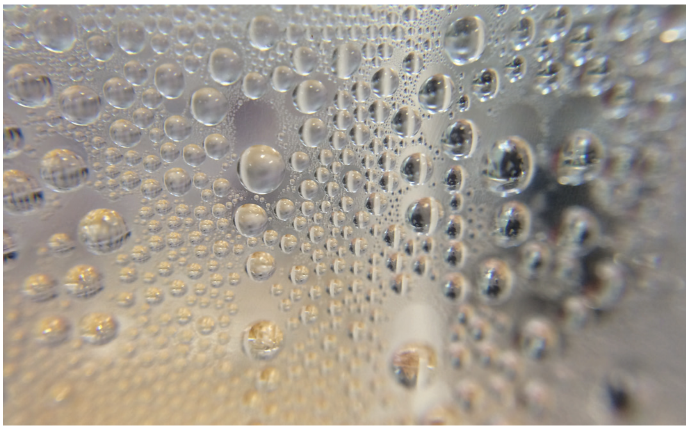


Figure 5.15 Water vapour in the air has condensed on the cold surface of this glass window.

Figure 5.16 Birds and animals in groups tend to huddle together when they get cold.

Did you know?

The volume of water expands by about 9% when it freezes into ice.

Investigation: What happens when we heat and then cool candle wax?

Aim

What is your aim for this investigation?

Hypothesis

What do you propose will happen in this investigation? This is your hypothesis.

Materials and apparatus

- empty tin can or foil pie dish
- bunsen burner or spirit lamp
- tripod stand
- wire gauze
- candle wax
- matches

Method

1. You need to write the method for this investigation. You will either plan this in a group, or your teacher may do the investigation as a demonstration. You must write down the steps for the investigation.

They must be clear enough to allow someone else to repeat your investigation.

2. Draw a diagram of your setup for the investigation in your exercise books. Remember to give your diagram a heading and to provide labels.

Results and observations

1. What state of matter is the candle wax in at room temperature (at the start of the investigation)?
2. What happened when you heated the candle wax?
3. What happens when a candle wax cools down?
4. Would you say the melting point of candle wax is higher or lower than room temperature?

Conclusion

Write a conclusion for this investigation. You must make reference to the particle model of matter in explaining the changes of state that occurred.

In the next activity we are going to have some fun with water balloons, but not in the usual way. We are going to blow up a balloon without blowing into it and we will make it rain inside the balloon! Sounds like magic? No, just science!

ACTIVITY (Optional): Hot water balloon

Materials

- large party balloon (plus spares)
- two teaspoons of tap water
- microwave oven
- oven gloves
- safety goggles
- large bowl of ice cold water

Figure 5.17 Let's have some fun with balloons!

Instructions

1. Before you begin, put on your safety goggles.
2. Pour water into the balloon and squeeze out all the air before tying a knot in the neck of the balloon.
3. Place the balloon in the microwave oven and heat on full power until you see the balloon starting to expand. Only a few seconds of heating should be enough for the balloon to reach its full size (if you heat it for too long it might pop).
4. Remove the heated balloon with the oven glove. Shake it gently. If you are very quiet you will hear something happening inside the balloon.
5. Place the balloon in the bowl of cold water.

Questions

1. Did the balloon have any air inside it at the start of the experiment?
2. What made the balloon expand?
3. What is the name of the gas that made the balloon expand?
4. What did you hear inside the balloon when it started to cool down?
5. What caused the sound?
6. Where did the water droplets inside the balloon come from?
7. What happened to the balloon when it was cooled down in the cold water?
8. Which changes of state did the water undergo in this experiment?

Next, we are going to look at three important properties of matter that are useful to scientists, namely density, mass and volume. These three properties are all related to each other.

5.4 Density, mass and volume.

Keywords

- mass
- volume
- density
- physical quantity

In everyday life when we say something is **dense** we generally mean to say that the particles of that substance are closely compacted together. For example, urban areas are generally **densely populated** than rural areas because houses in urban areas are closely packed to one another than in rural areas.

Substances have an intrinsic property called **density**. Density of a substance tells about how closely packed the particles of a substance are. Different materials have different densities, depending on a type of a material a substance is made of.

In the following activities we are going to quantitatively investigate about the density of materials.

Investigation: Mass-volume ratio of materials.

Investigative Question: Do materials made up of a same substance have the same mass-volume ratio?

Hypothesis: (formulate your own hypothesis)

Apparatus

- 4 blocks of different sizes made of a same material (e.g. wood or plastic)
- Ruler
- Digital scale

Method/ Procedure

1. Use the ruler to measure the length, the width and the height of one block (in cm) and record in the table of results.
2. Use the digital scale to measure the mass (in grams) of the same block and record in the table of results.

3. Use the formula V = L × B × H to calculate the volume of the block and record in your answer in the table of results.
4. Calculate the ratio of mass : volume for this block.
5. Repeat steps 1 – 4 for 3 more blocks of different sizes, but made of a same material as the one you started with.

Results

Record your results in the table below:

Block	Mass (g)	Length (cm)	Width (cm)	Height (cm)	Volume (cm^3)	mass-volume ratio ($g{\cdot}cm^{-3}$)
1						
2						
3						
4						
Average						

Discussion and conclusion

1. From your calculations, what did you observe about the values of the ratio mass : volume for each block?
2. Reflect back on your hypothesis and check whether the experimental results are in line with your prediction. If no, correct your hypothesis and write the conclusion based on your experimental results.
3. Do materials with the same volume have the same mass? Explain using an example.
4. Plot the graph of mass (on the y-axis) versus volume (on the x-axis).
5. Calculate the gradient of the graph.
6. Calculate the average ratio of mass to volume for all 4 blocks.

Relationship between mass, volume and density

This section introduces us to physical quantities that are important when we study science. Two of these quantities, namely **mass** and **volume**, are fundamental properties of matter.

Figure 5.18 Gold bars each with a mass of 1 000 g. How much is this in kg?

Mass

- **Mass** of an object tell us how much matter an object consists of. The greater the mass of an object, the more matter it contains.
- The measuring **SI uni**t of mass is **kilograms** (kg). However, in some instances, an object may have smaller mass, such that it is measured and expressed in **grams** (g) or sometimes **milligrams** (mg).
- One kilogram is equivalent to One thousand gram, that is 1 kg × 1000 g.
- One gram is equivalent to One thousand mg. That is, 1 g × 1000 g.

Volume

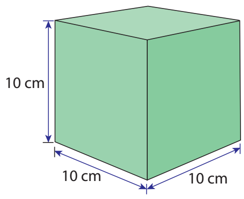
- The **volume** of an object tells about the amount of space the object occupies.
- The measuring SI unit of the volume of an object is meter cube (m^3). However, for objects of smaller volumes, the measuring units can be expressed in cubic centimetres (cm^3) or sometimes cubic millimetres (mm^3).
- One metre cube is equivalent to one million cubic centimetres. That is, $1\ m^3 = 1\ 000\ 000\ cm^3$.
- One cubic centimetre is equivalent to one million cubic millimetres. That is $1\ cm^3 =$ $1\ 000\ 000\ mm^3$

Figure 5.19 A carton of milk and a bottle of milk.

- The volume of liquid substances is usually measured in litres (L). Where One litre is equivalent to one cubic decimetre. That is $1\ L = 1\ dm^3$.
- However smaller liquid volumes can be measured in millilitres. Where one litre is equivalent to one thousand millilitres. That is $1\ L = 1\ 000\ mL$.

Take note

When calculating volume, $1\ cm \times 1\ cm \times 1\ cm = 1\ cm^3$. This is the same as 1 ml. That means that $10\ cm \times 10\ cm \times 10\ cm = 1\ 000\ cm^3$, which equals 1 000 ml or 1 litre.



This cube has a volume of 1 litre.

Determining the volume of an object

There are two ways in which the density of an object can be determined.

- If the object is in the shape of a box, we can use the ruler or a measuring tape to **measure its dimensions** (the length, the width and the height), the use the **formula** $V = L \times W \times H$ to **calculate** the volume.

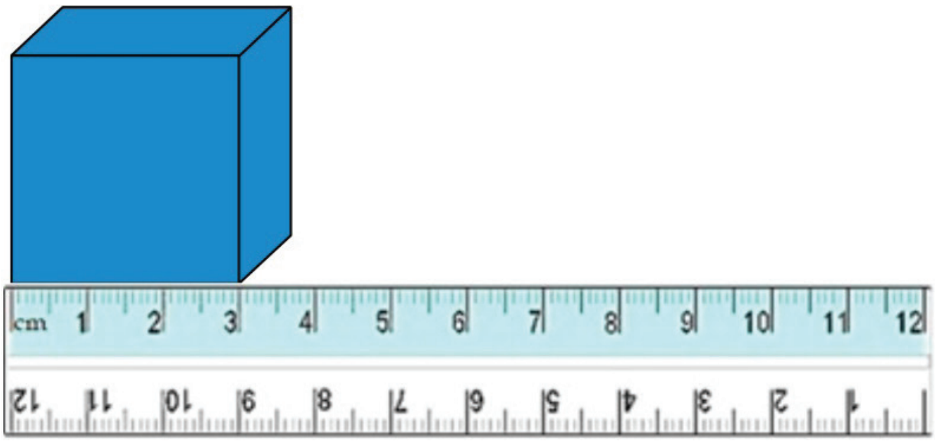


Figure 5.20 Measurement-Calculation method

- If the object is irregular-shaped, then we can use the **displacement method** to determine its volume. This method requires that an object be dropped into a measuring cylinder filled with water to a certain level, such that when the object is dropped the volume of water increases (that is, water gets displaced). The amount by which the volume of water increase will be the of the object.

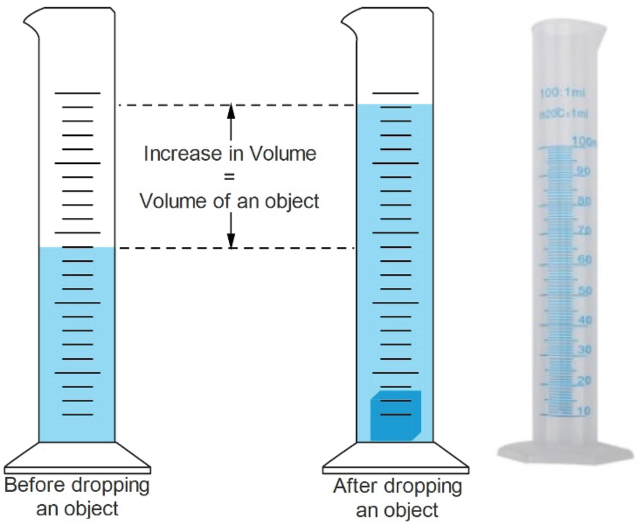


Figure 5.21 Displacement method

Density of a Material

- We have already mentioned that the term dense tells us how closely packed together the particles making up a substance are.
- The term density generally refers to the quantity of people or things in a given area or space.
- In science the term density is defined as the measure of how much mass of a material fits into a given volume.
- Therefore, density of a material is the of mass to volume of that particular material. This can be written mathematically as:
- In the investigation we were actually calculating the densities of the given blocks when we were calculating the ratio mass to volume.+


Figure 5.22 A dense piece of cake.

Investigation: Which material has a higher density?

Investigative Question: Do object of different material that have the same volume have the same mass?

Hypothesis: (Formulate your own hypothesis)

Apparatus

(NB the block must of the same shape and same size (volume))

- Wooden block, polystyrene block, metal block, sponge, and digital scale.

Procedure

1. Use your hand to compare the masses of the different materials you have been provided with.

Take note

We can also use symbols for density (D), mass (m) and volume (V), so the equation to calculate density can be written as $D = \frac{m}{V}$.

2. Use the digital weighing balance to measure the mass of each material, and record your findings in the table of results similar to the one given in this investigation.
3. Calculate the volume of the blocks. **Hint**: Volume = L × W ×H.

Results

Record your results in the table below:

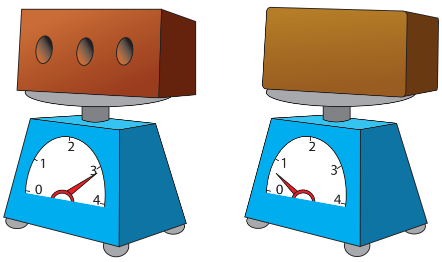
Material	Mass (g)	Volume (cm^3)
Wooden block		
Polystyrene block		
Metal block		
Sponge		

Discussion and Conclusion

1. Rank the objects in their order of increasing mass.
2. Why do different materials have different masses if though they have the same shape and volume?
3. Write your conclusion for this investigation.
4. What property of these materials makes them to have different masses even though their volumes and shapes are the same?
5. Rank these material in their order of increasing

5.5 Density and states of matter

We have now learnt about the three states of matter and the properties of each.



We know one of the ways in which solids, liquids and gases are different from each other has to do with the distances between the particles in each respective state. The particles in gases are much further apart than the particles in liquids or solids.

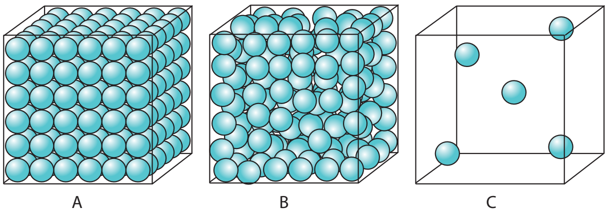
Does this mean that the different states of matter have different densities? We will find out in the next activity.

ACTIVITY: Which has the highest density: a solid, a liquid or a gas?

Instructions

1. Compare the three identical containers below.
2. They all have the **same volume** and contain the **same material**.
3. Container A contains a solid material, container B contains the liquid state of that material and, container C the gaseous state of the same material.
4. Answer the questions that follow.

Questions



1. Which container (A, B or C) contains the greatest number of particles? Which container contains the smallest number of particles?
2. Which container (A, B or C) contains the material with the greatest mass? Which container has the smallest mass? Why do you say so?

We have just performed a conceptual activity (a 'thinking' activity) in which we compared the densities of the three states of the same material.

The high density of a solid material explains why it cannot be compressed. The particles in a solid are tightly packed and cannot be squeezed closer together into a smaller volume.

Liquids are also very dense. The density of a liquid is roughly the same as the density of the solid state of the same substance. This is because their particles are close together, even though they are not locked into fixed positions. Most liquids cannot be compressed into smaller volumes.

Liquids are slightly less dense than their solid states, but water is an important exception. Have you ever wondered why your ice cubes float on top of the water in your glass?

Figure 5.23 Ice blocks floating in a glass of water.

The solid state of water (ice) is less dense than the liquid, because in ice the water molecules are packed in a unique way. The image below on the left shows that water molecules in ice are packed in such a way that there are open spaces between them. On the right, the same water molecules are shown in the liquid state.

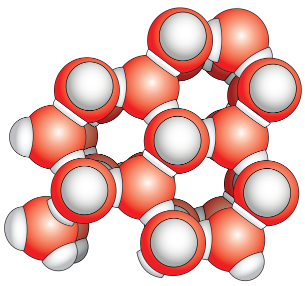


Figure 5.24 Water molecules in the solid state (ice).

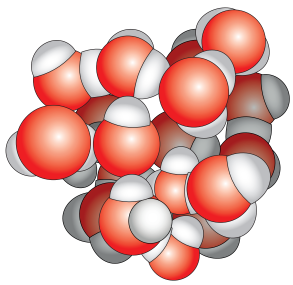


Figure 5.25 Water molecules in the liquid state.

Do you see how there are bigger spaces between the water molecules in a solid than in a liquid? This also helps to explain why icebergs are able to float in the sea.

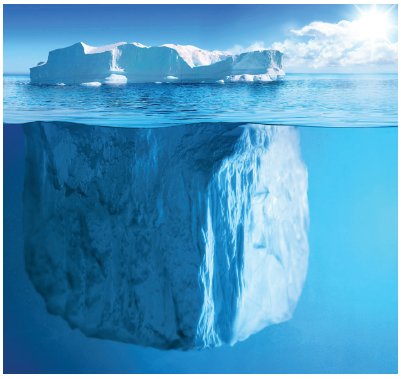


Figure 5.26 A big floating iceberg in the Arctic.

Have you ever seen a frozen bottle of water with the ice pushed up out of the bottle? Why did the water push out of the bottle when it turned to ice?

Gases are not very dense at all because of the large spaces between the gas particles. That means they contain a small number of particles in a large volume.

This is why gases can be compressed: their particles can be squeezed closer together to fit into a smaller volume. Think back to the air that is compressed to fit inside a gas tank for a scuba diver.

In the activity 'Which has the highest density, a solid, a liquid or a gas?' we compared the densities of different states of the same material. This is an easy comparison because the particles in the different states are identical. By comparing the number of particles in the same volume of each state, we can determine the density of each state.

The densities of different materials are slightly more difficult to compare, because different materials consist of particles with differing masses.

Did you know?

Light ice, heavy water! (video) bit.ly/14AyKxP

5.6 Density of different materials

Keywords

- cluster
- impact
- immiscible

We are now going to do a practical activity (a 'doing' activity) to compare the densities of a solid, a liquid and a gas. It would be quite difficult to compare the three states of the same material, as the material would have to be at three different temperatures to be in three different states! For this reason we will compare four different materials: sand, flour, water and air.

Investigation: Comparing the densities of sand, flour, water

Investigative question

Which material has the highest density: sand, flour, water or air?

Hypothesis

What do you predict: Which material has the highest density: sand, flour, water or air?

Identify variables

1. Which variables must be kept constant to make this a fair test?
2. What is the independent variable? (What is it that you have control over to change in this investigation?)
3. What are the dependent variables? (Which variables will you be measuring?)

Materials and apparatus

- four identical cups (paper or plastic)
- sand
- flour
- tap water
- triple beam balance or scale

Method

You will be designing this investigation yourself. If you are working in groups, you need to discuss first how you are going to conduct (carry out) this investigation. This is the planning. Write down your proposed method in your notebook or on scrap paper. Discuss this with your teacher. Remember also to think about how you are going to record your results. After you have conducted the investigation, write down your method. Summarise each step in sequence and number the steps.

Results and observations

What were the results of your investigation? Summarise them in your exercise books. You can draw a table. If you were able to measure the mass of each cup, show your calculations for the density of each material.

Analysis and evaluation

1. Did anything go wrong during the experiment? If so, what?
2. Can you think of anything that could have improved this experiment?
3. What steps did you include to ensure fair testing?

Conclusion

What is your conclusion? (What is your answer to the investigative question?)

In the last investigation we saw that two solids, namely sand and flour, have different densities as they are different materials. Do all liquids have the same density, or does the type of material of the liquid affect the density?

Figure 5.27 Oil floats on water.

Have you ever noticed that oil floats on water?

When you mix oil and water, as in the picture of the salad dressing, the two materials will eventually separate because they do not mix well. They are immiscible. When they separate, the oil will always float on top. The two separate layers of water and oil are referred to as 'phases', the oil phase and the water phase.

Oil floats on water for two reasons:

- A cup of oil has less mass than a cup of water. The oil is less dense than water. This makes oil float on water, in the same way a cork or an air-filled rubber duck floats on the surface of the water.
- Oil does not dissolve in water. The oil molecules **cluster** together and float on the surface. If a large amount of oil is poured into water, the oil will spread out and form a layer on the surface of the water. Oil that is spilled into the ocean or a lake spreads over a huge area. It poisons many animals, birds, fish and plants and is very expensive to clean up. That is why oil pollution has an extremely negative **impact** on our environment.

Figure 5.28 This homemade salad dressing contains oil that floats on top.

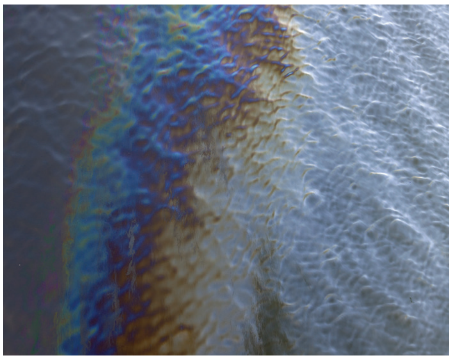


Figure 5.29 Oil pollution forms a thin layer on the surface of the sea water. The oil can spread out over a huge area as the layer is thin and it floats on top of the water.

Figure 5.30 Birds can easily become trapped in the oil from a spill. The oil gets in between their feathers, sticking them together and preventing them from flying.

- When two substances are in the same container, but not mixed (like oil and water for instance), they will form two layers. In a certain sense, water and ice also form two 'layers'. Which layer will be on top: the one which is more dense or the one which is less dense?

ACTIVITY: Some density calculations

Instructions

1. Below is a table with some different substances and their densities. Use this information to do the following calculations.
2. Show how you worked out each answer and do not forget to include the units in your answer.

Material	density (g/mL)
Water (liquid)	1
Ice	0.917
Glass	2.6
Salt	2.2
Chalk	2.36
Coal	1.5
Cork	0.25

Questions

1. You have a 500 g block of butter at home. You found out that its volume is 555 ml. What is the density of the butter?
2. Which is more dense, salt or chalk?
3. You have a large glass marble and you want to find out what its volume is. You measure the mass and find it to be 50 g. What is its volume?

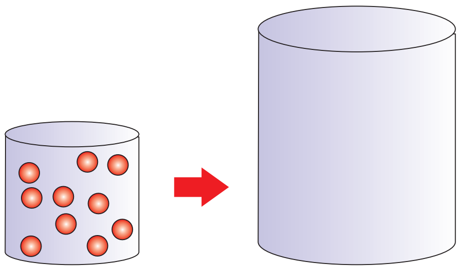
4. You have a piece of coal and a piece of cork which are exactly the same size. They have the same volume of 100 ml. Which one will have the greater mass? Calculate the exact mass of each piece.

Keywords

- expand
- contract
- reinforce

We have learnt that the density of a material depends on how tightly packed the particles inside the material are. The more tightly packed they are, the more dense we say they are.

The following diagram represents a container (on the left) that contains a small amount of gas. Imagine that all the gas from the small container is moved into the empty container on the right. Draw the gas particles in the container on the right.



A gas will expand to fill whatever space it is in. In the larger container we will still have the same number of gas particles, but now they are filling a much larger space.

If we take a certain amount of gas from one container and place it into another, larger container, the gas expands to fill the larger container. The same mass of gas is now in a larger volume, but the gas now has a lower density.

Solids and liquids cannot behave in this way. Their densities will remain more or less constant no matter in which container they are placed. This is because their particles are relatively close together with strong forces between them. But what happens when we heat them? We have learnt that this is the same as giving them extra energy. How will heating them affect the packing of the particles and the density? In the next section we are going to look more closely at what happens to the particles inside materials when they expand. We are also going to look at the opposite of expansion, namely contraction.

Activity: Density Activity

Questions

1. Answer the following multiple-choice questions by choosing the symbol corresponding to the correct answer.
   1.1. The mathematical formula that can be used to calculate the density of a material is…
      A. volume divided by mass.
      B. mass times volume.
      C. mass plus volume
      D. mass divided by volume.
   1.2. Which of the following statement is true about a bottle containing liquids that appear to be stacked?
      A. The liquid at the top is the most dense.
      B. The liquid at the top is the least dense.
      C. The liquids have the same volume.
      D. The liquids have the same density.

1.3. The density of water is 1 $g{\cdot}ml^{-1}$. What volume must a 58 g object have in order for it to float in water?
  A. 45 ml
  B. 50 ml
  C. 60 ml
  D. 55 ml
1.4. Within the water cycle, water vapour rises back into the atmosphere because…
  A. Water is decomposed in a chemical reaction.
  B. Water vapour has the same density as the surrounding air.
  C. Water vapour is more dense than the surrounding air.
  D. Water vapour is the less dense as the surrounding air.
1.5. Your friends at your lunch table all have different stuff for their lunch. Liquid A has a density of 1,07 g/ml, Liquid B has a density of 0,98 g/ml, Solid C has a density of 1,12 g/ml, and Mush D has a density of 1 g/ml. You decide to make a gross combination of the four in a glass. In which will the four things brought for lunch from appear, from bottom to top?
  A. Solid C, Mush D, Liquid A, and Liquid B on top.
  B. Solid C, Mush D, Liquid B, and Liquid A on top.
  C. Solid C, Liquid A, Mush D, and Liquid B on top.
  D. Liquid A, Liquid B, Solid C, and Mush D on top.

2. Mark each statement as true or false. If false, either correct the statement or provide an explanation why the statement is false.
  2.1. the liquids with the highest density will float when two different liquids are mixed together.
  2.2. The correct unit for density of a liquid is grams per millilitre.
  2.3. The weight of an object and its mass are the same thing.
  2.4. The densities of pure water, sugar water and salty water are always the same.
  2.5. heavy objects have higher density than lighter objects.
3. Define the term density.
4. Write the mathematical formula that can be used to calculate the density of an object.
5. During the water cycle, water vapor rise during evaporation, but water droplets fall down during condensation. Explain why this is the case by comparing the densities of the water vapor and that of water droplets to the density pf the surrounding air.
6. A cup of gold coloured metal beads was measured to have a of mass 425 grams. By water displacement, the volume of the beads was calculated to be 48 cm^3. Given the following densities, calculate the density of the metal beads and identify the metal.

Metal	Density
Gold	19,3 g/ml
Copper	8,86 g/ml
Bronze	9,87 g/ml

7. Refer to the table below and answer the questions that follow:

Substance	Density (g/ml)
Distilled water	1.00
Vegetable oil	0.79
Liquid mercury	13.55
Wood (pine)	0.12
Ice	0.92
Iron	7.87
Aluminium	2.7

7.1. List 2 substances that would float in water and explain why they would float based on their densities listed in the table above.
7.2. List 2 substances that would sink in water and explain why they would sink based on their densities listed in the table above.
7.3. List 2 substances that would float in liquid mercury and explain why they would float based on their densities listed in the table above.

8. Explain how you would determine the density of a stone that has an irregular shaped.

5.7 Expansion and contraction of materials

Have you ever been inside a tin-roofed house? On hot days, you often hear the metal roof panels groan and creak. Do you know why this happens? Some materials become slightly larger when they are heated. We say they **expand**. Materials can also shrink slightly when they are cooled. We say they **contract**.


Figure 5.31 A house with a tin roof.

The metal roof panels expand and contract as the outside temperature changes. When this happens, the panels scrape against each other and against the nails that keep them in place. The scraping of metal against metal causes the creaky, groaning noises.

How is it possible for materials to contract and expand? Can you think of an explanation?

To understand this phenomenon, we will look at some examples of expansion.

We will then try to explain expansion in terms of the particle model.

Some solids expand more than others. When we choose materials for a new job, it is important to know how much they will expand. This way we can allow for expansion when the materials get hot.

In the following diagram, the picture on the left shows a concrete path or road surface. How have the engineers who built the road allowed for expansion?

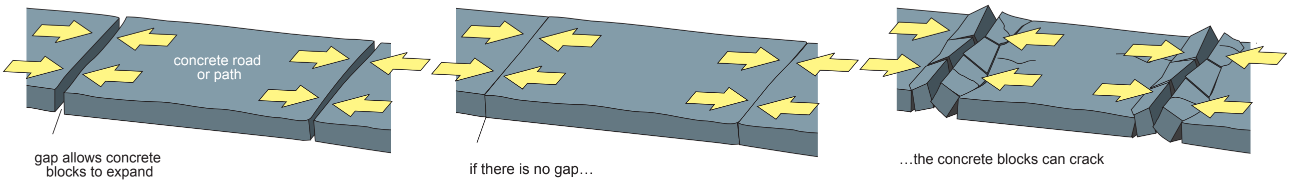


Figure 5.32 Expansion can create forces strong enough to damage materials.

Figure 5.33 The expansion joint in a bridge.

The picture above shows what could happen if no allowance is made for the expansion of the concrete blocks. The forces created by the expansion of the concrete are so strong that the road surface has cracked!

This is a very important principle to remember when building bridges. When engineers design a bridge, they must allow for contraction and expansion of the materials used to build the bridge. Have a look at the following photo showing a close-up of the gap between the two road surfaces of a bridge. Can you see the interlocking 'teeth'? These allow the bridge to expand and contract while the teeth slide past each other.

ACTIVITY: How much longer?

In this activity we will compare the expansion of different solid materials by drawing a graph. You will need the following information for your graph:

Material	How far a 100 metre length of the material will expand when the temperature increases by 10 °C
Brass	19 mm
Iron	12 mm
Steel	11 mm
Platinum alloy	10 mm
Concrete	11 mm
Ordinary glass	11 mm
Ovenproof glass	3,5 mm

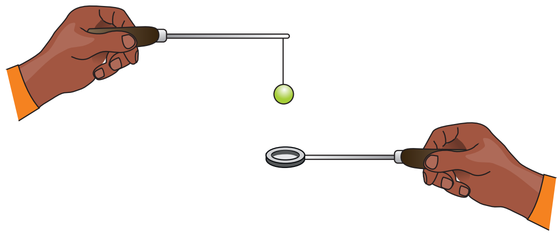
Draw a bar graph with 'Expansion' on the *y*-axis and 'Materials' as categories on the *x*-axis. Choose an appropriate title for your graph.

Questions

1. Which material expands the most upon heating?
2. Which material expands the least?
3. Which solid would be the best material to **reinforce** concrete? (Hint: the reinforcing material should expand as much as the concrete, otherwise it will damage the concrete during expansion.)
4. A man builds a house with large windows set in beautiful frames made of brass. The house is in a region where it gets very hot during summer. Imagine that the owner of the house has a problem: the windows of the house look beautiful in their shiny brass frames but they keep falling out

during the summer months. As a scientist, how would you explain this, and what would your advice to the owner of the house be? Should the frames be replaced? If so, with which material? What other solutions can you suggest?

5. The following diagram shows a metal ball-and-ring apparatus. The ring and ball are both made of brass. At room temperature, the ball is just the right size to pass through the ring. Do you think the ball will still fit through the ring when the ball has been heated?



6. Do you think the brass ball will have more mass when it has expanded? Explain your answer.
7. What will happen to the brass ball when its temperature drops back to room temperature? Will it be larger than, smaller than, or the same size as before it was heated? Explain your answer.

Now that we have seen that materials can expand, how can we explain expansion of a material in terms of the behaviour of the particles in that material?

We have learnt that when matter is heated, the particles of that matter will move faster and push further apart from each other. What happens to the particles in matter when it is cooled?

When a substance cools (energy is removed), the particles in that substance will slow down and move closer together. That is why most materials contract when they are cooled.

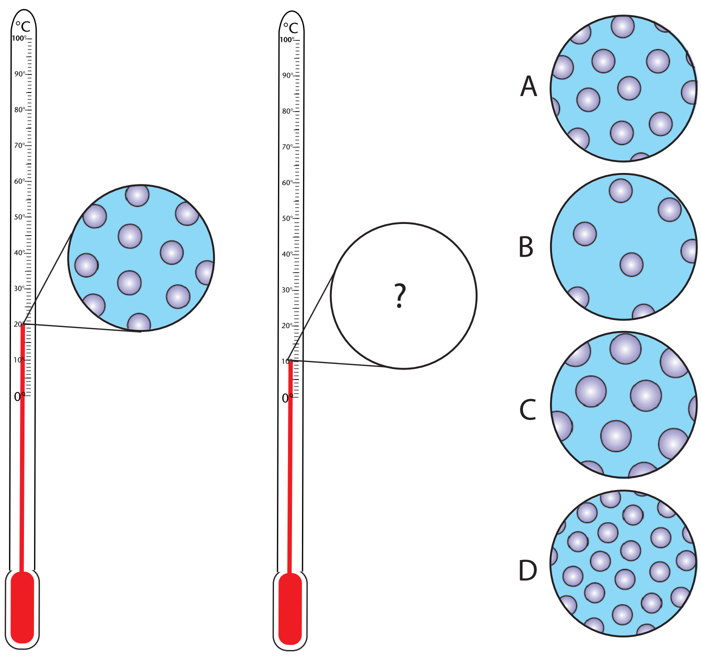
Expansion and contraction in a thermometer

Let's look at a thermometer to understand expansion and contraction.

ACTIVITY: How does a thermometer work?

The common glass thermometer is called a bulb thermometer. All bulb thermometers have a fairly large bulb that is connected to a long, thin tube. The thermometer has a brightly coloured liquid on the inside. Some thermometers contain mercury as it expands and contracts quite a lot when heated or cooled.

Look carefully at the following set of diagrams. They represent the same thermometer at two different temperatures.



Questions

1. The drawings represent the particles in the liquid inside a thermometer. What is the temperature measured on the thermometer on the left?
2. The drawing on the right is of the same thermometer, but slightly different. Can you tell the difference?
3. Which of the circles (A, B, C, or D) is the best representation of the liquid in the thermometer on the right? Why did you choose this one?
4. Does a material have less mass when it has contracted? Explain.
5. If the temperature was raised and the thermometer read 30 °C, which circle would now best represent the particles in the liquid of the thermometer? Why?
6. How does the volume change when a material is heated? Why?
7. How does the density change when a material is heated? Why?

Take note

When a material is heated, its particles move further apart. When the material cools down, the particles move closer again. Heating and cooling cause the volume of the material to change.

We have learnt that thinking about matter in terms of the particles inside it can help us to understand many interesting phenomena: the physical properties of the different states of matter change from one state of matter to another, density, and expansion and contraction.

Figure 5.34 We can use a scale to measure the mass of a person or any other object.

How can we measure how much of a liquid or a solid we have? If we want to know how much of a material we have, we can measure its mass. What instrument do we use to measure mass?

Think back to the investigation comparing the densities of sand, water, flour and air. How did you measure the mass of the air in a cup?

We are now going to shift our focus to gases. Gases have much lower densities compared to solids and liquids. That means a large volume of gas will have a small mass. Small masses can be difficult to measure without a special, super-sensitive scale. Scientists have devised a different way of measuring how much of a gas they have.

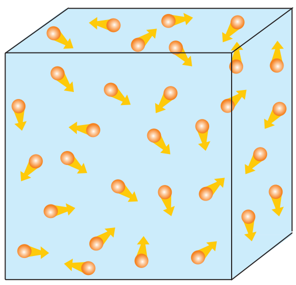


Figure 5.35 Gas particles in constant motion, inside a container. They collide with each other and with the inside of the container.

5.8 Pressure

What is gas pressure?

We have learnt that gases contain millions of fast-moving particles. The following picture represents gas particles inside a container.

Keywords

- pressure gauge
- air valve

As the particles whizz around, they bump and bounce off each other. They also bump against the inside of the container. The force of the particles bumping against the sides of the container causes a phenomenon called gas pressure. The number of bumps (or collisions) will depend on the number of gas particles in the container. More particles inside the container means more collisions, and more collisions mean a higher pressure.

Figure 5.36 A simple tyre pressure gauge.

If we can measure the pressure of the gas, we will have an idea of how much gas is inside the container.

How can gas pressure be measured?

Have you ever seen anyone check the pressure in a car tyre? You may have seen them use a device like those in the photo below. It is called a tyre **pressure gauge** and it is specially designed to measure the air pressure inside a tyre.

The round end of the gauge should be pressed against the **air valve** of the tyre.

This opens the valve and lets some of the air from the tyre escape into the gauge. The air particles bump against a disc inside the gauge. The force generated by many gas molecule collisions pushes out a bar at the back of the gauge. Can you see it in the picture? For this particular pressure gauge, the pressure inside the tyre is indicated by how far back the bar is pushed out of the back of the gauge. Note the numbers along the bar which allow us to measure the pressure.

Other, more complicated pressure gauges all work in a similar way.

Did you know?

Wind is simply moving air! The movement of the air is caused by differences in pressure between one area of the Earth's atmosphere and another. When the wind blows, it is the atmosphere equalling out uneven pressures by moving air from a high-pressure area to a low-pressure area.

Figure 5.37 Two more complicated types of tyre pressure gauges for measuring the air pressure inside car tyres. The right-hand one is a digital gauge.

How could we increase or reduce the amount of gas in a container? In the next activity we are going to see if we can understand gas pressure in terms of the particle model of matter.

Figure 5.39 By blowing air into the balloon, the girl is forcing air particles into it.

ACTIVITY: Understanding gas pressure

Materials

- brown paper bags (medium size)
- balloons
- empty plastic cold drink or water bottles (2-litre bottles are preferable)
- bicycle pump and tyre

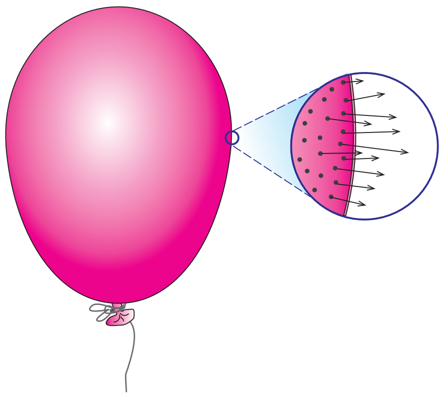
Instructions

1. This step requires a brown paper bag.
   a) Blow up a brown paper bag until it is fully inflated.
   b) Try blowing it up even more. See if you can make it pop by blowing into it.
   c) Write two or three sentences to describe what it feels like to blow into the bag when it is 'empty', compared to when it is 'full' of air. Does it feel different? Is it more difficult to blow into the bag when it is already full?
2. This step requires a balloon.
   a) Blow up the balloon until it is the size of an orange. Pinch it closed but do not tie a knot in the top.
   b) Now blow up the balloon as large as you can.
   c) Try blowing it up even more. See if you can make it pop by blowing into it.
   d) Write two or three sentences to describe what it feels like to blow into the balloon when it is 'empty', compared to when it is 'full' of air. Does it feel different? Is it more difficult to blow into the balloon when it is already full?
   e) Tie a knot in the top of an inflated balloon. Leave the balloon in the classroom and examine it again after one week. Does it look the same as when you inflated it a week ago? Perhaps it looks a bit like this balloon in the photo alongside:
   f) Remember to write down your observations.
3. This step requires a balloon and an empty plastic bottle.
   a) Stretch the balloon over the top of the bottle, with the balloon hanging down into the bottle.
   b) Blow into the balloon. What do you observe? Can you blow up the balloon?
   c) Now make a small hole in the bottom of the bottle. Blow into the balloon again. What do you observe now?
4. This step requires a bicycle tyre and pump.
   a) Use the pump to pump air into the tyre. Continue to pump until it becomes too difficult to pump any more air into the tyre.
   b) Write one or two sentences about your observations.

Questions

Try to answer the following questions by explaining what is happening to the air particles in each case. Use the words 'particles', 'collisions' and 'pressure' in your answers.

1. What happens when you blow up a paper bag or a balloon, or when you pump air into a tyre?
2. When you blow into a paper bag, why does the bag pop or start to leak air after a while?
3. When you blow into a balloon that is fully inflated, why does the balloon pop?
4. Why do you think the balloon became smaller when it was left for a week? The illustration alongside should provide a hint:
5. Explain why you think it was impossible to blow up the balloon inside the bottle? Why was it possible to blow up the balloon when there was a hole in the bottle?
6. Why does it become more and more difficult to pump air into the bicycle tyre?



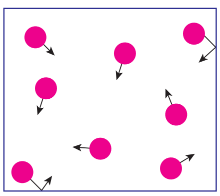
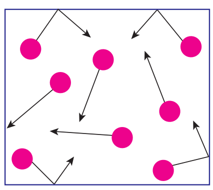
How does heating or cooling a gas change its pressure?

If the gas is heated, the particles will move faster as they gain more energy.

That means they will collide with the inside of the container more often and with more force. This causes an increase in pressure.

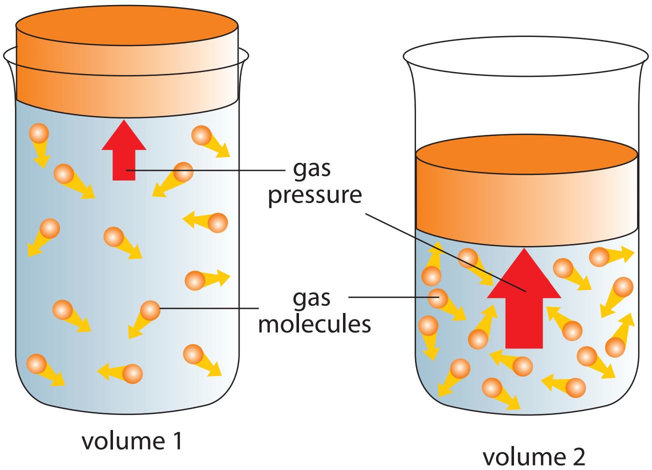
If the gas is cooled, the particles will move more slowly, because they will have less energy. The gas pressure will decrease, because the particles will bounce against the inside of the container less frequently and with less force. Look at the following table which illustrates this.

Figure 5.40 A deflated birthday balloon.

Cool gas	Hot gas
	
Fewer and less energetic collisions.	More and more energetic collisions.

How does changing the volume of a gas change its pressure?

When a gas is squeezed into a smaller volume, the particles have less space to move. This is shown in the diagram below. Have you noticed that when people are squashed into small spaces, they bump into things more often? In the same way, the gas particles will collide more often with each other and with the inside of the container if they have less space to move in. More collisions mean increased pressure!



We have learnt that a gas will expand to fill all the available space. So, what will happen if we take a certain amount of gas out of one container and place it into another container that is twice as large?

We still have the same number of gas particles, but now they are inside a much larger volume. There is twice as much space between the molecules as there was in the smaller container.

What has happened to the density of the gas? Has it increased, decreased or stayed the same?

In this unit, we learnt how many different physical properties of matter can be better understood when we think in terms of the behaviour of the particles in the matter.

Summary

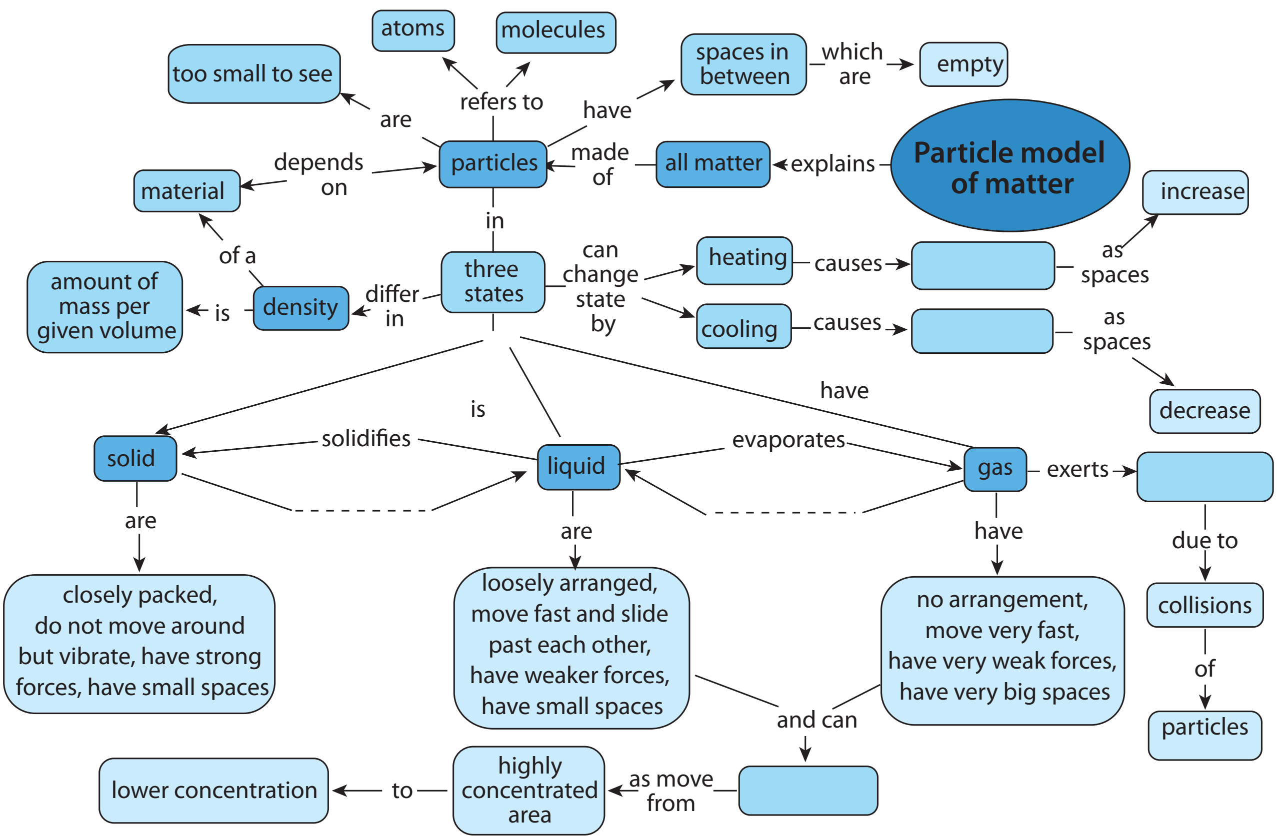
Key concepts

- All matter can be described in terms of the particles it consists of, and how they are arranged. These extremely small particles are called atoms or molecules, depending on the type of material.
- The theory that describes matter in terms of particles is called the particle model of matter. It helps us to understand the macroscopic properties of a material in terms of the behaviour of the particles in that material.
- The particle model describes the particles in **solids** as follows:
  - They are closely and regularly packed and locked into position;
  - The only movement they are allowed is vibration;
  - They are held together by strong forces; and
  - The spaces between them are very small.
- The particle model describes the particles in **liquids** as follows:
  - They are close together but not locked in position;
  - They are in constant motion and slide past each other;
  - They are held together by moderately strong forces; and
  - The spaces between them are very small (in most cases only slightly larger than the spaces between solid particles).
- The particle model describes the particles in **gases** as follows:
  - They are in constant fast motion;
  - They are not arranged in any way but free to move;
  - The forces between them are weak; and
  - They are far apart with large empty spaces between them.
- Since the particles of liquids and gases are in constant motion they are able to diffuse. Diffusion is a process in which particles spread out, through random movement from high to low concentration, until they are evenly distributed.
- When two substances mix, their particles intermingle until their composition is uniform throughout. This is also called diffusion, and the process is much faster in gases than in liquids, because the particles in gases are further apart.
- Changes of state are usually the result of heating or cooling:
- When a solid is heated it will change to a liquid (in a process called melting) and, when heated further, the liquid will change to a gas (in a process called evaporation).
- When a gas is cooled it will change to a liquid (in a process called condensation) and, when cooled even further, the liquid will change to a solid (in a process called freezing).
- The density of a material is a measure of its 'relative heaviness'. Denser materials have a greater mass in relation to their size; that is why they feel 'heavy'.
- The density of a material depends on two things:
  - the mass of the individual particles of that materials – the larger the mass, the denser the material; and
  - the size of the spaces between the particles in the material – the larger the spaces, the less dense the material.

- Materials with a loose texture (such as bread and sponge, for example) have empty spaces or holes inside them, which means they have less mass in relation to their volume. These materials tend to be less dense.
- Materials that are less dense always float on materials that are more dense.
- The particles of matter are constantly moving. In solids these movements are limited to vibrations, but in liquids and gases the particles have more freedom.
- Most materials will expand when they are heated and contract when they are cooled. This is because heating makes the particles move further apart and cooling makes them move closer together.
- When we want to know how much of a gas we have, we can measure its pressure.
- The 'pressure' of a gas is caused by the particles of the gas colliding with the inside of a container and with each other.
- More gas particles inside the container will mean more collisions against the sides, and therefore, more pressure.

Concept map

Have a look at the concept map that shows how the many concepts relating to the particle model of matter fit together. There are four empty blocks which you need to fill in.

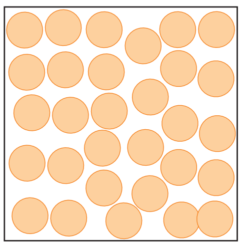


Revision

1. Write your own explanation of what you think the particle model of matter tells us. [2]
2. What is unusual about water in terms of the particle model of matter? Explain why water is an exception. [2]
3. In your exercise books copy and complete the following table with the terms and definitions of different changes of state. [4]

Change of state	Explanation
	When heat is added and a solid changes to a liquid
Condensation	
	When heat is added and the particles at the surface of a liquid change to the gas state
Solidifying	

4. Explain what happens to the particles in a solid when heat is added to the solid and it changes to a liquid. [3]
5. Complete the following sentence by writing it out in full again: During expansion, the spaces between the particles get, __________ , and during contraction, the spaces between the particles get __________. [2]
6. How can a piece of metal get bigger (expand) and still have the same mass? Explain this in terms of the behaviour of the particles. [2]
7. Why does oil float on top of water? [1]
8. Draw a picture to show the path of a perfume particle from a flower on one side of a room to your nose on the other. [2]
9. Next time you are at the petrol station, look around for a warning sign that shows you should not light a match or use a cell phone. Why do you think it is dangerous to light a match or use a cell phone anywhere near a petrol station? [2]
10. If you fill a bicycle pump with air, and seal the end with your finger, the plunger can still be pushed in quite a way before the pressure forces air out of the pump. If the pump is filled with water instead of air, the plunger can hardly move. Why is this so? Try to use the words 'particles', 'spaces', and 'compress' in your explanation. [4]
11. The following table represents a summary of the entire unit. You must copy and complete the table in your exercise books using your own words and or diagrams. Some of the blocks in the table already contain information to help you form your own sentences. [18]

State of matter	Solid	Liquid	Gas
Diagram showing how the particles are arranged			

State of matter	Solid	Liquid	Gas
Arrangement of the particles	Very closely packed Regular arrangement		
Spaces between particles			Very large
Forces of attraction between particles		Strong, but weaker than in solids	
Movement of particles			Fast and random movement
Shape		No fixed shape Depends on the container	
Volume			No fixed volume Depends on the container
Compressibility	Cannot be compressed		
Diffusion		Diffuses slowly	
Density compared to the other states	Highest density (except in the case of ice)	Almost as dense as the solid	

Total [42 marks]

6 Chemical reactions

Key questions

- What is a chemical reaction?
- What happens to atoms and the bonds between them during a chemical reaction?
- How can we identify the reactants and products of a reaction?
- What examples of chemical reactions are there in indigenous practices?

In the last unit we looked at the particle model of matter and specifically at changes of state. Do you remember heating and cooling candle wax to observe it melt and then solidify? The wax first changed from a solid into a liquid and then back to a solid again. These are **physical** changes. The chemical properties of the substance does not change.

We are now going to look at what happens when we get **chemical** changes in substances. These take place during **chemical reactions**.

6.1 How do we know a chemical reaction has taken place?

During a chemical reaction, one or more substances are changed into new substances. Do you know of any chemical reactions? Can you mention one or two examples?

How will we know when a chemical reaction is taking place? What are the signs?

We can tell if a chemical reaction has taken place when one or more of the following things happen:

- There has been a colour change inside the **reaction flask**.
- A gas has formed. Usually we know a gas has formed when we can see bubbles. This should not be confused with boiling, which happens only when a liquid is heated to its boiling point.
- A solid has formed. Usually we know that some solid material has formed when we can see a sludgy or cloudy deposit, or crystals forming.
- Our other senses can also help us to say whether or not there was a chemical reaction:
  - Sometimes chemical changes can be smelled, for instance when a new material, that has a strong smell, is formed.
  - Other chemical changes can be felt, for example when the reaction produces heat.
  - Some chemical changes can be heard, for example when an explosion takes place.

Keywords

- chemical reaction
- reaction flask or reaction vessel

ACTIVITY: The difference between physical and chemical changes

Instructions

1. Below is a table with some different chemical and physical changes listed.
   Copy the table in your exercise books and indicate whether the change is physical or chemical in the last column.

Change	Is it a physical or chemical change?
Cutting up potatoes into cubes	
Boiling water in a pot on the stove	
Frying eggs in a pan	
Whipping egg whites	
Dissolving sugar in water	
Burning gas in a gas cooker	
Your ice cream melts in the sun	
Milk turning sour	
An iron gate outside rusts	

We will now put our checklist into practice by looking at a reaction safe enough to try at home. Have you ever wondered what a raw egg would look like without its shell? We are going to use a chemical reaction to strip away the shell of an egg, without breaking the egg!

ACTIVITY: Can we use a chemical reaction to see inside an egg?

Materials

- eggs
- a glass
- white vinegar

Instructions

1. Carefully place the egg in the glass. Be careful not to crack the shell.
2. Cover the egg with vinegar. Wait a few minutes. Can you see anything happening on the surface of the eggshell?
   a) Write your observations in your exercise books.
   b) What is this observation a sign of?
3. Leave the egg in the vinegar for 4 – 5 days. You should complete the rest of the activity after this.

Did you know?

Bones, teeth and pearls will all dissolve in vinegar, just like the eggshell did, even though these may take much longer.

4. After 4 – 5 days, look at the egg in the vinegar and write down your observations.
5. Carefully scoop the egg out of the vinegar with a large spoon. Touch the surface of the egg. Write your observations in your exercise books. What has happened to the shell?
6. Rub the powdery coating off the egg and place it in some clean water. What does it look like now?
7. Draw and label pictures of what the contents of the glass looked like before and after the reaction took place.

Questions

1. What signs did you see that told you a chemical reaction had taken place?
2. Write a short paragraph to explain what happened to the eggshell.

How is it possible to change one compound into another? What happens to the particles when compounds react? In the next section we are going to answer these questions.

6.2 Reactants and products

In Unit 4 we learnt that compounds are formed by chemical reactions. Can you remember what a compound is? Write a definition here.

Write down the formulae of three different compounds.

Keywords

- reactant
- product
- chemical equation
- coefficients
- fermentation

ACTIVITY: Analysing the eggshell experiment

In the eggshell activity the calcium carbonate in the eggshell reacted with acetic acid and formed calcium acetate, carbon dioxide and water.

We can write this **chemical equation** as follows:

eggshell + vinegar → calcium acetate + carbon dioxide + water

Questions

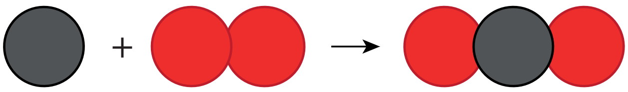
1. There are two starting substances **before** this chemical reaction takes place. What are they?
2. There are three substances present **after** the reaction. What are these?
3. What are the chemical formulae for the compounds water and carbon dioxide?
4. We call the substances that are present before the chemical reaction has taken place the **reactants**. What are the reactants of the experiment?
5. What do you think happened to the reactants during the chemical reactions?
6. We call the substances that are produced during the chemical reaction the **products**. What are the products of the experiment?

During a chemical reaction, the reactants are used to make the products. The atoms in the reactants have been rearranged into new compounds (the products).

A chemical reaction is a rearrangement of atoms

In order to change a compound into a different compound, we need to change the way in which the atoms in the compound are arranged. In a chemical reaction the atoms in the reactants are rearranged to form the products. The number of atoms of each reactants is the same as in the products.

We are going to use coloured circles to represent the atoms in the compounds which take place in chemical reactions. If you still have your beads or playdough from previously, you can also make these reactions yourself on your desk. Look at the following diagram.



We have carbon and oxygen on the left of the arrow reacting to make carbon dioxide on the right of the arrow.

To the left of the arrow, we have the 'before' reaction. This side represents the substances we have before the reaction takes place. They are called the **reactants**. To the right of the arrow we have the 'after' reaction. This side represents the substances that we have after the reaction has taken place. They are called the **products.**

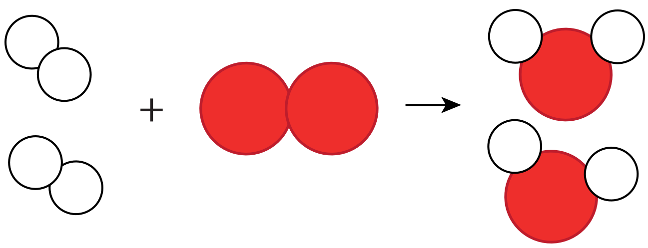
Figure 6.1 Coal is carbon.

REACTANTS (before the reaction) → PRODUCTS (after the reaction)

Do you see how the atoms have rearranged? This means a chemical reaction has taken place.

The reaction between carbon and oxygen takes place when we burn coal. Coal is carbon and when it burns in oxygen gas, carbon dioxide is formed.

The diagram below represents another chemical reaction. We have oxygen (red molecules) reacting with hydrogen (white molecule) to produce water.



1. What are the reactants in this reaction?
2. What is the product in this reaction?
3. Why do you think hydrogen and oxygen are represented as two atoms joined together?

Do you remember when we spoke about **chemical bonds** between atoms in a molecule in Unit 4? A chemical bond is a force which holds the atoms together. Therefore, during a chemical reaction, the bonds between atoms have to break so that the atoms can rearrange to form the products. New bonds form between the atoms in the product.

Next we will look at a chemical reaction that has been used by humankind for centuries.

Fermentation is a chemical reaction

Have you ever forgotten some milk or juice in a bottle, to find that it has 'gone off' a few days later? If you accidentally tasted it, it may have tasted sour and, in the case of the juice, a bit fizzy as well. Your senses may have warned you not to drink any more of it. Do you remember learning in Grade 7 that our sense of taste protects us from food that has spoiled?

The sour taste of the milk or juice is caused by the products of **fermentation**.

Which compounds have a sour taste?

Fermentation does not produce only unwanted products. Yoghurt, buttermilk and cheese are all fermented milk products. In these examples, the fermentation process creates acids that give these foods a sour taste.

Figure 6.2 Different dairy products which are made using fermentation.

Figure 6.3 Two buckets of ginger beer fermenting.

Fermentation is also the process by which a variety of fruits, vegetables and grains can be used to make alcohol. In many cultures the brewing of alcoholic drinks is part of their indigenous knowledge.

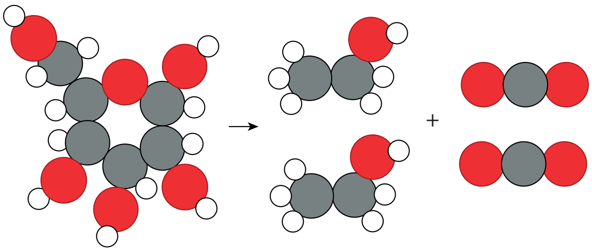
ACTIVITY: Studying the fermentation reaction

The basic reaction in the fermentation process can be summarised as follows:

glucose → alcohol + carbon dioxide

What are the reactants and products in this reaction?

We can draw pictures of the molecules to show how the atoms are rearranged during the reaction:



In the diagram above, the grey atoms are carbon (C), the red atoms are oxygen (O) and the small, white ones are hydrogen (H). Write in the names of the compounds in this reaction.

Glucose does not change into alcohol and carbon dioxide by itself!

Microorganisms like yeast and bacteria actively ferment glucose. In South Africa, a popular drink is ginger or pineapple beer. The fizzy bubbles in the ginger beer or pineapple beer are bubbles of carbon dioxide produced by the yeast during fermentation. Let's make some ginger beer!

Did you know?

Yeast produces special chemicals called enzymes that can break down the bonds in sugars, such as glucose, to form smaller molecules like alcohol and carbon dioxide.

Instructions

1. You need to research how to make traditional South African ginger beer.
2. Identify the different ingredients you will need.
3. Once you have done so, you can decide as a class about the best recipe you will use. You can then make ginger beer in class with your teacher.
4. Answer the questions that follow.

Questions

1. What are the reactants in the reaction to make ginger beer?
2. What is the product in the reaction taking place in the ginger beer?
3. Why are there fizzy bubbles in the ginger beer?
4. Where do you think the gas came from?
5. Another example of where we see a chemical reaction taking place is when we burn wood in a fire, either in our homes or to cook food. The wood burns and produces carbon dioxide gas and water vapour. What are the products and reactants in this reactions?

Chemical reactions can help us to detect certain substances

Some chemical reactions can produce results that are unique and even spectacular! Have you ever seen the volcano experiment? This experiment is shown in the video link in the visit box.

When ammonium dichromate burns in oxygen, the reaction produces bright orange sparks. The reaction forms nitrogen gas (N_2), water, and a dark-green compound called chromium oxide as products. This reaction is unique. Only ammonium dichromate reacts with oxygen to form these particular products with these particular visual effects.

Figure 6.4 Ammonium dichromate before it is burned in oxygen.

Figure 6.5 Chromium oxide is the product.

When two substances react in a unique and characteristic way when they are mixed, one of them can be used to *detect* the other.

ACTIVITY: Some chemical reactions from *Life and Living*

1. Do you remember we used clear limewater to detect carbon dioxide in our breath in Unit 1 in *Life and Living*? What colour did the clear limewater turn when we blew bubbles through it?
2. Limewater is a solution of calcium hydroxide in water. A reaction occurs between the limewater and the carbon dioxide to produce a white substance in the water called calcium carbonate. What are the reactants and products in this reaction?
3. We say that we used the colour change of the limewater to detect the carbon dioxide in our breath. Carbon dioxide is the by-product of the chemical reaction that takes place during respiration in all organisms. Write a word equation for respiration.
4. In *Life and Living* we spoke about the ingredients of respiration as we had not yet learned the terms reactant and product. What are the reactants and what are the products in respiration?
5. What are the reactants and products in photosynthesis?

We have also learnt that chemical reactions are simply rearrangements of atoms in molecules, to make different molecules. That is what many chemists do for a living! They find ways of rearranging atoms in order to make new compounds.

Take note

Next year you will choose the subjects that you will be studying until Grade 12. Will you choose Physical Sciences, Life Sciences and Mathematics? Before you decide which subjects to take, explore what you can do with each of them after school.

Figure 6.6 Marie Curie (1867 – 1934) was a famous chemist and physicist, honoured specifically for her research on radioactivity. She was the first woman to win a Nobel Prize, the only woman to win in two fields and the only person yet to win a Nobel Prize in multiple sciences!

Careers in chemistry

Natural Sciences is all about discovery! We want to show you how the things you study in class are useful in the real world. This subject is much too big for us to learn everything about it in school. There are many different careers based in science that you can choose.

Be curious about the world around you and explore it with your growing knowledge of science.

There are many, many applications and uses of chemistry, and many different careers make use of chemistry in some way. Let's find out.

ACTIVITY: Careers in chemistry

Instructions

1. Below is a list of different careers that all use chemistry in some way. Have a look through the list and then select the five careers you find most interesting.
2. Do an internet search to find out what each career is.
3. Write a one-line description of this career.
4. If there is a career that really interests you, draw a smiley face next to it and be sure to do some extra reading around the topic and where chemistry may take you! Find out what level of chemistry you will need for this particular career.
5. There are many other careers besides the ones listed here which use chemistry in some way, so if you know of something else which is not listed here and it interests you, follow your curiosity and discover the possibilities!

Some careers involving chemistry:

- Agricultural chemistry
- Biochemistry
- Biotechnology
- Environmental chemistry
- Chemical education/teaching
- Chemistry researcher
- Forensic science
- Food science/technology
- Geneticist
- Materials science
- Geochemistry
- Medicine and medicinal chemistry
- Oil and petroleum industry
- Organic chemistry
- Oceanography
- Patent law
- Pharmaceuticals
- Space exploration
- Zoology

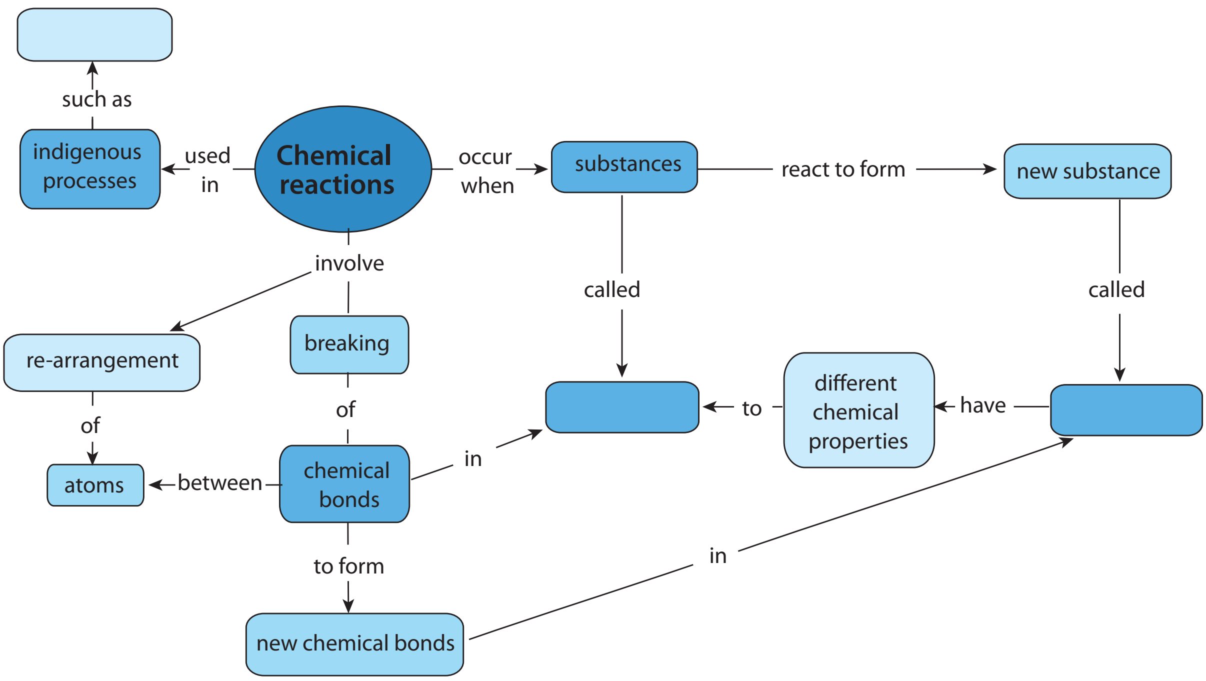
Summary

Key concepts

- During chemical reactions, materials are changed into new materials with new chemical and physical properties.
- The materials we start with are called reactants and the new materials that form are called products.
- During chemical reactions, atoms are rearranged. This requires that chemical bonds in the reactants are broken and that new bonds are formed, resulting in product formation.
- Fermentation in brewing is an example of a chemical reaction that is also part of indigenous knowledge.

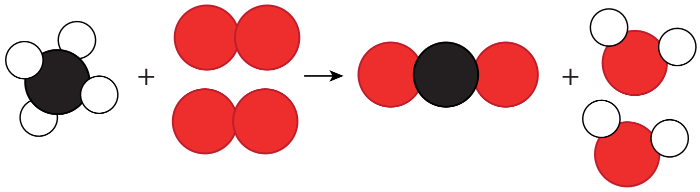
Concept map

Fill in the blanks in the concept map below.



Revision

1. Suppose you mix some chemicals in a beaker. How will you know if a reaction has taken place? Write a paragraph describing each of the signals that would indicate a reaction has taken place and what each signal tells you about that reaction. [6]
2. Write your own definition for what a reactant is. [1]
3. Write your own definition for what a product is. [1]
4. Explain what happens to the bonds between atoms in the reactants and products in a chemical reaction. [2]
5. Methane gas (CH_4) is a natural fuel gas that burns in oxygen gas to produce carbon dioxide and water. The reaction can be represented by the following diagram:



Key:
Carbon atoms (C): black
Oxygen atoms (O): red
Hydrogen atoms (H): white

a) Use the diagram and the 'key' below it to write formulae for each of the substances in the reaction in your exercise books. [4]

Name of compound	Formula
Methane	
Oxygen gas	
Carbon dioxide	
Water	

b) What are the reactants of the above reaction? [2]
c) What are the products of the above reaction? [2]
d) Write the names of the reactants and products under the colourful picture representations of each of the molecules. [2]

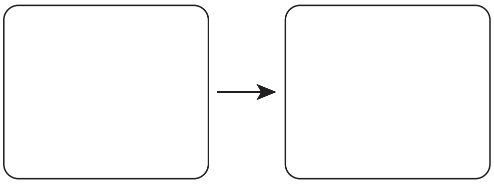
6. Ammonia (NH_3) is produced from hydrogen gas and nitrogen gas.

a) Copy the following table and draw one molecule of each of the substances in the reaction. [3]

Name of compound	Diagram of one molecule of the compound
Hydrogen gas, H_2	
Nitrogen gas, N_2	
Ammonia, NH_3	

b) Copy and use the template below in your exercise books to draw diagrams representing the particles before and after the reaction. Your diagram should also show how many of each type of particle take part in the reaction.

[4 marks: 2 marks each for 'before' (left) and 'after' (right) sketch]



c) What are the reactants of the above reaction? [2]

d) What is the product of the above reaction? [1]

7. Look at the following illustration which shows a test tube with milky limewater.

a) What gas must have been bubbled through it to make it turn milky? [1]

Figure 6.7 Limewater that has turned milky in a test tube.

b) What are the reactants in this chemical reaction? [1]

Total [32 marks]

GLOSSARY: Matter and Material

air valve: a device that works as a gateway to allow air to flow in only one direction (either into or out of something

atomic nucleus: a tightly packed cluster of protons and neutrons at the centre of the atom

atoms: the fundamental particles that all matter is made up of

boiling: occurs *within a liquid* when it is heated to its boiling point and particles escape as bubbles of gas from the liquid

boiling point: the temperature at which bubbles form in a heated liquid and rise to the surface

chemical bond: a special force that holds the atoms in a molecule together

chemical equation: a way of representing a chemical reaction in terms of the chemical formulae of the reactants and products

chemical formula: a combination of element symbols that shows the types and number of atoms in one molecule of a certain compound

chemical reaction: a process in which chemical bonds are broken and new ones are formed between atoms; atoms in the starting compounds, called reactants, are rearranged to form new compounds, called products

cluster: (verb) to come together and form a tight group

coefficients: the numbers in front of the atom and molecule formulae in the chemical equation; they represent the ratio of the numbers of individual molecules that take part in the chemical reaction

collide: (noun: collision) to bump or crash into something

compound: a pure substance in which atoms of two or more different chemical elements are bonded in some fixed ratio

compress: (adjective: *compressible*) to squeeze the particles of a material closer together

condensation: when energy is removed and a gas changes state to a liquid

constant motion: something that is in constant motion never stops moving

contract: the physical size of an object gets smaller

controlled experiment: an experiment in which the variables are controlled so that the results can be compared to those obtained in another experiment

decomposition reaction: a chemical reaction in which a given molecule is broken up and recombined into smaller molecules

density: the mass of a substance in a given space (volume)

diffuse: (noun: *diffusion*) particles move so that they end up spread out randomly and uniformly in a given space

disordered: untidy; without regular arrangement

distinction: the separation of things into different groups according to features or characteristics

electrons: the smallest of the three types of sub-atomic particles; they are negatively charged and are located outside the atomic nucleus

element: a pure substance made up only of atoms of the same kind

energetic: full of energy

evaporation: when energy is added and the particles *at the surface* of a liquid change state to a gas

expand: the physical size of an object gets bigger

fermentation: a chemical reaction that occurs in the presence of yeast and/or bacteria, during which a sugar is converted to an alcohol or an acid

forces of attraction: forces that particles experience which draw them closer to each other

immiscible: incapable of mixing or blending

impact: (noun) effect

mass: a measure of the amount of matter in an object or material

melting: when energy is added and a solid changes state to a liquid

melting point: the temperature beyond which a particular material changes from the solid to the liquid state (melts)

mixture: a combination of two or more pure substances mixed together

molecule : two or more atoms that have chemically bonded with each other; the atoms in a molecule can be of the same kind (in which case it would be a molecule of an element), or they can be of different kinds (in which case it would be a molecule of a compound)

neutrons: a type of sub-atomic particle similar to protons in mass and size, but neutral (without charge); neutrons together with protons make up the atomic nucleus

observation: an observation is something we can see, hear, taste, smell or feel

phenomenon: (plural: *phenomena*) an event or occurrence that we can observe with our senses

physical quantity: something that can be measured or estimated

postulate: a claim that can be supported by experimental evidence

pressure gauge: an instrument used to measure the gas pressure inside something

product: a substance that forms during the reaction; it will be present after the reaction has taken place

protons: a type of sub-atomic particle that is positively charged and occurs inside the atomic nucleus along with neutrons

pure substance: matter that consists of the same material throughout; two classes exist, namely elements and compounds

random: unpredictable

rate: how fast or slowly an event (e.g. diffusion) occurs

reactant: a substance that is present before the reaction takes place; it is a starting material of the reaction

reaction flask or **reaction vessel:** the container in which the reaction has taken place; small-scale chemical reactions done in a laboratory are usually performed in glass beakers or flasks

regular arrangement: an arrangement of particles in a neatly packed, consistent and repetitive pattern

reinforce: to make stronger, usually by the addition of another material or other form of support

reverse: 'opposite', as in: melting and freezing are *reverse* processes (the opposite of each other)

scientific model: a set of ideas that represents a concept, object, or process in nature to help us understand it

scientific theory: an explanation of scientific phenomena or aspects of the natural world, supported and confirmed by facts obtained through observation and experimentation

solidifying: (freezing) when energy is removed and a liquid changes state to a solid

sub-atomic particle: a particle that is smaller than the atom and occurs inside the atom

transformation: change; to transform is to change from one form into another

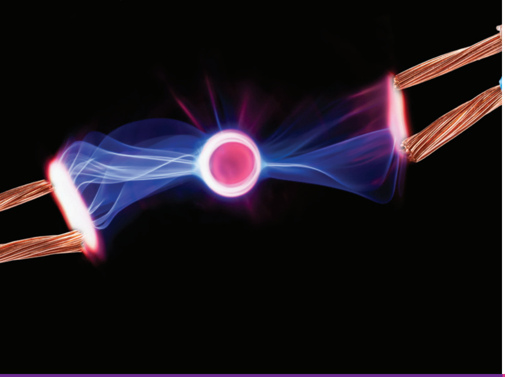
uniform: the same throughout

vapour: the gaseous state of a substance that is normally liquid or solid at room temperature, such as water that has evaporated into the air

vibrate: to move rapidly back and forth

vigorous: strong and forceful

volume: a measure of the amount of space occupied by a three-dimensional object or material



Strand

Energy and Change











7 Static electricity

Key questions

- What is static electricity?
- What is friction?
- Why does my hair stand on end and crackle when I pull a jersey off?
- What is lightning?
- What does to 'earth' an object mean?
- What does it mean when we say 'opposites attract'?

Have you ever pushed a trolley through the shops and suddenly felt a shock? Or pulled your school jersey over your head and heard it crackling? What causes those shocks and noises? Let's investigate.

Keywords

- static electricity
- friction

7.1 Friction and static electricity

The effects of **static electricity** are all around us, but we do not always recognise it when we see or feel them. Or perhaps you have, but you never realised what was causing it. For example, have you ever felt a slight shock when you put a jersey over your head on a cold day, or perhaps you have observed your hair stand on end when you touch certain objects?
Let's do a quick activity to demonstrate static electricity.

ACTIVITY: Sticky balloons

Materials

- balloons (or a plastic comb)
- small pieces of paper

Instructions

1. Work in pairs.
2. Blow up a balloon and tie it closed so that the air does not escape.
3. Hold the balloon a short distance away from your hair or pieces of paper. What do you notice?
4. Rub your hair with the balloon.
5. Now hold the balloon a short distance away from your hair or pieces of paper. What do you see?

Figure 7.1 Did you see your hair 'rise' like this?!

Questions

1. What did you do to make your hair or the pieces of paper stick to the balloon?

Let's look at an everyday example of static electricity. Sometimes when you comb your hair with a plastic comb your hair stands on end and makes crackling sounds. How does this happen?

You have dragged the surface of the plastic comb against the surfaces of your hair. When two surfaces are rubbed together there is **friction** between them.

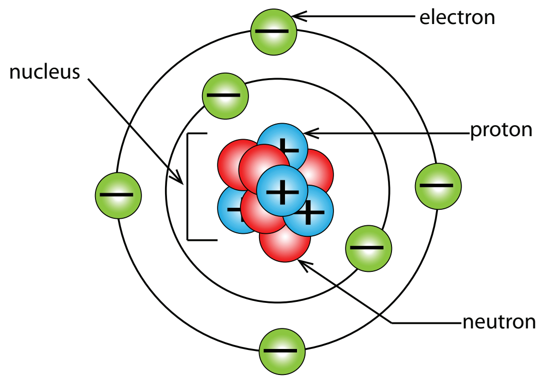
Friction is a resistance against the movement of an object as a result of its contact with another object. This means that when you rubbed the plastic comb along your hair, your hair resisted the movement of the comb and slowed it down.

Keywords

- friction
- electrostatic attraction
- attract
- repel
- neutral
- discharge
- earth
- earthing

The friction between two surfaces can cause electrons to be transferred from one surface to the other.

In order to understand how electrons can be transferred, we need to remember what we learnt about the structure of an atom last term in Matter and Materials.



All atoms have a nucleus which contains protons and neutrons. The nucleus is held together by a very strong force, which means that the protons within a nucleus can be considered to be fixed there. The atom also contains electrons.

- Where are the electrons arranged in the atom?
- What is the charge on a proton?
- What is the charge on an electron?
- What is the charge on a neutron?

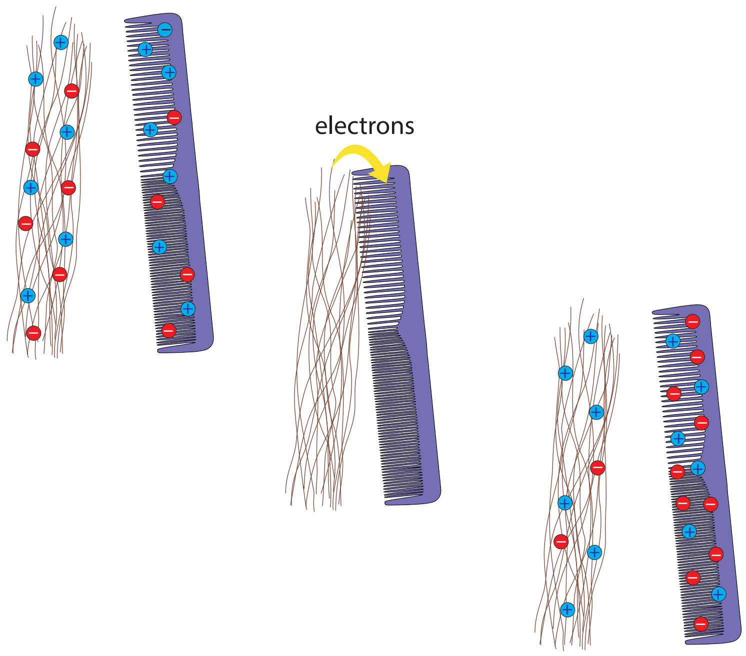
The atom is held together by the **electrostatic attraction** between the positively charged nucleus and the negatively charged electrons. Within an atom, the electrons closest to the nucleus are the most strongly held, while those further away experience a weaker attraction.

Take note

Remember, like charges repel and opposite charges attract.

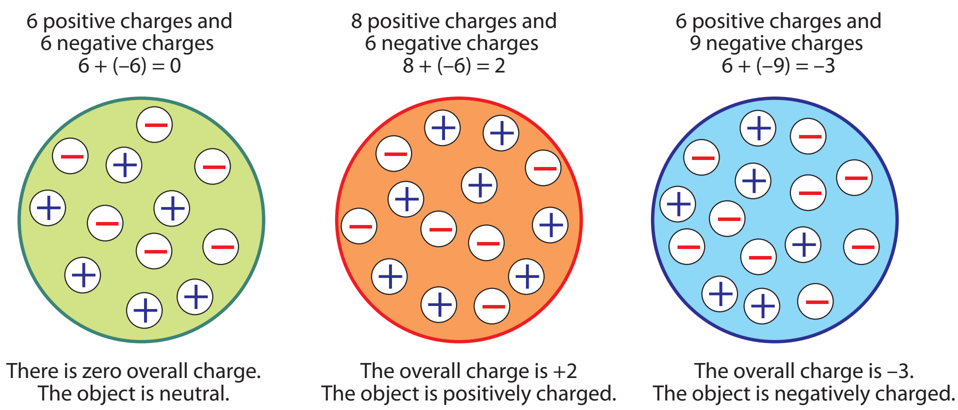
Normally, atoms contain the same number of protons and electrons. This means that atoms are normally **neutral** because they have the same number of positive charges as negative charges, so the charges balance each other out. All objects are made up of atoms and since atoms are normally neutral, objects are also usually neutral.

However, when we rub two surfaces together, like when you comb your hair or rub a balloon against your hair, the friction can cause electrons to be transferred from one object to another. Remember, the protons are fixed in place in the nucleus and so they cannot be transferred between atoms. It is only electrons that are able to be transferred to another surface. Some objects give up electrons more easily than other objects. Look at the following diagram which explains how this happens.



- Which object gave up some of its electrons in the diagram?
- Does this object now have more positive or more negative charges?
- Which object gained electrons in the diagram?
- Does this object now have more positive or more negative charges?
  - When an object has more electrons than protons overall, then we say that the object is **negatively charged**.
  - When an object has fewer electrons than protons overall, then we say that the object is **positively charged**.

Have a look at the following diagram, which illustrates this.



So, we now understand the transfer of electrons that takes place as a result of friction between objects. But how did that result in your hair rising when you brought the charged balloon close to your hair in the last activity? Let's look at what happens when oppositely charged objects are brought together.

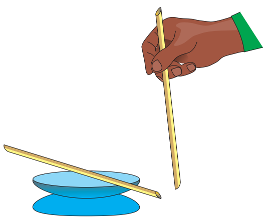
ACTIVITY: Turning the wheel

Materials

- two curved watch glasses
- two perspex rods
- cloth: wool or nylon
- plastic rod
- small pieces of torn paper

Instructions

1. Place a watch glass upside down on the table.
2. Balance the second watch glass upright on the first watch glass.
3. Rub one of the perspex rods vigorously with the cloth.
4. Balance the perspex rod across the top of the watch glass.
5. Rub the second perspex rod vigorously with the same cloth.
6. Bring the second perspex rod close to the first perspex rod. What do you see happening?
7. Repeat the activity but instead of the second perspex rod, use the plastic rod. What do you see happening?
8. Next, bring a rod that you have rubbed close to small pieces of torn paper lying on the table. What do you observe?



Questions

1. What happened when you brought the second perspex rod close to the first perspex rod?
2. What happened when you brought the plastic rod close to the first perspex rod?
3. What happened when you brought the plastic rod close to the pieces of paper?

When we rubbed the perspex rods with the cloth, electrons were transferred from the perspex to the cloth. What charge do the perspex rods now have?

Both the perspex rods now have the **same** charge. Did you notice that objects with the same charge tend to push each other away? We say that they are **repelling** each other.

When we rubbed the plastic rod with the cloth, electrons were transferred from the cloth to the plastic rod. What charge does the plastic rod now have?

The perspex rod and the plastic rod now have **opposite** charges. Did you notice that objects with different charge tend to pull each other together? We say that they are **attracting** each other.

In the example of the pieces of paper being attracted to the ruler, the paper starts off neutral. However, as the negatively charged plastic rod is brought closer, the electrons in the paper that are nearest to the rod will begin to move away, leaving behind a positive charge on the surfaces of the paper that are nearest to the rod. The paper is therefore attracted to the rod because opposite charges attract. Another example is dust that is attracted to newly polished glasses.

We have now observed the fundamental behaviour of charges.

In summary, we can say:

- If two negatively charged objects are brought close together, then they will repel each other.
- If two positively charged objects are brought close together, then they will repel each other.
- If a positively charged object is brought near to a negatively charged object, they will attract each other.

Do you now understand why your hair rises and is attracted to the balloon after you rub the balloon on your hair? Write a short description to explain what is happening using the words: electrons, transfer, negative charge, positive charge, opposite, attract, repel.

Sparks, shocks and earthing

A large build-up of charge on an object can be dangerous. When electrons transfer from a charged object to a neutral object we say that the charged object has discharged.

Keywords

- flammable
- ignite

Discharging can take place when the objects touch each other. But the electrons can also transfer from one object to another when they are brought close, but not touching. When electrons move across an air gap they can heat the air enough to make it glow. The glow is called a **spark**.

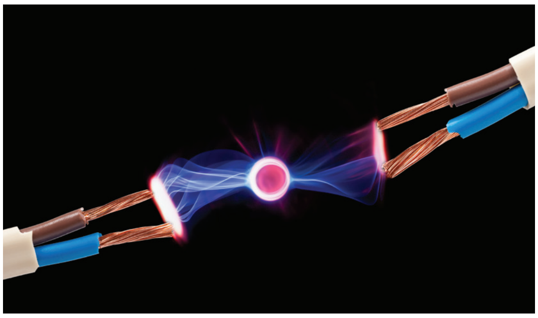


Figure 7.2 An electrostatic spark between two objects.

Sparks can be harmless, but they can also be very dangerous. Sparks can cause **flammable** materials to **ignite**. You will probably have noticed that you may not smoke cigarettes or have open flames near petrol tanks at petrol stations. This is because petrol fumes are very explosive and only need a small amount of heat to start them burning. A small electrostatic spark is enough to ignite flammable petrol fumes.

Electrostatic discharge can also cause **electric shocks**. Have you ever been shocked by a shopping trolley while you are pushing it around a shop? Or have you walked across a carpeted room and then shocked yourself when you touch the door handle to leave the room? You have experienced an electric discharge.

Electrons move from the door handle onto your skin and the movement of the electrons causes a small electric shock. Small electric shocks can be uncomfortable but mostly harmless. Large electric shocks are extremely dangerous and can cause injury and death.

Figure 7.3 Lightning is a huge electrostatic discharge.

Did you know?

Lightning bolts can travel at about 210 000 km/h and get as hot as 30 000 °C.

Do you know where else we can see sparks resulting from static electricity? Look at the photo for a clue!

During a thunderstorm, there is friction in the atmosphere between the particles that make up clouds, causing the build-up of regions of charge. Once the difference in charge between two regions becomes great enough, electrostatic discharge becomes possible. A lightning flash is a massive discharge between charged regions within clouds, or between clouds and the Earth.

In order to discharge extra electrons safely from an object we must earth it. **Earthing** means that we connect the charged object to the ground (the Earth) with an electrical conductor. The extra electrons travel along the conductor and enter the ground without causing any harm. The Earth is so large that the extra charge does not have any overall effect.

For example, think of the metal trolleys in shopping centres. Have you ever noticed that they normally have a metal chain hanging at the bottom which drags along the floor? This is to earth the trolley if it gets a charge so that charge cannot build up on the trolley. This protects the person pushing the trolley from getting a shock.

ACTIVITY: Research the practical applications of static electricity

Instructions

1. Use the internet or your school or community library to find information about the practical applications of static electricity.
2. Research one useful effect of static electricity and one problem caused by static electricity.
3. Write a short paragraph explaining your research.

Did you know?

The fundamental idea of using friction in a machine to generate a charge dates back to the 17th century, but the generator was invented by Robert Van de Graaff only in 1929 at Princeton University.

We are now going to look at two instruments which demonstrate static electricity.

Figure 7.4 These girls are touching the large dome of a Van de Graaff generator.

Van de Graaff generator

The Van de Graaff generator is a machine which uses friction to generate a large build-up of electric charge on a metal dome.

The Van de Graaff generator can be used to demonstrate the effects of an electrostatic charge. The big metal dome at the top becomes positively charged when the generator is turned on. When the dome is charged it can be discharged by bringing another insulated metal sphere close to the dome. The electrons will jump to the dome from the metal sphere and cause a spark.

You can also touch the dome and your hair will rise. Why do you think this happens?

Electroscope

An electroscope is an early scientific instrument used to identify the presence of a charged object or it can be used to identify the type of charge on a charged object.

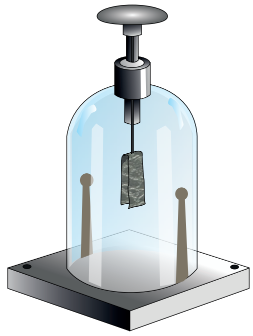


Figure 7.5 An example of an electroscope with a disc at the top and two gold foil strips at the bottom.

The illustrations alongside show some drawings of different types of electroscopes.

The electroscope is made up of an earthed metal box with glass windows. There is a metal rod hanging down and at the end two strips of thin gold are foil attached to it. A disc or ball is attached to the top of the metal rod, as seen in the illustrations.

When the metal ball or disc at the top is touched with a charged object, or a charged object is brought near to it, the gold foil strips spread apart, indicating that the object has a charge.

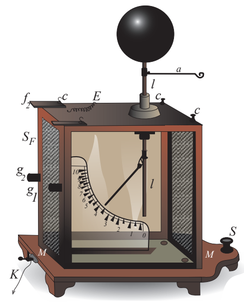
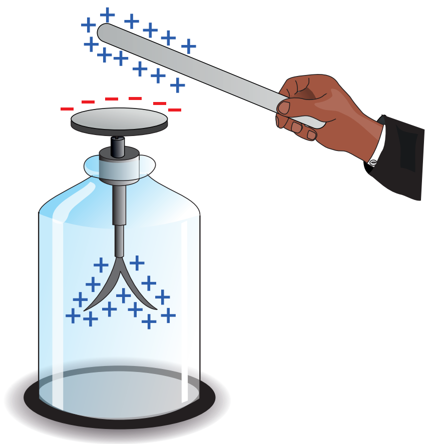


Figure 7.6 An early example of an electroscope with one gold strip at the bottom and a ball at the top.

Look at the next illustration, which shows how this works.



The positively charged rod attracts electrons to the disc from the gold foil strips.

The disc at the top becomes negatively charged and the gold foil strips at the bottom become positively charged. Why do the gold foil strips move apart?

You can make a simple electroscope with everyday items. Let's try.

ACTIVITY: Making a simple electroscope

Materials

- glass jar, with lid
- 14-gauge copper wire, about 12 cm in length
- plastic straw or plastic tubing
- two small pieces of aluminium foil
- piece of woollen cloth
- plastic ruler
- glass rod

Instructions

1. Twist one end of the copper wire into a spiral shape. This will increase its surface area.
2. Make a hole in the jar lid and push a small piece of the plastic tubing through the hole.
3. Put the other end of the copper wire through the straw so that the spiral end is on the outside of the lid.
4. Make a hook out of the pointed end of the copper wire.
5. Cut two rectangular strips of aluminium foil.
6. Put each piece of aluminium foil onto the hook. Make a small hole in the aluminium foil to allow it to hang from the hook.
7. Carefully put the hooked end of the copper wire into the glass jar and close the jar.
8. Rub the ruler with the woollen cloth for a minute.
9. Bring the ruler close to the spiral end of the copper wire.

Questions

1. What did you observe when you brought the ruler close to the copper wire?
2. What happens if you move the ruler away from the copper wire?
   Why do the pieces of aluminium foil move apart? When you rubbed the plastic ruler with the woollen cloth, the ruler became negatively charged. When the negatively charged ruler is brought close to the copper wire, the electrons on the wire are repelled downwards towards the aluminium foil. The pieces of aluminium foil then have extra electrons on them and they both become negatively charged. Two objects which are negatively charged will repel each other and so the pieces of aluminium foil move away from each other.
3. Write a short paragraph to explain what would happen if you brought a positively charged object close to your electroscope.

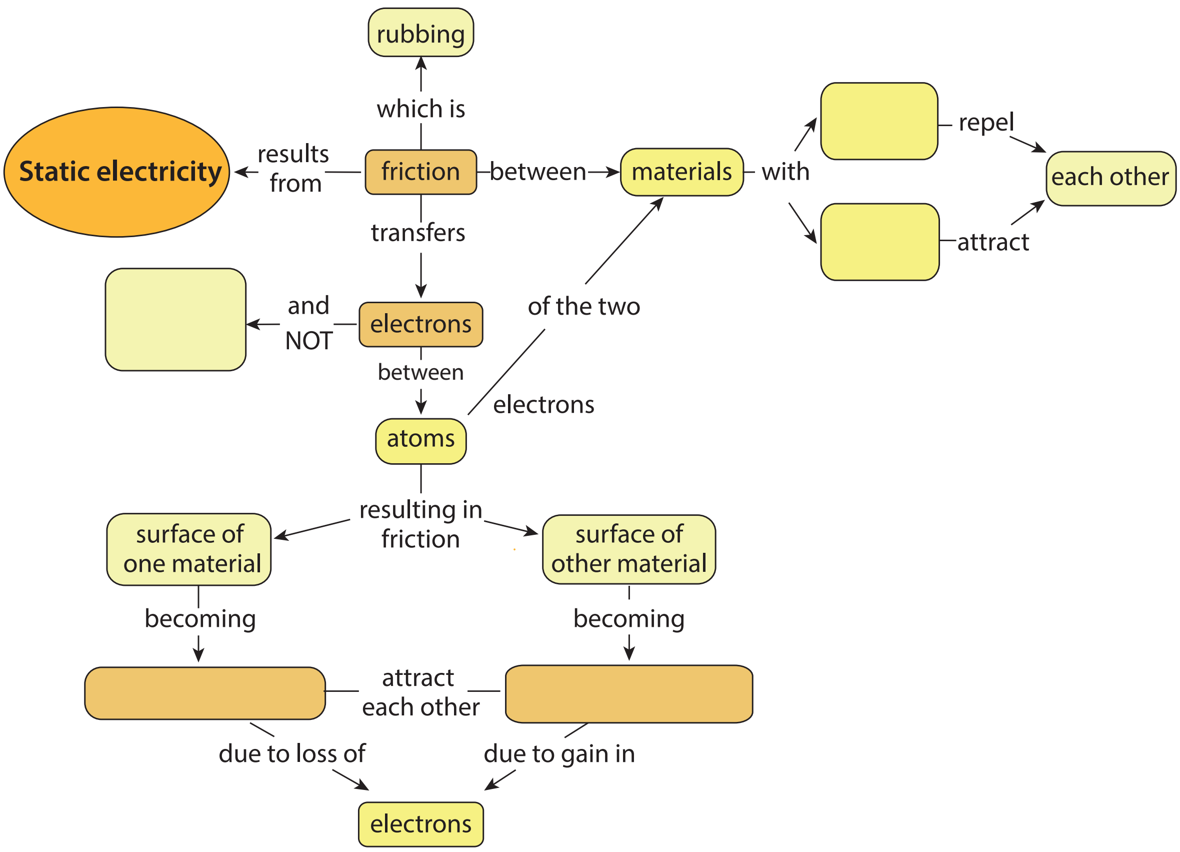
Summary

Key concepts

- Objects are usually neutral because they have the same number of positive and negative charges.
- Friction: the resistance that results when two surfaces are rubbed or moved against each other
- Objects can become negatively or positively charged when friction (rubbing) results in the transfer of electrons between objects.
- Protons and neutrons cannot be transferred, only electrons can be transferred by friction.
- If an object has more electrons than protons, then it is negatively charged.
- If an object has fewer electrons than protons, then it is positively charged.
- Like charges repel each other: negative repels negative; positive repels positive.
- Opposite charges attract each other: negative attracts positive; positive attracts negative.
- A discharge of the electrons from a charged object can cause sparks or shocks of static electricity, especially when the air is dry.

Concept map

Complete the following concept map to summarise what you have learnt in this unit about charge and static electricity.



Revision

1. Complete the following sentences. Just write the missing word on the line below.

a) An object which has a **negative** charge is said to have __________ electrons than protons. [1]

b) An object which has a **positive** charge is said to have __________ electrons than protons. [1]

2. Sarah uses a plastic comb to comb her hair. The comb becomes negatively charged.
The comb is negatively charged because the comb has: [1]

a) gained electrons

b) gained protons

c) lost electrons

d) lost protons

3. A perspex strip was rubbed with a cloth and became positively charged.
The correct explanation for why the perspex rod becomes positively charged is that: [1]

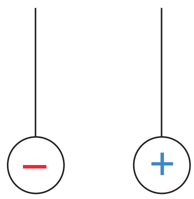
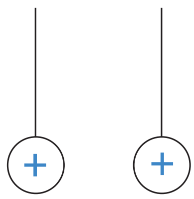
a) the perspex rod got extra protons from the cloth.

b) the perspex rod got extra protons due to friction.

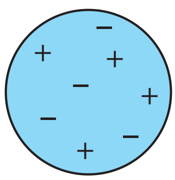
c) protons were created as the result of friction.

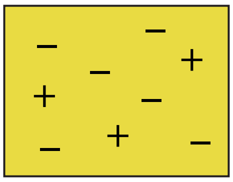
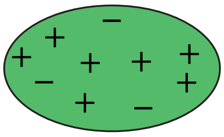
d) the perspex rod lost electrons to the cloth due to friction.

4. Look at the following images in the table. In your exercise books copy and redraw the images in the second column to show how the spheres will move because of the nature of the charges. Write an explanation in the last column. [6]

Charged spheres	Draw how they will move	Explanation
		
		

5. In your exercise books copy and complete the table by working out the overall charge on each object. Show your calculations. State whether the object is positively charged, negatively charged or neutral, and why. [9]

Object	Overall charge	Why is it positive, negative or neutral?
		

Object	Overall charge	Why is it positive, negative or neutral?
		
		

6. The comb in this illustration has been rubbed with a cloth. Describe what is happening in this illustration, and why. [4]

7. Sometimes, when you are pushing a trolley, you can get a small shock. Explain why this would happen. [2]
8. Why does your jersey make a crackling sound when you pull it over your head? [2]
9. Why do trucks transporting petrol drag a short length of metal chain on the road as they drive? [2]
10. What do you think these two girls are touching on the left of the photo? Explain your answer and what is happening to them. [3]

Total [32 marks]

8 Energy transfer in electrical systems

Key questions

- What is an electric current?
- What is an electric circuit?
- Where does the energy come from in a circuit?
- What are components?
- How do we draw electric circuits?
- What effects can an electric current produce?
- Why does the element in a light bulb glow and the element in a kettle become hot?
- What is an electromagnet, and are they useful to us?
- How to break down chemical compounds using electrical current?

In the last unit we looked at static electricity. We are now going to focus on current electricity. You will already be familiar with some of the concepts and terminology about electricity from previous grades. This year we are going to revise some of these concepts and also extend our knowledge about electricity.

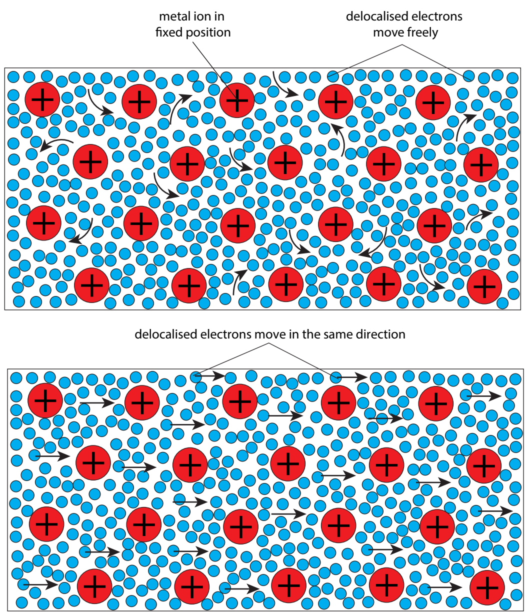
Keywords

- delocalised
- component
- conductor
- electric circuit
- electric current
- qualitative
- resistor
- switch

8.1 Circuits and current electricity

What is an electric current?

An electric current is the movement of charge in a closed, conducting circuit. As we know from Unit 7, and also from *Matter and Materials*, the electrons in an atom are arranged in the outer space around the central nucleus. We saw in the last unit how electrons can be transferred between objects resulting in a charge on the object. In metals, the electrons are able to move freely within the metal. The electrons are not associated with a particular atom in the metal. We say electrons in a metal are delocalised.



Have a look at the following diagram which shows this.

Conducting wire in an electric circuit is made of metal. If we supply it with a source of energy and a complete circuit, then the electrons will all move in the same general direction through the wire. This movement of electrons through a conductor is electric current.

Do you remember what you learnt in Grade 6 and 7 about circuits? Let's revise briefly:

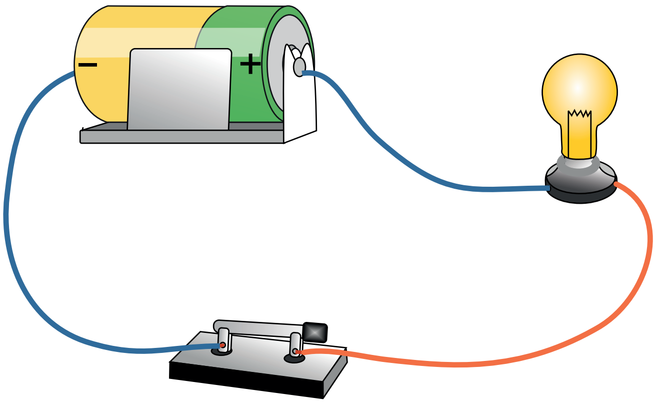
- An electric circuit needs a **source of energy** (a cell or battery).
- Cells have positive and negative terminals.

- A circuit is a **complete pathway** for electricity.
- The circuit must be **closed** in order for a device to work, such as a bulb which lights up.
- We can say that an electric circuit is a **closed system** which transfers electrical energy.
- A circuit is made up of various **components**, which we will look at in more detail.

ACTIVITY: A simple circuit

Instructions

1. Look at the example of a simple circuit.
2. Answer the questions which follow.



Questions

1. What are the parts that make up this system for transferring electrical energy?
2. Do you think this is an open or closed circuit? Explain your answer.
3. Which part is providing the source of energy?
4. What is the conducting material?
5. What type of energy does the cell have?
6. What is this energy transferred to when the circuit is closed and the electrons **move** through the wires?
7. What is the output of this system?
8. In most systems, the input energy is more than the useful output energy as some of the input energy is transferred to wasted output energy. In this simple circuit with a light bulb, what is the wasted output energy?

A circuit is a complete conducting pathway for electricity. It goes from one terminal of a cell along conducting material, through a device, and back to the other terminal of the cell.

Keywords

- ammeter
- cell

8.2 Components of a circuit

You are probably already familiar with the components of an electric circuit from previous grades. Do you remember that we have a specific way of drawing the components in a circuit in an electric circuit diagram? Each component has a different symbol.

ACTIVITY: Components in an electric circuit

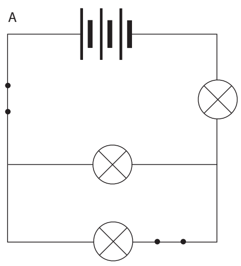
In your exercise books copy and complete the following table.. List the function of the component and draw the circuit symbol. The last two rows have been filled in for you as you may not yet know these symbols, but we will be using them in this unit.

Component	Function	Symbol
Cell		
Torch bulb		
Open switch		
Closed switch		
Electrical wire		
Resistor	A component that opposes or inhibits electrical current in a circuit. It can also convert electrical energy to heat or light.	 or 
Variable resistor	A resistor whose resistance can be adjusted higher or lower.	

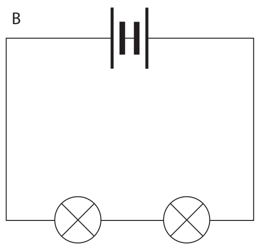
Let's now practice drawing some simple circuit diagrams. Draw the following circuit diagrams.

1. A closed circuit with one cell, two light bulbs and a switch.
2. An open circuit with two cells, two light bulbs and a switch.
3. A closed circuit with 4 cells and one light bulb.
4. Look at the following circuit diagram. Identify the number of bulbs, switches and cells in this circuit.
5. Study to Figure B and answer the question that follow.
   5.1. What is wrong with the circuit in figure B?
   5.2. Does it represent a closed circuit? Explain.
6. Why do you think it is useful to have a switch in a circuit?
7. Why are conducting wires made out of metal?

A



B



Let's take a closer look at the source of energy in electric circuits.

Did you know?

All muscles in our bodies move in response to electrical impulses generated naturally in our bodies.

Cells

Electrical cells are the source of energy for the electric circuit. Where does that energy come from?

Figure 8.1 Different-sized batteries.

Inside the cell are a number of chemicals. These chemicals store **potential energy**. When a cell is in a complete circuit, the chemicals react with each other. As a result, electrons are given the potential energy they need to start moving through the circuit. When the electrons move they have both potential and kinetic energy. The **electric current** is the movement of electrons through the conducting wires.

Cells come in many different sizes. Different sized cells provide different amounts of energy to the electrical circuit. The types of cells you would use in toys, torches and other small appliances range in size from AAA, AA, C and D, to 9-volt sizes. AAA, AA, C and D cells usually have a rating of 1,5V, but the larger cells have a larger capacity. This means that the larger cells will last longer before going 'flat'. A cell goes flat when it is no longer able to supply energy through its chemical reactions.

When we buy cells in the shop they are usually referred to as batteries. This can be a bit confusing because a battery is really two or more cells connected together. So when we refer to a battery in circuit diagrams we need to draw two or more cells connected together.

ACTIVITY: Recycling of batteries

Batteries which no longer work must not be thrown away in dustbins. They need to be recycled.

Instructions

1. Work in small groups.
2. Find out why batteries should not be thrown away in normal dustbins. Write a paragraph to explain why.
3. Find out where you can recycle batteries in your community. Write down the details of the centre(s) closest to where you live.

Resistors

What are resistors? In order to work out what they are, let's first remind ourselves about conductors and insulators.

We are specifically looking at electricity so we can now talk about **electrical conductors and insulators**. An electrical conductor is a substance which allows electric charge to move through it. An insulator is a substance which does not allow an electric charge to move through it.

Figure 8.2 Looking inside a kettle.

Think back to our model of a metal wire and how the electrons are able to move through the wire. The metal wire is a conductor of electricity. Write down some materials which do not conduct electricity.

Why do you think most conducting wires are surrounded with plastic?

Resistors are a bit of both. They allow electrons to move through them, but do not make it easy. They are said to **resist** the movement of electrons. Resistors therefore influence the electric current in a circuit.

But why would we want to resist the movement of electrons? Resistors can be extremely useful. Think about a kettle. If you look inside you will see a large metal coil.

This metal coil is the heating element. If you plug in and switch on the kettle, the element heats up and heats the water. The element is a large resistor.

When the electrons move through the resistor they expend a lot of energy in overcoming the resistance. This energy is transferred to the surroundings in the form of heat. This heat is useful to us as it heats our water.

A good example of where resistors are used is in light bulbs. Let's take a closer look at the different parts of a light bulb to see how it works.

Did you know?

The first electric light was made by Humphry Davy in 1800. He invented an electric battery, and when he connected wires to it and a piece of carbon, the carbon glowed as the carbon is a resistor, producing light.

ACTIVITY: Resistance in a light bulb

Materials

- light bulb
- lamp

Instructions

1. If you have light bulbs available, have a close look at the different parts, or have a look at the photos provided here.
2. Read the information about how a light bulb works and identify the parts that have been numbered.
3. Answer the questions that follow.

A light bulb consists of an air-tight enclosed glass case (number 1). At the base of the bulb are two metal contacts (numbers 7 and 10), which connect to the ends of an electrical circuit. The metal contacts are attached to two stiff wires (numbers 3 and 4).

Figure 8.3 An incandescent light bulb.

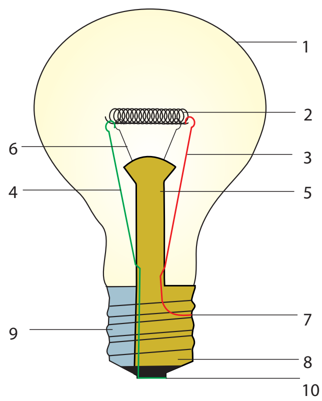


Figure 8.4 Diagram of the parts of a light bulb.

Take note

Incandescent means emitting light as a result of being heated.

These wires are attached to a thin metal filament. Have a look at a light bulb.

Can you identify the filament? This is number 2 in the diagram. The filament is made from tungsten wire. This is an element with high resistance.

Questions

1. When the electrons move through the filament they experience high resistance. This means that they transfer a lot of their energy to the filament when they pass through. The energy is transferred to the surroundings in the form of heat and bright light. Describe the transfer of energy in this light bulb.
2. What is the useful energy output and what is the wasted energy output in this light bulb?
3. Can you see that the filament is coiled? Why do you think this is so? Discuss this with your class and teacher.
4. The filament is mounted on a glass stem (number 5). There are two small support wires to hold the filament up (number 6). Why do you think the stem is made of glass?
5. The inside of the base of the bulb is made from an insulating material. This is the yellow part labelled number 8. On the outside of this is a metal conducting cap to which the wire is attached at number 7. Why is the wire attached at 7 making contact with the metal conducting cap?
6. If you have a lamp in the classroom, screw the bulb into the lamp and turn it on to observe the filament glow and also getting hot.

Figure 8.5 Some common resistors.

The amount of resistance a substance offers to the circuit is measured in ohms (Ω). If we want to use resistors to control the current flow, then we need to know the amount of resistance. There are some common resistors shown in the photo.

Can you see that there are different coloured bands on the resistors? This isn't just to make them look pleasing to the eye. The coloured bands are actually a code that tells us the resistance of the resistor. We also get resistors where we can adjust the resistance ourselves. This is called a variable resistor. You have already seen the symbol for drawing a resistor in a circuit diagram. Draw a circuit diagram in your exercise book with two bulbs, two cells, an open switch and a resistor.

Did you know?

The inventor, Thomas Edison, experimented with thousands of different resistor materials until he eventually found the right material so that the bulb would glow for over 1 500 hours

An electric current can have various effects. Let's find out more about what these are.

8.3 Effects of an electric current

Keywords

- fuse
- electromagnet

We are going to look at the effects of an electric current, and specifically how we use these effects. An electric current can:

- generate heat in a resistor;
- generate a magnetic field; and
- cause a chemical reaction in a solution.

Take note

You can easily make your own switch by sticking two metal drawing pins into a piece of wood with a metal paper clip in between, as shown in the diagram.

Take note

Remember that heat and temperature are not the same thing. Temperature is a measure of how hot or cold something is (measured in °C) whereas heat is the transfer of thermal energy from a hotter object to a colder object (measured in J).

Heating effect

As electrons move through a resistor they encounter resistance and transfer some of their energy to the resistor itself. We saw this in the last section, where we looked at the filament in a light bulb and the element in a kettle.

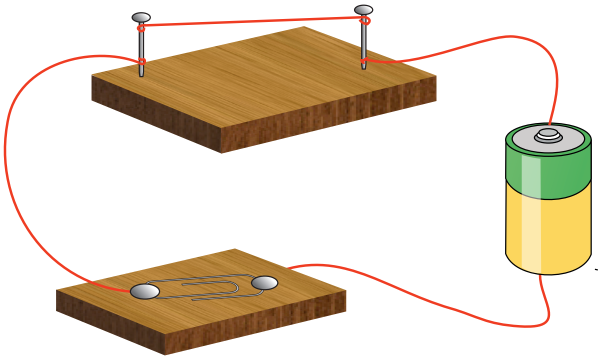
ACTIVITY: Heating a wire in a circuit

Materials

- 1,5 V cell
- conducting wires
- switch
- block of wood
- two nails
- hammer
- 10 cm of nichrome wire

Instructions

1. Hammer the two nails into the block of wood and attach the nichrome wire between the nails.
2. Build the following circuit and keep the switch open.



3. Feel the nichrome wire. Is it hot or cold?
4. Close the switch. Leave it on for a minute.
5. Open the switch again.
6. Feel the wire, briefly. Is it hot or cold?

Questions

1. When you felt the nichrome wire after the circuit had been on for a while, you felt an increase in **temperature** in your skin as **thermal energy**, which was transferred from the wire to your skin. Explain the heating effect of the electric current in the resistance wire.
2. List two useful applications of the heating effect of an electric current.
3. Choose one of the applications you listed in question 2 and explain how the heating effect of the electric current is used.
4. Look at the photo of a toaster.
   Can you see the glowing filament inside? Why does the element glow?

So now we know that an electric current can cause objects to heat up. Let's look at a useful application of the heating effect.

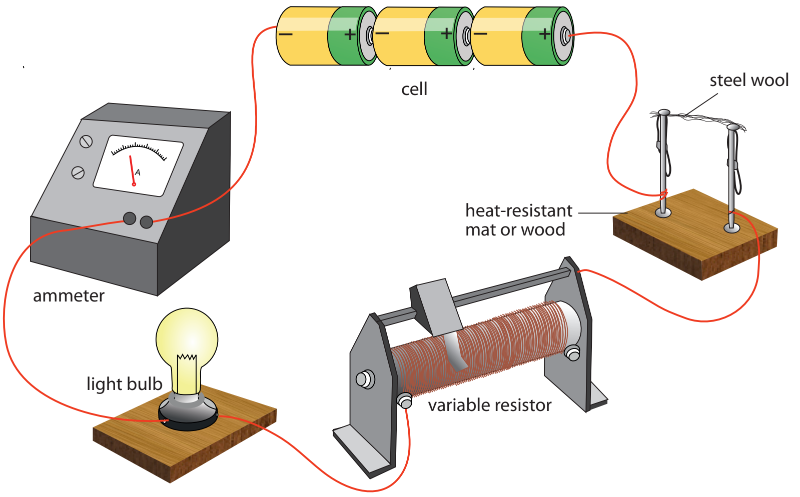
ACTIVITY: Melting metal

Materials

- three 1,5 V cells
- copper conducting wires with crocodile clips
- steel wool
- heat-resistant mat or piece of wood
- torch light bulb
- variable resistor

Instructions

1. Set up a circuit according to the following picture.



2. Twist a few strands of steel wool into a wire.
3. Use the steel wool to complete the circuit.
4. Set the variable resistor to its highest resistance.
5. Close the switch. What do you observe?
6. Open the switch.
7. Set the variable resistance to its lowest resistance.
8. Close the switch. What do you observe?

Questions

1. Draw a circuit diagram for your circuit.
2. Why is the light bulb included in the circuit?
3. What do you think happens to the resistance when the steel wool has burnt? Explain your answer.

Take note

An ammeter is used to measure the electric current in a circuit.

In this activity, we just demonstrated how a **fuse** works. The steel wool acted as a fuse. When the current was too high, the steel wool melted and prevented any further flow of electrons in the circuit.

What are fuses?

The heating effect of an electric current can be dangerous. If a circuit overheats it could cause a fire. To avoid overheating, circuits often contain a fuse. Fuses contain a low resistance wire made of a metal with a low melting

Take note

It is important never to remove a fuse from a circuit without first switching off the current. You could get a nasty shock if you do.

Take note

There are different types of fuses. The ones we have investigated so far require you to replace the fuse if the wire melts. However, some fuses work differently to break the circuit and can just be reset once the problem in the circuit is fixed.

point. Therefore, the piece of wire melts if it gets too hot, just like the steel wool in our activity.

Different circuits need different strength currents and so we need different types of fuses. Some fuses can only handle a little bit of heat, some can handle lot. We choose the fuse that suits the safety needs of our circuit. If the circuit overheats, the fuse will melt and break the circuit to reduce the danger of fire as well as protect electronic equipment.

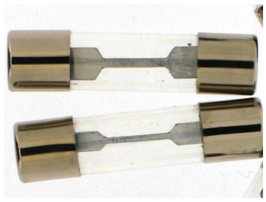


Figure 8.6 An example of a fuse. Can you see the low melting point wire inside?

How did you draw the fuse that we made using steel wool in the last activity?

The conventional symbol for drawing a fuse in a circuit diagram is shown here:

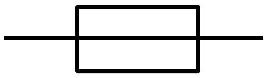


Figure 8.7 A fuse.

What is a short circuit?

Have you ever heard that something broke because it **short circuited**? A short circuit happens when another, easier path is accidentally made in an electric circuit. What do we mean by *easier*? We mean that the path offers very little resistance to the electric current. As there is so little resistance the current flows along the short circuit and doesn't pass through the main circuit. Short circuits can be dangerous and cause a lot of damage to appliances.

Have you ever had a piece of toast get stuck in a toaster? It's a real nuisance.

Lots of people are tempted to use their butter knife to unhook the bread. Don't be tempted. Your knife is a conductor and can act as a short circuit. All the electric current will flow through your knife and, because you are touching it, through you. What would be the safe way to unhook your toast?

ACTIVITY: How are fuses used in everyday circuits?

Instructions

1. Find out about common household appliances which use fuses. Choose one of these appliances on which to focus your research.
2. Write a short paragraph describing the appliance and explaining why a fuse is necessary for that appliance.

Most modern homes have **circuit breakers** instead of fuses. A circuit breaker is similar to a fuse in that it is designed to protect an electric circuit from damage, due to overload or a short circuit, by stopping the current flow. However, unlike a fuse which melts and must then be replaced, a circuit breaker can be reset to start operating again. This can be done manually or take place automatically.

Magnetic effect

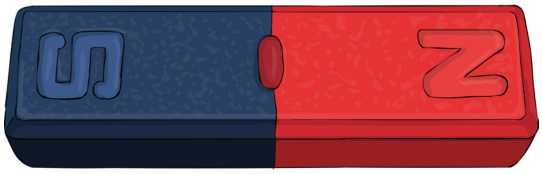


Figure 8.8 A bar magnet.

Before we look at how a current produces a magnetic field, let us first learn more about magnets. A magnet is a piece of material which produces a magnetic field. A magnet has a north pole and a south pole. Opposite poles will attract each other and the same poles will repel each other. A magnet has a magnetic field around it.

Did you know that the Earth is like a bar magnet with a North and a South Pole?

The Earth has a magnetic field. This is why we can use compasses to tell direction. A plotting compass has a needle with a small magnet. The needle points to magnetic north because the small magnet is attracted to the opposite magnetic pole and can be used to determine direction.

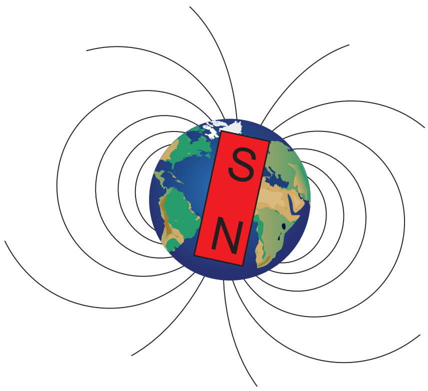


Figure 8.9 Earth has a magnetic field, as though there is a big bar magnet running through the core, with its South Pole under Earth's magnetic North pole.

Figure 8.10 A compass with the needle pointing North.

ACTIVITY: Playing with plotting compasses and magnets

Materials

- plotting compasses
- bar magnets
- piece of white paper
- iron filings

Instructions

1. Hold the plotting compass in your hand. The north end of the needle should point to magnetic north.
2. Put the bar magnet flat on the desk. Make sure you know which end is north and which is south. If you are not sure, ask your teacher.
3. Put plotting compasses in a circle around the bar magnet.

Draw what you see.
4. Next, place a sheet of white paper over the bar magnet and sprinkle iron filings over the sheet of paper on top of the magnet. Observe what happens to the iron filings.
5. Did you see something similar to what is shown in the illustration below? Describe what you see.

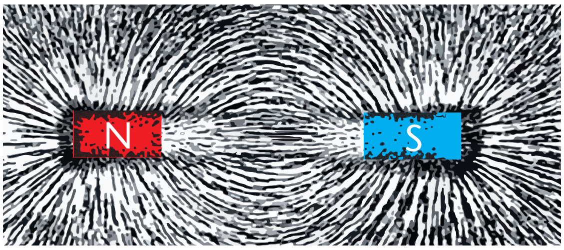


Figure 8.11 Iron filings on a piece of paper over a bar magnet.

So now we know that there is a magnetic field around a magnet and that plotting compasses and iron filings can be used to visualise that field. Is there anything else that has a magnetic field around it?

ACTIVITY: Magnetic field around a conductor

Materials

- plotting compasses
- three 1,5 V cells
- insulated copper conducting wires
- switch

Instructions

1. Construct a circuit which contains the batteries, copper wires and the switch.
2. Put the plotting compasses on either side of the conducting wire as shown in the illustration, as well as below and above the conducting wire.
3. Keep the switch open. What do you notice about the needles of the plotting compasses?
4. Close the switch and observe what happens to the needles.
5. Draw a picture of the wire and plotting compasses in your exercise book.
6. What does the pattern of the compasses tell us?

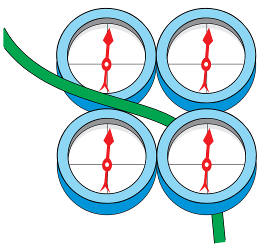


Figure 8.12 Plotting compasses placed around a conducting wire.

We saw from our first activity that plotting compasses react to magnetic fields. The plotting compasses changed direction when the current was switched on. This means there is a magnetic field around the wire. Was it there when the current was switched off? No, it was not. That means that the presence of the electric current in the wire must have produced a magnetic field.

The magnetic effect of an electric current has many useful applications.

ACTIVITY: Making an electromagnet

Materials

- one iron nail (approximately 15 cm long)
- 3 metres of 22-gauge insulated copper wire
- two D-cell batteries
- paper clips
- iron filings

Instructions

1. Wrap the insulated copper wire tightly around the nail. Make sure that you wrap the wire in the same direction.
2. Strip some of the insulation off each end of the insulated copper wire.
3. Attach the ends of the insulated copper wire to the terminals of the battery.
4. Hold the wrapped nail above the paper clips.
5. Disconnect the wire from the battery.
6. Hold the wrapped nail above the paper clips.
7. If you have iron filings, place some on a piece of paper around the electromagnet you have made and observe the magnetic field.

Questions

1. What happened when you held the nail over the paper clips?
2. Why were the paper clips attracted to the nail?
3. Did the disconnected nail attract the paper clips? Why?

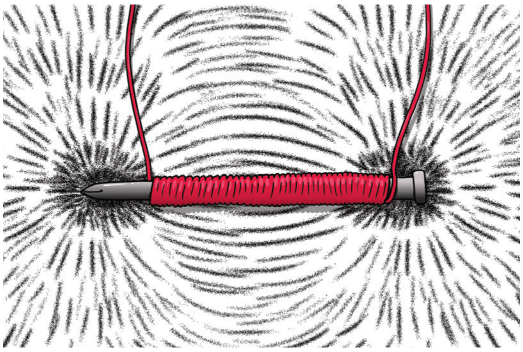


Figure 8.13 The magnetic field around an electromagnet.

Electromagnets can be used in all sorts of practical applications, including speakers and electric bells, as you can see in the photo.

ACTIVITY: Research the use of electromagnets

Instructions

1. Work in groups of two or three.
2. Research one of the following applications of the magnetic effect of an electric current to explain how the device works:
   a) speakers

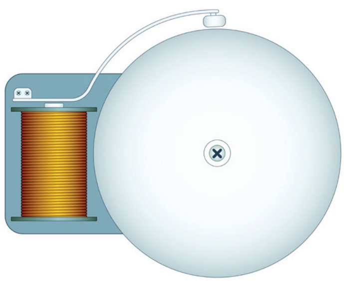


Figure 8.14 An electromagnet in a bell.

b) electric bells
c) telephones
d) magnetic trains
e) industrial lifters and separators.

3. Write a short paragraph showing what you've learnt. Remember to note down from where you got your information.
4. Share your paragraph with the rest of the class.

Chemical effect

The last effect of an electric current that we are going to look at is how an electric current can cause a chemical reaction in a solution.

ACTIVITY: Electrolysis

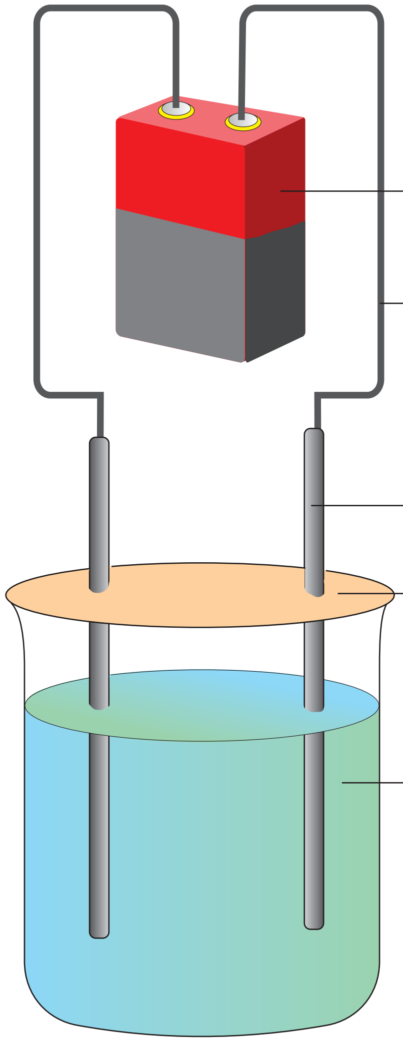
You might already have done this activity in Matter and Materials when we investigated the decomposition of copper chloride. We are going to perform it again, this time focusing on the effects of an electric current.

Materials

- 250 ml beaker
- 2 carbon electrodes
- sandpaper
- 3 copper conducting wires (with crocodile clips)
- copper chloride solution
- torch bulb
- power pack

Instructions

1. Sand down the electrodes with the sandpaper to make sure they are clean.
2. Connect the conducting wire from one electrode to the torch bulb and another wire from the torch bulb to the negative terminal of the power source.
3. Connect the crocodile clip from the second electrode to the positive terminal of the power source.
4. Pour 100 ml copper chloride solution into the beaker.
5. Put the electrodes into the beaker. Make sure that they do not touch each other.
6. Look at the electrodes. What do you observe?
7. Turn on the power source. Leave it on for a few minutes.



The setup may look something like this, which you have seen before. You may also have a light bulb connected in the circuit.

Questions

1. When you switch on the power source, does the torch bulb glow?
2. What do you observe happening at the two different electrodes?
3. Can you smell anything? What do you think this is?
4. What is happening to the copper chloride solution when the electric current is passed through it?
5. If you switch off the power source, what happens?
6. What is causing the separation of the copper chloride?
7. Why is it important that you do not let the carbon electrodes touch each other while the current is flowing?

The separation of the copper chloride means that an electric current can cause chemical reactions to occur. There are many ways in which we can harness this chemical effect for practical uses.

Keywords

- electrolysis
- electrodes
- electroplating

Electrolysis is the breaking down of a substance into its component elements by passing an electric current through a liquid or solution. We can also use electrolysis to purify substances.

Impure copper can be purified using electrolysis. Instead of using carbon electrodes in a copper sulphate solution we can use copper electrodes. If one of the copper electrodes is pure copper and the other is impure copper, then the impure electrode will break down and deposit pure copper on to the already pure copper electrode.

One of the most important uses of electrolysis is **electroplating**.

Electrolysis is used to electroplate metals. In the last activity, one of the carbon electrodes was coated with an even layer of pure copper. We say that the carbon electrode was electroplated with copper.

Why do we electroplate? An example is in the making of jewellery where an inexpensive metal is made into a ring, for example, and then coated with gold by electroplating. This makes it less expensive than if it were made from pure gold. Iron rusts easily and so it is useful to coat it with a layer of a zinc to protect it from corrosion. Many car parts, bathroom taps and wheel rims are electroplated with chromium.

Look at these examples.

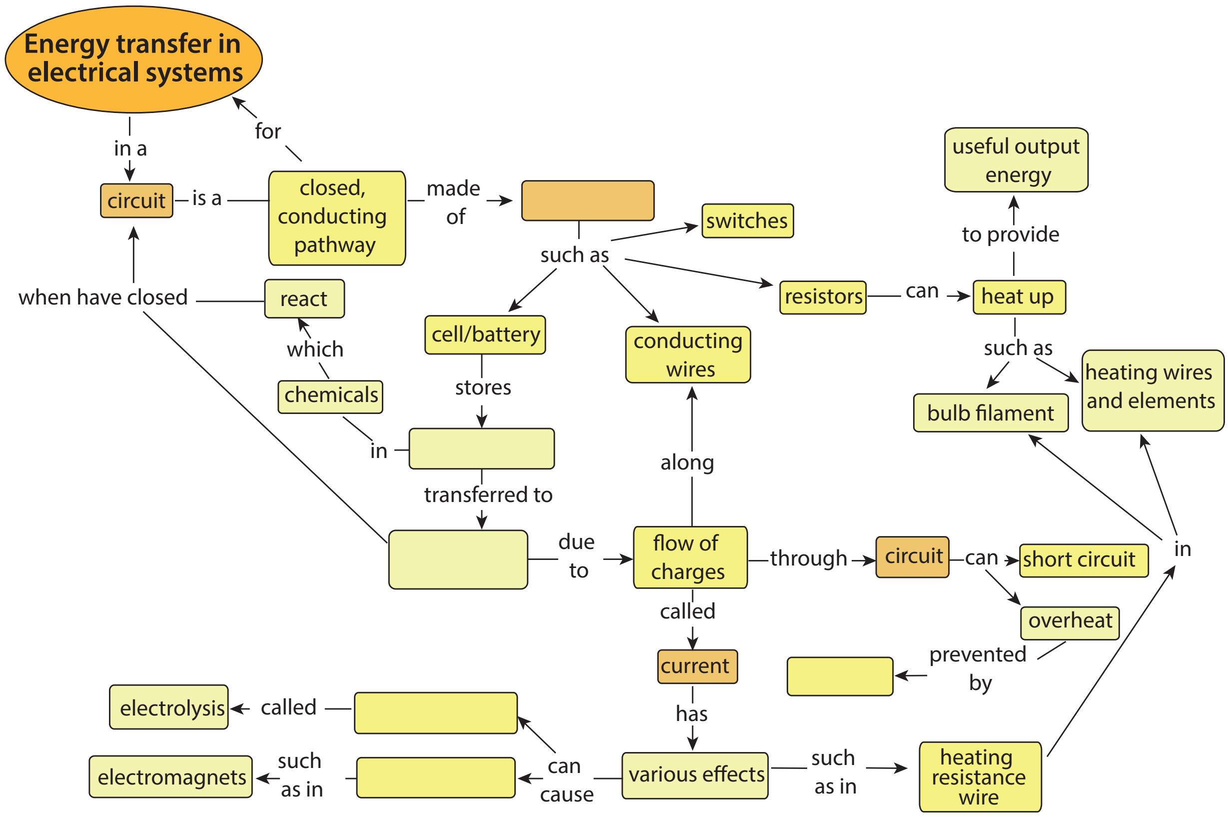
Summary

Key concepts

- A circuit is a system for transferring electrical energy.
- For a circuit to function there must be a complete, unbroken pathway for the electrons to follow, a source of energy (cell or cells), and a load (light bulb or any other resistor).
- We use symbols to represent components of an electric circuit so that everyone can interpret the diagrams.
- A resistor is a component in a circuit which resists the movement of electrons through the circuit.
- An electric current can heat a resistance wire. This heating effect is used in many everyday appliances, such as kettles and irons.
- An electric current causes a magnetic field. This magnetic effect is used in electromagnets.
- An electric current can cause a chemical reaction in solutions. This is called electrolysis, and is used to electroplate objects.

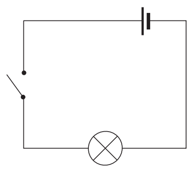
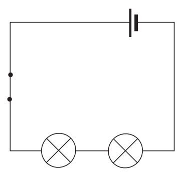
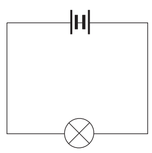
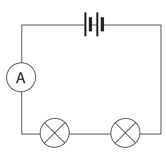
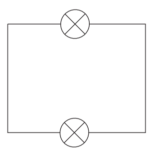
Concept map

Complete the concept map to summarise what you have learned about electric circuits and the effects of an electric current in this unit.

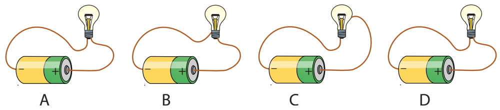


Revision

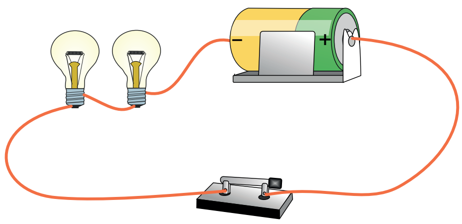
1. Write your own definition for an electric circuit. [2]
2. What type of energy does a battery have? [1]
3. When a battery is connected to a circuit, it causes an electric current in the circuit. Explain what an electric current is and why it is possible in metals. Use the word 'delocalised' in your explanation. [3]
4. List 3 materials which conduct electricity. [3]
5. List 3 materials that do not conduct electricity. [3]
6. You have a battery, insulated copper-conducting wires and a light bulb. Draw a setup which would allow you to test whether the materials you listed in questions 4 and 5 are conductors or not. [4]
7. Draw the symbols for the following components. [6]
   a) A cell A
   b) A light bulb
   c) A conducting wire
   d) An open switch
   e) A resistor
   f) A variable resistor
8. Look at the circuits below. If the bulb(s) will glow, place a tick next to the picture and explain why it (they) will glow. If the bulb(s) will not glow, place a cross next to the picture and explain why it (they) will not glow. Copy and complete the table below in your exercise books. [10]

Circuit	Glow/Not glow	Explanation
		
		
		
		
		

9. Which of the following setups shows the correct way to connect a light bulb to a battery? Explain your answer. [2]



10. In your exercise books, draw a circuit diagram to illustrate the following circuit: [3]

Image	Circuit diagram
	

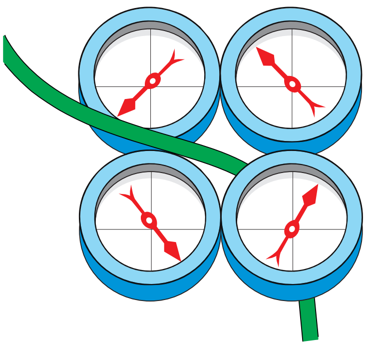
11. An electrician wants to replace a faulty fuse with a normal piece of conducting wire. Should you let him? Why or why not? [3]

12. A child, while inserting an electric plug into the socket, did not see that there was a thin piece of aluminium foil stuck between the pins of the plug. When he turned the switch on, he noticed a spark at the plug, and at the same time, the lights went out. What could have happened to cause the spark and to make the lights go out? [4]

13. What is the benefit of using a circuit breaker rather than a fuse? [2]

14. Look at the following photo of a light bulb. Label the filament and explain why it glows. [4]

15. You place some plotting compasses around an electric wire and observe the following.



a) Is there a current in the conducting wire? [1]

b) Explain your answer. [2]

16. Give two advantages of electroplating iron metal. [2]

Total [55 marks]

9 Series and parallel circuits

Key questions

- Are there different types of electric circuits?
- If all the light bulbs in a house are part of the same circuit, how can you switch one light off without the rest also turning off?
- What is a series circuit?
- What is a parallel circuit?
- What happens when you connect more components in series or in parallel?

Keywords

- series
- resistance

In the last unit, and in Grades 6 and 7, we have been looking at electric circuits.

These have mostly been series circuits. What does this mean? And how else can a circuit be arranged?

9.1 Series circuits

A **series circuit** is one in which there is only one pathway for the electric current to follow. The components are arranged one after another in a single pathway.

When we connect the components we say that they are **connected in series**.

We have already seen examples of series circuits in the last unit.

A series circuit provides only one pathway for the electrons to follow. Let's investigate what happens when we increase the resistance in a series circuit.

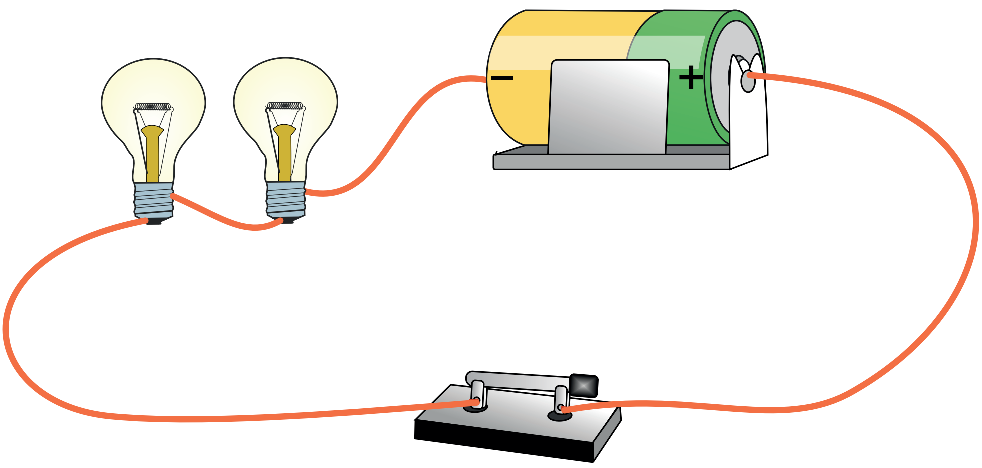


Figure 9.1 A series circuit with one pathway for the current, from the negative to the positive terminal of the battery.

Investigation: What happens when we add more resistors in series?

Aim

To investigate the effect of adding resistors to a series circuit.

Hypothesis

Write a hypothesis for this investigation.

Materials and apparatus

- 1,5 V cells
- three torch bulbs
- insulated copper conducting wires
- switch

Method

1. Construct the circuit with the cell, the ammeter, 1 bulb and the switch in series.

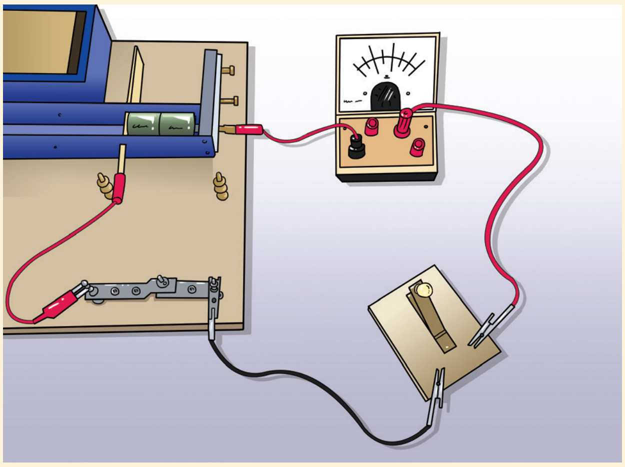


Figure 9.2 A photo showing the setup.

2. Close the switch, or the circuit if you are not using a switch.
3. Note how brightly the bulb is shining.
4. Draw a circuit diagram.
5. Open the switch.
6. Add another light bulb into the circuit.
7. Close the switch.
8. Note how brightly the bulbs are shining. Draw a circuit diagram.
9. Open the switch.
10. Add the third light bulb into the circuit.
11. Close the switch.
12. Note how brightly the bulbs are shining. Draw a circuit diagram for the last circuit you built.

Results

Copy and complete the table in your exercise books:

Number of bulbs in series	Brightness of bulbs
1	
2	
3	

Draw a graph to show the relationship between the number of bulbs and the current.

Analysis

1. What happened to the brightness of the bulbs as the number of bulbs increased?
2. When you had two bulbs, did they glow with the same brightness, or was one brighter than the other?
3. When you had three bulbs, did they all glow as brightly as each other, or was one brighter than the others?

Conclusion

1. Based on your answers, what happened to the brightness of the bulb when more bulbs were added in series?
2. Is your hypothesis accepted or rejected?

As more resistors are added in series, the total resistance of the circuit increases. As the total resistance increases, the current strength decreases.

What would happen if we increased the number of cells connected in series?

Would the current become larger or smaller? Let's investigate.

Investigation: How does adding more cells in series affect the the brightness of the bulbs?

Aim

To investigate the effect of increasing the number of cells connected in series on the brightness of the bulb.

Hypothesis

Write a hypothesis for this investigation. Remember to mention how the increase in the number of cells will affect the brightness of the bulb.

Materials and apparatus

- three 1,5 V cells
- insulated copper conducting wires
- two light bulbs (or one torch light bulb and one resistor)

Method

1. Construct a circuit with one cell, and the two light bulbs.
2. Observe the brightness of the bulbs.
3. Add a second cell in series and observe the brightness of the bulbs. Draw a circuit diagram of your circuit.
4. Add a third cell in series and observe the brightness of the bulbs. Draw a circuit diagram of your circuit.

Results

Copy and complete the table in your exercise books:

Number of cells in series	Brightness of bulbs
1	
2	
3	

Conclusion

1. What happens to the brightness of the bulbs as more cells were added in series?
2. Is your hypothesis true or false?

We have seen that increasing the number of cells in series increases the brightness of the bulb, but increasing the number of resistors decreases the brightness of the bulb.

We will now investigate the current strength at different points in a series circuit.

9.2 Parallel circuits

Parallel circuits offer more than one pathway for the electrons to follow. When constructing a parallel circuit, we say that components are connected **in parallel**.

Keywords

- parallel circuit

Look at the diagram which shows how two light bulbs are connected in parallel.

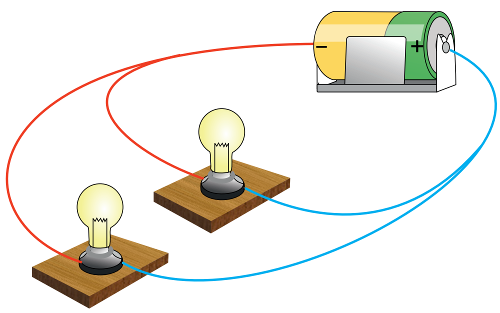


Figure 9.3 There are two paths for the current in this parallel circuit, one path through each of the bulbs.

How can you tell whether or not a circuit is connected in series or in parallel?

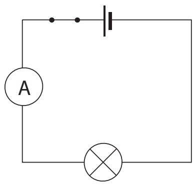
Let's look at some circuit diagrams to tell the difference.

ACTIVITY: Series or parallel?

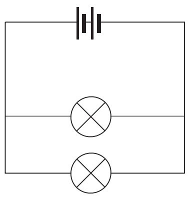
Instructions

Look at the following circuits and write down which are in series and which are in parallel. The series circuits will only offer one pathway, but the parallel circuits will have more than one pathway for the electrons to follow.

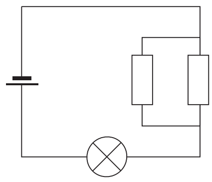
A.



B.



C.



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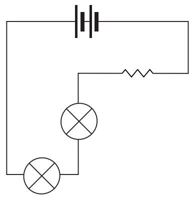


Let's investigate how parallel circuits work.

Investigation: How does adding resistors in parallel affect the brightness of the bulb?

Aim

To investigate the effect of adding resistors in parallel on the brightness of the bulb.

Hypothesis

Write a hypothesis for this investigation.

Materials and apparatus

- 1,5 V cell
- three identical torch bulbs
- insulated copper conducting wires
- switch

Method

1. Construct the circuit with the cell, one bulb and the switch in series.
2. Close the switch.
3. Note how brightly the bulb is shining. Draw a diagram of your circuit.
4. Open the switch.

5. Add another light bulb, in parallel to the first, into the circuit.
6. Close the switch.
7. Note how brightly the bulbs are shining.
8. Open the switch.
9. Add the third light bulb, in parallel to the first two, into the circuit.
10. Close the switch.
11. Note how brightly the bulbs are shining.

Results

Copy and complete the table in your exercise books:

Number of bulbs in parallel	Brightness of bulbs
1	
2	
3	

Analysis

1. What happened to the brightness of the bulbs as the number of bulbs increased?
2. When you had two bulbs, did they glow with the same brightness, or was one brighter than the other?
3. When you had three bulbs, did they glow with the same brightness, or was one brighter than the others?

Conclusion

1. Based on your answers, what happened to brightness of the bulbs when more bulbs were added in parallel?
2. Is your hypothesis true or false?

As more resistors are added in parallel, the brightness of the bulbs increases. The overall resistance of the circuit must therefore have decreased. The current in each light bulb was the same because all the bulbs glowed with the same brightness. This tells us that the current of electrons must have split up and moved through each of the branches.

We can also connect cells in parallel. What would happen if we increased the number of cells connected in parallel? Would the current get stronger or weaker?

Investigation: What happens to the current strength when cells are connected in parallel?

Aim

To investigate how increasing the number of cells connected in parallel affects the current strength in a circuit.

Hypothesis

Write a hypothesis for this investigation.

Materials and apparatus

- three 1,5V cells
- one torch light bulb
- insulated copper conducting wires

Method

1. Set up a circuit which has one cell, the ammeter and the torch light bulb in series with each other. Draw a circuit diagram of your circuit.
2. Observe the brightness of the bulb.
3. Connect another cell in parallel with the first cell. To connect the second cell in parallel, connect a wire from the positive terminal of the first cell to the positive terminal of the second cell. Connect another wire between the negative terminal of the first battery and the negative terminal of the second battery. Draw a circuit diagram of your circuit.
4. Observe the brightness of the bulb.
5. Connect a third cell in parallel to the other two cells. Draw a circuit diagram of your circuit.
6. Observe the brightness of the bulb.

Results

Copy and complete the table in your exercise books:

Number of cells in parallel	Brightness of bulb
1	
2	
3	

Conclusion

1. What did you notice about the brightness of the bulbs?
3. What conclusion can you draw from your results?

Adding cells in parallel has no overall effect on brightness of the bulb. The brightness of the bulb stays the same if you add cells in parallel. We saw that the brightness of the bulb increased when bulbs were connected in parallel.

ACTIVITY: Which metals offer the most resistance?

Materials

- one cell
- one torch light bulb
- insulated copper conducting wires
- lengths of copper, aluminium, zinc and nichrome wire
- crocodile clips (if available)

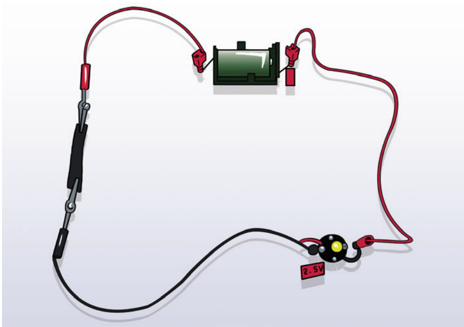


Figure 9.4 An example circuit with a cell, a light bulb and the piece of metal being tested.

Instructions

1. Build a circuit with the cell and the torch light bulb and leave a gap for the metal to be tested. You can use crocodile clips at the end of each piece of metal for easy insertion.
2. Insert each metal into the circuit (one at a time). Observe the brightness of the bulb.

Questions

1. Draw a circuit diagram of your apparatus.
2. Why can we use the brightness of the bulb to measure resistance qualitatively?
3. List the metals in order of increasing resistance.
4. Why do you think copper is used for connecting wires in electrical circuits?

Take note

In Gr. 9 we will look at the other factors that influence resistance. If you want to see the content in other grades, remember that you can visit http://www.curious.org.za

There are several factors which influence the amount of resistance a material offers to an electric current. We have seen that the type of material is one of those factors.

9.3 Other output devices

Light bulbs are not the only devices used in electrical circuits. Devices that use electrical energy to function, including light bulbs, are called output devices.

Let's look at some other common examples of output devices.

LEDs (Light-Emitting Diodes)

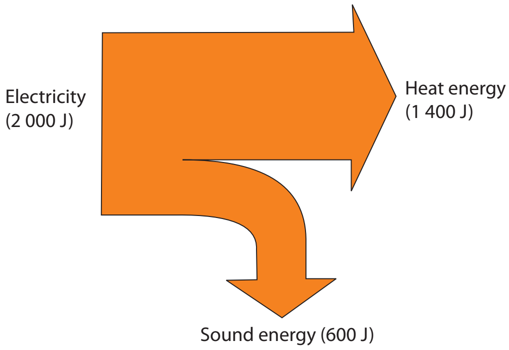
LEDs are widely used electronic devices. They are small lights but they do not have a filament like an incandescent bulb has. They therefore cannot burn out, as there is no filament to wear out, and they do not get as hot. LEDs are used in electronic timepieces, high-definition televisions, and many other applications. Larger LEDs are also replacing traditional light bulbs in many homes because they do not use as much electricity. They last longer than incandescent bulbs and are more efficient.

Figure 9.5 Different LED bulbs.

In the last unit, we looked at the energy transfers in an electrical system. We will now represent energy transfer within electrical systems in a different way. We will apply this new representation to the difference between energy outputs in an LED and an incandescent light bulb.

ACTIVITY: Sankey diagrams

You might have drawn Sankey diagrams in Grade 7. If not, here is some quick revision.



In an energy system, input energy is transferred to useful output energy and wasted output energy. A Sankey diagram is a visual and proportional representation of the energy transfers that happen in a system.

For example, a kettle uses about 2 000 J of input energy, but only about 1 400 J is used to heat the water. The remaining 600 J is wasted as sound. Here is the Sankey diagram to represent the energy transfer.

Questions

We will now compare an LED with an incandescent light bulb.

1. Draw a Sankey diagram for an LED if the input energy is 100 J, 75 J of energy is used to produce light, and the rest is lost as heat.
2. Draw a Sankey diagram for a filament light bulb if the input energy is 100 J, the wasted heat energy is 80 J, and the rest produces light.
3. Which bulb do you think is more efficient? Explain your answer.

Take note

Remember that energy is measured in joules (J).

Can you think of any other output devices?
Make a list of as many as you can.

ACTIVITY: History of electricity production

Instructions

1. Work in groups of three or four.
2. Research the history of electricity production: How was electricity discovered and how did electricity become widely used?
3. Create a basic timeline for the discovery of electricity and its production.

ACTIVITY: Careers

Instructions

1. Choose a career related to electricity production.
2. Write a short paragraph describing the career. Include information on how one can study or prepare for your chosen career.

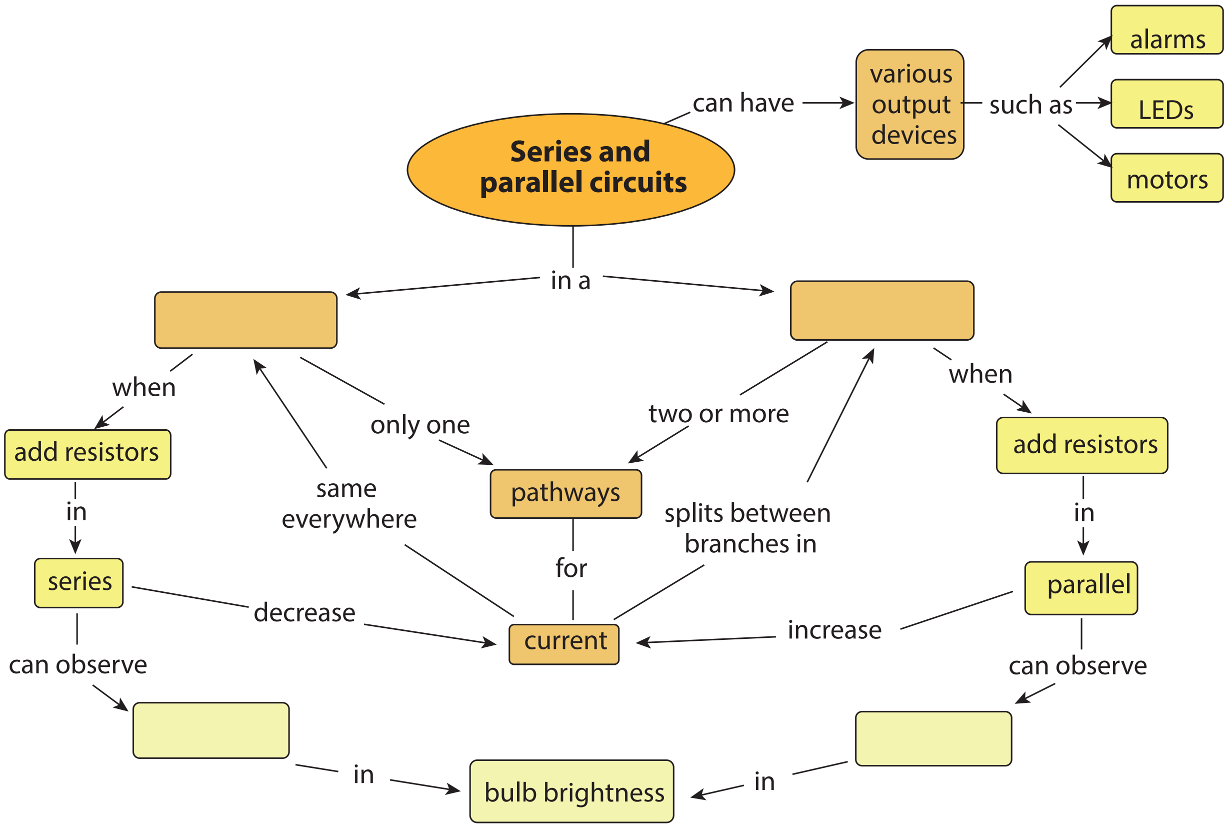
Summary

Key concepts

- A series circuit has only one pathway for the electrons to travel through.
- A parallel circuit has more than one pathway for the electrons to travel through.
- In a series circuit, the resistance increases as more resistors are added in series.
- In a parallel circuit, the resistance decreases as more resistors are added in parallel.

Concept map

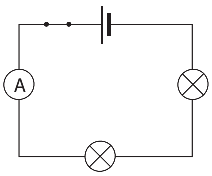
Complete the concept map on the following page to summarise what you have learned about series and parallel circuits.



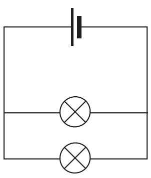
Revision

1. Look at the following circuit diagrams and decide whether they are series circuits or parallel circuits. Write the correct answer for each diagram. [6]

a.



b.



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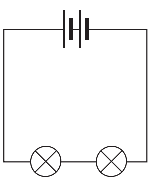

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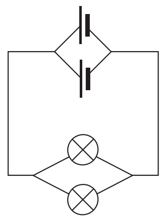
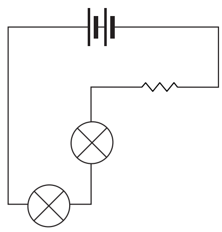
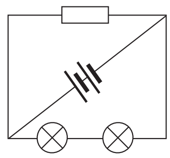


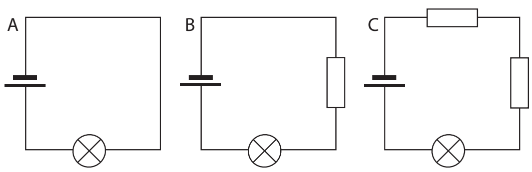
e.



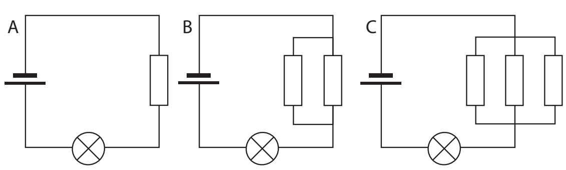
f.



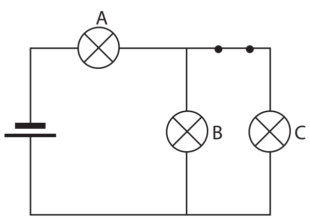
2. Look at the three circuit diagrams. Rank the circuits from brightest bulb to dimmest bulbs. [3]



3. Explain your choices in the previous question. [5 marks]
4. Look at the three circuit diagrams. Rank the circuits from brightest bulb(s) to dimmest bulb(s). [3]



5. Explain your choices in the previous question. [5 marks]
6. Look at the circuit diagram below. Each light bulb is identical.



   a) Is this a series or parallel circuit? Explain your answer. [2]
   b) How do the brightness of bulbs A, B and C compare? (Which is the brightest?) [3]
   c) What would happen to the brightness of the bulbs if the switch was opened? Explain your answer. [5]

Total [38 marks]

10 Visible light

Key questions

- Where does light come from?
- How does light travel?
- How do we see?
- Why do leaves look green?
- How do mirrors work?
- Why do my legs look crooked underwater?
- What happens when light passes through a prism?

In this unit we will learn about visible light. We call it visible light because we can see it with our own eyes. There are different forms of light which we cannot see with our naked eyes. Ultraviolet light is an example of a form of light which we cannot see with just our eyes. We will focus our attention on the visible light spectrum and investigate how we are able to see different colours and how light behaves.

Keywords
- luminous
- radiation
- rectilinear
- propagation

10.1 Radiation of light

Where does light come from? Natural light comes from luminous objects such as the Sun and light bulbs. We say that these objects emit light.

Figure 10.1 A light bulb is a luminous object as it emits light.

Figure 10.2 The Sun is our main source of light on Earth.

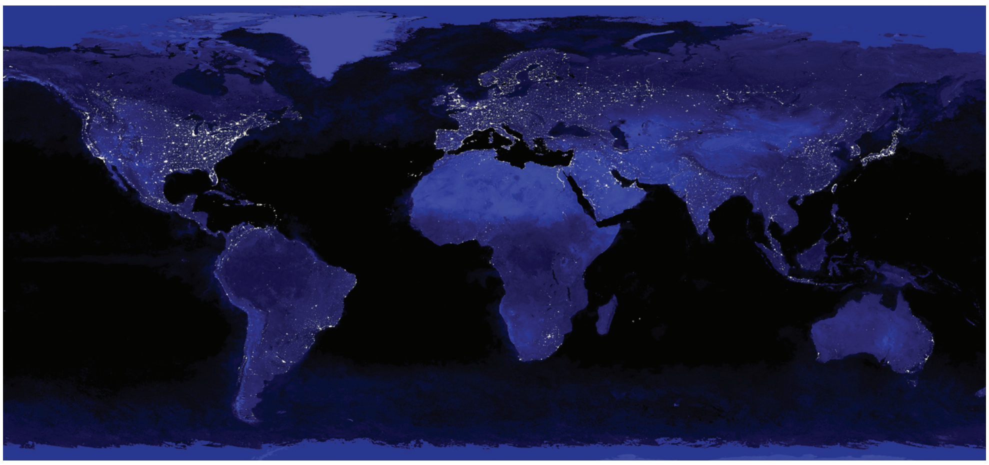


Figure 10.3 This image from NASA shows the Earth's lights at night. You can see how much we rely on light nowadays.

Did you know?

If you could travel at the speed of light you could travel around the equator 7,5 times in 1 second!

Take note

The Sun emits radiation in all directions, but in the illustration here, only the radiation which reaches Earth has been shown.

Did you know?

It takes light 8 minutes to travel from the Sun to the Earth.

Light travels through space at a speed of 300 000 kilometres per second. We say that energy is transferred by radiation. The energy of the light is transferred through space as **electromagnetic waves** in straight lines.

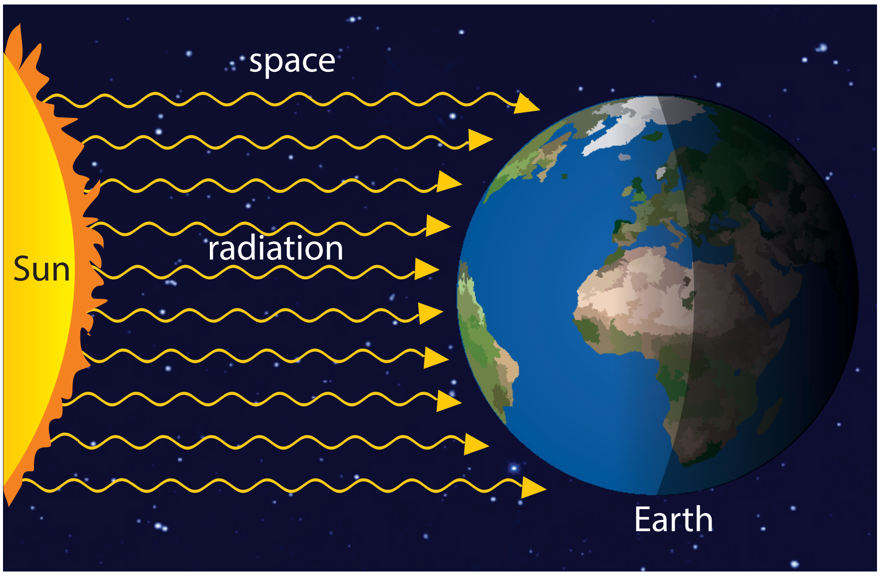


Figure 10.4 Light and heat are transferred to Earth through space from the Sun by radiation.

Let's look at how light travels. We will make a simple camera to investigate how light travels.

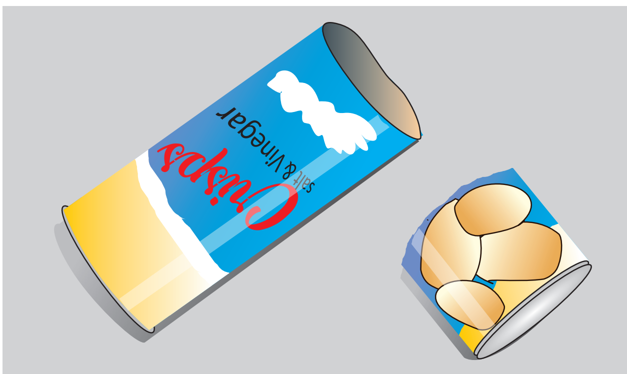
ACTIVITY: Make a pinhole camera

Materials

- Pringles chip container
- craft knife
- aluminium foil
- tape
- ruler
- drawing pin

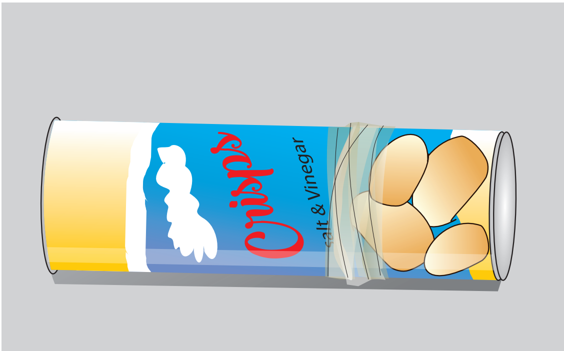
Instructions

1. Measure 5 cm from the bottom of the container (opposite end to the plastic lid) and make a mark all around the container.
2. Cut through the container along the line so that you have cut the container into two pieces.

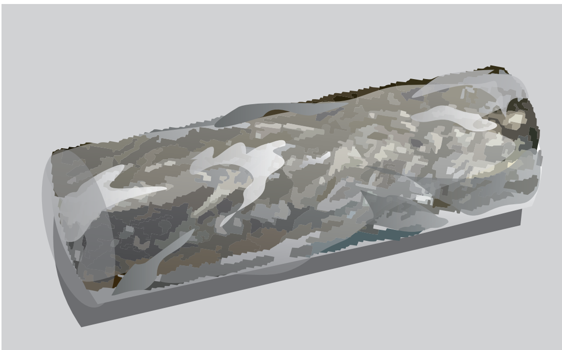


3. If you have a clear lid, put a piece of wax paper on top of the lid before sticking everything together.

4. Place the lid between the two pieces and stick it all together using tape.



5. Wrap the aluminium foil around the can to prevent any light from coming in from the sides.



6. Use a drawing pin to make a hole in the centre of the metal base of the container.
7. Go outside with your pinhole camera.
8. Point the metal end with the hole at an object which is in bright sunlight.
9. Cup your hands around the other end and look through the open end.

Questions

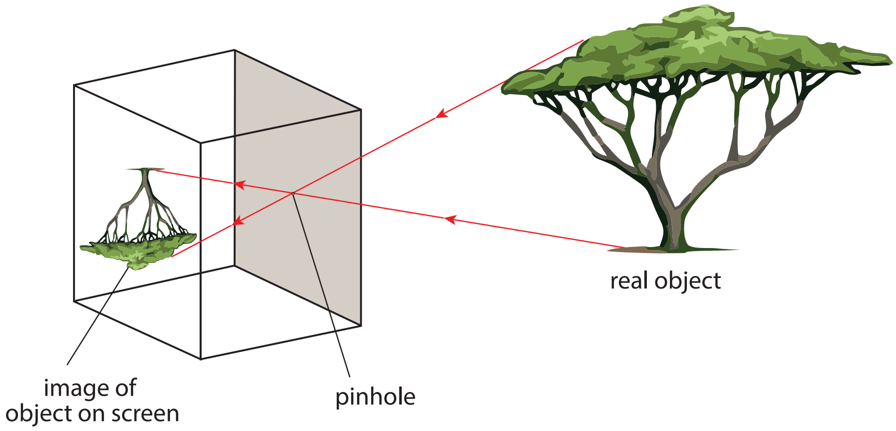
1. What did you see when you looked through the open end of the tube?
2. What happens when you move closer or further away from an object?

Did you see an upside-down image? Why is it upside down?

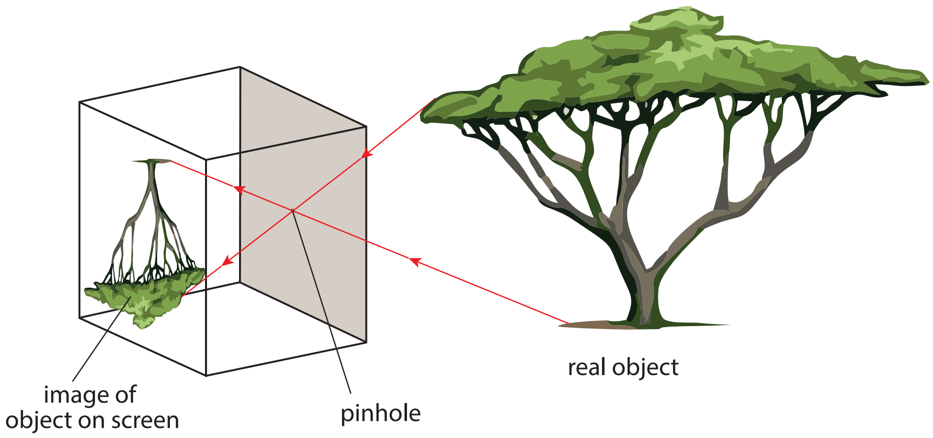
Take note

The Moon is NOT a luminous object as it does not emit its own light. It reflects the light from the Sun.

We see objects because light reflects off them and enters our eyes. If the image is upside down it means that the light from the bottom of the object has arrived at the top of the screen and the light from the top of the object has reached the bottom of the screen, as shown in the following diagram.



When you moved closer to the object, the image appeared bigger, as shown in the following diagram.



What does this mean? It means that light must be travelling in straight lines.

This is called the **rectilinear propagation** of light.

Ray diagrams

A ray diagram is a drawing that shows the path of light. Light rays are drawn using straight lines and arrowheads, because light travels in straight lines. The figure below shows some examples of ray diagrams.

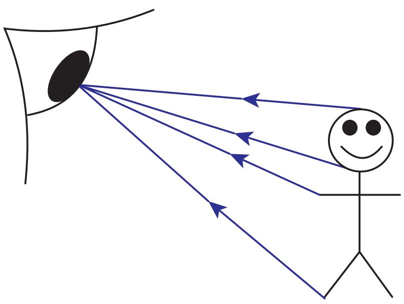


Figure 10.5 A ray diagram showing how you see another person.

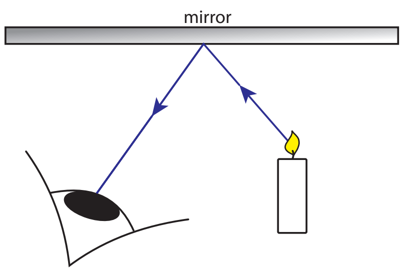


Figure 10.6 A ray diagram showing how you see a reflection in a mirror.

10.2 Spectrum of visible light

The visible light spectrum is the light that we are able to see with our naked eyes. Have you ever wondered why everything is colourful and not just black and white? Have you ever seen a rainbow and wondered where the colours have come from? The colours that we see every day are part of the visible light spectrum. Let's investigate the visible light spectrum.

Keywords

- composition
- visible spectrum
- dispersion

ACTIVITY: Splitting white light

Materials

- triangular perspex prism
- ray box and power source

Instructions

1. Connect the ray box to the power source. If you do not have a ray box, your teacher will show you how to use a piece of cardboard with a slit cut into it.
2. Place the triangular prism on a white background.
3. Shine a beam of white light through the side of the prism.

Questions

1. Draw a picture showing what you observe.
2. Write a description of what you observed.
3. Write down the order in which the colours appear.
4. If you repeat the experiment, does the order of the colours change?
5. What do the different colours we see tell us about the composition of white light?

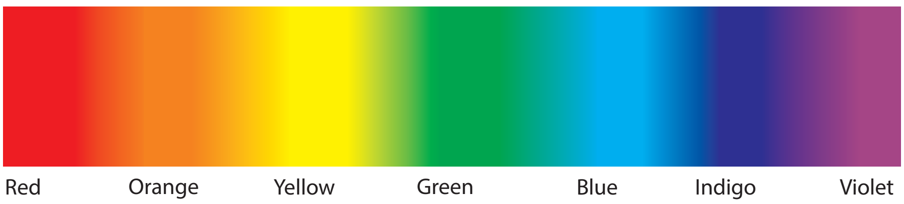
Take note

You can use the abbreviation ROYGBIV to remember the order of the colours. The primary colours of light are red, green and blue.

So, what have we learned so far? Light radiates from luminous objects and always travels in straight lines. The white light that we see is made up of the seven different colours of the spectrum. When the seven colours are travelling together we see them as white light.

Figure 10.1 The colours combine to form white light.

The seven colours of the visible spectrum are **R**ed, **O**range, **Y**ellow, **G**reen, **B**lue, **I**ndigo and **V**iolet. Each colour has a different wavelength and frequency. Have a look at the following image which shows the spectrum of visible light.



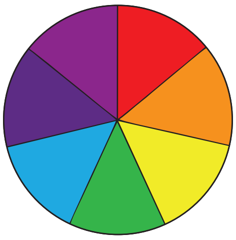
ACTIVITY: Colour spinning wheels

Materials

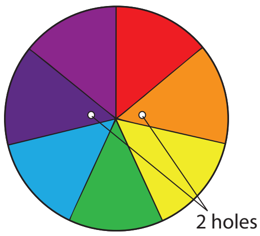
- white cardboard
- coloured pens or pencils (red, orange, yellow, green, blue, indigo, violet)
- string
- scissors
- round object

Instructions

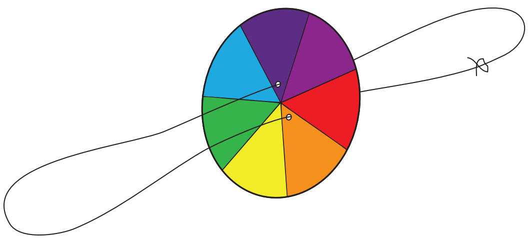
1. Draw a circle on the cardboard. You can trace around a round object such as a cup or saucer to do this. Cut out the circle.
2. Now divide the circle into 7 equal segments. If you do not have indigo and violet colours, but just one purple pen or crayon, then you can divide the circle into 6 equal segments rather.



3. Shade in each segment a different colour, in the order red, orange, yellow, green, blue, indigo, violet (or just purple if you do not have indigo and violet).
4. Next, make two holes, one on either side of the centre as shown below.



5. Thread the string through the holes and tie it in a loop.



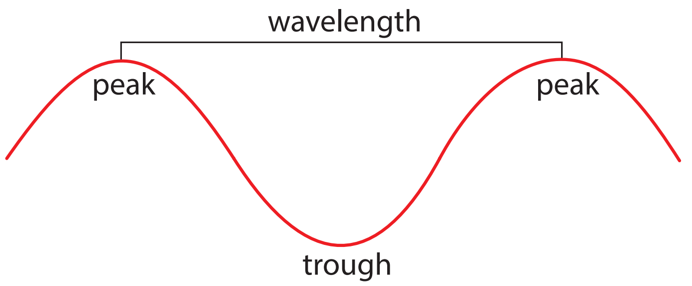
6. You are now ready to spin the wheel. Holding the ends of the loop in each hand, twirl the string over, like you would a skipping rope, so that the string twists. Once the string is tightly twisted, pull your hands apart, then bring them back together. Continue bringing your hands in and out and watch the circle spin.
7. What do you observe about the colour of the wheel as it spins faster?

Did you know?

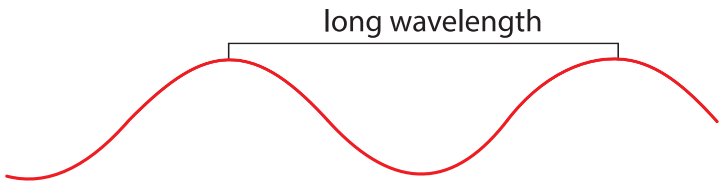
An artist might tell you that the primary colours of paint are red, yellow and blue. This is different from the primary colours of light. This is because the pigments yellow, blue and red cannot be mixed from other pigments. In printing, the primary colours are magenta, yellow and cyan.

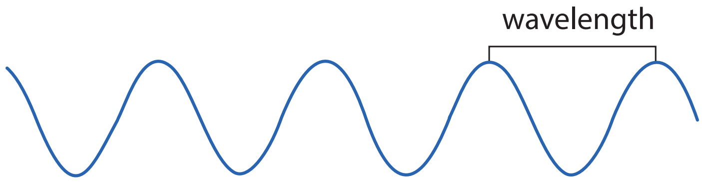
So far we have been talking about the **visible** light spectrum. As we mentioned in the beginning, this is the light that we can see. We also spoke about how light travels in **electromagnetic waves**. We can see light only with a certain range of **wavelengths**. What does this mean?

The size of a wave is measured in wavelengths. A wavelength is the distance between two corresponding points on two consecutive waves. Normally this is done by measuring from peak to peak or from trough to trough. Have a look at the following diagram which illustrates a wavelength.



The wavelengths of the different colours of visible light are different lengths, as shown in the following diagram.





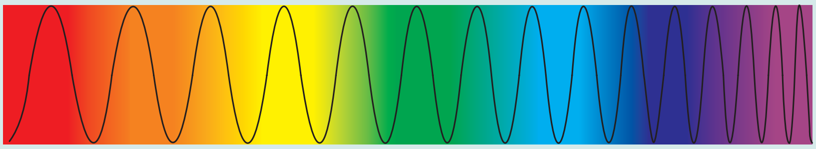
We can also talk about the frequency of a wave. If a wave has a long wavelength, then it has a low frequency; if it has a short wavelength, then it has a high frequency.

Did you know?

Wavelengths can be as small as one billionth of a meter, as with gamma rays. Wavelengths can even be as long as metres, for example in radio waves.

Did you know?

In police forensics, ultraviolet light can be used along with a special powder to detect finger and shoe prints that can help solve crimes.



Of visible light, orange and red light have the longest wavelengths (and lowest frequency) and violet, indigo and blue have the shortest wavelengths (and highest frequency).

Keywords

- opaque
- transparent
- translucent
- transmit

When it comes to visible light, we only see wavelengths of 400 to 700 billionths of a meter. This is called the visible spectrum. But light waves are just part of the wave spectrum. There is invisible light with shorter wavelengths, such as ultraviolet light, and there are longer wavelengths, such as infrared light.

Have you ever looked through a window and wondered why it is made of glass?

Let's find out how light behaves when it strikes the surface of different types of materials in the next section.

10.3 Opaque and transparent substances

Three different things happen when light hits a surface: it can be **reflected** (bounce off), **absorbed** or **transmitted** (pass through). Glass reflects some light but most of the light is transmitted straight through. That's why we can see objects on the other side of a closed window.

We say that glass is **transparent**. Let's find out more about what this means. If a substance is not transparent, it is **opaque**.

ACTIVITY: Shadow play

Materials

- cardboard
- clear plastic
- plastic shopping bag
- scissors
- light source (ray box or light bulb)

Instructions

1. Cut out three shapes from your cardboard. All of the shapes should be similar but three different sizes: small, medium and large.
2. Switch on the light source.
3. Hold your first shape a short distance in front of the light source.
4. Look at the shadow that forms. Write down what you observe.
5. Hold your second shape the same distance in front of the light source.
6. Look at the shadow that forms. Write down what you observe.
7. Hold your third shape the same distance in front of the light source.
8. Look at the shadow that forms. Write down what you observe.
9. The shadow is formed on the side furthest from the light source. It is dark in colour and larger than the first and second shadows.
10. Use your first cardboard shape as a template and cut the shape from the clear plastic and the plastic shopping bag.
11. Hold the clear plastic shape the same distance from the light source. Write down what you observe.
12. Hold the plastic shopping bag shape the same distance from the light source. Write down what you observe.

Questions

1. When you held the cardboard up to the light, did it allow light to pass through it? How do you know this?
2. Is the cardboard shape opaque or transparent?
3. What did you notice about the shadows formed by the different-sized cardboard shapes?
4. Draw a diagram to show how the shadow is formed behind the opaque shape. Use straight lines with arrowheads to represent the rays of light.
5. The distance between the shape and the light source was kept the same. What do you think would have happened to the shadow if the distance was increased?
6. Test your idea from question 5 by moving your cardboard shapes closer to and further away from the light source. What do you see? Were you correct in your prediction?
7. Is the clear plastic shape opaque or transparent?
8. Did the clear plastic cast a shadow?
9. Explain why the cardboard casts a shadow but the clear plastic does not.
10. Is the plastic shopping bag shape opaque or transparent?
11. Explain why the shopping bag casts a lighter shadow.

What have we learned? Shadows are formed because light travels in straight lines and cannot pass through opaque objects. Substances which transmit most of the light and only absorb or reflect a little bit are called **transparent**. Can you list some everyday objects which are transparent?

Substances which completely reflect or absorb light without transmitting any are called **opaque**. Can you list some everyday objects which are opaque?

Some substances, such as the plastic shopping bag, allow some light to pass through, but not all of it. This substance is **translucent**, or **semi-transparent.**

We can use transparent objects to make filters. If we want red light we use a red glass bulb or a red plastic film placed in front of the light. Only red light is able to transmit through the red glass or plastic. The other colours are absorbed by the filter.

Now that we have seen some examples of transparent and opaque substances, let's take a closer look at what it means to absorb or reflect light.

Figure 10.7 Shadows can be useful. Sundials have been used since ancient times as a time-keeping device, like a watch or a clock. As the position of the Sun changes in the sky, the shadow cast by the style moves across the surface of the sundial. The surface is marked with numbers, allowing the shadow to indicate time of day.

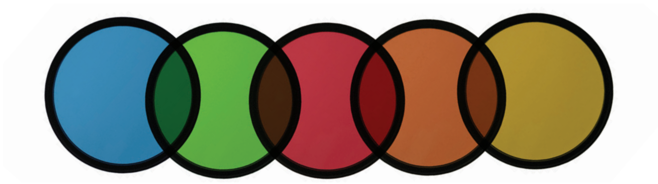


Figure 10.8 These are different colour filters for a camera. The red filter will allow only red light through, so the photograph will have a red effect applied to it. The other colours of light are absorbed by the filter.

10.4 Absorption of light

Figure 10.1 A ladybird.

Look at this picture of a ladybird. Why is it red and black? And why is the leaf so green? How do we see the different colours? It all has to do with what happens when light hits a surface.

When light hits a surface, some of the light is absorbed and the rest is reflected. It is the reflected light that reaches our eyes and allows us to see the object.

Previously, we learned that white light is a mixture of different colours. When white light from the Sun hits the red shell of the ladybird all of the colours are absorbed, except red. Red light is reflected back to our eyes and so we see a red ladybird.

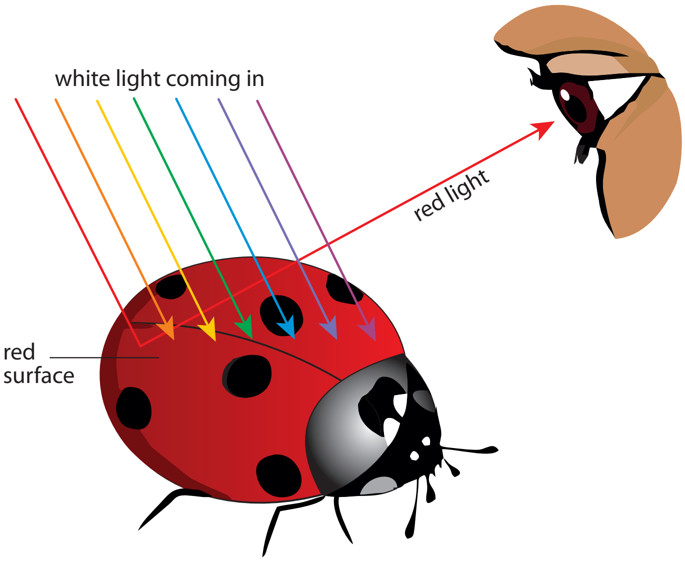


Figure 10.9 We see the red shell of the ladybird as red light is reflected and the other colours are absorbed.

The green leaf absorbs all the colours except green, which it reflects back into our eyes.

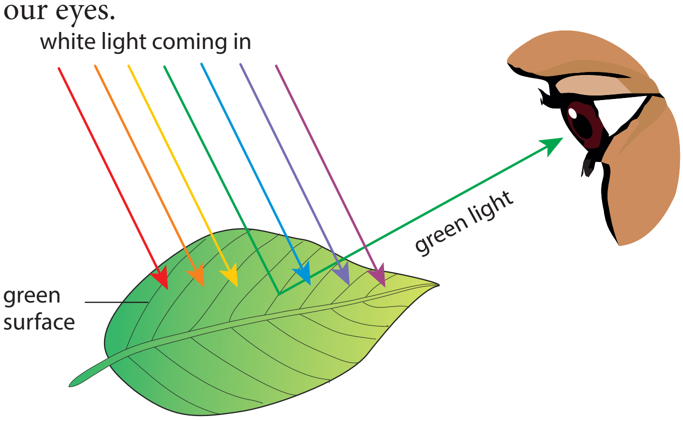
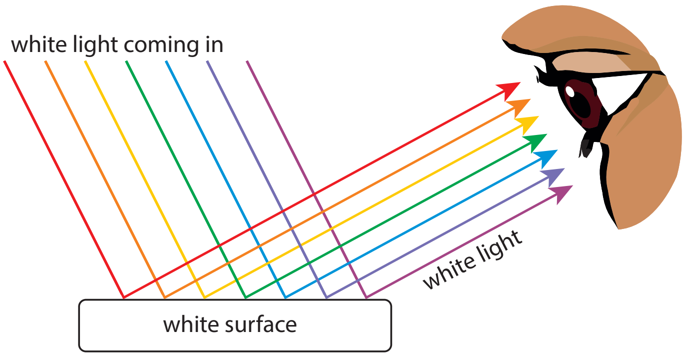


Figure 10.10 We see a green leaf as green light is reflected and the other colours are absorbed by the leaf's surface.

What about the black spots of the ladybird? Is black a colour? The black spots on the ladybird absorb **all** the colours and no light is reflected. That is why they appear black.

Do you remember learning about heat as energy transfer in Grade 7? We looked at the absorption of heat. We saw that black, matt objects absorbed all of the light energy, while white objects reflected all of it. Black, matt (not shiny) objects absorb all of the colours of light and reflect none and so appear black to our eyes.

What about a white object? Why do you think white objects look white? Have a look at the following diagram for a clue.



Take note

Although we can get black paint as a pigment, black is not a colour of light. Black is the result of the complete absorption of light.

ACTIVITY: Why do objects look red under red light?

Materials

- piece of red plastic to act as a filter
- light source (light bulb or torch)
- piece of white paper

Instructions

1. Place a piece of white paper on the desk.
2. Switch on your light source and place the red plastic in front of the light.
3. Shine the light (with the red plastic in front) onto the piece of white paper.

Questions

1. What colour was the page under normal light?
2. Why does the page appear white in normal light?
3. What did you see when the red plastic filter shone on the white page?
4. Explain why the paper changed colour.

Let's now look more at what we mean by reflection of light.

10.5 Reflection of light

When light hits a surface it is often reflected off the surface. This photograph shows how light is reflected off a still lake, creating a mirror image of the tree. The still, flat surface of the lake has acted as a mirror.

Figure 10.11 A tree reflection.

Keywords

- reflect
- incident ray
- reflected ray
- normal line
- angle of incidence
- angle of reflection
- perpendicular

Have some fun with these photos of reflections in water. One photograph is the right way up and the other one is upside down! Which one is which?

Most surfaces reflect light. When light strikes a reflective surface, it can change direction. Let's look at how this happens.

Figure 10.12 Reflections of a mountain on the river below it.

Figure 10.13 Reflections of a bridge at night time.

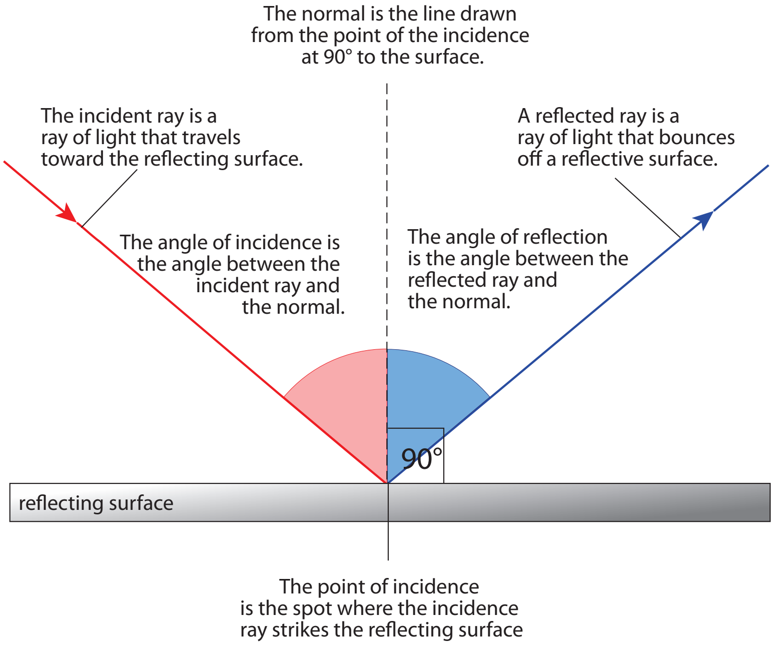
When light reflects off a surface the ray which hits the surface, it is called the **incident ray**. The ray of light which is reflected from the surface is called the **reflected ray**. When we draw diagrams of reflection we also draw in an imaginary line to help us measure different angles. This line is called the **normal**.

The normal line is always drawn perpendicular to the surface.

Between the normal line and the incident and reflected rays, there are two angles. These are:

- **angle of incidence** – the angle between the incident ray and normal line
- **angle of reflection** – the angle between the reflected ray and normal line

The following diagram explains these concepts.



Let's investigate the relationship between the angle of incidence and the angle of reflection.

Investigation: Is there a relationship between the angles of incidence and reflections?

Aim

To investigate the reflection of light from a surface.

Investigative question

Look at the diagram above and try to formulate an investigative question for this investigation.

Hypothesis

The angle of incidence is equal to the angle of reflection

Materials and apparatus

- mirror
- white paper
- pencil
- protractor
- ruler
- ray box

Method

1. Put a white piece of paper on the desk.
2. Use your ruler to draw a straight line near the top of the white paper.
3. Use your protractor to make a right angle in the middle of your pencil line. This is the **normal** line.

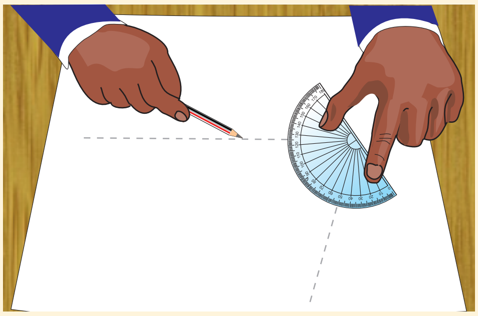


Figure 10.14 Marking a right angle with a protractor.

4. Place your mirror upright along the first line.

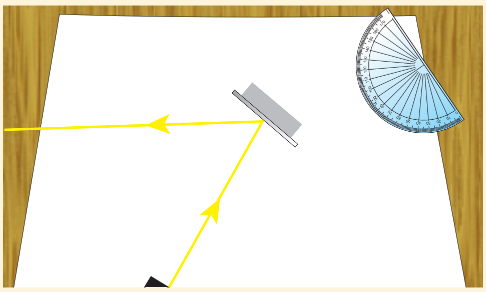


Figure 10.15 A mirror is placed on the line and a ray shone to strike the mirror at the normal line.

5. Shine a light from the ray box along the paper so that it 'hits' the mirror where your normal line and your mirror meet.

6. Use a pencil to mark the incident light ray.

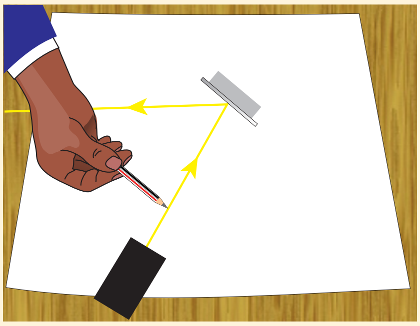


Figure 10.16 Marking the incident light ray.

7. Use a pencil to mark the reflected light ray.

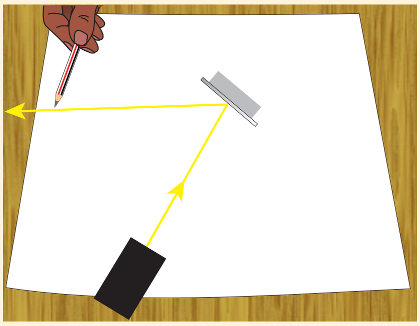


Figure 10.17 Marking the reflected ray.

8. Remove the mirror and switch off the ray box.
9. Use a ruler and pencil to draw a line from the points you have marked on each ray to the normal line.

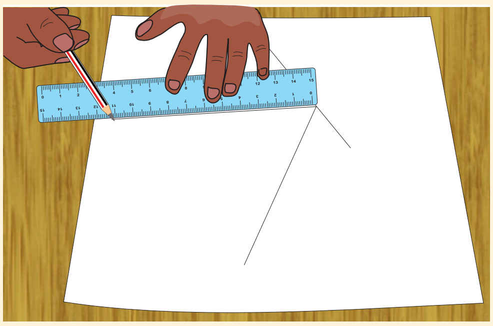


Figure 10.18 Drawing in the rays.

10. Mark the angle of incidence (i) and angle of reflection (r).

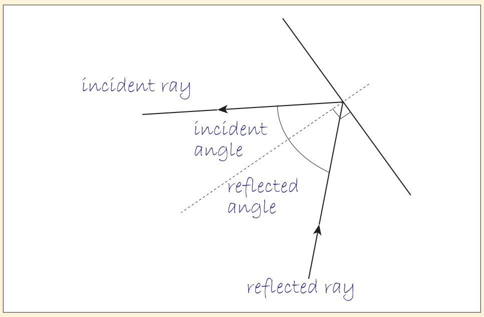


Figure 10.19 Your ray diagram should look similar to this.

11. Turn the ray box on again to confirm that your pencil lines follow the rays.

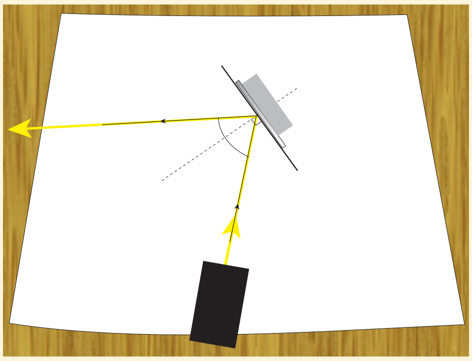


Figure 10.20 The ray diagram overlaps the actual rays.

12. Use a protractor and measure the angle of incidence and the angle of reflection and record your results in the table.
13. Repeat this method 3 more times, each time using a different angle of incidence.

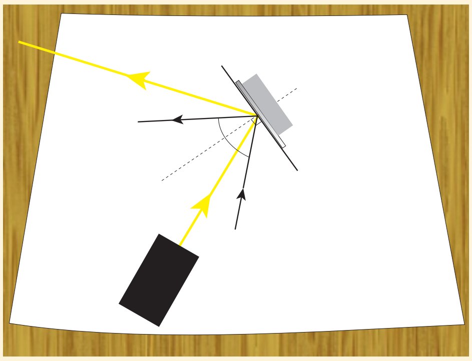


Figure 10.21 A different angle of incidence.

Take note

Keep one of the sheets with your drawn ray diagram for the next activity.

Results

Copy the table below in your exercise books and fill your results into it.

Repeat	Angle of Incidence	Angle of Reflection
1		
2		
3		
4		

Take note

In reflection, not only is the angle of incidence equal to the angle of reflection, but the incident ray and reflection ray are also in the same plane.

Analysis

1. Has your investigation provided everything you need to answer your investigative question?
2. How could you improve this investigation to get more accurate results?

Conclusion

What can you conclude based on your results?

Whenever light is reflected from a surface, the angle of incidence to equal to the angle of reflection. On a smooth surface all the light rays are reflected in the same way and so the image is clear and focused.

A mirror is an example of a smooth surface. The image you see is focused and clear. As you can see in the photograph, the scientists and engineers are clear and focused in the mirror image.

What happens when we do not have a smooth surface? Have a look at the photo.

Figure 10.22 A mirror segment from one of NASA's telescopes provides a clear and focused reflection.

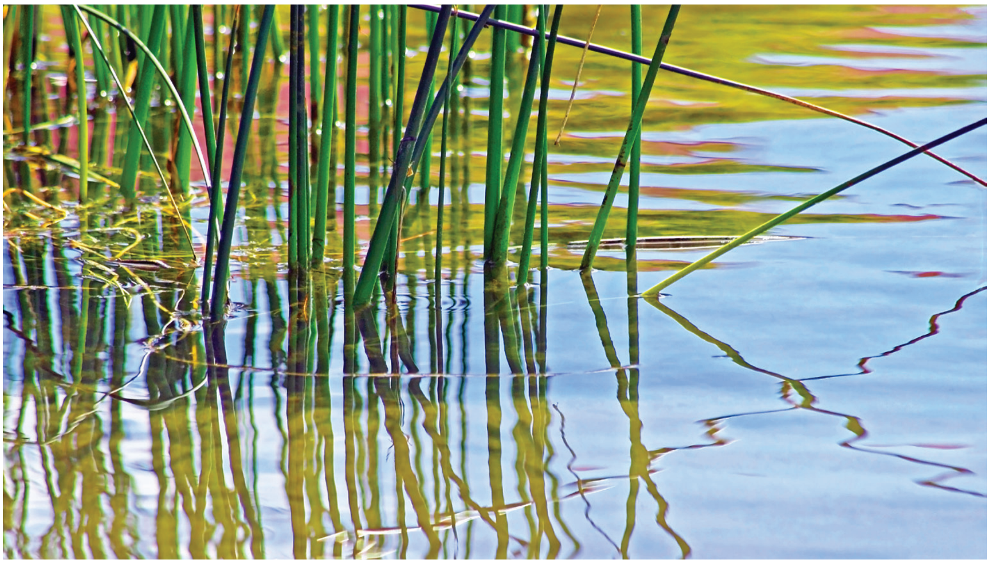


Figure 10.23 Why is the reflection of the grass and reeds not clear, but rather blurred?

ACTIVITY: Light reflection off aluminium foil

Materials

- aluminium foil
- white paper
- ray box

Instructions

1. If possible, use the sheets of white paper from the last investigation where you drew your ray diagrams.
2. Similar to what you did in the last investigation, set up a ray box and direct the ray along the line of incidence which you drew.

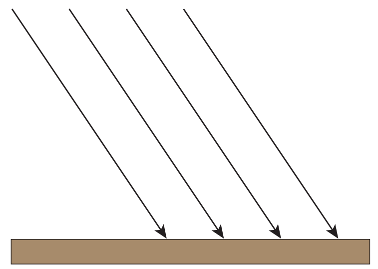
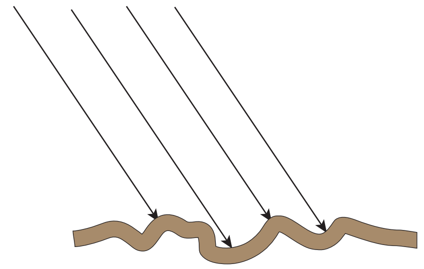
3. Crumple a piece of aluminium foil and place this in the spot instead of the mirror.
4. Observe the reflected ray.

Questions

1. Describe the reflected ray off the aluminium foil and how this compares to the reflected ray off the mirror.
2. Why do you think you observed these differences?

Can you now see why reflections off rippled water are not clear, but rather blurred? This is because the light rays have not reflected parallel to each other as they do from a smooth surface, but have scattered in different directions.

The following table shows the difference between a smooth surface and a rough surface. Straight parallel rays are approaching the surface. You need to draw in the reflected rays to show specular (clear) reflection from a smooth surface and diffuse (unclear) reflection from a rough surface.

Specular diffusion from a smooth surface	Diffuse reflection from a rough surface.
	

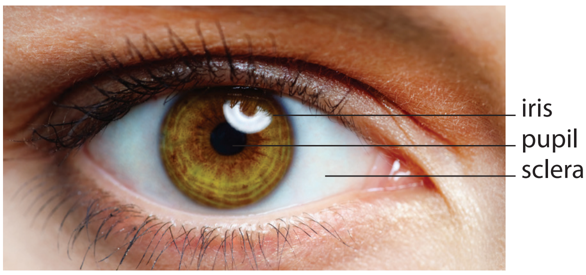
Take note

'Diffuse' can mean unclear as well as spread out. In this example, the reflection is unclear because the rays are spread out or diffuse.

Visible light is the range of frequencies of light that are visible to the human eye, and is responsible for the sense of sight. Are you curious to find out how we actually see light? Let's discover more in the next section.

10.6 How do we see light?

How is it that we are able to see light? Light that is absorbed by objects does not enter the eye. Only reflected light or direct light from luminous objects can enter the eye and be interpreted. Have a look at the following image which shows the outer structure of the eye.



Keywords

- retina
- stimulate

We can see the iris, the pupil and the sclera. The sclera is a tough, white, outer part of the eye, which acts as protection. The iris is the coloured part of the eye which differs from person to person. It is circular and surrounds the pupil. Light enters the eye through the pupil.

Take note

The fovea is the part of the eye located in the centre of the retina where the clearest image is formed.

Let's take a look at the internal structure of the human eye. The following illustration shows a cross section through the eye.

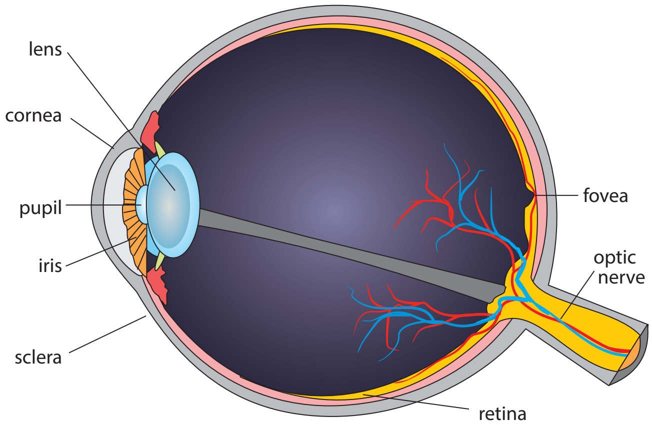


Figure 10.24 A diagram of the eye.

The eye is actually a large ball, and only a small part is visible on the outside. Covering the iris is a tough, transparent layer called the cornea. Behind the iris is the lens. Both the cornea and the lens help you to focus the light entering your eyes, as we will learn in the next section.

Take note

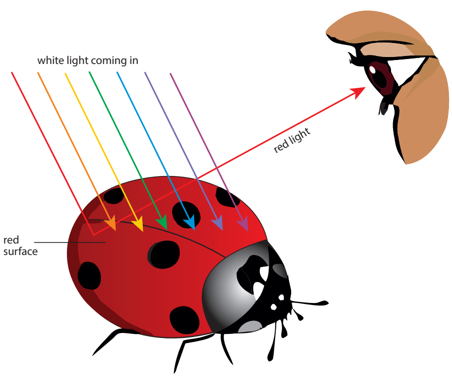
The cell is the basic structural and functional unit of all living things. We will be learning more about the cell next year in Grade 9 *Life and Living*.

Figure 10.25 The size of your pupil changes in different light conditions. In bright light, the pupil contracts (gets smaller) to let less light through (as on the left), and in low light your pupil dilates (gets bigger) to let more light through (as on the right).

The light travels through the eye and hits the retina at the back of the eyeball.

The retina is a layer of tissue lining the back of the eyeball. As indicated in the diagram, it is the yellow layer. The retina consists of cells which are sensitive to light. Light enters the eye and forms an image on the back of the eyeball. The way in which light hits the back of the eye is similar to what happens in a pinhole camera. The receptor cells convert the light energy into electrical nerve impulses. These impulses travel out of the eye through the optic nerve and to the brain where they are interpreted as sight.

So how do we see colour? Do you remember when we spoke about why the ladybird appears red and black? Look at the following diagram again.



The white light hits the ladybird's surface. The white light has all the colours of light, but when it hits the red surface, only the red light is reflected. The other colours are absorbed by the red surface. This means that when we look at the red parts of the ladybird, we get only red light reflected into our eyes.

Therefore, when this reflected light hits our retina and the electrical impulse is sent to our brains, we see the red colour.

ACTIVITY: Seeing colours

Materials

- coloured pens or pencils

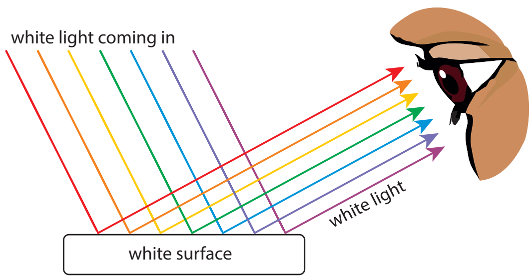
Instructions

1. Answer the following questions about how we see objects.
2. Draw a ray diagram to accompany your written answer.
3. An example has been done for you.

Look at the picture of a sunflower.

Figure 10.26 A black and yellow sunflower.

We can draw a ray diagram to show why we see the green leaves as green, as shown below. The green surface of the leaves absorbs all the colours of white light except green light which is reflected into our eyes.



Now explain why the petals appear yellow and the centre appears black. Use the concepts of absorption and reflection in your explanation. Draw diagrams to support your answer.

Heath has bought himself a blue car. Explain why we see the car as blue by using the absorption and reflection of light. Draw a diagram to support your answer.

Figure 10.27 Heath's blue car.

Did you know?

Each of your eyes has a small blind spot at the back of the retina where the optic nerve attaches. You do not normally notice the hole in your vision because your eyes work together to fill in each other's blind spot.

Did you know?

The cells in your eye come in different shapes. Rod-shaped cells allow you to see shapes, and cone-shaped cells allow you to see colour.

We have looked at opaque and transparent substances, absorption of light, reflection of light and how we see light. We are now going to go back to transparent substances and see how light can interact with these materials.

10.7 Refraction of light

Keywords

- refraction
- medium
- optical density

Do you remember the last time you drank a cooldrink with a straw? Did you notice that the straw did not look straight anymore once it was in the water or cooldrink?

Figure 10.28 Why does the pencil in this glass of water look bent?

Let's investigate this by examining what happens to light when it passes through a glass block.

We are going to investigate what happens to a ray of light when it passes from air and into a glass block and then from the glass block back into air. We are going to use a glass block with parallel sides.

Before we start the investigation, we need to think about how we are going to determine if light changes direction or not. Do you remember in the investigation on reflection where we measured the angle of incidence and the angle of reflection? What did we find in this investigation?

When light passes through a transparent substance, we can also measure the angles. Look at the following diagram. The angle of incidence (i) is measured between the incident light ray and the normal line. As the light passes through the transparent substance, the angle of refraction (r) is the angle between the refracted light ray and the normal.

Take note

The emergent ray from a parallel-sided block is parallel to the incident ray.

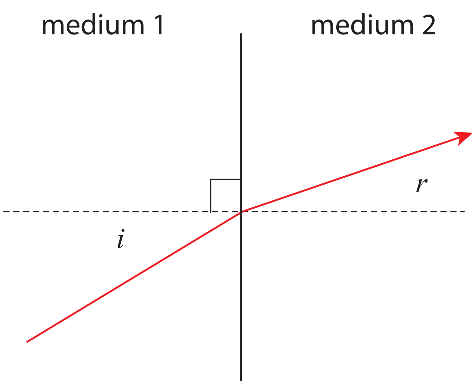


Figure 10.29 A light ray passing from one medium to another.

In the diagram above, you can see that the angle of refraction is smaller than the angle of incidence. Therefore, the refracted light ray changed direction when it entered the transparent medium. We can also say something about which direction it bent towards. Did the light ray bend towards or away from the normal line?

The next diagram shows another outcome.

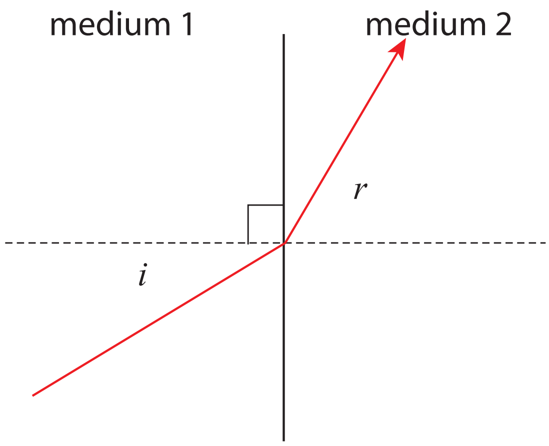


Figure 10.30 A light ray passing from one medium to another.

In the diagram above, does the refracted ray change direction when it enters the transparent medium? Give a reason for your answer.

In which direction did the refracted ray change?

We are now ready to start our investigation.

Investigation: What happens to light when it passes through a glass block?

Aim

To determine whether light changes direction when it passes through a parallel-sided glass block.

Hypothesis

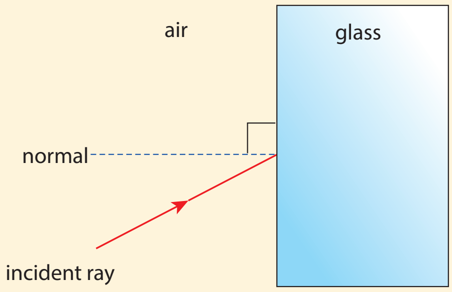
Write a hypothesis for this investigation.

Materials and apparatus

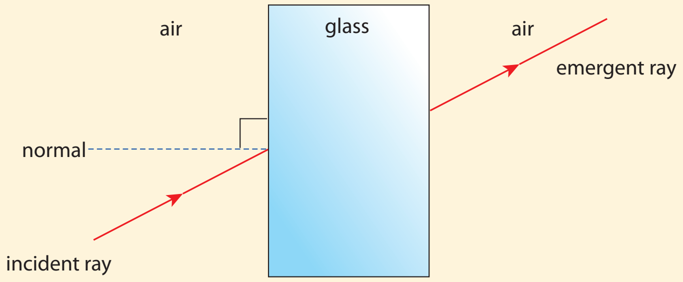
- glass block
- ray box, laser pointer or other light source
- protractor

Method

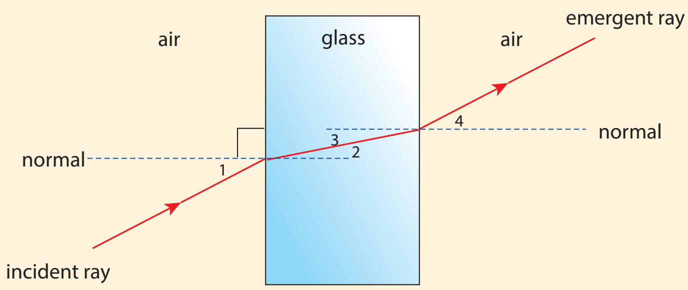
1. Put the glass block in the centre of a piece of white paper and trace around it.
2. Shine a ray of light into the glass block. The ray should be at an angle to the surface of the block.



3. Trace the light ray with pencil and mark the point at which it enters the glass block.
4. The light ray emerges on the other side of the glass block. Mark the point at which it emerges with a pencil and trace the emergent ray.



5. Remove the glass block. Your diagram should look similar to the one above.
6. Draw a line joining the incident ray and emergent ray. You have traced the refracted ray through the glass block.
7. Draw the normal lines where the incident ray meets the block and where the emergent ray leaves the block.



8. Measure the angles labelled 1, 2, 3 and 4 as shown on the diagram with a protractor.
9. Fill in the measurements in the table.
10. Repeat the steps above three times using different angles of incidence (angle 1).

Results and observations

Copy the table below in your exercise books and fill your results into the following table

Experimental repeat	Angle 1	Angle 2	Angle 3	Angle 4
1				
2				
3				
4				

1. Which pairs of angles are equal in the measurements you have taken?
2. Which of the angles you measured are the angles of incidence and which are the angles of refraction? Write this down below and mark them on the diagram above.
3. What do you notice about the angle of incidence and angle of refraction for each of your sets of measurements?

4. Did the light entering the glass block bend towards or away from the normal line?
5. Make the angle of incidence zero (make the light ray enter the block perpendicular to the surface). What is the angle of refraction?

Conclusion

What can you conclude from your results?

The angle of incidence is not equal to the angle of refraction because the light has changed direction as it enters the glass. Therefore, when light travels from one medium to another, it bends, or changes direction. This is called refraction.

When light enters a different medium at right angles then it does not change direction.

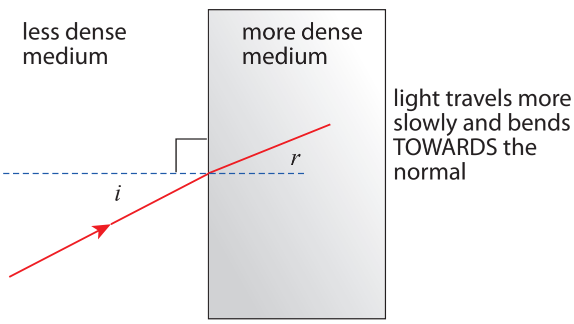
So why does the light refract? Light behaves as a wave does and waves travel at different speeds in different media. For example, light travels faster in air than it does in water. When light enters a different medium, it changes speed, and if it entered at an angle other than 90 °, it also changes direction. The more dense the medium, the more slow the light moves.

Do you remember learning about density last term in Matter and Materials?

Write down your own definition for density in your exercise book.

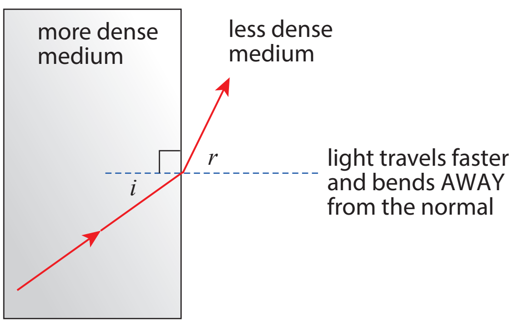
Take note

Remember that although we learn about Natural Sciences in four strands throughout the year, there are many connections and links between the strands.



If light moves from a less dense medium, like air, into a denser medium, like glass, the light slows down. The light will bend towards the normal line.

If light moves from a more dense medium to a less dense medium, the light speeds up and moves away from the normal.



When light refracts and changes direction as it passes through different mediums, it can distort what we see. Think back to the pencil or straw in a glass of water at the start of the section. We can now explain why a drinking straw or pencil in a glass of water looks bent. The light bends when it moves from one medium to another. Light moves from the air to glass to water, and therefore changes direction.

If you have stood in a pool of water before and looked down, have you noticed how short your legs appear to be? Let's have a look at this a bit more in the next activity.

ACTIVITY: Magic coin trick

Materials

- coin
- Prestik
- opaque bowl or cup
- water

Instructions

1. Work in pairs for this activity.
2. Put a small amount of Prestik onto the bottom of the bowl.
3. Stick the coin to the bottom of the bowl.
4. Take small steps back from the desk/table until you cannot see the coin over the lip of the bowl.
5. Ask your partner to pour water into the bowl slowly and observe.

Questions

1. What happened when your partner poured the water into the bowl?
2. Where does the coin appear to be?
3. Explain why the coin can be seen when the water is added, but not before.

The diagrams below will help you explain what is happening in words.

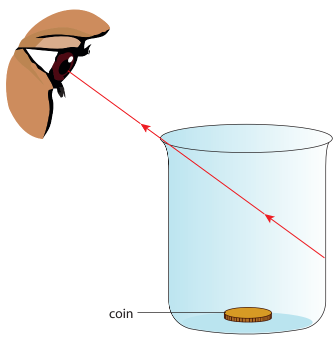


Figure 10.31 Empty container.

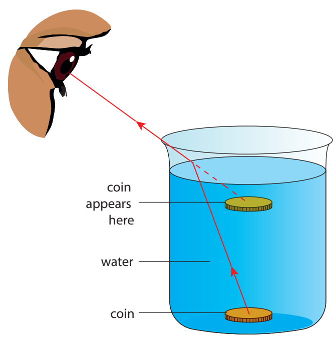


Figure 10.32 Container with water.

Take note

The diagrams used here show the container as transparent so that you can see the coin inside, whereas you will actually be using an opaque container.

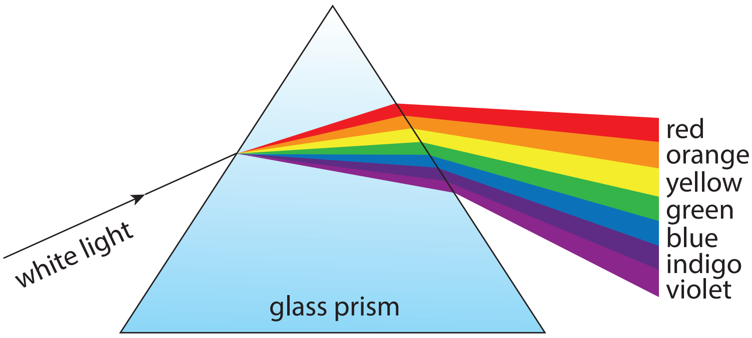
Refraction can be used to explain why images appear to be distorted when we view them through transparent mediums. For example, if you are looking at your legs or hands through water, they will appear closer than they actually are as the light is refracted. Look at the photograph of the glass with water in it in front of diagonal lines. Can you see how the lines are distorted when the light travels through the water and glass compared to when it does not?

Figure 10.33 Light refraction through glass and water.

Can you remember how we split white light into the separate colours of the visible spectrum in the beginning of this unit? What did we use to do this in the activity?

We can do this because the different colours of light bend by different amounts when the light enters a different medium. Different colours of light will slow down to different speeds, causing them to bend by different amounts.

When the white light entered the prism it refracted. The different colours of light travel at different speeds in the prism so they refracted at different angles and split up. Red light refracts the least and the violet light refracts the most, as you can see in the following diagram.



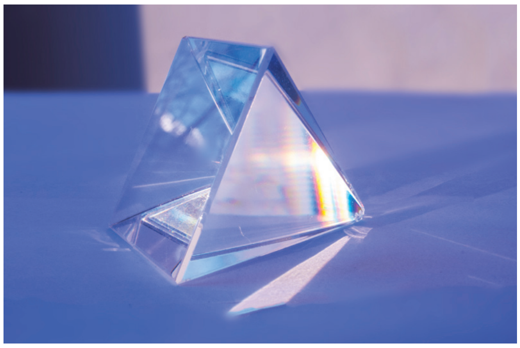


Figure 10.34 Refraction through a triangular prism.

Prisms are not the only objects that can split white light into separate colours. In fact, a rainbow is a good example of white light splitting up.

Figure 10.35 A rainbow.

Light from the Sun enters the raindrops and refracts. The light is then reflected off the back of the raindrop. When the light passes out of the raindrop it is refracted again and the colours split up even more, as shown in the diagram.

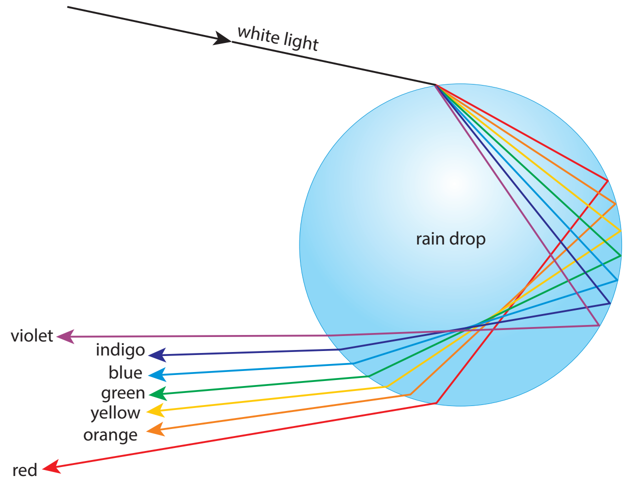


Figure 10.36 A raindrop refracts and reflects light, dispersing white light into the colours of the visible spectrum.

Keywords
- diverge
- converge
- focus

What colour is at the top of a rainbow and which colour is at the bottom?

Does this match the order which we see in the diagram showing how light is refracted and reflected in a raindrop?

How does this happen? When we see a rainbow, we see a combination of millions of raindrops. Although each raindrop refracts and reflects all seven colours, we see only the colour of light reflected from each particular raindrop. This depends on the angle of the raindrop from our position. Therefore, the raindrops higher up in the sky reflect red light to us and the raindrops lower down reflect violet light to us. This is shown in the following diagram.

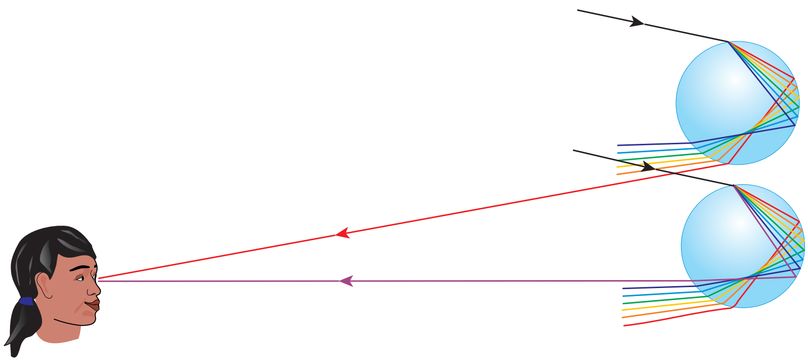


Figure 10.37 We see rainbows with red at the top and violet at the bottom because of the combination of millions of raindrops. We see only one colour reflected from a particular raindrop, depending on its position in the sky.

Take note

A lens can have two sides which are concave and it is then called a biconcave lens, or two sides which are convex and it is then called a biconvex lens.

We are now going to look at an application of the refraction of light.

Lenses

Do you remember when we spoke about how we see light and the structure of the eye, we mentioned that there is a lens just behind the iris? Another place where you may have seen lenses before are in reading glasses which some people wear to correct their vision. Or, have you seen how a magnifying glass makes things appear bigger? What are lenses, and how do they work?

A lens is a transparent object which focuses or refracts light. When light is spread out, we say it has **diverged**. Some lenses will diverge light while others will **converge** light, bringing the light rays together. When light rays are all brought to the same point, we say they have been **focused**. Let's have a look at this more closely.

Figure 10.1 A magnifying glass makes things look bigger.

ACTIVITY: Research careers in optics

There are many different careers in the field of geometric optics.

Instructions

1. Work in groups of 3.
2. Interview someone in the field of geometric optics and find out how they chose their career and what and where they studied.
3. Write a paragraph explaining the career and the study options available in order to qualify for that career.
4. Here are some examples of careers in geometric optics.
   a) Optometry
   b) Ophthalmology
   c) Optoelectronics
   d) Illumination engineering

Take note

Next term, in *Planet* we will look at how lenses are used in optical telescopes to view objects in space.

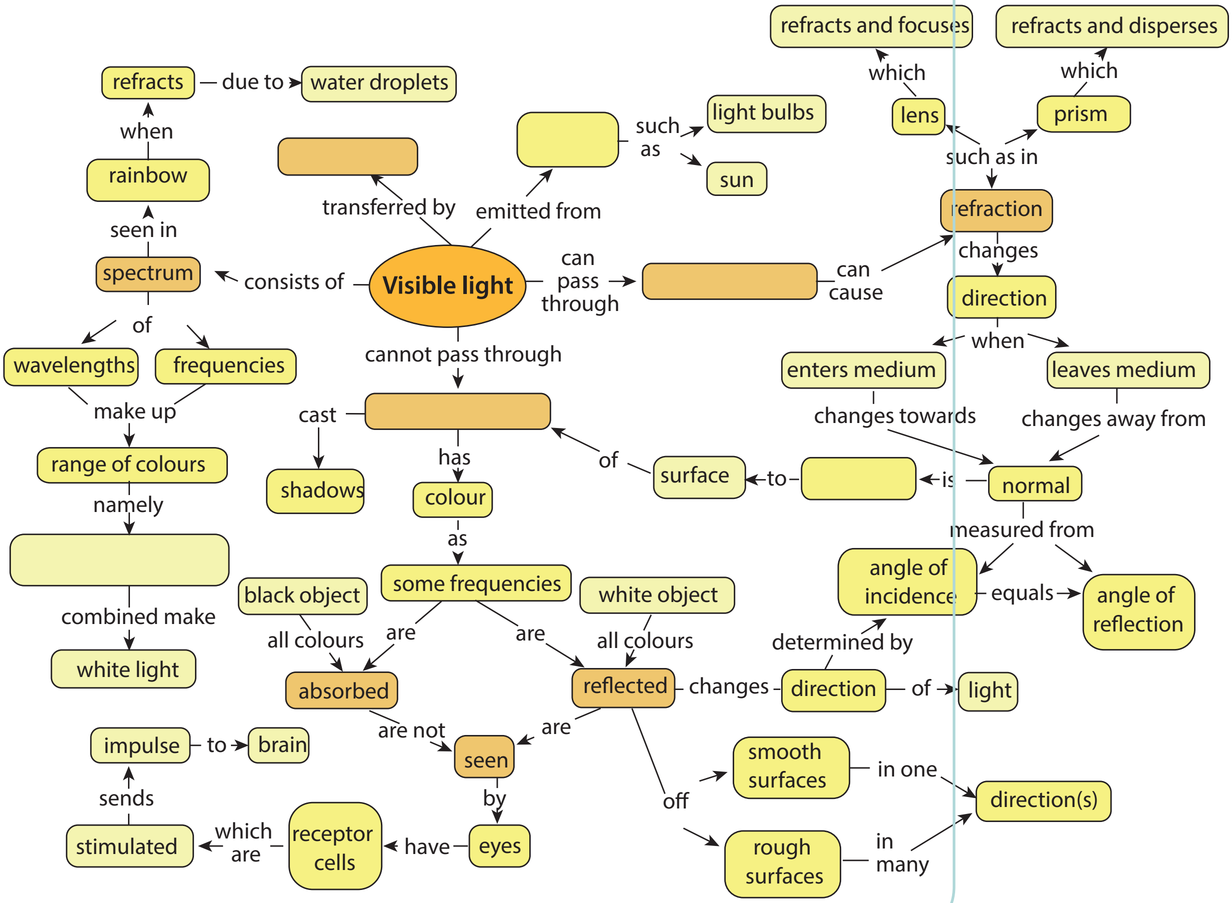
Summary

Key concepts

- Light travels in straight lines.
- White light consists of all the colours of the visible spectrum.
- The colour spectrum can be seen when white light is dispersed by a prism or a raindrop (rainbow).
- Light cannot pass through opaque objects.
- Light can pass through transparent objects.
- Light is absorbed by some materials.
- A material appears to be a certain colour because it reflects that part of the colour spectrum. Other wavelengths of light are absorbed.
- In reflection, the angle of incidence is equal to the angle of reflection.
- On a smooth surface, parallel rays of light are all reflected at the same angle.
- On rough surfaces, the light is scattered and the image produced is not clear.
- The human eye has specialised cells in the retina which convert light into electrical nerve impulses. The nerve impulses are transmitted to the brain via the optic nerve, where they are interpreted.
- Light travels at different speeds in different media.
- When light enters a different medium at an angle, the light is refracted.
- If the light slows down, the light bends towards the normal line.
- If the light speeds up, the light bends away from the normal line.
- Lenses have many applications, for example, in glasses to correct vision, microscopes, telescopes and magnifying glasses.

Concept map

The concept map on the next page shows how all the concepts relating to visible light link together. Complete the map to reinforce what you have learned in this unit.



Revision

1. Match the correct definitions to the terms in the following table. Write the letter of the definition next to the correct number below. [12]

Term	Definition
1. Radiation	A. Light cannot pass through.
2. Visible light	B. The angle of incidence equals the angle of reflection when a ray is reflected off a smooth surface.
3. Opaque	C. One of the ways in which energy is transferred, specifically through a vacuum
4. Transparent	D. When light enters a transparent medium it can change direction.
5. Absorption	E. Curved inwards.
6. Reflection	F. The spectrum of light which we are able to see.
7. Retina	G. Bulging outwards.
8. Refraction	H. A transparent object able to refract and focus light.
9. Diverging	I. Light can pass through.
10. Lens	J. When light rays are spread out from a point.
11. Concave	K. A layer of tissue at the back of the eye which is sensitive to light.
12. Convex	L. When the surface of a substance absorbs certain colours of light.

2. A beam of white light is shone through a glass prism. It splits up into seven colours which are shone on a screen. A learner took a photograph which is shown below and drew a ray diagram to show the prism. The colours are marked 1 to 7 in the diagram.

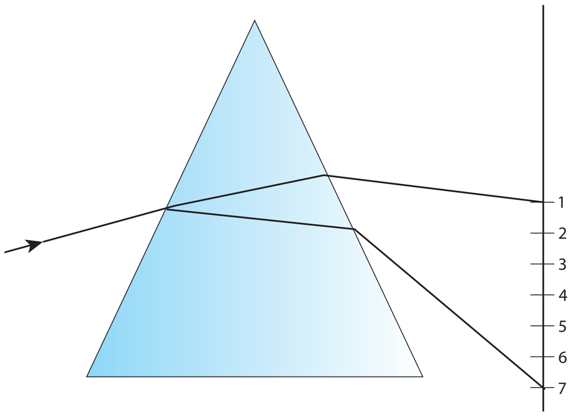


Figure 10.38 A diagram drawn by the learner.

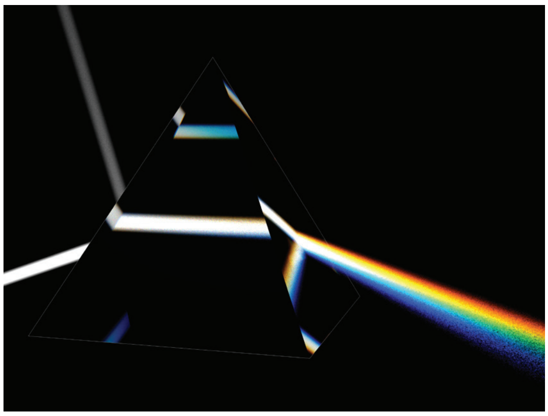


Figure 10.39 A photograph of the prism.

a) What does this tell us about white light? [1]
b) Why does the light do this when it passes through the prism? [3]
c) What colour is at label 1 and what colour is at label 7? Explain your answer. [3]
c) What label corresponds to the colour of grass? [1]
d) Can you see there are two other lighter, white rays emerging from the prism? What do you think this is the result of? [2]

3. Why does an opaque object cast a shadow? [2]

4. Look at the following photograph of water in a pond and answer the questions.

Figure 10.40 Water in a river.

a) How are we able to see the image of the trees on the edge of the pond? [2]

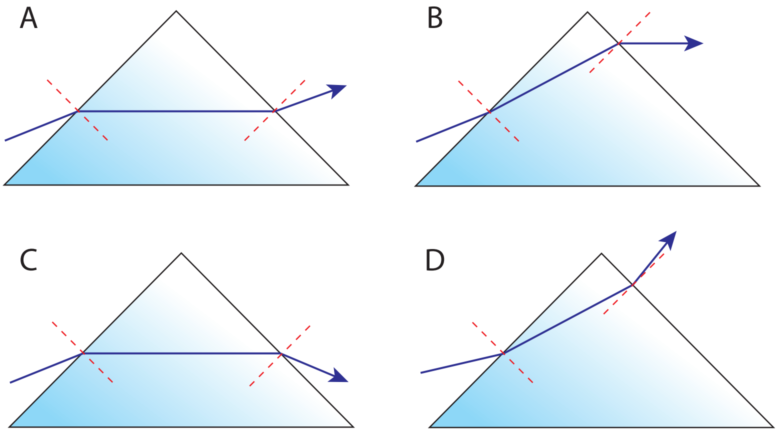
b) Why is the image not clear, but blurred? [2]

5. Two learners are discussing the colours of light. They decide that white and black are not really colours of light. If they are not colours, then how can we see them? [5]

6. Explain how we are able to see the different colours on the South African flag. [6]

7. Draw a ray diagram in your exercise book to show how we see the green part of the flag. [5]

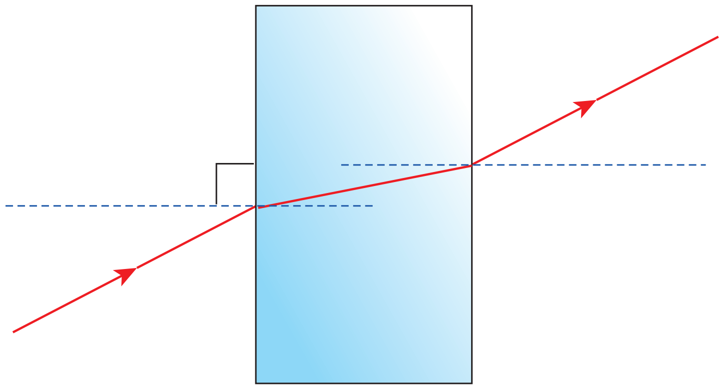
8. Which diagram shown below correctly shows the path of a ray of light through a triangular piece of glass? [2]



9. Complete the following sentence and write it out in full on the lines provided: When light travels from a less dense into a more dense transparent medium, it refracts and bends ______the normal line. When light travels from more dense to a less dense medium, it refracts and bends ______ from the normal line. [2 marks]

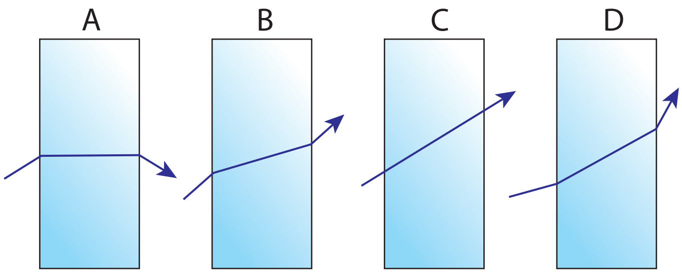
10. Draw a diagram to show what is meant by 'when the refracted ray bends towards the normal'. Mark the angle of incidence and angle of refraction. Indicate which medium is denser [4]

11. Study the following diagram and answer the questions that follow.



a) This diagram is a drawing that a learner made during an investigation into the refraction of light. What does the red line represent in this diagram? [1]
b) What do the blue lines represent? Label this on the diagram. [1]
c) The light passes from the air and into a block of another medium. Is this medium more or less dense than air? Give a reason for your answer. [2]
d) What type of medium could the block be made from? [1]
e) Label the incident ray and the emergent ray on the diagram. [2]
f) Label the angles of incidence (i) and angles of refraction (r) on the diagram. [2]

12. Which diagram shown below shows the path of a light beam passing through a rectangular glass prism correctly? [2]



Total [74 marks]

GLOSSARY: Energy and Change

angle of incidence: the angle between the incident ray and the normal line
angle of reflection: the angle between the reflected ray and the normal line
attract: to pull something closer
cell: a source of energy for an electric circuit
component: a part of a larger system
composition: the parts of a mixture
conductor: a substance which easily transmits electricity, heat, sound or light
delocalised: not limited to a particular place, free to move
discharge: the sudden flow of charged particles between two electrically charged objects
dispersion: spreading of something over an area
earth: (or ground) to connect with a conductor to the ground, or the earth
earthing: a way to prevent electrical charge from building up on an object, or to neutralise an electric charge, by allowing the excess charge to flow into the earth
electric circuit: a complete path through which electrons can move
electric current: the movement of charge in an electric circuit
electrodes: a conductor which allows electricity to enter a substance
electrolysis: the use of electricity to separate chemicals in a solution
electromagnet: a device which becomes a magnet when electric current passes through it
electroplating: covering an object with a thin layer of metal using electrolysis
electrostatic charge: the electric charge resulting from static electricity caused by an excess or deficiency of electrons on the surface of an object
flammable: is easily set on fire
focus: bring together to the same point
friction: the resistance that results when two surfaces are rubbed or moved against each other
fuse: a safety device designed to melt and break the circuit if an electric current reaches too high a level
ignite: to light something
incident ray: the ray of light which hits a surface
luminous: bright or shining
medium: substance through which waves (such as light) can travel
neutral: when the number of positive charges (from the protons) is equal to the number of negative charges (from the electrons); the (positive and negative) charges balance each other so that the object is neither positively nor negatively charged
normal line: this is an imaginary line which is drawn at 90o to the surface
opaque: something that you cannot see through; no light passes through the object
optical density: a measure of how well a medium allows light to travel through it
optics: the scientific study of sight and the behaviour of light
parallel circuit: a circuit that provides more than one pathway for the current to pass through it
perpendicular: at right angles
propagation: spreading into new areas
radiation: the emission of energy as electromagnetic waves
rectilinear: straight lines
reflect: throw back without absorbing
reflected ray: the ray of light which leaves a surface
refraction: the change in direction of a wave passing from one medium to another caused by its change in speed
repel: to push something away
resistance: the opposition to the movement of charge in a conductor
resistor: a component in an electrical circuit which slows the movement of charge
retina: a layer at the back of the eyeball which is made up of light sensitive cells
series: components connected in series provide only one pathway for electrical

current; they are connected one after another

static electricity: the build-up of a stationary electric charge (either positive or negative) on the surface of an object

stimulate: to cause activity

switch: a control component in an electrical circuit which opens or closes the circuit

translucent: semi-transparent; some light is able to pass through but not enough for details to be seen clearly

transmit: to cause light to pass through space or medium

transparent: something that you can see through; light passes through the object

variable: something that can vary or change

visible spectrum: the portion of the wave spectrum that is visible to the human eye

Strand

Planet Earth and Beyond

11 The solar system

Key questions

- How does the Sun produce its energy?
- How can we observe the Sun without damaging our eyes?
- What objects are in orbit around the Sun in our solar system?
- Why are there two types of planets?
- How do the planets in our solar system differ?
- What are asteroids and comets?
- What is the difference between a planet and a dwarf planet?
- Why is life possible on Earth?

Keywords

- solar system
- star
- nuclear fusion
- convection
- sunspot
- solar wind

Our solar system includes the Sun and all the objects that orbit around the Sun. As you will find out, a variety of objects are in orbit around the Sun: eight planets, many dwarf planets, asteroids, Kuiper Belt objects and comets.

11.1 The Sun

Before we look at the Sun close up, let's summarise what you learned about the Sun in Grades 6 and 7:

1. The Sun is our closest star and is very important for life on Earth as it provides us with light and heat.
2. The Sun is located at the very centre of our solar system.
3. The Earth and other planets all orbit around the Sun, held in orbit by the force of gravity.

What do you think the Sun would look like if it was further away, like the other stars we see at night?

Let's look at the Sun in more detail.

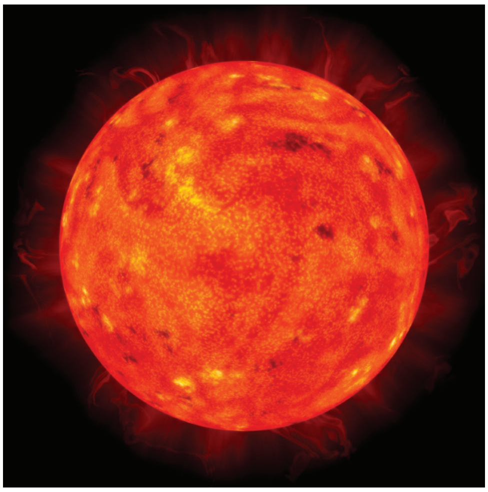


Figure 11.1 An image of the Sun taken with the SOHO space satellite.

Do you know what the Sun is made of? The Sun is mostly made up of hydrogen gas (about 71%), and also helium gas (about 27%) with a tiny amount of other gases. The temperature at the Sun's surface is very high, around 5 500 °C. However, that is nothing compared to deep inside the Sun. At the Sun's centre, or core, it is about 15 million °C. It is so hot at the Sun's centre that **nuclear reactions** can occur, which change atoms from one element to another. In the Sun's case, four hydrogen nuclei are squeezed or fused together to form a new helium nucleus. This process is called **nuclear fusion**.

Take note

It is very important that you do not look at the Sun directly! The Sun can damage your eyes permanently!

This nuclear fusion reaction releases energy because the new helium nuclei produced have very slightly less mass than the four hydrogen nuclei used to make them. How can this be? Well, according to the famous scientist Albert Einstein, energy and mass are equivalent. Some of the mass in the hydrogen nuclei is converted and released as energy when the nuclei fuse to make helium. A very large amount of energy is released. This energy travels outwards from the Sun's core towards its surface. The energy eventually reaches the Sun's surface somewhere between 17 000 and 100 000 years later! The Sun's energy then spreads out into the solar system in the form of heat and light.

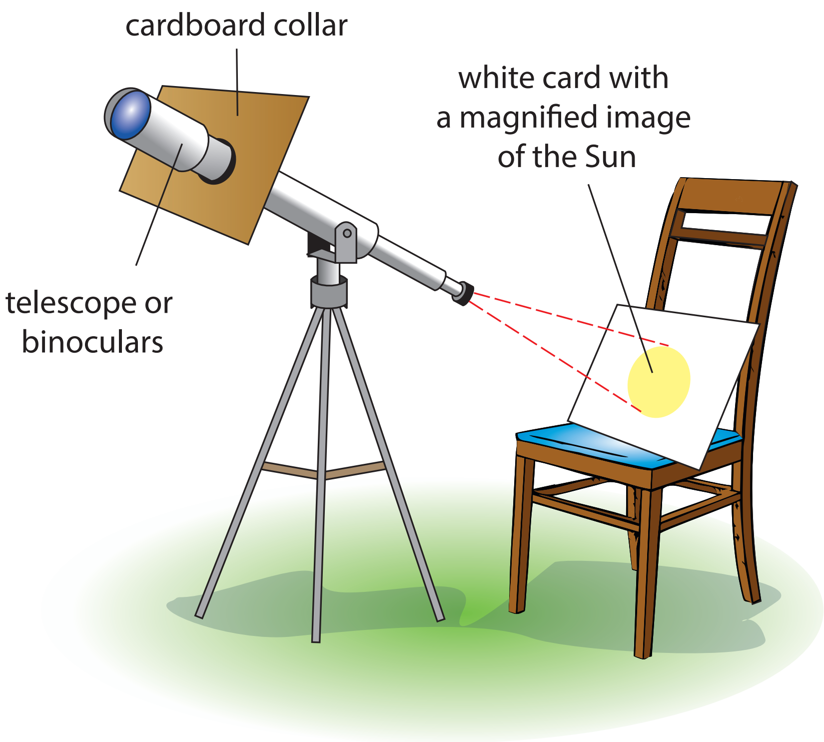
You are now going to observe the Sun to look at its surface features.

Remember, you should never look directly at the Sun as it can permanently damage your eyes. You can use either a telescope with a filter on it or a pinhole to project an image of the Sun onto a screen to safely view the Sun's image.

ACTIVITY: Observing the Sun using a telescope

Materials

- telescope
- white card
- chair to rest the card on
- cardboard to make a shade collar
- pair of scissors
- pencil

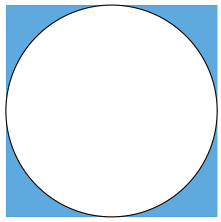


Take note

NEVER look directly at the Sun, even with sunglasses on, as you can permanently damage your eyes.

Instructions

1. Take a piece of cardboard and place it up against the narrowest end of the telescope.
2. Draw an outline around the edge of the telescope on the card to use as a guide for cutting to make the collar.



3. Cut out inside the circle you just drew so that the piece of cardboard can fit over the telescope as shown in the illustration above. You can cut a single slit into the circle from the edge of the card as shown in the diagram.
4. Place the collar on the telescope. Adjust the size of the cut-out circle if necessary (for example if your telescope is slightly wider in the middle than at the end, you may want to make your circle slightly larger). This collar shades the area where the image will fall from stray light.
5. Select the lowest magnification eyepiece lens you have and insert it into the telescope's eyepiece.
6. Focus the telescope by looking at a distant object (NOT the Sun).
7. Point the telescope at the Sun (do NOT look through the telescope to do this).
8. Place a chair behind the telescope and rest a white piece of card on it. The card should be tilted towards the telescope.
9. Adjust the direction in which the telescope is pointing until the image of the Sun appears on the white paper card. This may take some time.
10. Keeping the telescope still, move the white card toward or away from the eyepiece until the image of the Sun fits neatly in the middle of the card. Adjust the chair's position as needed.
11. Adjust the tilt of the white card until the Sun's image is circular.

Questions

1. Looking carefully, you should see that the Sun's image moves slowly across the white card. What causes this motion?
2. Draw a picture of what the surface of the Sun looks like on the white card in the circle below.

Take note

Revise the model of the atom that you learned about in *Matter and Materials* if you are unsure of some of the terms used here, such as nucleus, which is at the centre of an atom, and consists of protons and neutrons.

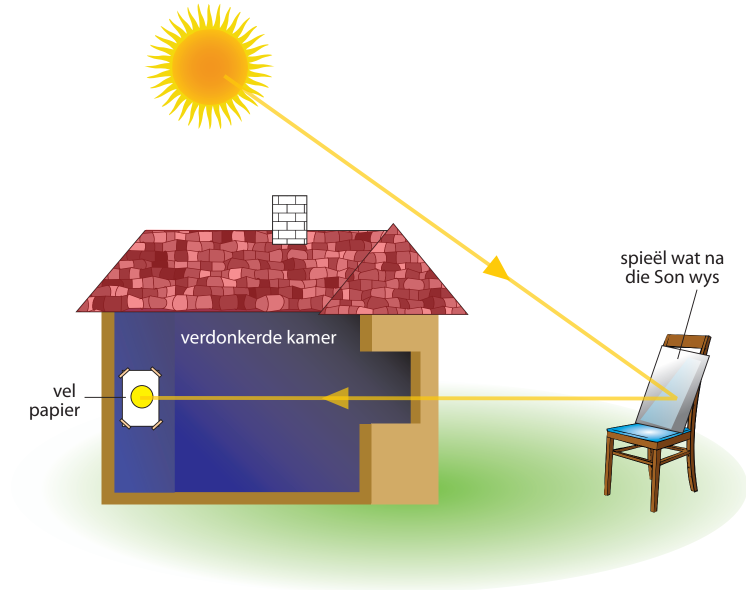
Alternatively, if you do not have access to a telescope or binoculars, you can perform the following activity to view the Sun.

ACTIVITY: Observing the Sun with a pinhole camera

In this activity you will reflect an image of the Sun onto a white card or screen for your learners to observe. This method has the advantage of not needing a telescope or binoculars. However, the solar image produced will be a bit fuzzy.

However, it should be good enough to show large sunspots. This activity is designed as a teacher-led demonstration. If you have a sunlit window or door to your classroom, you can do this activity inside. If you do not have a classroom with a sunlit window, or if your classroom is very small, you can do the activity outdoors, reflecting the Sun's image onto a shaded wall or back into a darkened classroom.

As a rough guide, begin with a distance of around 8 m between the white card and the mirror. The further away you place the mirror from the white screen, the fainter and larger the image will appear. At closer distances the image will be brighter, but it may not be in very good focus.



As mentioned in the previous activity, sunspots are sometimes (not always) visible on the Sun's surface. Therefore, you could repeat this activity over the course of several days to see if any sunspots or sunspot groups change shape, size, or position over time.

Materials

- small pocket mirror or hand mirror
- piece of plain cardboard (or paper) to fit over the mirror (or alternatively tape)
- white cardboard screen
- bin bags or curtains for darkening the classroom

Method

1. Cut the plain cardboard or paper so it fits over the mirror.
2. Cut or punch a very small hole, about 5 mm, in the middle of the plain cardboard.
3. If you do not have cardboard, you can use tape to cover all but a small portion of the surface of the mirror.
4. Place the mirror on a window sill in the Sun and tilt it so that it catches the sunlight and reflects it into the classroom. If your classroom is very small, placing the mirror outside on a chair may be a better option in order to get a larger image.
5. Darken the classroom using curtains or bin bags, excluding where the mirror is.
6. Reflect the sunlight from the mirror onto a wall of the darkened room.
7. Put the white cardboard or paper on the wall where the reflected light showing the Sun's image falls.
8. Observe the image of the Sun.
9. Remove the white cardboard from the wall and take three steps towards the mirror with the cardboard still facing the mirror. Note what happens to the image of the Sun on the cardboard.

Did you know?

Albert Einstein explained the mass–energy equivalence with the famous equation $E = mc^2$.

Questions

1. As you moved the white cardboard screen closer towards the mirror, what did you notice happened to the image of the Sun?
2. Draw a picture of what the surface of the Sun looks like on the white card.
3. When the Sun reflects off the surface of the mirror, what can you say about the angle of incidence and the angle of reflection of the ray?

Did you notice any features on the Sun's surface when you viewed it in class?

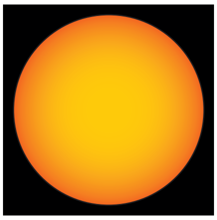
Let's find out what some of these surface features could have been in the next activity.

ACTIVITY: Observing sunspots on the Sun's surface

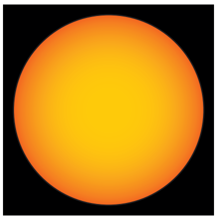
Instructions

1. Look at the images of the Sun which were taken in June 2013.
2. Answer the questions that follow.

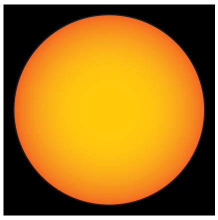
a) DATE: 02.06.2013



b) DATE: 03.06.2013



c) DATE: 04.06.2013



Take note

This information about the Sun's surface and sunspots is additional information for your interest. Be curious and discover more!

Questions

1. How many groups of dark spots do you see in each image?
2. What do you notice about the positions of the spots in each image?
3. Why do you think the spots have moved?
4. What do you think these spots are?

Sunspots and the Sun's surface

The Sun's surface often has little blemishes on it. These dark spots on the Sun are called sunspots. They are areas that are slightly cooler than the rest of the Sun's surface. The Sun's surface is typically about 5 500 °C and a typical sunspot has a temperature of about 3 900 °C.

As the Sun is made up of gas, there is no solid surface like on Earth. So when you say that you are looking at the Sun's surface, what are you actually looking at? Imagine that you are standing in thick fog (mist) with a friend. You can see things close to you, like your hand in front of you and your friend standing next to you. However, because the fog is so thick, you cannot see far into the distance. Similarly, when we look at the Sun, we cannot see right into the centre of the Sun. As you go deeper and deeper in towards the centre of the Sun, the gas begins to get thicker and thicker so that we cannot see through it. The deepest depth that we can see into the Sun's gas is what we call the Sun's surface.

Sunspots are areas that are slightly cooler, and therefore darker, than the rest of the Sun's surface. A typical sunspot lasts only a few days. When a sunspot lasts for several days you can observe it move across the Sun's disc. The sunspot appears to move across the Sun because the Sun is spinning slowly on its own axis.

The outer atmosphere of the Sun is called the **corona**. Gas particles from the corona are constantly escaping into space, forming the **solar wind**. When the Sun is very active, violent eruptions called solar flares occur on its surface.

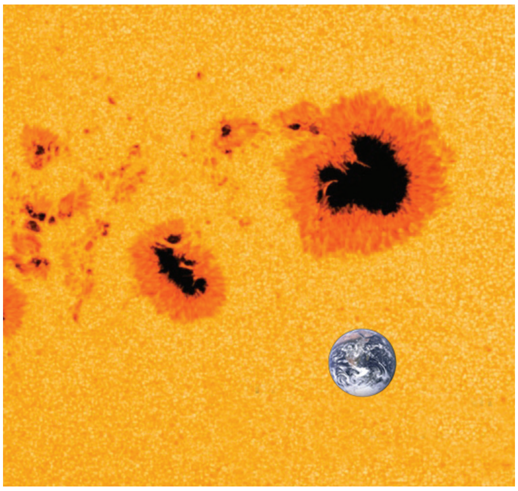


Figure 11.1 Image of a sunspot. For perspective, take note of the size of the Earth in the lower left.

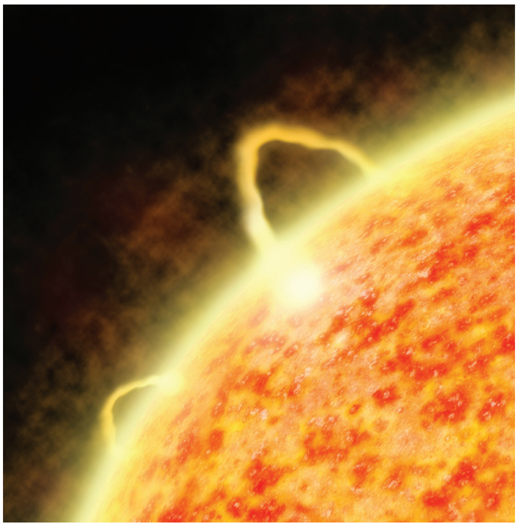


Figure 11.2 A large loop of gas extending over 35 Earth diameters out from the Sun's surface.

Did you know?

The number of sunspots on the Sun increases and decreases in a regular pattern which repeats every 11 years. When there are more sunspots the Sun is more active and there are more solar storms and more of the Sun's energy reaches the Earth.

11.2 Objects around the Sun

The Sun is by far the largest and most massive object in our solar system making up 98% of the total mass of the solar system. Due to the Sun's massive size, its large gravitational pull causes the planets and other objects in the solar system to orbit around it.

In orbit around the Sun are the eight planets along with their moons, dwarf planets and many much smaller objects like asteroids, Kuiper Belt objects and comets. You will learn all about these objects later on in this unit.

The four planets closest to the Sun are Mercury, Venus, Earth and Mars. These are called **terrestrial planets** because they have solid rocky surfaces. Further out, lie the **gas giants** Jupiter, Saturn, Uranus, and Neptune. These are much larger than the terrestrial planets and are mainly made of gas with small cores of rocky materials. In between the terrestrial planets and the gas giants lies the asteroid belt and out beyond the orbit of Neptune lies the Kuiper Belt.

Keywords

- terrestrial planet
- gas giant
- dwarf planet

Take note

'Terra' is the Latin word for land or earth.

As you can see, there are lots of different types of objects orbiting the Sun, and not all of them are planets! To be classed as a planet, an object must:

1. orbit around the Sun
2. be large enough that its own gravity pulls it into a spherical shape
3. clear out smaller objects in its orbit, by either flinging them into another orbit or by attracting and then sticking them to itself (this means that there are no other similar sized objects orbiting in their vicinity)

You will learn about planets and the other objects orbiting the Sun in more detail later on in this unit. Let's begin by learning more about the size and scale of the solar system.

ACTIVITY: The scale of the solar system

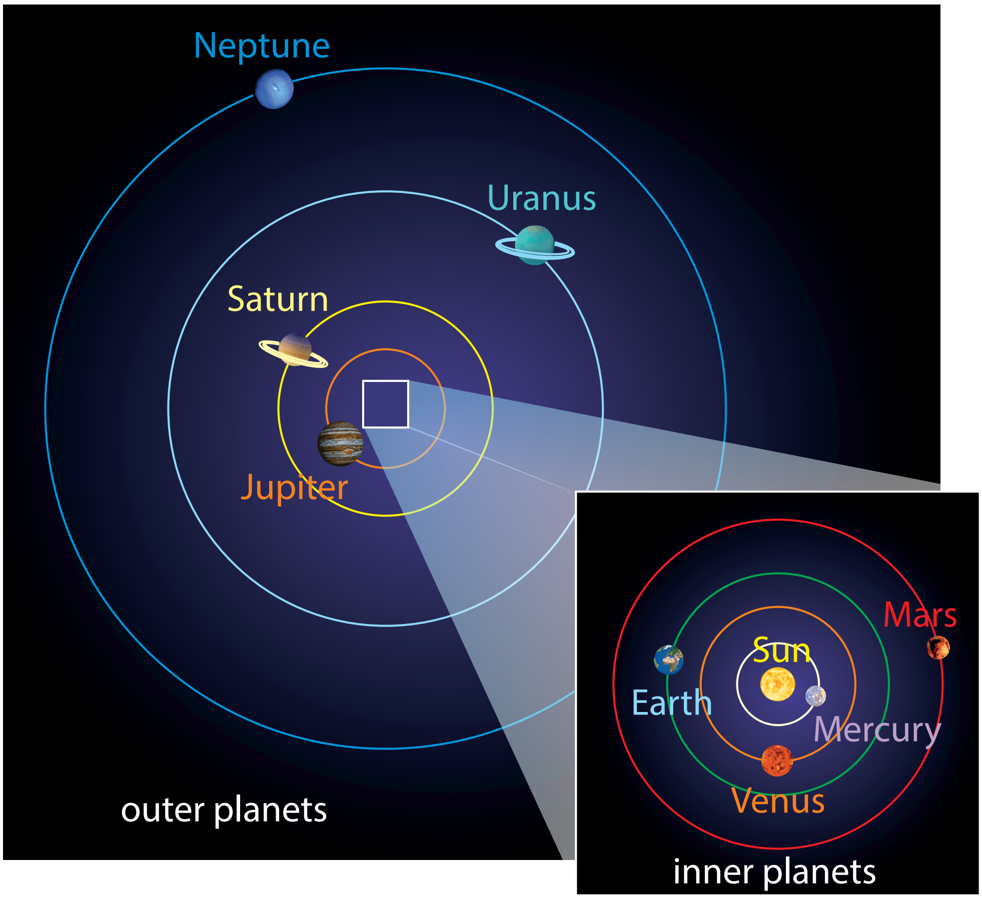


Figure 11.3 The orbits and planets in the solar system that we are going to make models of.

Materials

- grapefruit
- peppercorns
- salt grains
- poppy seeds
- pea
- grape
- measuring tape

Instructions

1. Go outside to a large field for this activity. Start at one end of the field.
2. Put the grapefruit on the ground. This represents the Sun.
3. Measure 4,2 m away from the grapefruit and put a grain of salt on the ground. This represents Mercury. If you do not have a measuring tape then count four big strides away from the Sun instead.
4. Repeat this for each of the planets in the solar system. Your teacher will tell you the distance each planet lies from the Sun and will give you the appropriate object to represent your planet.
5. Guess how far away you think the next closest star after the Sun is.

Let's now make a smaller model of the solar system.

ACTIVITY: Make a hanging solar system

Materials

- cardboard about 30 cm across
- paper
- string or thread
- pair of scissors
- tape
- string
- pencil, crayons, or markers
- compass (for drawing circles)
- nail (for making a hole in the cardboard)

Information table

Object	Orbit radius (cm)	Object radius (cm)
Sun	-	5,0* – this is NOT to scale
Mercury	0,4	0,2
Venus	0,7	0,8
Earth	1,0	0,8
Mars	1,5	0,4
Jupiter	5,0	5,1
Saturn	9,2	4,1
Uranus	18,6	1,6
Neptune	29,1	1,6

* Note that if the Sun were drawn at the same scale as the rest of the planets, its radius should be 50 cm rather than 5 cm!

Take note

The scale of the orbits differs from the scale of the object sizes in the table here. If they were on the same scale, the Sun and planets would be much smaller.

Instructions

1. Cut out the cardboard into a circle of radius 15 cm. Use a compass and pencil to mark out the circle for cutting.
2. Mark the centre of the circle. This will be the position of the Sun.
3. Using a compass, draw the orbits of the 8 planets on the card. The first four planets orbit relatively close to the Sun, then there is a gap (the asteroid belt), then the last five planets orbit very far from the Sun. The radius of each circle, representing each planet's orbit, is shown in the table.
4. Using the sharp point of the scissors' blade, or a large nail, punch a hole in the centre of the card (this is where the Sun will hang).

1. Punch one hole on each circle (orbit); a planet will hang from each hole.
2. Cut out one circle from the paper to represent the Sun.
3. Repeat this for each of the planets. The range in size of the Sun and the planets is far too large to represent accurately, so as a rough representation use the radii listed in the table to make your circles. The sizes of Mercury and Mars are very small in relation to the other planets. If you are battling to cut circles this size, then make them slightly bigger.
4. Colour in each planet and the Sun according to the pictures later in this unit.
5. Tape a length of string or thread to the Sun and each planet.
6. Lace the other end of each string or thread through the correct hole in the large cardboard circle.
7. Tape the end of the string to the top side of the cardboard.
8. After all the planets and the Sun are attached, adjust the length of the strings so that the planets and Sun all fall to the same depth when the circle is held up in the air.
9. To hang your model, tie three pieces of string to the top of the cardboard around the edge. Then tie these three together and tie them to a longer string (from which you'll hang your model).

Question

Why did you adjust the string lengths so that the Sun and all the planets hang at the same height?

Now that you have an idea of the size and scale of the planets in our solar system, let's compare the two groups of planets, the inner worlds, Mercury, Venus, Earth and Mars, with the outer worlds, Jupiter, Saturn, Uranus and Neptune, in more detail. Look at the following pictures which compare the features of the two groups of planets.

Did you know?

When it is winter on Mars you can see polar ice caps forming on the planet, like on Earth. However, unlike the Earth's polar ice caps, which are made of frozen water, the ice caps on Mars are made of frozen carbon dioxide. This frozen carbon dioxide comes from Mars's atmosphere.

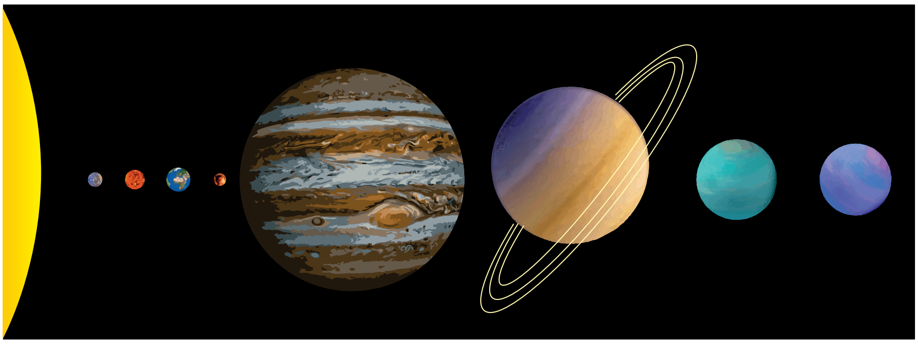
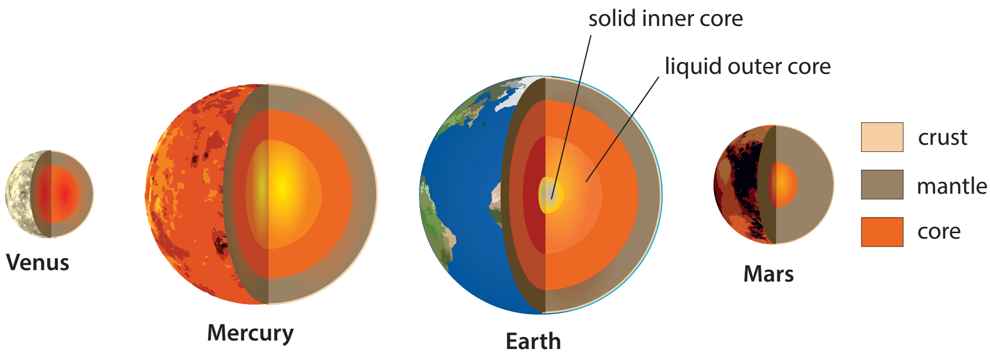


Figure 11.4 The relative sizes of the terrestrial planets and gas giants, from left to right: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Note that the planets are not spaced at equal separations from each other, but are shown in this way to fit on the page.

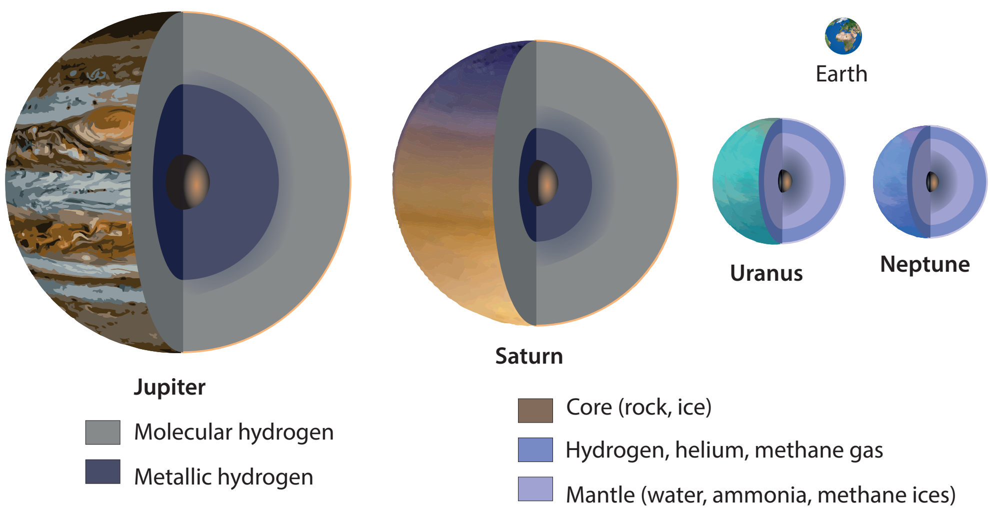
How do the sizes of the terrestrial planets and gas giants compare with each other?

Let's now look at the compositions of the two types of planets.



The above image shows the internal structure of the terrestrial planets. They all have a metal core, a rocky mantle and a thin outer crust. They also have a thin atmosphere (Mercury has an extremely thin atmosphere). The Earth's atmosphere is unique in the solar system in that it contains abundant oxygen, which is necessary to sustain life on Earth.

The image below shows the structure of the gas giants. They are mostly made of hydrogen and helium gases and are much less dense than the rocky terrestrial planets.



Did you know?

Pluto was reclassified from planet to dwarf planet in 2006. Although Pluto orbits the Sun and is almost round, it has not cleared out other objects in its orbit, and so it cannot be classified as a planet. There are many more dwarf planets at similar distances from the Sun to Pluto.

As you go deeper into the atmospheres of Saturn and Jupiter, their atmospheres get denser and denser until they gradually become a liquid. This liquid hydrogen is called metallic hydrogen. Deeper down they have a solid core made of rocky materials.

Uranus and Neptune have thick atmospheres which have methane in addition to hydrogen and helium. The methane gives them their blue colour. Scientists think that below their atmospheres they have a slushy mantle made of water, ammonia and methane ices. At their centres they have a rocky-icy core.

Did you know?

Hydrogen is a liquid deep inside Jupiter and Saturn because the hydrogen molecules have been squeezed together due to the enormous pressure at those depths caused by the weight of the planet's atmosphere above.

Look at the pictures below. They show images of the gas giants. What features do you see that the gas giants all have in common?

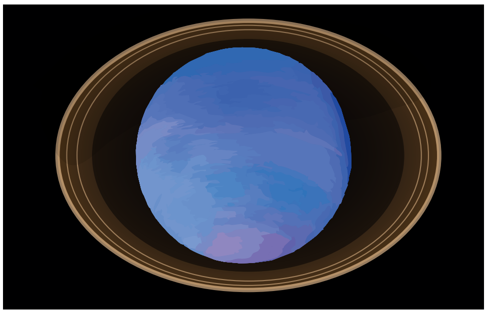


Figure 11.5 This image of Saturn was taken with the Hubble Space Telescope. Can you see some of its moons?

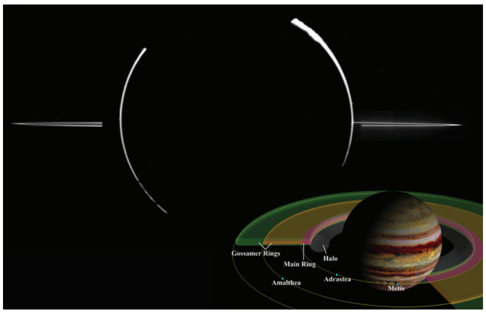


Figure 11.6 This image of Jupiter in shadow was taken by the space probe Galileo as it studied Jupiter in 1998.

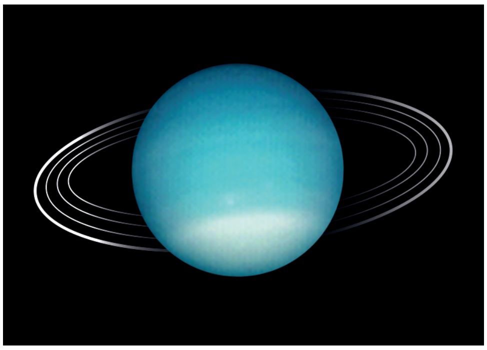


Figure 11.7 Uranus, taken with the Hubble Space Telescope. What do you notice that is strange about Uranus?

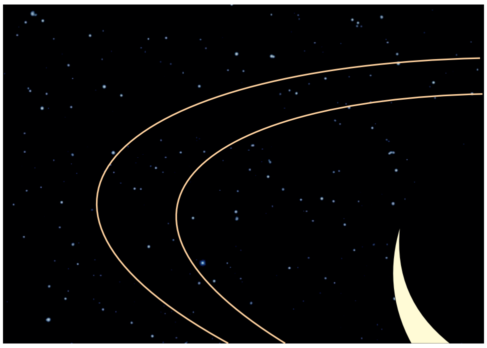


Figure 11.8 Neptune is to the bottom right of this picture, just out of view. This image was taken by the space probe Voyager 2 as it flew past Neptune in 1989.

You can see that *all* the gas giants have rings. None of the terrestrial planets have rings.

Another difference between the inner rocky and outer gas giant planets are the number of moons orbiting each planet. Look at the table below which shows the number of moons each planet in our solar system has.

What can you say in general about the number of moons that the two types of planet have?

Planet	Number of moons
Mercury	0
Venus	0
Earth	1
Mars	2
Jupiter	67
Saturn	62
Uranus	27
Neptune	13

Take note

Some older textbooks or websites that you visit may still refer to Pluto as a planet as they have not been updated.

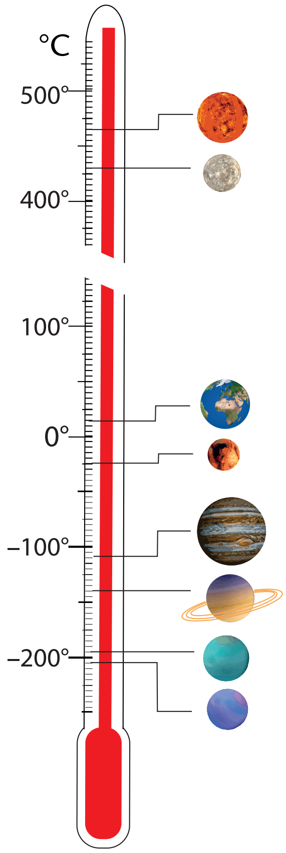
The terrestrial planets are much closer to the Sun than the gas giants. Because of this, the terrestrial planets orbit the Sun in less time than the gas giants, because they have a shorter distance to cover.

Let's see how the distance from the Sun affects the planets' temperatures.

ACTIVITY: Planetary temperatures

Instructions

1. Look at the table below. It shows the surface temperatures of each of the planets.
2. Correctly label each of the planets on the thermometer using the temperature information provided in the table.



Planet	Temperature (°C)
Mercury	167
Venus	464
Earth	15
Mars	– 65
Jupiter	– 110
Saturn	– 140
Uranus	– 195
Neptune	– 200

Questions

1. Which planet has the lowest average temperature?
2. Why do you think this is?
3. What do you notice about the average temperatures of the terrestrial planets compared with the gas giants?
4. If you exclude Venus, how does the ordering of the planets from the Sun compare with their average temperature?

Clearly the terrestrial planets and gas giants have very different properties.

Let's compare them.

Take note

New moons are discovered all the time, so these numbers may change over time.

Take note

Ice does not just refer to water ice, but other frozen elements and compounds too. Also, the rocky-ice materials do not resemble any rock or ice you would see on Earth, since the temperatures and pressures on these planets and gas giants are much, much higher.

ACTIVITY: Comparing terrestrial planets and gas giants

Instructions

1. The table below compares the two types of planet. Copy the table below in your exercise books and fill in the missing gaps.

Terrestrial planets	Gas giants
close to the Sun	__________ from the Sun
closely-spaced orbits	widely-spaced orbits
small masses	large masses
small radii	__________ radii
mainly rocky	mainly __________
solid surface	__________ surface
high density	__________ density
slower rotation	faster rotation
__________ moons	many moons
__________ rings	many rings
thin atmosphere	__________ atmosphere
warm	__________

2. Why do you think the two types of planets are so different?

When the solar system was forming, the difference in temperature across the early solar system caused the inner planets to be rocky and the outer ones to be gaseous. Close to the Sun it was hot and only materials with very high melting points, such as metals, could remain solid and form planets. Further away from the Sun, where it was cold, compounds like water and methane were frozen. Astronomers call these frozen compounds *ices*.

Therefore, the cores of the gas giants contain rocky and icy compounds. As the abundance of metals in the universe is very small, the inner planets are much smaller than the gas giants. The gas giants could also attract large amounts of hydrogen and helium to their atmospheres due to their size.

Let's continue to compare the rocky planets and the gas giants.

ACTIVITY: Comparing the inner and outer planets

Instructions

Use the information in the table below to answer the questions that follow.

Planet	Density (kg/m^3)	Diameter (km)	Distance from the Sun (million km)	Day length (hours)	Year length (Earth days)
Mercury	5 427	4 879	57,9	4 222,6	88
Venus	5 243	12 104	108,2	2 802,0	224,7
Earth	5 514	12 756	149,6	24,0	365,25
Mars	3 933	6 792	206,6	24,7	687,0
Jupiter	1 326	142 984	740,5	9,9	4 331
Saturn	687	120 536	1 352,6	10,7	10 747
Uranus	1 271	51 118	2 741,3	17,2	30 589
Neptune	1 638	49 528	4 444,5	16,1	59 800

Questions

1. Given that the density of water is 1 000 kg/m^3, which of the planets would float on water? Explain your answer.
2. Compare the densities of the rocky planets and the gas giants. Which type of planet tends to be more dense? Explain why.
3. Which planet has the shortest day?
4. Compare the day length for the rocky planets and the gas giants. Which type of planet tends to have the shortest day? What does this tell you about how fast the two types of planet rotate on their axis?
5. Which planet orbits around the Sun the fastest? Why is this?
6. Which planet's year is shorter than its day?

Mercury

- Mercury's atmosphere is very thin and is constantly being lost into space because the planet's gravity is too small to hold onto it.
- Mercury has the most extreme temperatures in the solar system, reaching 426 °C during the day and – 173 °C during the night.

Figure 11.9 Mercury, imaged by the Messenger spacecraft, is covered with craters like our Moon.

Take note

The following pages provide some interesting extra information about the planets in our solar system.

Venus

Take note

Venus has a thick dense atmosphere mostly made up of carbon dioxide which is an effective greenhouse gas. This is why Venus has the highest surface temperature, as you saw in the activity of Planetary Temperatures.

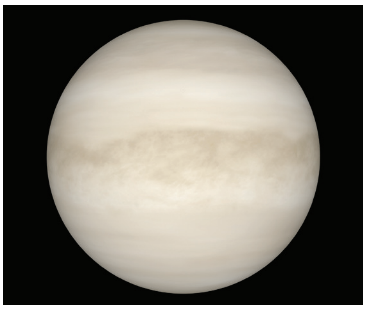


Figure 11.10 The atmosphere of Venus completely obscures the surface.

- Venus is the hottest planet in the solar system, the temperature is hot enough to melt lead!
- Venus has clouds of sulphuric acid.
- Venus rotates in the opposite direction to all the other planets.

Did you know?

As Voyager 1 was leaving the solar system, Carl Sagan, a famous astronomer, requested that they turn the camera around to take a photograph of Earth across a great expanse of space.

Earth

- To date, Earth is the only planet in the universe known to harbour life.
- The average distance between the Sun and Earth is called an *astronomical unit* (AU) and is equivalent to 150 million kilometres.

The coloured bands are scattered light rays from the Sun.

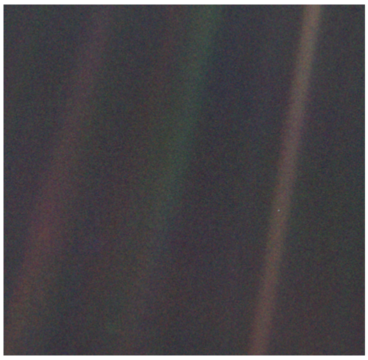


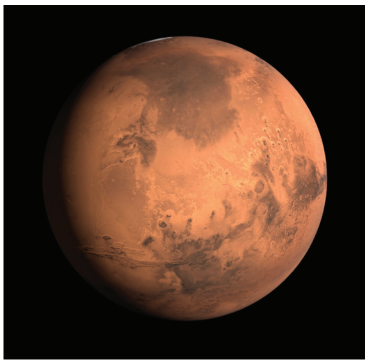
Figure 11.11 This famous image is a photograph taken of Earth in 1990 by Voyager 1 from 6 billion kilometres away. Earth appears as a tiny dot (the blueish-white speck approximately halfway down the brown band to the right).

Did you know?

The largest volcano in the solar system, Olympus Mons, is on Mars and is three times taller than Mount Everest.

Mars

- The surface of Mars is like a dry red desert. Mars has mountains, volcanoes and valleys just like Earth.
- Mars is home to the deepest and longest valley in the solar system, *Valles Marineris*, which is almost as wide as Australia!
- Mars is nicknamed the Red Planet because of its red surface, as the rocks on Mars are rich in iron. The white smudges in the middle are water-ice clouds.



Mars and the Search for Life

Figure 11.1 One of the first colour images of Mars's surface taken by the Curiosity rover. You can see part of the rover at the bottom of the photograph.

Scientists are interested in Mars because they think that Mars might have once had liquid water on its surface, and perhaps life. Channels, valleys, and gullies are found all over Mars, suggesting that liquid water might have once flowed through them. Although there is no liquid water on the planet's surface now, scientists think that there may still be some water in cracks and tiny holes in underground rock.

Mars has been visited many times by robotic landers. The first lander, NASA's Viking 1, landed on Mars in 1976, a long time before you were born! It took the first close-up pictures of the Martian surface but found no evidence of life. Water ice has been discovered below the planet's surface, and minerals indicating that liquid water was once present have also been found by Mars landers. The latest lander currently exploring Mars is NASA's Mars Science Laboratory mission, with its rover named Curiosity. Curiosity landed on Mars in August 2012 and is busy investigating the planet's rocks near a giant crater called the Gale crater. One of the main aims of the Mars Science Laboratory is to determine whether Mars ever had an environment capable of supporting life.

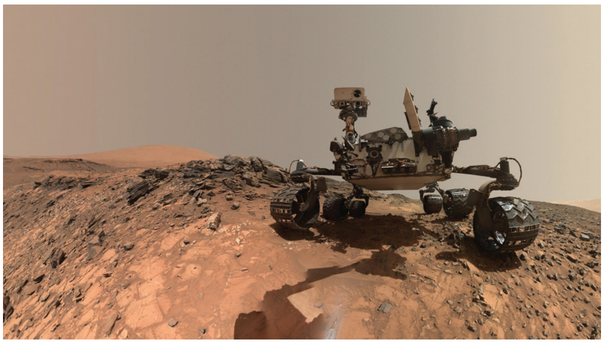


Figure 11.12 The Curiosity rover

Jupiter

Jupiter's diameter is over ten times the Earth's diameter.

Jupiter rotates slightly faster at the equator (remember it is not a solid object, but a large ball of gas).

Jupiter's famous great red spot, is a giant hurricane that has been raging for at least 300 years. This storm's area is larger than the Earth.

Figure 11.13 Magneticstormscause the aurorae seen on Jupiter near its poles.

Saturn

Saturn would float on water if you had an ocean large enough.

Saturn is famous for its rings. The rings are over 200 000 km wide and only a few tens of metres thick.

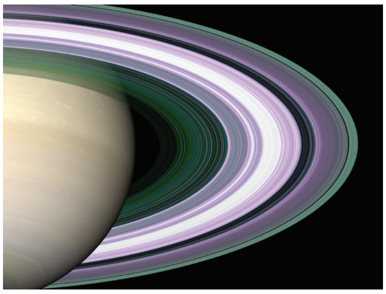


Figure 11.14 Saturn's beautiful rings, imaged with the Cassini spacecraft.

Uranus

Uranus is believed to have an ocean of liquid water, ammonia, and methane above a rocky core.

Uranus was the first planet discovered using a telescope.

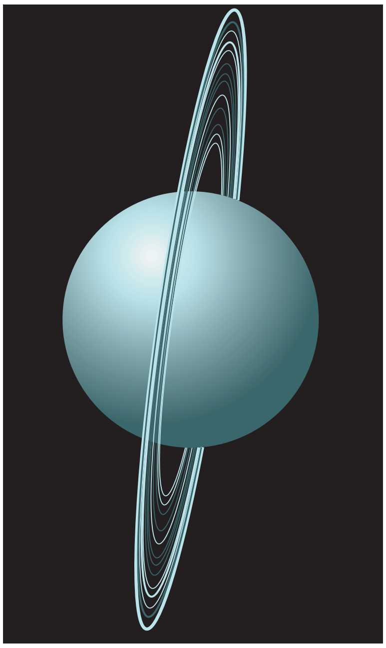


Figure 11.15 Uranus spins on its side. Scientists think Uranus may have been knocked on its side by a collision with a large object early in its history.

Neptune

Neptune has the strongest winds in the solar system. With storm winds recorded at over 10 times that of hurricanes on Earth.

Neptune has the most methane in its atmosphere out of all the gas giants, which gives it its blue colour.

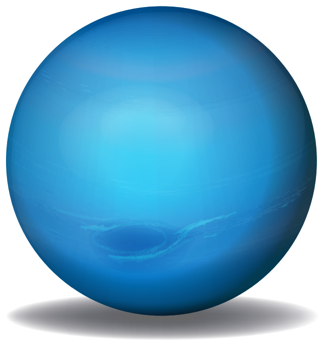


Figure 11.16 Neptune and its 'Great Dark Spot' (middle left). This is a giant storm that was raging on the planet until very recently. The winds reached nearly 1 931 km/hour.

ACTIVITY: Planetary holidays

In this activity you will write a travel brochure for a trip to your favourite planet.

Materials

- information about the planets
- pictures of the planets
- examples of travel brochures

Instructions

1. Research information about your chosen planet.
2. Write a travel brochure for a trip to your chosen planet. Include real facts about the planet and think about what unusual things you could see and do on the planet.

ACTIVITY: Planet fact sheet

In this activity you will make a one page fact sheet about your chosen planet.

Materials

- information about the planets
- pictures of the planets

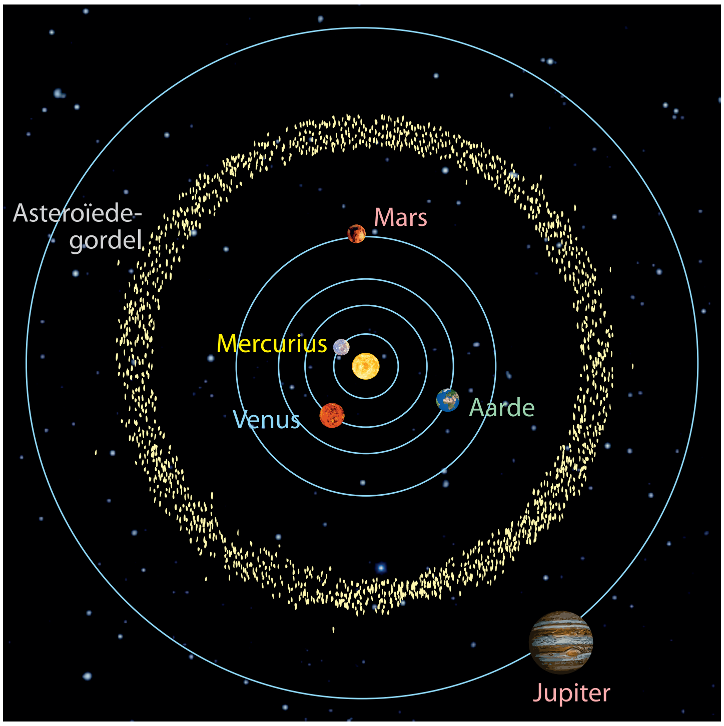
Instructions

1. Research information about your chosen planet.
2. Write a one page fact sheet about your chosen planet.

Keywords

- asteroid
- asteroid belt

Let's now look at some of the other objects that we find in our solar system.



Asteroids

Asteroids are small rocky objects that are believed to be left over from the formation of our solar system 4,6 billion years ago. They range in size from tens of metres across to several hundred kilometres across and come in a variety of shapes. Most asteroids are found in the **asteroid belt**, which lies between the orbits of Mars and Jupiter. More than 100 000 asteroids lie in the asteroid belt and several thousand of the largest ones have been named.

Although science fiction movies give the impression that the asteroid belt is a

Did you know?

In the region of the asteroid belt closest to the Sun, the asteroids are mainly metallic objects. Those further away are rocky objects. Rocky asteroids appear darker than metallic asteroids.

tightly packed region of dangerous rocks, in reality the asteroids are separated from each other by millions of kilometres. However, very rarely, collisions between asteroids do occur which is why asteroids are covered with impact craters. We will look at impact craters more closely in the following activity.

Figure 11.17 An image of asteroid 951 Gaspra taken with the Galileo spacecraft 5 300 kilometres away. Gaspra is 19 × 12 × 11 km. Notice how the asteroid's surface has many craters.

Investigation: Impact craters

Investigative questions

How does the mass of an object affect the size of the crater it leaves? How does the height at which an object is dropped affect the size of the crater it leaves?

Hypothesis

What do you think will happen?

Identify variables

1. What are you keeping constant in this experiment?
2. What are you changing in this experiment?

Materials

- deep tray or large plastic container
- measuring scales
- ruler
- sand
- a marble
- a ball bearing
- chair or step ladder
- measuring tape (at least 2 m long)

Method

1. Fill the tray or plastic container with sand to a depth of 10 cm.
2. Smooth the surface of the sand using the long edge of a ruler.
3. Measure the mass of the marble and record it in the table below.
4. Drop the marble from a height of 1 m into the tray of sand and observe the crater that forms.
5. Carefully remove the marble, without disturbing the shape of the crater and measure the diameter of the crater using the ruler.
6. Record the diameter of the crater in the table below.
7. Smooth the sand.

8. Repeat steps 3 – 7
9. Measure the mass of the ball bearing and record it in the table below.
10. Drop the ball bearing from a height of 1 m into the tray of sand and observe the crater that forms.
11. Carefully remove the ball bearing and measure the diameter of the crater using the ruler.
12. Record the diameter of the crater in the table below.
13. Smooth the sand.
14. Repeat steps 9 – 13.
15. Drop the ball bearing into the sand from a height of 2 m. You may need to stand on a chair or step ladder to do this.
16. Record the size of the crater formed in the table below.
17. Smooth the sand.
18. Repeat steps 15 – 17, dropping the ball bearing from heights of 1,5 m, 0,5 m and 0,25 m. Record all your measurements in the table below.
19. If you have time you can make repeated measurements.

Results and observations

Copy the table below in your exercise books and record your results and observations

Object	Mass (kg)	Drop height (m)	Crater diameter – reading 1 (cm)	Crater diameter – reading 2 (cm)	Average crater diameter (cm)
Marble		1			
Ball bearing		1			
Ball bearing		2			
Ball bearing		1,5			
Ball bearing		0,5			
Ball bearing		0,25			

Evaluation

How reliable was your experiment? How could it be improved?

Conclusion

Write a conclusion for this investigation based on your results.

Questions

1. How did the mass of the object affect the size of the crater?
2. How did the height at which the object was dropped affect the size of the crater?
3. Why do you think the drop height affected the size of the crater?
4. What does this investigation tell us about craters on the surfaces of planets?

Keywords

- Kuiper Belt
- Kuiper Belt object
- comet
- Oort Cloud

Kuiper Belt objects

The Kuiper Belt is a region of space filled with trillions of small objects that lies in the outer reaches of the solar system, past the orbit of Neptune. The Kuiper Belt is a region between 30 and 50 times the Earth's distance from the Sun. This belt is similar to the closer asteroid belt, except that the objects are not made of rock, but rather of frozen ices. These icy objects can range in size from a fraction of a kilometre to more than a 1 000 km across and are called Kuiper Belt objects. The two largest known members of the Kuiper Belt are Eris and Pluto, both dwarf planets.

Did you know?

As Jupiter is more massive than all the other planets in the solar system, its large gravity attracts many asteroids and comets travelling in towards the inner solar system that would otherwise potentially crash into the Earth.

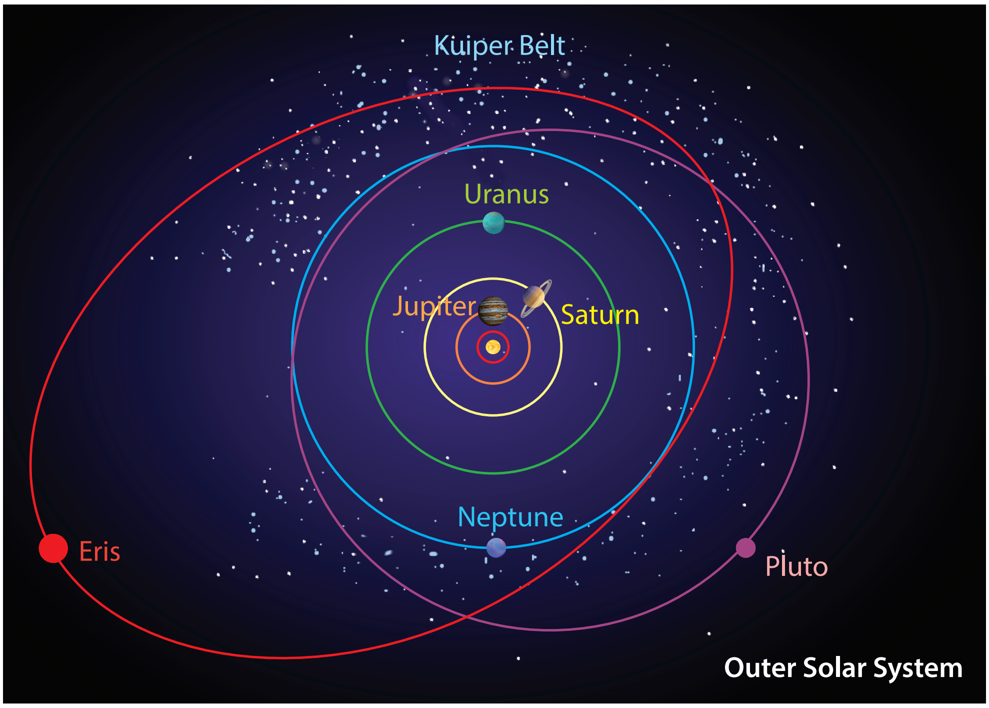


Figure 11.18 The Kuiper Belt (the pale blue dot dots) is shown beyond the orbit of Neptune. Its members include the dwarf planets Pluto and Eris.

What keeps the objects in the Kuiper Belt in orbit around the Sun?

Dwarf planets

Dwarf planets are objects that orbit the Sun, just like the planets. However, they are smaller than planets. Because of their small size, they are unable to meet the official definition of a planet. Can you remember what the three criteria are to be classed as a planet? List them.

Asteroids are clearly not planets as they have irregular shapes and they are not spherical. Some dwarf planets are spherical, but they do not meet the third criterion. With their weak gravities they are unable to clear out other objects from their orbits. Which famous ex-planet is now considered a dwarf planet because it failed to meet the third criterion?

For many years the object Pluto was considered to be a planet. However, since the 1990s many more objects very similar to Pluto have been discovered orbiting the Sun out past Neptune's orbit. This resulted in new criteria being drawn up to be considered a planet, and Pluto was demoted to dwarf planet status.

Figure 11.19 This image shows the five dwarf planets that have been discovered to date, Pluto, Haumea, Makemake, Eris and Ceres in relation to the size of the Earth. Some even have their own moons, which are shown. Ceres is in the asteroid belt and the other four are in the Kuiper Belt.

Comets and the Oort Cloud

Comets are icy, dusty objects, orbiting around the Sun at great distances.

Comets are found in the Kuiper Belt and in the predicted **Oort Cloud**. The Oort Cloud is thought to be a huge cloud of icy objects surrounding the Sun at the very edge of our solar system at a distance between 5 000 and 100 000 times the Earth's distance from the Sun!

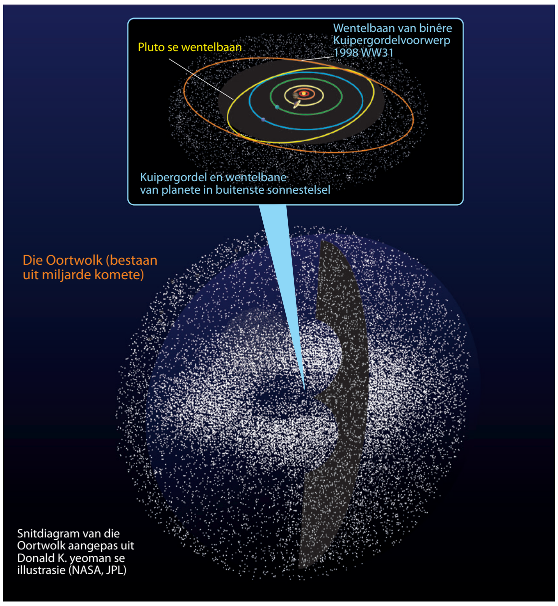


Figure 11.20 The hypothetical Oort Cloud is a huge cloud of icy objects or comets surrounding the outer reaches of our solar system.

A comet will remain in the Kuiper Belt or Oort Cloud unless it is disturbed by another comet. If this happens, then the comet's orbit changes and occasionally the comet will come into the inner solar system for us to see.

We can see comets directly only when they come into the inner solar system because they are small and visible only by reflected sunlight. As a comet approaches the Sun, the Sun's heat evaporates the dust and ices it consists of, forming a bright dust tail which is visible from Earth. Some comet dust tails can be millions of kilometres long. The dust tail usually points back along the path of the comet.

Did you know?

NASA launched a space probe called New Horizons to study Pluto and other Kuiper Belt objects in more detail in 2006. It arrived at Pluto in 2015.

Did you know?

Scientists estimate that there may be 200 or more dwarf planets in the Kuiper Belt, and thousands more beyond the Kuiper Belt.

Comets often have a second tail called an ion tail. The ion tail is made of ions that are pushed away from the comet's head by particles emitted from the Sun's atmosphere, called the solar wind. Let's find out more about this type of tail.

Did you know?

Pluto was named by Venetia Burney, an 11–year old from Oxford, England, in 1930. She suggested that the planet be named after the Roman god of the underworld, Pluto.

Take note

An ion is an atom with an electrical charge resulting from the gain or loss of electrons.

ACTIVITY: A comet's ion tail

In this activity you will make your own comet and explore how a comet's ion tail moves.

Materials

- table tennis ball
- cellotape
- tissue paper or crepe paper
- scissors

Instructions

1. Cut the tissue paper or crepe papers into several strips (at least 4) about 1 cm wide by about 15 cm long.
2. Attach the paper strips to the ping pong ball, evenly spread around the equator of the ball, using the cellotape. Wrap the cellotape around the ball a few times if needed to secure the paper in place. You have now made your comet and ion tail.
3. Hold out your comet in front of you and blow on the ball hard so that the ion tail is blown away from you. You are representing the Sun and your breath represents the solar wind, blowing on the comet's ion tail.
4. Continuing to blow fairly hard on the ball, move the ball from left to right and observe which way the paper moves.

Questions

1. Which direction did the ion tail move when you held up the comet in front of you and blew on the comet?
2. Which direction did the ion tail move when you moved the ball left and right while still blowing?

In a similar way, a comet's ion tail always points away from the Sun.

Comets that come into the inner solar system do not live forever. The Sun's heat melts comets, just like a snowman melts out in the Sun. After several thousand years the remains are so small that they no longer form a tail. Some comets completely melt away.

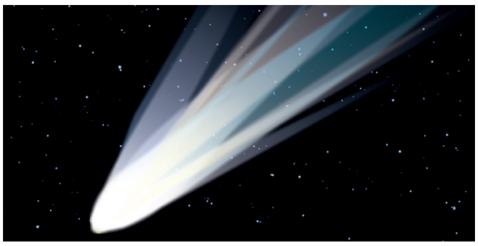


Figure 11.21 Comet West, photographed in 1995. Here you can see that the comet actually has two tails. The white tail is the dust tail and the blue tail is the ion tail, made of charged particles evaporated from the comet's surface.

11.3 Earth's position in the solar system

As you discovered in the last section, the Earth, along with the other planets, orbits around the Sun. The Earth is the third most distant planet from the Sun, lying in between Venus and Mars. Let's compare the Earth and its two neighbours in more detail.

ACTIVITY: The Sun's Habitable Zone

Property	Venus	Earth	Mars
Distance from Sun (AU)	0,7	1,0	1,5
Average temperature (°C)	464	15	–63

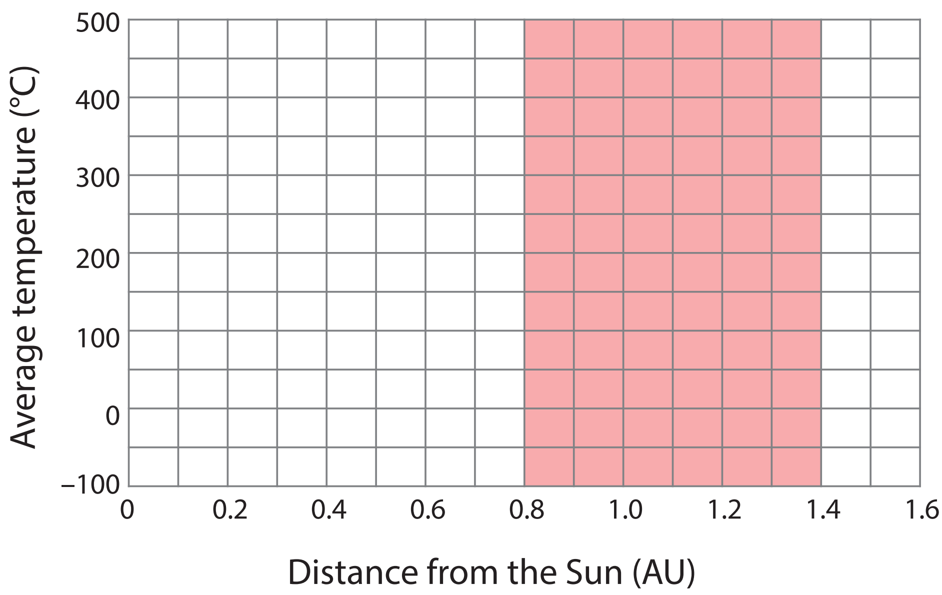
Materials

- pencil
- ruler

Instructions

1. Look at the data provided in the table. It shows the distance from the Sun for three planets (in units of one Earth–Sun distance or Astronomical Unit). It also shows the average temperature on each planet in degrees Celsius.
2. Plot a graph to show the data in the table. Mark each point with an X.
3. The Sun's habitable zone extends from 0,8 to 1,4 AU and is shaded in red in the graph paper. This is the region where scientists think a planet has to lie in order for there to be life on the planet.

Graph showing the average temperature and the distance from the Sun of Venus, Earth and Mars.



Keywords

- astronomical unit (AU)
- habitable zone
- photosynthesis

Did you know?

It is completely safe to fly through a comet's tail. The only thing that would hit your space ship would be microscopic pieces of dust.

Take note

An astronomical unit corresponds to the average distance between the Earth and the Sun.

Questions

1. What is the average temperature on Venus?
2. Can liquid water exist on Venus? Why?
3. What is the average temperature on Mars?
4. Is liquid water likely to be found on Mars? Why?
5. What is the average temperature on Earth?
6. Can liquid water exist on Earth? Why?
7. Which planet(s) lie within the Sun's habitable zone (the red-shaded region in the graph)?

Did you know?

The habitable zone is sometimes called the Goldilocks zone after the famous children's story where Goldilocks eats the porridge that is neither too hot nor too cold.

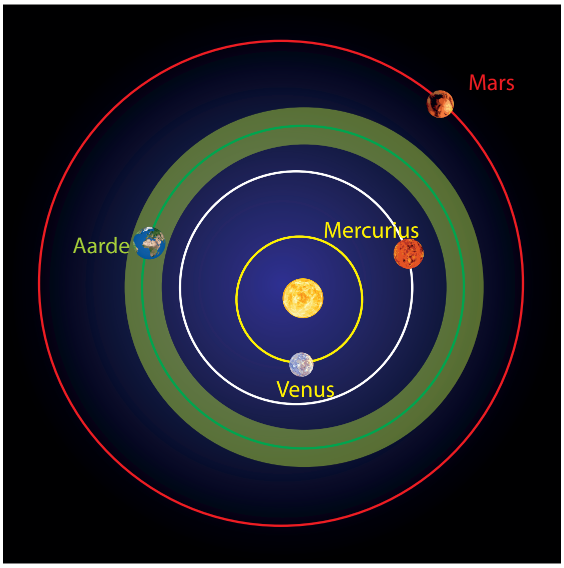
The average temperature on Earth is a moderate 15 °C. Because of this, water can exist in liquid form on Earth. *This is important because scientists think that liquid water is one of the key things needed for life.* Venus has an average temperature of 464 °C , so no liquid water exists on Venus because it is too hot.

On Mars, the opposite is true. The average temperature on Mars is – 63 °C and any water on Mars would be frozen. Earth is unique in our solar system as it is the only planet known to have liquid water on its surface and to harbour life.

If the Earth were too close to the Sun it would be too hot and all the water would evaporate from the oceans, as it has on Venus. If the Earth were too far from the Sun it would be too cold, and all the water would be frozen, like on Mars. Earth is at just the right distance from the Sun to have liquid water on its surface. The other planets in the solar system are either too close or too far from the Sun. The range of distances that a planet can lie from the Sun and still have liquid water on the planet's surface is called the **habitable zone**. Estimates for the habitable zone in our solar system range from 0,8 – 1,4 astronomical units (AU).

Take note

Other stars also have habitable zones. Scientists believe that planets orbiting other stars within the habitable zone could support life forms.



Our Sun's habitable zone (light green). The Earth is the only planet in our solar system which lies within our Sun's habitable zone. It is just the right distance from the Sun for liquid water to remain on the planet, something which scientists think is essential for life.

What other conditions do you think are necessary for life on Earth or other planets?

Scientists think that in order for life to arise and survive on a planet:

- There must be sunlight for plants to grow.
- The planet must be located in the habitable zone of a star so that there are moderate temperatures and liquid water.
- There must be oxygen for respiration.

Which of the planets in the solar system receive light from the Sun?

Which of the planets in the solar system have moderate temperatures and liquid water on their surface?

Which of the planets in the solar system have significant amounts of oxygen in their atmosphere or oceans?

As you can see, the Earth is very fortunate, because it lies at just the right distance from the Sun to have moderate temperatures and abundant liquid water. The Sun provides the energy for plants to grow. There is plenty of oxygen in Earth's present-day atmosphere and oceans, which means that life can survive on land and in the Earth's oceans. The Earth is unique in that it is the only planet we know of that has and supports life as we know it.

> **Take note**
>
> You may have heard a lot about global warming and the greenhouse effect in the news and in our studies in *Energy and Change*.

The greenhouse effect

During the day, the Sun shines through the atmosphere heating the Earth's surface. At night, the Earth's surface cools, releasing the heat back into space. Some of the heat is trapped by greenhouse gases in the air, such as carbon dioxide, which causes the Earth to remain warmer than it would have otherwise. This is called the **greenhouse effect**.

Scientists think that as a result of human activities, like cutting down forests and burning fossil fuels, the greenhouse effect is now too strong. Scientists are more than 90 % certain that the increase in greenhouse gases has caused the average temperature on Earth to rise. This is known as global warming. Venus provides us with a clue as to what might happen to the Earth if global warming continues. Venus's thick atmosphere has led to a runaway greenhouse effect on the planet, heating it to 462 °C. Venus's oceans have boiled away, leaving behind a hot, inhospitable planet. We should therefore try our best to look after our precious planet!

The beginnings of life

Scientists do not know how life began on Earth, but they estimate that the early ancestor of modern bacteria was alive on Earth 3.5 billion years ago. The early Earth's atmosphere had almost no oxygen. Instead, it was composed mainly of carbon dioxide, nitrogen and water vapour with some methane and ammonia.

Carbon dioxide and water vapour were pumped into the atmosphere during volcanic eruptions, which caused the atmosphere to change over time. Eventually the water vapour in the atmosphere condensed to form rain, forming the first oceans. Eventually living organisms (bacteria) appeared in

> **Did you know?**
>
> The moons Europa (orbiting Jupiter) and Titan (orbiting Saturn) are considered to be places where life may exist. Europa's surface is covered in smooth water ice and scientists think that there might be a water ocean beneath the icy surface. Titan has liquid lakes and seas on its surface, although they are not made of water, but rather liquid methane and ethane. Some scientists think that life may be able to survive in these lakes.

the oceans. These simple organisms used sunlight, water and carbon dioxide in the oceans to produce sugars and oxygen. What is this process called?

This is where the first oxygen in the ocean and atmosphere came from. That oxygen made it possible for other organisms to develop and flourish and is the reason that you are here today.

Figure 11.22 Scientists are busy exploring the possible locations for the origin of life, including hot springs and tidal pools. Recently, some scientists have started to support the hypothesis that life originated in deep sea hydrothermal vents, as shown in the image. These vents are like underwater volcanoes. The investigation continues to try to understand how life originated on Earth.

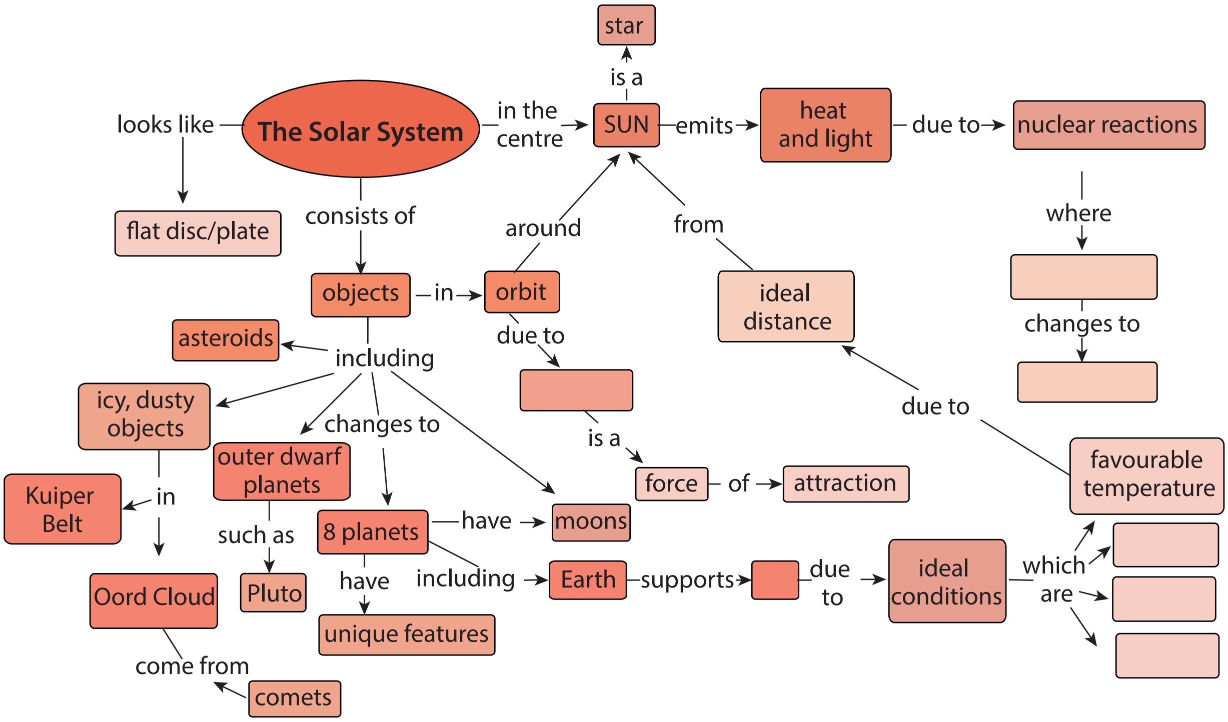
Summary

Key concepts

- The Sun produces its energy at its centre via nuclear fusion reactions, where hydrogen nuclei are squeezed together to form helium nuclei.
- The Sun's energy is transported to the surface and radiates equally in all directions.
- Our solar system consists of the Sun and all the objects that are held in orbit around the Sun by gravity.
- Objects such as planets, dwarf planets, asteroids, comets and Kuiper Belt objects orbit around the Sun.
- The 8 planets in our solar system have their own properties and characteristics.
- The planets can be split into two groups, the inner small rocky terrestrial planets and the outer large gas giants.
- The asteroid belt is the area where most asteroids are found in our solar system, lying between the orbits of Mars and Jupiter
- The Oort Cloud is a hypothetical huge cloud of icy objects (comets) surrounding the Sun at the very edge of our solar system.
- Sometimes, comets from the Oort Cloud come close to the sun. We can see them only when they come into the inner solar system because they are small and visible only by reflected sunlight.
- Scientists think that some of the conditions necessary for sustained life include moderate temperatures, liquid water, sunlight (energy) and oxygen.
- The Earth is the third planet from the Sun and the only planet in the solar system known to harbour life.
- The Earth lies within the Sun's habitable zone, the range of distances that a planet can lie from a star and still have liquid water on the planet's surface.

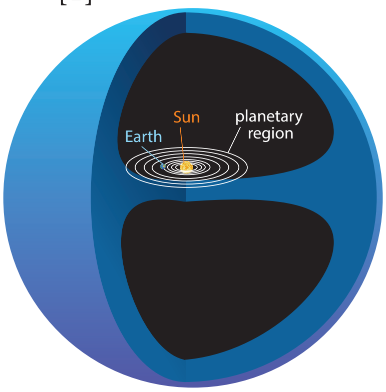
Concept map

Complete the concept map which summarises the key concepts from this unit about our solar system.



Revision

1. How does the Sun produce its energy? [2]
2. Why do sunspots look darker than the rest of the surface of the Sun? [2]
3. What keeps the planets and other bodies in our solar system in orbit? [1]
4. Name the terrestrial planets. [4]
5. Name the gas giants. [4]
6. Where is the asteroid Belt located? [1]
7. Where is the Kuiper Belt located? [1]
8. Why are the gas giants so much larger than the terrestrial planets? [2]
9. List the planets in increasing distance from the Sun. [4]
10. Which planets have rings? [4]
11. Why is Venus so hot? [2]
12. On which planet have landers found frozen water in the rocks under the planet's surface? [1]
13. The following diagram shows the solar system at the centre.
    - **a)** What does the blue space represent? [1]
    - **b)** What is mostly found in this space? [1]



14. Why can we see comets only as they come close to the Sun? [3]
15. What is the official definition of a planet, and why was Pluto downgraded to a dwarf planet? [4]
16. Why can the Earth support life? [4]
17. What would happen to the Earth if it warmed significantly, as Venus has in the past? [2]
18. The following diagram shows the system of planets around the star Gliese 667C.

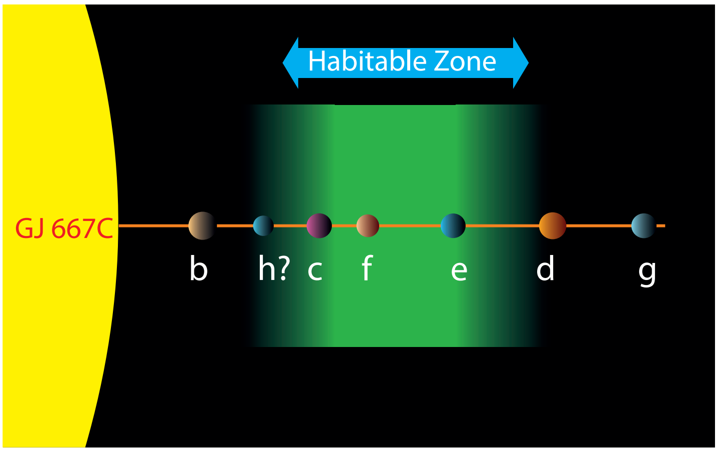


Figure 11.23 The planets around another star.

- **a)** Which of these planets are possible candidates for life? [1]
- **b)** Explain your answer above. [2]

Total [46 marks]

Did you know?

Average temperatures on Earth have increased by 0,8 °C around the world since 1880, with the biggest increase in the last few decades. The rate of warming is also increasing.

12 Beyond the solar system

Key questions

- How far is our second closest star, Proxima Centauri?
- What is a galaxy and how many different types of galaxy are there?
- Where is our Sun located within our own Milky Way Galaxy?
- How do galaxies arrange themselves on the largest scales in the Universe?
- How large is the observable Universe and how many galaxies does it contain?

Keywords

- galaxy
- galaxy disk
- galaxy bulge
- spiral arm

12.1 The Milky Way Galaxy

At the darkest places on Earth, far away from city lights, you can see thousands of stars at night using nothing but your eyes. In fact there are many more stars in the sky which are too faint for us to see.

All of the individual stars that you can see are members of our **Milky Way Galaxy**. A galaxy is a massive collection of stars, gas and dust all held together by gravity. The Milky Way has about 200 billion stars and our Sun is just one of those stars in the Milky Way Galaxy.

From the Earth, the Milky Way looks like a bright hazy band of light across the sky, mixed in with dark dusty patches. This was called *Galaxies Kuklos* by the Greeks, which means the *Milky Circle,* because they thought it looked like milk spilled across the sky. The Romans changed the name to *Via Lactea* which means the *Milky Road* or the *Milky Way.*

Figure 12.1 The Milky Way, stretching across the sky, viewed in Richtersveld in the Northern Cape Province.

If you could travel outside the Milky Way and look down on it from above, the galaxy would look like a giant spiral in space as shown in the image on the next page.

The image shows what scientists think our galaxy looks like. You can see the spiral arms of our Milky Way. These are bluish in colour and are filled with dust and gas and hot young stars. The thin, dark wisps in the image are dust lanes, regions where the gas is very dusty. The central part of the galaxy is more orange in colour than the spiral arms. This is because the stars found at the centre of the galaxy tend to be older and cooler than the young hot blue stars. Scientists think that there are five major spiral arms in our galaxy. These are the Norma Arm, the Scutum-Crux Arm, the Sagittarius Arm, the Perseus Arm and the Cygnus Arm.

Our Sun is located in a small spiral arm called the Orion (or Local) Arm which lies between the Sagittarius Arm and the Perseus Arm. Our Sun is about halfway out from the centre of the galaxy.

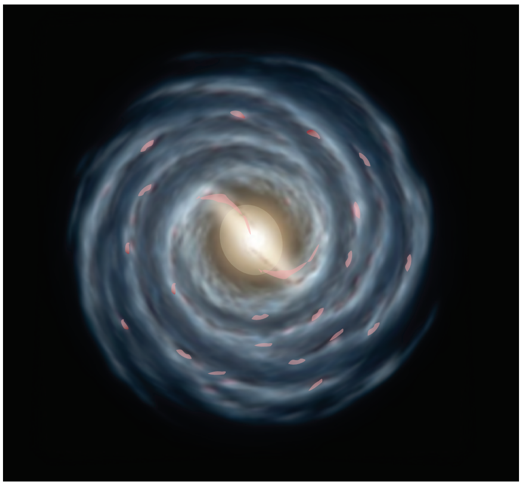


Figure 12.2 This is what the Milky Way would look like if you could see it from far away in space. Scientists know this only from many observations made from Earth. No one has actually been that far away from our galaxy to look at it. The structure is what we have inferred from other observations.

All the stars in this galaxy are revolving around the centre of the galaxy. Just as the Earth travels around the Sun, the Sun and our entire solar system is travelling around the centre of the Milky Way Galaxy at a speed of 250 km/s. Even though we are travelling incredibly fast, it takes the Sun about 225 million years to complete one orbit around the galaxy centre. The Milky Way is truly massive, measuring a staggering 950 000 000 000 000 000 km across!

If, instead of looking down on the Milky Way Galaxy, you looked at it from one side, you would see that the Galaxy looks like this:

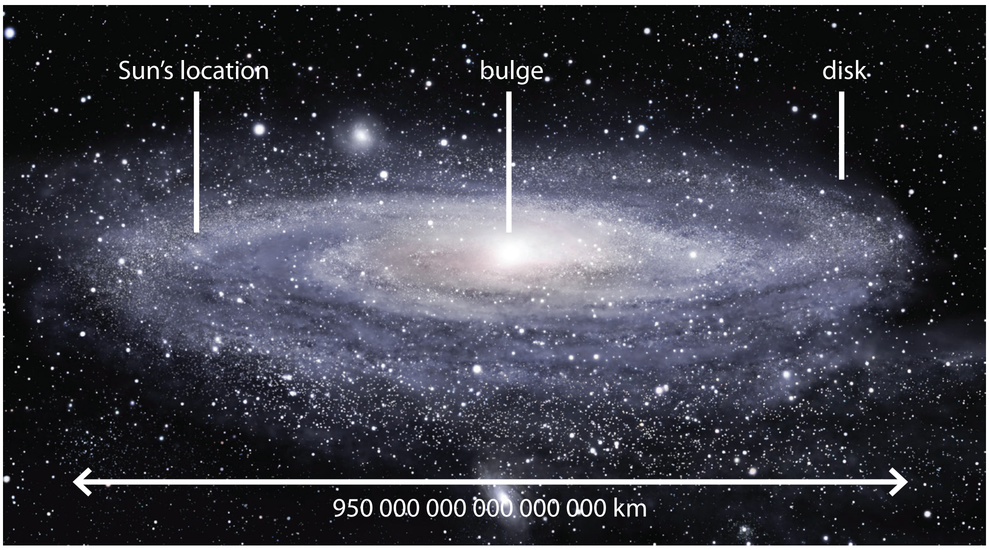


Figure 12.4 Looking at the Milky Way from the side.

The Milky Way is shaped like a giant fried egg. It is about a hundred times wider than it is thick, and it bulges in the middle. The central lump is called the **bulge** and the rest of the galaxy outside the bulge is called the **disk**.

As you know, we are inside the Milky Way Galaxy. So when you look at the thin milky-looking band stretching across the sky at night, what do you think you are actually looking at?

Did you know?

Our Solar System is orbiting around the centre of the Milky Way at thousands of kilometres per hour. But even at that speed, it still takes over 200 million years for us to make one complete orbit around the Milky Way Galaxy.

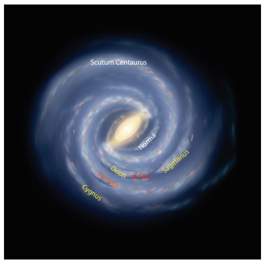


Figure 12.3 The Sun's position in the Milky Way.

Did you know?

If you could shrink the solar system so that the distance from the Sun to Pluto is 2,5 cm, the Milky Way would have a diameter of 2 000 km (about the distance from Durban to Windhoek!).

Did you know?

To us the Earth seems big, but the Earth is only a very small part of the Solar System. And our Solar System is a very small part of the Milky Way Galaxy. And our galaxy is only a very small part of the whole Universe.

The thin band of light that you see is actually the stars in the Sagittarius arm as you look inwards towards the centre of the galaxy. There are so many stars densely packed together that you cannot make out individual stars with your eyes. Therefore you just see a haze of light. Above and below the plane of the disk there are very few stars.

Figure 12.5 A globular cluster called M80. The stars in this globular cluster are around 12,5 billion years old. Our Sun is a mere 4,5 billion years old.

If you look closely at the image of the Milky Way above, you can see several round, fuzzy blobs dotted about above and below the disk. These are called **globular clusters** and are vast collections of hundreds of thousands of ancient stars tightly packed together by gravity. The Milky Way has an estimated 160 globular clusters. The oldest stars in the galaxy are found in these globular clusters. Some are almost as old as the Universe itself.

ACTIVITY: Draw the Milky Way

Materials

- black paper
- white crayon, pencil or paint
- glue – optional
- glitter or sand – optional
- newspaper for working on
- white or silver pencil/pen for labelling
- sticker – optional

Instructions

1. Draw or paint a picture of the Milky Way. You can use the picture in the text above as a guide. The galaxy has five major spiral arms, and some smaller ones including our Orion Arm. The galaxy also has a bulge in the middle.
2. If you are going to use glitter or sand, glue along your spiral arms and in the central bulge.
3. Scatter glitter or sand over the picture. Each grain represents a star in our Milky Way.
4. Tilt the picture onto the newspaper to remove any excess glitter.
5. Label each of the major arms of the Milky Way Galaxy.
6. On the Orion Arm place a sticker or mark a point halfway out from the galaxy centre. This marks the position of the Sun.

Beyond the solar system

How do you think astronomers know what the Milky Way looks like from the outside when they have never been outside the Milky Way? The task is similar to trying to figure out the shape of a forest from outside when you are in the middle of the forest. How would you go about this?

Astronomers look at the sky in all directions and count the number of stars that they see. They also measure the distance to each of the stars so that they can build up a three-dimensional map of the galaxy. One of the difficulties that astronomers have in doing this is seeing through all the dust in the galaxy which dims the optical light coming from the stars.

ACTIVITY: Make the Milky Way

Materials

- thick piece of black cardboard at least 30 cm across
- other materials for your model, either collected by you or supplied by your teacher

Instructions

1. You need to build a 3-dimensional (3-D) model of the Milky Way Galaxy. You will either need to collect the most appropriate materials for your model beforehand, or else your teacher will supply you with a selection of materials to use in class.
2. Cut out a circle of radius 15 cm from the black card and use this to build your 3-D model.
3. You must show the central bulge, the spiral arms and the different coloured stars.
4. Mark the position of our Sun on your model.
5. Using your model, view it from different angles and compare the view you have with the images of the Milky Way in this unit.

Questions

1. What are the two main parts that make up our Milky Way Galaxy?
2. Where are the spiral arms located, in the disk or the bulge of our galaxy?
3. Is our Sun found in the central bulge or in a spiral arm in the disk?
4. How far from the centre of the galaxy is our Sun located?

Take note

We will learn more about the life cycle of stars in Grade 9. Younger stars are hotter and bright white or blue in colour, while older stars are cooler and more yellow and red in colour.

12.2 Our nearest star

The Sun is our closest star, and is *only* 150 million kilometres from Earth. When you look up at the sky at night, if you are lucky enough to be far from the glare of city lights, you can see thousands of stars. For those of you in a city, perhaps you can see hundreds of stars, depending on the amount of light pollution from street lights and other light sources. As you know, there are actually billions of stars in our galaxy but most of them are too faint to see from Earth.

Keywords
- Proxima Centauri
- Alpha Centauri
- constellation

A **constellation** is a group of stars that, when viewed from Earth, form a pattern in the sky. One famous **constellation** that is visible, even from big cities in South Africa, is the Southern Cross or Crux. The two bright stars at the bottom left pointing towards the cross are called the pointers.

Did you know?

You can find south using the Southern Cross Constellation. Just extend the long axis of the cross 4 times and then go straight down to the horizon to find south.

The brightest of the Pointers looks slightly orange if you look closely. This star is called **Alpha Centauri** and is our closest easily visible star after the Sun. Alpha Centauri is actually part of a triple star system which is where three stars are in orbit around each other. The two main stars of the system are called Alpha Centauri A and Alpha Centauri B. They orbit close together, on average about eleven times the Earth–Sun distance from each other.

Figure 12.6 The Pointers (circled) and the Southern Cross.

A smaller, fainter star, called **Proxima Centauri**, orbits much farther out. If you were to look at Alpha Centauri through a small telescope, instead of one star you would be able to make out the two separate stars Alpha Centauri A and B next to each other. Proxima Centauri is much fainter and further away from the other two so you would not see this one with the other two.

Did you know?

Proxima Centauri was discovered in 1915 by the Scottish astronomer Robert Innes. He was the director of what was then the Union Observatory in South Africa.

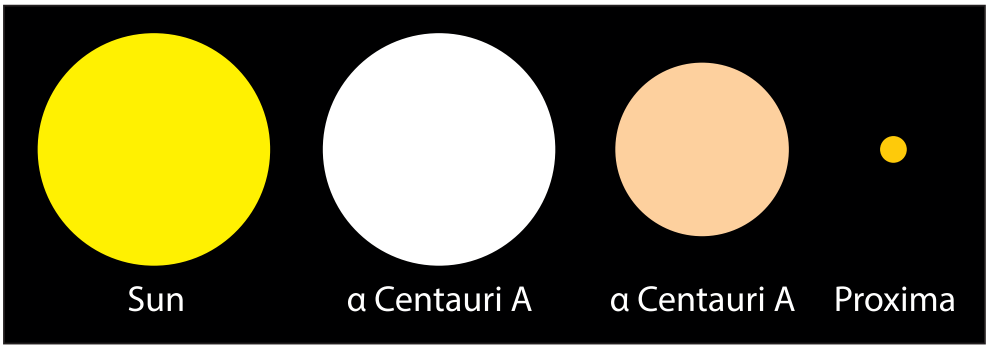


Figure 12.7 A comparison of the sizes of the Alpha Centauri star system and the Sun.

Proxima Centauri, the closest star to our own Sun, is about 40 trillion km away from the Earth. Alpha Centauri A and B are slightly farther away, at 42 trillion km away from us. Our closest star is 694 times farther away than Pluto is. These numbers are astronomically large! As the numbers are so large, astronomers do not use kilometres to measure the distances to stars, but use larger units based on the speed of light, which you will discover in the next section of this unit.

Did you know?

Astronomers have recently discovered a planet similar in size to the Earth orbiting around Alpha Centauri B, but we think it is too close to the star to have life on it.

Do you know how much a trillion or a billion is?
Have a look at the following table:

In words	In number format
One thousand	1 000
One million	1 000 000
One billion	1 000 000 000
One trillion	1 000 000 000

12.3 Light years, light hours and light minutes

Keywords

- light minute
- light hour
- light year

Our solar system is a pretty big place. Our nearest neighbour, the Moon, is on average 384 400 kilometres away, and the closest to us that our nearest planet Venus gets is about 42 million kilometres. The Sun is about 150 million kilometres away and the closest that Pluto can ever get to us is 4,3 billion kilometres. These large numbers are impractical to use and so we rather use much larger distance units based on the speed of light. This makes the numbers smaller and easier to deal with. This is just like using metres instead of centimetres to make the numbers smaller when you measure a distance. For example, if you are telling a friend how far it is from your house to school, you would say it is 7,5 km, and not 7 500 000 cm. Let's begin by comparing the speed of light with the speed of some other things that move very fast.

ACTIVITY: Travelling fast

Figure 12.16 A Peregrine Falcon, the fastest animal, can fly as fast as 389 km/h.

Figure 12.17 A cheetah, the fastest land mammal, can reach speeds of 120 km/h, as fast as cars on the highway.

Figure 12.18 NASA's scramjet, the X-43 flies at 7 000 km/h.

Figure 12.19 Japan's high speed train, JR-Maglev MLX01, has reached 581 km/h.

Figure 12.20 The international space station (ISS) orbits the Earth at a speed of 27 744 km/h.

What about light? Light travels at about 1 080 million km/h, or 299 792 458 m/s.

Instructions

1. Imagine you are going on a trip from Cape Town to Durban, which is a distance of 1 753 km.
2. Calculate how long it would take you to complete the trip travelling at the speeds of the animals and modes of transport in the examples above.
3. Copy the table below in your exercise books and fill in the answers.

Remember the formula: time = $\frac{\text{distance}}{\text{speed}}$

Mode of transport	Speed (km/h)	Distance between Cape Town and Durban (km)	Time taken for the journey
Cheetah	120	1 753	14,6 hours
Peregrine Falcon		1 753	________ hours
High speed train		1 753	________ hours
NASA's scramjet		1 753	________ minutes
International space station		1 753	________ seconds
Light		1 753	________ seconds

Light is amazingly fast. Look at the examples below.

In one second light can travel…	Light takes…
between Cape Town and Johannesburg 214 times.	0,0000003 seconds to travel 100 m.
between Cape Town and London, England, 31 times.	1,3 seconds to travel from the Earth to the Moon.
around the Earth 7,5 times.	8 minutes to travel from the Sun to the Earth.

For distances within the solar system, astronomers use units called **light hours** and **light minutes**.

A light hour is the **distance** that light travels in one hour. Despite its name, a light hour is not a unit of time, it is a **unit of distance**.

What do you think a light minute corresponds to?

Which do you think is a smaller distance, a light hour or a light minute, and why?

Astronomers use units called **light years** to measure the distances between stars and galaxies. One light year is almost 10 trillion kilometres. As you can see, a light year is very, very far.

Light years, light hours and light minutes measure distances. They also tell us something else very interesting. If you measure the distance to a light source in light travel time, you can work out how long light emitted from the distant source takes to reach you. Light that is emitted from an object one light year away from you, takes one year to reach your eyes. Similarly, light that is emitted from an object one light hour away, takes one hour to reach your eyes.

How long do you think light emitted from one light minute away takes to reach your eyes?

This may sound very strange to you because when you switch on a lamp in your home you see the light straight away. You do not have to wait for the light from the lamp to reach you. You do not notice that it actually takes some time for the light from the lamp to reach your eyes because light travels extremely fast.

Light travels so fast, that if you were standing a metre away from the lamp it would only take only three billionths of a second for the light from the lamp to reach your eyes. It is therefore no surprise that you don't notice the delay.

ACTIVITY: Scale of the solar system

Instructions

1. The table below shows the distance that each planet lies from the Sun in kilometres (km) and then in light hours or light minutes.
2. Study the table and answer the questions that follow.

Distances of each planet from the Sun.

Planet	Distance from the Sun (million km)	Distance from the Sun in light hours or minutes
Mercury	57,9	3,2 light minutes
Venus	108,2	6,0 light minutes
Earth	149,6	8,3 light minutes
Mars	227,9	12,7 light minutes
Jupiter	778,6	43,3 light minutes
Saturn	1 433,5	1,3 light hours
Uranus	2 872,5	2,7 light hours
Neptune	4 495,1	4,2 light hours

Questions

1. How far away from the Sun is Earth?
2. How long does light take to travel from the Sun to the Earth?
3. What does the answer to (2) imply about our view of the Sun?
4. How many times further away from the Sun than the Earth is Neptune?
5. How far away from the Sun is Neptune in light hours?
6. How long does light from the Sun take to reach Neptune?
7. Imagine you have a cousin living on Neptune. You and your cousin both decide to look at the Sun, each of you using a telescope with a special solar filter so as not to damage your eyes. As you are watching the Sun you suddenly notice a big blob of gas thrown off in a massive solar flare. Your cousin says she cannot see it. Why is that?

Did you know?

The speed of light is special. Nothing can move faster than the speed of light; it is like a cosmic speed limit.

As you can see, the solar system is very large. The orbit of Neptune is over 4 light hours from the Sun, and the Kuiper Belt and Oort Cloud extend even further out than this. The distance to the next closest star, Proxima Centauri, is 40 trillion km. This corresponds to 4.24 light years. This means that light from the star takes just over four years to reach Earth. Let's investigate the distances to some of our closest stars.

ACTIVITY: Our closest stars

Take note

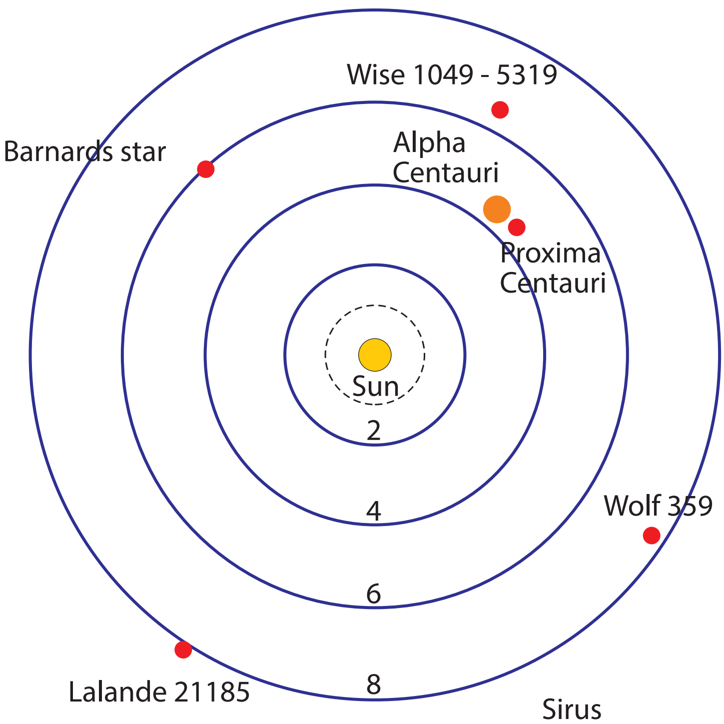
The star map is shown in two dimensions, on a flat plane. Remember that the stars are located in three dimensions in space.

Instructions

1. Look at the table showing our closest stars and the star map.
2. Answer the questions below.

Star	Distance (light years)
Proxima Centauri	4,24
Alpha Centauri	4,37
Barnard's Star	5,96
WISE 1049-5319	6,52
Wolf 359	7,78
Lalande 21185	8,29
Sirius	8,58

The following map shows the Sun in the centre with the locations of our closest stars. Each solid ring represents a distance of 2, 4, 6 and 8 light years from the Sun respectively. The dotted circle represents the Oort Cloud.



Questions

1. Which star is our closest neighbour, excluding the Sun?
2. How far is Sirius?
3. How long does light from Barnard's Star take to reach us?
4. Explain in your own words what the statement 'Sirius is 8.58 light years away from Earth' means.

Our closest stars are less than ten light years away. However most stars in our galaxy are much farther away. The distances to stars are generally measured in tens, hundreds or even thousands of light years, and the distances between galaxies are truly enormous, as you will discover in the next section.

12.4 What is beyond the Milky Way Galaxy?

Our galaxy, the Milky Way, is only one out of a total of about 100 to 200 billion galaxies that astronomers estimate to be in the **Universe**. That's more than 10 times the total number of people on Earth.

Figure 12.8 Our closest neighbouring galaxy, Andromeda. Light from the galaxy takes 2,5 million years to reach Earth and so the light that hits your eyes now from that galaxy was emitted before there were humans on Earth.

As well as stars, galaxies contain vast amounts of gas and dust. Galaxies come in a variety of shapes and sizes. The Milky Way is an average-sized spiral galaxy: it is 100 000 light years across and contains around 200 billion stars.

Small galaxies may contain only a few million stars, while large galaxies can have several trillion stars.

Our closest galaxy neighbour is called the Andromeda Galaxy. Andromeda is 2,5 *million* light years away from the Milky Way. If you wanted to travel to Andromeda and could travel as fast as light, it would still take you 2,5 million years to get there.

Figure 12.9 This illustration shows a stage in the predicted collision between our Milky Way Galaxy and the neighbouring Andromeda Galaxy, as it will unfold over the next several billion years. This image shows how we think Earth's night sky will look like in 3,75 billion years' time.

There are five main types of galaxies. You do not need to know these names.

Did you know?

The Milky Way is so large that light takes 100 000 years to cross from one side to the other side.

Keywords

- galaxy group
- galaxy cluster
- filament
- void
- Universe

Take note

The distances between galaxies are even larger than the sizes of galaxies and are measured in millions or even billions of light years.

Did you know?

The Milky Way and Andromeda galaxies are on a collision course. Astronomers estimate that the two galaxies will collide in around 4 billion year's time. No need to worry just yet!

This is included for your interest. The five types of galaxies are:

- spiral
- barred spiral
- elliptical
- lenticular
- irregular

Figure 12.10 Spiral galaxy, named NGC 4414.

Figure 12.11 Barred spiral galaxy, named NGC 1300.

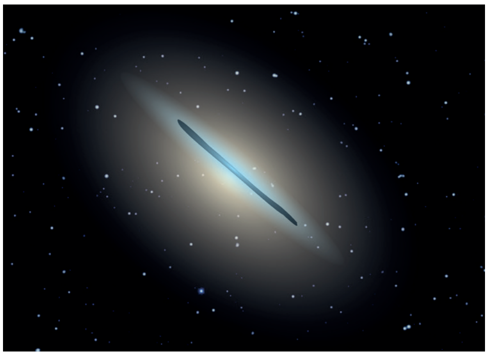


Figure 12.12 Elliptical galaxy, named NGC 1132.

Figure 12.13 A lenticular galaxy, named NGC 5866.

Let's do an activity to explore the different types of galaxies we see.

Figure 12.14 Irregular galaxy, named NGC 1427A.

ACTIVITY: Comparing galaxies

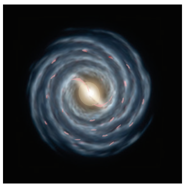
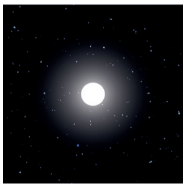
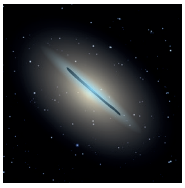
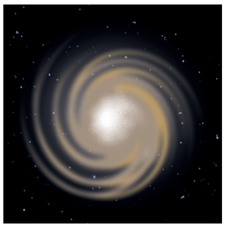
Materials

- images of the galaxies to be compared

Instructions

1. Look at the images of the of six galaxies used in this activity.
2. Using the information in this unit, write down in the table what type of galaxy our Milky Way Galaxy is.

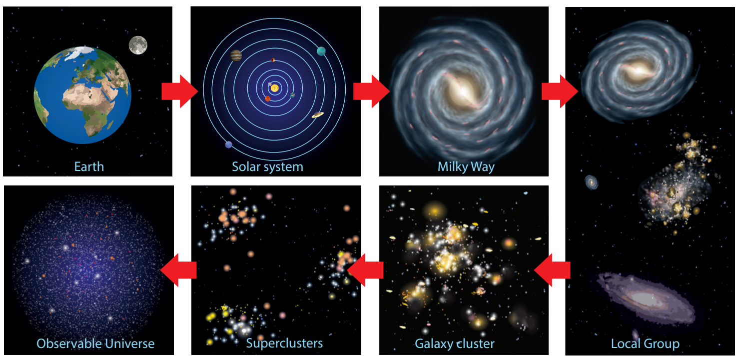
3. Copy the table below in your exercise books and write down what type of galaxy (spiral, barred spiral, elliptical or irregular) you think each galaxy is.

Galaxy Name	Galaxy type	Galaxy Name	Galaxy type
 The Milky Way Galaxy.		 The Large Magellanic Cloud galaxy. This satellite galaxy of our own Milky Way is only 163 000 light years away.	
 Galaxy M 89. The galaxy is 60 million light years away.		 The Spindle Galaxy, 44 million light years away.	
 Galaxy NGC 4622. The galaxy is 111 million light years away.			

Question

List the galaxies in the table above in increasing order of distance from our Milky Way Galaxy.

Have a look at the following diagram which shows the location of Earth in the Universe. **You do not need to know this classification**; this is included for your interest.



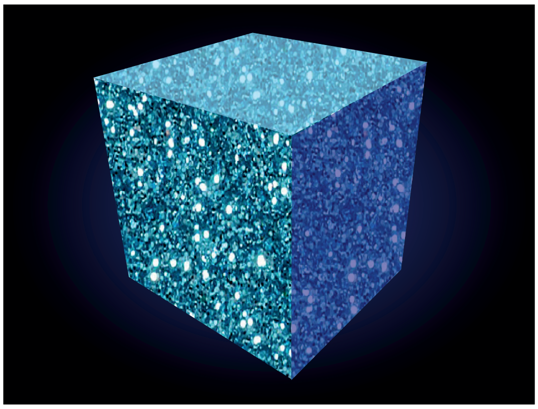
- Most galaxies are found gathered together in gigantic galaxy neighbourhoods, called **galaxy groups**. Our Milky Way is found in a group of galaxies called the **Local Group**.
- **Galaxy clusters** are even larger, spanning tens of millions of light years, and can contain hundreds or even thousands of galaxies.
- Many clusters of galaxies come together to form **superclusters** of galaxies. Our own local group is part of the Virgo supercluster.
- Gravity holds the galaxies in groups, clusters and superclusters together.

Did you know?

The Hubble Extreme Deep Field is the most distant picture of the Universe ever taken. Astronomers used the Hubble Telescope to take an image of a small patch of sky. Around 5 500 galaxies of all shapes, sizes and colours were discovered in the image.

Figure 12.15 Galaxies in the Hubble Extreme Deep Field. Every smudge in the image is a distant galaxy.

The observable Universe



This computer-generated graphic represents a slice of the sponge-like structure of the Universe. All the galaxies lie along thin walls called filaments. The darker areas show the voids where there are no galaxies.

Astronomers estimate that the age of the Universe is 13,7 billion years old. This might make you imagine that you can see objects from as far as 13,7 billion light years away in all directions. If you were to draw a sphere around the Earth, with a radius of 13,7 billion light years, with the Earth placed at the centre, the surface of the sphere would represent the limit of how far light could travel to Earth in 13,7 billion years. The surface would represent the edge of the observable Universe as seen from Earth. You may therefore assume that the diameter of the **observable Universe** is 27,4 billion light years (2 times 13,7).

However, you would actually be wrong. Astronomers estimate the size of the observable Universe to be 93 billion light years in diameter, which is much, much larger. The reason that the size is much larger than expected is because the Universe is expanding and galaxies are moving further and further away from the Earth as the space between them expands. So we are able to see galaxies that are now very far away because when they emitted their light they were closer to Earth. The size of the whole Universe, which includes regions too far from Earth for us to see at this time, is unknown.

Did you know?

On the largest scales the Universe resembles a giant bath sponge. The galaxy clusters are arranged in thin walls called filaments. Between the filaments are huge gaps which contain very few galaxies and so are called voids.

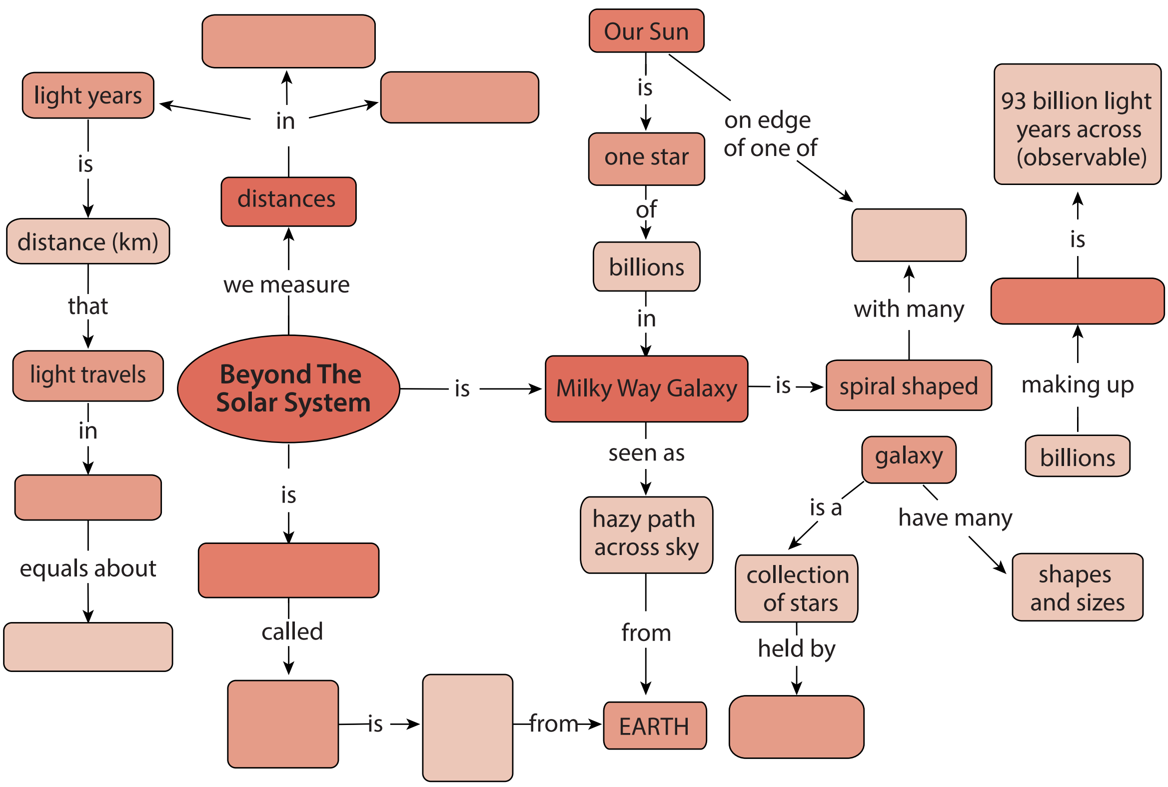
Summary

Key concepts

- A galaxy is a collection of millions or billions of stars, together with gas and dust, held together by gravity.
- Galaxies come in all shapes and sizes.
- Our home galaxy, the Milky Way Galaxy, is a spiral galaxy containing around 200 billion stars. Our Sun is just one of those stars.
- After the Sun, our nearest star is Alpha Centauri, the brighter of the two pointer stars in the Southern Cross Constellation
- Light minutes, light hours and light years are used to measure distances in space because the distances are so immense.
  - A light minute is the distance that light can travel in one minute.
  - A light hour is the distance that light can travel in one hour.
  - A light year is the distance that light can travel in one year.
- Beyond the Milky Way Galaxy are many more galaxies.
- Astronomers estimate the size of the observable Universe to be 93 billion light years in diameter.

Concept map

Remember that you can also add your own notes to the concept maps to expand and personalise them.



Revision

1. What is the name of our second closest star? How far away is it? [2]
2. What is the name of our second closest easily visible star? Is it really a single star? [2]
3. What is the definition of a light year? [2]
4. What is a galaxy? [3]
5. Where is the Sun located within the Milky Way? [2]
6. How many stars are in our Milky Way Galaxy? [1]
7. Name the 4 main types of galaxies. [4]
8. What kind of galaxy is the Milky Way? [2]
9. Draw an image of the Milky Way Galaxy as viewed from the top and as viewed from the side. Note the position of the Sun in both images. Include the labels: spiral arm, bulge, disk. [8]
10. Why does it look as though the Milky Way is a splash of milk or a starry road across the sky? [2]
11. What is a group of galaxies? [2]
12. What is the name of the group of galaxies that the Milky Way is a member of? [1]
13. What are clusters of galaxies and superclusters of galaxies? [2]
14. What is the size of the observable Universe? [1]
15. **Extension question:** On the largest scales, what does the Universe look like? Name the two types of structure which make up the Universe on the largest scales. [2]

Total [34 marks]

Total with extension [36 marks]

13 Looking into space

Key questions

- How did early cultures observe and interpret the night sky?
- How does a telescope help us to see more objects in the sky and in greater detail?
- What kind of telescopes are there?
- Why is South Africa a good place for locating telescopes?

Keywords

- constellation
- starlore

13.1 Early viewing of space

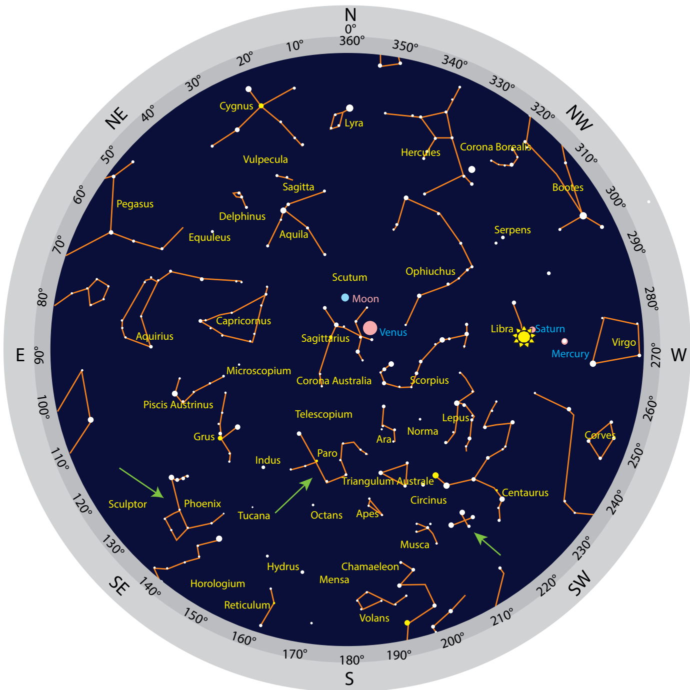
In dark conditions away from city lights, thousands of stars are visible in the night sky. Early cultures around the world gazed at the stars in wonder. They noted the movement of the stars and planets across the sky and used this to mark the passage of time. People often grouped the stars they saw into patterns called **constellations**. Early cultures tended to associate the stars and planets they saw in the night sky with animals or gods and told stories, which were passed on from generation to generation, about the patterns in the sky which were passed down from generation to generation.

The stars that are visible depend upon your location on Earth and also the time of year. The southern sky, which we see from South Africa, is full of beautiful stars and several prominent constellations are visible in the sky including the Southern Cross or Crux, Orion, and Pavo the Peacock. In the following activities you will have the opportunity to observe the night sky and familiarise yourself with some of the most famous southern constellations.

ACTIVITY: Using star maps to observe the night sky

Materials

- star map
- clear skies
- pencil
- paper or this workbook
- torch – optional



This is an example star map of the Southern Hemisphere. Ignore the positions of the Moon and the planets. You can generate your own, customised star map for your exact location using the link in the **Visit** margin box.

Instructions

1. Go outside at night with your star map.
2. Wait a few minutes to let your eyes adjust to the dark.
3. Try to identify the following constellations in the sky: Pavo, Phoenix and Crux (indicated with green arrows on the star map).
4. Draw a picture of each of the constellations as you see them.
5. See if you can spot any of the planets. These will not twinkle like the stars do.

ACTIVITY: Observing the Southern Cross (Crux)

Materials

- picture of the Southern Cross constellation and star map
- clear skies
- pencil
- paper or this workbook

Instructions

1. Go outside around 8 pm with your star map (if in the Western half of the country, closer to Cape Town), or if you live in the Eastern half of the country (closer to Johannesburg or Durban), go out an hour earlier around 7 pm.
2. Wait a few minutes to let your eyes adjust to the dark.
3. Try to identify the Southern Cross constellation using the star map.

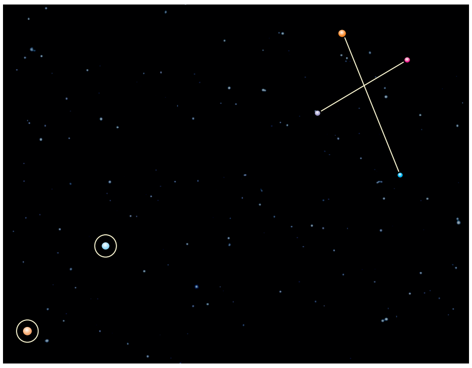


Figure 13.1 The Southern Cross or Crux (top right) and the Pointers (bottom left).

4. Draw a picture of the Southern Cross and the Pointers as you see them. Make a note of the date and time of your picture and in roughly which direction you are facing (north, south, east or west).
5. Repeat the observations at least twice so that you have a minimum of three observations on different nights, over the course of a few weeks, and try as best as possible to make your observations at the same time each night.

Did you know?

Early telescopes were used by merchants to spot approaching trade ships or pirates. Telescopes also gave rise to the first high-speed telecommunications networks, as spyglasses were used to observe signals from kilometres away.

Did you know?

Today professional astronomers formally recognise 88 constellations, 23 of which are in the southern hemisphere.

Did you know?

These workbooks were created by Siyavula with the help of contributors and volunteers. Read more about Siyavula here. www.siyavula.com

Did you know?

Some people believe that the builders of the ancient pyramids of Giza in Egypt placed them specifically to look the same from above as the three 'belt stars' of the constellation Orion look from Earth.

Question

What did you notice about the orientation of the Southern Cross as you made your observations?

Although the stars appear to lie in patterns when viewed from the surface of the Earth, in reality the stars within a constellation are unrelated, and they can lie at vastly different distances from Earth. When we look at the stars at night, we only see a two dimensional projection on the sky of three dimensional space, as you can see in this photograph showing the constellation, Orion.

Figure 13.2 The Orion Constellation, seen here as the three bright stars in the middle making up Orion's belt and the 4 stars in each corner.

You might imagine that all the stars lie at the same distance from Earth. This isn't true, the stars lie at different distances. The closest star in Orion is called Bellatrix and is around 250 light years away. The furthest star, Meissa, is around 1 100 light years away, roughly the same distance as the Orion nebula (1 300 light years). But, when viewed from Earth, we see them making up a pattern in relation to each other.

Now that you are familiar with some of the constellations in the Southern sky, including the Southern Cross, you can learn what some of the early cultures in Southern Africa thought about them.

As you can imagine there are many stories associated with the constellations in the sky. In the following activity you will carry out research to find an example story to tell to your class.

ACTIVITY: Constellation starlore

The /Xam Bushman imaged that the two pointer stars of the Southern Cross were two male lions who had once been men before they were thrown by a magical girl up into the sky to be stars. The three brightest stars in the Southern Cross were seen as female lions, perhaps women also changed into stars by the magical girl.

The Khoikhoi thought that the Pointers were the eyes of some great beast and they were called *Mura*, which means *the eyes*.

In Sotho, Tswana and Venda cultures, these stars are called *Dithutlwa*, which means *the Giraffes*. The bright stars of the Southern Cross are male giraffes, and the two Pointer stars are female giraffes. The Venda named the fainter stars of the Southern Cross *Thudana*, which means *the Little Giraffe*. The Sotho used these stars to indicate the beginning of the cultivating season, which began when the giraffe stars were seen close to the south-western horizon just after sunset.

Instructions

1. Search for a story about a constellation found in the South African sky.
2. Use a South African star map as a guide to the constellations found in South Africa.
3. Research information on the origin of the story and any beliefs associated with it.
4. Tell your classmates about the constellation and story you have found out about.
5. Your teacher will decide on the format of this presentation which may be a poster or oral presentation.

In their quest to find out more about planets, stars and galaxies, people invented instruments to observe them in more detail. In the next section we will learn about the telescope: an invention used to study the stars.

13.2 Telescopes

Unfortunately, we cannot visit distant stars or galaxies to study them directly as they are so far away. Instead, astronomers study stars and galaxies by analysing the visible light, radio waves and electromagnetic radiation that they receive from them.

Keywords

- celestial
- telescope
- chromatic aberration
- primary mirror

Figure 13.3 The Andromeda galaxy, viewed with the Hubble Space Telescope. Humans can see it only as a tiny, faint smudge in the sky with the naked eye.

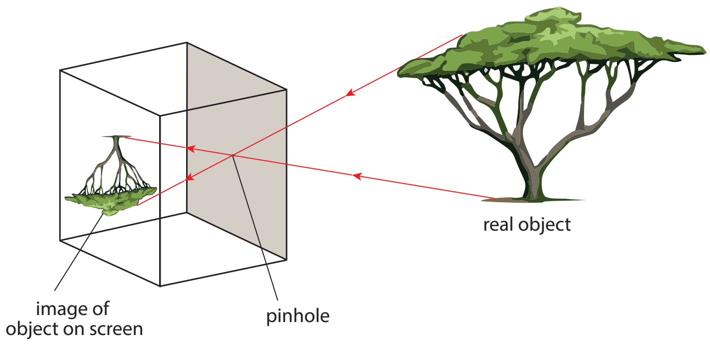
Human eyes can see very far. Andromeda Galaxy, which is 2,5 million light-years away, is visible to the naked eye. However, we cannot make out any detail, as it appears as only a tiny smudge on the sky to our eyes, even though in reality it is 220 000 light years across.

Light is emitted from stars and galaxies and travels in a straight line in all directions. When you look at a star, you only see the light rays that hit your eye. In Energy and Change, we learnt about visible light. How is the energy of light transferred through space?

Take note

Luminous objects, such as the Sun and other stars, emit light. The tree is NOT a luminous object as it does not emit its own light. It reflects the light from the Sun.

The further away a star is, the more the starlight is spread out and so less of the total light from the star reaches your eye. This makes distant objects faint and difficult to see clearly. If we had huge eyes we would be able to see distant objects more clearly because our eyes would gather more of their light.



Do you remember making a pinhole camera in Energy and Change? Have a look at the following diagram which illustrates this again.

Which way is the image projected onto the screen?

This is the same way in which images are formed on your retina when you view an object, as shown in the following image.

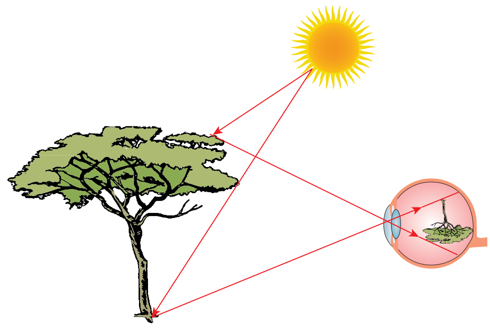


Figure 13.4 Images formed on the light-detecting retina at the back of your eye are upside down.

An object that is far away projects a small image of the object onto the retina at the back of your eye making it difficult to see fine details in the image.

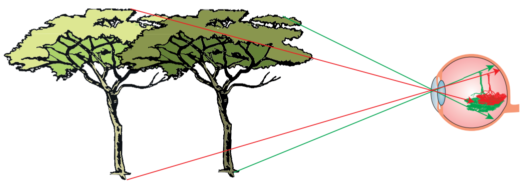


Figure 13.5 More distant objects appear smaller on our retina.

Telescopes help us see faint, distant objects more clearly because they collect more light from the objects than our eyes do. They also magnify the image.

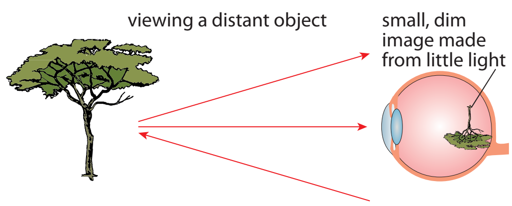


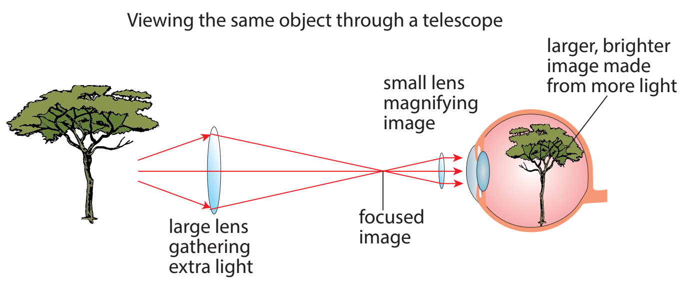
Figure 13.6 More distant objects appear smaller on our retina.

As revision of what we learned in Energy and Change last term, answer the following questions.

What type of lens is shown in the above image?

What happens to the light when it passes through the lens?

Let's take a closer look at how a telescope works.



Did you know?

Images formed on your retina are actually upside down. Your brain 'corrects' the image, so that you do not notice

ACTIVITY: Telescopes as light buckets

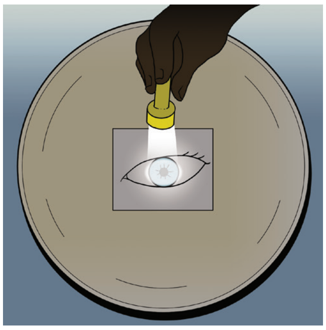
There is only so much light emitted from an object each second. Little packets of light are called **photons**. Our eye needs at least 500 photons, or packets of light, coming into it every second for our brains to sense that something is there. In this activity you are going to represent photons from a distant galaxy using pepper grains or hundreds and thousands.

Materials

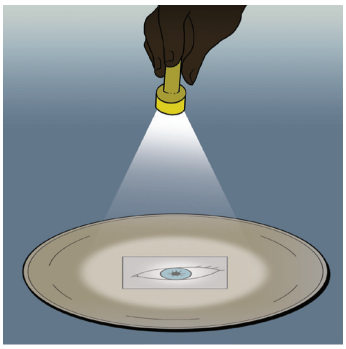
- paper plate
- piece of paper 3 cm by 3 cm
- pencil or pen
- torch
- pepper grains or hundreds and thousands
- wooden skewers
- foam (bath sponge will do, ideally as wide as the paper plate in one direction)
- tape – optional
- scissors

Instructions

1. On the piece of paper draw an image of your eye, including the pupil and iris.
2. Tape or place the image of your eye onto the middle of a paper plate. The paper plate represents a telescope mirror or lens.



3. Take the foam and cut it into a thin strip about 3 cm wide and as long as the paper plate across.
4. Stick six skewers into the foam equally spaced along the strip. Trim the pointed edges out that are sticking out of for safety. You will use this foam strip later in this activity.
5. Shine a torch light just above the picture of the eye on the plate. When an object is closer, more light reaches your eye.
6. Slowly move the torch further away from the plate and watch how the light spreads out and dims.



7. Note how much of the torch light the eye's pupil receives compared to the paper plate.
8. Now remove the torch and get ready to use the pepper grains or hundreds and thousands. These will represent *photons* or *packets of light*.
   The further away an object, the less light reaches your eye.

9. Sprinkle these photons for one second over the plate.
10. Note roughly how many photons get into the eye compared with how many hit the paper plate representing the telescope mirror or lens.
11. Now place the foam across the centre of the paper plate. The skewers should be pointing straight up. This represents a strip of the telescope mirror with the skewers representing light rays from distant objects.
12. The telescope mirror is actually curved. Bend the foam upwards at either end so that the skewers begin to come together in the middle.
    The skewers represent the light rays hitting the mirror of the telescope.
13. Turn the foam over and direct the skewers into the picture of the eye.
    The light rays from a large strip of the mirror are now entering the small pupil of the eye.

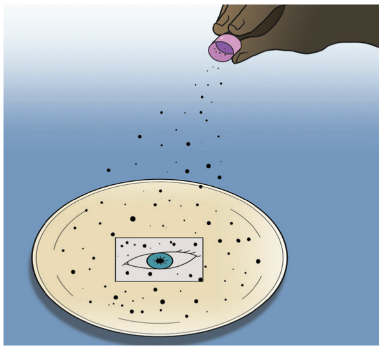


Figure 13.7 Sprinkle the pepper grains or hundreds of thousands.

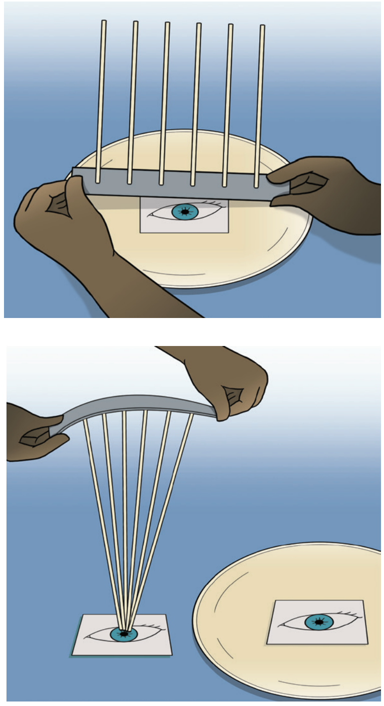


Figure 13.8 Now you can see how a telescope's mirror can collect lots of light and direct it into a small detector, like your eye.

Questions

1. Which collects more of the torch light as the torch moves further away: the eye's pupil or the paper plate?
2. Did the eye collect enough photons in one second to detect the light?
3. Did the telescope mirror (paper plate) collect enough photons for the eye to detect the light?
4. How do you think all the light that hits the telescope mirror is concentrated so that it can enter our eyes or a small telescope detector?

Telescopes have big lenses or mirrors to collect as much light as possible. This is how they are able to see faint objects. Telescopes also concentrate or focus the light and redirect it into our small eye so that we can see the dim object. Alternatively, telescopes can redirect the light into special detectors that record images, similar to a cell phone camera.

ACTIVITY: Compare your eye with SALT

The Southern African Large Telescope (SALT) takes pictures of some of the most distant and faintest objects in the Universe. SALT's camera takes images with exposure times typically of twenty minutes, after which the camera shutter closes and the resulting image is displayed on a computer. The longer the exposure, the more light the telescope can gather to make the image. The human eye does not have a shutter. We seem to see continuously, rather than as a succession of still images. However, the eye does have a kind of exposure time. In this activity you will estimate the exposure time of your eye by estimating your reaction time and then compare it with SALT's typical exposure time.

Materials

- ruler
- calculator
- pencil or pen

Instructions

1. Work in pairs for this activity.
2. Look at your partner's eyes. Estimate the diameter of their pupils using a ruler held close to their eye. Be careful not to actually touch your partner's eyes.
3. Write down the diameter of pupil in the table below.
4. Compare the diameter of the pupil with that of the Southern African Large Telescope (SALT) which is roughly 10 m in diameter.
5. Calculate how many times larger than an eye SALT is. (Remember to compare the areas rather than the diameters.)
6. One of the pair: hold a pen or pencil directly in front of you, while the other person stands opposite you and prepares to catch it.
7. Drop the pen or pencil and see if your partner can catch it.
8. Estimate the reaction time of your partner. Is it a second? Is it a tenth of a second? Is it a thousandth of a second?
9. Repeat steps 6 – 8, swapping places.
10. Copy the table into your exercise books and fill in your reaction times. These represent the exposure time of your eye.
11. Complete the questions.

Copy the table in your exercise books to record your results:

	Eye	SALT	SALT / Eye
Diameter of collecting lens/ mirror	________ cm	________ cm	
Area of collecting lens/mirror	________ cm^2	________ cm^2	
Exposure time	________ seconds	________ seconds	

Hint: Convert the diameter of SALT to cm. Convert the exposure time of SALT to seconds. To simplify the calculation of the area of the SALT mirror, assume it is a circle with a radius of 5 m. The area of a circle is given by the formula $A = \pi r^2$.

Questions

1. Why should you compare the area of the telescope and eye's pupil rather than their diameters?
2. How many times more light does the SALT telescope collect compared with your eye?
3. What would happen to your reaction time if your eye had to accumulate light over a longer interval before sending an image to the brain?
4. How many times longer can SALT expose for than your eye?

Telescopes can collect more light from faint and distant objects because they have larger collecting areas *and* because they can accumulate light over longer periods of time to make an image. This means that you can see fainter objects with telescopes that you would be able to see using just your eye. Telescopes also **magnify** (enlarge) the image that you see, so it takes up more room on your retina, allowing you to see the object more clearly.

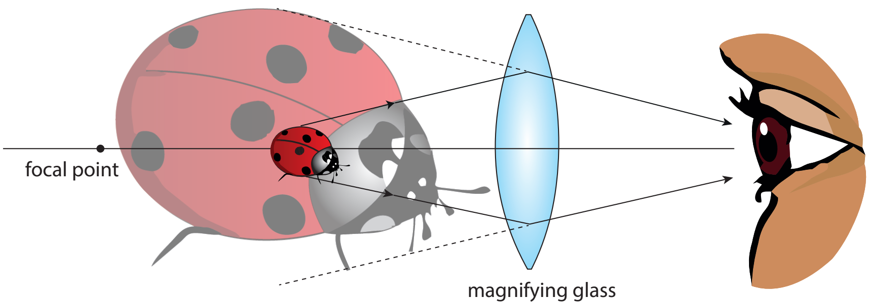


Figure 13.9 A convex (converging) lens used as a magnifying glass. The resulting image is larger than the object. Telescopes magnify images from distant stars and galaxies.

Magnification comes at a price, however. A fixed amount of light is received from any object, so if you make the image larger, its gets fainter as the light is spread out within the image. This is why it is so important to collect as much light as possible.

The larger a telescope's mirror or lens, the better it is at seeing narrowly-separated objects as individual objects and the sharper the images look. The most important feature of a telescope is how much light it can collect, which depends upon the area of the lens or mirror. The larger the light collecting area, the more light a telescope gathers and the higher resolution (ability to see fine detail) it has. So the size of a telescope is far more important than its magnification.

Now that we have briefly looked at how telescopes work, we are going to look at the different types of telescopes, namely:

- optical telescopes
- radio telescopes
- space telescopes.

Optical telescopes

Optical telescopes collect visible light from celestial objects. There are two types of optical telescopes.

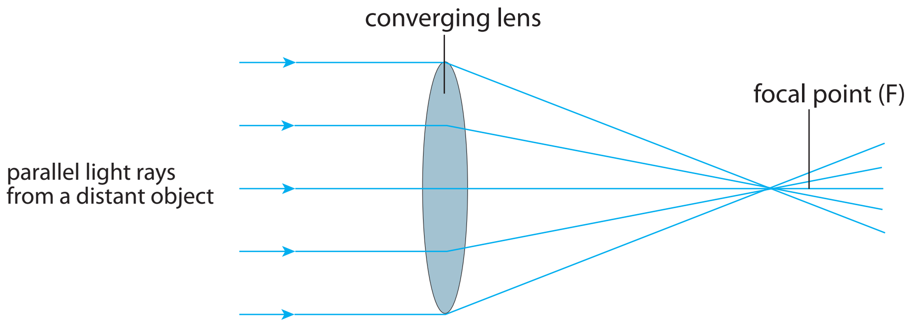
1. Refracting telescopes use **lenses** to collect and focus the light from distant objects.
2. Reflecting telescopes use **mirrors** to collect and focus the light from distant objects.

> **Take note**
>
> As astronomical objects are so far away, their light rays are considered to be parallel to each other.

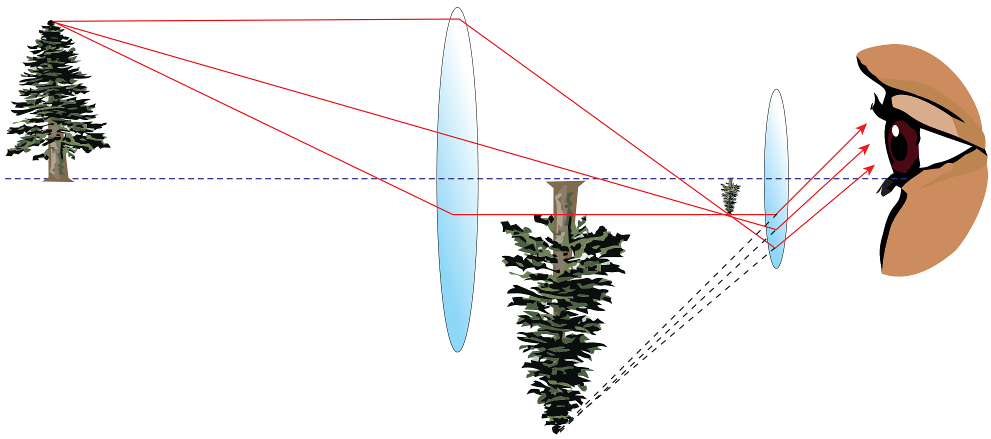
Looking into space

Refracting telescopes

Refracting telescopes use a converging (convex) lens to collect and bend the light rays inwards to the focal point (also called the focus) of the telescope. The light-collecting lens is called the objective lens.



Once light is brought to a focus, it is then magnified by another lens called the eyepiece lens. Look at the optical ray diagram below showing a simple refracting telescope.



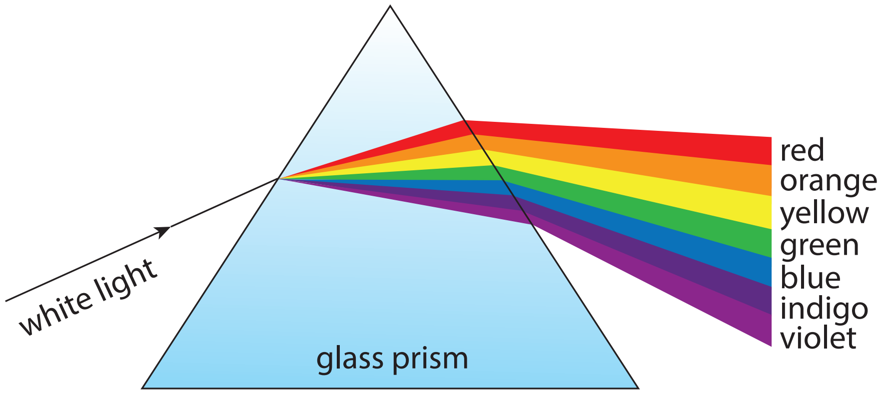
The telescope objective lens collects and focuses the light from a distant tree, forming a real, inverted image of the tree. The eyepiece lens, like a magnifying glass, then enlarges the image collected by the objective lens, producing a larger, virtual image. This image is what we see when we look through the telescope.

What kind of lenses are the objective lens and the eyepiece lens?

Look at the following picture, which shows how white light is refracted (bent) as it travels through a prism. As we learnt in Energy and Change, when light travels through glass it slows down and so it bends or refracts.

Take note

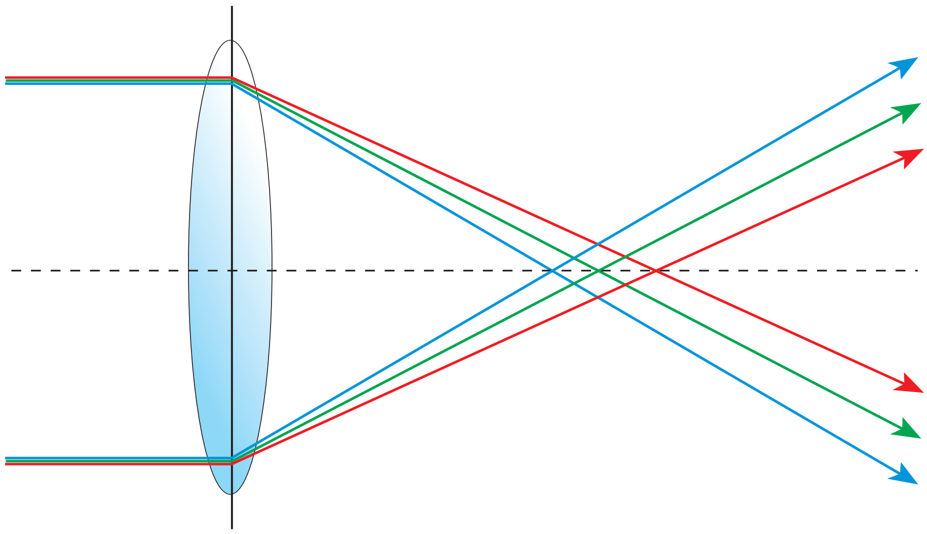
A real image is called real because light rays actually pass through the point where the image is formed. A virtual image is called a virtual image because the light rays do not actually come from the image; they just appear to have come from the image.



Do all the colours undergo the same amount of refraction? Which colour is bent the most?

White light is a mixture of all the colours of the rainbow. Different colours are refracted by different amounts as they travel through the prism so the white light is split into its different colours. How do you think this affects the images produced by refracting telescopes?

Lenses are shaped to bend light by a certain desired amount. However, the different colours that make up white light bend by slightly different amounts. This means that different colours come to a focus at slightly different distances from the objective lens. Each colour will produce its own image and they will be slightly misaligned with each other, resulting in a slightly blurry image. This effect is called **chromatic aberration**, and all lenses suffer from this effect.



Blue light is bent more than red light and so different colours are focused at different distances from the lens. The different coloured images are overlaid upon each other and, because they are misaligned, the resulting image is blurry.

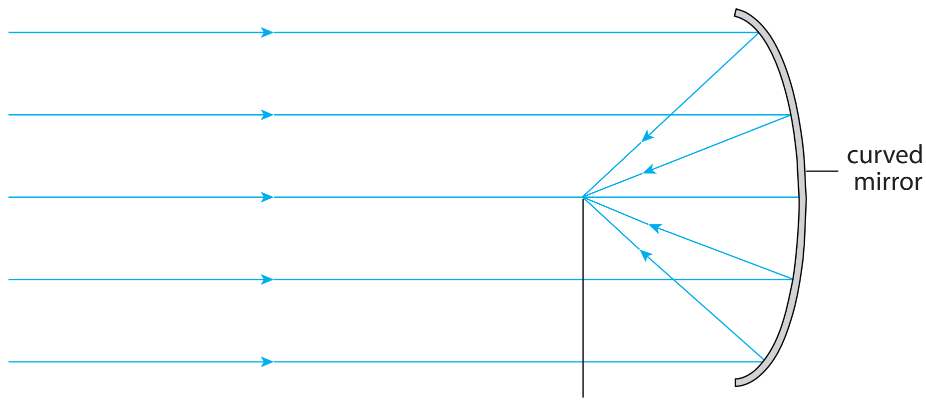
The main disadvantages of refracting telescopes are:

1. Light travels through the lenses in the telescope and so the lenses have to be perfect. There must be no bubbles of air in the glass which would distort the image. It is difficult and expensive to make large perfect lenses.

2. The light travels through the lenses and so they can be supported only around their edges, where they are thinnest and weakest. This limits the size of refracting telescopes, because if a lens is too large, it will sag under its own weight and distort the image.
3. Lenses suffer from chromatic aberration, which blurs the image.

Reflecting telescopes

In the 1680s, Isaac Newton invented the reflecting telescope. Reflecting telescopes use a curved primary mirror to collect light from distant objects and reflect it to a focus.



There are many different types of reflecting telescopes. A prime focus reflector is the simplest type of reflector telescope. In this design, a recording structure is placed at the focal point to obtain the focused image. In the old days, in very large telescopes, a person would actually sit in an 'observing cage' to view the image directly or operate a camera. However, now a detector is used and is operated from outside the telescope. The position of the detector is shown in the following diagram with a red cross.

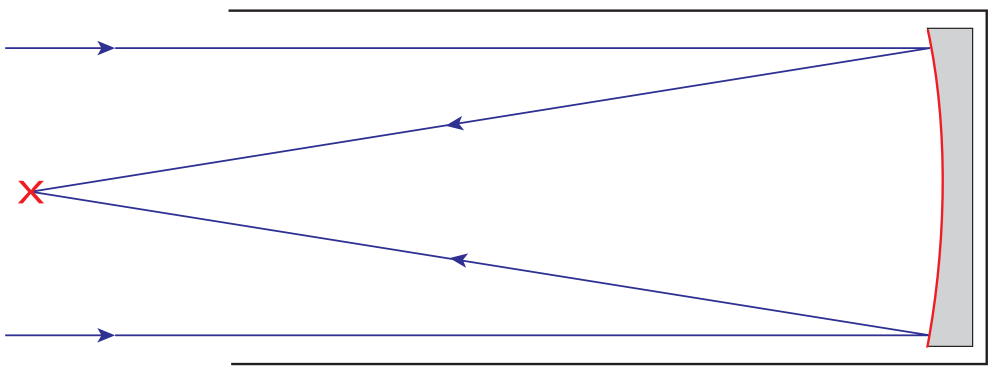


Figure 13.10 A prime focus reflector with a detector at the focal point, marked with an X.

More complex designs of reflecting telescopes use a secondary small mirror to reflect the light towards the eyepiece lens.

- A **Newtonian reflector** reflects the light to an eyepiece on the side of the telescope tube. This design is often used for amateur telescopes because having the eyepiece on the side of the tube makes the telescope easy to use.

Did you know?

The first successful reflecting telescope built was the Newtonian Telescope, by Isaac Newton, which is where the design gets its name.

Take note

Remember that for each ray, the angle of incidence is equal to the angle of reflection, as you learned in *Energy and Change*.

Did you know?

The Cassegrain reflector is named after a reflecting telescope design that was published in 1672 and has been attributed to Laurent Cassegrain.

- A **Cassegrain reflector** reflects light through a small hole in the primary mirror. This kind of telescope is often used for large professional telescopes as it allows heavy detectors to be placed at the bottom of the telescope. This makes them easy to reach for repairs and also means that the weight of the detectors does not affect the telescope tube.

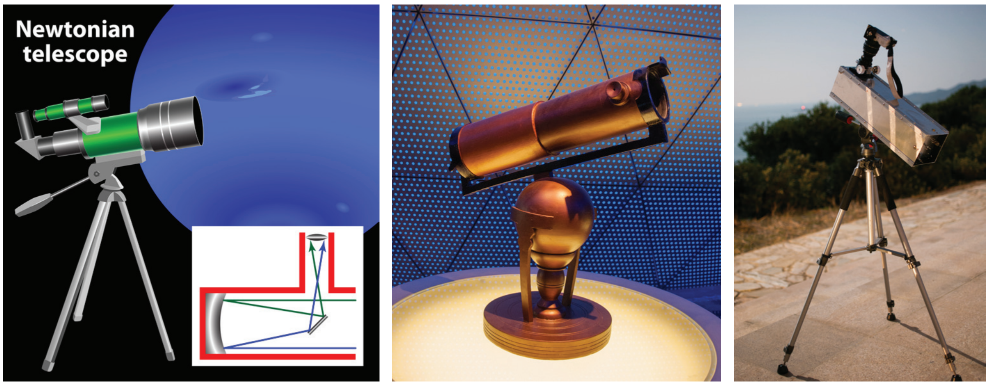


Figure 13.11 A group of Newtonian telescopes.

The following ray diagrams show the difference between a Newtonian and Cassegrain reflector.

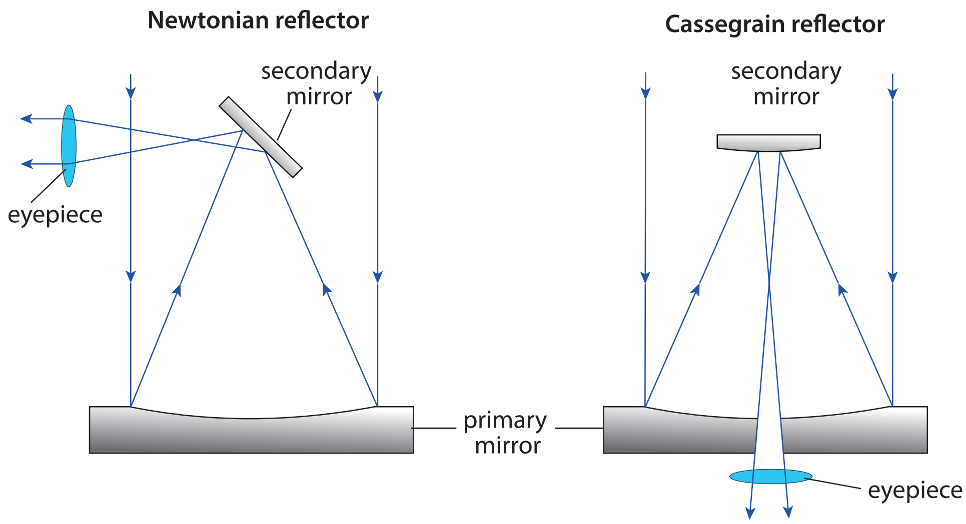


Figure 13.12 Ray diagrams for some example-reflecting telescopes. The Newtonian reflector is often used in amateur telescopes. The Cassegrain telescope is often used at large observatories.

Did you know?

NASA is currently planning the successor for the Hubble Space Telescope, called the James Webb Space Telescope (JWST). It will be launched into space in 2018.

The secondary mirror in a reflecting telescope must be very small. Why do you think this is so?

Do you think that reflecting telescopes suffer from chromatic aberration? Why?

The advantages of a reflecting telescope include:

1. The glass of the mirror does not have to be perfect throughout; only the surface has to be perfect.
2. The mirror can be supported across the whole of its back so it won't sag.
3. Making large mirrors is easier and cheaper than making big lenses.
4. They do not suffer from chromatic aberration.

Optical telescopes on the ground do, however, have some disadvantages:

1. They can be used only at night.
2. They cannot be used in bad weather (rain, cloud, snow, and so on). Optical telescopes are best placed on the tops of remote mountains.

Discuss within your class why you think this is.

The largest telescopes in the world today are reflecting telescopes. In the next section you will learn about one of the largest reflecting telescopes in the world which is located right here in South Africa.

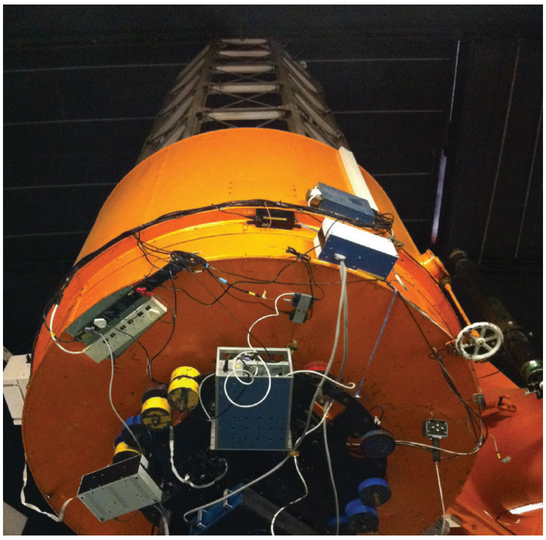


Figure 13.14 The SAAO 1,9 m reflecting telescope. Detectors are bolted onto the Cassegrain focus at the bottom of the telescope (metal boxes under the orange tubing). (Credit: SAAO).

SALT

The Southern African Large Telescope (SALT) is the largest optical telescope in the southern hemisphere and among the largest in the world. SALT was completed in 2005 and is located in the Karoo in the Northern Cape, near the town, Sutherland. Astronomers use telescopes like SALT to study planets, stars and galaxies. SALT can detect the light from faint or distant objects in the Universe a billion times too faint to be seen with the naked eye.

Keywords

- SALT

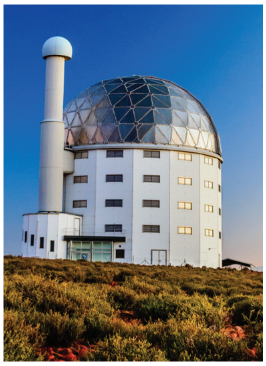


Figure 13.15 The SALT telescope just outside Sutherland.

The SALT telescope has a large mirror which collects light. SALT's primary mirror is a hexagonal shape measuring 11,1 m by 9,8 m across and is made up of 91 individual 1,2 m hexagonal mirrors. SALT is a prime focus reflector. What does this mean?

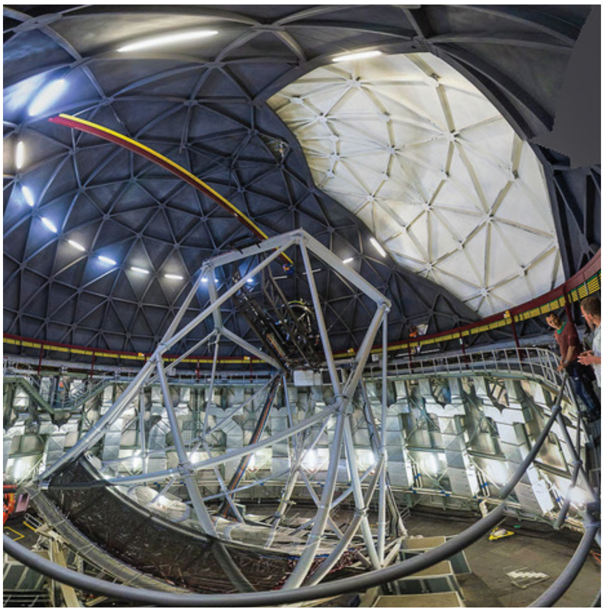


Figure 13.16 SALT's giant mirror, made up of 91 individual mirrors.

SALT does not have a telescope tube. Instead there is a network of metal struts which support the tracker and payload at the top of the telescope. The whole Telescope structure weighs 85 tons. The payload contains detectors which take pictures of the night sky.

Stars move during the night just as the Sun moves across the sky in the day. The telescope must follow the stars as they move. The tracker at the top of SALT is used to follow the drifting stars carrying the detectors along with it as it tracks the stars.

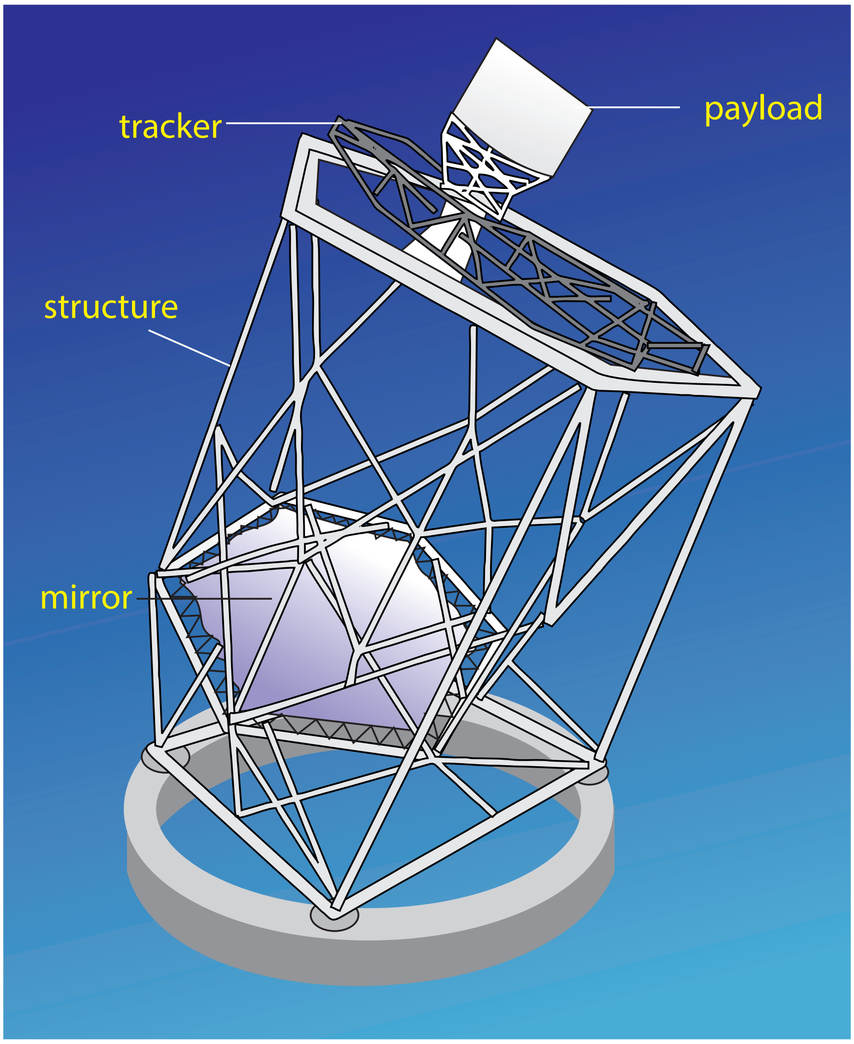


Figure 13.17 The SALT telescope structure. (Credit: SALT)

SALT is currently being used to study stars, in particular binary star systems where two stars orbit around each other. Astronomers also use the telescope to study galaxies and some of the most violent explosions in the Universe, called supernovae and Gamma Ray Bursts, which occur when massive stars explode at the end of their lives. SALT is also looking at the Universe on the largest of scales, in order to answer the questions how did the Universe begin, and what will happen to it in the future?

The Karoo is an ideal place to host SALT because it is far away from towns and cities so there is very little light pollution. The area is also at a high elevation, dry and there are no extreme weather conditions, such as flooding or storms. Despite its being so remote at the observatory site, there is good infrastructure, including roads and electricity, in the surrounding area of Sutherland.

Radio telescopes

Radio waves are a type of electromagnetic radiation (or light) that humans cannot see with their eyes. They have very long wavelengths compared to optical light. Purple light, for example, has a wavelength of 400 nm, whereas red light has a wavelength of 700 nm. Radio wavelengths are much longer; radio waves have wavelengths from approximately one millimeter to hundreds of metres.

Radio telescopes detect radio waves coming from distant objects. Radio telescopes have several advantages over optical telescopes. They can be used in bad weather, as radio waves are not blocked by clouds. They can also be used during the day and at night.

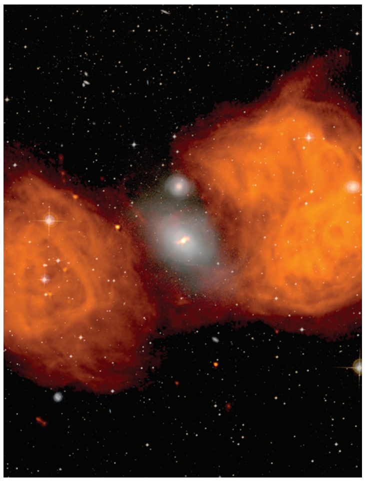


Figure 13.18 An optical (white) and radio (orange) image of the galaxy NGC 1316. The radio emission spans over one million light years and engulfs the optical light at the centre.

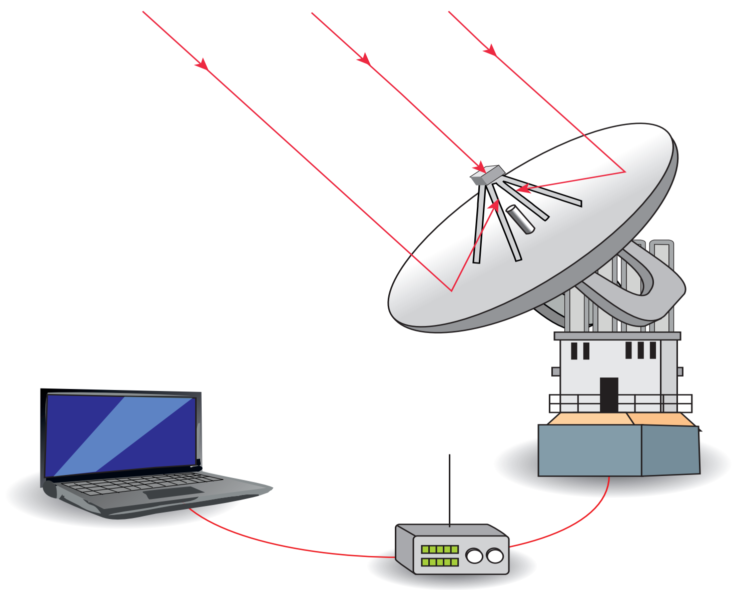
Keywords
- antenna
- receiver
- amplifier
- SKA

Many objects in space emit radio waves, for example some galaxies, stars and nebulae which are giant clouds of dust and gas where stars are born. Some objects emit radio waves but do not emit optical light, therefore looking at the sky at radio wavelengths reveals a completely different picture of our Universe.

If your eyes could see radio waves at night, rather than white light, instead of seeing point like stars, you would see distant star-forming regions, bright galaxies and beautiful giant clouds around old exploded stars.

> **Did you know?**
>
> The SKA central computer will have the processing power of about one hundred million computers. The dishes of the SKA will produce 10 times the global internet traffic.

Radio telescopes typically look like large dishes. The **dish** or **antenna** acts like the primary mirror in a reflecting telescope, collecting the radio waves and reflecting them up to a smaller mirror which then reflects the radio waves to a radio wave detector. Radio wave detectors are called **receivers**. An **amplifier** amplifies the signal and sends it to a computer which processes the information from the receiver to create colour images which we can see.



Radio telescopes need to be placed far away from cities and towns as man-made radio interference can interfere with the telescope's observations.

> **Did you know?**
>
> Rapidly rotating star remnants, called pulsars, were first discovered using a radio telescope in 1967. Astronomers initially considered the possibility that the regular pulses of radio waves were signals from an alien civilisation but quickly realised that this was not the case.

> **Take note**
>
> Do you remember learning about wavelength in *Energy and Change*? A wavelength is the distance between two corresponding points on two consecutive waves.

MeerKAT and the SKA

The MeerKAT radio telescope under construction in the Northern Cape, and scheduled for completion in 2018. It will have 64 radio dishes each 13,5 m in diameter. The MeerKAT array will be the most sensitive radio telescope in the southern hemisphere until the Square Kilometre Array (SKA) is completed.

The Square Kilometre Array (SKA) will be the most powerful telescope ever. It will have a total collecting area of one square kilometer. It will have 3 000 radio dishes each about 15 m wide which will act together as one large telescope. As well as the 3 000 radio dishes, there will be two other types of radio wave detectors.

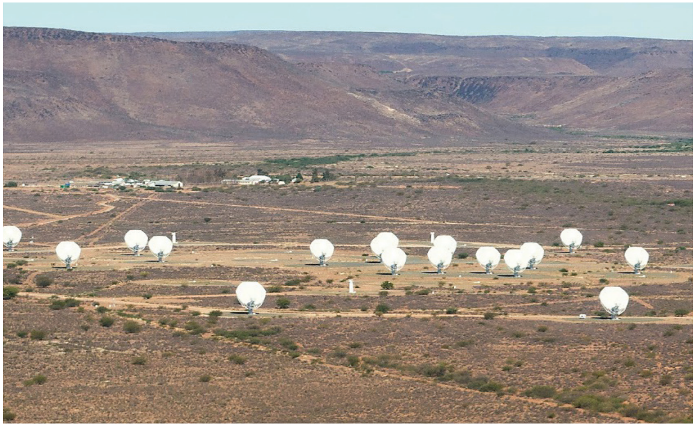


Figure 13.19 An aerial view of the MeerKAT core at the SKA Losberg site in the Northern Cape.

Figure 13.20 Part of the KAT-7 radio telescope array in the Northern Cape.

Many different countries are working together to build, and pay for, the SKA. At least 13 countries and close to 100 organisations are already involved, and more are joining the project. Most of the SKA will be located in South Africa. There will also be locations in Australia and some stations in eight African partner countries, namely, Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia.

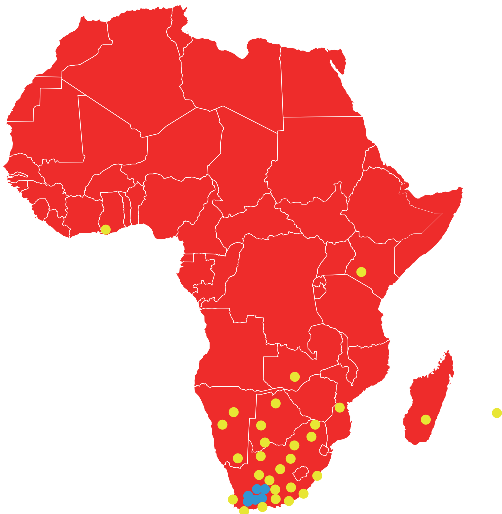


Figure 13.13 The location of SKA in South Africa, and other African countries.

Did you know?

The data collected by the SKA in a single day would take nearly two million years to playback on an iPod.

Did you know?

Jobs are not limited just to astronomers: engineers, computer scientists and administrative staff are needed to run the telescopes.

MeerKAT and the SKA will be used to investigate how galaxies change over time, our understanding of gravity, the origin of cosmic magnetism, how the very first stars formed, other planets around other stars, and whether we are alone in the Universe.

Figure 13.22 One of the MeerKAT dishes currently being built outside Carnarvon in the Northern Cape.

ACTIVITY: Careers in Astronomy

Instructions

Discuss in class with your teacher and classmates what sorts of careers you think are now available in astronomy in South Africa because of the construction of SALT and MeerKAT/SKA. Think about and discuss the skills needed in each of the roles you discuss.

Did you know?

Radio astronomy observatories use diesel cars around the telescopes because the ignition of the spark plugs in petrol cars can interfere with radio observations.

ACTIVITY: Draw a telescope

Materials

- paper
- pencils or crayons

Instructions

1. Pick either an o ptical telescope or radio telescope and draw a picture of the telescope.
2. Label the different parts of the telescope and describe what they do.

Did you know?

The SKA will be so sensitive it could detect TV signals from planets orbiting other stars.

Space telescopes

Radio waves and visible light form part of what is called the electromagnetic spectrum of light. There are other types of light at different wavelengths that we cannot see with our eyes including X-rays, ultraviolet and infrared light.

The Earth's atmosphere blocks X-rays, ultraviolet and infrared light and stops them from reaching the ground. So if we want to observe this kind of light from stars and galaxies, we need to put telescopes in space. This is why X-ray telescopes and infrared telescopes are placed in space.

Figure 13.21 A picture of an X-ray telescope called XMM-Newton.

Take note

The sensitivity of a radio telescope depends on the area of the collecting dish and the sensitivity of the radio receiver. To produce sharp radio images comparable to images from optical telescopes a radio telescope must be much larger than an optical telescope.

Did you know?

The Hubble Space Telescope is named after Edward Hubble, considered to be one of the most important cosmologists of the 20th century. Hubble discovered there were galaxies beyond our own and helped confirm that the universe is expanding.

The advantages of space telescopes are that they can observe the whole sky and operate during both night and day. Images taken with space telescopes are far sharper than images taken with telescopes on the ground, because images are not smeared or blurred by turbulence in the Earth's atmosphere, as with images take from ground telescopes. This is why the Hubble Space Telescope images are so detailed, even though it is a relatively small reflective telescope.

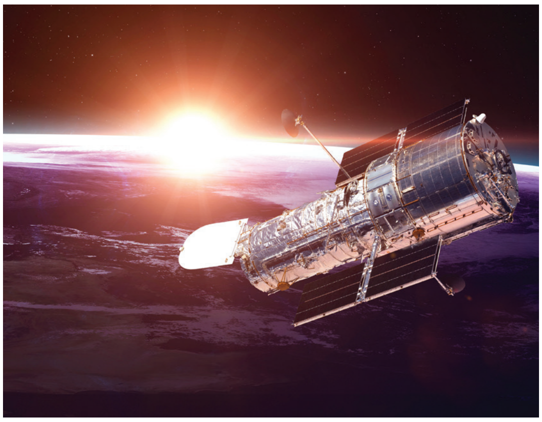


Figure 13.23 The Hubble Space Telescope has a 2.4m diameter collecting mirror.

The major disadvantages of space telescopes are their costs and the fact that if something goes wrong, they are extremely difficult to fix.

ACTIVITY: Telescope information poster

Materials

- paper
- pencils or crayons
- pictures downloaded from the internet or copied from books – optional

Instructions

1. Pick a telescope that you want to make a poster about. It can be a ground-based or space-based telescope.
2. Describe the telescope and explain how it works. Include a diagram or picture of the telescope and label its main parts in your poster.
3. List some of the science that the telescope is used for in your poster.
4. List some of the advantages and disadvantages of the type of telescope you have chosen in your poster.

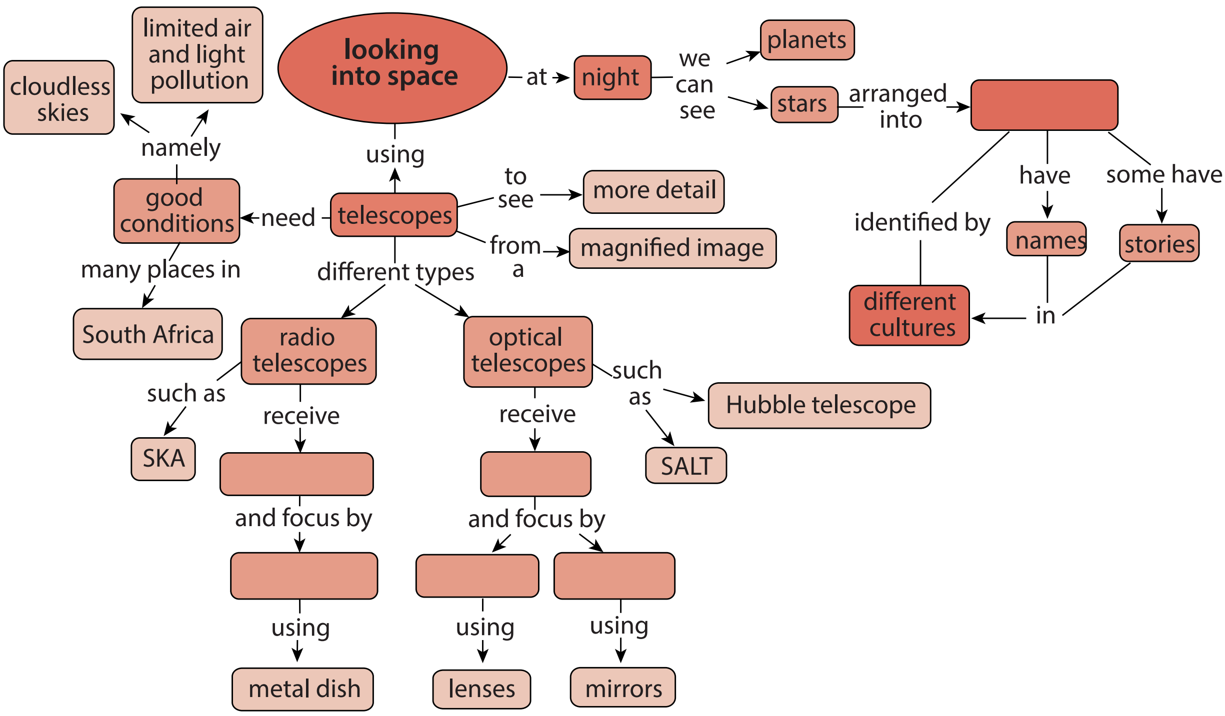
Summary

Key concepts

- Early cultures observed the stars and grouped them together in patterns or constellations.
- Telescopes allow astronomers to see distant, faint objects in more detail.
- The performance of a telescope is measured by how much light it can collect. Larger telescopes can collect more light and see finer details than smaller telescopes.
- Optical telescopes detect optical light from distant objects.
- Most modern day optical telescopes use mirrors to collect and focus the light from distant objects.
- Radio telescopes collect and focus radio waves, emitted from distant objects in space.
- South Africa is host to one of the the most advanced optical telescopes in the world, the Southern African Large Telescope (SALT).
- South Africa will also host a large part of the soon to be constructed SKA radio telescope which will be the largest radio telescope in the world once complete.

Concept map

The concept maps in this workbook we made using an open source, free programme. If you would like to make your own concept maps for your other subjects, you can download the programme from the link in the visit box.



Revision

1. What do astronomers call patterns of stars in the sky? [1]
2. Name three famous southern constellations. [3]
3. What do optical refracting telescopes use to collect and focus light from distant objects? [1]
4. What do optical reflecting telescopes use to collect and focus light from distant objects? [1]
5. List two advantages that reflecting telescopes have over refracting telescopes. [2]
6. What sort of light do radio telescopes detect? [1]
7. List two advantages that radio telescopes have over optical telescopes. [2]
8. Why are X-ray telescopes located in space? [1]
9. Why does the Hubble Space Telescope produce such sharp images even though it is much smaller than most professional ground based telescopes? [1]
10. Why should astronomers look at objects at different wavelengths? [1]
11. What is the name of the largest optical telescope located in the Northern Cape? [1]
12. List three reasons why the SALT telescope is located near Sutherland in the Northern Cape. [3]
13. How many dishes will the MeerKAT array have? [1]
14. How many dishes will the SKA array have? [1]
15. List two areas of astronomy that will be studied using the SKA telescope. [2]

Total [22 marks]

GLOSSARY: Energy and change

Alpha Centauri: our second closest easily visible star after the Sun; it is actually two stars orbiting very close together
amplifier: a device which amplifies (to make something bigger) the radio wave signals
antenna: the dish or other device used to collect radio wave in a radio telescope
asteroid: a small rocky object orbiting the Sun
asteroid belt: the area where most asteroids are found in our solar system, lying between the orbits of Mars and Jupiter
astronomical unit (AU):the average distance between the Earth and the Sun, equal to around 150 million kilometres
celestial: positioned in or relating to the sky, or outer space as observed in astronomy
chromatic aberration : an optical effect where different colours are refracted by different amounts in a lens leading to a distorted image
comet: a small object made of ice and dust which sometimes enters the inner solar system; when a comet enters the inner solar system, part of it evaporates to form a long tail of ice and dust pointing away from the Sun
constellation: a group of stars that form a pattern in the sky when viewed from Earth
convection: one of the three ways to transport heat energy (the other two are conduction and radiation); as a liquid or gas is heated, it becomes less dense and rises; while denser colder material sinks, creating a flow of moving liquid or gas which transports heat energy along with it
dwarf planet: a large, roughly spherical object orbiting a star which cannot be classed as a planet because it is not large enough to sweep out other objects from its orbit
filament: a threadlike structure in space containing galaxies and galaxy groups and clusters
galaxy bulge: a spheroidal (rugby ball-shaped) distribution of old stars at the centre of a galaxy
galaxy cluster: a collection of over 50 or more galaxies, held together by gravity
galaxy disk: the flat distribution of stars, gas and dust in a galaxy
galaxy: a collection of millions or billions of stars, gas and dust all held together by gravity
galaxy group: a collection of about 50 or less galaxies, held together by gravity
gas giant: a large planet made mostly of gas with no solid surface; the four outermost planets in the solar system are gas giants
habitable zone: the region surrounding a star in which water can remain in its liquid state
Kuiper Belt: region of space filled with trillions of small objects that lie in the outer reaches of the solar system, past the orbit of Neptune
Kuiper Belt object: a small icy object orbiting the Sun out beyond the orbit of Neptune
light hour: the distance that light travels in one hour
light minute: the distance that light travels in one minute
light year: the distance that light travels in one year
nuclear fusion: the process by which stars produce their energy; light atomic nuclei come together and merge to form heavier atomic nuclei, releasing energy as they do so; in the Sun, hydrogen nuclei fuse with other hydrogen nuclei to form heavier helium nuclei
Oort Cloud: a hypothetical huge cloud of icy objects (comets) surrounding the Sun at the very edge of our solar system at a distance between 5 000 and 100 000 times the Earth's distance from the Sun
photosynthesis: the process by which green plants and some other organisms use sunlight to synthesise foods from carbon dioxide and water producing oxygen as a by-product
primary mirror: the light-collecting mirror in an optical telescope
Proxima Centauri: our second closest star after the Sun

receiver: a device that detects radio wave signals

SALT: the Southern African Large Telescope, the largest optical telescope in the southern hemisphere

SKA: the Square Kilometre Array, the largest planned radio telescope array in the world

solar system: the Sun, and the collection of planets and smaller objects that orbit around the Sun

solar wind: the continuous flow of charged particles from the Sun that extends out to the far reaches of the solar system

spiral arm: a region of stars, gas and dust forming a curved shape spiralling out from the centre of a spiral galaxy

star: a huge ball of burning gas which emits energy in the form of light and heat

starlore: mythical stories about the stars, planets and constellations

sunspot: a dark region or spot which appears on the surface of the Sun from time to time; sunspots are cooler than the rest of the Sun's surface

telescope: an instrument used to look at distant objects, which makes distant objects appear brighter, larger and clearer; optical telescopes collect visible light and radio telescopes collect radio waves

terrestrial planet: a planet with a rocky surface like the Earth's surface; the four innermost planets in the solar system are terrestrial planets

Universe: all of existence, including all planets, stars, galaxies, the space between objects, and all matter and energy

void: a vast empty bubble in space found between filaments