# Natural Sciences
## Grade 8-B (CAPS)

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A World Without Boundaries

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

# Periodic Table of the Elements

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H | | | | | | | | | | | | | | | | | 2 He |
| 3 Li | 4 Be | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 11 Na | 12 Mg | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 19 K | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 37 Rb | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 55 Cs | 56 Ba | 57-71 La-Lu | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 87 Fr | 88 Ra | 89-103 Ac-Lr | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Uut | 114 Uuq | 115 Uup | 116 Uuh | 117 Uus | 118 Uuo |

Key: No / Element

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 La | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu |
| 89 Ac | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr |

- Transition Metal
- Metal
- Metalloid
- Non-metal
- Noble Gas
- Lanthanide
- Actinide

# Natural Sciences

Grade 8-B

CAPS

developed by

SIYAVULA
TECHNOLOGY-POWERED LEARNING

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sasol inzalo foundation

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This book was written by Siyavula with the help, insight and collaboration of volunteer educators, academics, students and a diverse group of contributors. Siyavula believes in the power of community and collaboration by working with volunteers and networking across the country, enabled through our use of technology and online tools. The vision is to create and use open educational resources to transform the way we teach and learn, especially in South Africa.

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***www.sasolinzalofoundation.org.za***

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# ENERGY AND CHANGE

# 1 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 it mean to 'earth' an object?
- 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.

## 1.1 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?


*Did you see your hair 'rise' like this?!*


**QUESTION:**

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?

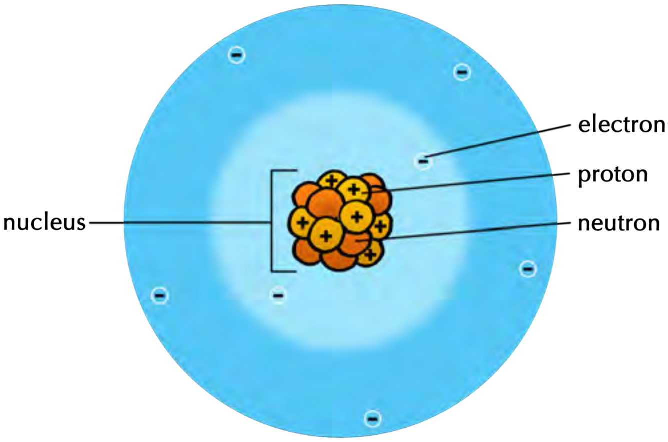
You have dragged the surface of the plastic comb against the surfaces of your hair. When two surfaces are rubbed together there is **friction** between them. Friction is a resistance against the movement of an object as a result of its contact with another object. This means that when you rubbed the plastic comb along your hair, your hair resisted the movement of the comb and slowed it down.

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.

**NEW WORDS**

- friction
- static electricity
- electrostatic charge
- attract: to pull something closer
- repel: to push something away
- neutral
- discharge
- earth
- earthing




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?

---

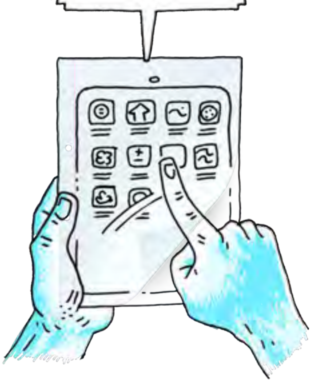


What is the charge on an electron?

---

**TAKE NOTE**

Remember, **like charges repel** and **opposite charges attract.**



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, whilst those further away experience a weaker attraction.

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?



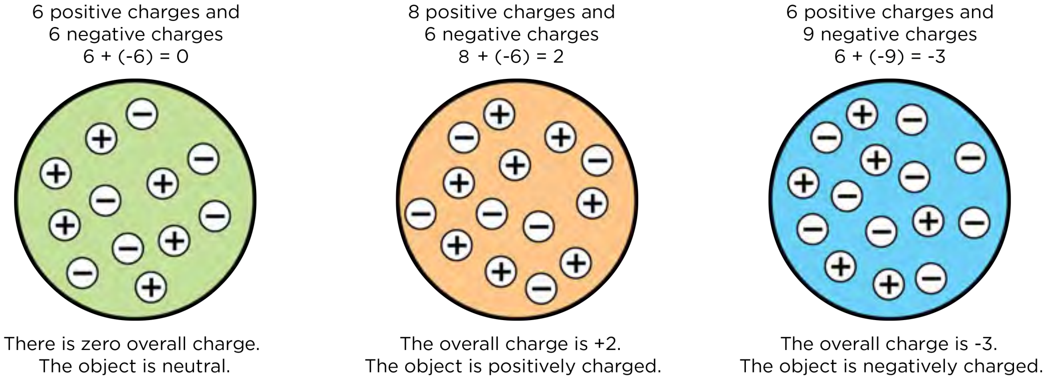
___

Does this object now have more positive or more negative charges?

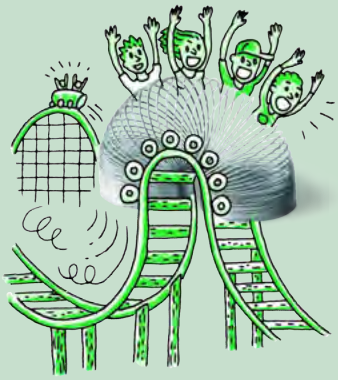
___

- 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.



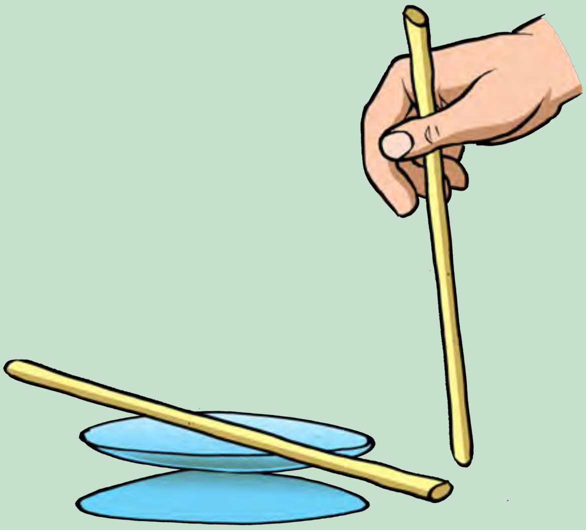
## ACTIVITY: Turning the wheel

**MATERIALS:**

- 2 curved watch glasses
- 2 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?

VISIT

Discover more with a simulation on rubbing balloons and a jersey.

bit.ly/GzwlIt

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.

VISIT

Opposites attract and like repel (video)

bit.ly/16ThzBL

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.

**NEW WORDS**
- flammable
- ignite

**VISIT**
A video showing the dangers of sparks of static electricity at a petrol station.
bit.ly/17mYLiC

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.

______________________________________________

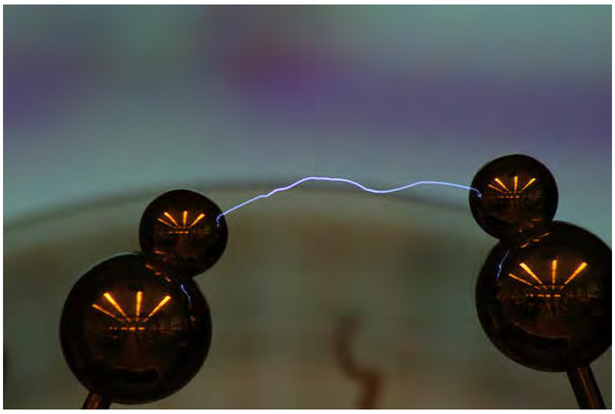
______________________________________________

______________________________________________

## 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.

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**.



*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.

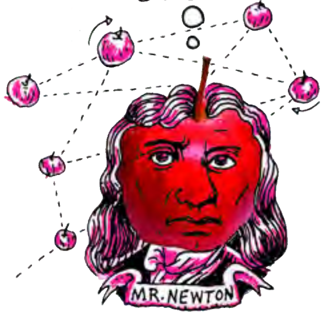
Electrostatic discharge can also cause **electric shocks**. Have you ever been shocked by a shopping trolley while you are pushing it around a shop? Or have you walked across a carpeted room and then shocked yourself when you touch the door handle to leave the room? You have experienced an electric discharge. 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.

Do you know where else we can see sparks due to static electricity? Look at the photo for a clue!

*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.




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.

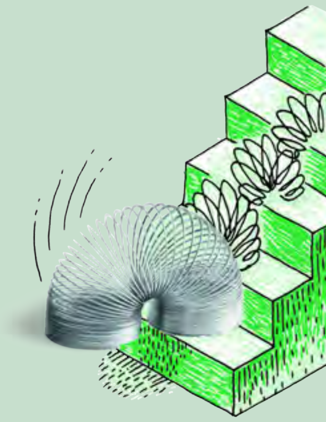
For example, think of the metal trolleys in shopping centres. Have you ever noticed that they normally have a metal chain hanging at the bottom which drags along the floor? This is to earth the trolley if it gets a charge so that charge cannot build up on the trolley. This protects the person pushing the trolley from getting a shock.

**VISIT**

How to survive a lightning strike.

bit.ly/18nTOps

## 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.

**VISIT**
Should a person touch 20 000 Volts? Visit this link to find out!
bit.ly/19mUtun

We are now going to look at two instruments which demonstrate static electricity.

### 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.

**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 only invented by Robert Van de Graaff in 1929 at Princeton University.

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.

*These girls are touching the large dome of a Van de Graaff generator.*

**VISIT**
Watch this video so see how a Van de Graaff generator works
bit.ly/1a5YNKE

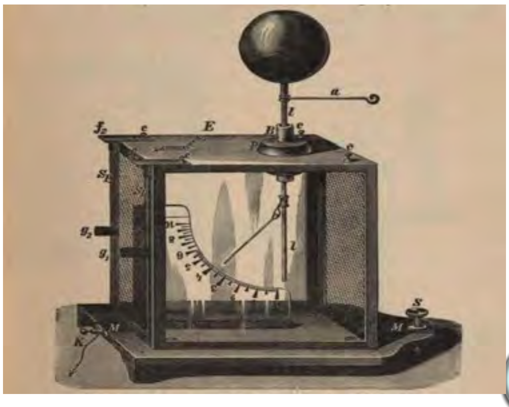
You can also touch the dome and your hair will rise. Why do you think this happens?

### Electroscope

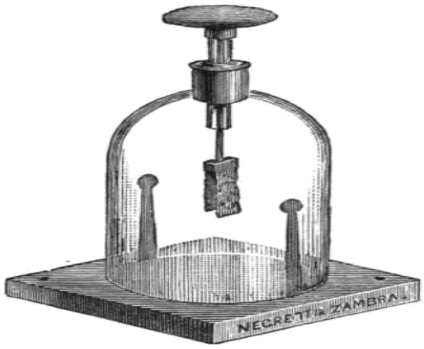
An electroscope is an early scientific instrument used to identify the presence of a charged object or it can be used to identify the type of charge on a charged object.

*An electroscope used in a laboratory.*

The following images show some drawings of different types of electroscopes.



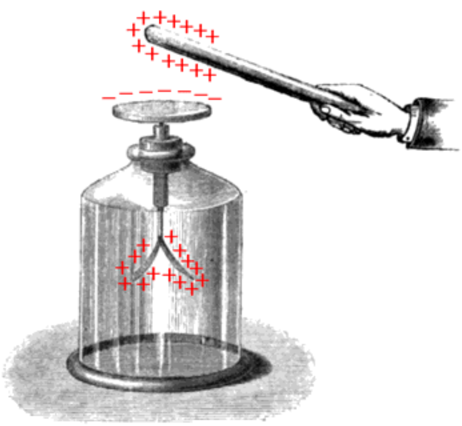
*An early example of an electroscope with one gold strip at the bottom and a ball at the top.*




*Another example of an electroscope with a disc at the top and two gold foil strips at the bottom.*

The electroscope is made up of an earthed metal box with glass windows. There is a metal rod hanging down and at the end are two strips of thin gold foil attached to it. A disc or ball is attached to the top of the metal rod, as seen in the illustrations above. 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.

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
- 2 small pieces of aluminium foil
- piece of wool 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 hook end of the copper wire into the glass jar and close the jar.
8. Rub the ruler with the wool cloth for a minute.
9. Bring the ruler close to the spiral end of the copper wire.

**VISIT**
Make your own electroscope (video)
bit.ly/18JyxWc

**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 wool 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.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

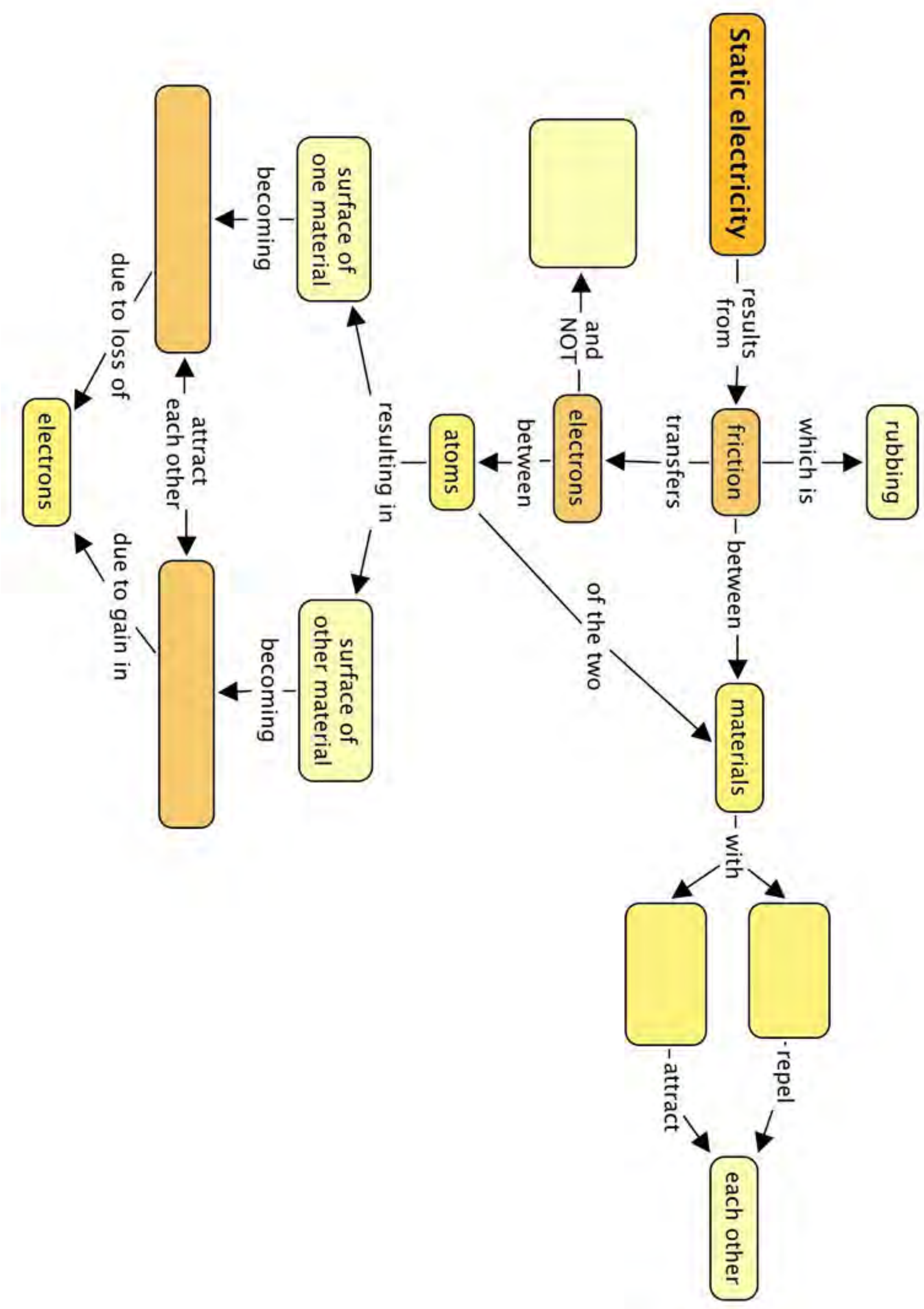
## SUMMARY:

### Key Concepts

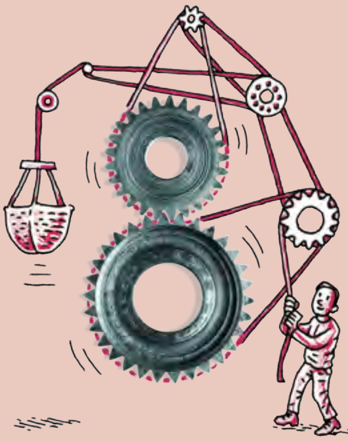
- Objects are usually neutral because they have the same number of positive and negative charges.
- Objects can become negatively or positively charged when friction (rubbing) results in the transfer of electrons between objects.
- Protons and neutrons cannot be transferred, only electrons can be transferred 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, i.e. negative repels negative; positive repels positive.
- Opposite charges attract each other, i.e. 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 chapter about charge and static electricity.


Static electricity
results from
friction
which is
rubbing
between
materials
with
repel
attract
each other
transfers
electrons
and NOT
between
atoms
of the two
resulting in
surface of one material
surface of other material
becoming
becoming
attract each other
due to loss of
due to gain in
electrons

## REVISION:



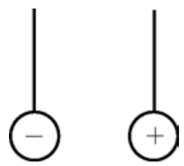
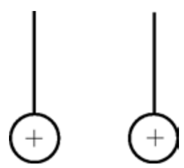
1. Complete the following sentences. Just write the missing word on the line below.
   a) An object which has a **negative** charge is said to have _________________ electrons than protons. [1 mark]

---

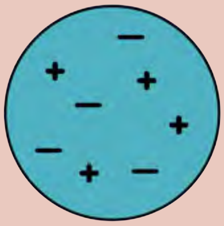
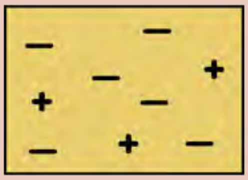
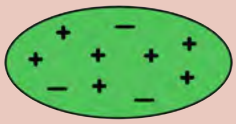
2. An object which has a **positive** charge is said to have _________________ electrons than protons. [1 mark]

---

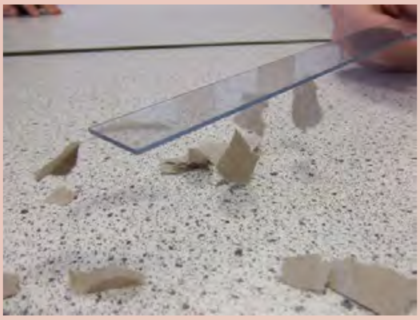
3. Sarah uses a plastic comb to comb her hair. The comb becomes negatively charged. The comb is negatively charged because the comb has: [1 mark]
   a) gained electrons
   b) gained protons
   c) lost electrons
   d) lost protons
4. A perspex strip was rubbed with a cloth and became positively charged. The correct explanation for why the perspex rod becomes positively charged is that: [1 mark]
   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.
5. Look at the following images in the table. 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 marks]

| **Charged spheres** | **Draw how they will move** | **Explanation** |
|---|---|---|
|  | | |
|  | | |

6. 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 marks]

| Object | Overall charge | Why is it positive, negative or neutral? |
|---|---|---|
|  | | |
|  | | |
|  | | |

7. The ruler in this photo has been rubbed with a cloth. Describe what is happening in this photo and why. [4 marks]



*What is happening?*

8. Sometimes, when you are pushing a trolley, you can get a small shock. Explain why this would happen. [2 mark]

9. Why does your jersey make a crackling sound when you pull it over your head? [2 mark]

10. Why do trucks transporting petrol drag a short length of metal chain on the road as they drive? [2 mark]

11. 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 marks]

*What is happening in this photo?*

Total [32 marks]

# 2 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 do you plate metal rings and earrings in gold to produce jewellery?

In the last chapter 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.

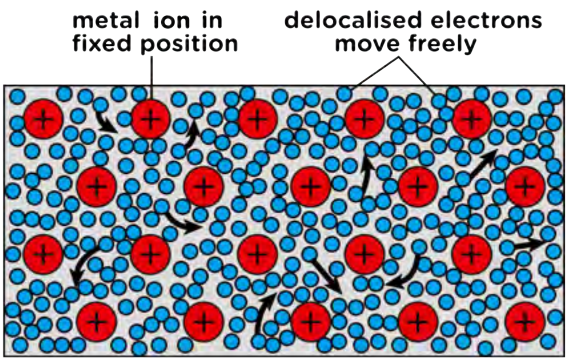
## 2.1 Circuits and current electricity

### What is an electric current?

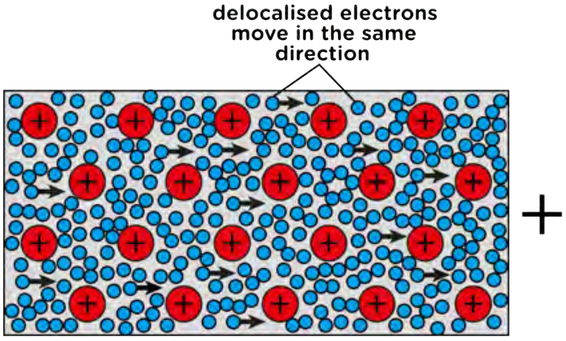
**NEW WORDS**

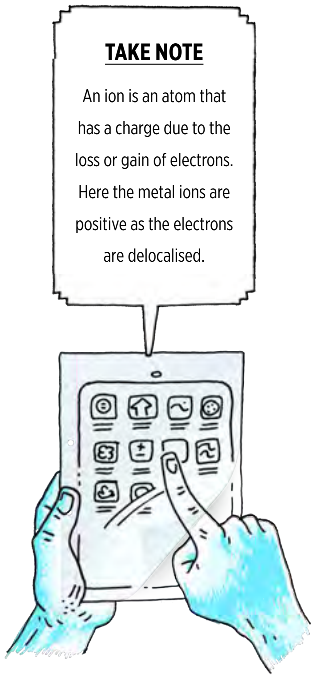
- delocalised
- component
- conductor
- electric circuit
- electric current
- qualitative
- resistor
- switch

An electric current is the movement of charge in a closed, conducting circuit. As we know from Chapter 1, 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 chapter 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**.



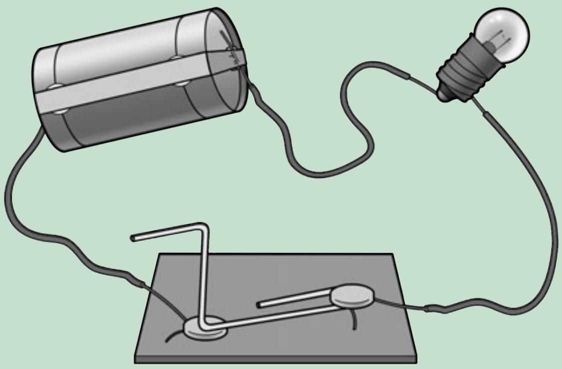

Do you remember what you learnt in Grade 6 and 7 about circuits? Let's revise briefly:

- 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?

**VISIT**
Electricity and circuits bit.ly/17ni2R4 and Revise a simple circuit. [video]
bit.ly/1eWpN5k

4. What is the conducting material?

5. What type of energy does the battery 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?

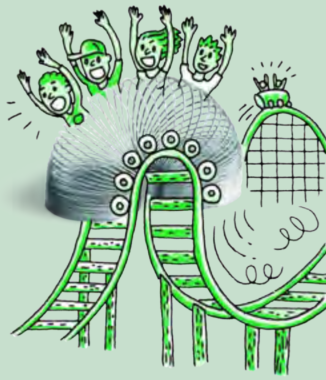
**NEW WORDS**
- ammeter
- cell

A complete 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. Let's look at the components of a circuit.

## 2.2 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



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 chapter.

| 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. |  |

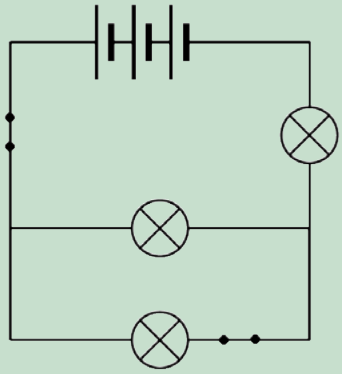
Let's now practice drawing some simple circuit diagrams. Draw the following circuit diagrams.

1. A closed circuit with one cell, two light bulbs and a switch.

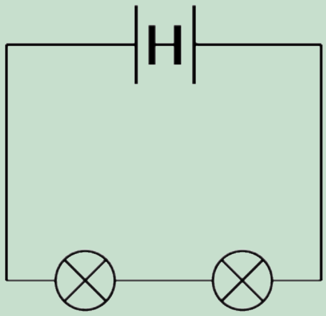
2. An open circuit with two cells, two light bulbs and a switch.

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. What is wrong with the following circuit diagram? Does it represent a closed circuit? Explain your answer.



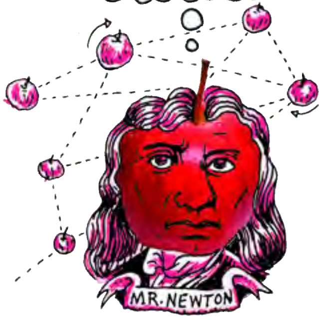

6. Why do you think it is useful to have a switch in a circuit?

7. Why are conducting wires made out of metal?

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

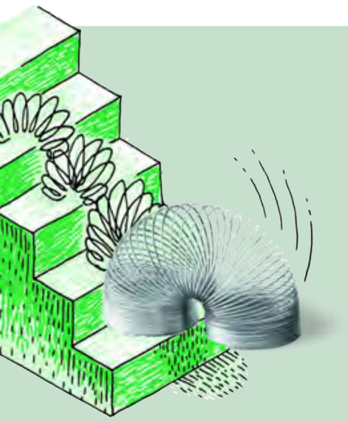
Electrical cells are the source of energy for the electric circuit. Where does that energy come from?

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, D, and 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.


*Different sized batteries.*



## 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 electric charge to move through it.

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.

**VISIT**
A guide to recycling in South Africa.
bit.ly/19Sygzg

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.

*Looking inside a kettle.*

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.

**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.

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.

## ACTIVITY: Resistance in a light bulb

*An incandescent light bulb.*

**MATERIALS:**

- light bulb
- lamp

**INSTRUCTIONS:**

1. If you have light bulbs available, have a close look at the different parts, otherwise 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.

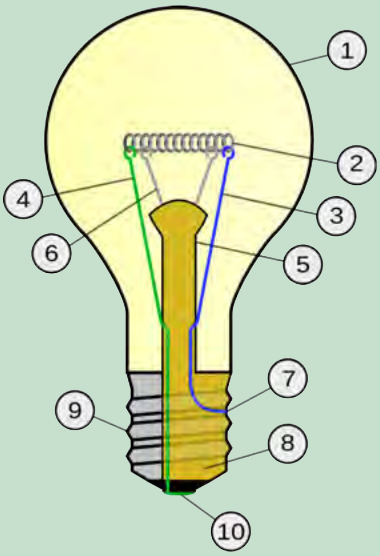




*Diagram of the parts of a light bulb.*

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).

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.

**TAKE NOTE**

Incandescent means to emit light as a result of being heated.

2. What is the useful energy output and what is the wasted energy output in this light bulb?

3. Can you see 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?

**VISIT**

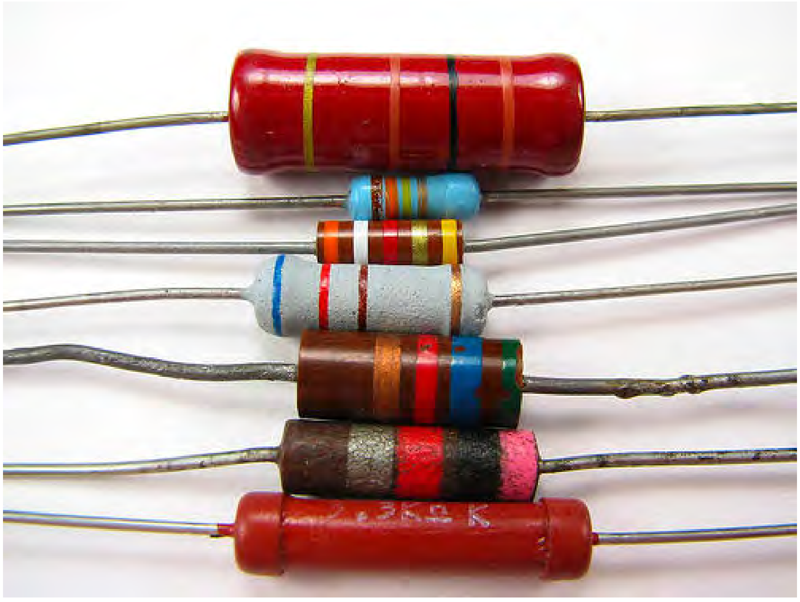
A fun game about electric circuits.

bit.ly/15lcr49

5. The inside of the base of the bulb is made from an insulating material.This is the yellow part labeled 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.

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.



Some common resistors.

**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 1500 hours.

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 the space below with two bulbs, two cells, an open switch and a resistor.

**NEW WORDS**

- variable
- fuse
- electromagnet
- electric current

An electric current can have various effects. Let's find out more about what these are.

## 2.3 Effects of an electric current

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.

### Heating effect

As electrons move through a resistor they encounter resistance and they 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.

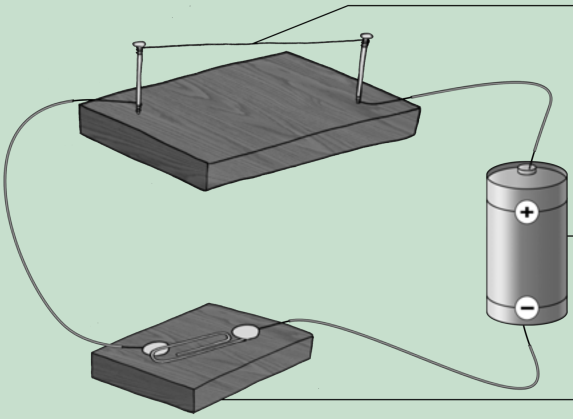
## ACTIVITY: Heating a wire in a circuit

**MATERIALS:**

- 1,5 V cell
- conducting wires
- switch
- block of wood
- 2 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?

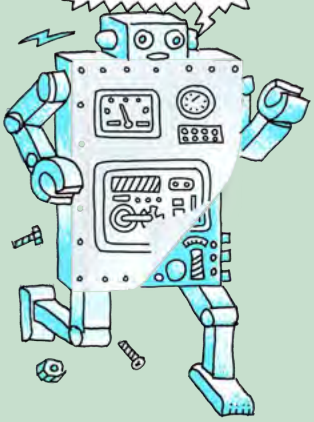
---

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?

---

**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.



**QUESTIONS:**

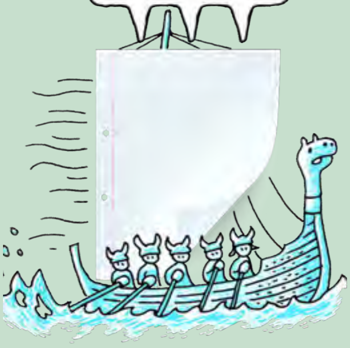
1. When you felt the nichrome wire after the circuit had been on for a while, you felt an increase in **temperature** in your skin as **thermal energy,** which was transferred from the wire to your skin. Explain the heating effect of the electric current in the resistance wire.

2. List 2 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.

**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).



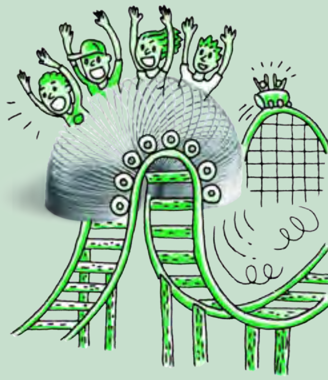
4. Look at the following photo of a toaster.

*An electric 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

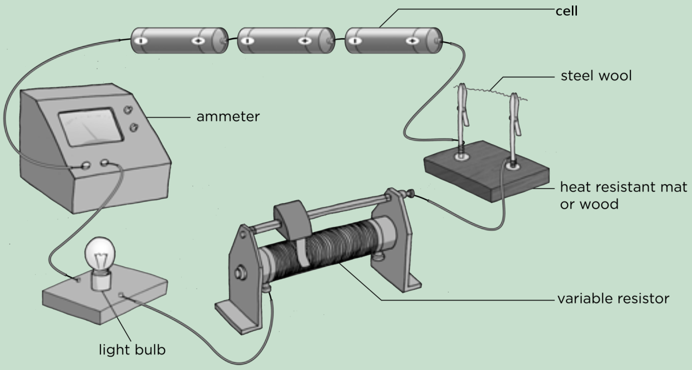


**MATERIALS:**

- 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
- ammeter

**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. Take note of the reading on the ammeter which measures the current in the circuit.
7. Open the switch.
8. Set the variable resistance to its lowest resistance.
9. Close the switch. What do you observe?

---

**TAKE NOTE**

An ammeter is used to measure the electric current in a circuit.

**QUESTIONS:**

1. Draw a circuit diagram for your circuit.


*This is the symbol for an ammeter.*

2. Why is the light bulb included in the circuit?

3. When you decreased the resistance, what happened to the current? In other words, what happened to the reading on the ammeter?

4. What do you think happens to the electric current when the steel wool has burnt? Explain your answer.

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 current 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 point. Therefore, the piece of wire melt if it gets too hot, just like the steel wool in our activity.

*An example of a fuse. Can you see the low melting point wire inside?*

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 a 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.

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:

*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 accidently 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?

______________________________________________________________________________

______________________________________________________________________________

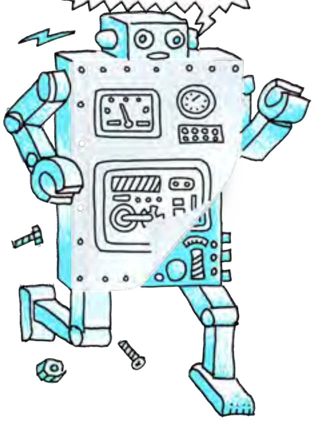
______________________________________________________________________________

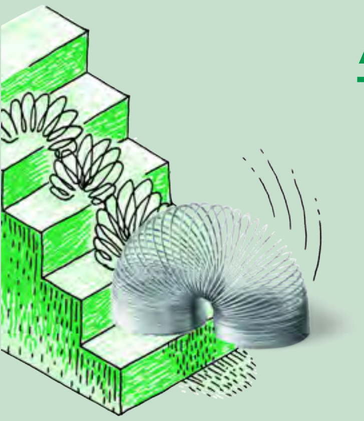
**TAKE NOTE**

It is important to never 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.





## 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.

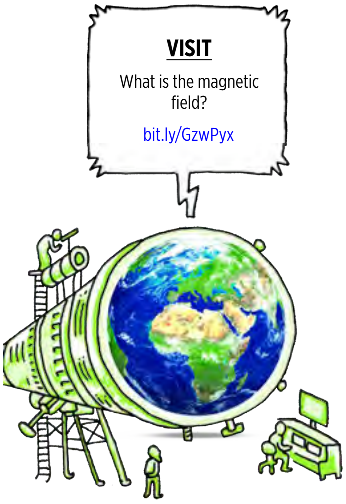
### Magnetic effect

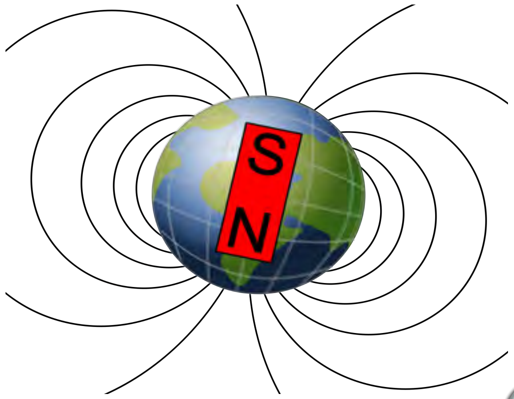
Before we look at how a current produces a magnetic field, let us first learn more about magnets. A magnet is a piece of material which produces a magnetic field. A magnet has a north pole and a south pole. Opposite poles will attract each other and the same poles will repel each other. A magnet has a magnetic field around it.


*A bar magnet.*

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.

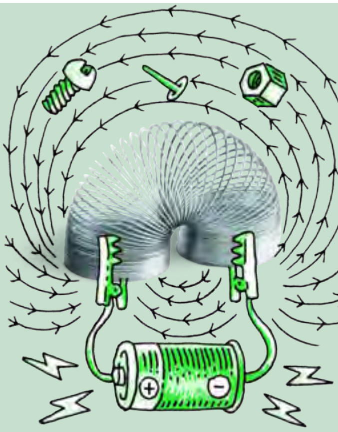



*Earth has a magnetic field, as though there is a big bar magnet running through the core, with its South Pole under Earth's magnetic North pole.*

*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.

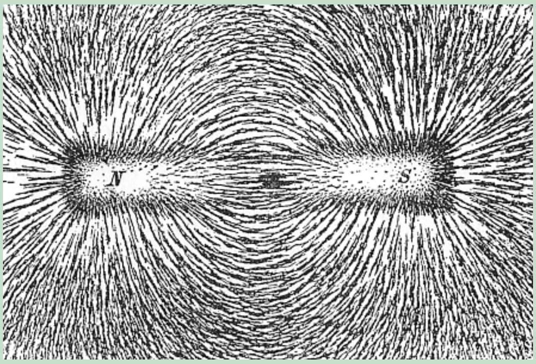
Draw what you see.

4. Next, place a white sheet of paper over the bar magnet and sprinkle iron filings over the sheet of paper over the magnet.
Observe what happens to the iron filings. Did you see something similar to what is shown in the photograph below? Describe what you see.

**VISIT**

Explore the interactions between a compass and bar magnet with this simulation.

bit.ly/19etINQ




*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?

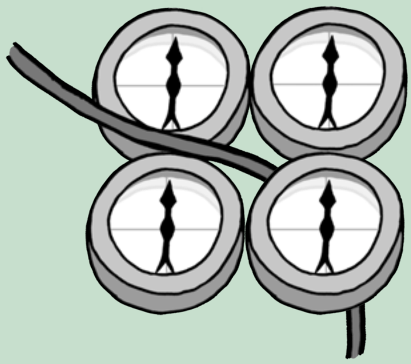
## ACTIVITY: Magnetic field around a conductor

**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 diagram, as well as below and above the conducting wire.



*Plotting compasses placed around a conducting wire.*

**VISIT**
Discover how the Earth is a magnet that protects us from damaging radiation from the sun!
bit.ly/GCCtjK

3. Keep the switch open. What do you notice about the needles of the plotting compasses?

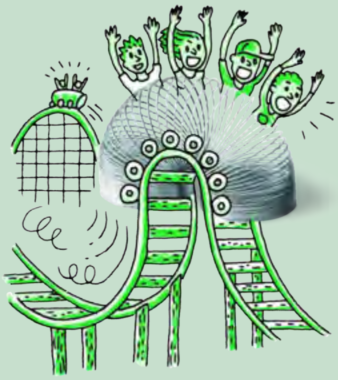
___

4. Close the switch and observe what happens to the needles.
5. Draw a picture of the wire and plotting compasses in the space below:
6. What does the pattern of the compasses tell us?

___

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.



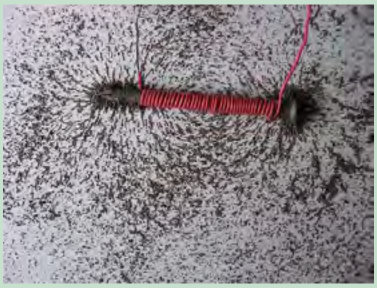
## ACTIVITY: Making an electromagnet

**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.



*The magnetic field around an electromagnet.*

**QUESTIONS:**

1. What happened when you held the nail over the paper clips?

___

2. Why were the paper clips attracted to the nail?

___

___

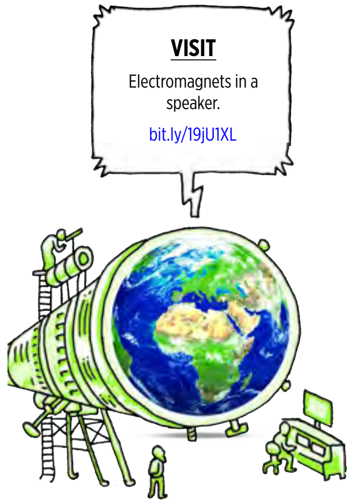
3. Did the disconnected nail attract the paper clips? Why?

___

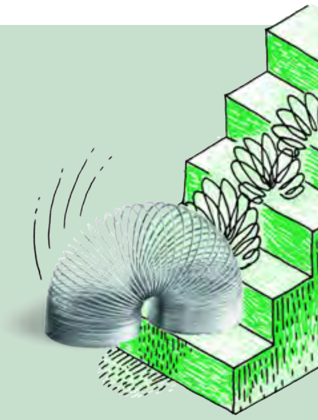
___

Electromagnets can be used in all sorts of practical applications, including speaker and electric bells, as you can see in the photo.

*An electromagnet in a bell.*




## ACTIVITY: Research the use of electromagnets



**INSTRUCTIONS:**

1. Work in groups of 2 or 3.
2. Research one of the following applications of the magnetic effect of an electric current to explain how the device works:
   a) speakers
   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.

______________________________________________

______________________________________________

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### 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 focussing on the effects of an electric current.

**MATERIALS**

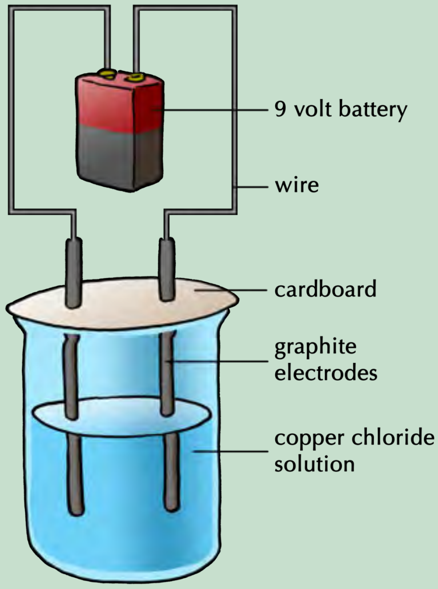
- 250 ml beaker
- 2 carbon electrodes
- sandpaper
- 3 copper conducting wires (with crocodile clips)
- copper chloride solution
- torch bulb
- power pack

**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 might look something like this, which you have seen before. You might 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?

**VISIT**

Learn more about silver refining through electrolysis. bit.ly/1fZQ5SW and the process of electroplating (video) bit.ly/GzH851

**NEW WORDS**

- electrolysis
- electrodes
- electroplating

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.

**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.

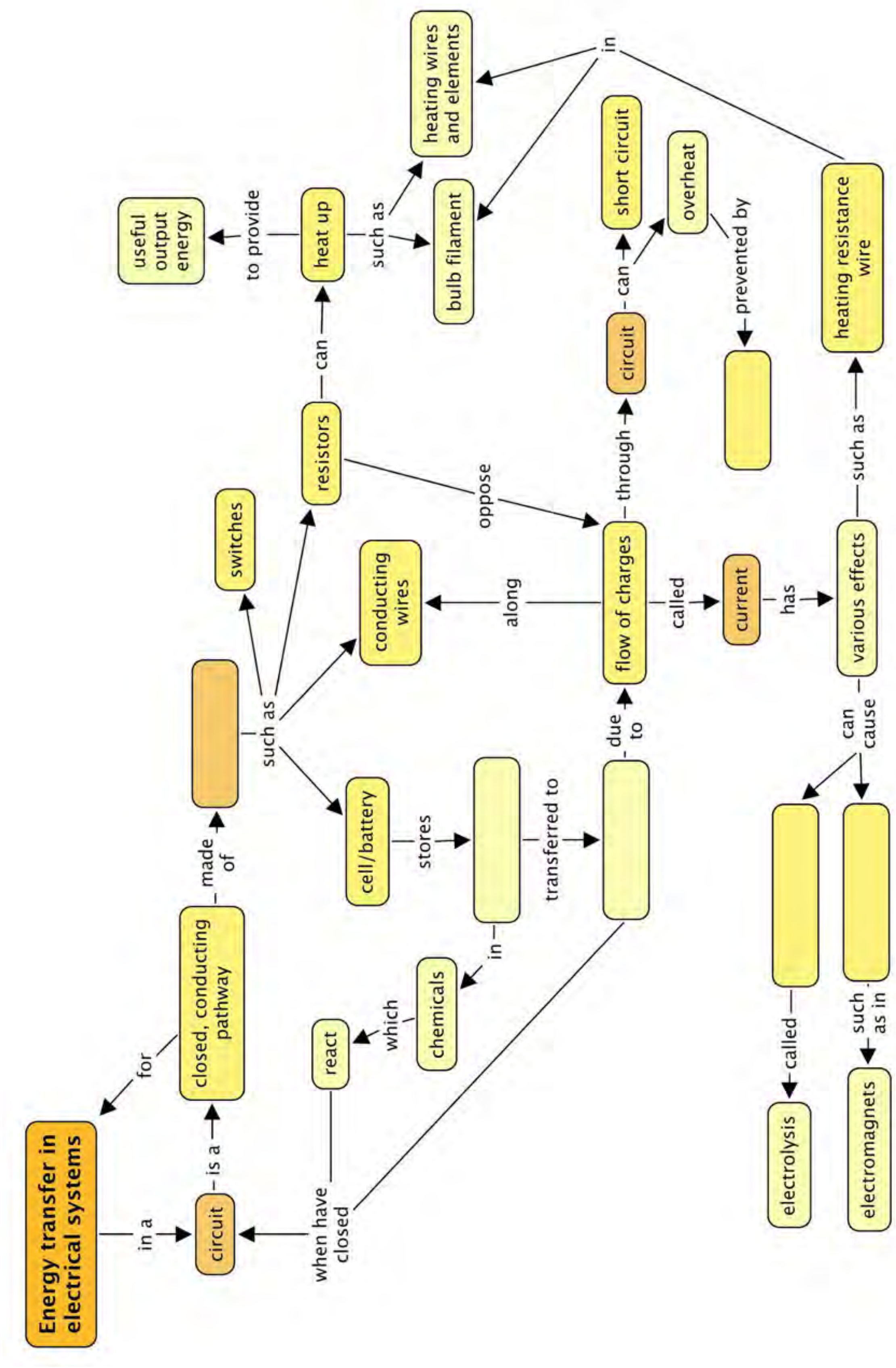
## SUMMARY:

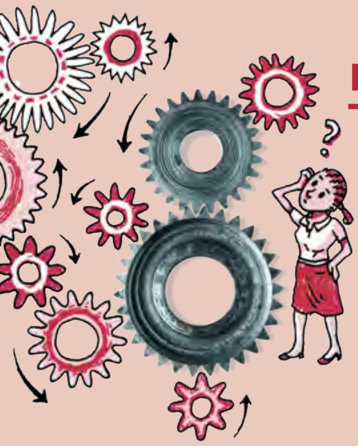
### Key Concepts

- 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 (lightbulb 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 chapter.


Energy transfer in electrical systems
in a
circuit
is a
closed, conducting pathway
for
made of
such as
cell/battery
conducting wires
switches
resistors
can
heat up
to provide
useful output energy
such as
bulb filament
heating wires and elements
in
stores
transferred to
in
chemicals
which
react
when have closed
due to
flow of charges
along
oppose
through
circuit
can
short circuit
overheat
prevented by
called
current
has
various effects
such as
heating resistance wire
can cause
called
electrolysis
such as in
electromagnets



## REVISION:

1. Write your own definition for an electric circuit. [2 marks]

2. What type of energy does a battery have? [1 mark]

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 marks]

4. List 3 materials which conduct electricity. [3 marks]

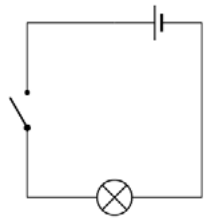
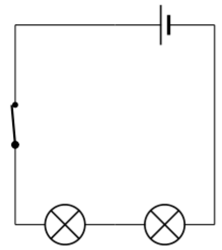
5. List 3 materials that do not conduct electricity. [3 marks]

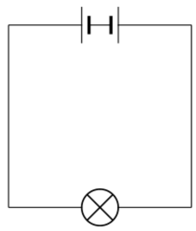
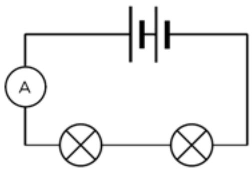
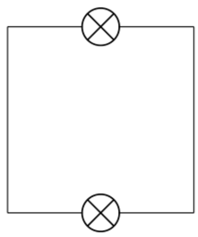
6. You have a battery, insulated copper conducting wires and a light bulb. Draw a setup which would allow you to test whether the materials you listed in questions 1 and 2 are conductors or not. [4 marks]

7. Draw the symbols for the following components. [6 marks]

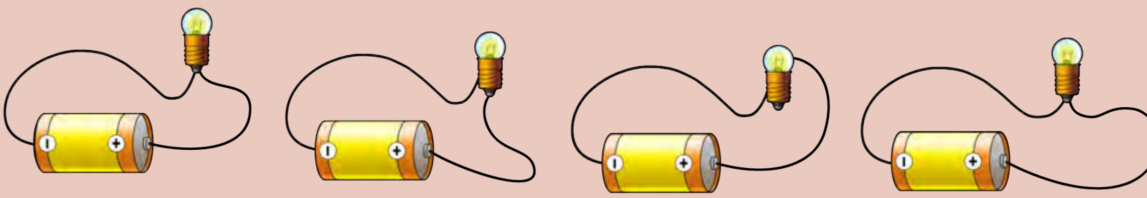
| | |
|---|---|
| A cell | A light bulb |
| A conducting wire | An open switch |
| A resistor | A variable resistor |

8. Look at the circuits below. If the bulb(s) will glow, place a tick next to the picture and explain why it will glow. If the bulb(s) will not glow, place a cross next to the picture and explain why it will not glow. [10 marks]

| **Circuit** | **Glow/Not Glow** | **Explanation** |
|---|---|---|
|  | | |
|  | | |

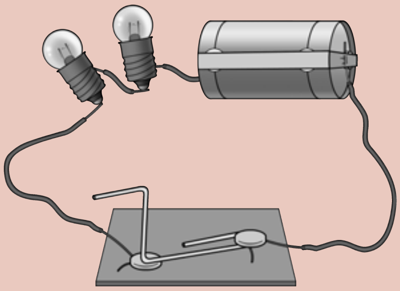
| Circuit | Glow/Not Glow | Explanation |
|---|---|---|
|  | | |
|  | | |
|  | | |

9. Which of the following setups shows the correct way to connect a light bulb to a battery? Explain your answer. [2 marks]



A B C D

10. Draw a circuit diagram to illustrate the following circuit: (3 marks)

| **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 marks]

______________________________________________

______________________________________________

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 marks]

______________________________________________

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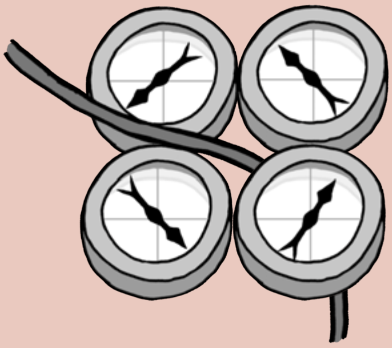
13. What is the benefit of using a circuit breaker rather than a fuse? [2 marks]

______________________________________________

______________________________________________

14. Look at the following photo of a light bulb. Label the filament and explain why it glows. [4 marks]

15. You place some plotting compasses around an electric wire and observe the following.



a) Is there are current in the conducting wire? [1 mark]

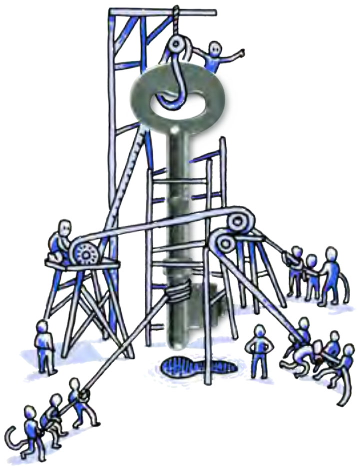
b) Explain your answer. [2 marks]

16. Give two advantages of electroplating iron metal. [2 marks]

Total [55 marks]

Curious? Discover the possibilities with a magnifying glass.

# 3 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?

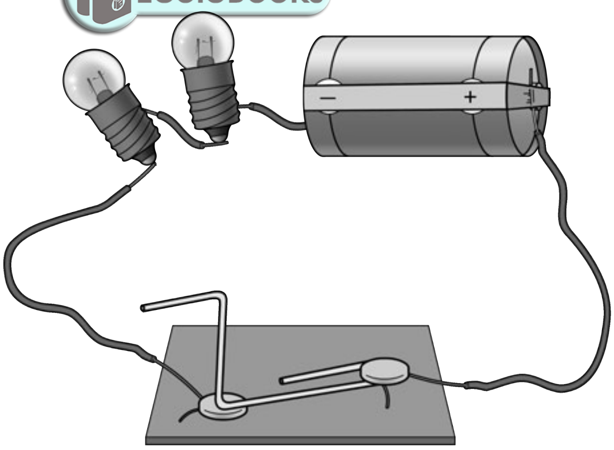
In the last chapter, and in Gr 6 and 7, we have been looking at electric circuits. These have mostly been series circuits. What does this mean? And how else can a circuit be arranged?

**NEW WORDS**

- series
- ammeter
- ampere
- resistance

## 3.1 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 chapter.




*A series circuit with one pathway for the current, from the negative to the positive terminal of the battery.*

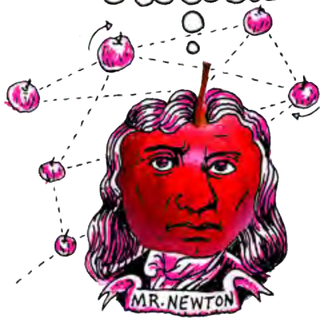
### Ammeter

An ammeter is a measuring device used to measure the electric current in the circuit. It is connected into the circuit in series. The current is measured in **amperes** (A).


*An ammeter.*

**DID YOU KNOW?**

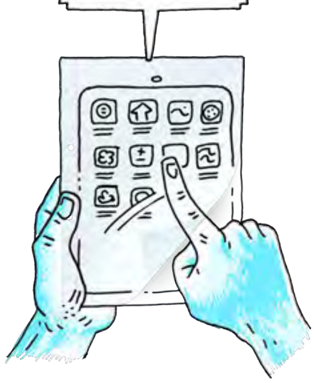
The ampere is named after André-Marie Ampère (1775-1836), a French mathematician and physicist. He is considered the father of electrodynamics, which is the study of the effect of electromagnetic forces between electric charges and currents.




What is the symbol for an ammeter? Draw it here.

**TAKE NOTE**

The ampere is often shortened to 'amp'.



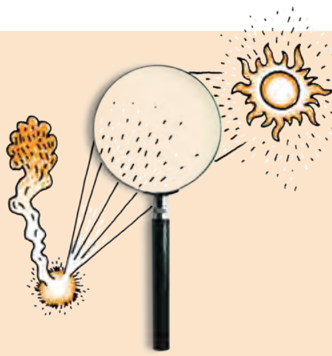
Do you think that an ammeter would have a high resistance or a low resistance to the current? Explain your choice.

___

___

A series circuit only provides one pathway for the electrons to follow. Let's investigate what happens when we increase the resistance in a series circuit.

## 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.

___

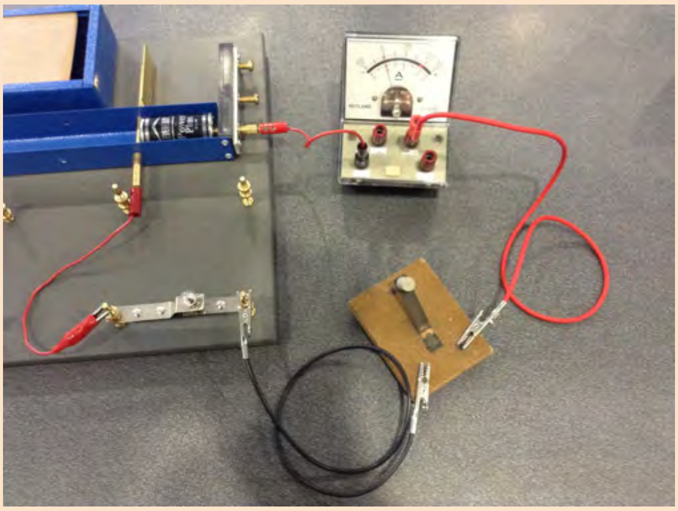
___

**MATERIALS AND APPARATUS:**

- 1,5 V cells
- 3 torch bulbs
- insulated copper conducting wires
- switch
- ammeter

**METHOD:**

1. Construct the circuit with the cell, the ammeter, 1 bulb and the switch in series.



*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 and write down the ammeter reading. Draw a circuit diagram.

4. Open the switch.
5. Add another light bulb into the circuit.
6. Close the switch.

7. Note how brightly the bulbs are shining and write down the ammeter reading. Draw a circuit diagram.

8. Open the switch.
9. Add the third light bulb into the circuit.
10. Close the switch.
11. Note how brightly the bulbs are shining and write down the ammeter reading. Draw a circuit diagram for the last circuit you built.

**RESULTS:**

Complete the table:

| Number of bulbs in series | Brightness of bulbs | Reading on ammeter (A) |
|---|---|---|
| 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 glow the same as each other or was one brighter than the others?

4. What do your answers to the previous questions tell you about the current in the series circuit?

5. What happened to the reading on the ammeter as you added more bulbs in series?

**CONCLUSION:**

1. Based on your answers, what happened to the current 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 current?


**AIM:** To investigate the effect of increasing the number of cells connected in series on the electric current strength.

**HYPOTHESIS:** Write a hypothesis for this investigation. Remember to mention how the increase in the number of cells will affect the current strength.

**MATERIALS AND APPARATUS**

- three 1,5 V cells
- insulated copper conducting wires
- ammeter
- 2 torch light bulbs (or 1 torch light bulb and one resistor)

**METHOD:**

1. Construct a circuit with 1 cell, the ammeter and the two torch light bulbs.
2. Observe the brightness of the bulbs and record the ammeter reading in the table of results. Draw a circuit diagram.

3. Add a second cell in series and observe the brightness of the bulbs. Draw a circuit diagram of your circuit.
4. Record the ammeter reading in the table of results. Draw a circuit diagram.

5. Add a third cell in series and observe the brightness of the bulbs. Draw a circuit diagram of your circuit.

6. Record the ammeter reading in the table of results. Draw a circuit diagram.

**RESULTS:**

Complete the table:

| Number of cells in series | Brightness of bulbs | Reading on a mmeter (A) |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

**CONCLUSION:**

1. What can you conclude from the shape of the graph?

2. Is your hypothesis true or false?

We have seen that increasing the number of cells in series increases the current, but increasing the number of resistors decreases the current.

We will now investigate the current strength at different points in a series circuit.

## INVESTIGATION: Testing the current strength

**INVESTIGATIVE QUESTION:** Is the current strength the same at all points in a series circuit?

**HYPOTHESIS:** Write a hypothesis for this investigation. What do you think will happen in this investigation?

___

___

___

**MATERIALS AND APPARATUS:**

- insulated copper connecting wires.
- two 1,5V cells
- two torch light bulbs
- ammeter

**METHOD:**

1. Set up a series circuit with two cells and two torch light bulbs in series with each other.
2. Insert an ammeter in series between the positive terminal of the batteries and the first torch bulb.
3. Measure the current strength using the ammeter. Draw a circuit diagram of this set up.

4. Remove the ammeter and close the circuit again.
5. Insert the ammeter in series between the two torch bulbs.
6. Measure the current strength using the ammeter. Draw a circuit diagram of this set up.

7. Remove the ammeter and close the circuit again.
8. Insert the ammeter in series between the last torch bulb and the negative terminal of the batteries.
9. Measure the current strength using the ammeter. Draw a circuit diagram of this set up.

**RESULTS:**

Complete the following table:

| **Position of ammeter in circuit** | **Ammeter reading (A)** |
|---|---|
| Between positive terminal of cell and first bulb | |
| Between two bulbs | |
| Between negative terminal of cell and last bulb | |

**CONCLUSIONS:**

1. Write a conclusion based on your results.

___

2. Is your hypothesis true or false?

___

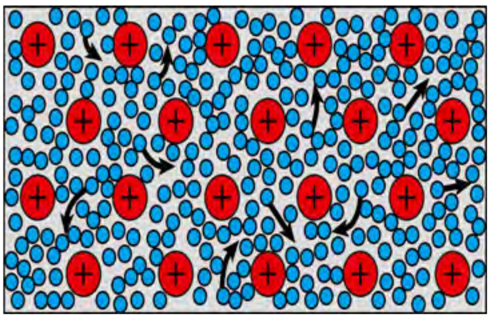

In a series circuit, there is only one pathway for the electrons to move through. The current strength is the same everywhere in that pathway.

What have we learned about series circuits?

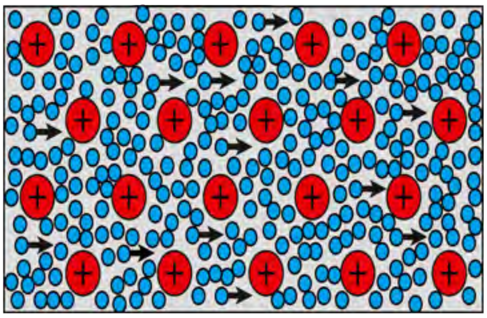
- There is only **one** pathway for the electrons to follow.
- The current flows at the **same strength** everywhere in a series circuit, because there is only one pathway. We say that the current is the same at all points in the circuit.
- If you add more resistors in series, the current in the whole circuit **decreases**.

Why does the current stay the same at all points? Let's think about how electric current moves through a circuit. Do you remember that we spoke about the delocalised electrons in metals in the last chapter?

The electrons in a conductor normally drift in various different directions within a metal, as shown in the diagram.

*Delocalised electrons move freely in a conducting wire.*



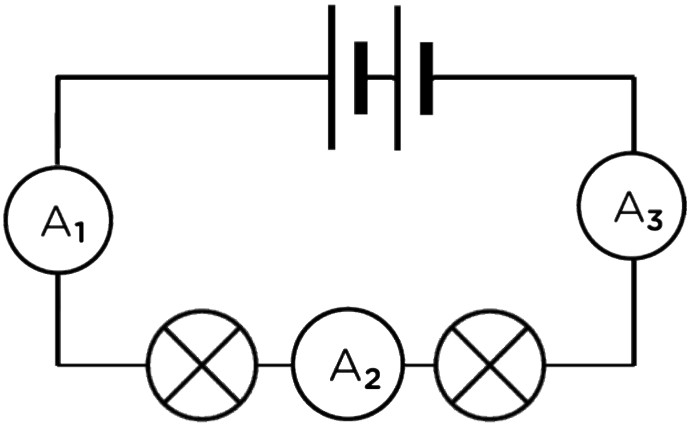
*When the wire is connected in a closed circuit, the electrons move towards the positive terminal of the battery.*

When we build a closed circuit with a cell as an energy source, the electrons will all begin to move towards the positive side of the cell. The rate at which the electrons move, is determined by the resistance of the conductor.

There are electrons everywhere in the conducting wires and electrical components. When the circuit is closed, all the electrons start moving in the same general direction **at the same time**. This is why a light bulb turns on immediately when you close the switch.

In a series circuit, all the electrons travel through every component and wire as they travel through the circuit. All the electrons experience the same resistance and so they all move at the same rate.

This means that in the diagram below, the readings on all three ammeters will be the same, so: $\mathbf{A_1 = A_2 = A_3}$

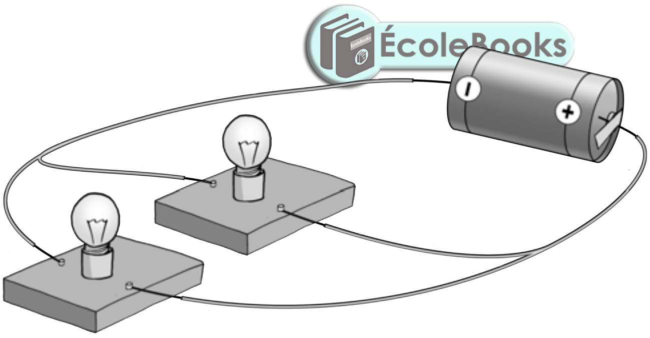



NEW WORDS
- parallel circuit

## 3.2 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**.

Look at the diagram which shows how two light bulbs are connected in parallel.



*There are two paths for the current in this parallel circuit, one path through each of the bulbs.*

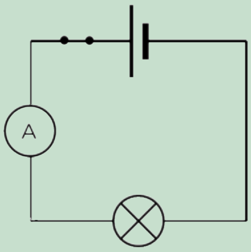
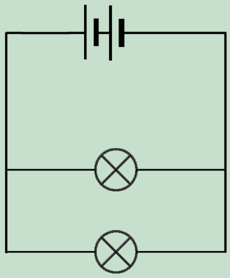
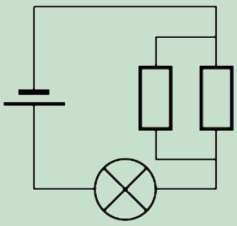
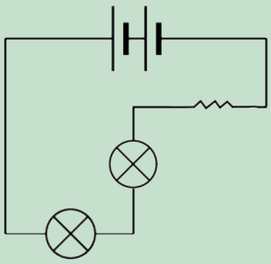
**VISIT**
Watch a video that explains the difference between series and parallel circuits
bit.ly/1f5hZOW

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.

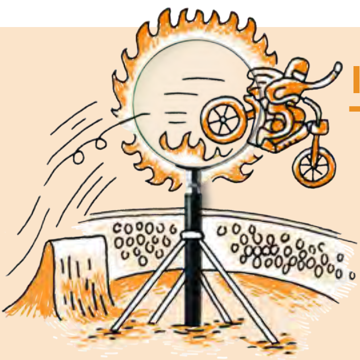
## ACTIVITY: Series or parallel?

**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.

| | |
|---|---|
|  |  |
| | |
|  |  |
| | |

Let's investigate how parallel circuits work.



## INVESTIGATION: How does adding resistors in parallel affect the current strength?

**AIM:** To investigate the effect of adding resistors in parallel on the current strength.

**HYPOTHESIS:** Write a hypothesis for this investigation.

**MATERIALS AND APPARATUS:**

- 1,5 V cell
- three identical torch bulbs
- insulated copper conducting wires
- switch
- ammeter

**METHOD:**

1. Construct the circuit with the cell, ammeter, one bulb and the switch in series.
2. Close the switch.
3. Note how brightly the bulb is shining and record the ammeter reading. 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 and record the ammeter reading.
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 and record the ammeter reading.

**RESULTS:**

Complete the table:

| **Number of bulbs in parallel** | **Brightness of bulbs** | **Reading on ammeter (A)** |
|---|---|---|
| 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 glow the same brightness or was one brighter than the others?

4. What do your answers to the previous questions tell you about the current in the parallel branches of the circuit?

5. What happened to the reading on the ammeter as you added more bulbs in parallel?

**CONCLUSION:**

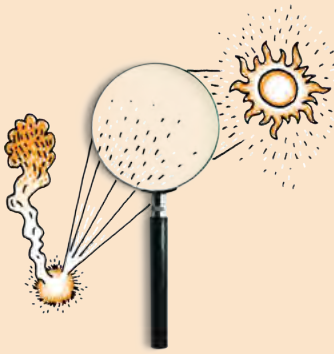
1. Based on your answers, what happened to the current when more bulbs were added in parallel?

2. Is your hypothesis true or false?

As more resistors are added in parallel, the total current strength 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
- ammeter

**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 and record the ammeter reading.
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 and record the ammeter reading.
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 and record the ammeter reading.

**RESULTS:**

Complete the table:

| Number of cells in parallel | Brightness of bulb | Reading on ammeter (A) |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

**CONCLUSION:**

1. What did you notice about the brightness of the bulbs?

2. What did you notice about the ammeter readings?

3. What conclusion can you draw from your results?

Adding cells in parallel has no overall effect on the current strength. The current strength stays the same if you add cells in parallel.

We saw that the current strength increased when bulbs were connected in parallel. However, we were only testing the current strength at one point in the parallel circuit. How does the current compare in the different pathways of the circuit? Let's do an investigation to find out.

## INVESTIGATION: Testing the current strength

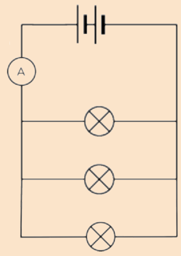

**INVESTIGATIVE QUESTION:** Is the current strength equal at all points in a parallel circuit?

**MATERIALS AND APPARATUS:**

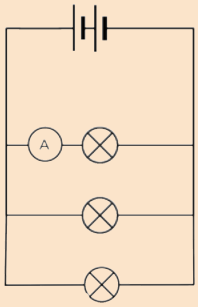
- insulated copper connecting wires.
- two 1,5V cells
- three identical torch light bulbs
- ammeter

**METHOD:**

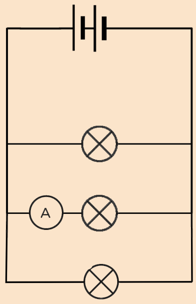
1. Set up a parallel circuit with two cells in series with each other and three torch light bulbs in parallel with each other.
2. Insert an ammeter in series between the cells and the first pathway, as shown in the diagram.



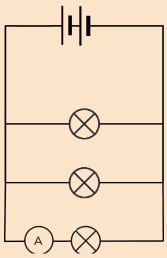

3. Measure the current strength using the ammeter.
4. Remove the ammeter and close the circuit again.
5. Insert the ammeter in series in the first pathway.



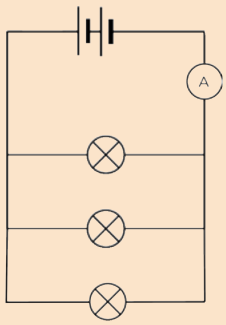

6. Measure the current strength using the ammeter.
7. Remove the ammeter and close the circuit again.
8. Insert the ammeter in series in the second pathway.




9. Measure the current strength using the ammeter.
10. Remove the ammeter and close the circuit again.
11. Insert the ammeter, in series, in the third pathway.



12. Measure the current strength using the ammeter.
13. Remove the ammeter and close the circuit again.
14. Insert the ammeter in series between the first pathway and the cells on the opposite side to the first reading.




15. Measure the current strength using the ammeter.

**RESULTS:**

| Position of ammeter in circuit | Ammeter reading (A) |
|---|---|
| between the cell and first pathway | |
| in the first pathway | |
| in the second pathway | |
| in the third pathway | |
| between the cell and the first pathway | |

**CONCLUSION:**

1. Write a conclusion based on your results.

___

___

___

2. Is your hypothesis true or false?

___

What have we learned about parallel circuits?

- There is **more than one** pathway for the current to follow.
- The current divides between the different branches so that each branch gets some of the current. As the torch bulbs in each branch in our example were identical, the current divided equally between them.
- If you add more resistors in parallel, the total current supplied by the cell in the circuit **increases**.

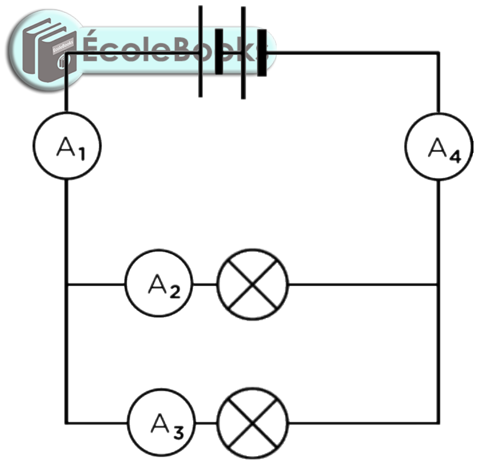
Why does the current divide when offered an alternative pathway?

Imagine that you are sitting in a school hall during assembly. You are bored and waiting for it to end so that you can go out to break to chat to your friends. There is only one exit from the hall. When you are dismissed, everyone has to exit through the same door. It takes a while because only some learners can leave at a time.

Now imagine that there is a second door that is the same as the first door. Now you and your friends have a choice of which door to go through. The speed at which the learners exit the hall will increase and some of you will exit through the first door while others will exit through the second door. No one can go through both doors at the same time.

This is similar to the way current behaves when in a parallel circuit. As the electrons approach the branch in the circuit, some electrons will take the first path and others will take the other path. The current is divided between the two pathways.

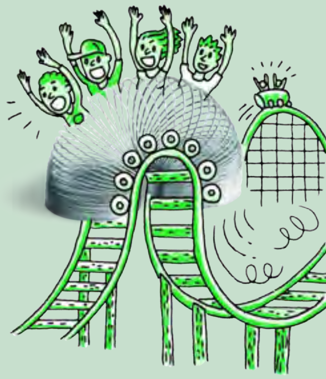
In the following circuit $A_1 = A_4$ and $A_1 = A_2 + A_3$ and $A_4 = A_2 + A_3$




We have looked at how resistors and cells behave in series and parallel circuits. Let's look at how different metals conduct electricity. All conductors have some resistance in a circuit. Are some metals better conductors of electricity than others?

Let's have a look at which metals offer more resistance than others to the flow of charge (current) through an electric circuit .

## **ACTIVITY:** Which metals offer the most resistance?

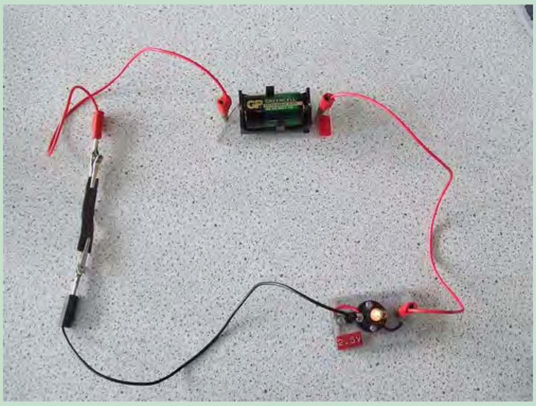


**MATERIALS:**

- a cell
- torch light bulb
- insulated copper wires
- lengths of copper, aluminium, zinc and nichrome wire
- crocodile clips (if available)

**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).



*An example circuit with a cell, a light bulb and the piece of metal being tested.*

Observe the brightness of the bulb.

**QUESTIONS:**

1. Draw a circuit diagram of your apparatus.

**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

2. Why can we use the brightness of the bulb to qualitatively measure resistance?

3. List the metals in order of increasing resistance.

4. Why do you think copper is used for connecting wires in electrical circuits?

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.



## 3.3 Other output devices

**VISIT**

Watch this video about the history of the LED

bit.ly/1bC5qKc

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.

*Different LED bulbs.*

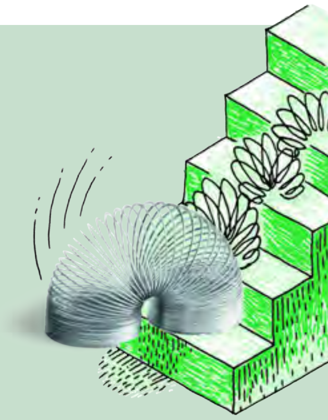
VISIT

Video on drawing a basic Sankey diagram.

bit.ly/19Wwxsu

In the last chapter, 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.

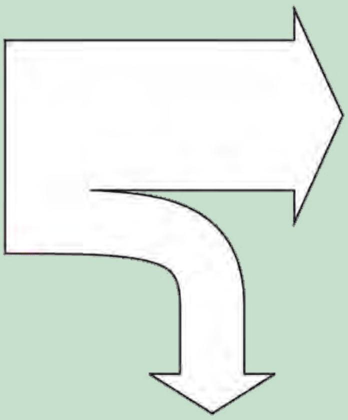
## ACTIVITY: Sankey diagrams



You might have drawn Sankey diagrams in Grade 7. If not, here is some quick revision.

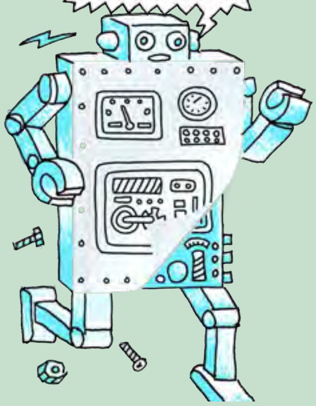
In an energy system, input energy is transferred to useful output energy and wasted output energy. A Sankey diagram is a visual and proportional representation of the energy transfers that happen in a system.

For example, a kettle uses about 2000 J of input energy, but only about 1400 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.




TAKE NOTE

Remember that energy is measured in joules (J).



**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.

______________________________________________

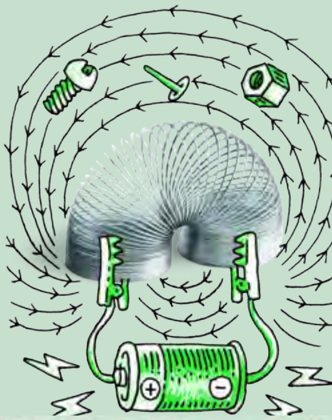
______________________________________________

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 it's 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.

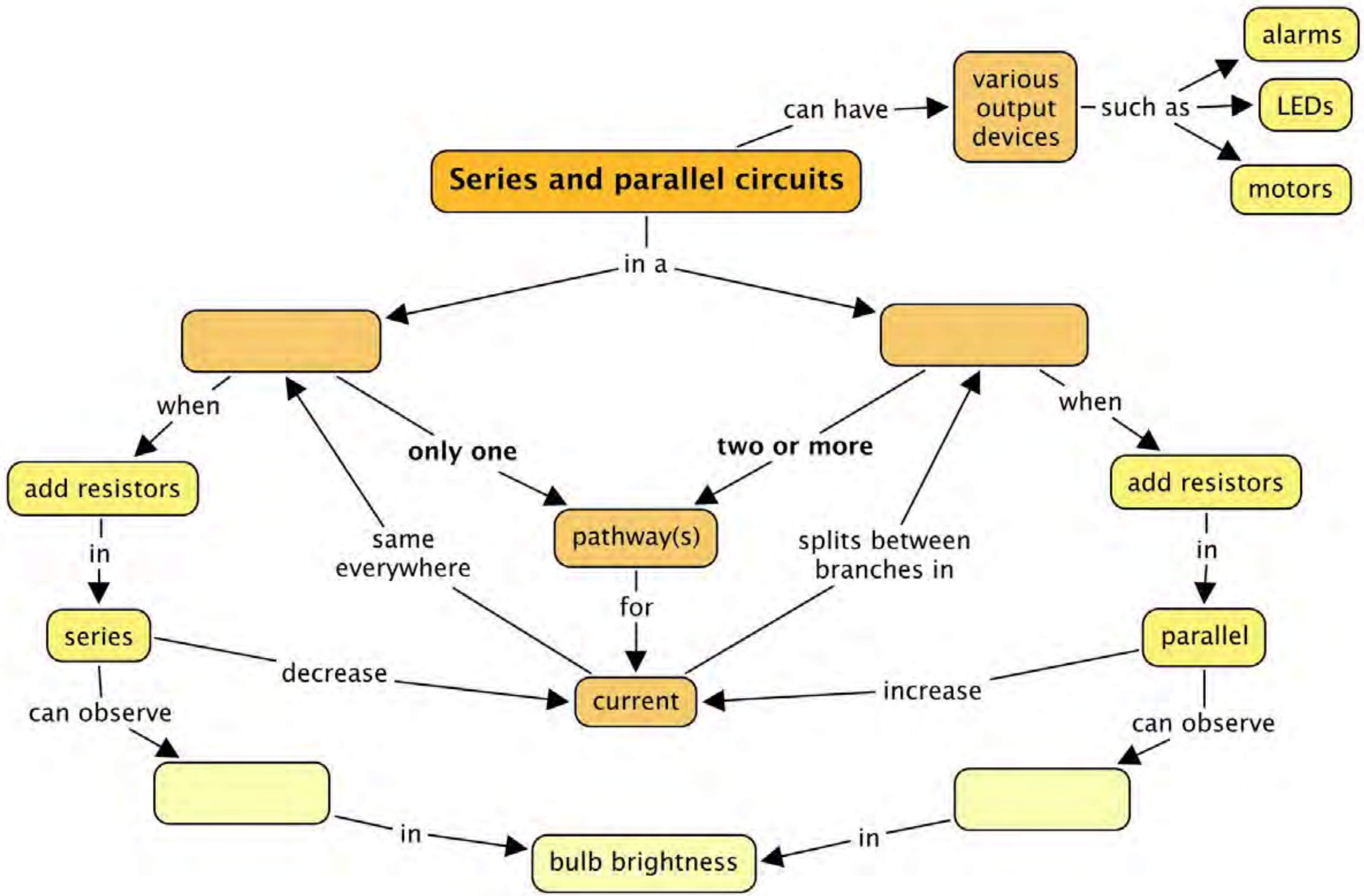
## SUMMARY:

### 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 current is the same at all points in the circuit.
- In a series circuit, the resistance increases as more resistors are added in series.
- In a parallel circuit, the current splits between the available paths.
- In a parallel circuit, the resistance decreases as more resistors are added in parallel.

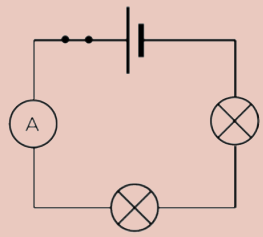
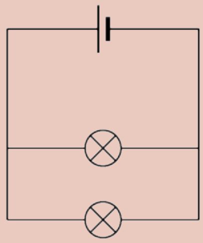
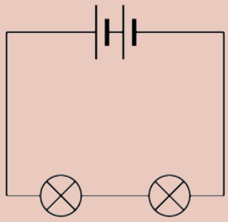
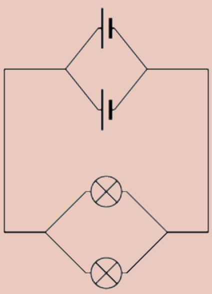
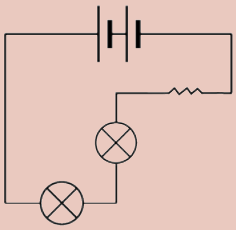
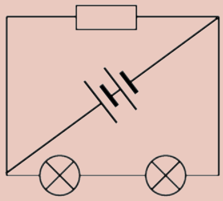
### Concept Map

Complete the concept map on the following page to summarise what you have learned about series and parallel circuits.

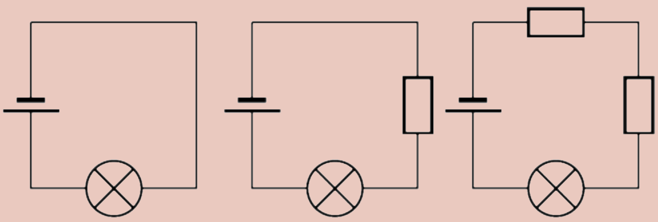

Series and parallel circuits
can have
various output devices
such as
alarms
LEDs
motors
in a
when
add resistors
in
series
can observe
only one
same everywhere
pathway(s)
for
current
two or more
splits between branches in
when
add resistors
in
parallel
can observe
decrease
increase
in
in
bulb brightness

## REVISION:

1. Look at the following circuit diagrams and decide whether they are series circuits or parallel circuits. Write the correct answer in the space below each diagram. [6 marks]

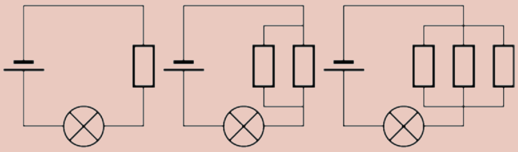
| | | |
|---|---|---|
|  |  |  |
| | | |
|  |  |  |
| | | |

2. Look at the three circuit diagrams. Rank the circuits from brightest bulb to dimmest bulbs. [3 marks]



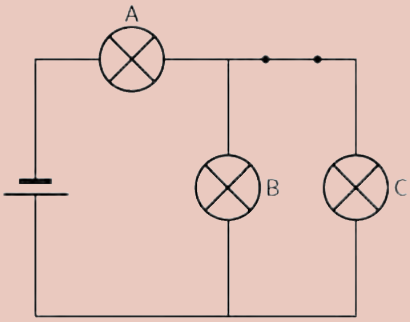
3. Explain your choices in the previous question. [5 marks]

4. Look at the three circuit diagrams. Rank the circuits from brightest bulb(s) to dimmest bulb(s). [3 marks]



5. Explain your choices in the previous question. [5 marks]

6. Look at the circuit diagram below. Each light bulb is identical.

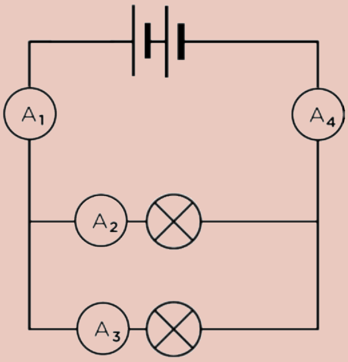



a) Is this a series or parallel circuit? Explain your answer. [2 mark]

b) How do the brightness of bulbs A, B and C compare? (which is the brightest?) [3 marks]

c) What would happen to the brightness of the bulbs if the switch was opened? Explain your answer. [5 marks]

7. Study the following diagram.




a) What is the relationship between the ammeter readings on A1 and A4? In other words, how do the current strengths compare at these points in the circuit? Explain your answer. [3 marks]

b) What is the relationship between the ammeter readings on A1, A2 and A3? In other words, how do the current strengths compare at these points in the circuit? Explain your answer. [3 marks]

Total [38 marks]

Draw and discover the possibilities of what a slinky can be.

# 4 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?

In this chapter 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.

**NEW WORDS**
- luminous
- radiation
- rectilinear
- propagation

## 4.1 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.

*The Sun is our main source of light on Earth.*

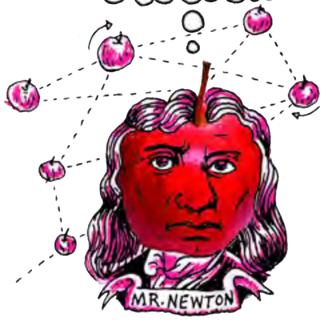
*A light bulb is a luminous object as it emits light.*

**VISIT**
The speed of light (video)
bit.ly/GAMgFW

*This image from NASA shows the Earth's lights at night. You can see how much we rely on light nowadays.*

**DID YOU KNOW?**

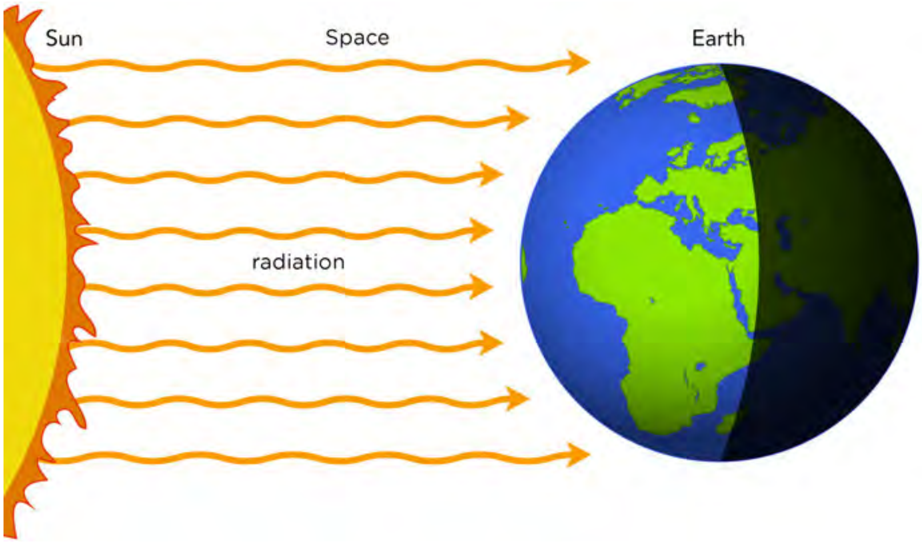
If you could travel at the speed of light you could travel around the equator 7,5 times in 1 second!




Light travels through space at a speed of 300 000 kilometers 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.

**TAKE NOTE**

The Moon is NOT a luminous object as it does not emit its own light light. It reflects the light from the Sun.




*Light and heat are transferred to Earth through space from the Sun by radiation.*

**DID YOU KNOW?**

It takes light 8 minutes to travel from the Sun to the Earth.

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 can
- craft knife
- aluminium foil
- tape
- ruler
- drawing pin

**INSTRUCTIONS:**

**TAKE NOTE**

The Sun emits radiation in **all directions**, but in the diagram here, only the radiation which reaches Earth has been shown.

1. Measure 5 cm from the bottom of the can (opposite end to the plastic lid) and make a mark all around the can.

2. Cut through the can along the line so that you have cut the can into 2 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 2 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 can.
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?

______________________________________________

______________________________________________

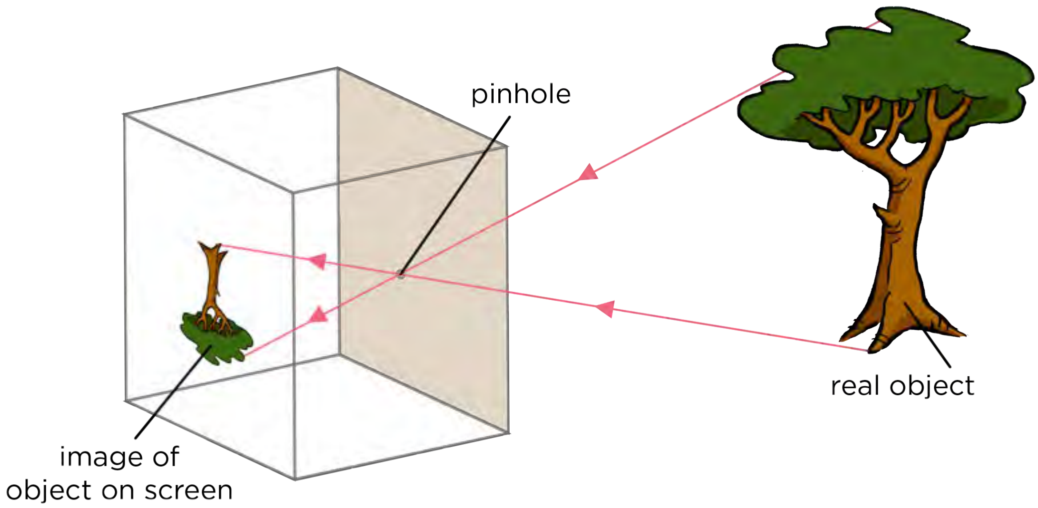
2. What happens when you move closer or further away from an object?

______________________________________________

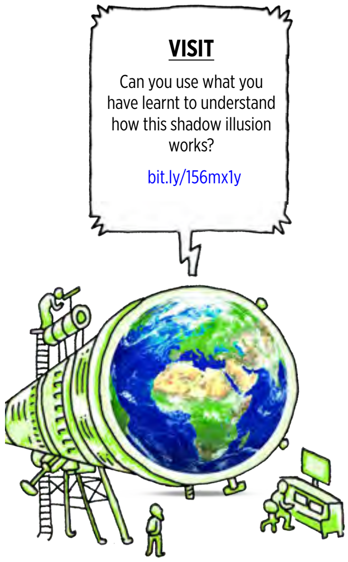
______________________________________________

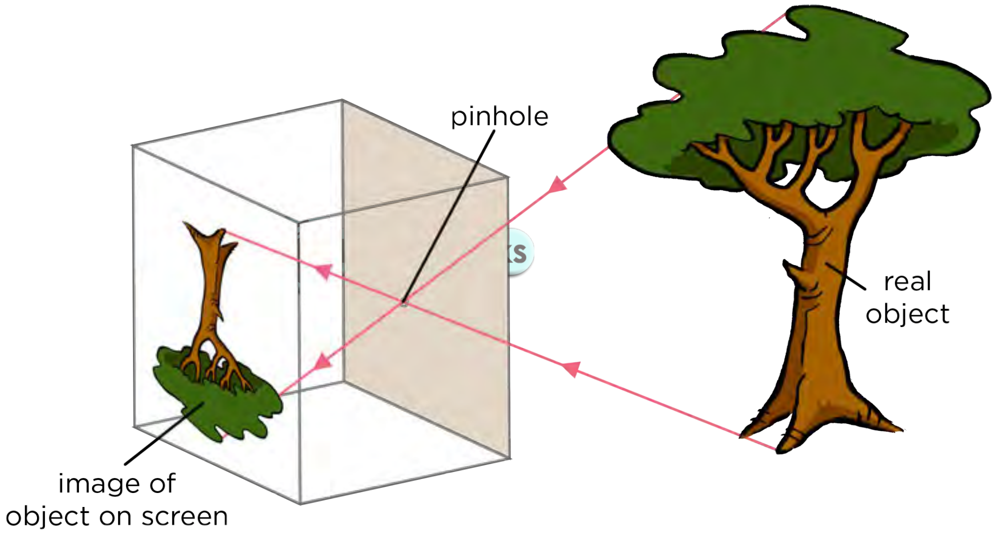

Did you see an upside down image? Why is it upside down?

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.

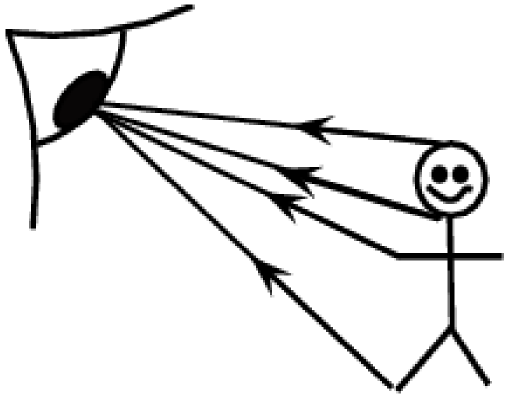


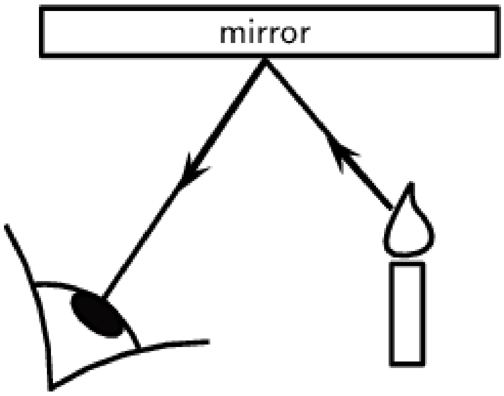

What does this mean? It means that light must be travelling in straight lines. This is called the **rectilinear propagation** of light.

## 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.

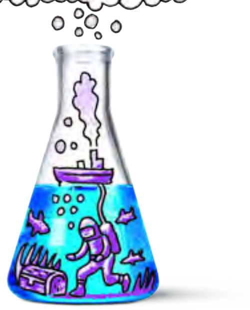


*A ray diagram showing how you see another person.*




*A ray diagram showing how you see a reflection in a mirror.*

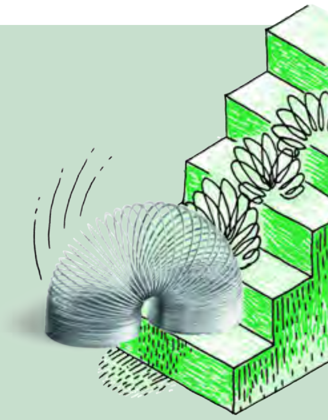
**NEW WORDS**
- composition
- visible spectrum
- dispersion



## 4.2 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 everyday are part of the visible light spectrum. Let's investigate the visible light spectrum.

### 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?

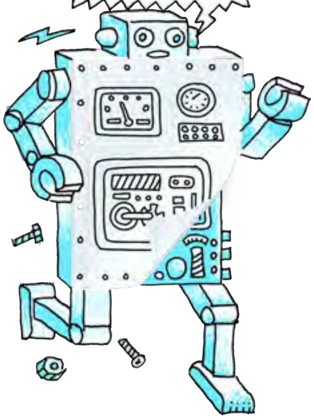
5. What do the different colours we see tell us about the composition of white light?

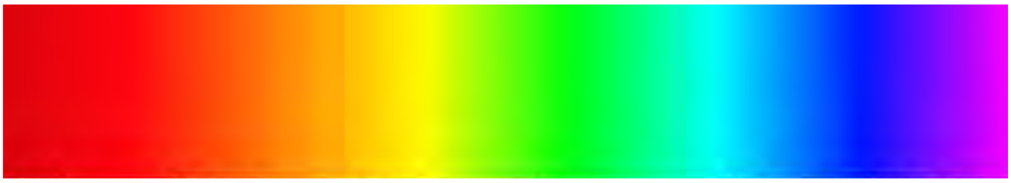
So, what have we learned so far? Light radiates from luminous objects and always travels in straight lines. The white light that we see is made up of the 7 different colours of the spectrum. When the 7 colours are travelling together we see them as white light.

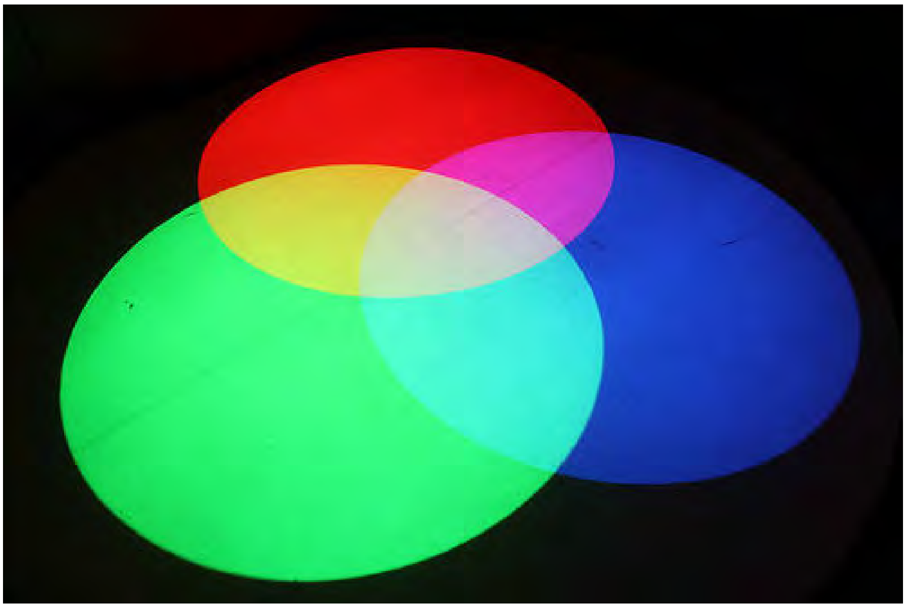
The 7 colours of the visible spectrum are **R**ed, **O**range, **Y**ellow, **G**reen, **B**lue, **I**ndigo and **V**iolet. Each colour has a different wavelength and frequency. Have a look at the following image which shows the spectrum of visible light.

**TAKE NOTE**

You can use the abbreviation ROYGBIV to remember the order of the colours.



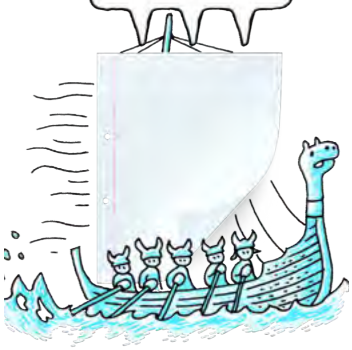


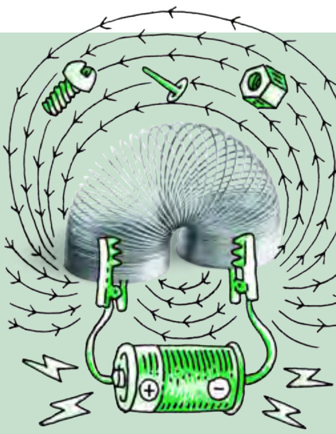
*The colours combine to form white light.*

**TAKE NOTE**

The primary colours of light are red, green and blue.



## **ACTIVITY:** Colour spinning wheels



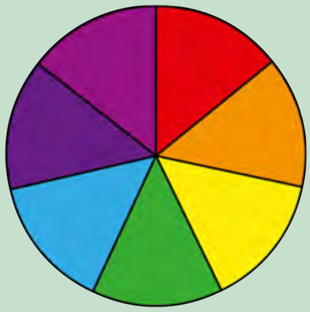
**MATERIALS:**

- white cardboard
- coloured pens or pencils (red, orange, yellow, green, blue, indigo, violet)
- string
- scissors
- round object

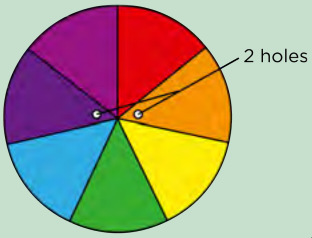
**INSTRUCTIONS:**

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.

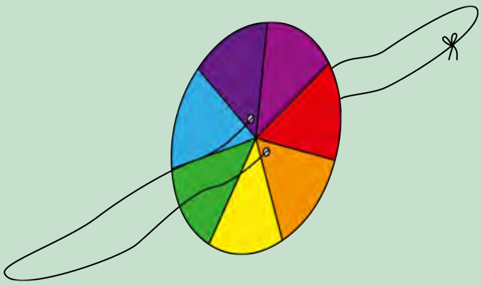
2. Now divide the circle into 7 equal segments. If you do not have indigo and violet colours, but just one purple pen or crayon, then you can divide the circle into 6 equal segments rather.
3. Shade in each segment a different colour, in the order red, orange, yellow, green, blue, indigo, violet (or 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 to 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.

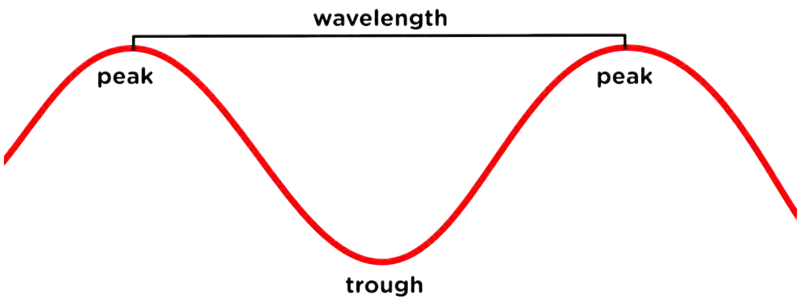
**VISIT**

There is no pink light.

bit.ly/1b2gFXU

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 only see light with a certain range of **wavelengths**. What does this mean?

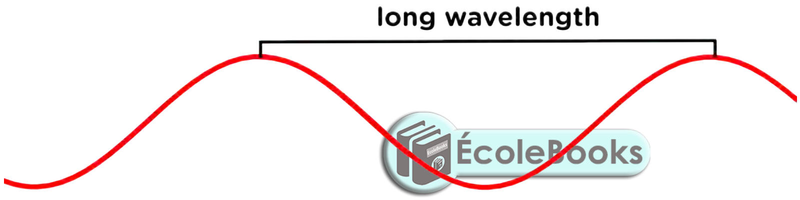
The size of a wave is measured in wavelengths. A wavelength is the distance between two corresponding points on two consecutive waves. Normally this is done by measuring from peak to peak or from trough to trough. Have a look at the following diagram which illustrates a wavelength.

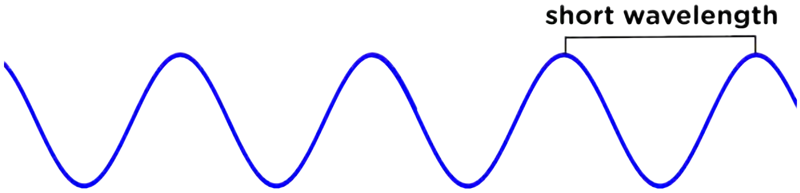



**DID YOU KNOW?**

Wavelengths can be as small as one billionth of a meter, as with gamma rays. Wavelengths can even be as long as meters, for example in radio waves.

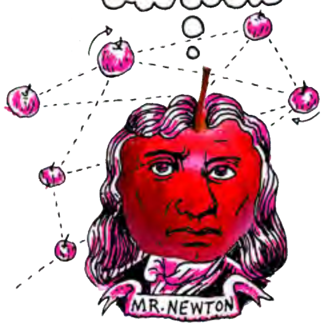
The wavelengths of the different colours of visible light are different lengths, as shown in the following diagram.



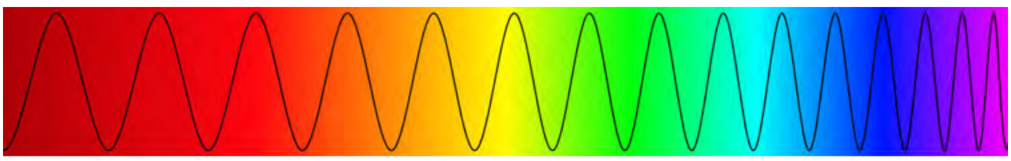




**DID YOU KNOW?**

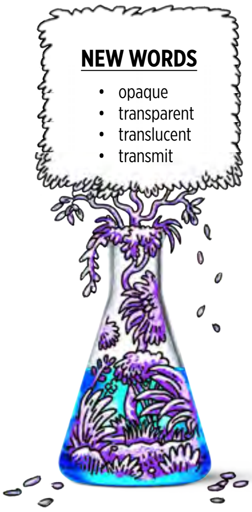
In police forensics, ultraviolet light can be used along with a special powder to detect finger and shoe prints that can help solve crimes.




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.



*Of visible light, orange and red light have the longest wavelengths (and lowest frequency) and violet, indigo and blue have the shorter wavelengths (and highest frequency).*




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.

## 4.3 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 size 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.**

*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.*

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.


*These are different colour filters for a camera. The red filter will only allow red light through and so the photograph will have a red effect applied to it. The other colours of light are absorbed by the filter.*

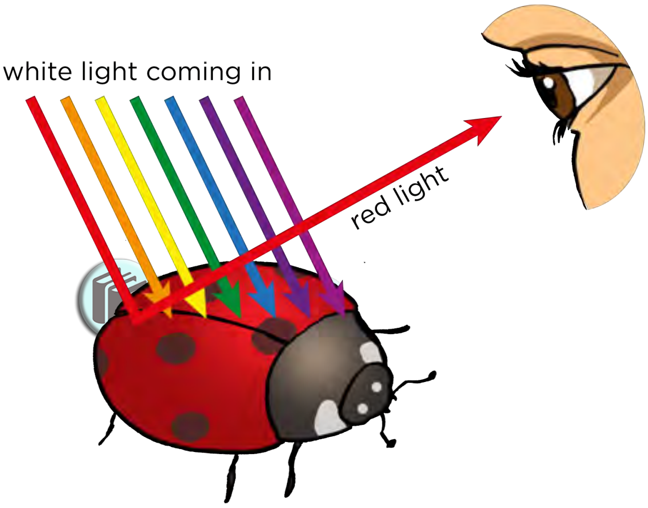
Now that we have seen some examples of transparent and opaque substances, let's take a closer look at what it means to absorb or reflect light.

## 4.4 Absorption of light

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.

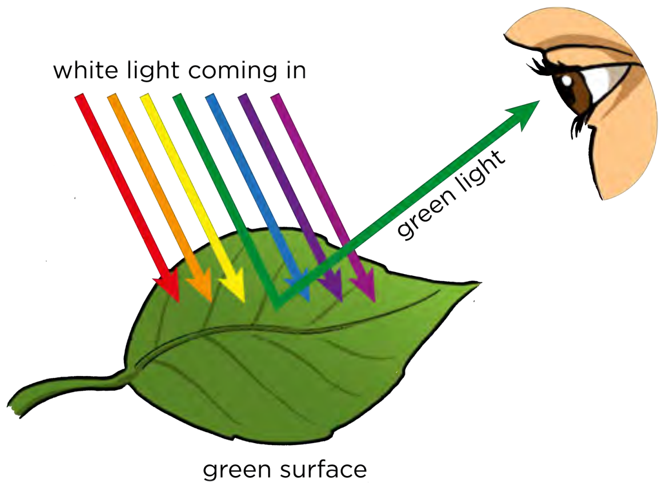
*A ladybird.*

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.




*We see the red shell of the ladybird as red light is reflected and the other colours are absorbed.*

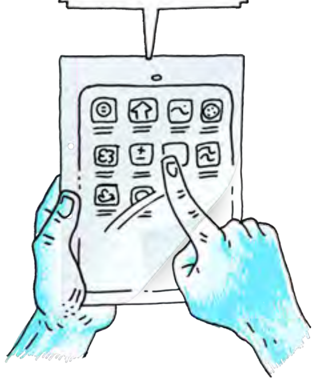
The green leaf absorbs all the colours except green which it reflects back into our eyes.




*We see a green leaf as green light is reflected and the other colours are absorbed by the leaf's surface.*

**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.



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 Gr 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.



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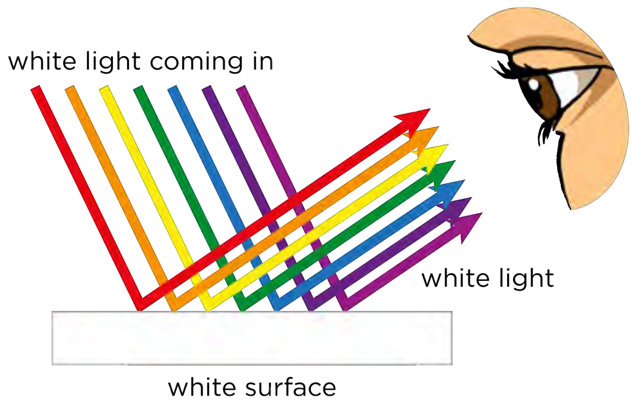
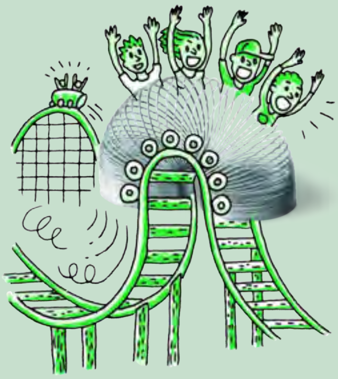




## ACTIVITY: Why do objects look red under red light?

**MATERIALS:**

- piece of red plastic to act as a filter
- light source (light bulb or torch)
- white object

**INSTRUCTIONS:**

1. Place a white object 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.

## 4.5 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.

*A tree reflection.*

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?

*Reflections on the Negro River in the Amazon.*

*Reflections in the Arno River in Italy.*

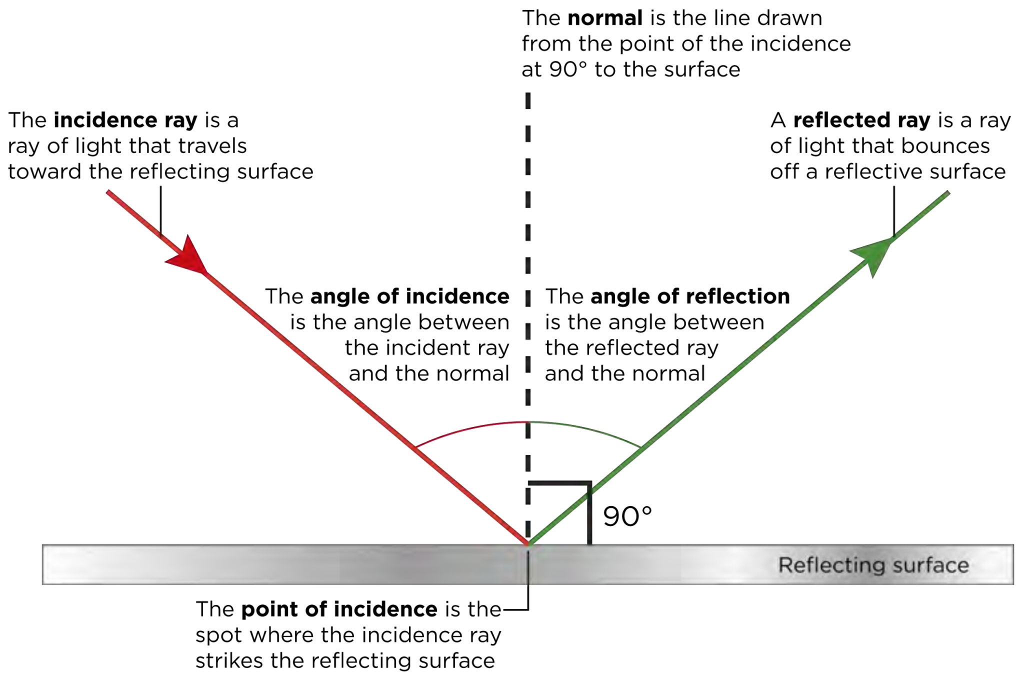
Most surfaces reflect light. When light strikes a reflective surface, it can change direction. Let's look at how this happens.

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

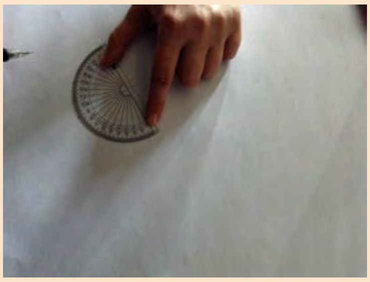
**MATERIALS AND APPARATUS:**

- 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.



*Marking a right angle with a protractor.*

4. Place your mirror upright along the first 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.

*A mirror is placed on the line and a ray shone to strike the mirror at the normal line.*

6. Use a pencil to mark the incident light ray.

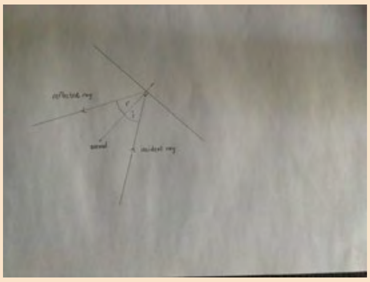
*Marking the incident light ray.*

7. Use a pencil to mark the reflected light ray.

*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.

10. Mark the angle of incidence (i) and angle of reflection (r).



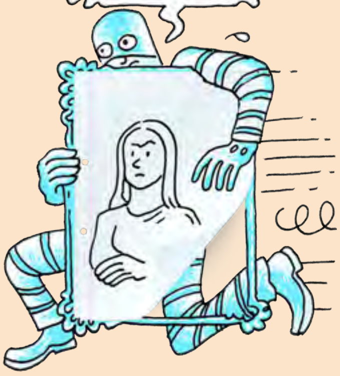
*Your ray diagram should look similar to this.*

11. Turn the ray box on again to confirm that your pencil lines follow the rays.

*The ray diagram overlaps the actual rays.*

**TAKE NOTE**

Keep one of the sheets with your drawn ray diagram for the next activity.



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.

*A different angle of incidence.*

**RESULTS:**

Fill your results into the following table.

| Repeat | Angle of Incidence | Angle of Reflection |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |

**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:**

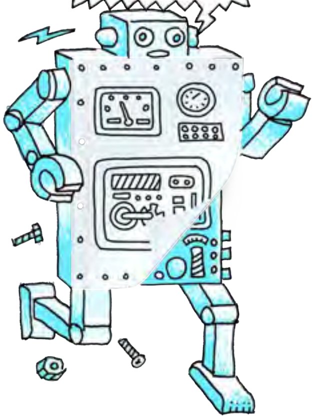
What can you conclude based on your results?

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.

**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**.



*A mirror segment from one of NASA's telescopes provides a clear and focused reflection.*

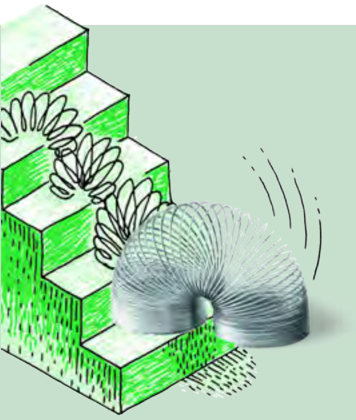
**VISIT**

What colour is a mirror? (video)

bit.ly/GABdNZ

What happens when we do not have a smooth surface? Have a look at the photo.

*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 white sheets of 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.

______________________________________________

______________________________________________

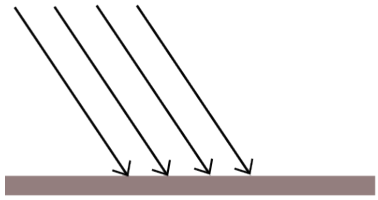
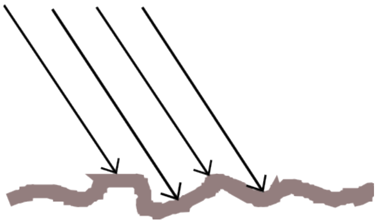
2. Why do you think you observed these differences?

______________________________________________

______________________________________________

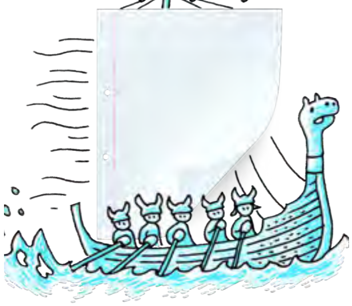
Can you now see why reflections off rippled water are not clear, but rather blurred? This is because the light rays have not reflected parallel to each other as they do from a smooth surface, but have scattered in different directions.

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.

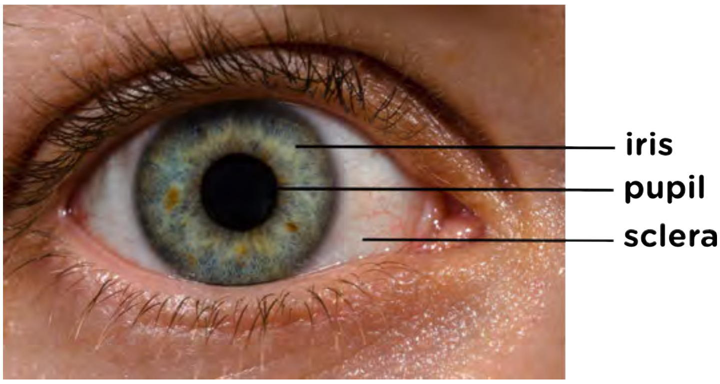
## 4.6 How do we see light?

**NEW WORDS**

- retina
- stimulate

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.






**VISIT**

2012 Nobel Prize: How do we see light?

bit.ly/1a4zs2D

We can see the iris, the pupil and the sclera. The sclera is a the 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**

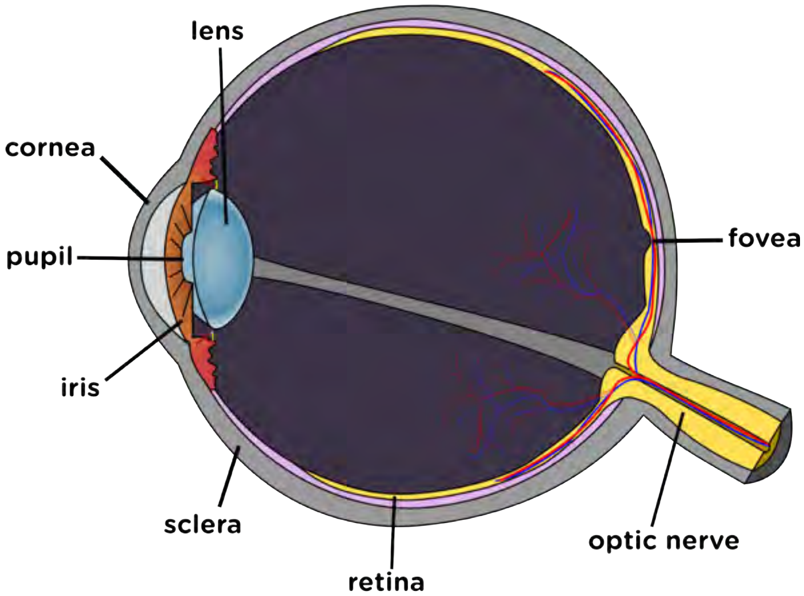
The fovea is the part of the eye located in the centre of the retina where the clearest image is formed.

*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).*

Let's take a look at the internal structure of the human eye. The following diagram shows a cross section through 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 about 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 Gr 9 Life and Living.




*A diagram of the eye.*

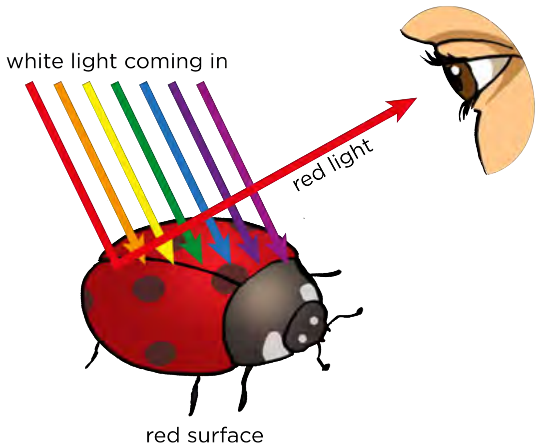
**VISIT**

Find your blind spot with this optical illusion.

bit.ly/19jumEr

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.

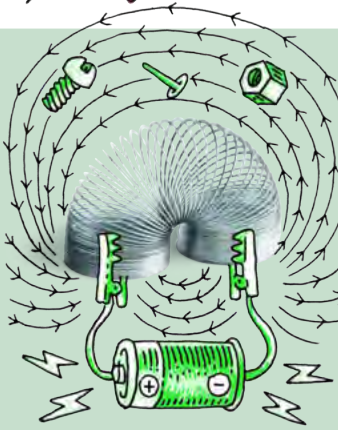
So how do we see colour? Do you remember when we spoke about why the ladybird appears red and black? Look at the following diagram again.




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 only get 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.

**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.



## 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.

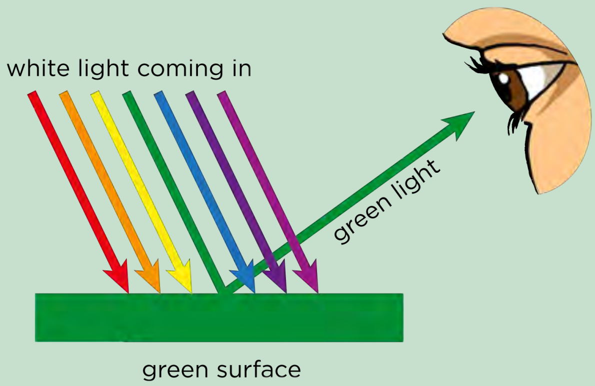
Look at the picture of a sunflower.

*A black and yellow sunflower.*

**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 can draw a ray diagram to show why we see the green leaves as green, as shown below. The green surface of the leaves absorb 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.

*Heath's blue car.*

**VISIT**
A simulation on colour vision.
bit.ly/18TbpEA

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.

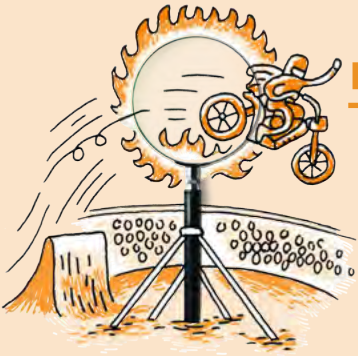
**NEW WORDS**
- refraction
- medium
- optical density

## 4.7 Refraction of light

Do you remember the last time you drank a cold drink with a straw? Did you notice that the straw did not look straight anymore once it was in the water or cool drink?

*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.



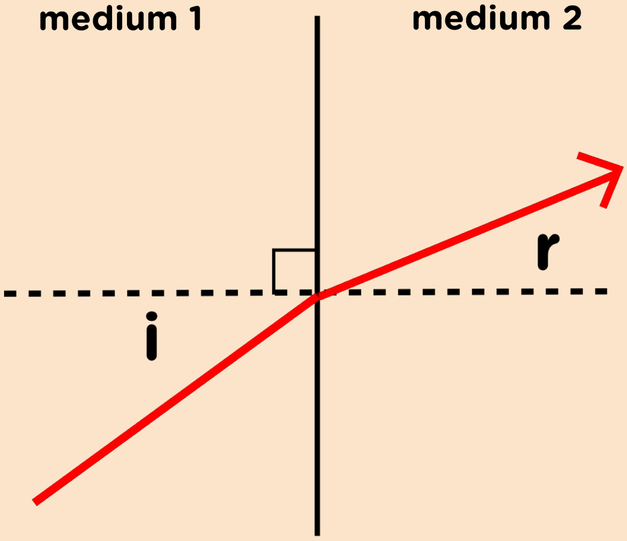
## INVESTIGATION: What happens to light when it passes through a glass block

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.

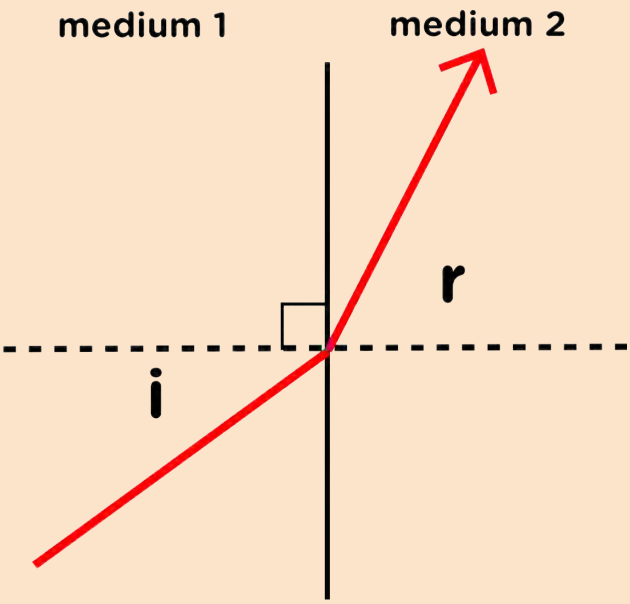



*A light ray passing from one medium to another.*

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.




*A light ray passing from one medium to another.*

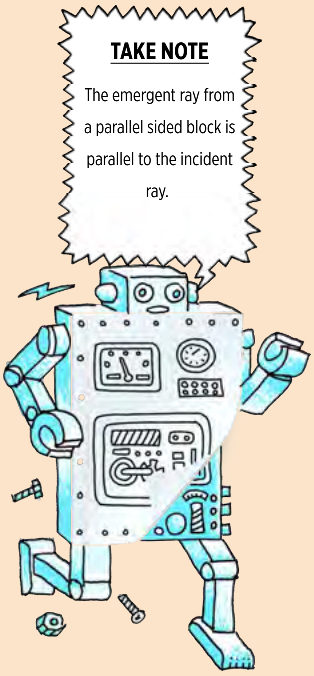
In the diagram above, does the refracted ray change direction when it enters the transparent medium? Give a reason for your answer.

In which direction did the refracted ray change?

We are now ready to start our investigation.

**AIM:** To determine whether light changes direction when it passes through a parallel-sided glass block.

**HYPOTHESIS:** Write a hypothesis for this investigation.

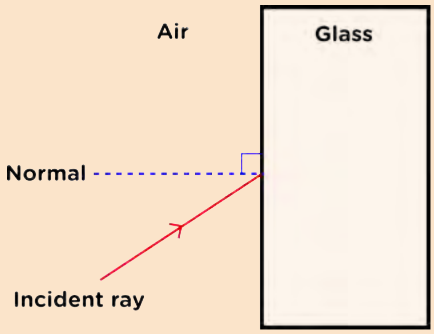



**MATERIALS AND APPARATUS:**

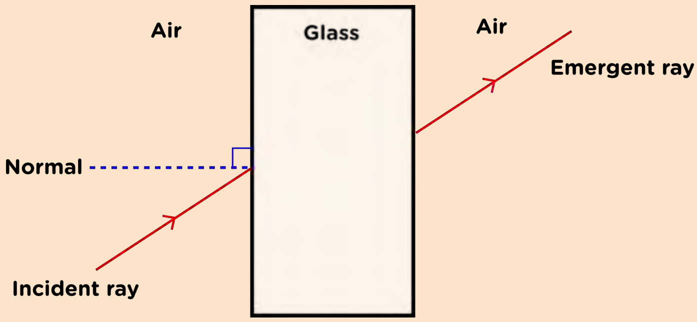
- glass block
- ray box, laser pointer or other light source
- protractor

**METHOD:**

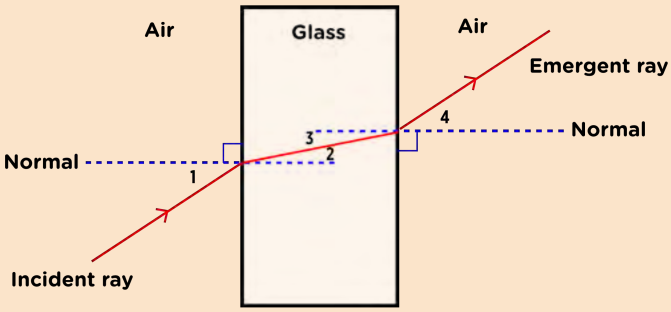
1. Put the glass block in the centre of a piece of white paper and trace around it.
2. Shine a ray of light into the glass block. The ray should be at an angle to the surface of the block.




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:**

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?

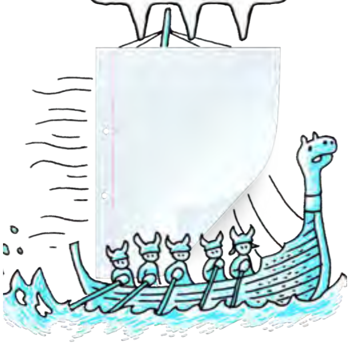

**CONCLUSION:**

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**.

**TAKE NOTE**

Remember that although we learn about Natural Sciences in 4 strands throughout the year, there are many connections and links between the strands.



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°, then it also changes direction. The more dense the medium, the slower the light moves.

Do you remember learning about density last term in Matter and Materials? Write down your own definition for density in the space below.

__________________________________________________________

__________________________________________________________

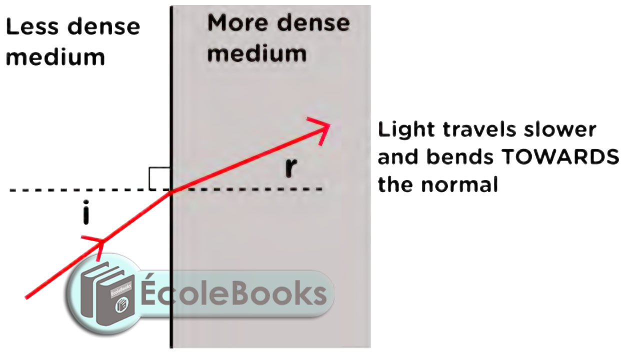
__________________________________________________________

If light moves from a less dense medium, like air, into a denser medium, like glass, then the light slows down. The light will bend towards the normal line.

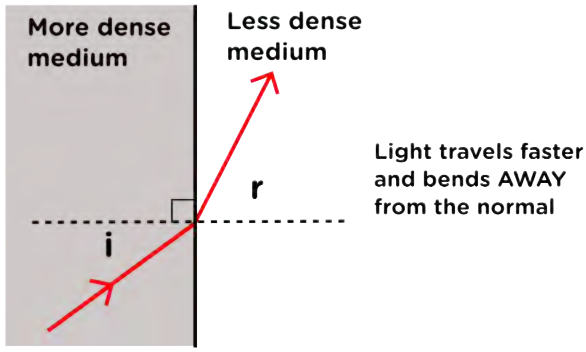
**VISIT**

The speed of light in glass.

bit.ly/1fcfJVZ




If light moves from a more dense medium to a less dense medium then 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 slowly pour water into the bowl and observe.

**QUESTIONS:**

1. What happened when your partner poured the water into the bowl?

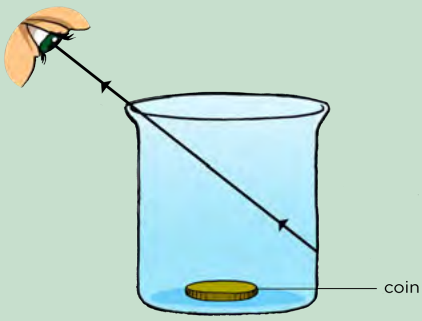
____________________________________________

____________________________________________

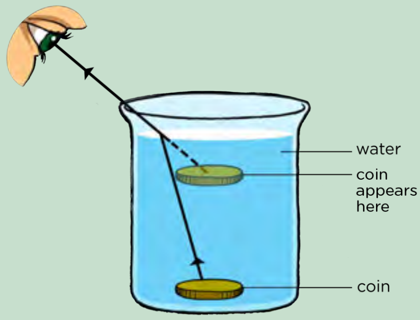
2. Where does the coin appear to be?

____________________________________________

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.




*Empty container.*




*Container with water.*

____________________________________________

____________________________________________

____________________________________________

**VISIT**

Watch a video that shows and explains the coin activity.

bit.ly/15NmXXO

**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 some 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?

*Light refraction through glass and water.*



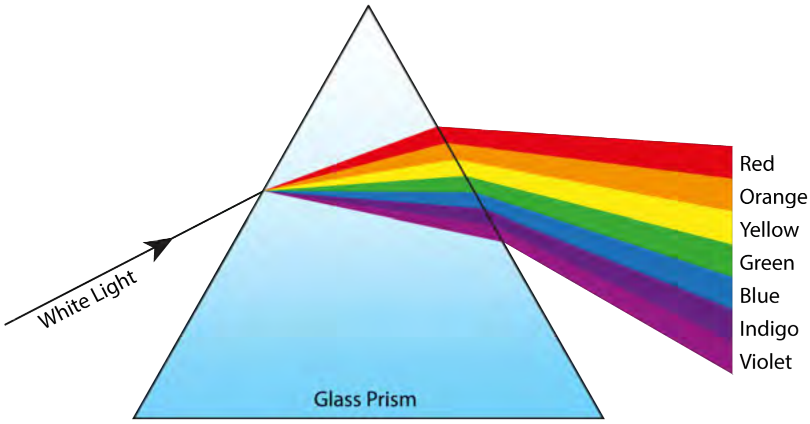
Can you remember how we split white light into the separate colours of the visible spectrum in the beginning of this chapter? What did we use to do this in the activity?

---

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.

*Refraction through a triangular prism.*

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.

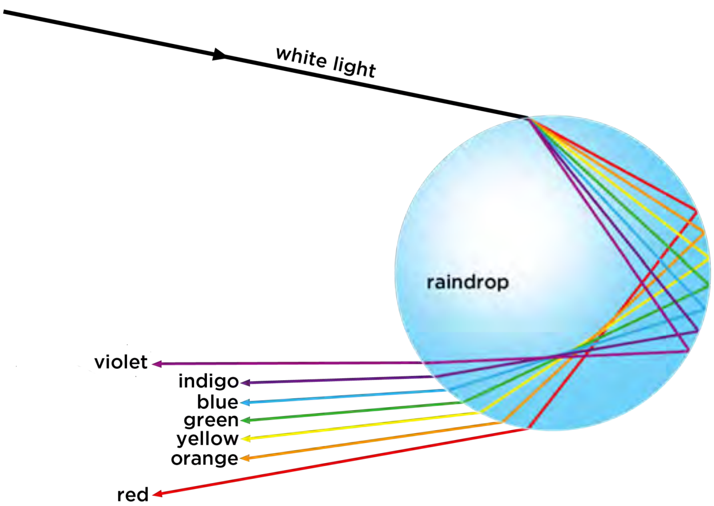



Prisms are not the only objects that can split white light into separate colours. In fact, a rainbow is a good example of white light splitting up.



*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.




*A raindrop refracts and reflects light, dispersing white light into the colours of the visible spectrum.*

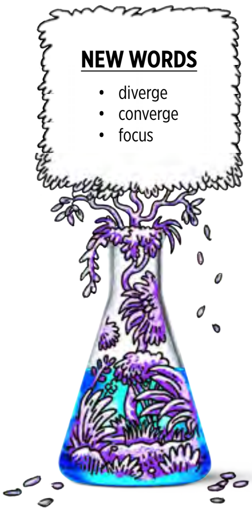
What colour is at the top of a rainbow and which colour is at the bottom?

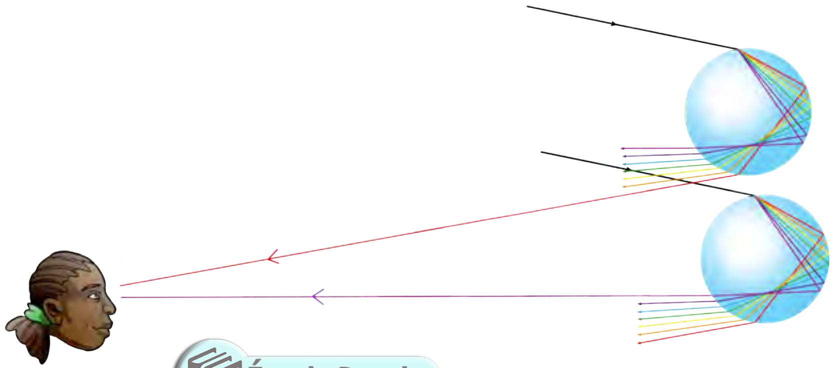
---

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 7 colours, we only see only 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 rain drops lower down reflect violet light to us. This is shown in the following diagram.



*We see rainbows with red at the top and violet at the bottom due to the combination of millions of raindrops. We only see one colour reflected from a particular raindrop, depending on its position in the sky.*

We are now going to look at an application of the refraction of light.

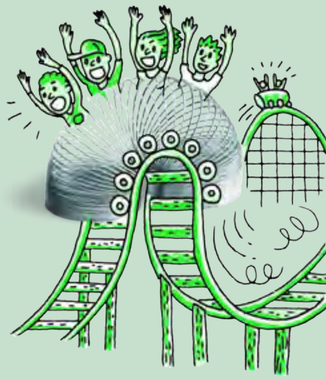
## Lenses

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 magnifying glass makes things look bigger.*

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.

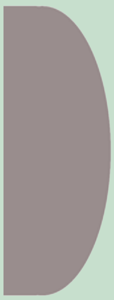
## ACTIVITY: Diverging and converging light with lenses



**MATERIALS:**

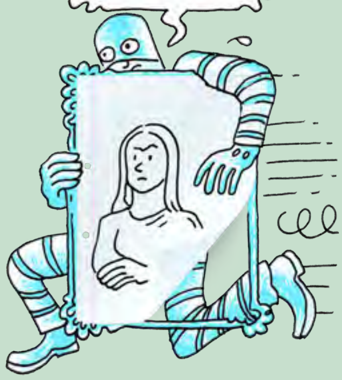
- ray box or light source
- concave lens
- convex lens
- piece of paper
- pencil

Before we start, it is important that you know the difference between a convex and a concave lens.

| Convex lens | Concave lens |
|---|---|
|  |  |
| A convex lens has one side which curves or bulges **outwards.** A convex lens **converges** light. | A concave lens has one side which curves or is hollowed **inwards.** A concave lens **diverges** light. |

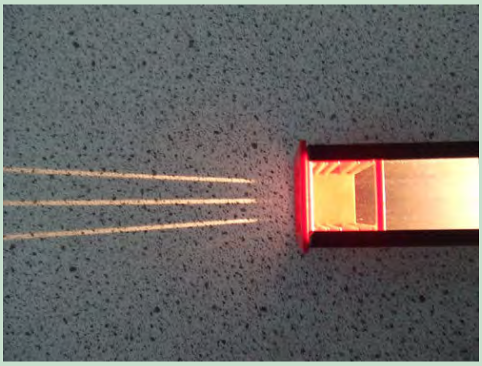
**TAKE NOTE**

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.



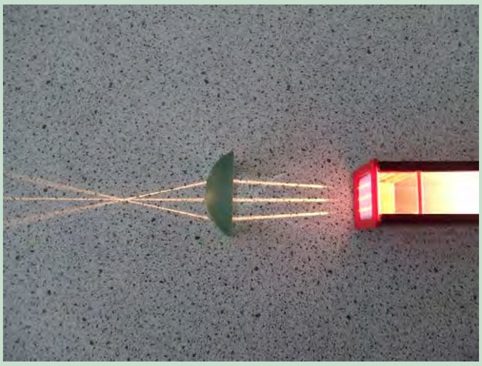
**INSTRUCTIONS:**

1. Place a ray box or light source on one side of a piece of paper and turn it on. Observe the light rays. You might see something as shown in the photograph here.



*Three rays coming out of a ray box.*

2. Turn the ray box off.
3. Place the convex lens (with the rounded surface) on the piece of paper where the light rays will pass through it. Trace around it.
4. Turn on the ray box or light source and observe what happens to the rays when they pass through the lens.



*Light rays passing through a convex lens.*

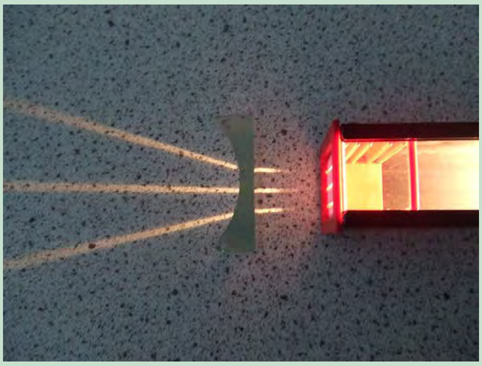
5. Trace the path of the light rays on your piece of paper.
6. Describe what has happened to the light rays.

---

---

7. Mark the point where the light rays cross. This is called the **focal point** of a convex lens.
8. Turn off the ray box or light source and place a new piece of paper in front of it.
9. Now place the concave lens in the path of the light rays and trace around the lens.
10. Turn on the light source and observe what happens to the rays.

11. Trace the path of the rays on the piece of paper.



*A concave lens in front of the rays of light.*

12. Describe what has happened to the light rays.

______________________________________________

______________________________________________

13. Turn off the light rays and extend the rays you have drawn until they meet at a point in front of the lens. This is the **focal point** of a concave lens.
14. If you still have your pin hole cameras, place a convex and concave lens in front of the camera and observe the image that forms.

*Viewing a light source through a pinhole camera with different lenses.*

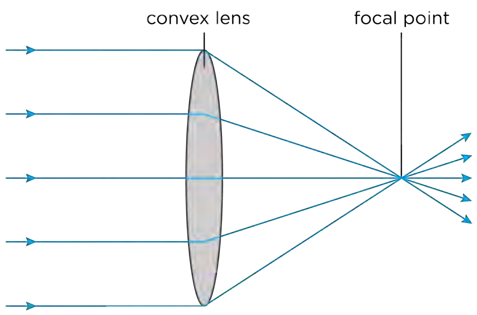
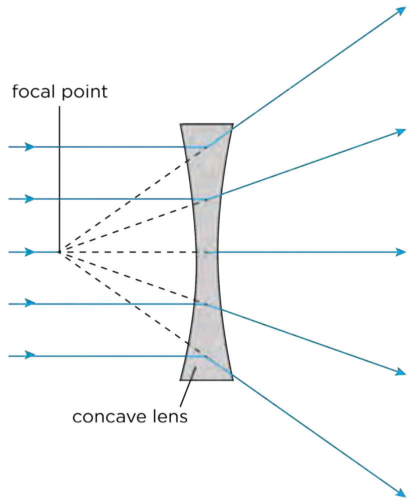
15. Is the image larger or smaller when you observe through a concave lens?

______________________________________________

16. Is the image larger or smaller when you observe through a convex lens?

______________________________________________

We have now seen how lenses can disperse or focus light. Have a look at the following diagrams which show how a biconvex lens converges light and a biconcave lens diverges light.

| Converging lens | Diverging lens |
|---|---|
|  |  |
| A converging lens refracts the light entering it and bends the light rays to a **focal point** on the other side of the lens. | A diverging lens refracts the light entering it and bends the light rays away from each other. The light rays can be traced back to a **focal point** in front of the lens. |



What do we use lenses for? Think of a magnifying glass. If you hold a magnifying glass over a picture or words then it enlarges the image. Is a magnifying glass an example of a diverging or converging lens?

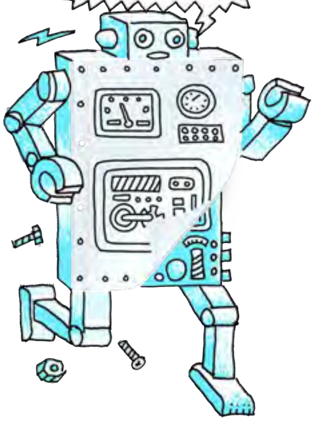
---

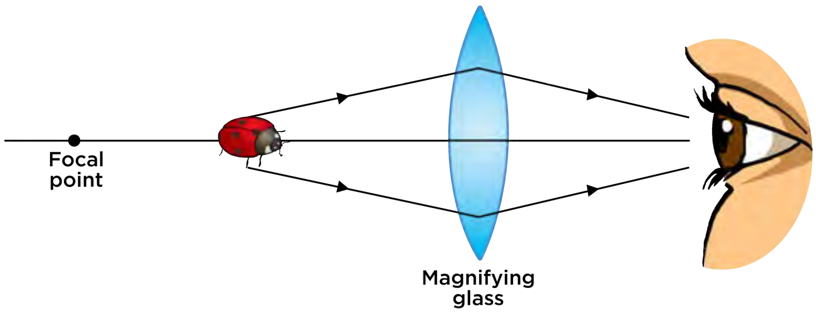
Let's think about how this works. Imagine you are looking at the ladybird from the beginning of the chapter through a magnifying glass. The ladybird looks bigger than what it actually is. When the object you are viewing is **closer** to the lens than the focal point, you see a virtual image of the ladybird that is **larger** than the object.

Have a look at the first diagram below. Can you see that the ladybird is between the focal point and the lens? The rays reflected from the ladybird are refracted by the magnifying glass and enter the person's eye.

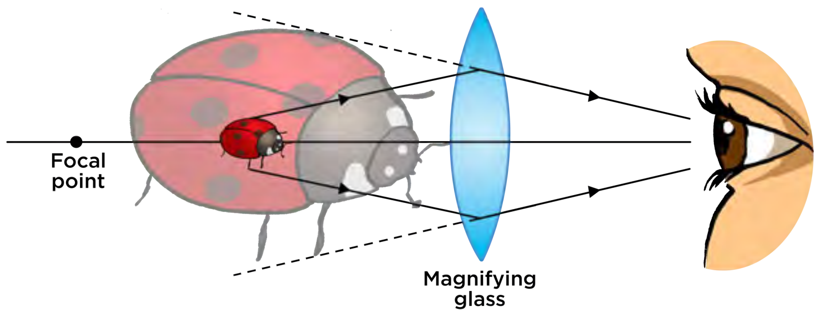
**TAKE NOTE**

When you hold a magnifying glass up and view a distant object, the object appears smaller and upside down. Unlike when viewing the ladybird close up, the distant object is **beyond** the focal point of the lens, which results in this effect.






In the next diagram you can see how your eyes see a virtual image of the ladybird which is bigger than the object. The more curved the convex lens is in a magnifying glass, the greater its ability to magnify objects.




**VISIT**

How do lenses work?

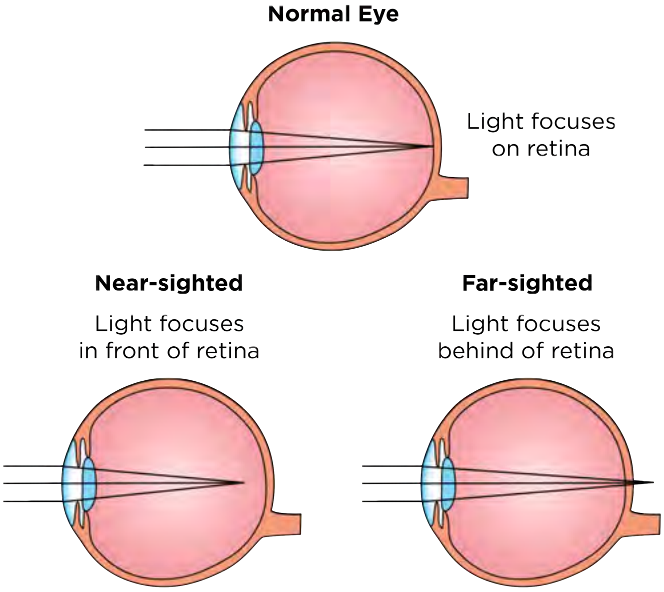
bit.ly/GABjoO

Do you remember what the human eye looks like? We have lenses in our eyes to allow us to see. The light enters the eye and passes through the lens. The lens focuses the light onto the back of our retina so that a clear image is formed. What type of lens do we have in our eyes? Give a reason for your answer.

___

___

In order for a clear image to form, the lens in our eye needs to focus the light rays coming into our eyes so that the focal point falls on the retina. This depends on the shape of the lens in our eyes. Sometimes, people have lenses in their eyes that cannot focus properly. Have a look at the following diagram which shows a normal eye and then an eye which focuses before the retina (near-sighted) and behind the retina (far-sighted).




Optical glasses, or spectacles, are used to correct near or far-sightedness.

If you are near-sighted you need a diverging lens. Would this be a biconcave or biconvex lens?

______________________________________________

If you are far-sighted you need a converging lens. Would this be a biconcave or biconvex lens?



______________________________________________

*An optometrist holds a lens in front of a patient's eye to correct her vision.*

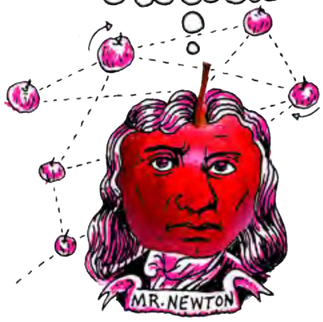
The following image shows how lenses can be used to correct far and near-sightedness.

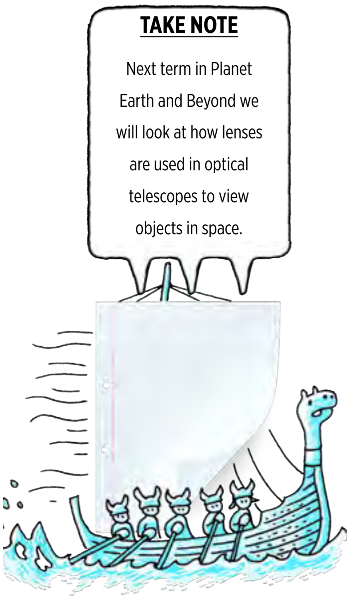
**DID YOU KNOW?**

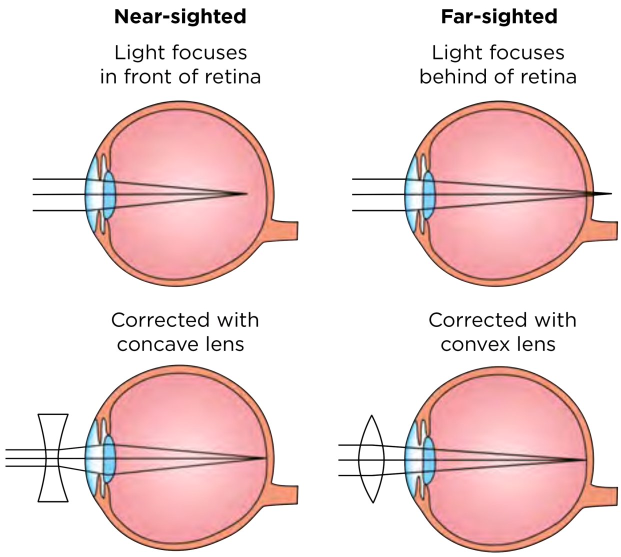
A contact lens is designed to rest on the cornea of the eye and correct vision. Leonardo da Vinci was the first to come up with the idea in the 16th century to help prevent eye infection.

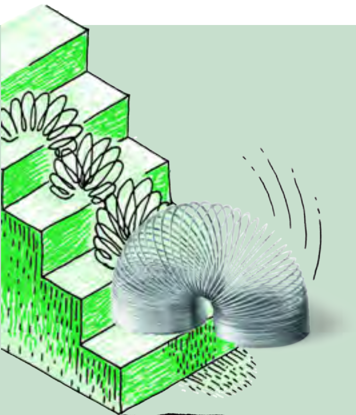
**DID YOU KNOW?**

A **microscope** makes a tiny, nearby object look much bigger. A **telescope** makes a large, distant object look much closer and brighter. In both, light from the object passes through two or more lenses to form an image. The lens shapes and distances between them determine how the image is produced.





## 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

Remember to discover more online by visiting http://www.curious.org.za and by typing the links in the Visit margin boxes into your internet browser to watch any videos, play with simulations or read an interesting article.


*Type the bit.ly link for the video or site that you want to visit into the address bar of your browser on your computer, tablet or mobile phone.*

**VISIT**

Want to take part in some real science research? Check out these citizen science projects to get involved easily.

bit.ly/15KjnmD

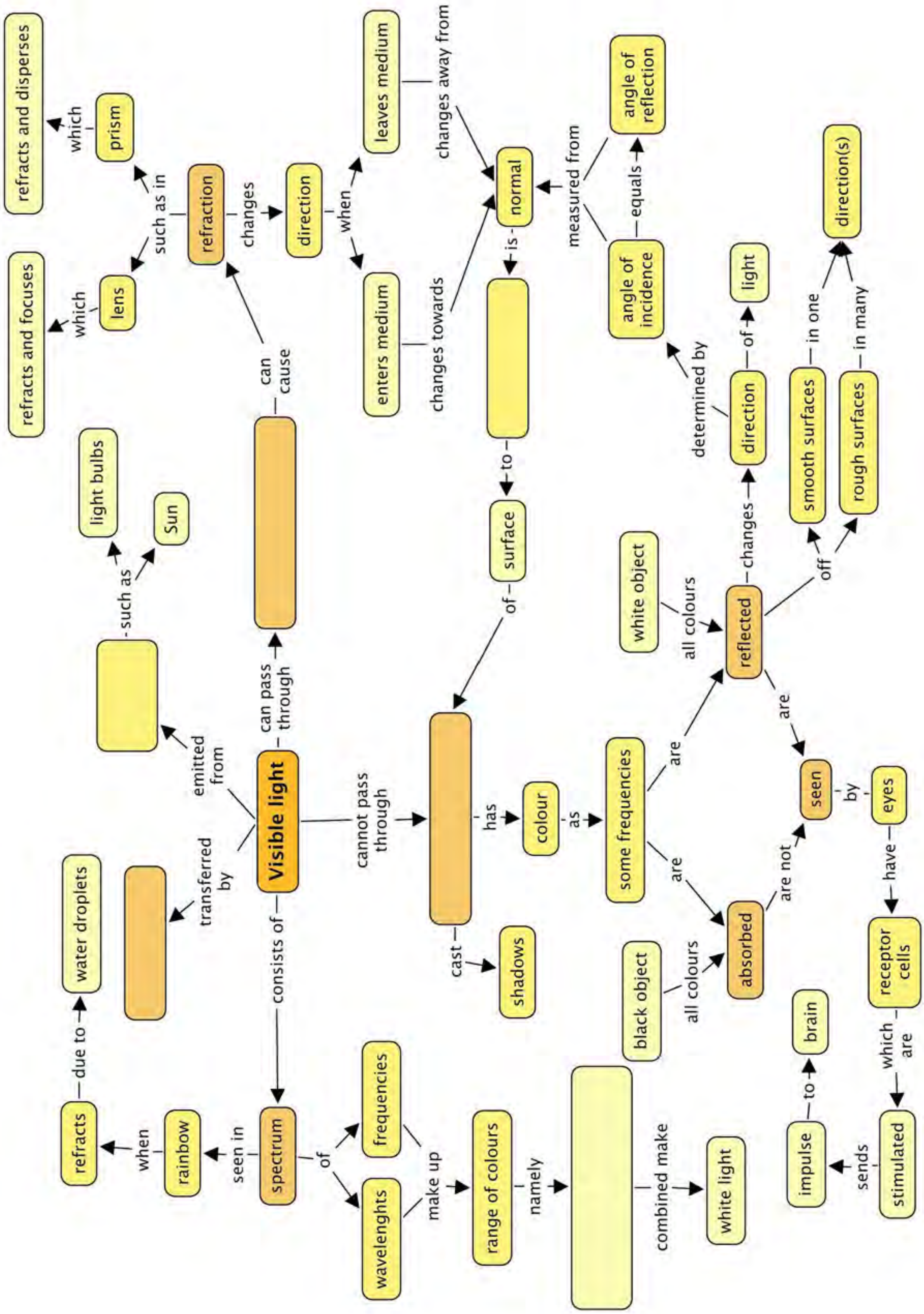
## SUMMARY:

### Key Concepts

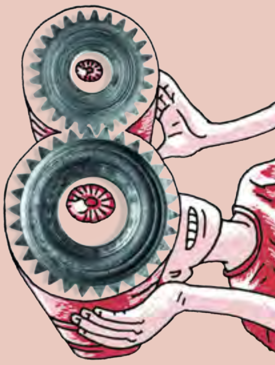
- Light travels in straight lines.
- White light consists of all the colours of the visible spectrum.
- The colour spectrum can be seen when white light is dispersed by a prism or a raindrop (rainbow).
- Light cannot pass through opaque objects.
- Light can pass through transparent objects.
- Light is 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.
- Converging lenses refract and focus light.
- Diverging lenses and triangular prisms refract and disperse light.
- 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 chapter.


Visible light
emitted from
such as
light bulbs
Sun
transferred by
consists of
spectrum
seen in
rainbow
when
refracts
due to
water droplets
of
wavelengths
frequencies
make up
range of colours
namely
combined make
white light
can pass through
can cause
refraction
such as in
lens
which
refracts and focuses
prism
which
refracts and disperses
changes
direction
when
enters medium
leaves medium
changes towards
changes away from
normal
is
to
surface
of
cannot pass through
cast
shadows
has
colour
as
some frequencies
are
absorbed
reflected
black object
all colours
white object
all colours
are not
are
seen
by
eyes
have
receptor cells
which are
stimulated
sends
impulse
to
brain
changes
direction
of
light
determined by
angle of incidence
measured from
equals
angle of reflection
off
smooth surfaces
in one
rough surfaces
in many
direction(s)

## 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 marks]

| 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. |

| Term | Definition |
|---|---|
| 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. |

Answers:

1:

2:

3:

4:

5:

6:

7:

8:

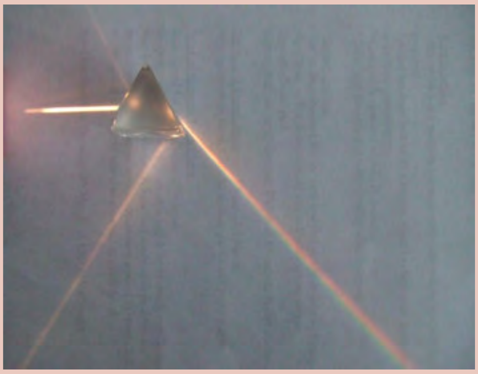
9:

10:

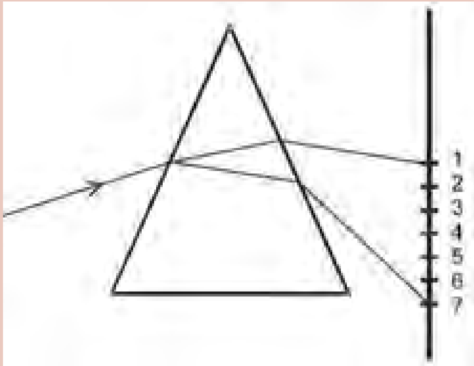
11:

12:

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.



*A photograph of the prism.*




*A diagram drawn by the learner.*

a) What does this tell us about white light? [1 mark]

b) Why does the light do this when it passes through the prism? [3 marks]

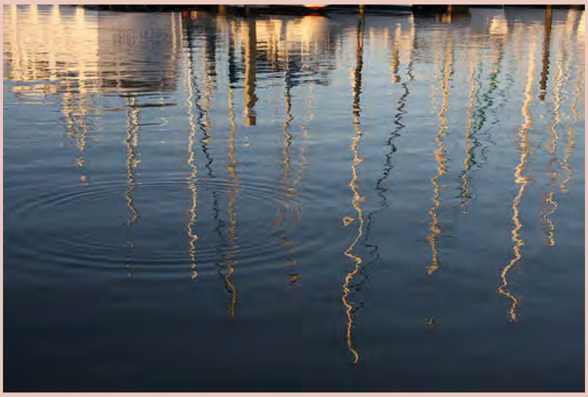
c) What colour is at label 1 and what colour is at label 7? Explain your answer. [3 marks]

d) What label corresponds to the colour of grass? [1 mark]

e) Can you see there are two other lighter, white rays emerging from the prism? What do you think this is the result of? [2 marks]

3. Why does an opaque object cast a shadow? [2 marks]

4. Look at the following photograph of water in a pond and answer the questions.



*Water in a pond.*

a) How are we able to see the image of the wooden poles sticking up on the edge of the pond? [2 marks]

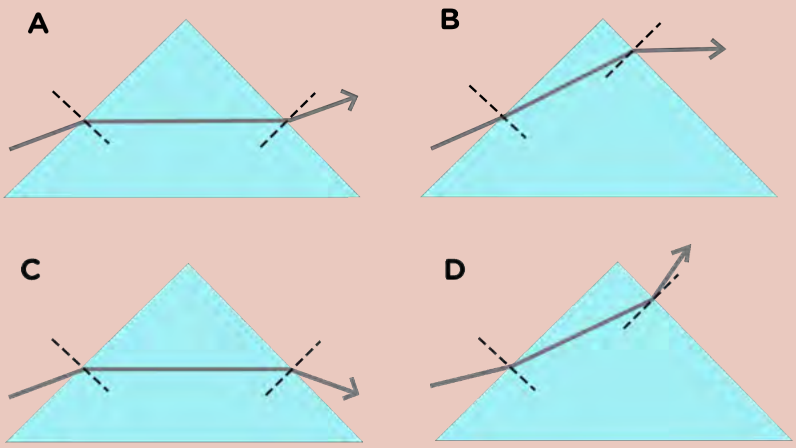
b) Why is the image not clear, but blurred? [2 marks]

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 marks]

6. Explain how we are able to see the different colours on the South African flag. [6 marks]

7. Draw a ray diagram in the space provided to show how we see the green part of the flag. [5 marks]

8. Which diagram shown below correctly shows the path of a ray of light through a triangular piece of glass? [2 marks]



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]

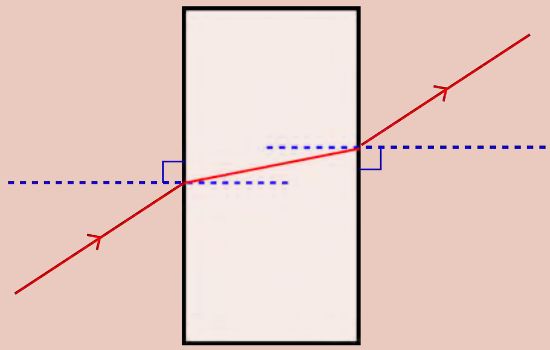
_______________________________________________

_______________________________________________

_______________________________________________

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 marks]

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 mark]

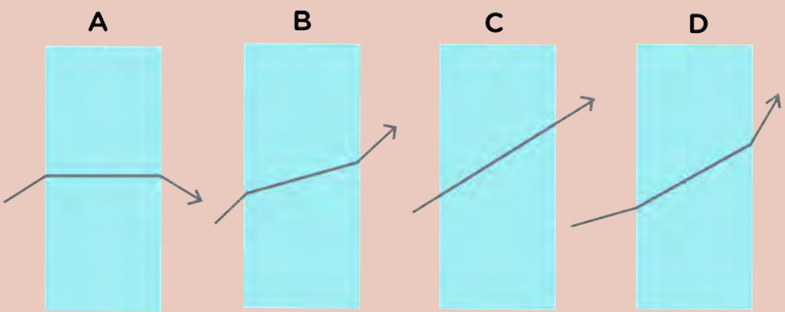
_______________________________________________

b) What do the blue lines represent? Label this on the diagram. [1 mark]
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 marks]

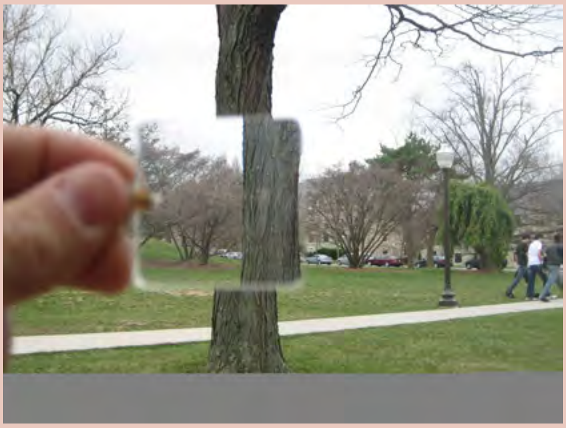
d) What type of medium could the block be made from? [1 mark]

e) Label the incident ray and the emergent ray on the diagram. [2 marks]
f) Label the angles of incidence (i) and angles of refraction (r) on the diagram. [2 marks]

12. Which diagram shown below shows the path of a light beam passing through a rectangular glass prism correctly? [2 marks]




13. Why does it look like the tree trunk in the photograph is skew? [2 marks]



14. What shape does a lens have to have in order to focus the light? [1 mark]

15. Draw a ray diagram to show how a converging lens focuses light to a point. [4 marks]

16. Which eyesight defect can be fixed by using a converging lens? Explain what this defect is and why it can be corrected. [4 mark]

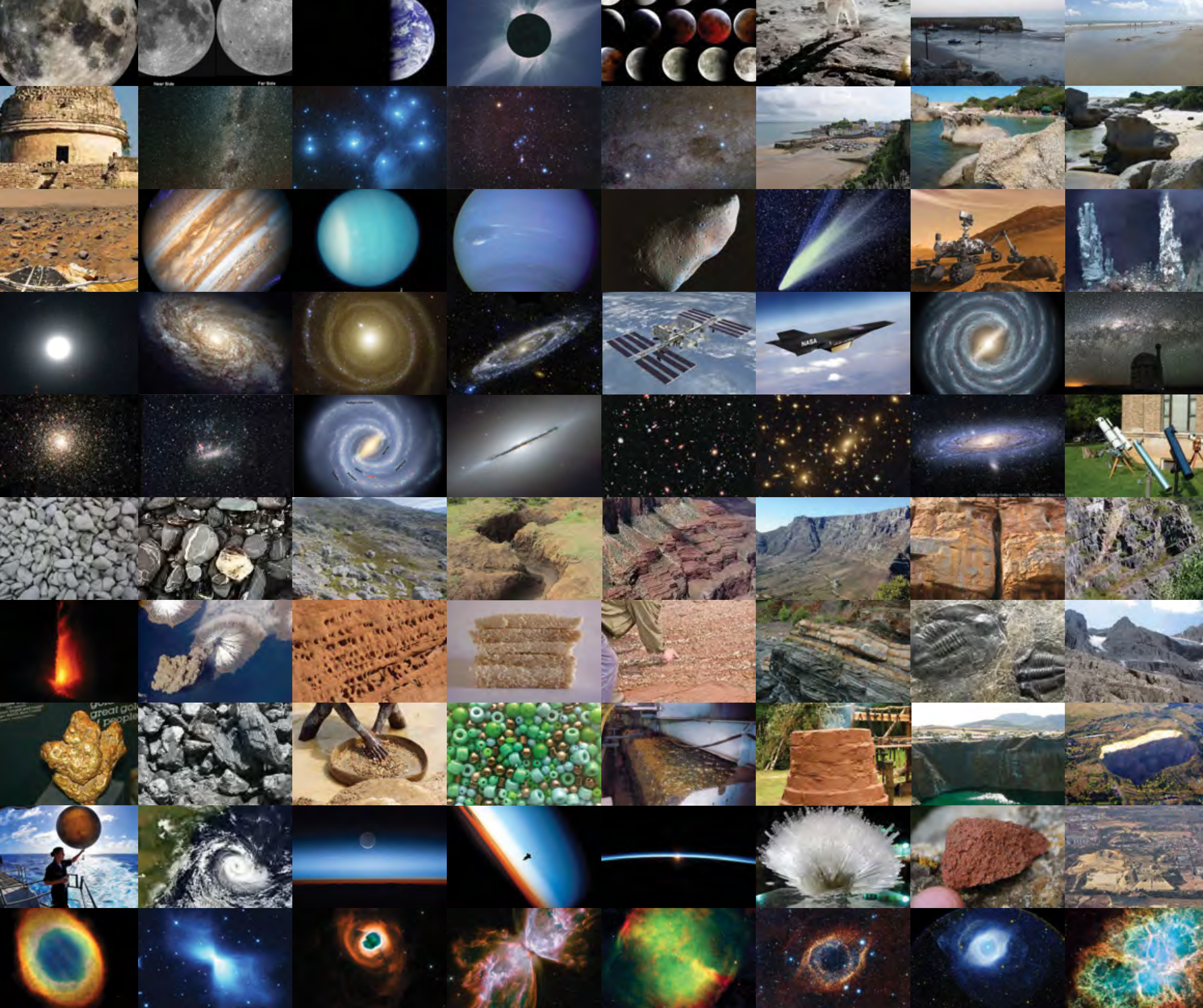
Total [74 marks]

## GLOSSARY

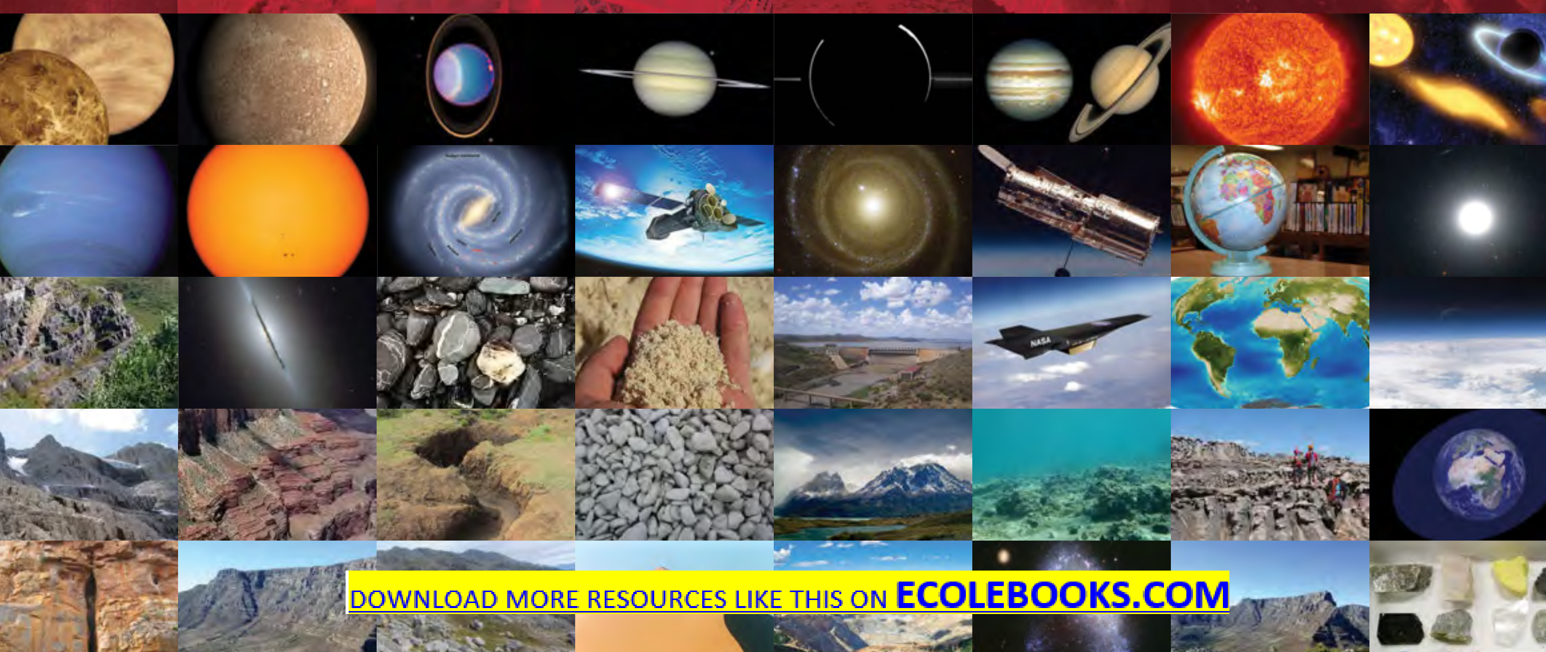
| | |
|---|---|
| **ammeter:** | device that measures the strength of an electric current |
| **ampere:** | the standard unit for measuring electric current |
| **angle of incidence:** | the angle between the incident ray and the normal line |
| **angle of reflection:** | the angle between the reflected 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 |
| **converge:** | light rays that come together and focus on a point |
| **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 |
| **diverge:** | light rays that spread apart as they move further and further away from a point |
| **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:** | something 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 90° 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 |
| **qualitative:** | describing something in terms of its properties or characteristics rather than by a number or measurement |
| **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 |



# PLANET EARTH AND BEYOND



# 1 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?

**NEW WORDS**

- 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.

## 1.1 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?

______________________________________________

______________________________________________

______________________________________________

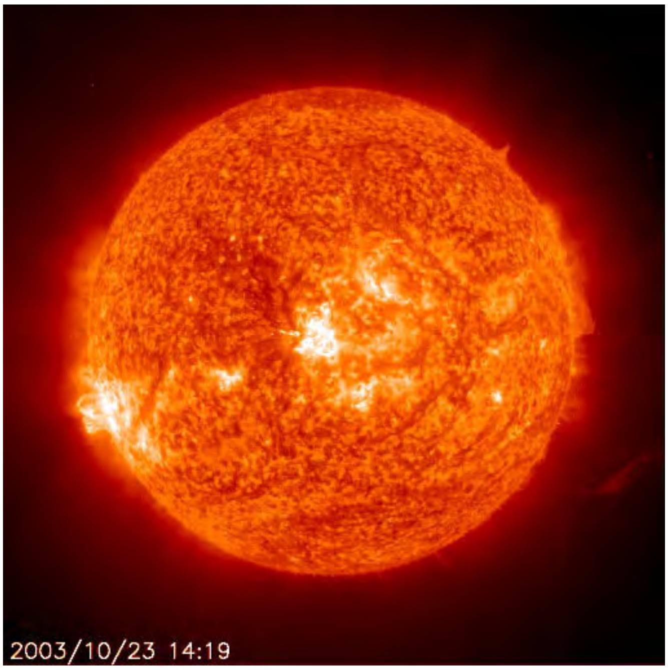
______________________________________________

**VISIT**

Secrets of a dynamic Sun (video)

bit.ly/1h0io4b

Let's look at the Sun in more detail.




*An image of the Sun taken with the SOHO space satellite.*

**TAKE NOTE**

It is very important that you do not look at the Sun directly! The Sun can damage your eyes permanently!

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 5500 °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**.

**VISIT**

The birth of the solar system (video)

bit.ly/1i8Bfrx

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.

**VISIT**

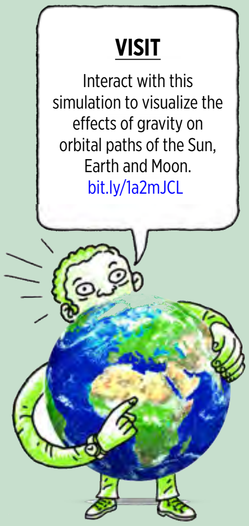
How the Sun works.

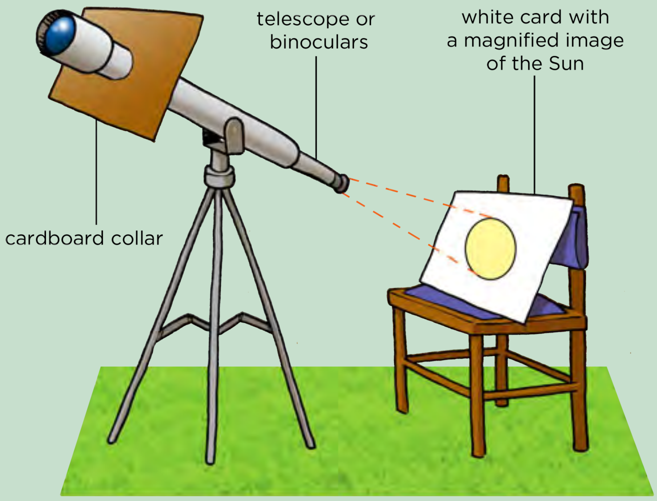
bit.ly/1gy769C

## 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




**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 cardboard can fit over the telescope as shown in the figure 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:**

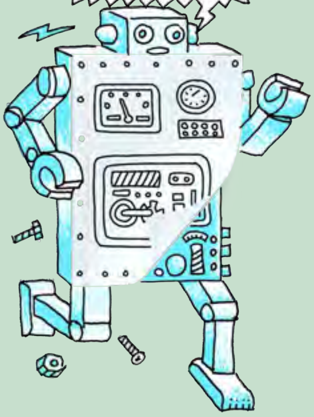
1. Looking carefully you should see that the Sun's image moves slowly across the white card. What causes this motion?

---

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.



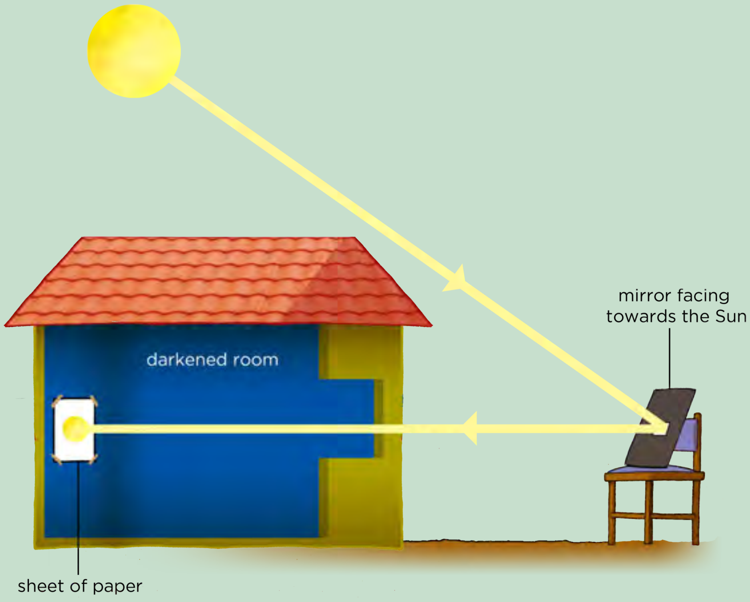
Alternatively, if you do not have access to a telescope or binoculars, you can perform the following activity to view the Sun.

## 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 class you can do this activity in the classroom. If you do not have a classroom with a sunlit window, or if your class 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.



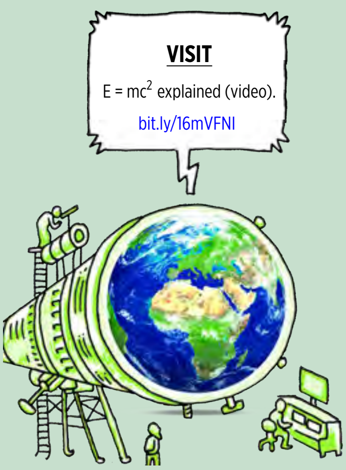


**MATERIALS:**

- 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.

**QUESTIONS:**

1. As you moved the white cardboard screen closer towards the mirror, what did you notice happened to the image of the Sun?

---

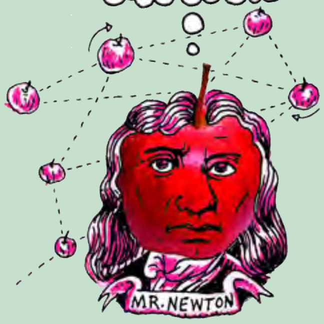
2. Draw a picture of what the surface of the Sun looks like on the white card in the circle below.

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 KNOW?**

Albert Einstein explained the mass-energy equivalence with the famous equation $E = mc^2$.

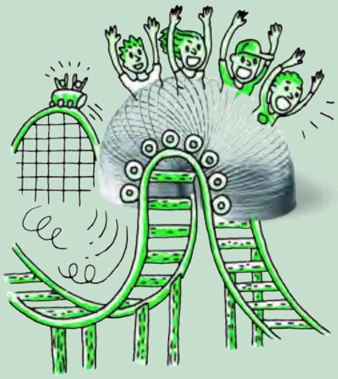



**VISIT**

Fiery looping rain on the Sun (video)

bit.ly/16qmriQ

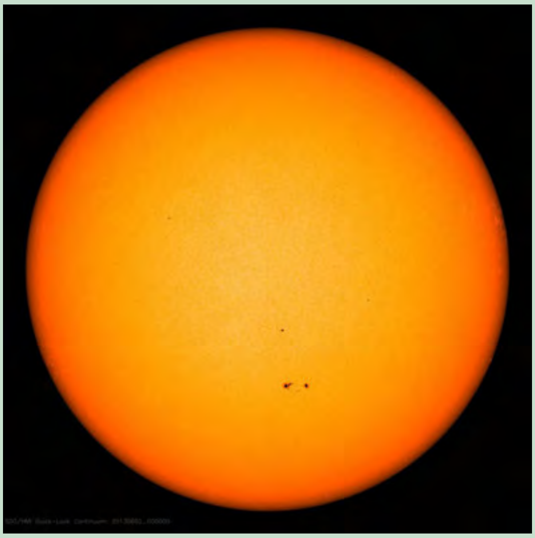
Did you notice any features on the Sun's surface when you viewed it in class? Let's find out what some of these surface features could have been in the next activity.



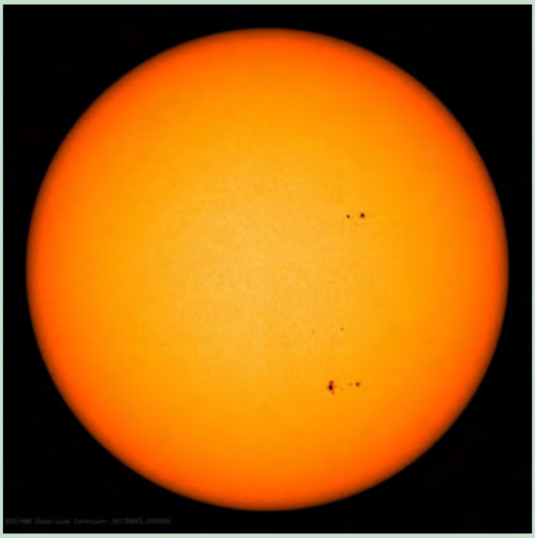
## ACTIVITY: Observing sunspots on the Sun's surface

**INSTRUCTIONS:**

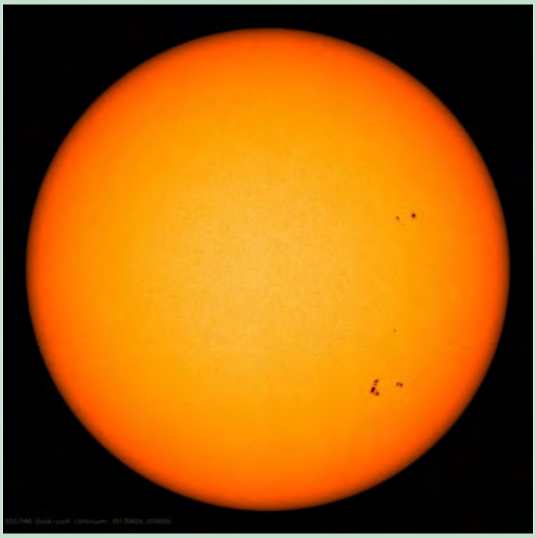
1. Look at the images of the Sun which were taken in June 2013.
2. Answer the questions that follow.



*A: DATE: 02.06.2013*



*B: DATE: 03.06.2013*



*C: DATE: 04.06.2013*

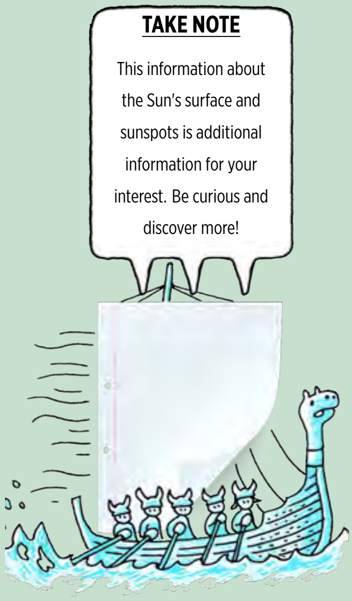
**QUESTIONS:**

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 5500 °C and a typical sunspot has a temperature about 3900 °C.

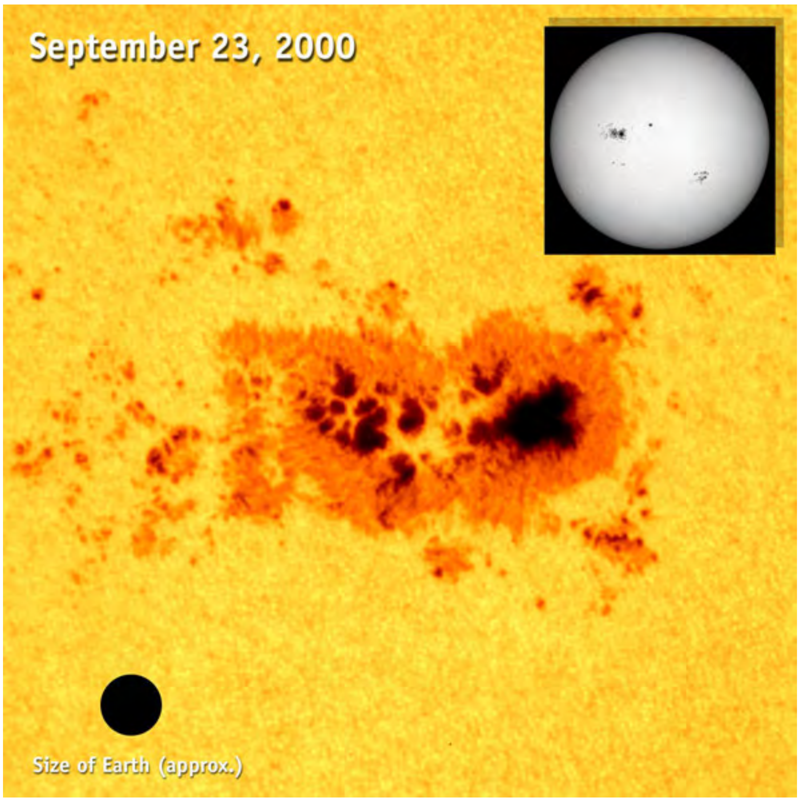



*Image of a sunspot. For perspective, take note of the size of the Earth in the lower left.*

**VISIT**

View real time images of the Sun and track sunspots.

bit.ly/19ZoU6c

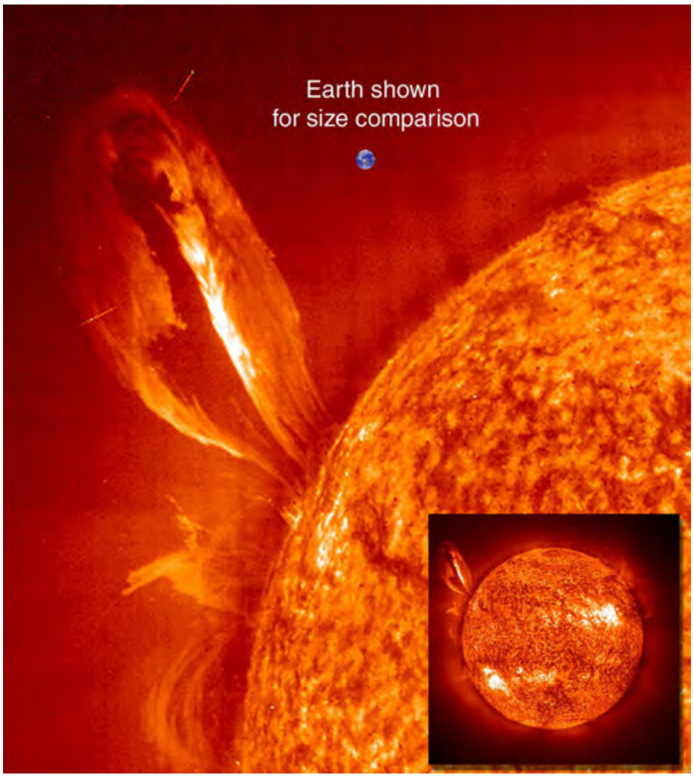
**DID YOU KNOW?**

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.

As the Sun is made up of gas, there is no solid surface like on Earth. So when one says 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 only lasts 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.




*A large loop of gas extending over 35 Earth diameters out from the Sun's surface.*

## 1.2 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 chapter.

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.

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 chapter. Let's begin by learning more about the size and scale of the solar system.

**VISIT**

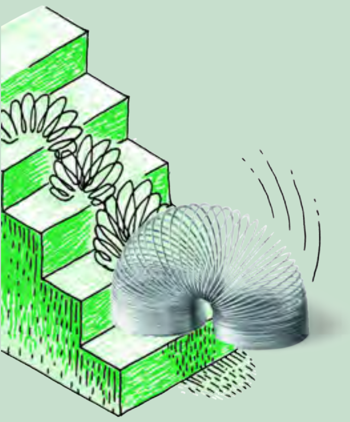
Explore the solar system from your computer with this 3D environment bit.ly/1c9rpbM and view any objects in the solar system with this interactive simulator bit.ly/1gyasJR

**NEW WORDS**

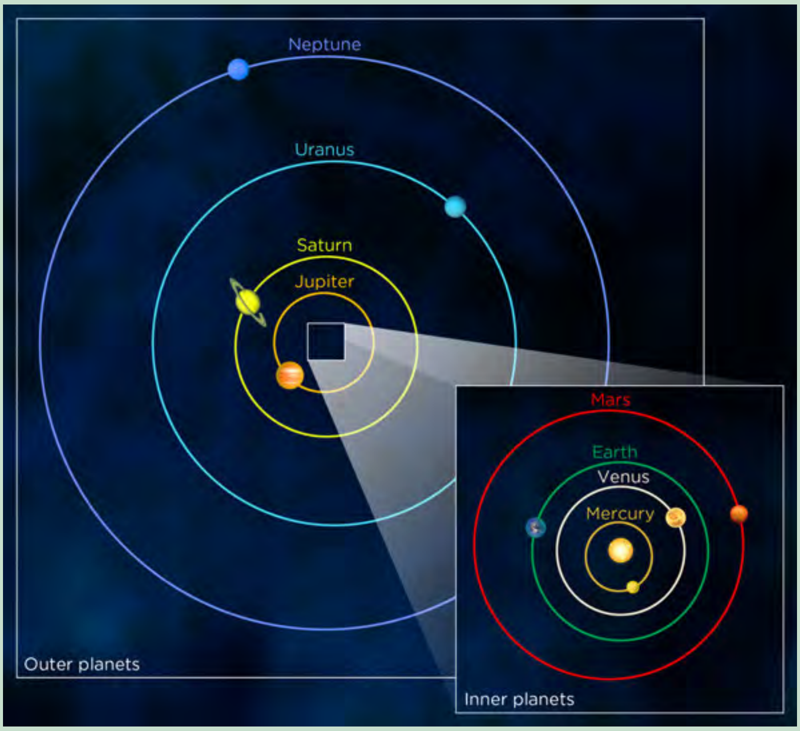
- terrestrial planet
- gas giant
- dwarf planet

**TAKE NOTE**

'terra' is the Latin word for land or earth.



## ACTIVITY: The scale of the solar system




*The orbits and planets in the solar system which we are going to model.*

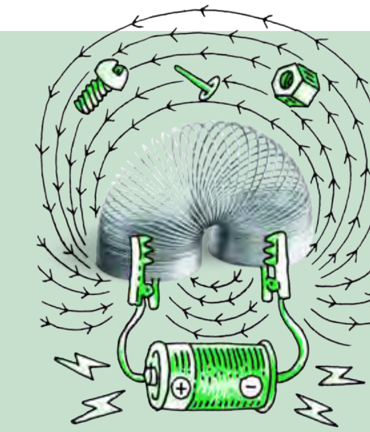

**MATERIALS:**

- 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)

**VISIT**

Compare the planets using this tool from NASA.

bit.ly/16qoflJ

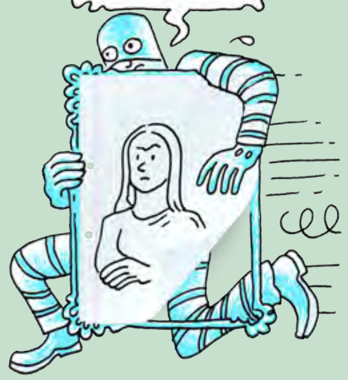
**INFORMATION TABLE:**

| 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 then the Sun and planets would be much 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 above.
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).
5. Punch one hole on each circle (orbit); a planet will hang from each hole.
6. Cut out one circle from the paper to represent the Sun.

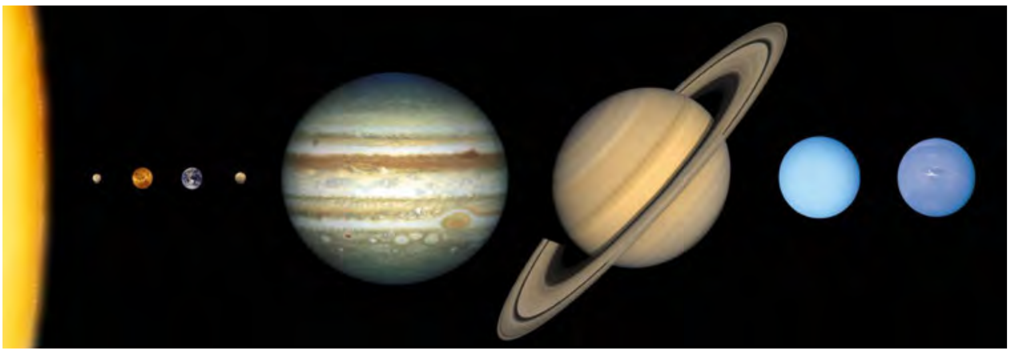

7. Repeat this for each of the planets. The range in size of the Sun and the planets is far too large to represent accurately, so as a rough representation use the radii listed in the table to make your circles. The sizes of Mercury and Mars are very small in relation to the other planets. If you are battling to cut circles this size, then make them slightly bigger.
8. Colour in each planet and the Sun according to the pictures later in this chapter.
9. Tape a length of string or thread to the Sun and each planet.
10. Lace the other end of each string or thread through the correct hole in the large cardboard circle.
11. Tape the end of the string to the top side of the cardboard.
12. 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.
13. 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 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.

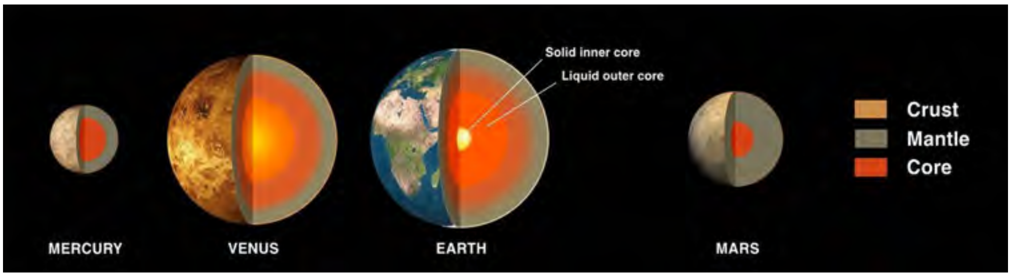


*The relative sizes of the terrestrial planets and gas giants, from left to right: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Note that the planets are not spaced at equal separations from each other, but are shown in this way to fit on the page.*

How do the sizes of the terrestrial planets and gas giants compare with each other?

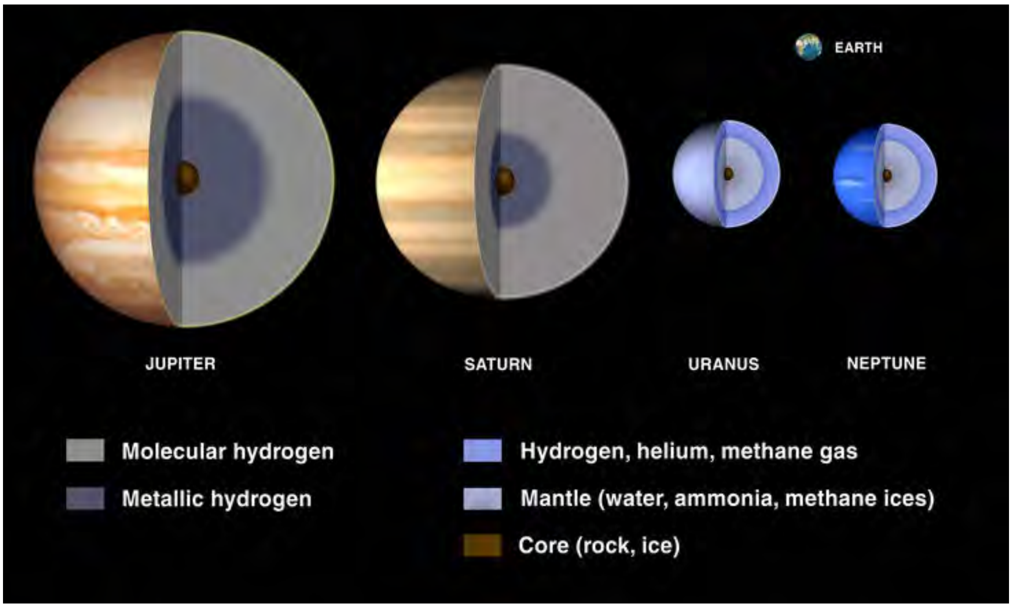
---

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.




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.

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?

---

**DID YOU KNOW?**

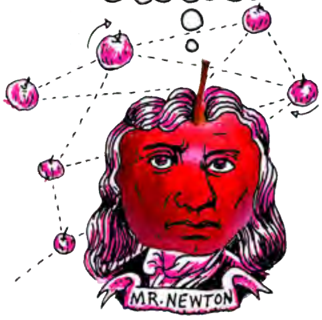
When it is winter on Mars you can see polar ice caps forming on the planet, like on Earth. However, unlike the Earth's polar ice caps which are made of frozen water, the ice caps on Mars are made of frozen carbon dioxide. This frozen carbon dioxide comes from Mars' atmosphere.

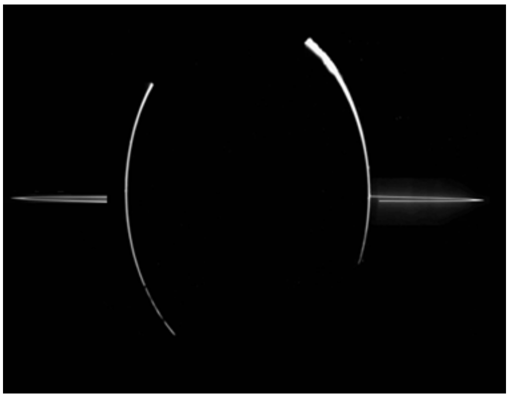
**DID YOU KNOW?**

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 as Pluto.

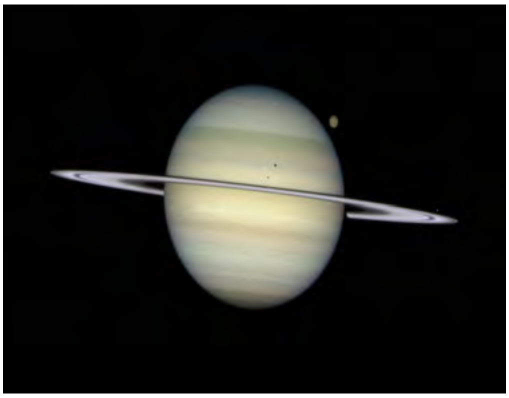
**DID YOU KNOW?**

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.

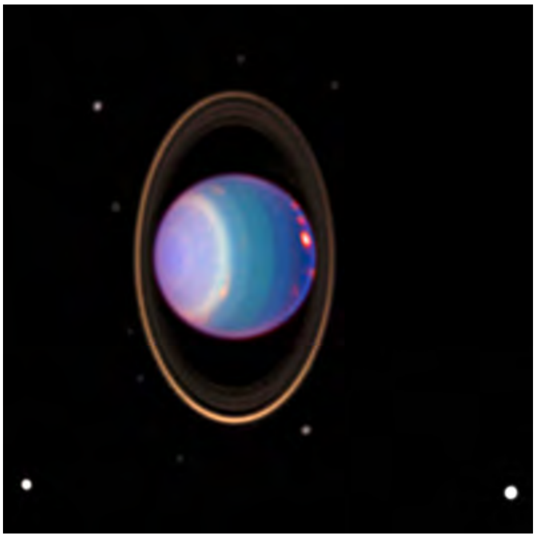


*This image of Jupiter in shadow was taken by the space probe Galileo as it studied Jupiter in 1998.*



*This image of Saturn was taken with the Hubble Space Telescope. Can you see some of its moons?*



*Uranus, taken with the Hubble Space Telescope. What do you notice that is strange about Uranus?*

**VISIT**

Discover more online at NASA's Solar System Exploration site.

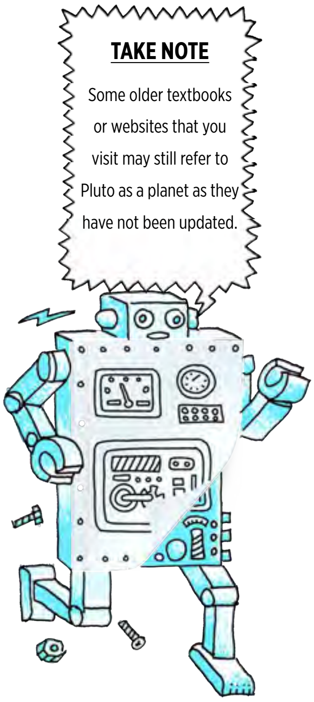
bit.ly/1azHL6M

*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.

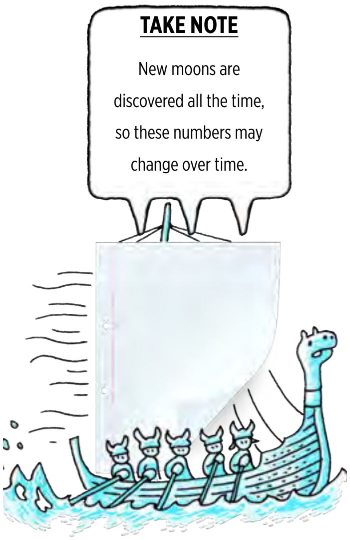
| Planet | Number of Moons |
| --- | --- |
| Mercury | 0 |
| Venus | 0 |
| Earth | 1 |
| Mars | 2 |
| Jupiter | 67 |
| Saturn | 62 |
| Uranus | 27 |
| Neptune | 13 |




What can you say in general about the number of moons that the two types of planet have?

______________________________________________________________

______________________________________________________________



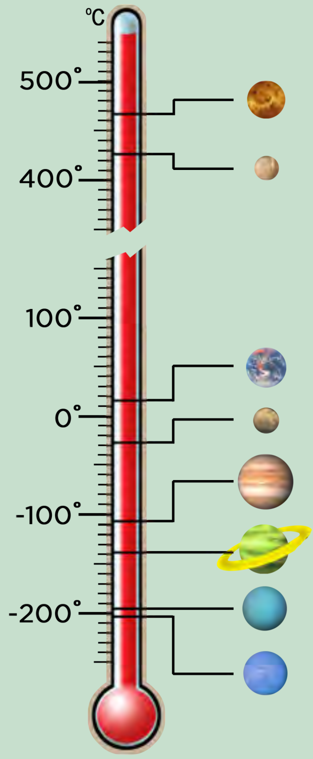

The terrestrial planets are much closer to the Sun than the gas giants. Because of this, the terrestrial planets orbit the Sun in less time than the gas giants, because they have a shorter distance to cover.

Lets see how the distance from the Sun affects the planets' temperatures.

## ACTIVITY: Planetary Temperatures

**INSTRUCTIONS:**

1. Look at the table, 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.




**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.

| 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?

_______________________________________________

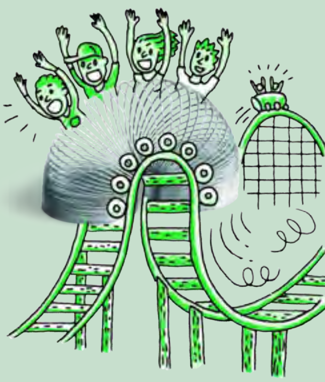
4. If you exclude Venus, how does the ordering of the planets from the Sun compare with their average temperature?

_______________________________________________

_______________________________________________

Clearly the terrestrial planets and gas giants have very different properties. Let's compare them.

## ACTIVITY: Comparing terrestrial planets and gas giants



**INSTRUCTIONS:**

1. The table below compares the two types of planet. 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 |

| Terrestrial Planets | Gas Giants |
|---|---|
| mainly rocky | mainly ___________________ |
| solid surface | ___________________ surface |
| high density | ___________________ density |
| slower rotation | faster rotation |
| ___________________ moons | many moons |
| ___________________ rings | many rings |
| thin atmosphere | ___________________ atmosphere |
| warm | ___________________ |

Why do you think the two types of planets are so different?

___________________________________________________________________________

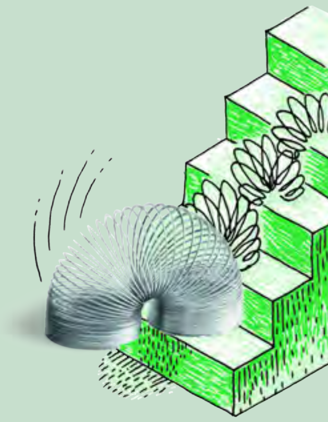
___________________________________________________________________________



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 | 5427 | 4879 | 57.9 | 4222.6 | 88 |
| Venus | 5243 | 12104 | 108.2 | 2802.0 | 224.7 |
| Earth | 5514 | 12756 | 149.6 | 24.0 | 365.25 |
| Mars | 3933 | 6792 | 206.6 | 24.7 | 687.0 |
| Jupiter | 1326 | 142984 | 740.5 | 9.9 | 4331 |
| Saturn | 687 | 120536 | 1352.6 | 10.7 | 10747 |
| Uranus | 1271 | 51118 | 2741.3 | 17.2 | 30589 |
| Neptune | 1638 | 49528 | 4444.5 | 16.1 | 59800 |

**QUESTIONS:**

1. Given that the density of water is 1000 $kg/m^3$, 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?

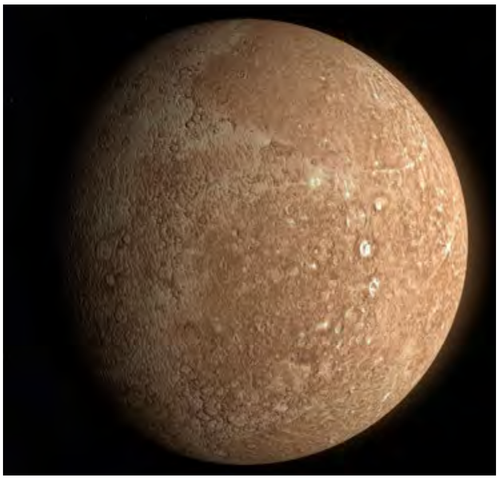
7. Plot a bar graph to show the distance each planet is from the Sun. Use the following space for your graph.

**VISIT**

Solar System 101: NASA's 'Homework helper' can show you where to look to find out more.

bit.ly/H6nbDD

## Mercury



*Mercury, imaged by the Messenger spacecraft, is covered with craters like our Moon.*

- Mercury's atmosphere is very thin and 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.

**TAKE NOTE**

The following pages provide some interesting, extra information about the planets in our solar system.

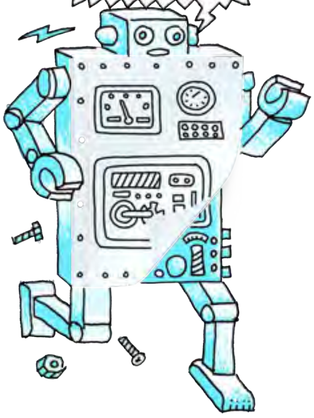
## Venus

*The surface of Venus in false colour (bottom left) and the top of the atmosphere (top left) as seen with the Magellan spacecraft.*

- 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.

**TAKE NOTE**

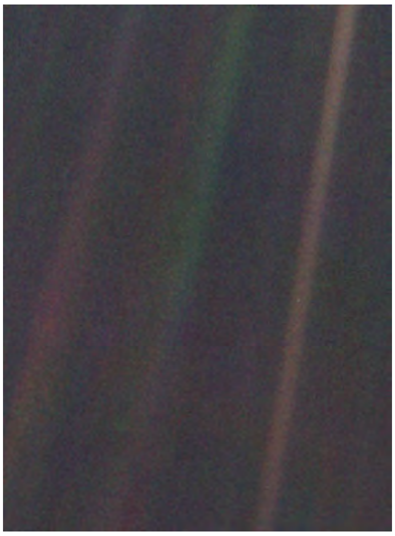
Venus has a thick dense atmosphere mostly made up of carbon dioxide which is an effective greenhouse gas. This is why Venus has the highest surface temperature, as you saw in the activity of Planetary Temperatures.



**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



*This famous image is a photograph taken of Earth in 1990 by Voyager 1 from 6 billion kilometers away. Earth appears as a tiny dot (the blueish-white speck approximately halfway down the brown band to the right). The coloured bands are scattered light rays from the Sun.*

- 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.

**VISIT**

Carl Sagan - Pale Blue Dot (video)

bit.ly/1h0msBx

## Mars

*Mars is nicknamed the Red Planet because of its red surface, as the rocks on are rich in iron. The white smudges in the middle are water-ice clouds.*

- Mars' surface 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!

**DID YOU KNOW?**

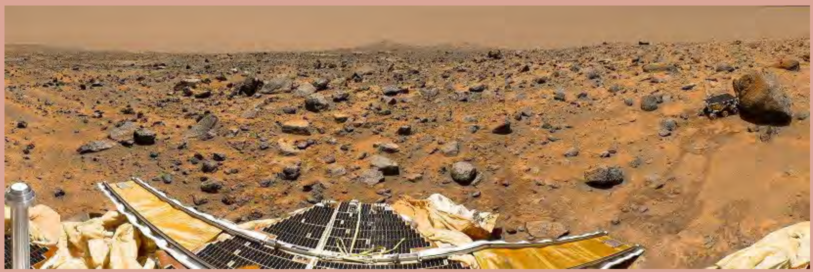
The largest volcano in the solar system, Olympus Mons, is on Mars and is three times taller than Mount Everest.

## Mars and the Search for Life

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.

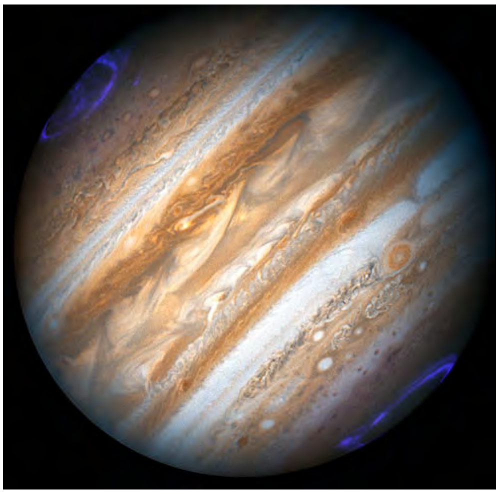
*The Curiosity rover.*



*One of the first colour images of Mars' surface taken by the Curiosity rover. You can see part of the rover at the bottom of the photograph.*


VISIT
Saturn close-up (video).
bit.ly/15XvvyG

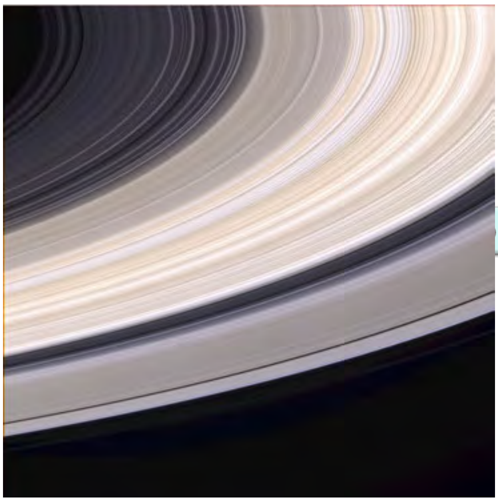
## Jupiter



*Magnetic storms cause the aurorae seen on Jupiter near its poles.*

- 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.

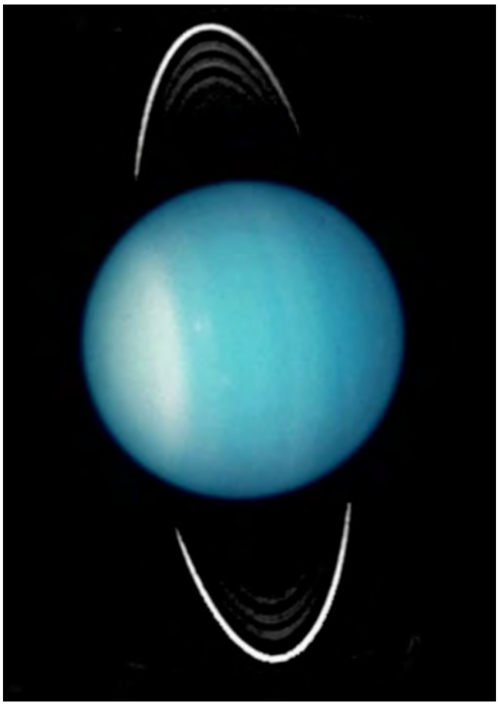
## Saturn



*Saturn's beautiful rings, imaged with the Cassini spacecraft.*

- 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.

## Uranus

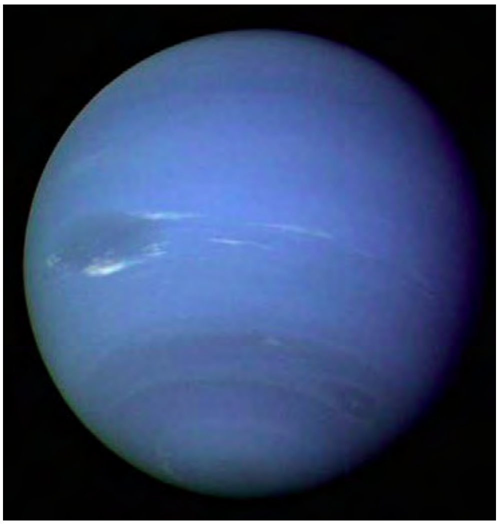


Uranus spins on its side. Scientists think Uranus may have been knocked on its side by a collision with a large object early in its history.

- 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.


## Neptune





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 1931 km/hour.

- 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.

## 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
- example 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

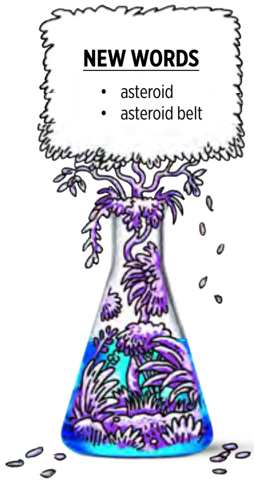
**INSTRUCTIONS:**

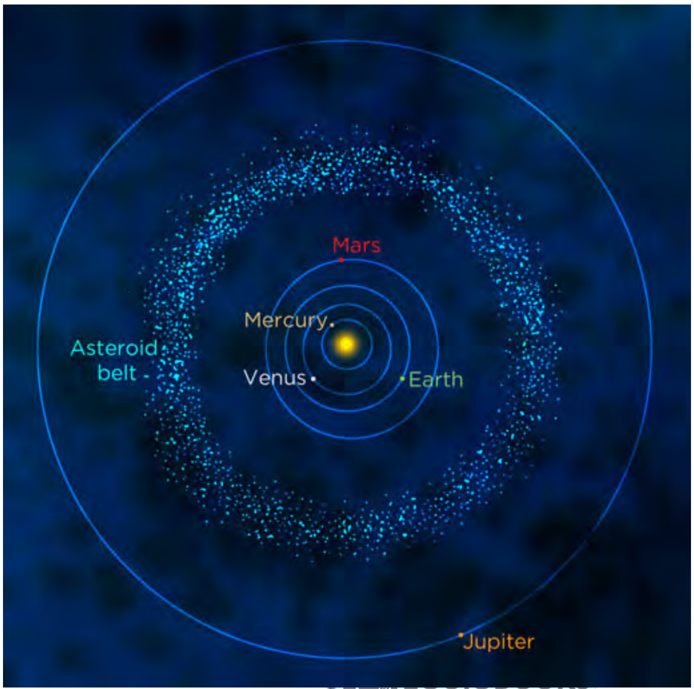
1. Research information about your chosen planet.
2. Write a one page fact sheet about your chosen planet.

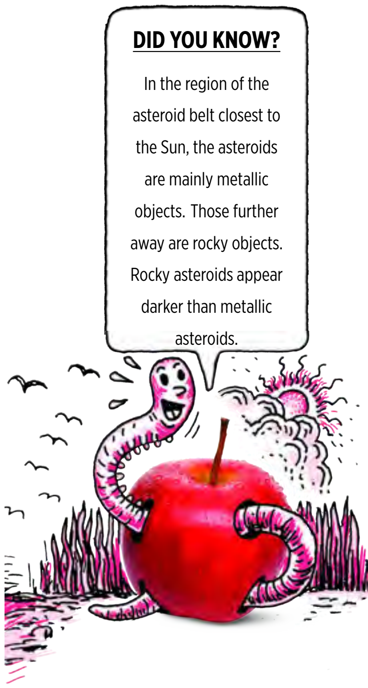
Let's now look at some of the other objects that we find in our solar system.

## 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.

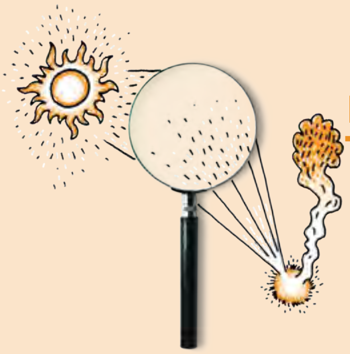



*An image of asteroid 951 Gaspra taken with the Galileo spacecraft 5300 kilometres away. Gaspra is 19 x 12 x 11 km. Notice how the asteroid's surface has many craters.*


Although science fiction movies give the impression that the asteroid belt is a 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.



## 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?

______________________________________________

______________________________________________

**VISIT**

Join NASA on an underwater mission, called NEEMO, which is actually about practicing exploration to an asteroid. Help the crew prepare by classifying the underwater images.

bit.ly/15XvI4P

**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 1.5m, 0.5m and 0.25m. Record all your measurements in the table below.
19. If you have time you can make repeated measurements.

**RESULTS AND OBSERVATIONS:**

Record your results and observations in the following table.

| 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?

______________________________________________

______________________________________________

______________________________________________

**CONCLUSIONS:**

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?

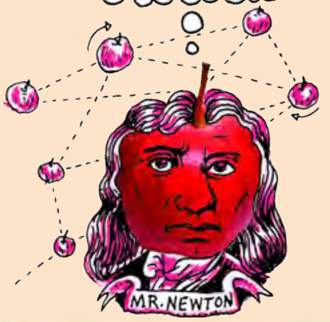
2. How did the height at which the object was dropped affect the size of the crater?

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?

**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.

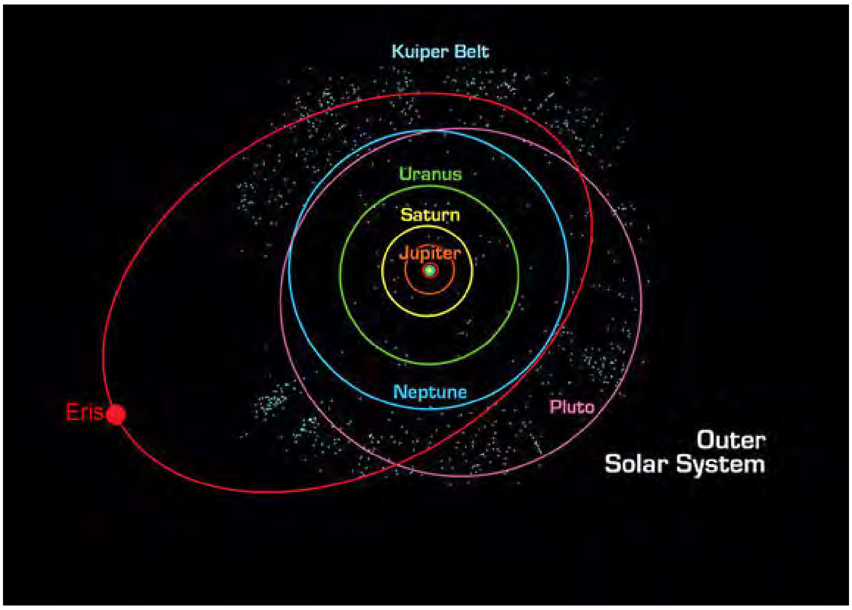



**NEW WORDS**

- Kuiper Belt
- Kuiper Belt object
- dwarf planet
- 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 1000 km across and are called Kuiper belt objects. The two largest known members of the Kuiper Belt are Eris and Pluto, both dwarf planets.




*The Kuiper belt (the pale blue dot dots) is shown beyond the orbit of Neptune. Its members include the dwarf planets Pluto and Eris.*

**VISIT**

Gerard Kuiper (1905 - 1973) is regarded by many as the father of modern planetary science. He is well known for his many discoveries. Read more about them here.

bit.ly/16mZX7C

What keeps the objects in the Kuiper Belt in orbit around the Sun?

---

**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 will arrive at Pluto in 2015.

## Dwarf planets



Dwarf planets are objects that orbit the Sun, just like the planets. However, they are smaller than planets. Due to 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 below.

To be classed as a planet an object must:

---

---

---

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?

---

**VISIT**

Why Pluto is not a planet anymore (video).

bit.ly/1fQiWLd

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 to be drawn up to be considered a planet and Pluto was demoted to dwarf planet status

**VISIT**
Read more about dwarf planets.
bit.ly/H6nJtd

*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.*

**DID YOU KNOW?**
Scientists estimate that there might be 200 or more dwarf planets in the Kuiper Belt, and thousands more beyond the Kuiper Belt.

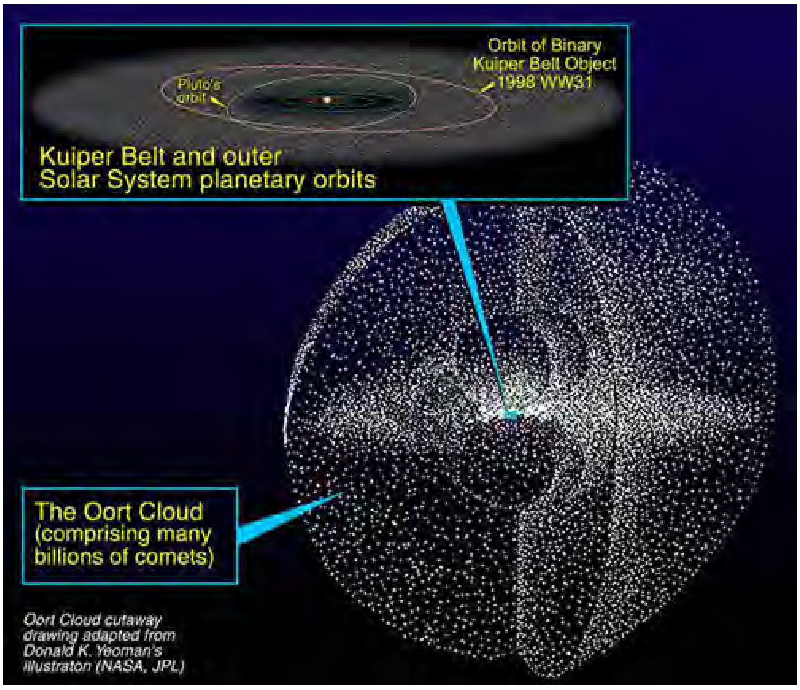
## Comets and the Oort Cloud

**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!



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.

**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.



*The hypothetical Oort Cloud is a huge cloud of icy objects or comets surrounding the outer reaches of our solar system.*

We can only see comets directly when they come into the inner solar system because they are small and only visible 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.

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.

## 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:**

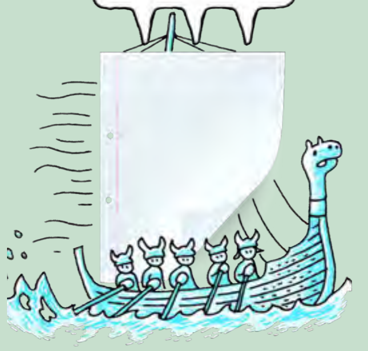
- table tennis ball
- sellotape
- tissue paper or crepe paper
- scissors

**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 sellotape. Wrap the sellotape 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.

**TAKE NOTE**

An **ion** is an atom with an electrical charge due to the gain or loss of electrons.



**QUESTIONS:**

1. Which direction did the ion tail move when you held up the comet in front of you and blew on the comet?

______________________________________________

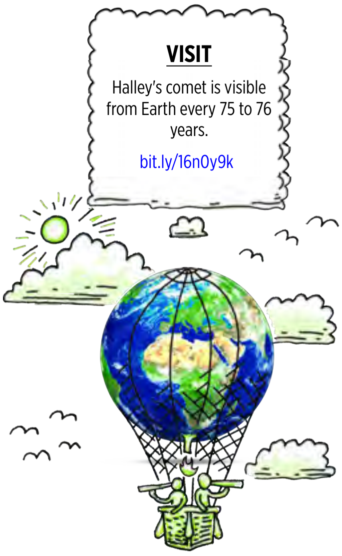
2. Which direction did the ion tail move when you moved the ball left and right while still blowing?

______________________________________________

______________________________________________

In a similar way, a comet's ion tail always points away from the Sun.


*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.*

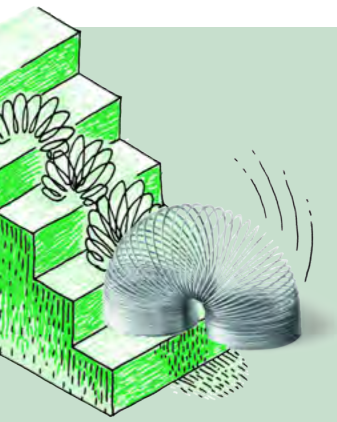



Comets that come into the inner solar system do not live forever. The Sun's heat melts comets, just like a snowman melts out in the Sun. After several thousand years the remains are so small that they no longer form a tail. Some comets completely melt away.

## 1.3 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:**

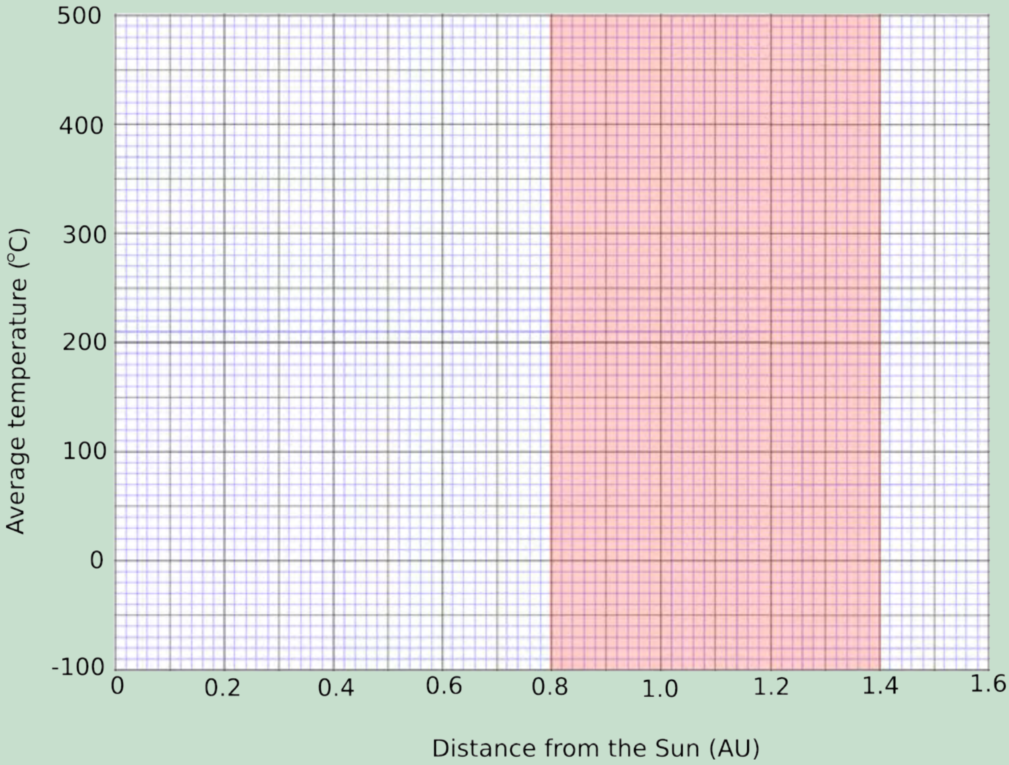
- pencil
- ruler

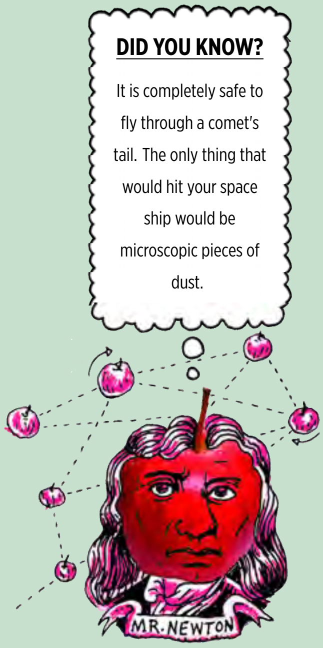
**INSTRUCTIONS:**

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.




**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)?

**TAKE NOTE**

An astronomical unit corresponds to the average distance between the Earth and the Sun.

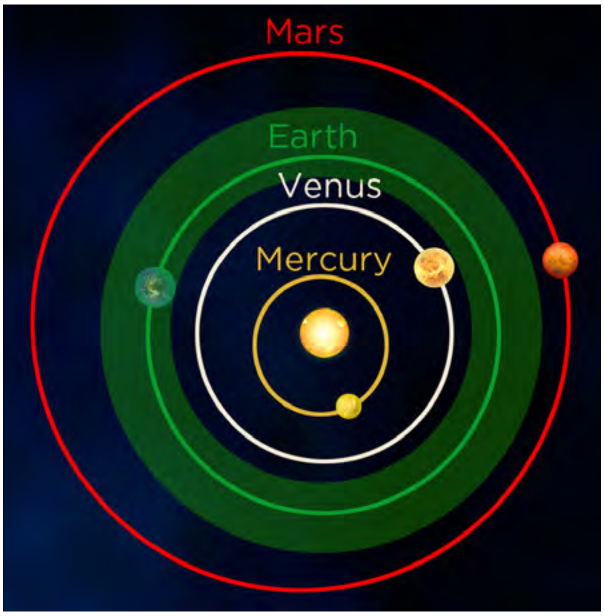
The average temperature on Earth is a moderate 15 °C. Because of this, water can exist in liquid form on Earth. *This is important because scientists think that liquid water is one of the key things needed for life.* Venus has an average temperature of 464 °C and no liquid water exists on Venus because 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, like 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).



**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.




*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? List your answers in the space below.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

**TAKE NOTE**
Other stars also have habitable zones. Scientists believe that planets orbiting other stars within the habitable zone could support life forms.

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?

______________________________________________

**VISIT**
Kepler Mission: A search for habitable planets.
bit.ly/HdBXYI

Which of the planets in the solar system have significant amounts of oxygen in their atmosphere or oceans?



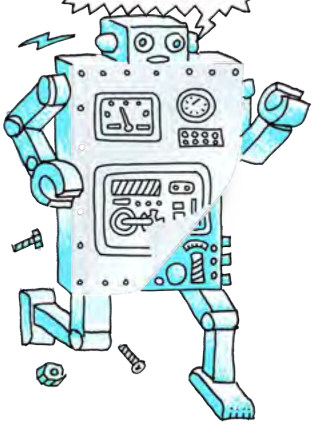
______________________________________________

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 life.

## 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 like carbon dioxide, which causes the Earth to remain warmer than it would have otherwise. This is called the **greenhouse effect**.

**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.



Scientists think that due to 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' 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!

**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.

**VISIT**

Do you enjoy English and Science? Read more about a career as a science writer.

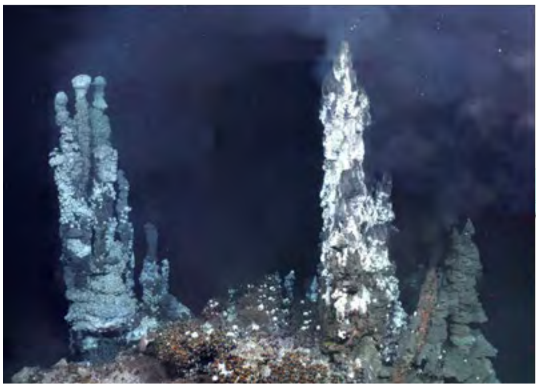
bit.ly/18CxYiZ

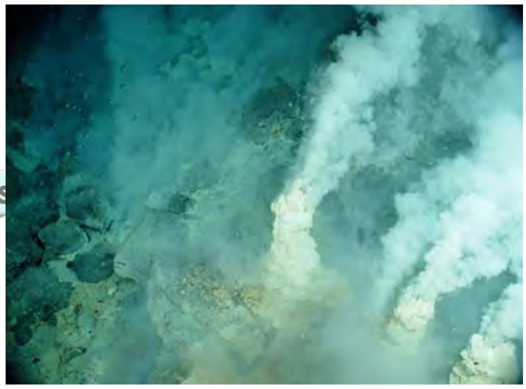
## The beginnings of life

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 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.





*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 only see them when they come into the inner solar system because they are small and only visible 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 chapter about our solar system.

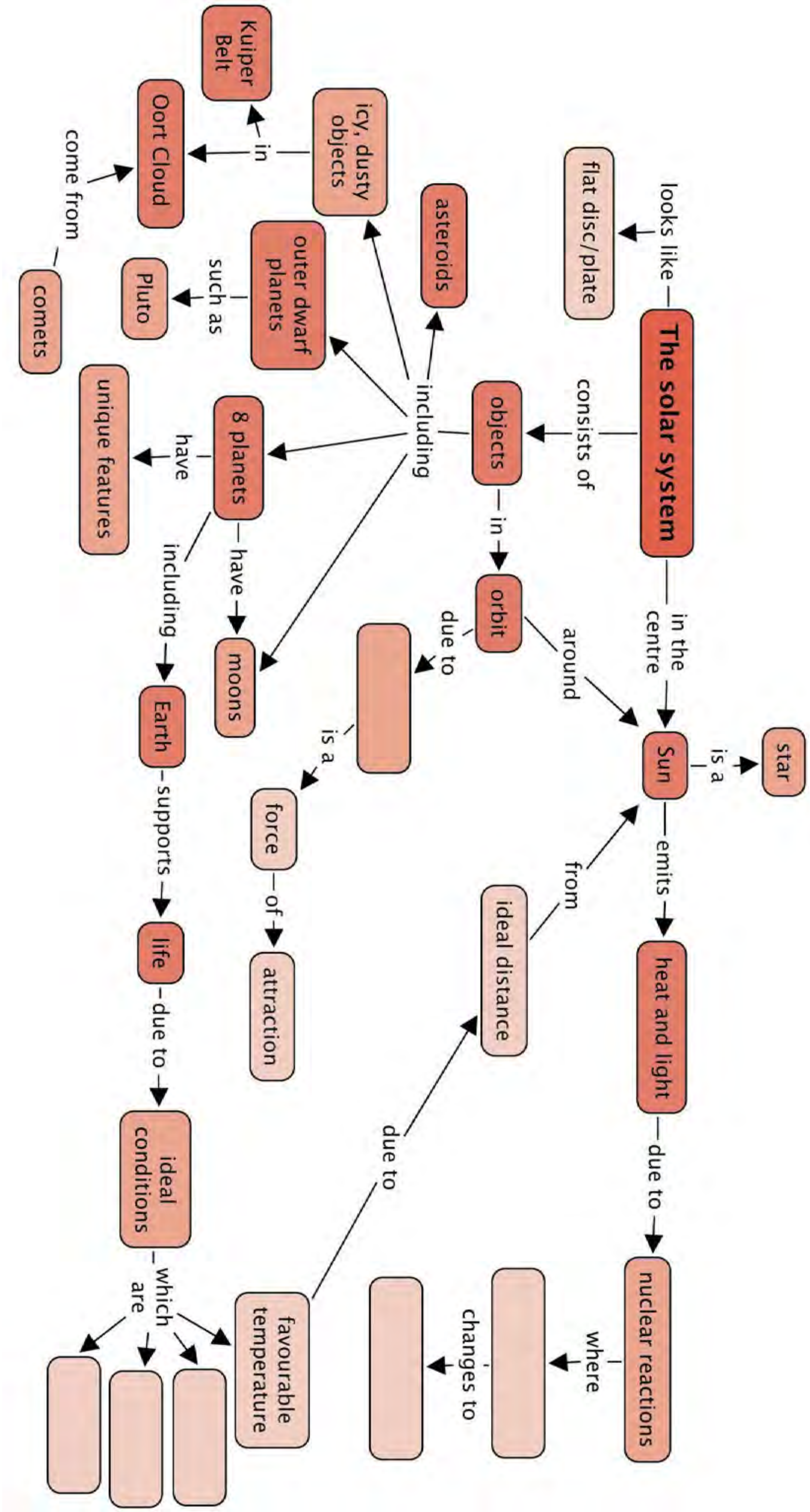
**VISIT**

Global warming: How humans are affecting our planet.

bit.ly/1c9toNa

**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.


The solar system
looks like
flat disc/plate
consists of
objects
in
orbit
around
in the centre
Sun
is a
star
emits
heat and light
due to
nuclear reactions
where
changes to
due to
is a
force
of
attraction
including
asteroids
icy, dusty objects
in
Kuiper Belt
Oort Cloud
come from
comets
outer dwarf planets
such as
Pluto
8 planets
have
unique features
have
moons
including
Earth
supports
life
due to
ideal conditions
which are
favourable temperature
due to
ideal distance
from

## REVISION:

1. How does the Sun produce its energy? [2 marks]

2. Why do sunspots look darker than the rest of the surface of the sun? [2 marks]

3. What keeps the planets and other bodies in our solar system in orbit? [1 mark]

4. Name the terrestrial planets. [4 marks]

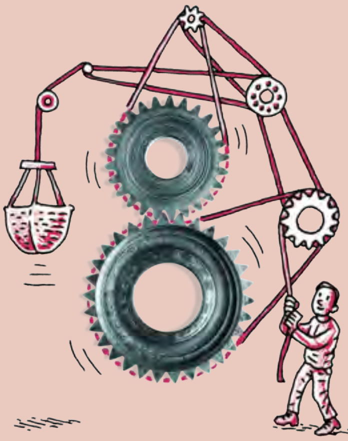
5. Name the gas giants. [4 marks]

6. Where is the asteroid belt located? [1 mark]

7. Where is the Kuiper belt located? [1 mark]

8. Why are the gas giants so much larger than the terrestrial planets? [2 marks]

9. List the planets in increasing distance from the Sun. [4 marks]

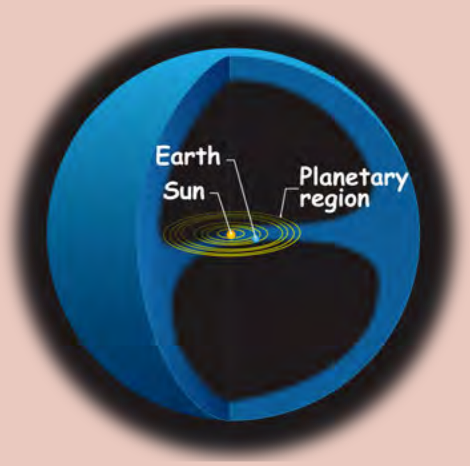


10. Which planets have rings? [4 marks]

11. Why is Venus so hot? [2 marks]

12. On which planet have landers found frozen water in the rocks under the planet's surface? [1 mark]

13. The following diagram shows the solar system at the centre.




a) What does the blue space represent? [1 mark]

b) What is mostly found in this space? [1 mark]

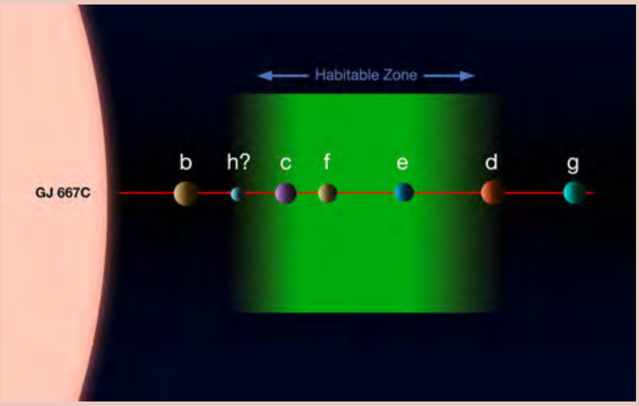
14. Why can we only see comets as they come close to the Sun? [3 marks]

15. What is the official definition of a planet and why was Pluto downgraded to a dwarf planet? [4 marks]

16. Why can the Earth support life? [4 marks]

17. What would happen to the Earth if it warmed significantly, like Venus has in the past? [2 marks]

18. The following diagram shows the system of planets around the star Gliese 667C.



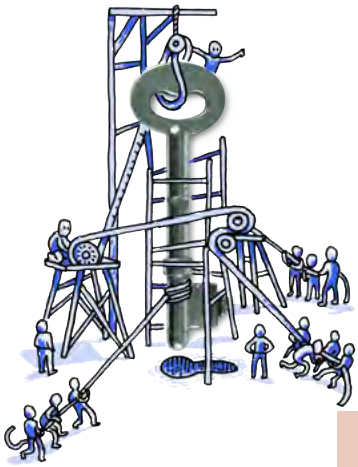

*The planets around another star.*

a) Which of these planets are possible candidates for life? [1 mark]

b) Explain your answer above. [2 marks]

Total [46 marks]

# 2 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?

## 2.1 The Milky Way Galaxy

**NEW WORDS**

- galaxy
- galaxy disk
- galaxy bulge
- spiral arm

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.*

*The Milky Way stretching across the sky viewed from Sutherland. The dark shape of the SALT telescope can be seen in the foreground with the night sky in the background (SAAO)*

**VISIT**

Time lapse video of the Milky Way.

bit.ly/19Ylkal

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 following image.

*This is what the Milky Way would look like if you could see it from far away in space. Scientists only know this 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.*


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 orangey 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.

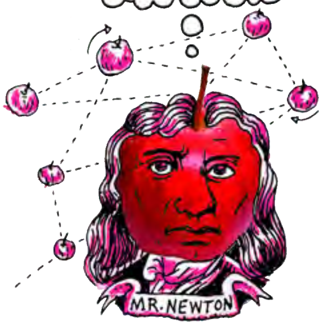
Scientists think that there are five major spiral arms in our galaxy. These are the Norma Arm, the Scutum-Crux Arm, the Sagittarius Arm, the Perseus Arm and the Cygnus Arm.

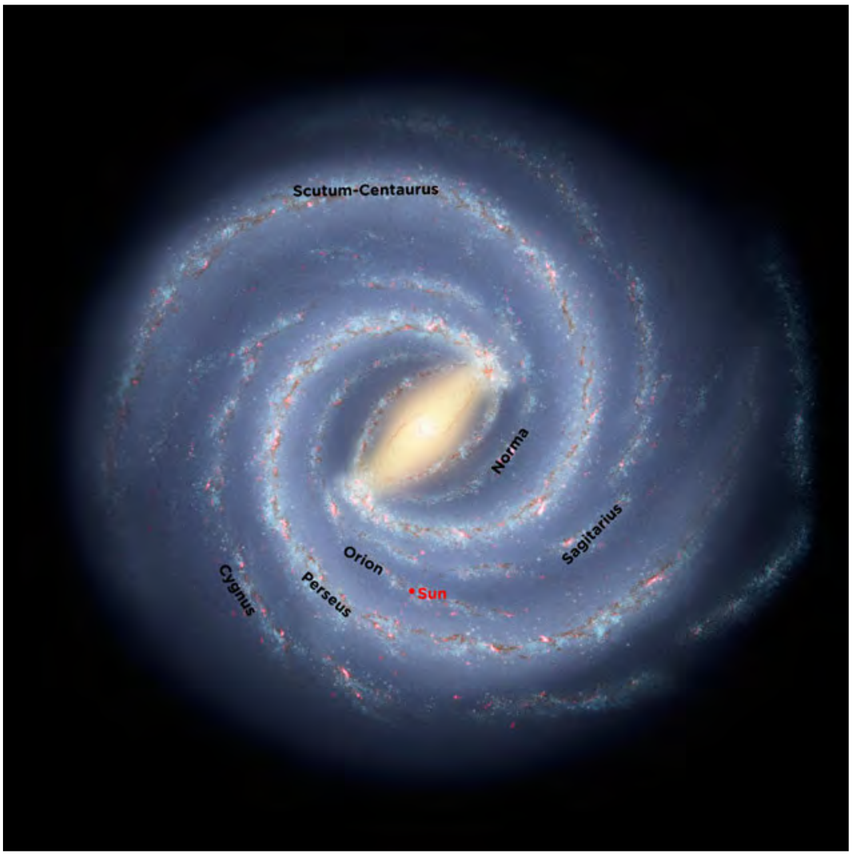
Our Sun is located in a small spiral arm called the Orion (or Local) Arm which lies between the Sagittarius Arm and the Perseus Arm. Our Sun is about halfway out from the centre of the galaxy.

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!

**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.



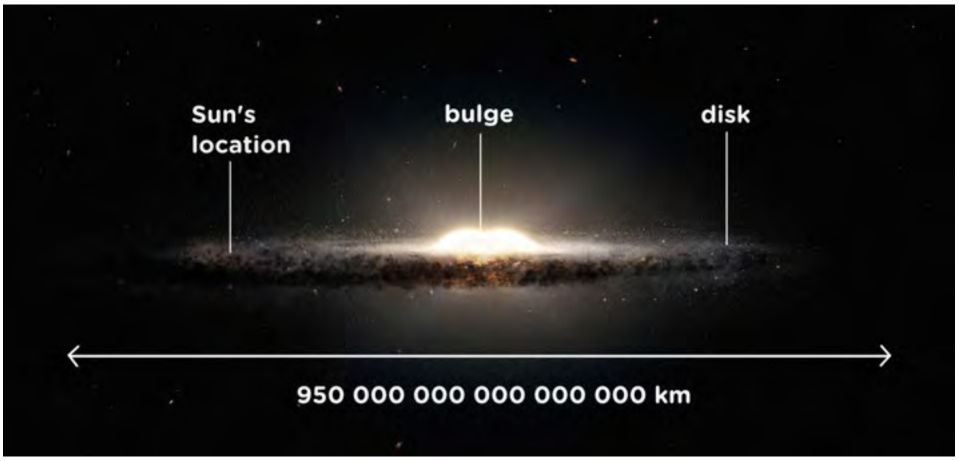



*The Sun's position in the Milky Way.*

**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 2000 km (about the distance from Durban to Windhoek!)

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:




*Looking at the Milky Way from the side.*

**TAKE NOTE**

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 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**.

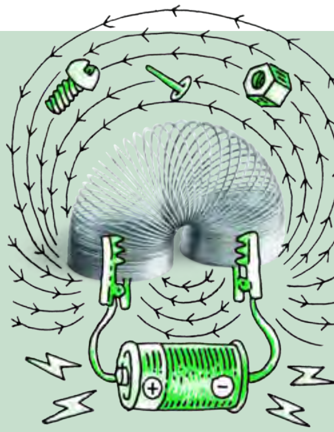
As you know, we are inside the Milky Way Galaxy. So when you look at the thin milky-looking band stretching across the sky at night, what do you think you are actually looking at?

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.


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.

*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.*

## 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.

**VISIT**

The sound of interstellar space.

bit.ly/1cbfjil

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:**

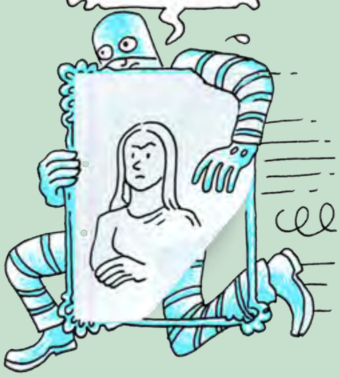
- thick piece of black cardboard at least 30 cm across
- other materials for your model, either collected by you or supplied by your teacher

**INSTRUCTIONS:**

1. You need to build a 3 dimensional 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 3D 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 chapter.

**TAKE NOTE**

We will learn more about the life cycle of stars in Gr 9. Younger stars are hotter and bright white or blue in colour, while older stars are cooler and more yellow and red in colour.



**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?

______________________________________________

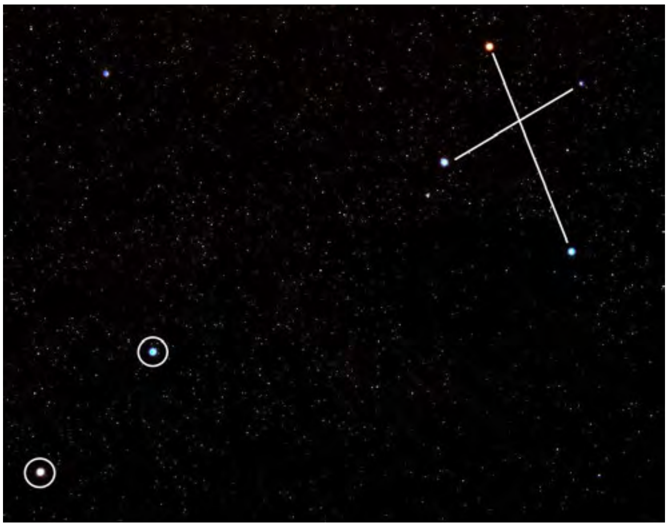
**NEW WORDS**

- Proxima Centauri
- Alpha Centauri
- constellation

## 2.2 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.

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.



*The Pointers (circled) and the Southern Cross.*

**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.

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.

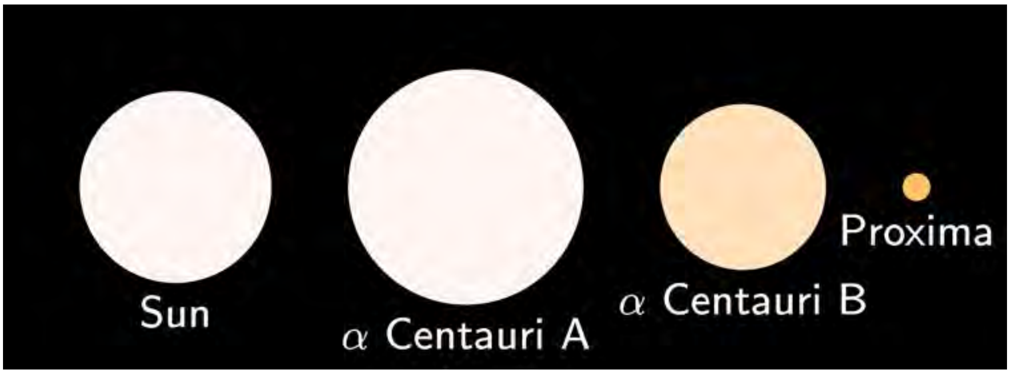
**VISIT**

Scale of the Universe.

bit.ly/185Yjlc

**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.



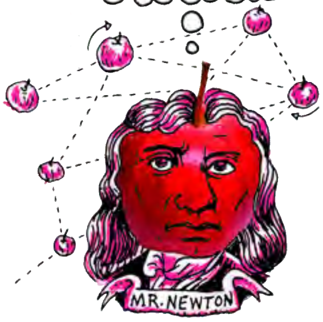

*A comparison of the sizes of the Alpha Centauri star system and the Sun.*

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 chapter.

Do you know how much a trillion or a billion is? Have a look at the following table:

**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.




| 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 |



## 2.3 Light years, light hours and light minutes

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.

**NEW WORDS**

- light minute
- light hour
- light year

## ACTIVITY: Travelling fast

A cheetah, the fastest land mammal, can reach speeds of 120 km/h, as fast as cars on the highway.

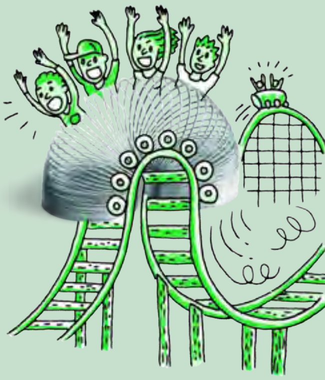
A Peregrine Falcon, the fastest animal, can fly as fast as 389 km/h.


Japan's high speed train the JR-Maglev MLX01 has reached 581 km/h.

NASA's scramjet the X-43 flies at 7000 km/h.


The international space station (ISS) orbits the Earth at a speed of 27 744 km/h.

What about light? Light travels at about 1080 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 1753 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. Fill in your answers in the table below.

Remember the formula: $\text{time} = \frac{\text{distance}}{\text{speed}}$

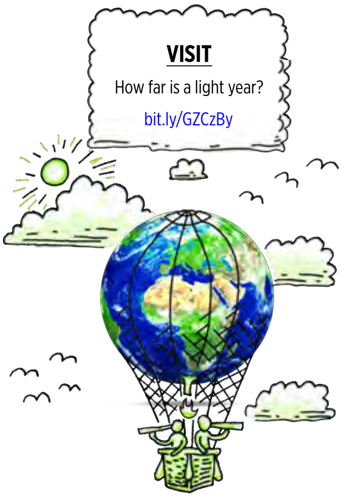
| Mode of transport | Speed (km/h) | Distance between Cape Town and Durban (km) | Time taken for the journey |
|---|---|---|---|
| cheetah | 120 | 1753 | 14.6 hours |
| peregrine falcon | | 1753 | hours |
| high speed train | | 1753 | hours |
| NASA's scramjet | | 1753 | minutes |
| International space station | | 1753 | seconds |
| light | | 1753 | 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?

______________________________________________________________

______________________________________________________________

______________________________________________________________

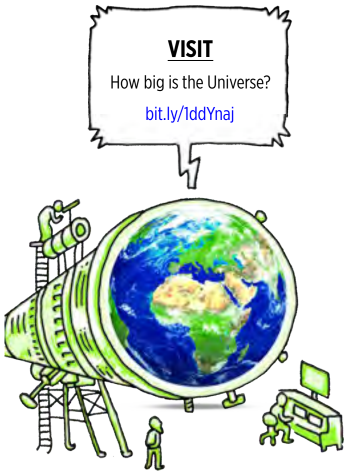

Astronomers use units called **light years** to measure the distances between stars and galaxies. One light year is almost 10 trillion kilometres. As you can see, a light year is very, very far.

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.



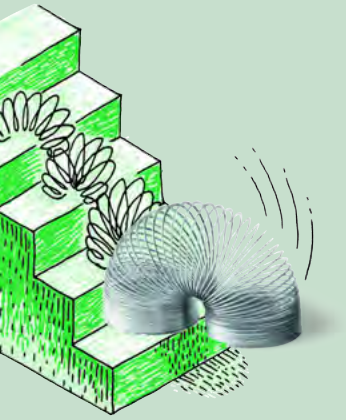
How long do you think light emitted from one light minute away takes to reach your eyes?

______________________________________________________________




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 | 1433.5 | 1.3 light hours |
| Uranus | 2872.5 | 2.7 light hours |
| Neptune | 4495.1 | 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. You cousin says she cannot see it. Why is that?

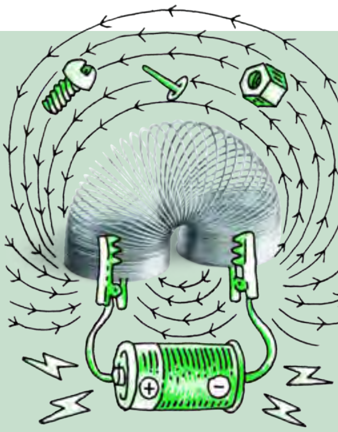
___

___

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 out even further 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



**INSTRUCTIONS:**

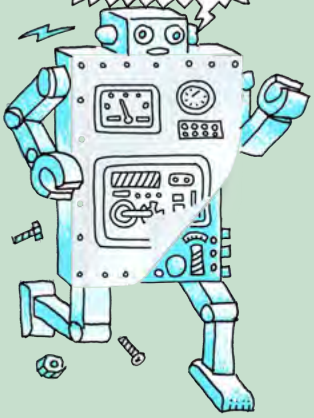
1. Look at the table showing our closest stars and the star map.
2. Answer the questions below.

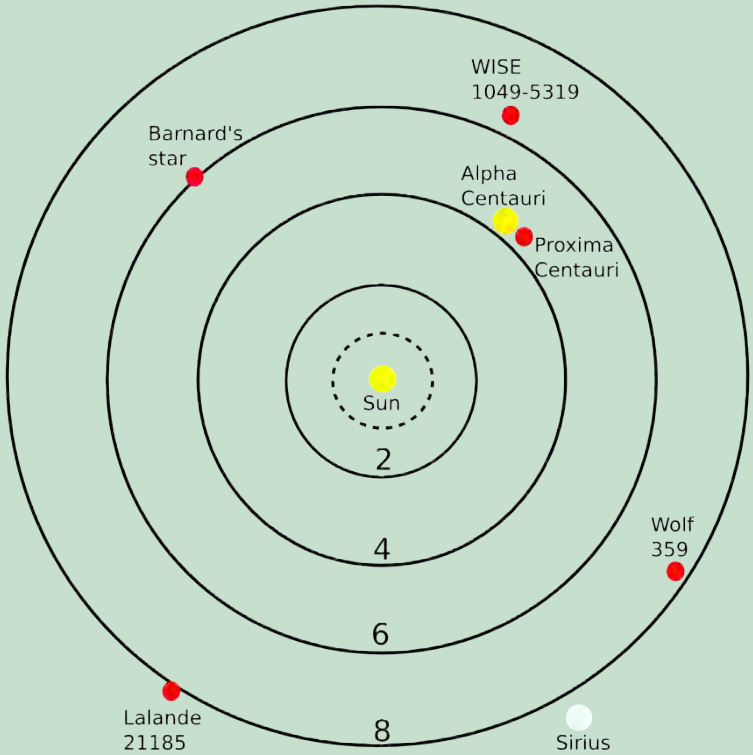
| Star | Distance (light years) |
|---|---|
| Proxima Centauri | 4.24 |
| Alpha Centauri | 4.37 |
| Barnard's Star | 5.96 |
| WISE 1049-5319 | 6.52 |
| Wolf 359 | 7.78 |
| Lalande 21185 | 8.29 |
| Sirius | 8.58 |

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.

**TAKE NOTE**

The star map is shown in two dimensions, on a flat plane. Remember that the stars are located in 3 dimensions in space.






**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.

**DID YOU KNOW?**

The Milky Way is so large that light takes 100 000 years to cross from one side to the other side.

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.

**NEW WORDS**

- galaxy
- galaxy group
- galaxy cluster
- filament
- void
- Universe

## 2.4 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.

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.

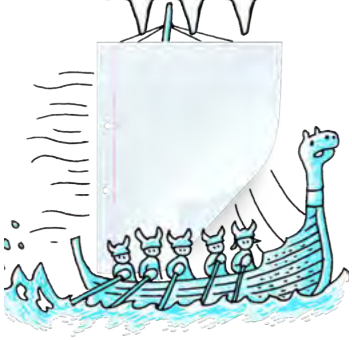
Our closest galaxy neighbour is called the Andromeda Galaxy. Andromeda is 2.5 *million* light years away from the Milky Way. If you wanted to travel to Andromeda and could travel as fast as light, it would still take you 2.5 million years to get there.

*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.*



**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.



*This illustration shows a stage in the predicted collision between our Milky Way Galaxy and the neighboring 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.*

**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 years time. No need to worry just yet!

**VISIT**
The largest known galaxy in the Universe.
bit.ly/1ddXJcR

**VISIT**
What is the Universe?
bit.ly/1eFW3XI
How big is the Universe?
bit.ly/16sqdIB

**VISIT**
Something fun - have a look at this picture of a cheetah created using thousands of images of galaxies from Galaxy Zoo.
bit.ly/177itzq

There are five main types of galaxies. You do not need to know these names. This is included for your interest.

- spiral
- barred spiral
- elliptical
- lenticular
- irregular

*Spiral galaxy named NGC 4414.*

*Barred spiral galaxy named NGC 1300.*

*Elliptical galaxy NGC 1132.*

*A lenticular galaxy, called NGC 5866.*

*Irregular galaxy named NGC 1427A.*

Let's do an activity to explore the different types of galaxies we see.

## 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 chapter, write down in the table what type of galaxy our Milky Way Galaxy is.
3. Write down in the table below what type of galaxy (spiral, barred spiral, elliptical or irregular) you think each galaxy is.

| Galaxy Name | Galaxy type |
|---|---|
|  The Milky Way Galaxy. | |
|  Galaxy M 89. The galaxy is 60 million light years away. | |
|  Galaxy NGC 4622. The galaxy is 111 million light years away. | |

| Galaxy Name | Galaxy type |
|---|---|
|  The Large Magellanic Cloud galaxy. This satellite galaxy of our own Milky Way is only 163 000 light years away. | |
|  The Spindle Galaxy, 44 million light years away. | |

**VISIT**
What is dark matter?
bit.ly/1ab5oFO

**QUESTION:**

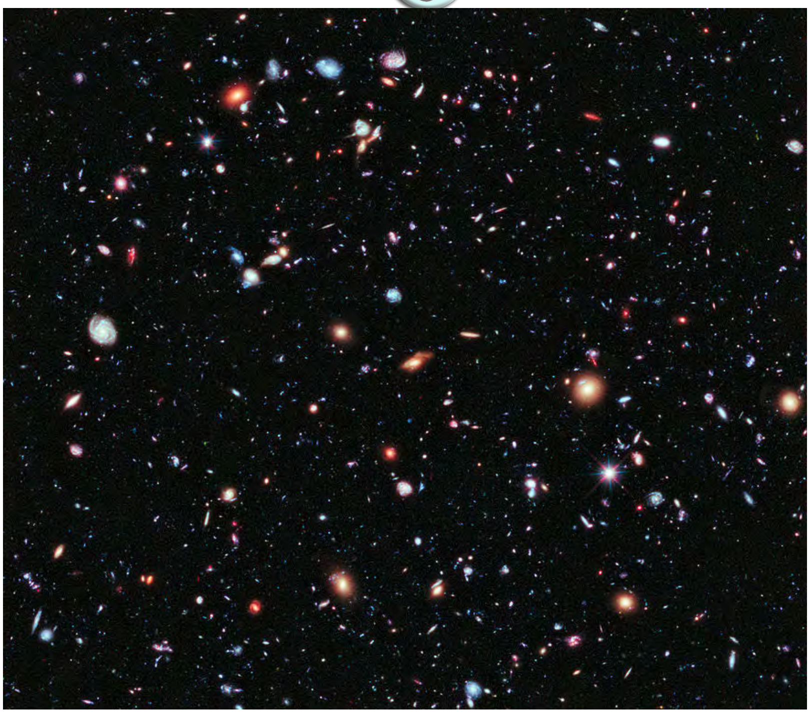
List the galaxies in the table above in increasing order of distance from our Milky Way Galaxy.

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.

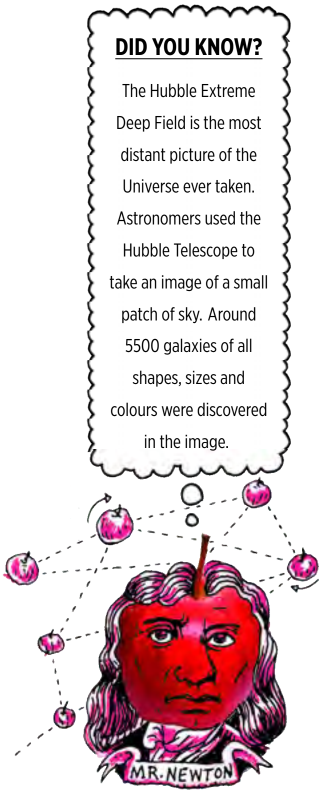


- Most galaxies are found gathered together in gigantic galaxy neighbourhoods, called **galaxy groups**. Our Milky Way is found in a group of galaxies called **The Local Group.**
- **Galaxy clusters** are even larger, spanning tens of millions of light years, and can contain hundreds or even thousands 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.





*Galaxies in the Hubble Extreme Deep Field. Every smudge in the image is a distant galaxy.*



**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**.

**VISIT**

Do we expand with the Universe?

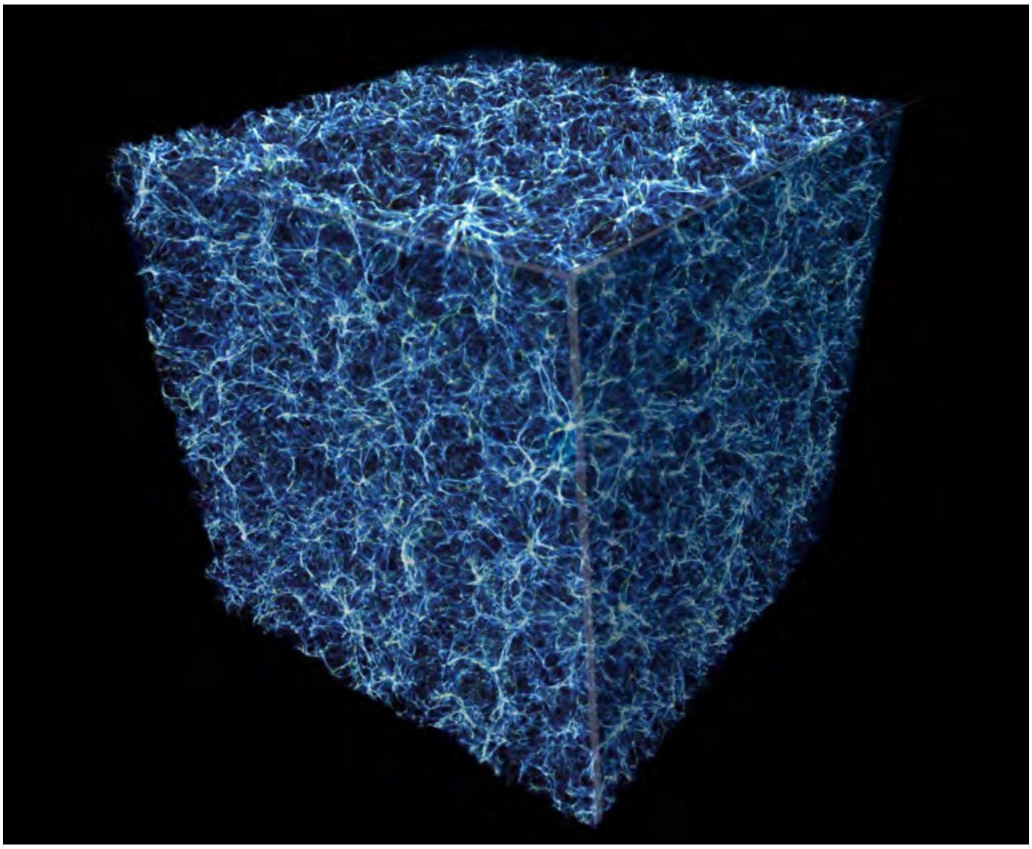
bit.ly/1ddYyTd

**VISIT**

Read interesting articles on the latest developments in astronomical research on **Space Scoop**, an astronomy news service.

bit.ly/1fSxJ84

### 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 might 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.

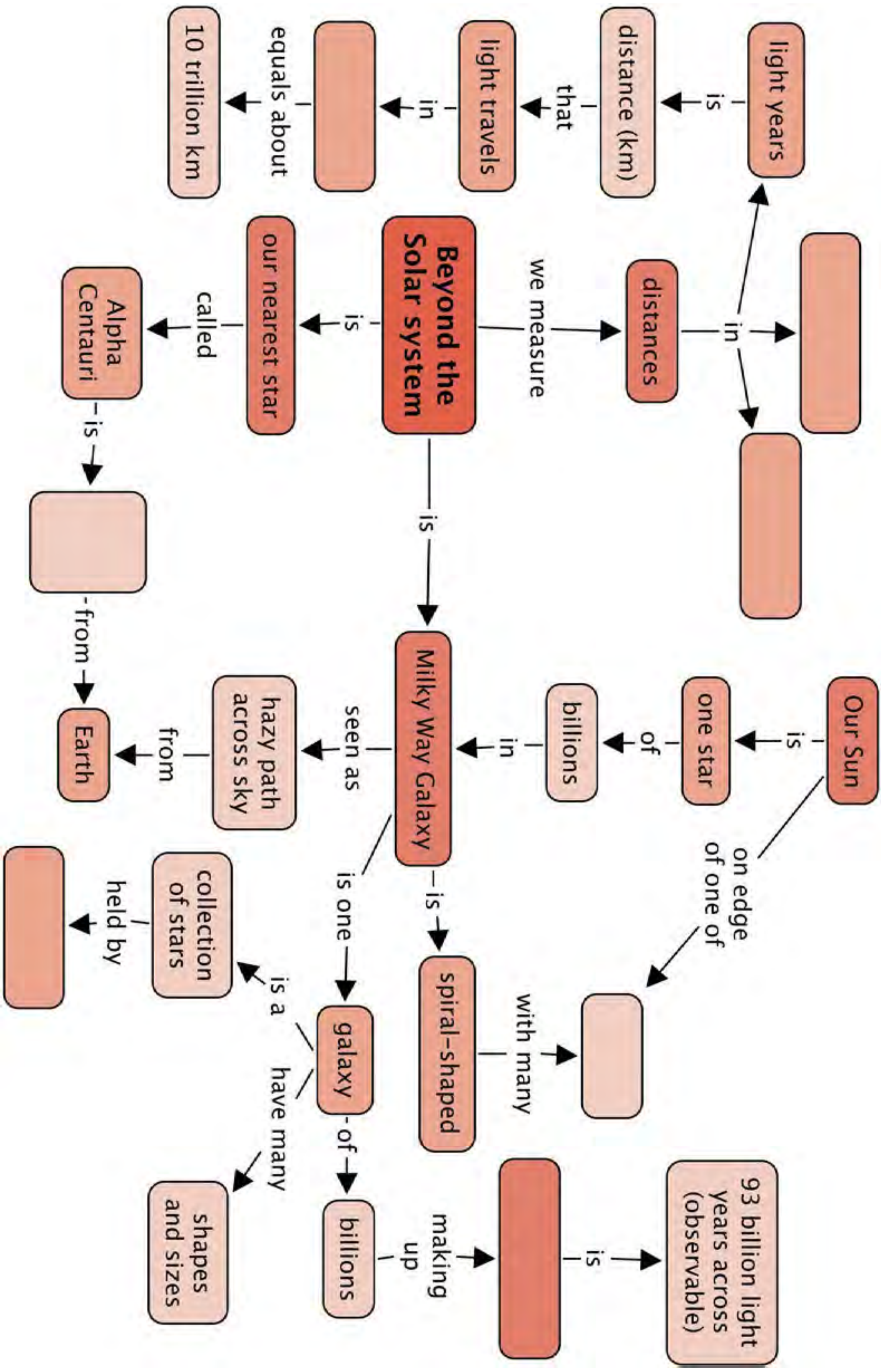
## SUMMARY:

### Key Concepts

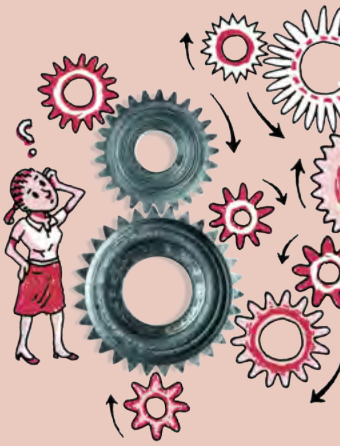
- A galaxy is a collection of millions or billions of stars, together with gas and dust, held together by gravity.
- Galaxies come in all shapes and sizes.
- Our home galaxy, the Milky Way Galaxy, is a spiral galaxy containing around 200 billion stars. Our Sun is just one of those stars.
- After the 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.


Beyond the Solar system
we measure
distances
in
light years
is
distance (km)
that
light travels
in
equals about
10 trillion km
is
our nearest star
called
Alpha Centauri
is
from
Earth
is
Milky Way Galaxy
Our Sun
is
one star
of
billions
in
seen as
hazy path across sky
from
on edge of one of
is
spiral-shaped
with many
is one
galaxy
is a
collection of stars
held by
of
billions
making up
is
93 billion light years across (observable)
have many
shapes and sizes

## REVISION:



1. What is the name of our second closest star? How far away is it? [2 marks]

2. What is the name of our second closest easily visible star? Is it really a single star? [2 marks]

3. What is the definition of a light year? [2 marks]

4. What is a galaxy? [3 marks]

5. Where is the Sun located within the Milky Way? [2 marks]

6. How many stars are in our Milky Way Galaxy? [1 mark]

7. Name the 4 main types of galaxies. [4 marks]

8. What kind of galaxy is the Milky Way? [2 marks]

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 marks]

10. Why does it look as though the Milky Way is a splash of milk or a starry road across the sky? [2 marks]

11. What is a group of galaxies? [2 marks]

12. What is the name of the group of galaxies that the Milky Way is a member of? [1 mark]

13. What are clusters of galaxies and superclusters of galaxies? [2 marks]

14. What is the size of the observable Universe? [1 mark]

15. **Bonus 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 marks]

Total [34 marks]

Total with extension [36 marks]

# 3 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?

## 3.1 Early viewing of space

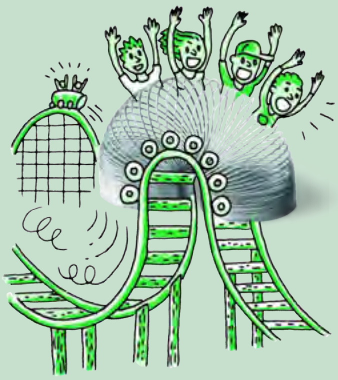
**NEW WORDS**

- constellation
- starlore

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.

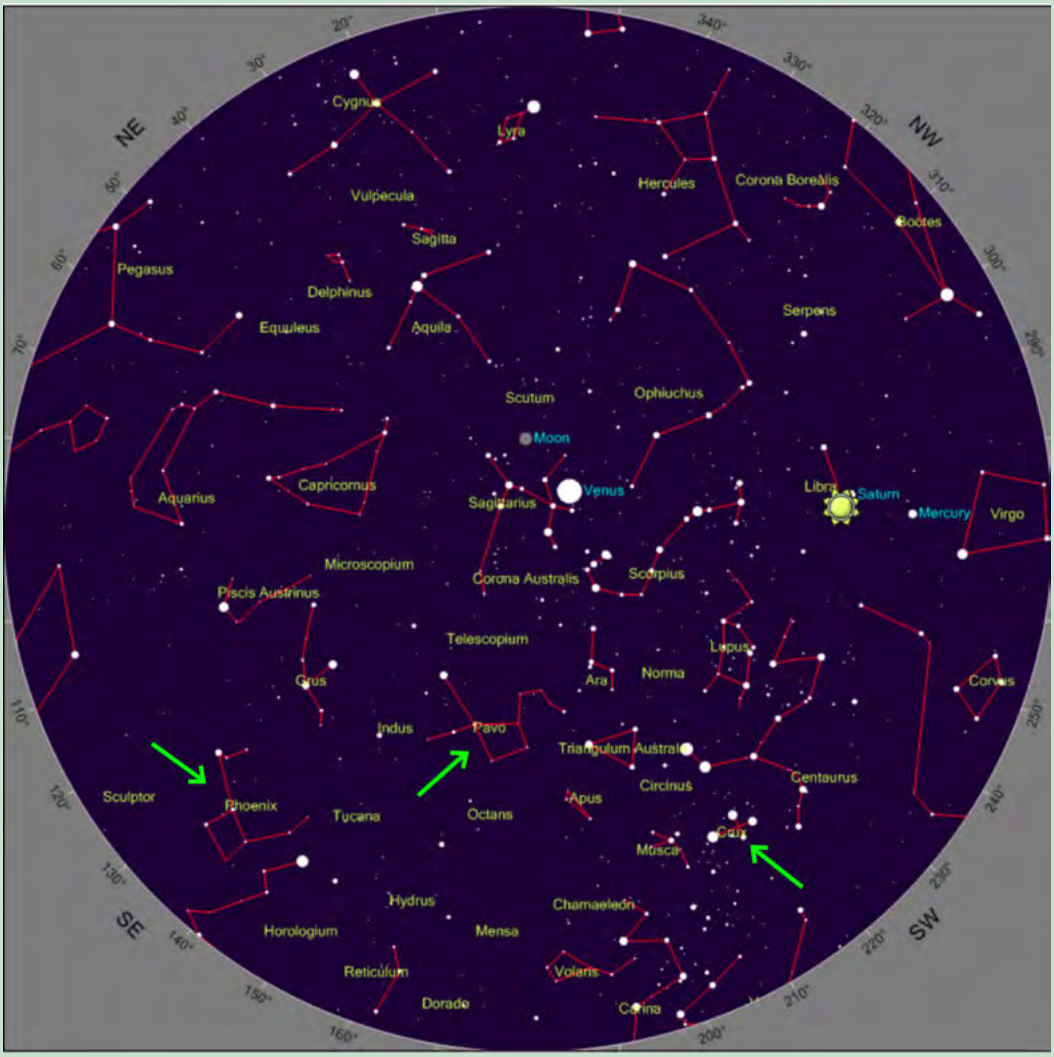


## ACTIVITY: Using star maps to observe the night sky

**MATERIALS:**

- star map
- clear skies
- pencil
- paper or this workbook
- torch - optional

Below 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.

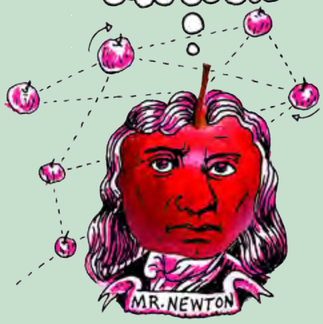
**VISIT**

Create your own star map for your area.

bit.ly/1a4N1nU

**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.



**TAKE NOTE**

Today professional astronomers formally recognise 88 constellations, 23 of which are in the southern hemisphere.

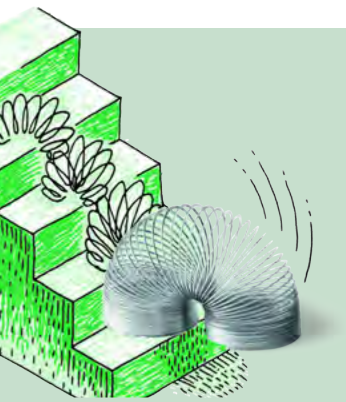
**VISIT**

Learn how to view the night sky with Google Earth.

bit.ly/16pYL3u

**DRAWINGS:**

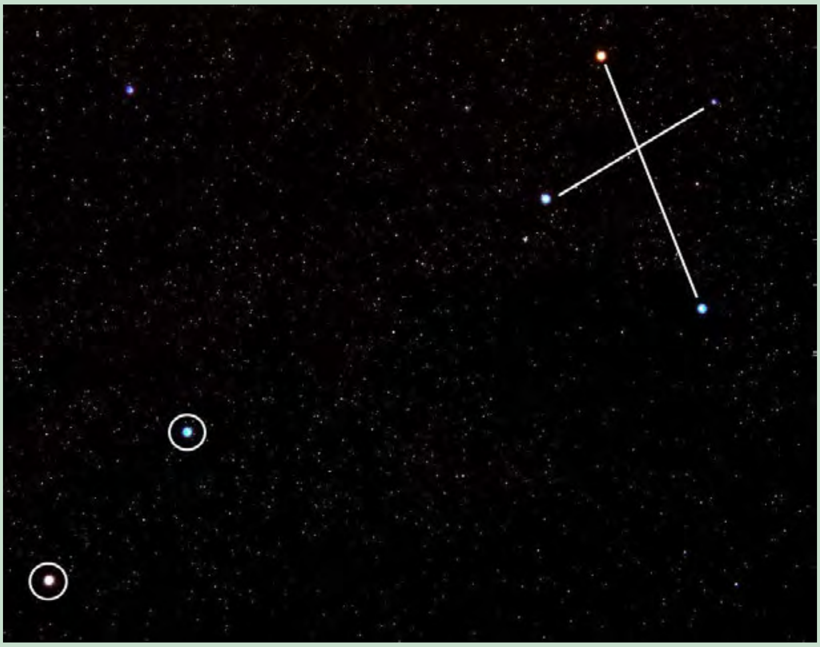
Draw your pictures in the space below. If you have used separate paper you can stick your pictures in here.



## ACTIVITY: Observing the Southern Cross (Crux)

**MATERIALS:**

- picture of the Southern Cross constellation and star map
- clear skies
- pencil
- paper or this workbook



*The Southern Cross or Crux (top right) and the Pointers (bottom left).*

**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 7pm.
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.
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. Draw or paste your image (if you have used separate paper) into the space below.
6. 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.

**DRAWINGS:**

**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?

______________________________________________

______________________________________________

______________________________________________

______________________________________________

**VISIT**

Stellarium - a free, open source programme for your computer to to generate a realistic, real-time 3D simulation of the night sky.

bit.ly/1aE2Imj

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.

*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.*

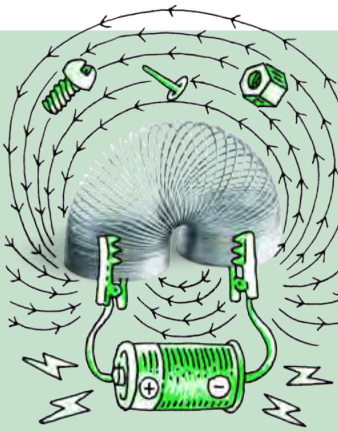

You might imagine that all the stars lie at the same distance from Earth. This isn't true, the stars lie at different distances. The closest star in Orion is called Bellatrix and is around 250 light years away. The furthest star Meissa is around 1100 light years away, roughly the same distance as the Orion nebula (1300 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 up into the sky to be stars by a magical girl. 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.

**VISIT**
Read more about some South African starlore: bit.ly/1cbF7uu and bit.ly/1abUL5z

**INSTRUCTIONS:**

1. Search for a story about a constellation found in the South African sky.
2. Use a South African starmap 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 might 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.

**NEW WORDS**
- celestial
- telescope
- chromatic aberration
- primary mirror

## 3.2 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.


*The Andromeda galaxy, viewed with the Hubble Space Telescope. Humans can only see it 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.

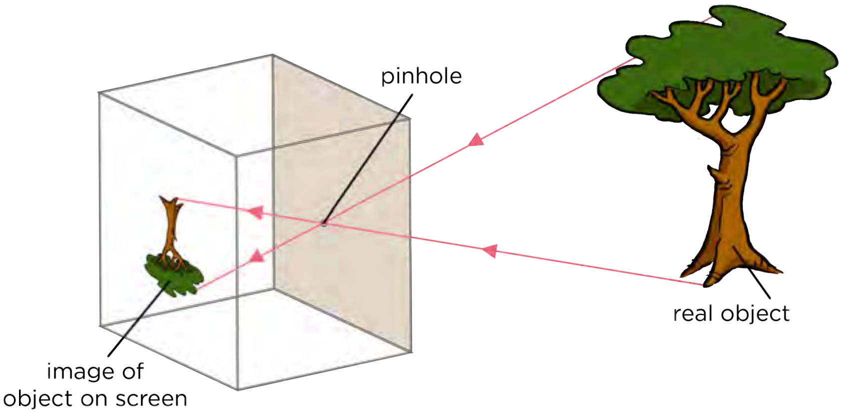
**VISIT**
History of the telescope.
bit.ly/1ibkZ9o

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?

___

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.

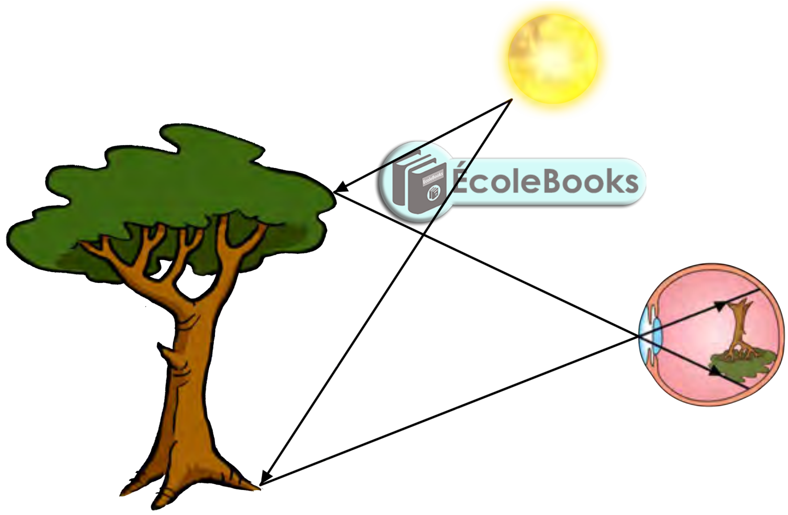
Do you remember making a pinhole camera in Energy and Change? Have a look at the following diagram which illustrates this again.




Which way is the image projected onto the screen?

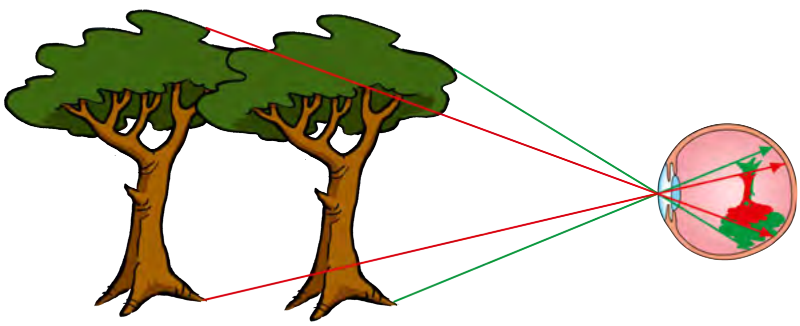
---

This is the same way in which images are formed on your retina when you view an object, as shown in the following image.



*Images formed on the light-detecting retina at the back of your eye are upside down.*

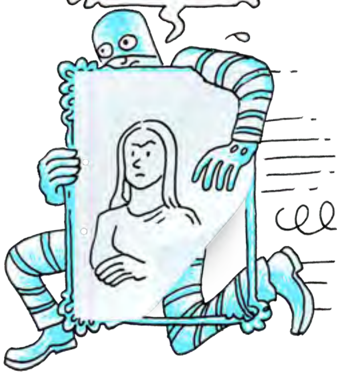
An object that is far away projects a small image of the object onto the retina at the back of your eye making it difficult to see fine details in the image.



*More distant objects appear smaller on our retina.*

**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 light. It reflects the light from the Sun.



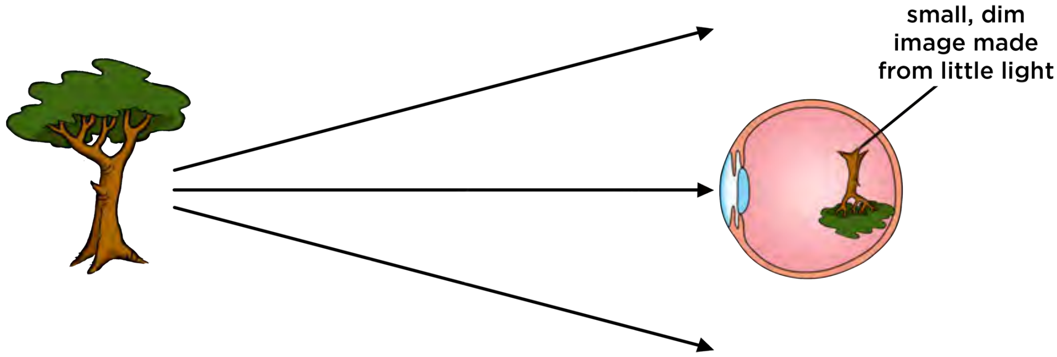
**VISIT**

The beauty of the night sky.

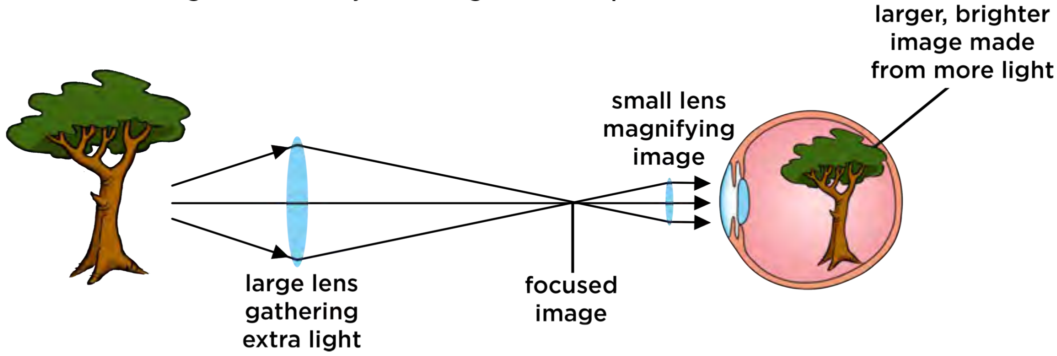
bit.ly/1h5dy5M

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.

**Viewing a distant object**




**Viewing the same object through a telescope**




**DID YOU KNOW?**

Images formed on your retina are actually upside down. Your brain "corrects" the image, so that you do not notice.

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.

## ACTIVITY: Telescopes as light buckets

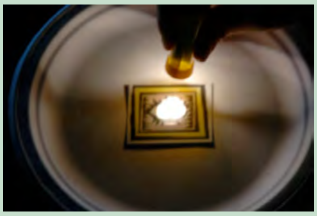
There is only so much light emitted from an object each second. Little packets of light are called **photons**. Our eye needs at least 500 photons, or packets of light, coming into it every second for our brains to sense that something is there. In this activity you are going to represent photons from a distant galaxy using pepper grains or hundreds and thousands.

**MATERIALS:**

- paper plate
- piece of paper 3cm by 3cm
- 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:**

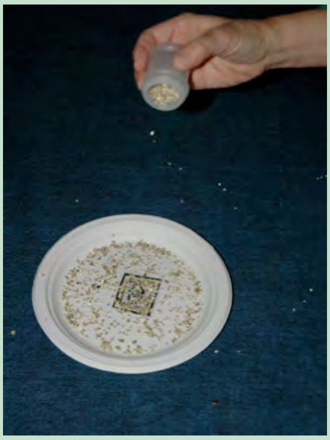

1. On the piece of paper draw an image of your eye including the pupil and iris.
2. Tape or place the image of your eye onto the middle of a paper plate. The paper plate represents a telescope mirror or lens.
3. Take the foam and cut it into a thin strip about 3 cm wide and as long as the paper plate across.
4. Stick six skewers into the foam equally spaced along the strip. Trim the pointed edges off that are sticking out 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.*

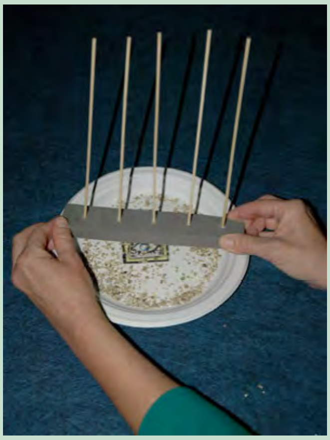
*The further away an object, the less light that reaches your eye.*



Sprinkle the pepper grains or hundreds of thousands.

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.



The skewers represent the light rays hitting the mirror of the telescope.

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.

Now you can see how a telescope's mirror can collect lots of light and direct it into a small detector, like your eye.

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.


**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?

______________________________________________________________________

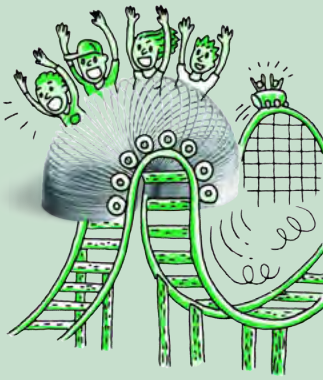
4. How do you think all the light that hits the telescope mirror is concentrated so that it can enter our eyes or a small telescope detector?

______________________________________________________________________

______________________________________________________________________

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 that 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 you 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. Fill in your reaction times in the table below, these represent the exposure time of your eye.
11. Complete the questions.

Table 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?

______________________________________________

______________________________________________

______________________________________________

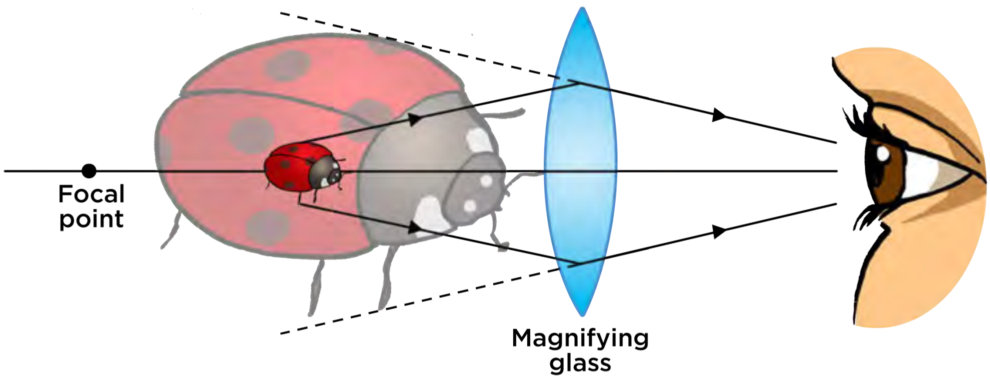
4. How many times longer can SALT expose for than your eye?

______________________________________________

______________________________________________

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.




*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

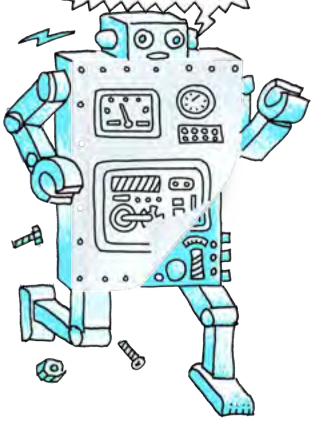
Optical telescopes collect visible light from celestial objects. There are two types of optical telescopes.

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.

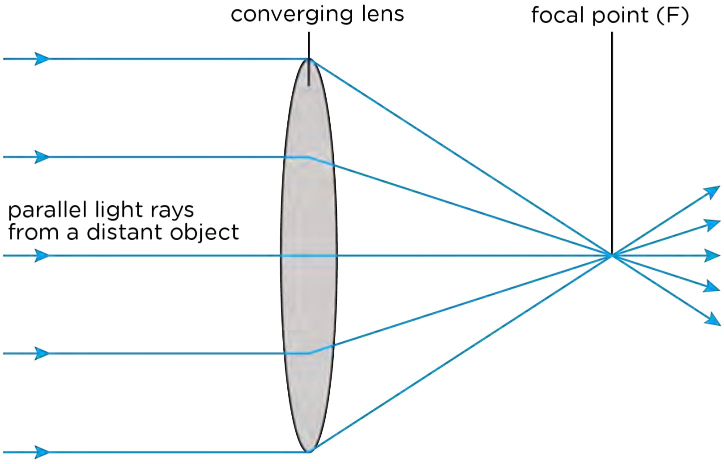
## 1. Refracting telescopes

**TAKE NOTE**

As astronomical objects are so far away, their light rays are considered to be parallel to each other.



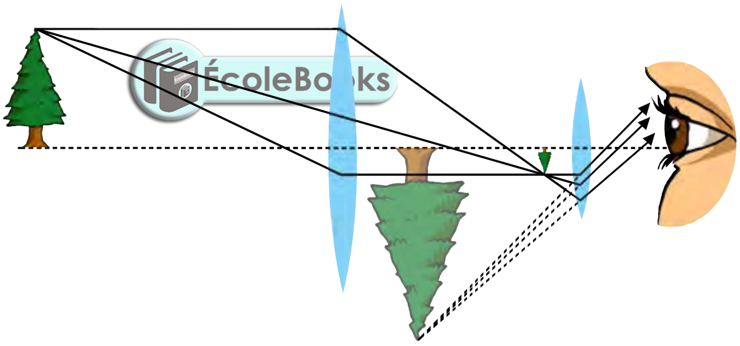
Refracting telescopes use a converging (convex) lens to collect and bend the light rays inwards to the focal point (also called the focus) of the telescope. The light collecting lens is called the objective lens.

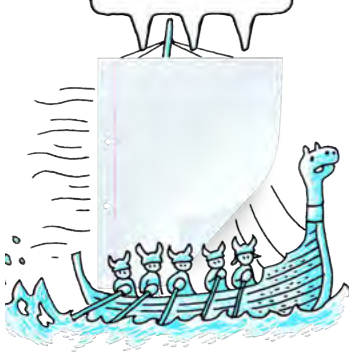



Once light is brought to a focus, it is then magnified by another lens called the eyepiece lens. Look at the optical ray diagram below showing a simple refracting telescope.

**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.





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 images is what we see when we look through the telescope.

What kind of lenses are the objective lens and the eyepiece lens?

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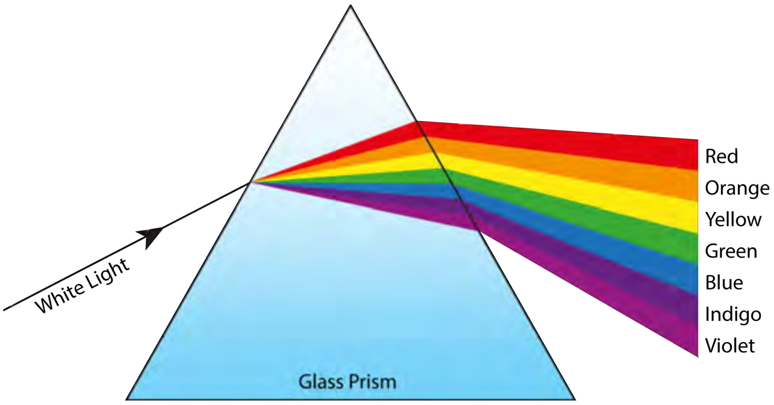
Look at the following picture which shows how white light is refracted (bent) as it travels through a prism. As we learnt in Energy and Change, when light travels through glass it slows down and so it bends or refracts.

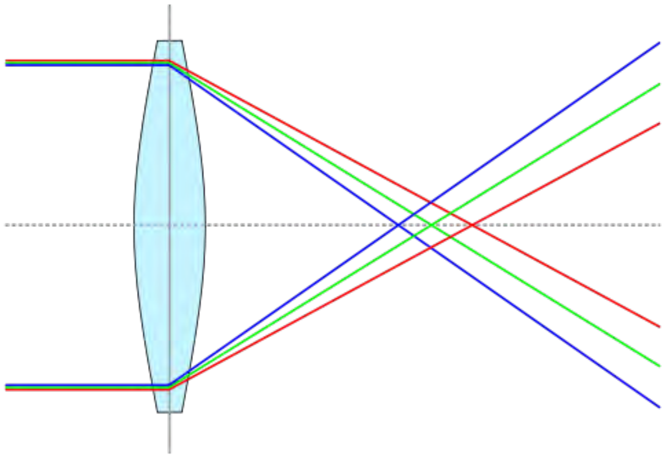



Do all the colours undergo the same amount of refraction? Which colour is bent the most?

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?



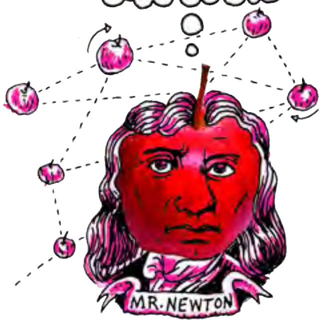
Lenses are shaped to bend light by a certain desired amount. However, the different colours that make up white light bend by slightly different amounts. This means that different colours come to a focus at slightly different distances from the objective lens. Each colour will produce its own image and 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.*

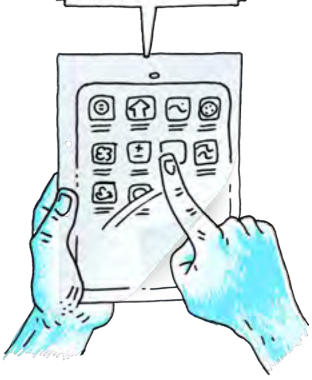
**DID YOU KNOW?**

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.

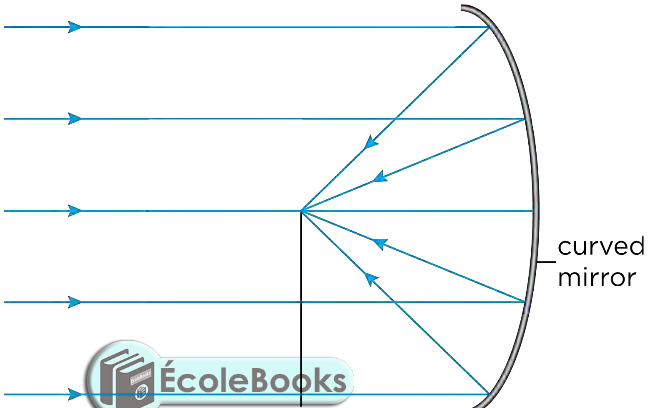


The main disadvantages of refracting telescopes are:

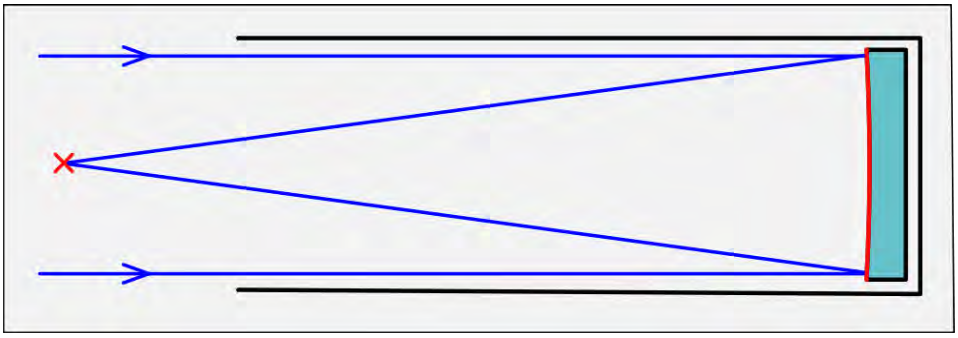
1. Light travels through the lenses in the telescope and so the lenses have to be perfect. There must be no bubbles of air in the glass which would distort the image. It is difficult to and expensive to make large perfect lenses.
2. The light travels through the lenses and so they can only be supported 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.

## 2. 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 of the telescope. The position of the detector is shown in the following diagram with a red cross.



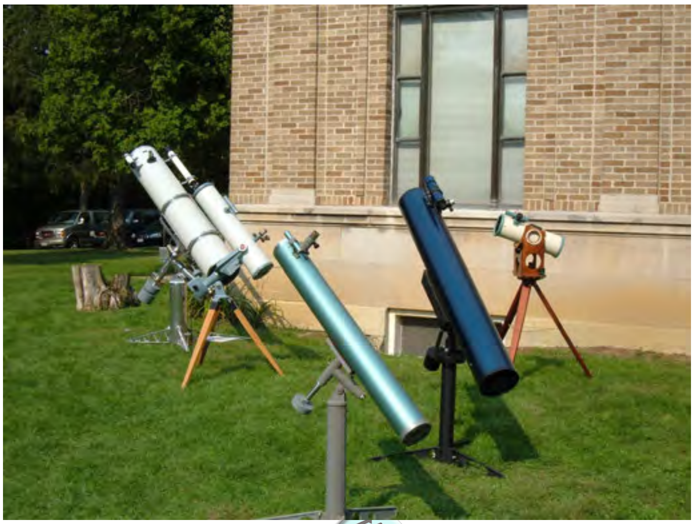
*A prime focus reflector with a detector at the focal point, marked with an X.*

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.
- 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.

**DID YOU KNOW?**

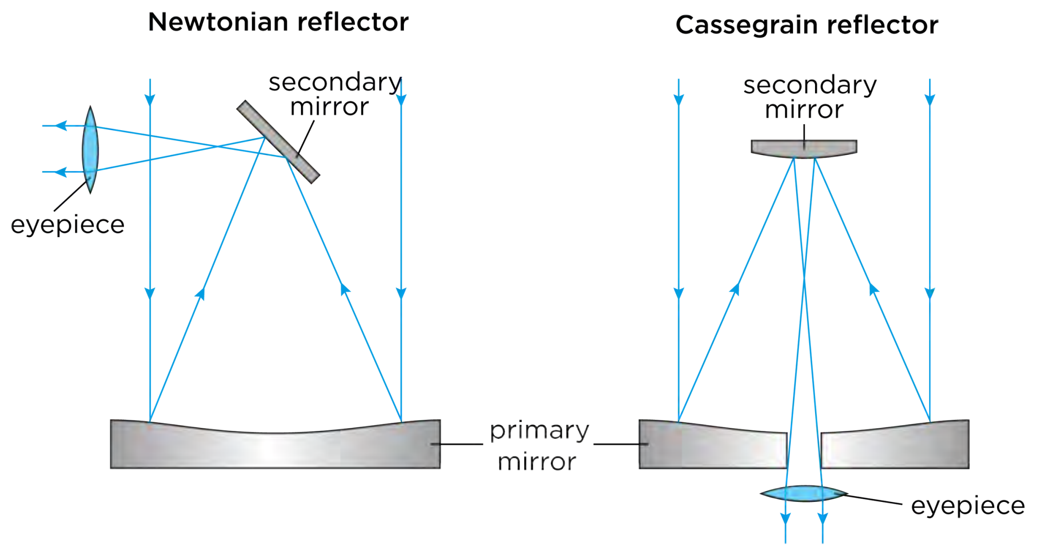
The Cassegrain reflector is named after a reflecting telescope design that was published in 1672 and has been attributed to Laurent Cassegrain.



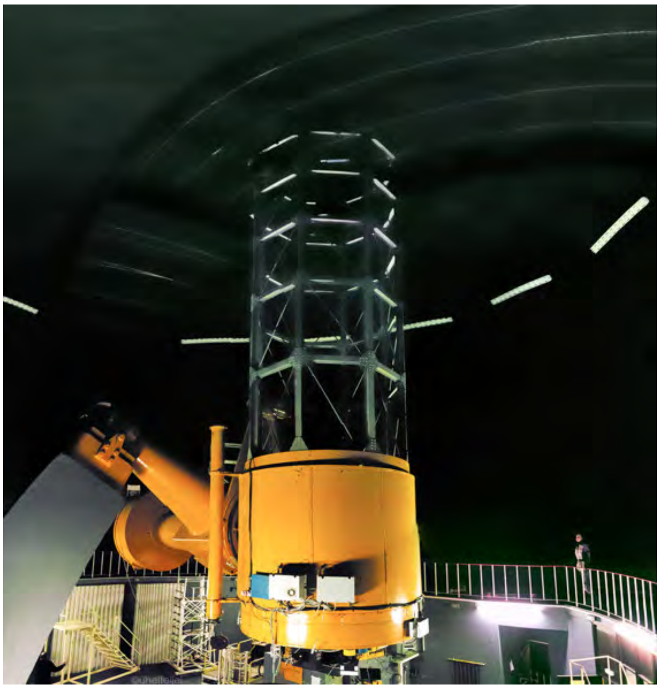
*A group of Newtonian telescopes.*



The following ray diagrams show the difference between a Newtonian and Cassegrain reflector.




*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.*



*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).*

**VISIT**

Curious about the Universe, but don't know where to start? Have a look at this step-by-step guide to becoming an awesome amateur astronomer.

bit.ly/1gBwrQ8

The secondary mirror in a reflecting telescope must be very small. Why do you think this is so?

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Do you think that reflecting telescopes suffer from chromatic aberration? Why?

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**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 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 only be used at night.
2. They cannot be used in bad weather (rain, cloud, snow etc).

Optical telescopes are best placed on the tops of remote mountains. Discuss within your class why you think this is. Take some notes in the space below.

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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.

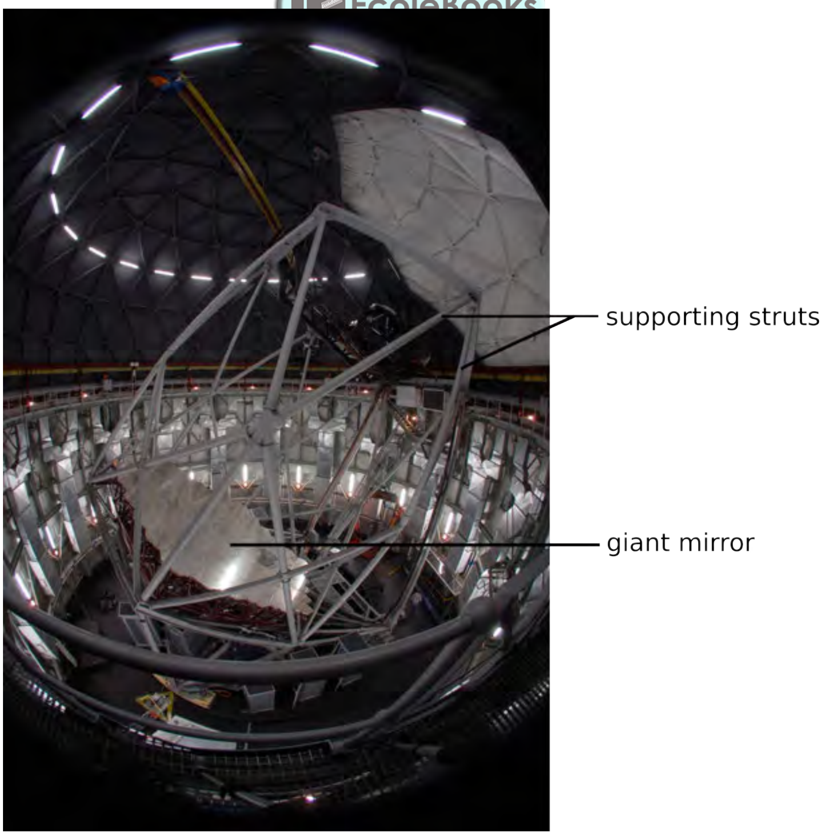

## SALT

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.

*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?


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.




*SALT's giant mirror, made up of 91 individual mirrors.*

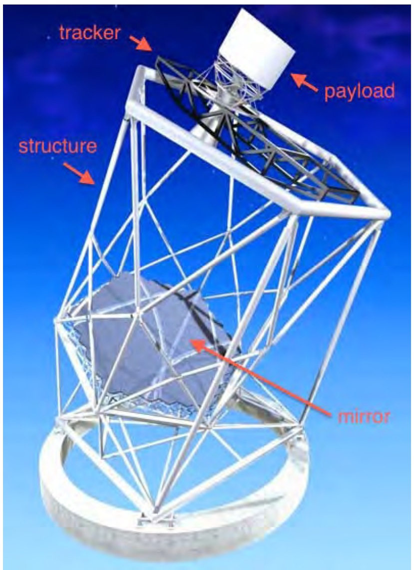
**VISIT**

What is a radio telescope?

bit.ly/1a4LbTW

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.

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 SALT telescope structure. (Credit: SALT)*

**NEW WORDS**

- antenna
- receiver
- amplifier
- SKA

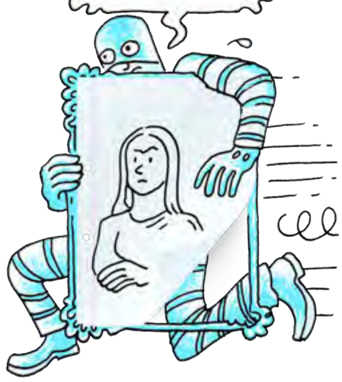
The Karoo is an ideal place to host SALT because it is far away from towns and cities so there is very little light pollution. The area is also at a high elevation, dry and there are no extreme weather conditions, such as flooding or storms. Despite it being so remote at the observatory site there is 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.

**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.



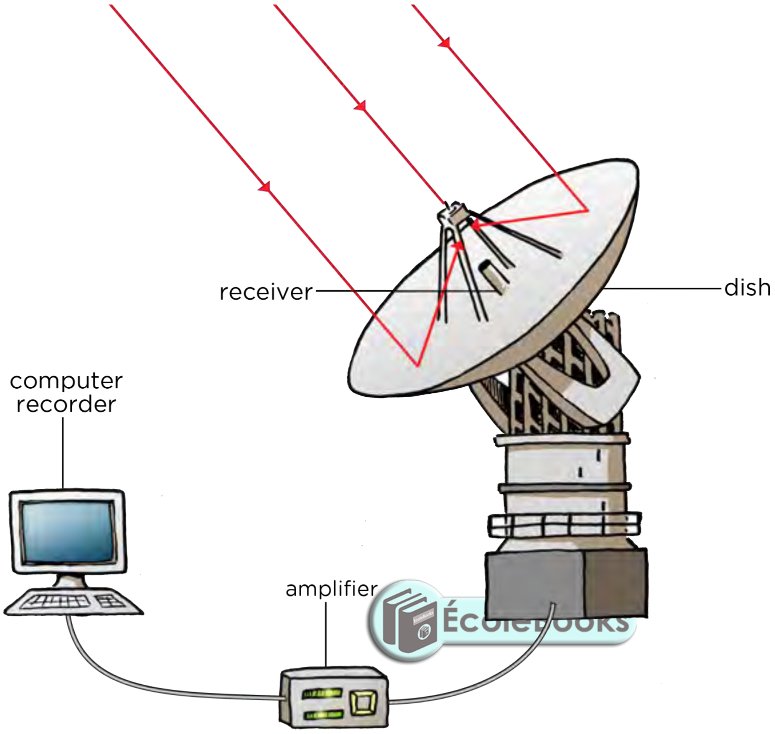
Radio telescopes detect radio waves coming from distant objects. Radio telescopes have several advantages over optical telescopes. They can be used in bad weather, as radio waves are not blocked by clouds. They can also be used during the day and at night.

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.

*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.*

If your eyes could see radio waves at night, rather than white light, instead of seeing pointlike stars, you would see distant star-forming regions, bright galaxies and beautiful giant clouds around old exploded stars.

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.

*Part of the KAT-7 radio telescope array in the Northern Cape.*

**VISIT**

Atacama Large Millimeter/sub-millimeter Array (ALMA) is a new radio telescope in Chile's Atacama desert. It will open an entirely new 'window' into the Universe, allowing scientists to search for our cosmic origins. Watch a video on some of the latest research and images released from ALMA.

bit.ly/17GzMnB

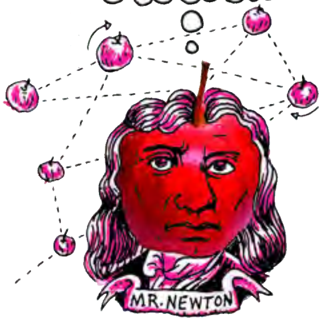
**DID YOU KNOW?**

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.

## MeerKAT and the SKA

**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.




The MeerKAT radio telescope array is currently under construction in the Northern Cape. MeerKAT is scheduled to be complete in 2016 and when it is finished it will have 64 radio dishes each 13.5 m in diameter. The MeerKAT array will be the largest and most sensitive radio telescope in the southern hemisphere until the Square Kilometre Array (SKA) is completed around 2024.

*The KAT-7 test array in the Northern Cape is a test array for the larger MeerKAT array.*

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 3000 radio dishes each about 15 m wide which will act together as one large telescope. As well as the 3000 radio dishes there will be two other types of radio wave detectors.

**VISIT**

A video on the SKA.
bit.ly/1aE3b2A
Read more about the SKA online.
bit.ly/H02OHY

*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.

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.

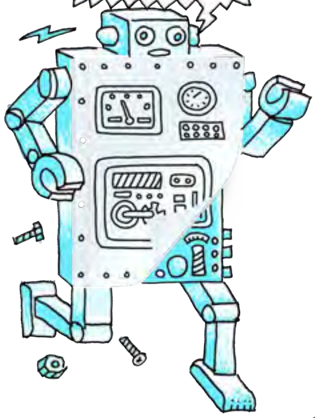
**DID YOU KNOW?**

Radio astronomy observatories use diesel cars around the telescopes because the ignition of the spark plugs in petrol cars can interfere with radio observations.

*One of the SKA dishes.*

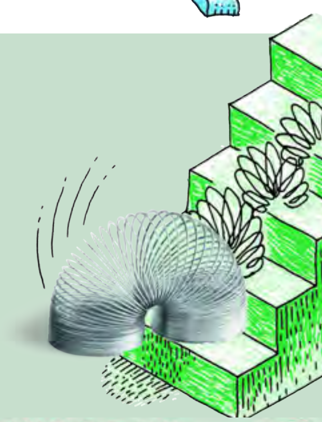
**TAKE NOTE**

Jobs are not just limited 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.

## 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.

## ACTIVITY: Draw a telescope

**MATERIALS:**

- paper
- pencils or crayons

**INSTRUCTIONS:**

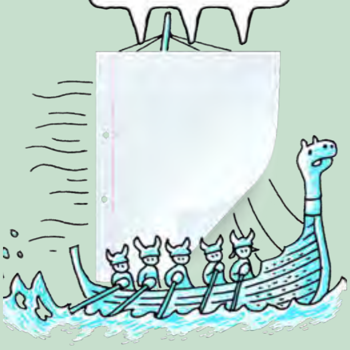
1. Pick either an optical telescope or radio telescope and draw a picture of the telescope.
2. Label the different parts of the telescope and describe what they do.

**DID YOU KNOW?**

The SKA will be so sensitive it could detect TV signals from planets orbiting other stars.

**TAKE NOTE**

The sensitivity of a radio telescope depends upon the area of the collecting dish and the sensitivity of the radio receiver. In order to produce sharp radio images comparable to images from optical telescopes a radio telescope must be much larger than an optical telescope.



## 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.

*A picture of an X-ray telescope called XMM-Newton.*

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. The major disadvantages of space telescopes are their costs and the fact that if something goes wrong they are extremely difficult to fix.

*The Hubble Space Telescope has a 2.4m diameter collecting mirror.*

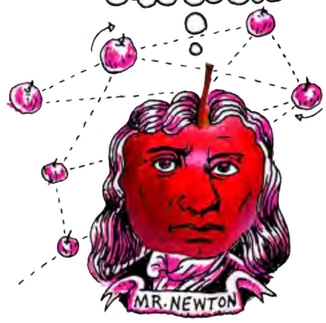
**VISIT**

The Hubble Space Telescope (videos) bit.ly/1873WQd and bit.ly/1abWliG and some of the best images from Hubble

bit.ly/1delJLS

**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.



## 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.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## 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.

**VISIT**

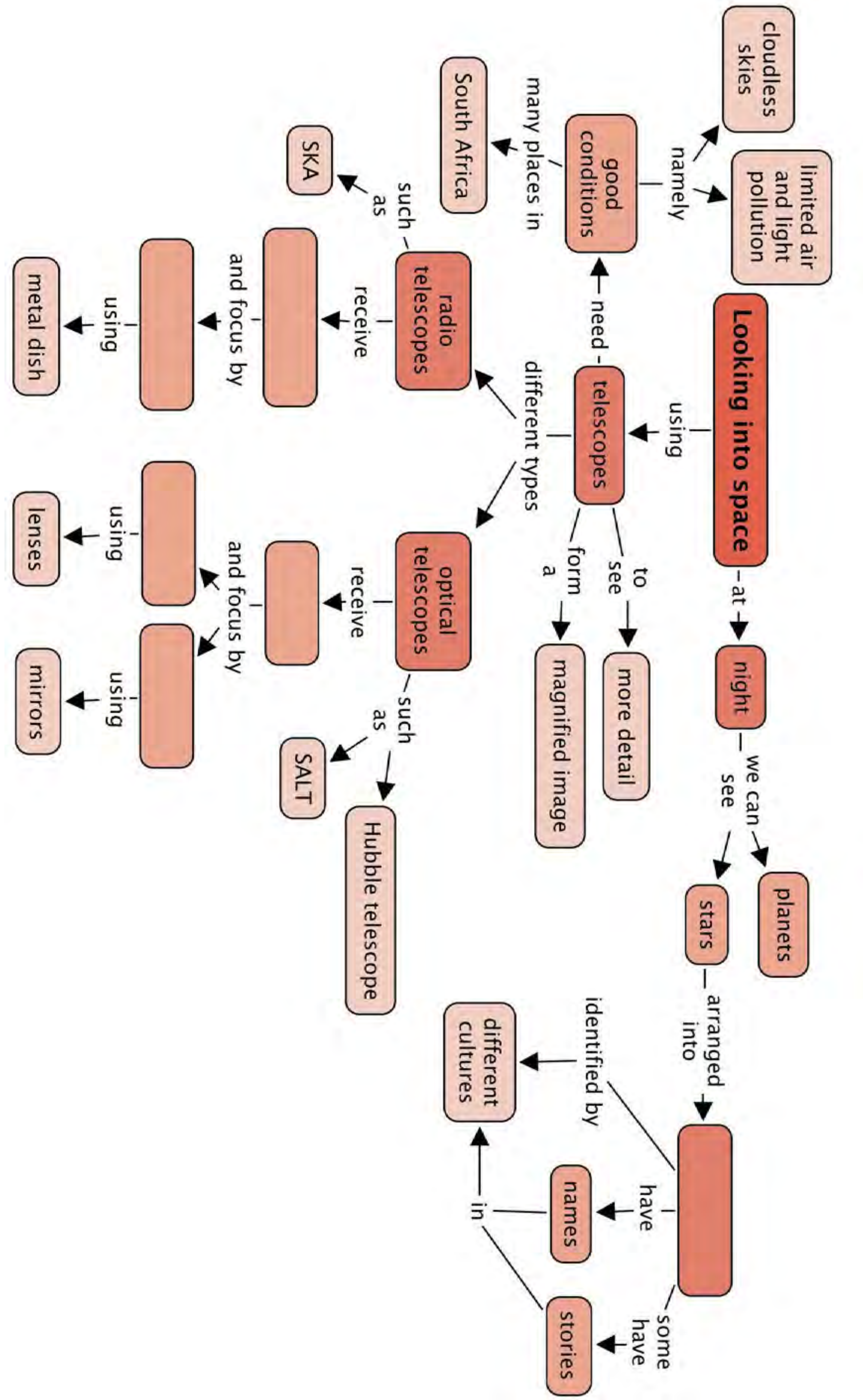
The concept maps in your workbooks were created at Siyavula using an open source programme. You can download it from this link if you want to use it to create your own concept maps for your other subjects.

bit.ly/1fSWS2s

**VISIT**

Science is about curiosity, discovery and innovation!

bit.ly/18GzSyZ


Looking into space
using
telescopes
need
good conditions
namely
cloudless skies
limited air and light pollution
many places in
South Africa
to see
more detail
form a
magnified image
different types
radio telescopes
optical telescopes
receive
and focus by
using
metal dish
lenses
mirrors
such as
SKA
SALT
Hubble telescope
at
night
we can see
planets
stars
arranged into
have
names
some have
stories
identified by
in
different cultures

## REVISION:

1. What do astronomers call patterns of stars in the sky? [1 mark]

2. Name three famous southern constellations. [3 marks]

3. What do optical refracting telescopes use to collect and focus light from distant objects? [1 mark]

4. What do optical reflecting telescopes use to collect and focus light from distant objects? [1 mark]

5. List two advantages that reflecting telescopes have over refracting telescopes. [2 marks]

6. What sort of light do radio telescopes detect? [1 mark]

7. List two advantages that radio telescopes have over optical telescopes. [2 marks]

8. Why are X-ray telescopes located in space? [1 mark]

9. Why does the Hubble Space Telescope produce such sharp images even though it is much smaller than most professional ground based telescopes? [1 mark]

10. Why should astronomers look at objects at different wavelengths? [1 mark]

11. What is the name of the largest optical telescope located in the Northern Cape? [1 mark]

12. List three reasons why the SALT telescope is located near Sutherland in the Northern Cape. [3 marks]

13. How many dishes will the MeerKAT array have? [1 mark]

14. How many dishes will the SKA array have? [1 mark]

15. List two areas of astronomy that will be studied using the SKA telescope. [2 marks]

Total [22 marks]

What can you transform our Earth into? Be curious!

## GLOSSARY

| | |
|---|---|
| **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 waves in a radio telescope |
| **asteroid belt:** | the area where most asteroids are found in our solar system, lying between the orbits of Mars and Jupiter |
| **asteroid:** | a small rocky object orbiting the Sun |
| **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 group:** | a collection of about 50 or less galaxies, held together by gravity |
| **galaxy:** | a collection of millions or billions of stars, gas and dust all held together by gravity |

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| **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 byproduct |
| **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 |

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| **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 |

# Image Attribution

1 http://www.flickr.com/photos/chefranden/3507963245/ . . . . . . . . . . . . . . . . . . . . . . . . . . 106
2 http://en.wikipedia.org/wiki/File:Prime_focus_telescope.svg . . . . . . . . . . . . . . . . . . . . . . . . 228