Oxford
KS3 Science

Activate

Question • Progress • Succeed

Physics

Helen Reynolds

Assessment Editor
Dr Andrew Chandler-Grevatt

OXFORD

Oxford
KS3 Science

Activate

Question • Progress • Succeed

Physics

Helen Reynolds

Assessment Editor
Dr Andrew Chandler-Grevatt

OXFORD
UNIVERSITY PRESS

Contents

Introduction IV

Working Scientifically

1.1 Asking scientific questions 2
1.2 Planning investigations 4
1.3 Recording data 6
1.4 Analysing data 8
1.5 Evaluating data 10

Physics P1

Physics P1 Unit Opener 12

Chapter 1: Forces

1.1 Introduction to forces 14
1.2 Squashing and stretching 16
1.3 Drag forces and friction 18
1.4 Forces at a distance 20
1.5 Balanced and unbalanced 22
1.6 P1 Chapter 1 Summary 24

Chapter 2: Sound

2.1 Waves 26
2.2 Sound and energy transfer 28
2.3 Loudness and pitch 30
2.4 Detecting sound 32
2.5 Echoes and ultrasound 34
2.6 P1 Chapter 2 Summary 36

Chapter 3: Light

3.1 Light 38
3.2 Reflection 40
3.3 Refraction 42
3.4 The eye and the camera 44
3.5 Colour 46
3.6 P1 Chapter 3 Summary 48

Chapter 4: Space

4.1 The night sky 50
4.2 The Solar System 52
4.3 The Earth 54
4.4 The Moon 56
4.5 P1 Chapter 4 Summary 58

Physics P2

Physics P2 Unit Opener 60

Chapter 1: Electricity and magnetism

1.1 Charging up 62
1.2 Circuits and current 64
1.3 Potential difference 66
1.4 Series and parallel 68
1.5 Resistance 70
1.6 Magnets and magnetic fields 72
1.7 Electromagnets 74
1.8 Using electromagnets 76
1.9 P2 Chapter 1 Summary 78

Chapter 2: Energy

2.1 Food and fuels 80
2.2 Energy adds up 82
2.3 Energy and temperature 84
2.4 Energy transfer: particles 86
2.5 Energy transfer: radiation 88
2.6 Energy resources 90
2.7 Energy and power 92
2.8 Work, energy, and machines 94
2.9 P2 Chapter 2 Summary 96

Chapter 3: Motion and pressure

3.1 Speed 98
3.2 Motion graphs 100
3.3 Pressure in gases 102
3.4 Pressure in liquids 104
3.5 Pressure on solids 106
3.6 Turning forces 108
3.7 P2 Chapter 3 Summary 110

Physics P3

Physics P3 Unit Opener 112

Chapter 1: New technology

1.1 Your phone 114
1.2 Your house 116
1.3 Your hospital – intensive care 118
1.4 Your hospital – seeing inside 120
1.5 Your sports 122
1.6 Your planet 124
1.7 P3 Chapter 1 Summary 126

Chapter 2: Turning points in physics

2.1 Discovering the Universe 1 128
2.2 Discovering the Universe 2 130
2.3 The Big Bang 132
2.4 Spacecraft and satellites 134
2.5 Mission to the Moon 136
2.6 Radioactivity 1 138
2.7 Radioactivity 2 140
2.8 Electromagnetism 1 142
2.9 Electromagnetism 2 144
2.10 P3 Chapter 2 Summary 146

Chapter 3: Detection

3.1 Detecting planets 148
3.2 Detecting alien life 150
3.3 Detecting position 152
3.4 Detecting messages 154
3.5 Detecting particles 156
3.6 P3 Chapter 3 Summary 158

Glossary 160
Index 168

Introduction

Learning objectives

Each spread has a set of learning objectives. These tell you what you will be able to do by the end of the lesson.

Key Words

The key words in each spread are highlighted in bold and summarised in the key-word box. They can also be found in the Glossary.

Link

Links show you where you can learn more about something mentioned in the topic.

Summary Questions

1 Questions with one conical-flask symbol are the easiest.

2 The questions get harder as you move down the list.

3 The question with three conical-flask symbols is the hardest. In these questions you need to think about how to present your answer.
In QWC questions you need to pay attention to the Quality of Written Communication.

Welcome to your *Activate* Physics Student Book. This introduction shows you all the different features *Activate* has to support you on your journey through Key Stage 3 Physics.

Being a physicist is great fun. As you work through this Student Book, you'll learn how to work like a physicist, and get answers to questions that physics can answer.

This book is packed full of fantastic (and foul!) facts, as well as plenty of activities to help build your confidence and skills in physics.

Q These boxes contain short questions. They will help you check that you have understood the text.

Maths skills

Physicists use maths to help them solve problems and carry out their investigations. These boxes contain activities to help you practise the maths you need for physics. They also contain useful hints and tips.

Literacy skills

Physicists need to be able to communicate their ideas clearly. These boxes contain activities and hints to help you build your reading, writing, listening, and speaking skills.

Working scientifically

Physicists work in a particular way to carry out fair and scientific investigations. These boxes contain activities and hints to help you build these skills and understand the process so that you can work scientifically.

Fantastic Fact!

These interesting facts relate to something in the topic.

Opener
Each unit begins with an opener spread. This introduces you to some of the key topics that you will cover in the unit.

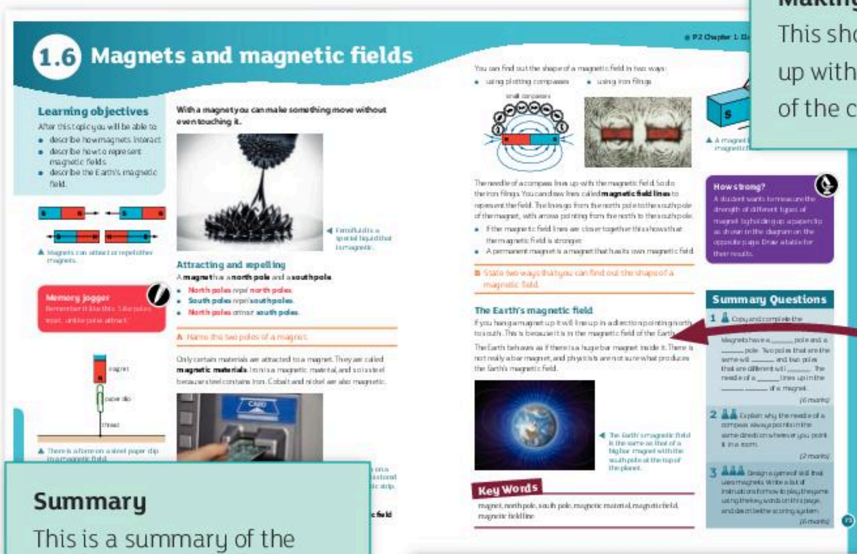
You already know
This lists things you've already learnt that will come up again in the unit. Check through them to see if there is anything you need to recap on.

Big questions
These are some of the important questions in science that the unit will help you to answer.

Picture Puzzlers
These puzzles relate to something in the unit – can you work out the answers?

Making connections
This shows how what you will learn in the unit links up with the science that you will learn in other parts of the course..

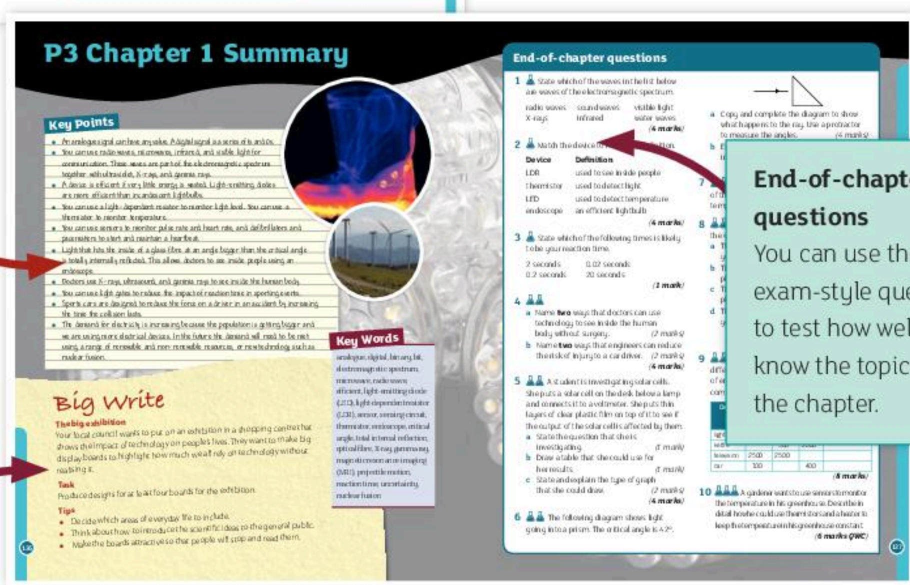
Topic spreads
Each topic in the chapter has a double-page spread containing learning objectives, practice questions, key words, and task boxes to help you work through the chapter.



Summary
This is a summary of the chapter. You can use it to check that you have understood the main ideas in the chapter and as a starting point for revision.

Big write/Maths challenge/Case study
This is an activity that you can do at the end of the chapter. It will help you to practise using your scientific skills and knowledge.

End-of-chapter questions
You can use these exam-style questions to test how well you know the topics in the chapter.



1.1 Asking scientific questions

Learning objectives

After this topic you will be able to:

- describe how scientists develop an idea into a question that can be investigated
- identify independent, dependent, and control variables.

▲ What affects the battery life of your mobile phone?

▲ The balls are changed every seven or nine games during a tennis match.

Why does the battery last longer in some mobile phones than others? What might mobile phones be like in the future? We can ask lots of different questions about the world. Some are questions that science can answer.

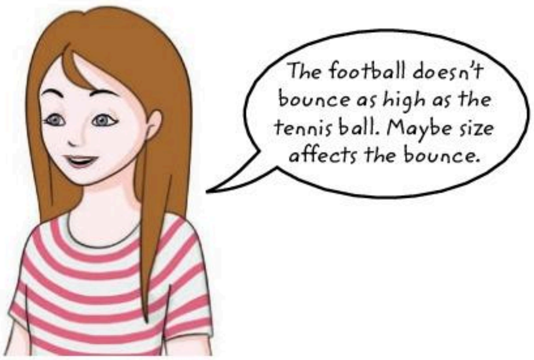
What's the question?

Scientists make **observations** of the world, and ask questions such as, 'How do fossil fuels form?' or 'Why are there are so many different animals on Earth?' These are scientific questions.

Scientists do **investigations**. They collect **data** to try to answer their questions.

Suggesting ideas

Tom and Katie are talking about balls used in sport.



Katie makes an observation about footballs and tennis balls. An observation can give you an idea that you can test in an investigation.

Developing ideas into questions

Tom watches a tennis match. New tennis balls are brought out from a refrigerator during the match.

Here are some questions that Katie and Tom might investigate:

- How does the size of a ball affect how high it bounces?
- How does the temperature of a ball affect how high it bounces?

What's a variable?

The size and temperature of the ball are not the only things that might affect the height of the bounce.

In science, anything that might affect the outcome of an investigation is called a **variable**. The thing that is affected as a result of the change is also a variable.

The temperature is the **independent variable**. It is independent because you change it. How high the ball bounces is the **dependent variable**. It is dependent because it changes when you change the temperature.

A State the two types of variable that you can change in an investigation.

Other variables

Katie and Tom think about all the other variables that might affect the bounce height. Here is their list:

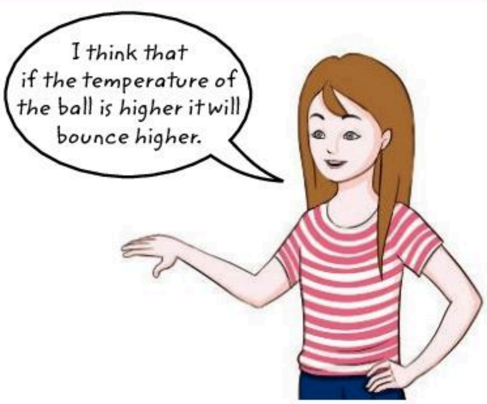
- the height you drop the ball from
- the type of ball
- the surface that you drop it onto
- the size of the ball

Katie and Tom need to keep these variables the same during their investigation so that they do not affect the bounce. These are called **control variables**.

B Name the type of variables that you keep the same in an investigation.

Making a prediction

Katie makes a **prediction** about what might happen. This is only part of the prediction. Katie should use her scientific knowledge to explain *why* she thinks that the ball will bounce higher.



Name those variables!

Imagine that you are going to investigate whether the size of a ball affects how high it bounces.

a State your dependent and indepedent variables.

b List all the variables that you would need to control.

Key Words

observation, investigation, data, variable, independent variable, dependent variable, control variable, prediction

Fantastic Fact!

Over 50 000 tennis balls are used during the Wimbledon tennis championship each year.

Summary Questions

1 Copy the sentences below, choosing the correct bold word.

You can turn an **idea/question** into an **idea/question** that you can investigate. You can answer some scientific **ideas/questions** by doing an investigation. You collect **data/observations** or make **data/observations**. Things that can change in an investigation are called **predictions/variables**. Science can answer **all/some** questions.

(7 marks)

2 A student is looking at an ice cube melting in a glass of water.

a Suggest a question that she could answer by doing an investigation. *(1 mark)*

b Explain why this is a question that science can answer.

(2 marks)

3 Suggest three questions that scientists could investigate about food, and three that they could not. Explain your choices.

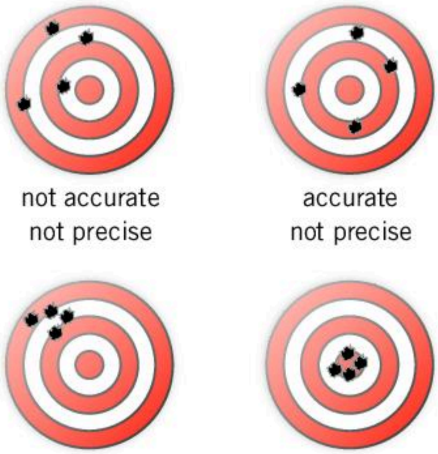
(6 marks QWC)

1.2 Planning investigations

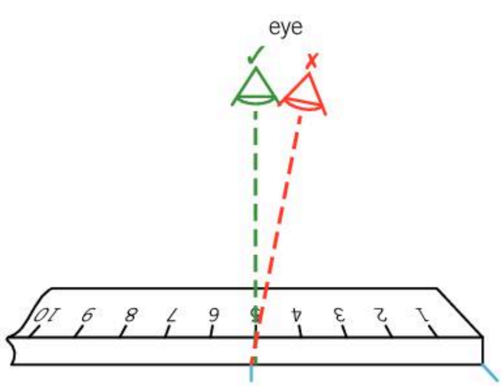
Learning objectives

After this topic you will be able to:

- describe how to write a plan for an investigation
- recognise what makes data accurate and precise
- describe a risk assessment.



▲ Readings can be precise but not accurate.



▲ You should look straight at a scale to make an accurate measurement.

Have you ever cooked from a recipe? Did it turn out the way you wanted? The plan for an investigation or experiment is a bit like a recipe. It says what equipment and materials you are going to use, and what you are going to do with them.

Make a plan

Katie and Tom need to write a **plan** for their investigation. They need to think about how they will collect data to test their ideas. Their plan should include:

- what equipment they are going to use, and why
- what method they are going to use, and why.

A State two things that you need to include in an investigation plan.

Accurate and precise data

The measurements you make in an investigation are called data. It is important to collect data that is **accurate** and **precise**.

Accurate data is close to the true value of what you are trying to measure. For example, Tom needs to look directly at the ruler to get an accurate reading.

Precise data gives similar results if you repeat the measurement. Scientists talk about the **spread** of their sets of repeat data. Precise data has a very small spread when measurements are repeated. The repeat measurements in each set are grouped closely together.

B State how to use a ruler accurately to measure length.

Uncertainty

If you look at a thermometer it might be hard to tell whether the temperature is 21.5 °C, 22.0 °C, or 22.5 °C. There is an **uncertainty** in your measurement because of the measuring instrument that you are using.

Repeatability and reproducibility

If Katie and Tom do the same investigation several times, or repeat a measurement in an investigation, the data should be similar. It is **repeatable**.

If other students do the same investigation they should get data similar to Katie and Tom. The data is **reproducible**.

Types of data

The data you collect might be words or numbers. Data can be:

- **continuous** – it can have any value, such as length or temperature
- **discrete** – it can have only whole-number values, such as number of paperclips or woodlice
- **categoric** – the value is a word, such as 'blue' or 'hot'.

How many measurements?

Katie and Tom need to plan what temperatures to test. They need to decide:

- the biggest and smallest temperatures – this is the **range**
- how many different temperatures they will test.

Is it safe?

A plan should also include a **risk assessment** . This explains how you will reduce the chance of damage to equipment, or injury to people.

What should a plan include?

Katie and Tom write a plan for their investigation. They include:

- the scientific question that they are trying to answer
- the independent and dependent variables
- a list of variables to control and how they will do it
- a prediction: what they think will happen and why
- a list of the equipment they will need
- a risk assessment
- how they will use the equipment to collect accurate and precise data.

Key Words

plan, accurate, precise, spread, uncertainty, repeatable, reproducible, continuous, discrete, categoric, range, risk assessment

Investigating dissolving

Does the temperature of water affect the mass of salt that dissolves in the water?

Write a plan to investigate this.

Summary Questions

1 Copy and complete the sentences below.

The plan for an investigation includes a list of the ______ that you will use and how you will use it. It shows how you will collect data that is ______, ______, ______, and ______. To make your investigation as safe as possible you need to do a ____ ________.

(6 marks)

2 A student investigates whether the type of surface affects the bounce of a ball.

a Explain why she should read the scale on the ruler by looking straight at it. *(2 marks)*

b Explain why the readings are not exactly the same when she repeats them. *(2 marks)*

c State and explain whether she needs to do a risk assessment. *(2 marks)*

3 Explain in detail why Katie and Tom's is a good plan.

(6 marks QWC)

1.3 Recording data

Learning objectives

After this topic you will be able to:

- describe how to make and record observations and measurements
- calculate a mean from repeat measurements
- present data appropriately in tables and graphs.

You usually collect data in a table. It is easier to see patterns in the data if you then draw a graph or chart.

Collecting data

Each time Katie and Tom change their independent variable they should take repeat measurements of their dependent variable.

Recording data

Katie and Tom make a table for their results. They need to record their measurements as they go, including all the repeat measurements.

A results table helps you to organise your data. This is Katie and Tom's results table:

Temperature	Height of bounce (cm)			
	1st Measurement	2nd Measurement	3rd Measurement	Mean
cold	45	40	35	40
warm	50	60	20	55
hot	65	75	70	70

A State the best way of recording data collected during an investigation.

Repeat readings

You should check your data for **outliers**. An outlier, or anomalous result, is a result that is very different to the others. You should repeat the measurement to replace an outlier.

In the table above, the third measurement for the warm temperature, 0.20 m, is an outlier. Katie and Tom do not include it when they work out the **mean**.

The mean is a type of average. You add up all the results and divide by the number of results. For example, the mean of the heights measured at the cold temperature in the table above is:

$$0.45 \text{ m} + 0.40 \text{ m} + 0.35 \text{ m} = 1.2 \text{ m}$$

then divide by 3 as there were 3 results:

$$\frac{1.2}{3} = 0.40 \text{ m}$$

B State how to calculate the mean of a set of numbers.

Fantastic Fact!

The first ever tennis balls were hand stitched, so no two ever bounced in the same way.

Key Words

outlier, mean, line graph, bar chart, pie chart

Which graph?

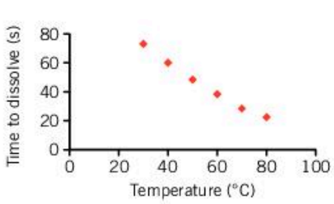
Tom and Katie have collected lots of data. They want to present their results in a graph or chart. To work out which graph or chart to plot you need to look at the variables in your investigation.

- If both your independent and your dependent variables are continuous, then you should plot a **line graph**.
- If your independent variable is categoric, you should plot a **bar chart**. In some cases you might want to display discrete or categoric data in a **pie chart**.
- For both line graphs and bar charts, you plot the independent variable on the *x* axis and the dependent variable on the *y* axis.

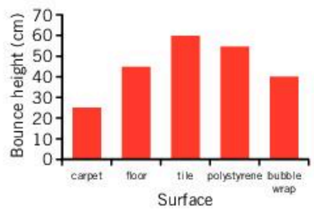
Temperature (°C)	Time to dissolve (s)
30	75
40	60

Surface	Height of bounce (cm)
Carpet	25
Floor	45

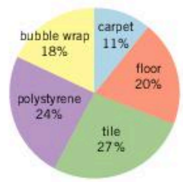
You plot a line graph:



You plot a bar chart:



... or a pie chart



C State what type of graph or chart you should plot if one of your variables is discrete.

When you draw a chart or plot a graph you should do the following:

- Choose scales for your axes so that your graph is as big as possible.
- Use a pencil and a ruler.
- Label the axes with the quantity and the unit, such as 'time (s)'.
- Write a title for your graph.

Dealing with results

A student investigated how fertiliser affects how high plants grow. Copy it and complete the final column of the table.

Mass of fertiliser (g)	Height of plant after 10 days (cm)			
	1st Measurement	2nd Measurement	3rd Measurement	Mean
2	3.2	3.7	3.6	
4	4.7	7.3	5.0	
6	5.1	5.5	5.3	

Summary Questions

1 Copy and complete the sentences below.

When you are collecting data you need to make sure that you are using ______ ______ correctly. You need to make ______ measurements to check that your data is repeatable. You need to look for ______, which are readings that are very different to the others. Then you calculate the ______.

(5 marks)

2 A student is investigating how the temperature of water affects how long it takes sugar to dissolve.

a Describe two things that he should do when collecting data. *(2 marks)*

b Draw a table that he could use for his results. *(2 marks)*

c State and explain the type of graph that he should draw. *(2 marks)*

3 Design a hint sheet for students carrying out investigations.

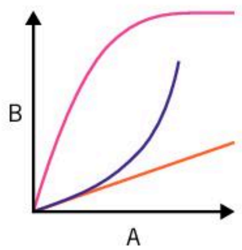
(6 marks)

1.4 Analysing data

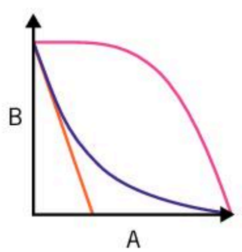
Learning objectives

After this topic you will be able to:

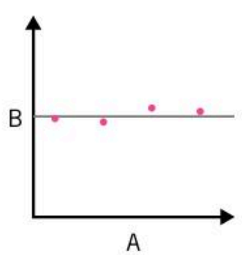
- find a pattern in data using a graph or chart
- interpret data to draw conclusions.



In these graphs, if A increases then B increases.



In these graphs, if A increases then B decreases.



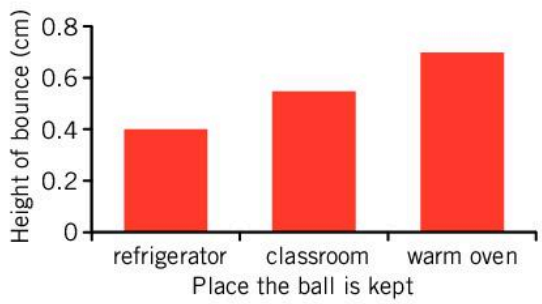
In this graph, if A increases B does not change.

Key Words

analyse, line of best fit, conclusion

Katie and Tom have collected data and plotted a bar chart. Now they need to:

- work out what their graph tells them
- write a conclusion
- compare what they found out with their prediction.



▲ Katie and Tom's bar chart.

Using graphs or charts

When you **analyse** your data, plotting a line graph or chart helps you to spot a pattern. It shows how the dependent variable depends on the independent variable.

Your scientific knowledge will help you suggest why the independent variable affects the dependent variable in this way.

Find a pattern on a line graph

Once you have plotted a line graph you need to draw a **line of best fit**. This is a line that goes through as many points as possible, with equal numbers of points above and below the line. If there are any outliers, you should ignore these when you draw your line of best fit.

A State what is meant by a line of best fit.

Writing a conclusion

Once you have analysed your graph you can write a **conclusion**.

State what you have found out

Start by saying what the investigation shows. Then describe any relationship you can see between the two variables. Use your graph to support your conclusion.

B State two things to include in your conclusion.

Tom and Katie look at their bar chart and start to write a conclusion:

Explain what you found out

Saying what your results show is only part of analysing results. You also need to use scientific knowledge to explain the pattern.

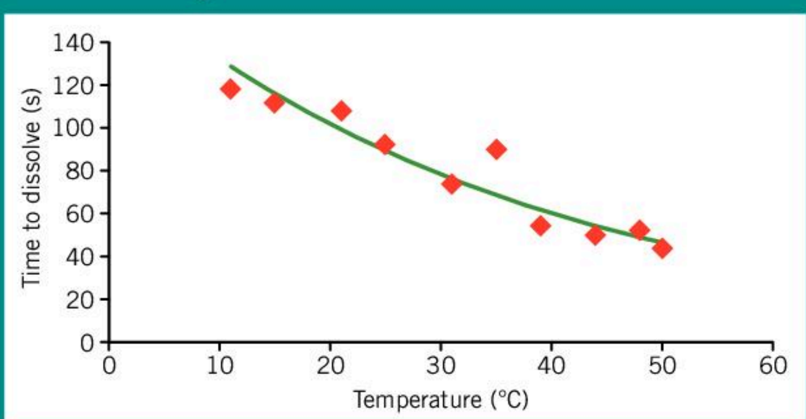
Tom begins to explain the relationship between temperature and the height of the bounce. However, to come up with a good explanation he needs to understand why balls bounce.

Comparing results with predictions

Finally, you can compare your results with your prediction.

What's the relationship?

A student plots a graph of water temperature and the time that it takes sugar to dissolve in the water.



Use information from the graph to describe what happens when you double the temperature of the water.

Link

You can learn more about why balls bounce in P1 1.1 Introduction to forces

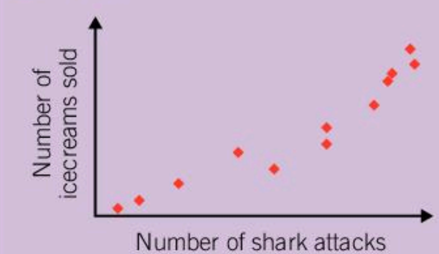
Summary Questions

1 Copy and complete the sentences below.

To analyse your data you plot a graph or chart and work out the _______ between the variables. Then you write a _______ that includes what you have found out, and explains why, using _______ _______. Finally you compare your results with your _______.

(5 marks)

2



A student has drawn a graph for an investigation into the relationship between the number of icecreams sold and the number of shark attacks in a certain period. Draw a flow chart to show how he should complete the analysis of his data and draw conclusions.

(4 marks)

3 Look at the graph in Question 2. Describe and explain in detail what the graph shows and suggest a conclusion that you can draw from the data.

(6 marks QWC)

1.5 Evaluating data

Learning objectives

After this topic you will be able to:

- describe the stages in evaluating data
- suggest ways to improve a practical investigation.

▲ Evaluating means working out what is good and what is not so good.

Katie and Tom have collected data and analysed it by plotting a bar chart. Now they need to evaluate their data and their methods.

There are two ways to **evaluate** your investigation. You should:

- discuss the quality of the data that you have collected
- suggest and explain improvements to your method so you can collect data of better quality if you did it again.

Your suggested improvements should increase the **confidence** that you have in your conclusion.

Evaluating the data

Katie and Tom look at their data. They had only one outlier in their experiment – the third measurement for 'warm'. If there were lots of outliers then they would have less confidence in their conclusion.

What's the spread?

The spread of data tells you how precise the data is. The spread is the difference between the highest and the lowest readings in a set of repeat measurements.

A State what is meant by the spread of a set of measurements.

In their experiment the measurements for one temperature do not overlap with the measurements for another. That makes the data very precise.

A small spread in the data will give you more confidence in your conclusion. You should discuss this in your evaluation.

Key Words

evaluate, confidence, random error, systematic error

Errors and uncertainty

There is uncertainty in any measurement that you make. This is one of the reasons why there is usually a spread in experimental data.

There are two types of error that can affect scientific measurements. These are:

- **random error** – this can affect the spread, or cause outliers. An example is the temperature of the room suddenly changing because someone opens a door.
- **systematic error** – this can make your measurements less accurate. An example is a newtonmeter reading 1 N even when there is nothing attached to it.

You should think about possible errors as well as the outliers and spread to help you to decide how confident you are in your conclusion.

Range and number of results

Tom and Katie only measured at three different temperatures. It would be better to have a wide range.

B State whether it is better to measure a wide range or a narrow range of values.

Suggesting improvements

You might get better data by:

- including a bigger range, or taking more readings
- using different apparatus – giving a smaller spread and fewer outliers.

Evaluating data

Ali and Emma do the same tennis-ball investigation as Katie and Tom. They produce this data:

Temperature (°C)	Height of bounce (cm)			
	1st Measurement	2nd Measurement	3rd Measurement	Mean
–4	25	27	45	
4	30	26	25	
20	42	59	49	
40	54	59	61	
60	65	42	71	

a Identify the outliers.

b Calculate the mean bounce height for each value of temperature.

c Comment on the spread of data for each value of temperature.

Improving data

Use your data to decide if your method was good, or could be improved. You should say how any improvements would make the data better.

Summary Questions

1 Copy and complete the sentences below.

When you evaluate your data you need to look at how many ______ you had. Then you need to look at the spread, which is the difference between the ______ and ______ reading within each set of repeat measurements. You need to look at the ______ and ______ of values. Finally, you can propose how to improve the ______ if you did it again.

(6 marks)

2

a State two ways that Katie and Tom could improve their data. *(2 marks)*

b Suggest one other way that they could improve the quality of their data. *(3 marks)*

3 Explain how using a video camera could improve the quality of Katie and Tom's data. *(6 marks QWC)*

Physics 1

The first astronaut to walk on the Moon, Neil Armstrong, looked back and saw the Earth as no-one had ever seen it before. In P1 you will learn about how you see, and how light and sound waves behave. You will learn about the place of the Earth in the Universe. You will also learn about the forces that keep you from falling through the floor and allow astronauts to stand on the Moon.

You already know

- The force of gravity pulls objects to the Earth.
- Friction, air resistance, and water resistance slow down moving objects.
- You see things because light reflects off them.
- Light travels in straight lines, which explains the size and shape of shadows.
- Vibrating objects make sound, which varies in pitch and loudness, and gets fainter as you move away.
- The Earth orbits the Sun and the Moon orbits the Earth.
- The length of a day and the temperature change during the year.
- Day and night and the Sun's movement across the sky happen because the Earth spins on its axis.

Q

What happens to the length of a day during the year?

BIG Questions

- Where do forces come from?
- How do we hear and see things?
- What is outside the Solar System?

Picture Puzzler
Key Words





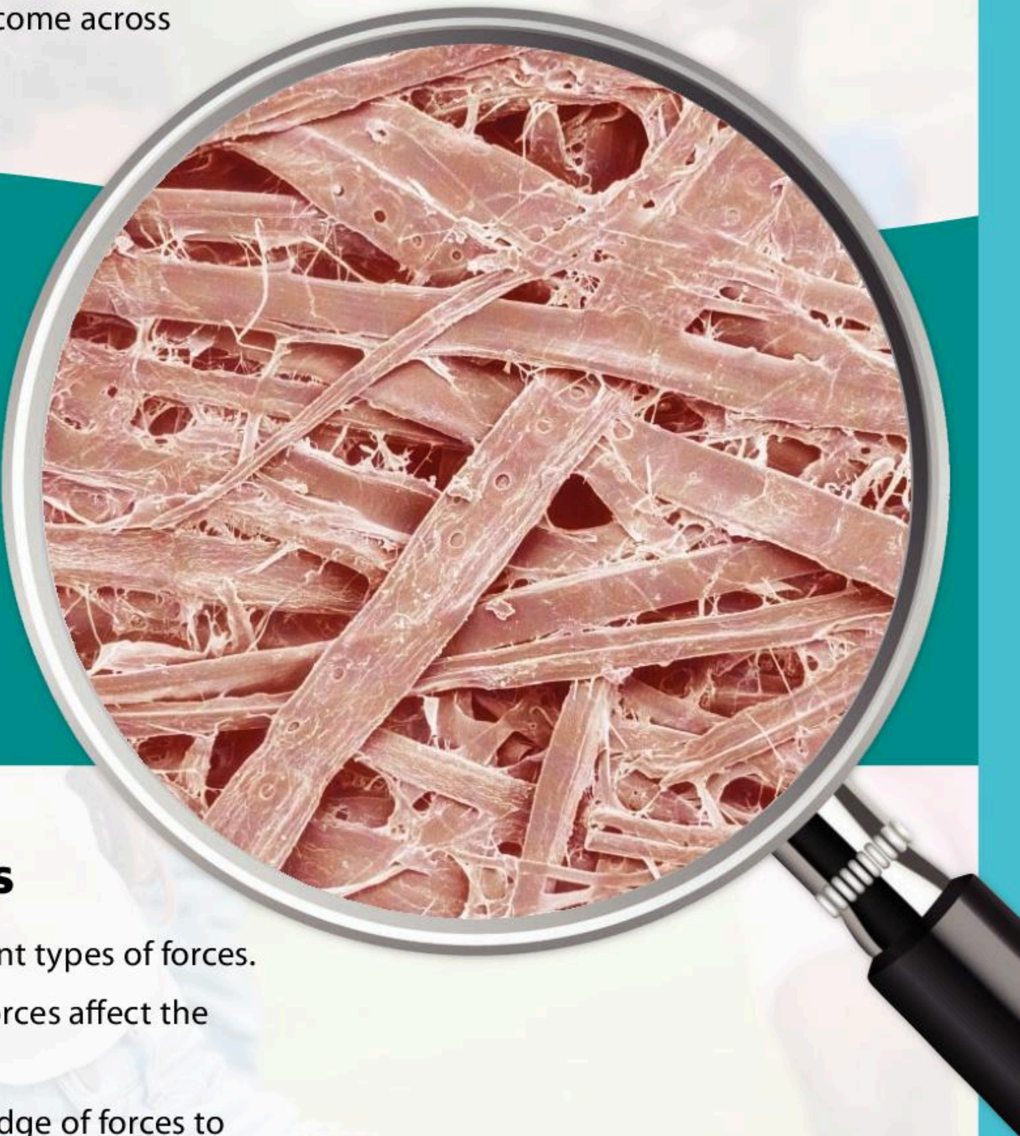
Can you solve this Picture Puzzler?

The first letter of each of these images spells out a science word that you will come across in this book.

Picture Puzzler
Close Up

Can you tell what this zoomed-in picture is?

***Clue**: The person floating in the sea is reading one.*



Making connections

In **P1** you will learn about different types of forces.

In **P2** you will learn about how forces affect the motion of objects.

In **P3** you will apply your knowledge of forces to planetary motion.

1.1 Introduction to forces

Learning objectives

After this topic you will be able to:

- explain what forces do
- describe what is meant by an interaction pair.

▲ This rocket took a rover to Mars.

What does a rocket have in common with you? There are forces acting on you and on the rocket.

What do forces do?

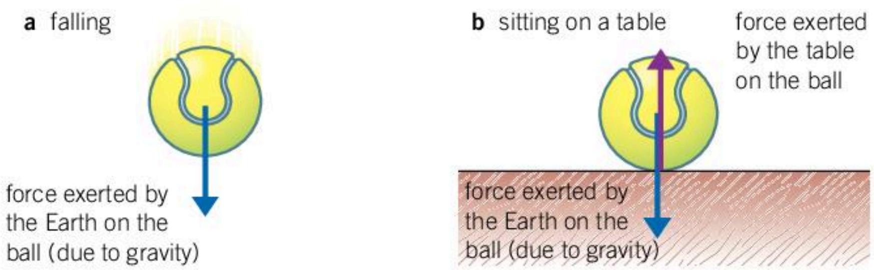
A rocket going to Mars moves away from the surface of the Earth very quickly. There is a force pushing the rocket up and forces pulling it down. A force can be a **push** or a **pull**.

Forces explain *why* objects move in the way that they do, or why they don't move at all. That's not all. Forces can change the direction that objects are moving in, and change their shape.

A List three things that forces do.

Describing forces

You can't see forces but you can see the effect of them. When you draw a diagram you add arrows to show the forces that are acting. 'Force arrows' show the direction *and* the size of the force. Forces act on objects so the arrow must touch the object in the diagram.



▲ These force arrows show the forces acting on a tennis ball.

Different types of force

Some forces act when you are touching something. This is a **contact force**. **Friction** and **air resistance** are contact forces. Support forces, like upthrust, are also contact forces.

The force of **gravity** acts on a tennis ball travelling through the air. The Earth pulls the ball down even though it is not touching it. Gravity is a **non-contact force**. The force between magnets is another non-contact force.

B Describe the difference between a contact force and a non-contact force.

Foul Fact!

Astronauts on the International Space Station cannot burp. The gas and liquid does not separate in their stomachs while they are in orbit.

Pairing up

A girl and her sister are hanging from a bar in a playground. Think about the forces acting on the girls.

▲ Forces act on the girls hanging from a bar.

- Gravity pulls the girls down. *This is the force of the Earth on the girls.*
- The girls pull the Earth up. *This is the force of the girls on the Earth.*

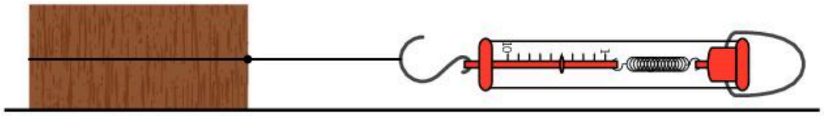
Forces always come in pairs. The pairs are called **interaction pairs**.

There is another interaction pair of forces acting on the girls.

- The bar supports the girls. *This is the force of the bar on the girls.*
- The girls pull on the bar. *This is the force of the girls on the bar.*

How do you measure forces?

You can measure force with a **newtonmeter** (sometimes called a spring balance). All forces are measured in **newtons** (N).



▲ A student is pulling the block with a force of 5 N.

C State the unit of force.

Newton predicts...

In the 1600s, Isaac Newton first explained how gravity affects objects. Scientists later used his ideas to predict that there was a planet beyond Uranus. In 1846 they discovered Neptune. A good explanation means that you can make predictions and test them.

▲ Upthrust supports you when you float.

Link

You can learn more about non-contact forces in P1 1.4 Forces at a distance

Key Words

push, pull, contact force, friction, air resistance, gravity, non-contact force, interaction pair, newtonmeter, newton (N)

Summary Questions

1 Copy and complete the sentences below.

A force is a ______ or a ______.
We can show the forces acting on an object using force ______.
Forces come in pairs, called ______ pairs. To measure forces you use a ______.

(5 marks)

2 Describe one of the interaction pairs for an apple hanging from the branch of a tree.

(2 marks)

3 You are probably sitting on a chair as you read this book. Explain in detail why the two forces acting on you are not two forces in the same interaction pair.

(6 marks QWC)

1.2 Squashing and stretching

Learning objectives

After this topic you will be able to:

- describe how forces deform objects
- explain how solid surfaces provide a support force
- use Hooke's Law.

▲ Even a solid golf ball changes shape when you hit it.

Foul Fact!

When a footballer heads a ball the forces deform both the ball and the footballer's head.

Link

You can learn more about particles in solids, liquids, and gases in C1 1.1 The particle model

Key Words

deform, compress, stretch, reaction, extension, tension, elastic limit, Hooke's Law, linear

Why don't you fall through the chair you're sitting on? The chair changes shape, or deforms, when you sit on it. This produces the force that pushes you up.

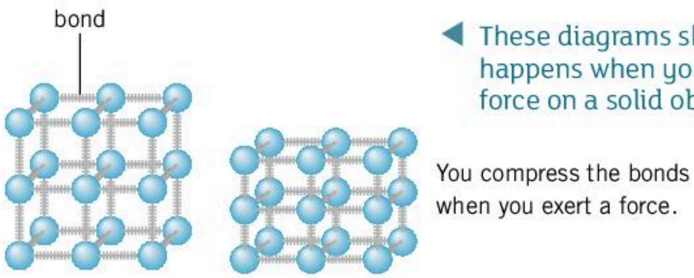
Changing shape

When a ball hits the floor the ball **deforms**. Forces can **compress** (squash) or **stretch** objects. When you exert a force you can deform an object. You can compress it or you can stretch it.

A Describe what happens to a tennis ball when it hits the ground.

How can the floor push you up?

The floor pushes up on you when you stand on it. It seems strange to talk about the floor exerting a force on you. You can't see anything happening.



◀ These diagrams show what happens when you exert a force on a solid object.

The floor is a solid; solids are made up of particles arranged in a regular pattern. The particles are joined strongly together by bonds. This is what happens when you stand on the floor:

- Your weight pushes the particles together.
- The bonds are compressed.
- They push back and support you.

Solid materials are only compressed a very small amount when you apply a force to them. A support force from a chair or the floor is called the **reaction** force.

Stretching

Bungee cords, springs, and even lift cables all stretch when you exert a force on them. The amount that they stretch is called the **extension**.

A bungee cord stretches as the jumper falls. When the bungee cord has stretched as far as it will go, it pulls her back up. This force is called **tension**.

What happens when you stretch a spring?

Springs are special. If you ***double*** the force on the spring the extension will ***double***. You can use the length of the spring to measure the size of a force. When you remove the force the spring goes back to its original length.

What's the limit?

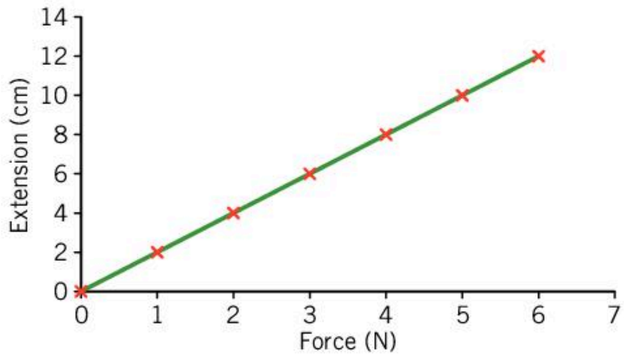
At some point the spring will not go back to its original length when you remove the force. This is the **elastic limit**. Trampoline springs are designed to never go past their elastic limit.

◀ The shape of a bungee cord changes when you stretch it.

Hooke's Law

If the extension doubles when you double the force then the object obeys **Hooke's Law**. The graph of force against extension is a straight line, or **linear**. Hooke's Law is a special case. Not everything behaves like a spring when you stretch it. If you double the force on an elastic band the extension may not double.

B State Hooke's Law.



▲ This graph shows how the extension of a spring changes as you pull it.

A straight-line graph

Using the graph below, find the extension when the force is 3 N and again when it is 6 N. Does this spring obey Hooke's Law? Explain your answer.

How long?

You have a spring that is 4 cm long. When you exert a force of 3 N it stretches to a length of 6 cm. What is the extension? What would the extension be if you doubled the force?

Summary Questions

1 Copy and complete the sentences below.

Forces can change the shape of objects or ______ them. Solid surfaces are made of ______. The bonds between particles are compressed when you apply a force. They ______ back on you. This provides a ______ force called the ______ force.

(5 marks)

2 Describe how your chair pushes you up.

(2 marks)

3 Design a new style of trampoline that would make trampolining more fun. Use the ideas on this page to explain how it works.

(6 marks)

1.3 Drag forces and friction

Learning objectives

After this topic you will be able to:

- describe the effect of drag forces and friction
- explain why drag forces and friction arise.

Fantastic Fact!

Which material has the lowest friction? BAM is a material that contains aluminium, magnesium, and boron. It is twice as slippery as ice.

▲ You need friction to move across surfaces.

Fantastic Fact!

In 1995 Fred Rompelberg travelled at 167 mph... on a bicycle! He did it by cycling behind a lorry where there was very little air resistance.

Slide your finger along the desk. Does the surface feel smooth or rough? Even really smooth surfaces exert a force.

What is friction?

A surface such as a metal slide in a playground looks and feels really smooth. Now imagine zooming in on it; you will see that it is actually rough.

When a book is resting on the table you can push on it but it may not move. **Friction** grips objects. As you increase the force by pushing harder the book will start to move. If you remove the force the book slows down and stops. This is because the rough surfaces can no longer move past each other.

A State two things that friction does.

Is friction useful?

Friction can be a good thing. You need friction to walk, as the friction between your foot and the road produces the force to move you forward. The brakes on your bike and in a car work because of friction.

B Describe how friction helps you to walk.

How can you reduce friction?

One way to reduce friction is by using oil or grease. This is called **lubrication**. When you oil the chain of your bike the surfaces move past each other more easily. Snowboarders wax their boards to reduce the friction between the board and the snow.

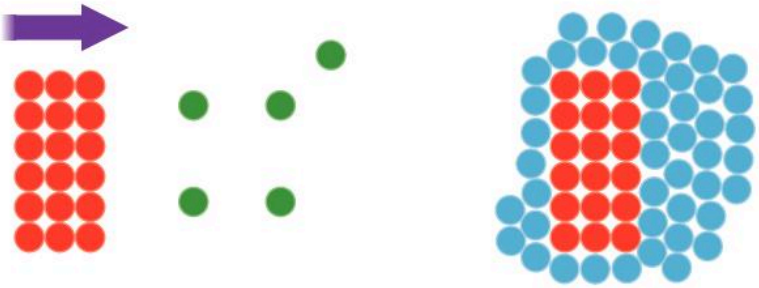
C Suggest why the hinges of a door need to be lubricated.

What are drag forces?

A dolphin swimming through the water and a surfer paddling through water will both experience **water resistance**. As a snowboarder jumps through the air he will experience **air resistance**. Water resistance and air resistance are **drag forces**.

▲ When you move through water you experience water resistance.

To understand drag forces you need to think about the particles in the air and the water.



A solid moves through a gas. A solid moves through a liquid.

▲ A moving object is in contact with air or water particles.

As a dolphin moves through the water it pushes the water particles out of the way. This produces a drag force, which slows it down.

D Name the drag force acting on an aeroplane in flight.

How can you use drag forces?

Parachutes are used to slow down drag-racing cars and skydivers. The contact with the air produces a drag force.

How can you reduce drag forces?

An Olympic cyclist will tuck her arms in close to her body as she cycles. She will even make sure that her thumbs are as close to the handlebars as possible. This makes her more **streamlined**, which reduces the force of air resistance.

Testing a parachute

A company wants to compare different materials for making parachutes. Name **three** ways that they could make it a fair test.

Key Words

friction, lubrication, water resistance, air resistance, drag force, streamlined

Summary Questions

1. Copy and complete the sentences below.

   The force of _______ acts between two solid surfaces in contact that are sliding across each other. The surfaces are _______ and will grip each other. This is why you need to exert a _______ to make something move. There are two drag forces: _______ and _______. When a moving object is in contact with _______ or _______ particles it has to push them out of the way.

   (7 marks)

2. Describe the effect of water resistance acting on a bird diving into a lake to catch a fish.

   (1 mark)

3. Suggest and explain a reason why the brake blocks on a bicycle need to be replaced from time to time.

   (2 marks)

4. A dragster is a car that uses a parachute as a brake. Use the ideas on this page to compare the drag force due to the parachute acting on cars travelling at different speeds, or using parachutes of different sizes.

   (6 marks QWC)

1.4 Forces at a distance

Learning objectives

After this topic you will be able to:

- describe the effects of a field
- describe the effect of gravitational forces on Earth and in space.

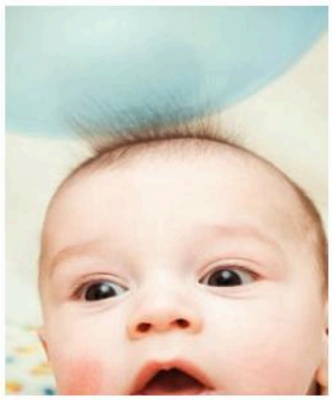
If you let go of your pen and it moved upwards you'd be very surprised. We are so familiar with the force of gravity that sometimes we don't even think of it as a force.

Gravitational forces

A gravitational force acts on a diver jumping off a diving board. It is a non-contact force. There are other types of non-contact force.

Magnets exert a **magnetic force** on magnetic materials or other magnets without touching them. If you rub a balloon you can pick up bits of paper with it. This is an electric or **electrostatic force**. Magnetic and electrostatic forces are non-contact forces.

▲ A magnet picks up filings.



▲ A balloon rubbed on your jumper attracts a baby's hair.

A Identify three forces that act at a distance.

Force fields

In physics a **field** is a special region where something experiences a force. There is a magnetic field around a magnet where magnetic materials experience a force. There are gravitational fields where things with mass experience a force.

Gravitational, magnetic, and electrostatic fields have something in common. As you get further away from the mass, magnet, or charge, the field gets weaker. Contact forces only act when the objects are touching each other. Non-contact forces act at any distance, even if the objects are not touching.

B Describe what is meant by a field.

Link

You can learn more about electrostatic forces in P2 1.1 Charging up

Foul Fact!

The strongest gravitational field in the Universe is made by a black hole. It is called a 'black' hole because even light cannot escape from its gravitational field. If you stood close to a black hole, the force of gravity on your feet would be much bigger than the force of gravity on your head. You'd be stretched. This is called 'spaghettification'.

Key Words

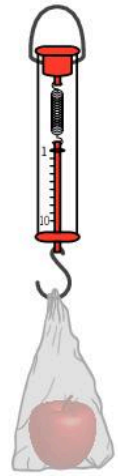
magnetic force, electrostatic force, field, weight, mass, kilogram (kg), gravitational field strength

What do I weigh?

You can use a newtonmeter to find the **weight** of an apple. The Earth pulls the apple downwards. Measuring the weight of the apple means measuring the force of the Earth on it.

What is the difference between weight and mass?

Weight is a force so it is measured in newtons (N). **Mass** is the amount of 'stuff' something is made up of. It is a measure of how hard it is to get something to move. Mass is measured in **kilograms** (kg).



An apple has a weight of about 1 N.

Units of mass

Smaller masses are measured in grams (g).

There are 1000 g in 1 kilogram (kg).

Convert these masses into grams: **a** 2 kg **b** 3.5 kg **c** 0.4 kg

Convert these masses into kilograms: **d** 4700 g **e** 250 g

You can calculate weight using an equation.

weight (N) = mass (kg) x **gravitational field strength**, *g* (N/kg)

On Earth gravitational field strength is about 10 N/kg.

This means that, if your mass is 50 kg, for example, then your weight on Earth is:

weight = 50 kg × 10 N/kg

= 500 N

Gravitational field strength is different on other planets and stars. Your weight would be different on different planets because *g* would be different.

The Apollo astronauts could jump much higher on the Moon because *g* on the Moon is about one sixth of *g* on Earth.

C State the unit of mass and the unit of weight.

What would happen to my weight in space?

Imagine blasting off from the Earth in a spacecraft. As you move away from the Earth the gravitational field gets weaker. If you stood on scales in the spacecraft the reading would be less than it would be on Earth.

The amount of 'you' would not change. Your mass stays the same. It is the force of the Earth on you, your weight, that is less.

Summary Questions

1 Copy and complete the sentences below.

Some forces act a distance. The force of gravity acts on things that have ______. A balloon has an ______ force when you rub it. You can feel a ______ force between two magnets. Your weight is a ______ and is measured in ______. Your ______ is the amount of stuff you are made up of and is measured in ______.

(7 marks)

2 Explain one reason why your weight on Jupiter is 2.7 times your weight on Earth.

(3 marks)

3 Describe what happens to the force of gravity as you move away from the Earth.

(1 mark)

4 Imagine the first Olympic Games conducted on the Moon in a specially designed dome. Use the ideas on this page to state and explain which sports would produce new records, and which would not.

(6 marks)

1.5 Balanced and unbalanced

Learning objectives

After this topic you will be able to:

- describe the difference between balanced and unbalanced forces
- describe situations that are in equilibrium
- explain why the speed or direction of motion of objects can change.

▲ When the teams pull with the same force the forces are balanced.

Equal and opposite...?

Isaac Newton said, 'For every action there is an equal and opposite reaction'. The forces in an interaction pair are equal and opposite. Is lying in bed an example of this law? No, it is not. Each of the forces acting on you comes from a *different* interaction pair.

Key Words

balanced, equilibrium, unbalanced, driving force, resistive force

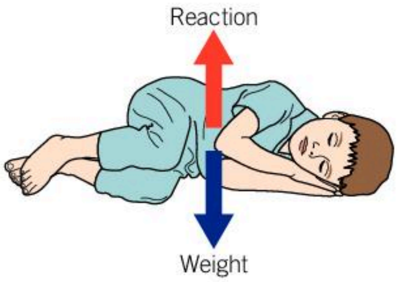
To get out of bed in the morning you need a force to get you moving.

What are balanced forces?

When the forces acting on an object are the same size but in opposite directions we say that they are **balanced**. You can think of balanced forces like two teams in a tug of war. If each team pulls with the same force the rope doesn't move. The forces cancel out. The object is in **equilibrium**.

A State what equilibrium means.

All stationary objects are in equilibrium. There has to be a support force acting on them to balance out their weight.



◀ You are in equilibrium when lying in bed.

B Draw a diagram showing the forces acting on a stationary mass hanging on a spring.

What are unbalanced forces?

The forces acting on this rocket-powered car are **unbalanced**. They are not the same size so they do not cancel out.

The **driving force** from the engine is much, much bigger than the **resistive forces** from air resistance and friction.

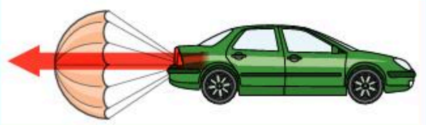
▲ The Thrust SSC was the first car to travel faster than sound.

C State the difference between balanced forces and unbalanced forces.

How do unbalanced forces change speed?

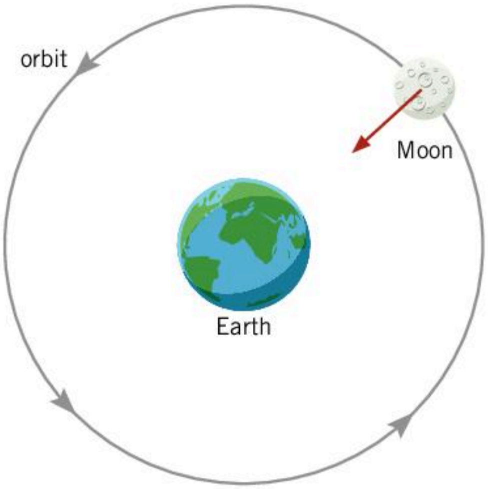
When the car's rocket-powered engine starts up the driving force will become very big very quickly. When the driver wants to stop he will fire a parachute to slow the car down. In both cases the forces on the car are unbalanced.

The driver uses a parachute because this gives a much bigger resistive force on the car than just using the brakes. The speed of the car will change much more quickly. The car will stop in a much shorter time.

	
The driving force is bigger than the resistive forces acting on the car.	The only forces acting on the car are resistive forces.
The speed of the car increases.	The speed of the car decreases.

How do unbalanced forces change direction?

Isaac Newton worked out that the Earth exerts a force on the Moon. The force of gravity acting on the Moon keeps the Moon in orbit around the Earth. It is this same force that acts on an apple and pulls it to the ground. It changes the *direction* of motion, not the speed.



The force of gravity keeps the Moon in orbit.

Every time you go around a corner in a car the friction between the tyres and the road changes the direction of the car.

Link

You can learn more about speed in P2 3.1 Speed

Friction changes the direction of a motorbike.

Summary Questions

1 Copy and complete the sentences below.

If the forces on an object are the same______ but act in ______ directions they are balanced. This is called ______. The forces acting on any stationary object are ______. If the forces on an object are unbalanced the ______ will change. If the ______ force is bigger than the ______ force it speeds up. If the ______ force is bigger than the ______ force it slows down.

(9 marks)

2 A cyclist is slowing down as she is cycling along a road.

a Draw a diagram to show the forces acting on the cyclist. *(1 mark)*

b Label the forces using the words 'resistive' and 'driving'. *(1 mark)*

c Explain why her speed is decreasing. *(1 mark)*

3 Design a new ride for a theme park. Describe and explain the motion of people who go on the ride using the ideas on this page.

(6 marks)

P1 Chapter 1 Summary

Key Points

- Forces are pushes or pulls, measured in newtons (N) using a newtonmeter.
- Forces exist when objects interact – this produces an interaction pair.
- Forces can deform objects, change their speed, or the direction of motion.
- Contact forces occur when objects are touching.
- Friction, air resistance, and water resistance are contact forces.
- Friction can be reduced by lubrication. Air resistance and water resistance can be reduced by streamlining.
- Non-contact forces occur when objects are not touching.
- Gravitational, electrostatic, and magnetic forces are non-contact forces.
- Solid surfaces provide a support force when they are compressed.
- Springs or ropes extend when you apply a force.
- For some objects if you double the force the extension doubles. This is Hooke's Law.
- A field is a region where something feels a force, for example, a mass in a gravitational field.
- Mass is the amount of stuff an object is made up of, measured in kilograms.
- Weight is the force of the Earth on an object, measured in newtons.
  Weight (N) = mass (kg) x g (N/kg)
- When the forces acting on an object are equal in size and acting in opposite directions they are balanced. The object is in equilibrium.
- If the forces are not balanced the object will speed up, slow down, or change direction.

BIG Write

Mission to Mars

NASA's Curiosity rover landed on Mars in August 2012. Imagine that the first astronauts have just returned from Mars in the year 2034.

Task

You were one of the astronauts on the mission. Write a blog that covers the whole mission. Start from when you take off from the Earth and finish with splash down when you return home.

Tips

- Explain the motion of the rocket during each stage of the journey to and from Mars.
- Use what you have learnt about where forces come from and how they affect motion.

Key Words

push, pull, contact, non-contact, interaction pair, newtonmeter, weight, newton (N), deform, compress, stretch, reaction, extension, tension, elastic limit, Hooke's Law, linear, friction, lubrication, water resistance, air resistance, drag forces, streamlined, gravity, magnetic, electrostatic, field, mass, weight, kilograms (kg), gravitational field strength, balanced, equilibrium, unbalanced, driving force, resistive force

End-of-chapter questions

1 State which of the forces below are contact forces and which are non-contact forces.

magnetic force, friction, air resistance, gravitational force, electrostatic force, upthrust

(***6 marks***)

2 For each object below state whether the forces on it are balanced or unbalanced.

a a boat that is speeding up *(1 mark)*

b a boy who is floating in a swimming pool *(1 mark)*

c a cyclist who is slowing down *(1 mark)*

(***3 marks***)

3 A student is investigating friction. She puts a block of wood on a ramp and lifts the ramp until the block starts to move. She repeats the experiment with different types of surface on the ramp.

a State the variable that she is changing (the independent variable). *(1 mark)*

b State the variable that she is measuring (the dependent variable). *(1 mark)*

c State the variable or variables that she should control. *(1 mark)*

d Explain why she will need to plot a bar chart in this investigation. *(2 marks)*

(***5 marks***)

4 A cyclist is sitting on her bicycle at the start of a race.

a Draw a diagram of the cyclist and label the forces acting on her. *(2 marks)*

b Explain how the bicycle seat exerts a force on the cyclist. *(2 marks)*

c The race begins. State whether the forces on her when she goes around a corner are balanced or unbalanced. *(1 mark)*

(***5 marks***)

5 A student wants to make a newtonmeter. He coils a piece of wire around his pencil to make a spring. He puts a 100 g mass on the spring. A 100 g mass has a weight of 1 N. He measures the extension.

a Describe how to measure the extension of a spring. *(3 marks)*

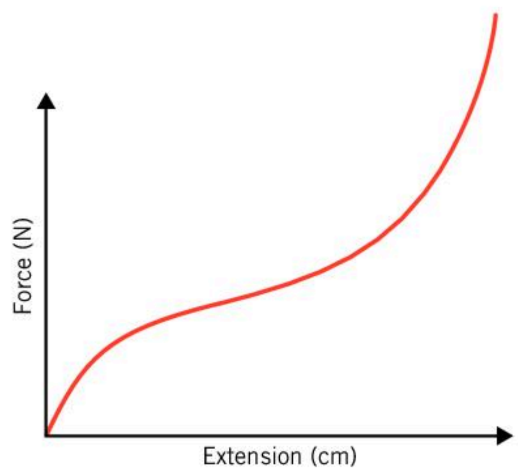
b Explain the difference between a mass of 100 g and a weight of 1 N. *(2 marks)*

The student measures the extension for different forces and plots his results on a graph. The line on the graph is a straight line.

c Use the shape of the graph to explain why the spring obeys Hooke's Law. *(2 marks)*

(***7 marks***)

6 Another student decides to use an elastic band as a newtonmeter and plots these results.



Explain in detail why the elastic band cannot be used as a newtonmeter but a spring can.

(***6 marks QWC***)

2.1 Waves

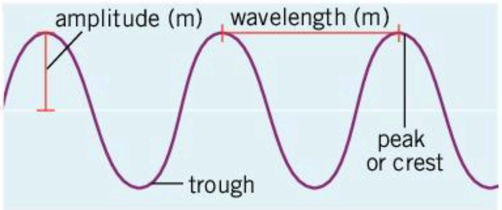
Learning objectives

After this topic you will be able to:

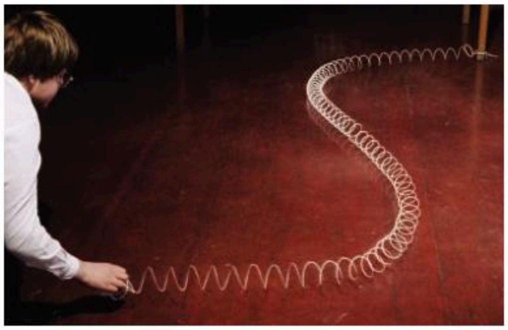
- describe the different types of wave and their features
- describe what happens when water waves hit a barrier
- describe what happens when waves superpose.

Key Words

oscillation, vibration, energy, undulation, sound, amplitude, frequency, wavelength, peak, crest, trough, transverse, longitudinal, compression, rarefaction, reflection, incident wave, reflected wave, superpose



▲ This diagram shows the amplitude and wavelength of a wave.



▲ You can make a transverse wave on a slinky.

Mexican waves are very popular at concerts and sporting events. But what is a wave?

What is a wave?

In science a wave is an **oscillation** or **vibration** that transfers **energy** or information. A wave can also be an **undulation** on the surface of water. Matter does not get transferred. Waves have many uses, for example, microwaves cook food, and **sound** waves help you communicate.

Features of a wave

All waves have three important features:

- an **amplitude**, which is the distance from the middle to the top or bottom of a wave
- a **frequency**, which is the number of waves that go past a particular point per second
- a **wavelength**, which is the distance from one point on a wave to the same point on the next wave.

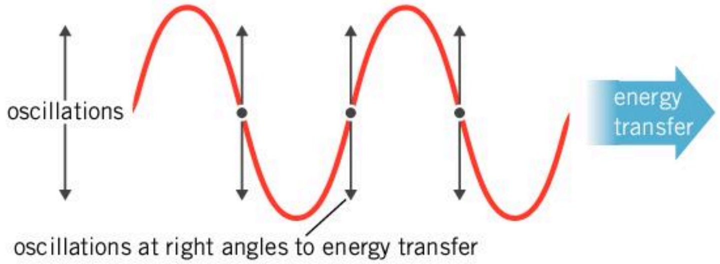
The top of a wave is called a **peak** or **crest**, and the bottom of a wave is called a **trough**.

A Name three properties of a wave.

Transverse or longitudinal?

You can send pulses down a slinky spring. You can make the pulses in two ways.

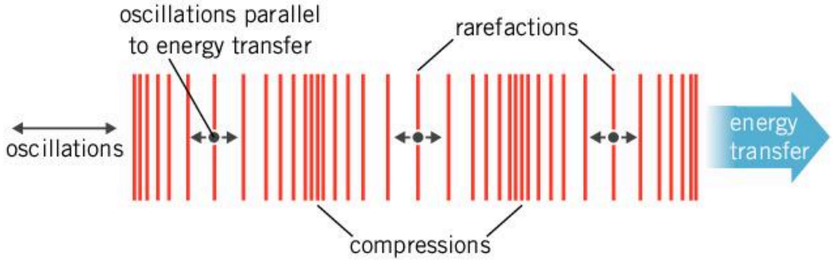
You can move your hand at right angles to the spring. This produces a **transverse** wave on the slinky. In a transverse wave the oscillation is at 90° to the direction of the wave.



▲ In a transverse wave the oscillation is at 90° to the direction of the wave.

You can also push and pull the spring. This produces a **longitudinal** wave on the slinky. The oscillation is parallel to the direction of the wave – it is in the same direction as the spring itself.

In a **compression** the coils of the spring are close together. In a **rarefaction** the coils are further apart. Sound is a longitudinal wave and light is a transverse wave.



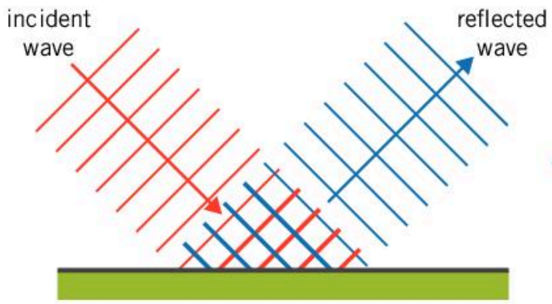
▲ In a longitudinal wave the oscillation is parallel to the direction of the wave.

B State the direction of the oscillation of a longitudinal wave.

Reflecting waves

Waves bounce off surfaces and barriers, just like a football bounces off a wall. This is called **reflection**.

The wave coming into the barrier is called the **incident wave**. The wave bouncing off is called the **reflected wave**.



◀ A wave reflects off a barrier.

C State the name of the wave that hits the barrier.

Adding waves

When waves are put together they **superpose**. This means that they add up or they cancel out.

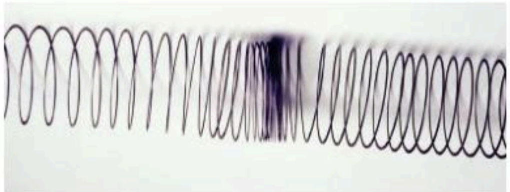
If the waves are in step they will add up. You get more than you had before. If they are not in step then they cancel out and you get less than you had before.

Spot the word

Write the word from each of these definitions:

a the distance from the top to the bottom of a wave

b where the links of a spring are squashed together



▲ You can make a longitudinal wave on a slinky.

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

A wave is an oscillation or vibration that transfers **energy/matter**. The distance from the centre to the top of the wave is the **amplitude/wavelength**. The distance from one crest to the next crest is the **amplitude/wavelength**. Waves can **reflect/superpose** when they hit a barrier, and cancel out or add up when they **reflect/superpose**.

(5 marks)

2 Describe the difference between a compression and a rarefaction in a longitudinal wave on a spring.

(2 marks)

3 Explain in detail the difference between longitudinal and transverse waves, giving examples of each.

(6 marks QWC)

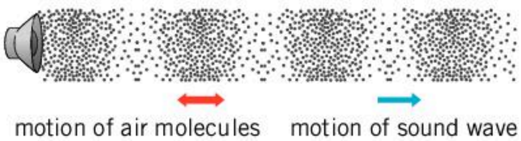
2.2 Sound and energy transfer

Learning objectives

After this topic you will be able to:

- describe how sound is produced and travels
- explain why the speed of sound is different in different materials
- contrast the speed of sound and the speed of light.

▲ The ends of a tuning fork are vibrating.



▲ Air molecules move backwards and forwards.

▲ Dolphins communicate underwater.

If you very gently press the front of your throat while you are talking you will feel a vibration. This is your vocal chords vibrating. The vibration produces the sound waves that travel through the air from your mouth.

What is a sound wave?

A **vibration** produces a sound wave. All speakers, like the ones in your headphones, have something that moves backwards and forwards, or vibrates. This makes the air molecules move backwards and forwards, which produces a sound wave.

Some people think that sound just 'dies away'. It doesn't. It spreads out as it moves away from the source.

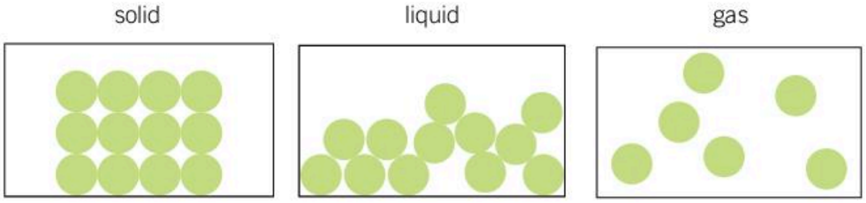
A State what produces a sound wave.

What does sound travel through?

Dolphins and whales use sound waves to communicate underwater. Elephants stamp their feet when a predator comes near – the warning travels through the ground to other elephants. Sound needs a **medium** like a solid, liquid, or gas to travel through. It cannot travel through empty space, a **vacuum**, because there are no air molecules to vibrate.

How fast does sound travel?

Sound travels at 340 m/s in air. Sound travels much faster in liquids, about 1500 m/s. Sound travels fastest in solids. In metals like steel it can travel at 5000 m/s. You can explain why a sound wave travels faster in a solid than in a gas if you think about particles. The particles in a solid are very close together, so the vibration is passed along more quickly than in a gas.



▲ The arrangement of particles explains the speed of sound in different materials.

Some people talk about the 'sound barrier'. There is no difference between travelling at or beyond the **speed of sound**.

Felix Baumgartner found this out when he became the first human to travel faster than the speed of sound when he jumped from a balloon 24 miles above the surface of the Earth.

Felix Baumgartner travelled faster than sound.

B State the speed of sound.

How fast?

A student uses some secondary sources of information to make a list of the speed of sound in different materials.

a Draw a suitable table that she could use to record the data.

b State and explain which type of graph she could plot to show the data.

C Name the three types of medium that sound can travel through.

Which is faster: sound or light?

Light travels much faster than sound. The **speed of light** is 300 000 000 m/s, so it is almost a million times faster than sound. You notice this difference during a thunderstorm. The thunder and lightning are produced at the same time. You see the lightning immediately but it takes time for the sound of thunder to reach you.

Light can travel through a vacuum. It doesn't need a medium to travel through.

Key Words

vibration, medium, vacuum, speed of sound, speed of light

Stormy night

A girl sees a flash of lightning and then hears the thunder four seconds later.

a How far away is the storm? State your answer in kilometres.

b What would she notice about the thunder and lightning when the storm is directly overhead?

Summary Questions

1 Copy and complete the sentences below.

Sound is produced by objects that are ____________ .
This makes the air molecules ____________ and produces a sound wave. Sound travels fastest in __________ and slowest in __________, and it cannot travel through a __________.

(5 marks)

2 Explain why sound travels slower in a gas compared to a liquid.

(2 marks)

3 Compare the time it takes the light to travel from your teacher to your eye with the time it takes sound to travel the same distance.

(6 marks QWC)

2.3 Loudness and pitch

Learning objectives

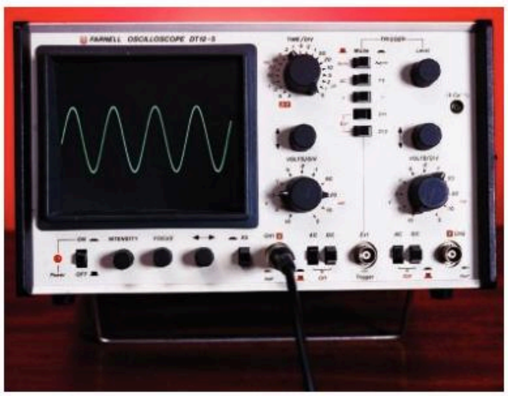
After this topic you will be able to:

- describe the link between loudness and amplitude
- describe the link between frequency and pitch
- state the range of human hearing and describe how it differs from the range of hearing in animals.

If you play a loud note of exactly the right pitch then you can shatter a glass. What's the difference between loudness and pitch?

Seeing sound

You can plug a **microphone** into an **oscilloscope** to see what the sound of your voice looks like. The wave on the screen is transverse but the wave that you are making when you talk is longitudinal. The microphone produces a signal that represents the sound wave.



▲ An oscilloscope shows a representation of a sound wave made, for example, by a tuning fork.

What affects the loudness of a sound?

If a drummer hits the drum harder the sound is louder.

▲ A drum produces a sound with a large amplitude.

loud

soft

▲ A loud sound has a bigger amplitude than a soft sound.

You bang a drum harder or pull a guitar string more to produce a louder sound. A loud sound has a bigger amplitude than a soft sound. It transfers more energy than a soft sound. To make a louder sound you need to make the vibration bigger.

A State the property of a sound wave that affects the loudness of the sound.

What affects the pitch of a sound?

Some singers can sing higher-pitched notes than others. The **pitch** of a note depends on the frequency. High-pitched sounds have a high frequency and low-pitched sounds have a low frequency. Frequency is measured in **hertz** (Hz) or **kilohertz** (kHz).

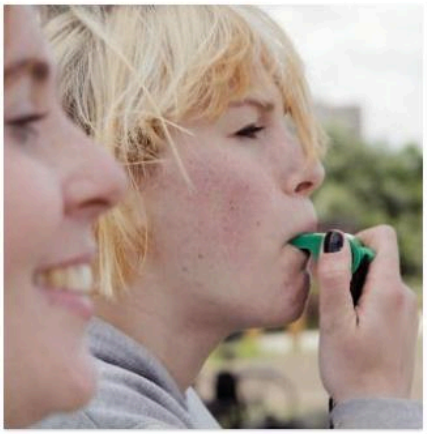
1 kHz = 1000 Hz. To make a higher-pitched sound you need to make something vibrate faster, so that there are more waves per second.

Key Words

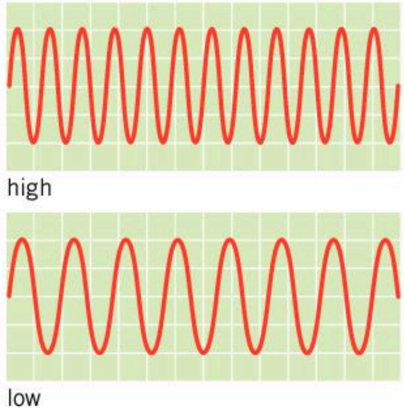
pitch, loudness, microphone, oscilloscope, hertz, kilohertz, audible range, infrasound, ultrasound

Fantastic Fact!

Grasshoppers make sounds that they cannot even hear.



▲ A whistle produces a sound with a high frequency.



▲ A high sound has a higher frequency than a low sound.

You can have a loud, high-pitched sound or a loud, low-pitched sound. Changing the frequency does not affect the amplitude.

B State the property of a sound wave that affects the pitch of the sound.

What frequencies can you hear?

You can only hear a particular range of frequencies, called the **audible range**. You have the biggest audible range when you are young: 20–20 000 Hz. Your audible range changes as you get older. You will find it more difficult to hear high-frequency sounds.

What frequencies can other animals hear?

Bats, dolphins, and grasshoppers have a completely different audible range to humans. Lots of animals can hear frequencies that are much higher than the frequencies we can hear. Frequencies below 20 Hz are called **infrasound**. Frequencies above 20 000 Hz are called **ultrasound**.

Species	Audible range (Hz)
bat	2000–110 000
cat	45–64 000
dog	67–45 000
dolphin	1000–100 000
goldfish	20–3000
hedgehog	250–45 000
whale	1000–123 000

Conversions

a Convert the audible range for humans into kilohertz.

b Convert the audible range of the whale into kilohertz.

Link

You can learn more about ultrasound in P1 2.5 Echoes and ultrasound

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

The loudness of a sound depends on the **amplitude/frequency** and the pitch of the sound depends on the **amplitude/frequency**. Frequency is measured in **hertz/metres**. The range of frequencies you can hear is called the **audible/visible** range.

(4 marks)

2 State the range of human hearing and compare it to the range of dolphin hearing.

(2 marks)

3 A singer produces sounds that vary in pitch and loudness. Use the ideas above to suggest and explain in detail what her vocal chords do to produce different types of sound wave.

(6 marks QWC)

2.4 Detecting sound

Learning objectives

After this topic you will be able to:

- describe how the ear works
- describe how your hearing can be damaged
- describe how a microphone detects sound.

Your ear is your body's microphone. If you listen to really loud music it doesn't hurt but can it damage your hearing?

How do you hear?

Your **ear** detects sound waves. The part of your ear that you can see, called the **pinna**, directs the sound wave into your auditory canal towards your ear drum. The pinna, **auditory canal**, and **eardrum** make up your **outer ear**.

Your eardrum vibrates and passes the vibration on to the **ossicles**. The ossicles make up your **middle ear**. They are tiny bones that **amplify** the sound. They make the **oval window** vibrate.

This passes the vibration on to liquid in the **cochlea**. This contains thousands of tiny hairs. As the liquid moves the hairs move. Specialised cells at the base of the hairs convert the movement to an electrical signal. The signal travels down the **auditory nerve** to your brain. You hear the music.

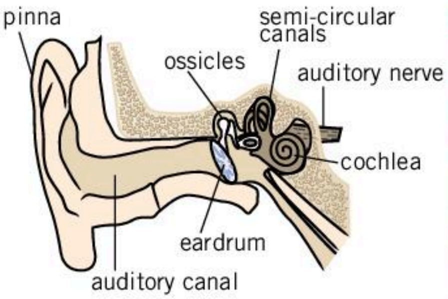
The cochlea and the semi-circular canals make up your **inner ear**. The semi-circular canals help you to balance.

Link

You can learn more about specialised cells B1 1.3 Specialised cells

Key Words

ear, pinna, auditory canal, eardrum, outer ear, ossicle, middle ear, amplify, oval window, cochlea, auditory nerve, inner ear, decibel, diaphragm, amplifier



▲ Structure of the ear.

▲ Without these tiny hairs inside your cochlea you would not be able to hear.

Foul Fact!

Your ossicles don't grow. They are the correct size when you are born. They are the smallest bones in your body.

A Name the first part of the ear that vibrates when a sound wave enters it.

How do you measure loudness?

In the 2010 World Cup in South Africa the crowd used vuvuzelas to make very loud sounds. Vuvuzelas can be so loud that they are painful.

You measure sound intensity in **decibels** (dB). The decibel scale is not like a ruler. Each increase of 10 dB increases the sound intensity by 10 times. A 40 dB sound is 100 times more intense than a 20 dB sound.

0 dB	20 dB	40 dB	60 dB	80 dB	100 dB	120 dB	140 dB
cannot be heard	leaves rustling	talking quietly	normal speech	heavy traffic	jet taking off	pain threshold	gun shot

How can you damage your hearing?

Your hearing can be damaged if a sharp object makes a hole in your eardrum but your eardrum will grow back. A build-up of ear wax can also be damaging. Very loud sounds or head injuries can permanently damage your hearing.

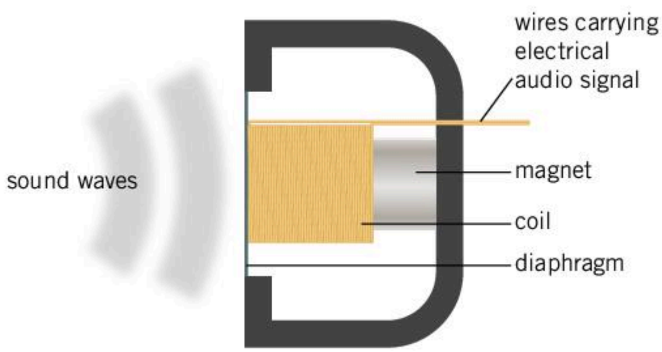
You can reduce the risk of damage by turning down the volume or using ear defenders.

B Describe one way that your hearing can be damaged.

How does a microphone work?

When a singer sings into a microphone the sound wave hits a flexible plate called a **diaphragm**. The diaphragm vibrates, like your eardrum. It produces an electrical signal, just like the cells in your cochlea. The signal carries the information that the sound wave carried.

You can use an **amplifier** to make the sound louder. Loudspeakers convert the electrical signal back into sound when they vibrate.



▲ A microphone detects sound in a similar way to your ear.

What protection?

Two companies make ear defenders. Plan an experiment to find out which pair is best at reducing sound intensity.

Summary Questions

1 Copy and complete the sentences below.

When a sound wave enters your ear it makes the ______________ vibrate. This makes the ______________ vibrate. The ______________ vibrates and this makes the liquid inside your ______________ vibrate. Cells at the base of ______________ inside your ______________ produce an electrical signal that travels up your ______________ to your brain. Sound intensity is measured in ______________. Your hearing can be ______________ by loud sounds. In a microphone a ______________ vibrates, which produces an electrical signal.

(10 marks)

2 Describe one way that your hearing can be damaged that is not permanent, and one way that it can be permanently damaged.

(2 marks)

3 Compare the ear and the microphone.

(6 marks QWC)

2.5 Echoes and ultrasound

Learning objectives

After this topic you will be able to:

- describe what ultrasound is
- describe some uses of ultrasound.

▲ This room is designed to produce no echoes.

Where is the quietest place in the world? Scientists have designed a room where it is so quiet you can hear your own heartbeat. The surfaces are designed to absorb sounds. There are no echoes.

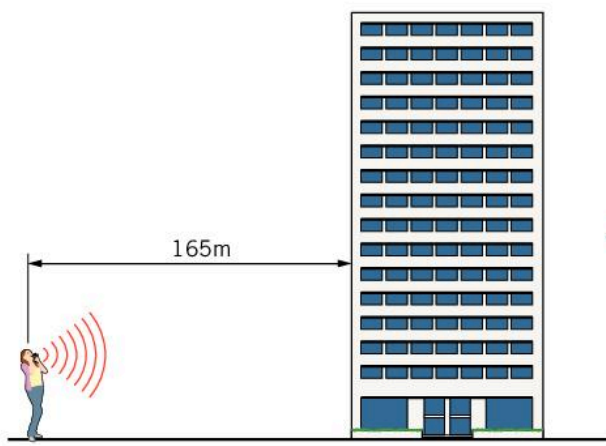
What is an echo?

When sound reflects off a surface it produces an **echo**. Sound takes time to travel. There is a time delay between making a sound and hearing an echo.

Measuring distances

Imagine that you are standing a long way from the school sports hall. You clap and you hear an echo one second later. How far away is the wall?

The speed of sound in air is 340 m/s. The sound travels a total distance of 340 m in one second. The distance to the wall is 165 m because the sound has travelled there and back. You can use the time taken to hear the echo to work out distance.



◀ You can work out how far away a wall is using echoes.

A State what an echo is.

How do you reduce echoes?

If lots of echoes join together to produce a longer sound this is called a **reverberation**. Reverberations can be a nuisance in concert halls or cinemas. You can reduce the effect of echoes by covering the walls with soft materials and putting carpet on the floor.

Key Words

echo, reverberation, transmitter, receiver

Fantastic Fact!

People used to think that a duck's quack and a wolf's howl don't echo. They do. Sometimes the echo gets mixed in with noise so you don't hear it.

What is ultrasound?

Bats use ultrasound to find their food. Doctors use ultrasound to make images of unborn babies. Ultrasound is sound with a frequency above 20 000 Hz.

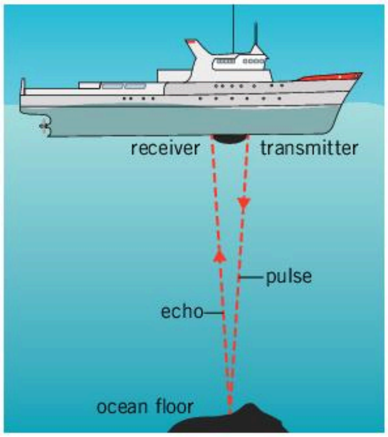
B State the frequency of ultrasound.

When doctors make images of unborn babies, the ultrasound wave travels through the woman and reflects off the fetus. The machine detects the echo. It uses the time taken for the echo to build up an image of the fetus.

This shows an ultrasound image of a baby and a photograph of the same baby after he was born.

Doctors also use ultrasound in physiotherapy. For example, ultrasound reduces the pain and swelling of a damaged tendon. They can also look for cancer..

Another use of ultrasound is sonar, used on ships. A **transmitter** under the ship sends out a beam of ultrasound. It travels through the water and reflects off the seabed. A **receiver** detects the reflection and uses the time taken to work out the depth of the water.



Ships use ultrasound to work out the depth of the ocean.

Literacy

The word "sonar" is an acronym. It comes from the term "Sound Navigation And Ranging'.

C State a use of ultrasound.

How deep?

A ship's sonar detects an echo 1.6 s after it sends the pulse. The speed of sound in water is 1500 m/s. Work out how deep the water is.

Summary Questions

1 Copy and complete the sentences below.

An echo is a ________ of sound. You can use the ________ between making a sound and hearing an echo from a surface to calculate the ________ to it. Soft materials ________ sound and reduce echoes. Animals use ultrasound to ________ and ________.
Ultrasound is used to make an ________ of a fetus, or break down ________ .
Fishermen can use ultrasound to find the ________ of the ocean.

(9 marks)

2 Describe one way that a doctor might use ultrasound.

(2 marks)

3 Imagine that you are the captain of a fishing boat. Write a detailed presentation that you will show to the fishermen, explaining how to use sonar to detect shoals of fish.

(6 marks)

P1 Chapter 2 Summary

Key Points

- Waves are oscillations or vibrations that have an amplitude, wavelength, and frequency. The top of a wave is a crest and the bottom is a trough.
- In a transverse wave the oscillation is at 90° to the wave direction, and in a longitudinal wave it is parallel to the wave direction.
- Waves can reflect from barriers and add up or cancel out.
- A sound wave is produced by vibrating objects and is longitudinal.
- Sound travels at 340 m/s. Sound travels fastest in solids and slowest in gases and cannot travel through a vacuum.
- The loudness of a sound depends on its amplitude, and the pitch depends on its frequency. Frequency is measured in hertz (Hz).
- A human's audible range is from 20–20 000 Hz.
- Your outer ear consists of the pinna, auditory canal, and eardrum. Your middle ear contains your ossicles. Your inner ear contains your cochlea and semi-circular canals.
- Vibrations travel from your eardrum to the hairs in your cochlea. This produces a signal that is sent to your brain.
- Loudness is measured in decibels (dB).
- An echo is a reflection of sound that you can use to work out distance. Soft materials absorb sound and don't produce echoes.
- Ultrasound is sound with a frequency of more than 20 000 Hz. Humans use ultrasound to produce images of inside the body, and to find the depths of water.

Big Write

Sound campaign

You are a scientific advisor to a council. There are several issues to do with sound in the area:

- Shopkeepers want to install high-frequency speakers to put off young people hanging around outside their shops.
- People who live near a busy road are concerned about the traffic noise.

Task

Produce an information pack that includes:

- what a sound wave is, its properties, and how it behaves
- how you hear, and how hearing can be damaged.

Key Words

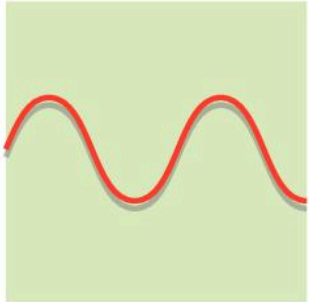
oscillation, vibration, energy, undulation, sound, amplitude, frequency, wavelength, peak, crest, trough, transverse, longitudinal, compression, rarefaction, reflection, incident wave, reflected wave, superpose, vibration, medium, vacuum, speed of sound, speed of light, pitch, loudness, microphone, oscilloscope, hertz, kilohertz, audible range, infrasound, ultrasound, ear, pinna, auditory canal, eardrum, outer ear, ossicles, middle ear, amplify, oval window, cochlea, auditory nerve, inner ear, decibels, diaphragm, amplifier, echo, reverberation, transmitter, receiver

End-of-chapter questions

1 Draw a wave and label the amplitude and the wavelength.

(2 marks)

2 A tuning fork produces this wave on an oscilloscope:



a Draw the wave you would see if the sound was louder. *(1 mark)*

b Draw the wave you would see if the sound had a higher pitch. *(1 mark)*

(2 marks)

3 A note has a frequency of 400 Hz. State how many sound waves pass a point per second.

(1 mark)

4

a Describe what happens when a wave hits a barrier. *(1 mark)*

b Describe what happens when waves superpose. *(2 marks)*

(3 marks)

5

a Explain why a Mexican wave is transverse. *(1 mark)*

b Explain why sound is a longitudinal wave. *(1 mark)*

(2 marks)

6 Suggest a situation where you might need to use ear defenders.

(1 mark)

7 Here is a table showing the speed of sound in three different materials: A, B, and C.

Material	Speed (m/s)
A	1250
B	300
C	5000

a State which material, A, B or C, is probably a solid. *(1 mark)*

b State which material, A, B or C, is probably a gas. *(1 mark)*

c Suggest a reason why the three speeds are different. *(3 marks)*

(5 marks)

8 A student is measuring sound intensity with a meter. He wonders if there is a link between the loudness of a sound and how far away you are from the source.

a Suggest a question that the student could investigate based on this idea. *(1 mark)*

b Name the independent, dependent, and control variables in the investigation. *(1 mark)*

c State the type of graph that he could plot with the results of this investigation. *(1 mark)*

(3 marks)

9 A loudspeaker produces a sound wave that you can hear. Describe in detail how the sound is produced, travels, and is detected by your ear.

(6 marks QWC)

3.1 Light

Learning objectives

After this topic you will be able to:

- describe what happens when light interacts with materials
- state the speed of light.

▲ You can see a starfish through water.

▲ Frosted glass is translucent.

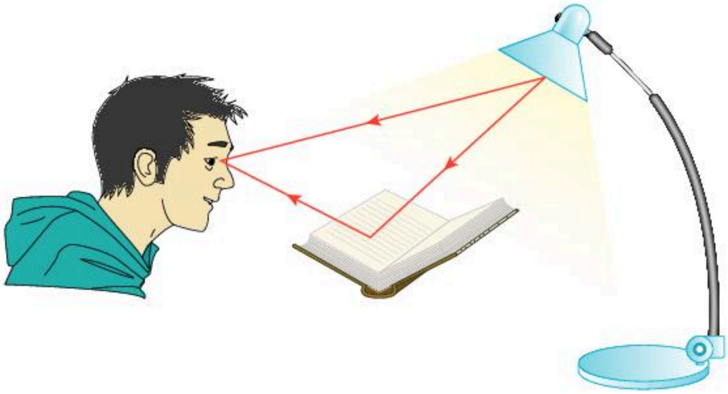
How long? How far?

It takes light eight minutes to travel here from the Sun. Sound is about a million times slower. Calculate how long it would take sound to travel the same distance. Convert your answer to years.

As you go deeper and deeper into an ocean it gets darker and darker until you can hardly see a thing. Some fish that live there make their own light. Why is it so dark?

What happens to light as it travels?

You look at a book. A **source** of light, like a light bulb, **emits** light. This light **reflects** off the book and into your **eye**. You see the book when the light is **absorbed** in your eye.



▲ You see objects because light reflects off them.

Something that gives out light is **luminous**. Most objects that you look at are **non-luminous**. You see them because they reflect light into your eyes. Light spreads out, just like sound.

When you look through a window, light travels through the glass and into your eye. The glass **transmits** the light. When light travels through glass, Perspex, or shallow water most of the light goes through but a small amount is absorbed. They are **transparent** and you can see through them. In very deep water most of the light is absorbed.

A State the difference between 'emit' and 'transmit'.

Materials like frosted glass or tissue paper are **translucent**. Light can travel through them but it is scattered so you cannot see clearly. Materials that do not transmit light are **opaque**.

Opaque materials produce shadows. You can predict the size and shape of shadows. This is because light travels in straight lines.

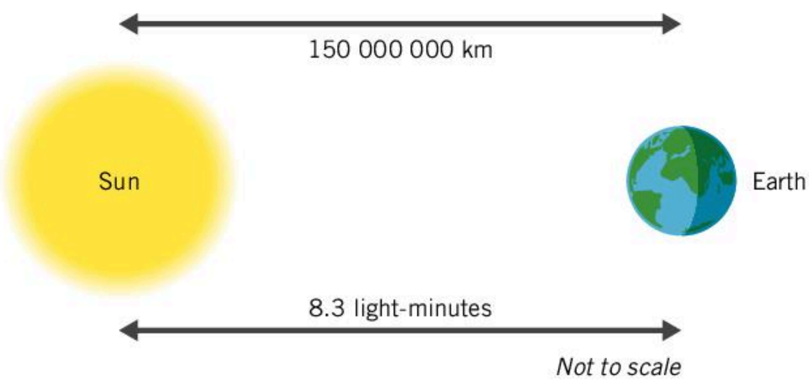
B State the difference between a translucent and a transparent material.

What can light travel through?

Light can travel through gases like the air, some liquids like water, and some solids like glass. It can even travel through completely empty space, which is called a **vacuum**. It does not need a medium to travel in. Light travels as a **wave**.

How fast does light travel?

It takes light about eight minutes to reach the Earth from the Sun, a distance of 150 million km. The speed of light is about 300 000 km/s. Sound travels about a million times slower than light. Astronomers use '**light-time**' to measure distances in space. A light-minute is the distance that light travels in one minute. A light-year is how far it travels in a year. Light-time is a measure of distance, not time.



▲ There are two ways of showing the distance to the Sun.

C State what is meant by a light-year.

Sort those words

Use the words below to make up three sentences involving a light bulb and a flower in a vase of water. The words can be used more than once but try to use them only once if you can.

emit transmit reflect absorb luminous non-luminous transparent opaque

Key Words

source, emit, reflect, eye, absorb, luminous, non-luminous, transmit, transparent, translucent, opaque, vacuum, wave, light-time

Link

You can learn more about the properties of waves in P1 2.1 Waves

Fantastic Fact!

If light from the Sun travelled at 100 mph it would take 100 000 years to reach Earth.

Summary Questions

1 Copy these sentences, choosing the correct bold words.

The Sun is **luminous/non-luminous** because it **emits/transmits** light. The light **reflects/transmits** off an object that is **luminous/non-luminous** into your eye so that you see it. Most objects do not transmit light; they are **translucent/opaque**.

(5 marks)

2 Explain why it is so dark at the bottom of the ocean even though water is transparent.

(2 marks)

3 Describe the journey that light takes from the Sun to your eye when you are looking at fish in a pond.

(6 marks QWC)

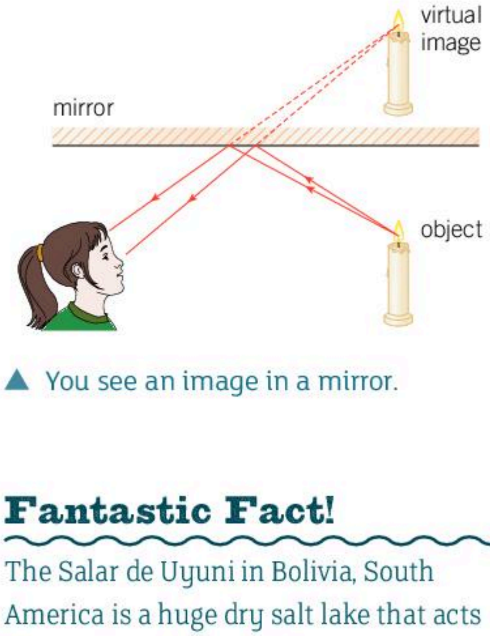
3.2 Reflection

Learning objectives

After this topic you will be able to:

- explain how images are formed in a plane mirror
- explain the difference between specular reflection and diffuse scattering.

▲ You see a reflection in a window.



▲ You see an image in a mirror.

Fantastic Fact!

The Salar de Uyuni in Bolivia, South America is a huge dry salt lake that acts like a mirror. It is so big that you can see it from space.

There are lots of places that you see your reflection every day. Shop windows, saucepans, car doors . . . but why do you see your image in some surfaces but not others?

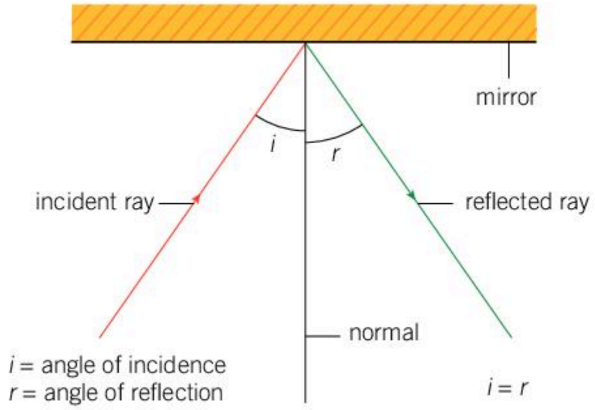
Why do I see an image in the mirror?

When you look in the mirror it appears that there is someone who looks just like you behind the mirror. The **image** is a **virtual** image. Your brain uses the fact that light travels in straight lines to work out where the light appears to come from. This is where you see the image.

When you look at your mirror image in a flat, or **plane**, mirror, it is the same shape and size as you are. It appears to be as far behind the mirror as you are in front of the mirror. Left and right appear swapped.

The law of reflection

You know that you need light to reflect from an object for you to see it. Light reflects off a mirror in the same way that a wave reflects off a barrier.



▲ Light is reflected at equal angles.

The ray that hits the mirror from your ray box is called the **incident ray**. The ray that reflects off the mirror is called the **reflected ray**.

There is an imaginary line at 90° to the mirror called the **normal**. You measure angles from the normal to the rays of light. The angle between the incident ray and the normal is the **angle of incidence**. The angle between the normal and the reflected ray is the **angle of reflection**.

When light is reflected from a mirror, the angle of incidence is equal to the angle of reflection. This is the **law of reflection**.

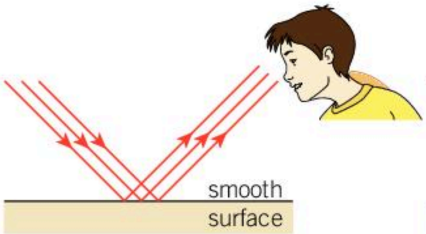
A State the law of reflection.

Rough surfaces

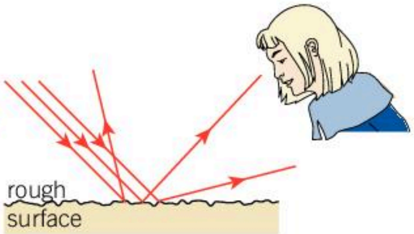
Every surface reflects at least some light. You can only see your image in surfaces that reflect light in a regular way.

Reflection from a smooth surface is called **specular reflection**. Reflection from a rough surface is called **diffuse scattering**.

To form an image, the rays from each part of the object have to reflect off a surface in the same way. If two rays that are parallel are reflected at different angles you won't see an image.



▲ Reflection from a smooth surface (specular reflection).



▲ Reflection from a rough surface (diffuse scattering).

B State the type of reflection when light hits a mirror.

Bouncing light

A student wants to investigate the light that is reflected from different types of material using a light meter.

a Explain why the student should repeat the experiment several times.

b State and explain which type of graph she should plot from the data that she collects.

Key Words

image, virtual, plane, incident ray, reflected ray, normal, angle of incidence, angle of reflection, law of reflection, specular reflection, diffuse scattering

Angular problem

A student makes a mistake and measures the angle between the mirror and the incident ray. It is 40°.

a What is the angle of incidence?

b What is the angle of reflection?

c He says the angle of incidence and the angle of reflection always add up to 90°. Is he correct? Explain your answer.

Summary Questions

1 Copy and complete the sentences below.

When you look in a mirror you see a ________ image of yourself. The image is the same ________, ________, and ________ from the mirror. When you close your left eye the image appears to close their ________ eye. The image is formed because light reflects off the mirror so that the angle of ________ is equal to the angle of ________.

(7 marks)

2 Explain why you cannot see an image of your face when you look at a white wall, even though most of the light hitting it is reflected.

(2 marks)

3 Design a model to demonstrate how light can be diffusely scattered but still obey the law of reflection. Use marbles and footballs instead of light in your model. Explain how it works.

(6 marks)

3.3 Refraction

Learning objectives

After this topic you will be able to:

- describe and explain what happens when light is refracted
- describe what happens when light travels through a lens.

▲ A pencil looks bent when you put it in a glass of water.

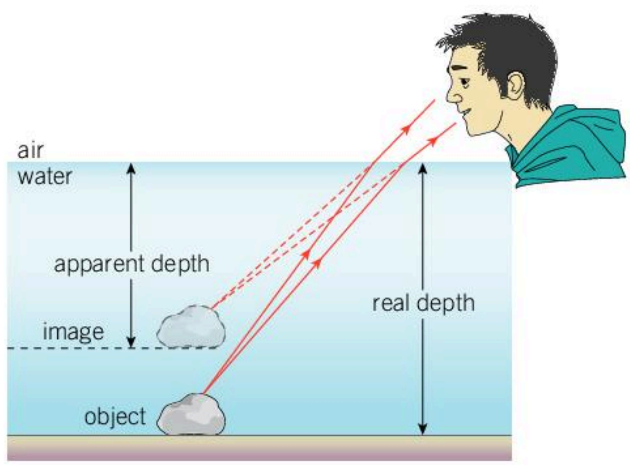
You can bend a pencil without touching it. Put it in a glass and fill it with water. It looks bent but it isn't. Why?

Optical illusions

The pencil reflects light and the light travels from the pencil through the water. It then travels through the air into your eye. As the light leaves the water, the direction it is travelling in changes. This is called **refraction**.

Refraction happens whenever light travels from one **medium** (material) to another.

The change in direction explains why the pencil appears to be bent. Your brain thinks that the light has travelled in a straight line. You see the end of the pencil in a different place to where it actually is. The pencil looks bent. Refraction also explains why a swimming pool looks shallower than it actually is.



▲ A rock at the bottom of a pool looks closer to the surface than it actually is.

A State the difference between reflection and refraction.

Fantastic Fact!

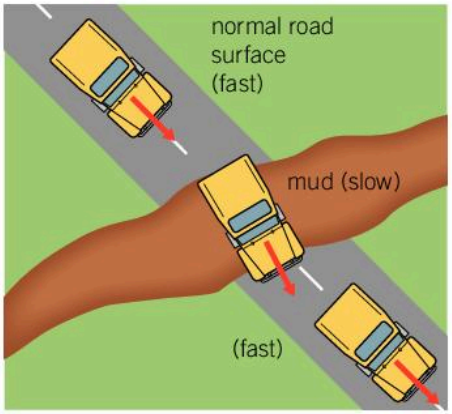
Stars twinkle because light is refracted as it travels through the atmosphere.

Why does light change direction?

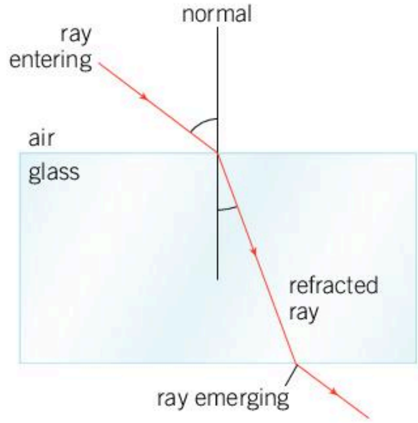
Imagine a truck driving from a road onto mud. When the first wheel of the truck hits the mud it slows down. The other wheels keep going – this pushes the truck in another direction. This is similar to what happens when light travels from air into water or glass, or when water waves go from deep to shallow.

Key Words

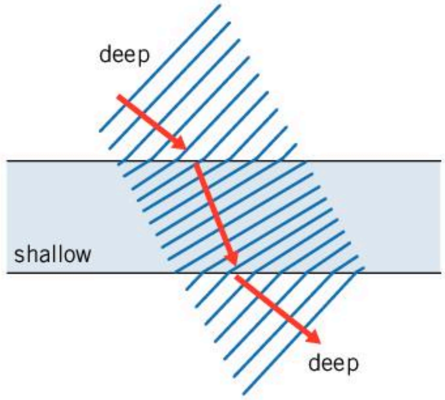
refraction, medium, lens, convex, converging, focus, focal point



▲ A truck changes direction as it slows down.



▲ Light is refracted when it slows down.

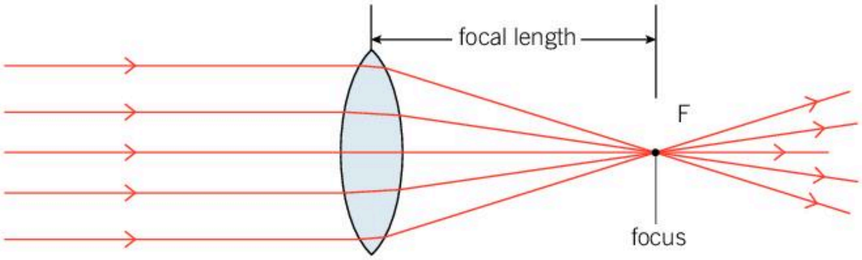


▲ Waves are refracted when they slow down.

When light travels through a glass block it slows down when it goes in, and speeds up again when it comes back out. The direction changes twice. Light bends towards the normal when it goes into glass. It bends away from the normal when it comes out. The two rays outside the block are parallel.

What does a lens do?

There are two lenses in your body. The **lens** in each of your eyes is a **convex** or **converging** lens. It focuses the light and enables you to see. The point where the rays cross is called the **focus** or **focal point**. The light is refracted as it goes into the lens and as it comes back out.



▲ A piece of glass shaped like a lens focuses light.

B Describe what a lens does to light.

Watch that spelling!

In each list below, choose the correct spelling of the word. Make up a rule that will help you to remember the spelling.

a lense, lenz, lens

b parallel, parrallel, paralell

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

When you look at a rock in the bottom of a swimming pool it appears **above/below** where it actually is. That is because the light **reflects/refracts** when it travels from water into air.
It bends **towards/away from** the normal as it goes into the air.
This is because it **slows down/ speeds up**.

(4 marks)

2 Explain what would happen to:

a the speed and direction of water waves if they went straight into the area of shallow water rather than at an angle *(2 marks)*

b the speed and direction of light waves if they went straight into the glass block rather than at an angle. *(2 marks)*

3 Describe in detail how you could use the idea of marching soldiers to make a model of light refracting as it goes through a glass block.

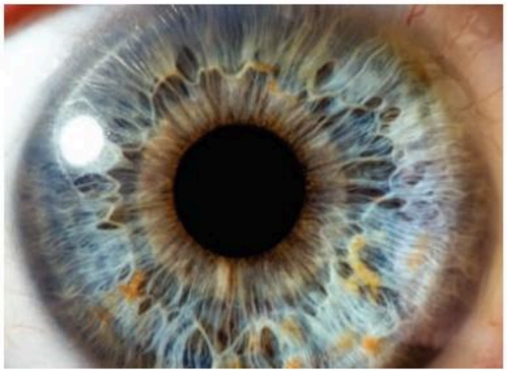
(6 marks QWC)

3.4 The eye and the camera

Learning objectives

After this topic you will be able to:

- describe how the eye works
- describe how a simple camera forms an image.



▲ No-one has the same pattern in their iris as you.

Key Words

retina, pupil, iris, cornea, inverted, photoreceptor, optic nerve, brain, pinhole camera, real (image), pixel, charge-coupled device (CCD)

Foul Fact!

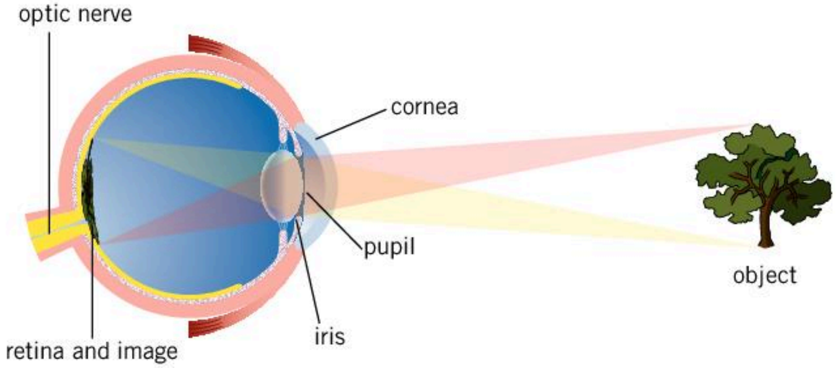
The pupil is a hole in the front of your eye. If you dissect a cow's eye you can put your finger through it.

Link

You can learn more about specialised cells in B1 1.3 Specialised cells

The iris is the coloured part of your eye. Everyone's iris is unique. It is like a fingerprint.

How do you see?



▲ How an image is formed in your eye.

When you look at your friend, an image of your friend is formed on the **retina** of your eye. Light reflected from your friend goes through the **pupil** of your eye. The **iris** is a muscle that controls the size of the pupil. The **cornea** (the transparent outer part of your eye) and the lens focus the light onto the retina. This forms an image. The image is **inverted** (upside down) but your brain sorts it out so you see an image of your friend that is the right way up.

A State which parts of the eye focus the light.

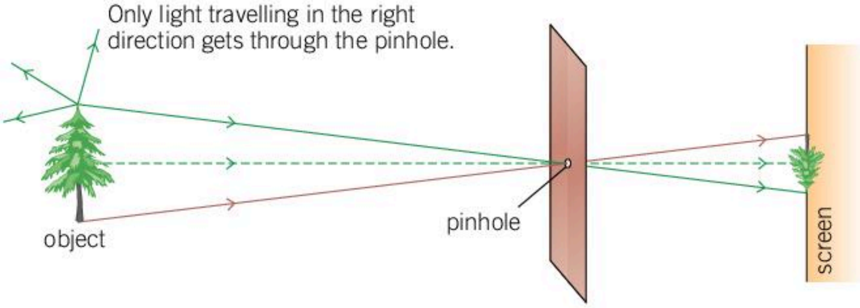
What happens in the retina?

The retina is a photosensitive material that contains cells that respond to light. They are called photoreceptors. There are two types of **photoreceptor**: rods and cones. Rods are sensitive to movement and dim light. Cones are sensitive to bright light and colour. When light hits the rods and cones, chemical reactions produce an electrical impulse that travels up the **optic nerve** to your **brain**.

B State the type of reaction that takes place in the retina.

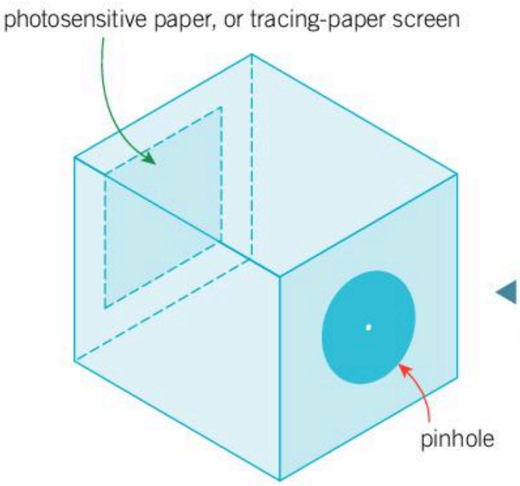
How is the eye like a camera?

A camera produces an image, just like your eye. One of the simplest cameras is a **pinhole camera**.



▲ An image is formed in a pinhole camera.

Light enters the camera through the pinhole, just like it does through your pupil. An image is formed on the screen, just like it is on your retina. The image is a **real** image, not like your image in a mirror. Any image that you can make on a screen is a real image.



◀ This is a simple pinhole camera.

Cameras used to contain photographic film, which was photosensitive. When light hit the film there was a chemical reaction that changed the chemicals in the film. When you processed the film you saw the image.

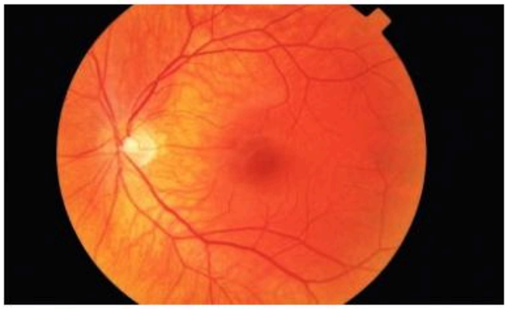
At the back of a digital camera there is a grid of photosensitive picture elements, or **pixels**. This is called a **charge-coupled device** (CCD). When light hits each pixel it produces charge. The light produces an electrical, not chemical, effect. When you take a picture, this charge is moved off each of the pixels and stored. That is why there is a slight delay before you can take another picture.

C Name the photosensitive grid at the back of a digital camera.

Real or virtual?

Here are some words that describe real and virtual images. Use these words to explain the difference between the two types of image.

screen virtual real mirror



▲ This is the view of your retina that an optician would see.

Summary Questions

1 Copy and complete the sentences below.

When you look at an apple, light ________ off the apple into your eye. The light enters your eye through the ________. The ________ and the ________ focus the light onto the ________. The light forms a ________ image. A chemical reaction produces an ________ signal that is sent down your ________ ________ to your brain.

(9 marks)

2 Describe how the camera in your phone is different to a pinhole camera.

(2 marks)

3 Compare the eye and the pinhole camera.

(6 marks QWC)

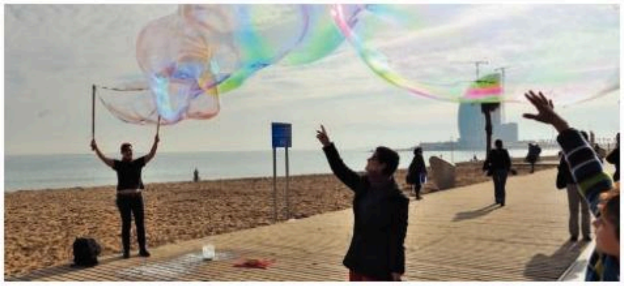
3.5 Colour

Learning objectives

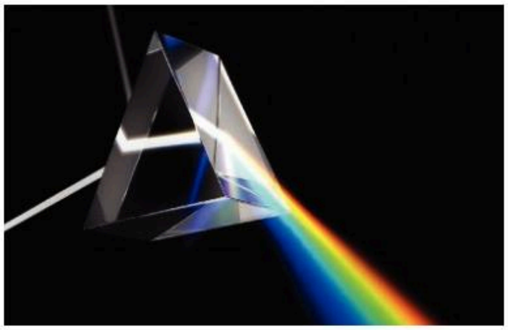
After this topic you will be able to:

- explain what happens when light passes through a prism
- describe how primary colours add to make secondary colours
- explain how filters and coloured materials subtract light.

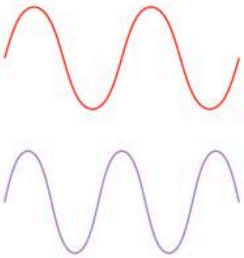
Have you ever seen really big bubbles? There are colours on the bubbles just like the colours in a rainbow or on a CD or DVD.



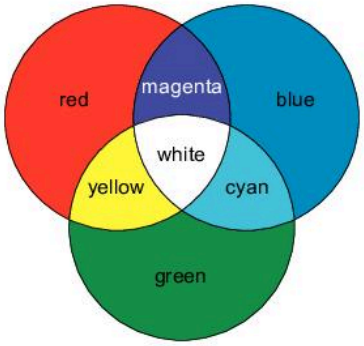
Where do the colours come from?



A prism splits white light into a spectrum.



Red light has a lower frequency than blue light.



This Venn diagram shows the primary and secondary colours of light.

Splitting white light

White light is made up of seven different colours of light. You can use a **prism** to split white light into a **spectrum**. This is called **dispersion**. The spectrum of white light is **continuous**. There are no gaps between the colours. Sir Isaac Newton first did this experiment in about 1666.

Dispersion happens because different colours of light are refracted by different amounts. Violet is refracted the most and red is refracted the least. Violet light has a higher **frequency** than red. Light with a higher frequency is refracted more than light with a lower frequency.

A State what a prism does to light.

Adding colours

You can make all the colours of light from just three colours: red, green, and blue. These are called the **primary colours** of light. Your eye detects these three colours. You can make any colour from different amounts of red, green, and blue. When you mix two primary colours you get **secondary colours** of light: cyan, yellow, and magenta. You get white light when you mix all three colours of light.

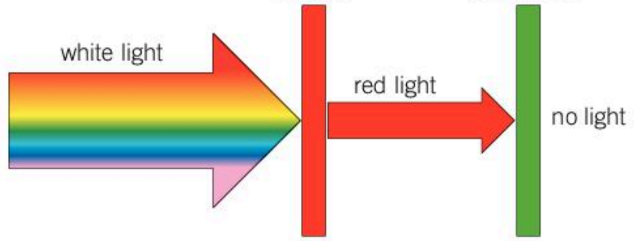
B Name the secondary colours of light.

Subtracting colours

Coloured lights on a stage can make a spectacular display. White light contains all the colours of light so if you want blue light you need to get rid of all the other colours.

What do filters do to light?

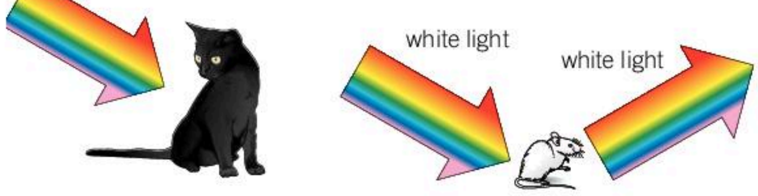
A red **filter** subtracts colours from white light. It transmits red light and absorbs the rest. It does not change the colour of light. If you put a red and a green filter together no light would get through them.



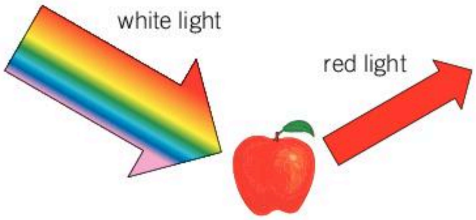
▲ Filters transmit the colours that they are and absorb the rest.

Why are objects different colours?

A red car reflects red light into your eyes. When the white light from the Sun hits the car, the paint absorbs all the other colours except red. Any coloured object reflects the colour that it is and absorbs the rest. Black objects absorb all the colours. White objects absorb no colours and reflect all the light.



▲ Black objects absorb all the colours of light and white objects reflect all the colours of light.



◀ An apple reflects red light and absorbs the other colours.

What table?

A student wants to record data in an experiment where she is shining all the primary and secondary colours of light onto pieces of coloured material. Draw a table to show how she could record her results.

C State what a black object does to white light.

Fantastic Fact!

You can never see a rainbow when the Sun is in front of you.

Key Words

prism, spectrum, dispersion, continuous, frequency, primary colour, secondary colour, filter

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

When white light goes through a prism, red light is **reflected/refracted** the **most/least** and violet light is refracted the **most/least**. This is called **dispersion/refraction**. A green filter **absorbs/transmits** green light and **absorbs/transmits** the rest. A cyan object **absorbs/reflects** red light, **absorbs/reflects** blue light, and **absorbs/reflects** green light. A magenta object would look black in **blue/green** light.

(10 marks)

2 Explain why a green shirt looks black in red light.

(2 marks)

3 Explain in detail why you cannot have a white filter or a black filter.

(6 marks QWC)

P1 Chapter 3 Summary

Key Points

- Light is emitted from luminous sources. It can be transmitted through, reflected, or absorbed by non-luminous objects.
- Objects are transparent, translucent, or opaque.
- Light travels through a vacuum at 300 000 km/s.
- A light-year is the distance light travels in one year. Light-years are used to measure very large distances.
- Your brain uses the fact that light travels in straight lines and you see a virtual image when you look in the mirror.
- The law of reflection says that the angle of incidence equals the angle of reflection.
- Images are formed when reflection is specular but not when there is diffuse scattering from a surface.
- When light slows down it is refracted towards the normal.
- A lens can focus light to a focal point.
- Light enters your eye through the pupil. The cornea and lens focus light to produce a real image on your retina. A chemical reaction in the photoreceptors in your eye produces an electrical signal. The signal travels down the optic nerve to your brain.
- Light forms an image in a camera in the same way. Digital cameras store images produced when light hits a charge-coupled device (CCD).
- Prisms disperse white light to produce a continuous spectrum. Primary colours of light add up to make secondary colours. All three colours add to make white light.
- Filters and coloured objects subtract colours from white light by transmitting or reflecting the colour that they are and absorbing the rest.

Key Words

source, emit, reflect, eye, absorb, luminous, non-luminous, transmit, transparent, translucent, opaque, umbra, penumbra, vacuum, wave, light-time, image, virtual, plane, incident ray, reflected ray, normal, angle of incidence, angle of reflection, law of reflection, specular reflection, diffuse scattering, refraction, medium, lens, convex, converging, focus, focal point, retina, iris, pupil, cornea, inverted, photoreceptor, optic nerve, brain, pinhole camera, real (image), pixel, charge-coupled device (CCD), prism, spectrum, dispersion, continuous, frequency, primary colour, secondary colour, filter

Big write

The big production

A theatre has asked you to come up with some ideas for a play about ghost hunters.

Task

Write a plan for your team to do some investigations to produce special effects. The effects could include reflection in mirrors and glass and different-coloured lights and materials.

Tips

- As well as what happens on the stage, you could design posters and programmes that look different in different-coloured lights.

End-of-chapter questions

1 Mirrors reflect light. State which capital letters of the alphabet would look the same if you saw them in a mirror.

(***1 mark***)

2 An actor is wearing a uniform that has a blue jacket and red trousers. Suggest and explain what the audience would see if he stood on stage in:

a white light *(2 marks)*
b green light *(2 marks)*

(***4 marks***)

3 A hunter is trying to spear a fish.

a Explain why he aims above where he sees the fish. *(2 marks)*
b Explain why diving birds dive straight down to catch fish. *(2 marks)*

(***4 marks***)

4 A student has collected data about different types of plastic block. He measured the mass and the angle of refraction of a ray of light going into the block. Each block is the same size.

Here are his results:

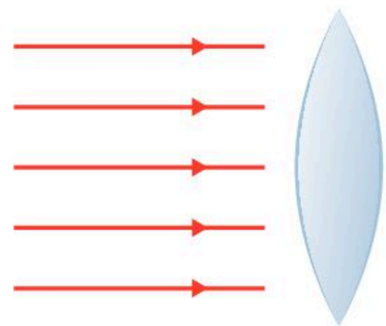
Mass of block (g)	Angle of refraction (°)
250	27
220	32
275	24
300	21

a State **one** variable that the student must keep the same during this investigation. *(1 mark)*
b State the name of the independent variable. *(1 mark)*
c State the name of the dependent variable. *(1 mark)*
d Describe the relationship between the mass and the angle of refraction. *(1 mark)*
e Describe **one** way that the student could improve the way that the results are presented in the table *(1 mark)*

(***5 marks***)

5 Copy and complete the diagram below to show what happens when light goes through a lens.

(***4 marks***)



6 Light slows down from 300 000 km/s to 200 000 km/s in glass and to 226 000 km/s in water. A ray of light enters each medium with an angle of incidence of 40°. State and explain whether the angle of refraction would be bigger or smaller in water than in glass.

(***2 marks***)

7 Here is some information about the speed of light in different materials. Describe and explain what you would see if you shone rays of light through a lens made of each material.

Material	Speed of light in the material (million km/s)
diamond	125
glass	200
plastic	187

(***6 marks QWC***)

4.1 The night sky

Learning objectives

After this topic you will be able to:

- describe the objects that you can see in the night sky
- describe the structure of the Universe.

▲ An astronaut on a spacewalk is building part of the ISS.

Foul Fact!

The odds of being killed by falling space debris are one in five billion.

Key Words

artificial satellite, orbit, Earth, Moon, natural satellite, planet, Sun, Solar System, comet, meteor, meteorite, star, galaxy, Milky Way, Universe, astronomer

When you look at the stars in the night sky you do not see them as they are today. The light from them has taken years to get here. You are looking back in time.

Satellites

The nearest objects that you can see without a telescope are **artificial satellites**. They **orbit** the **Earth**. You can see the International Space Station (ISS) with the naked eye (without using binoculars or a telescope). The light reflected from the ISS reaches us in a fraction of a second.

Light reflected from the **Moon** reaches us in just over a second. The Moon orbits the Earth. It is the Earth's only **natural satellite**.

A Name the natural satellite that orbits the Earth.

What is wandering across the sky?

There are five **planets** that most people can see with the naked eye: Mercury, Venus, Mars, Jupiter, and Saturn. Like the Earth they orbit the **Sun**. Venus gets closest to the Earth, about two light-minutes away. Light from Saturn takes about 1.5 hours. The planets form part of the **Solar System**.

B Name the planets that are visible to the naked eye.

Comets and meteors

A **comet** is one of the most spectacular sights in the night sky. They are huge snowballs that orbit the Sun.

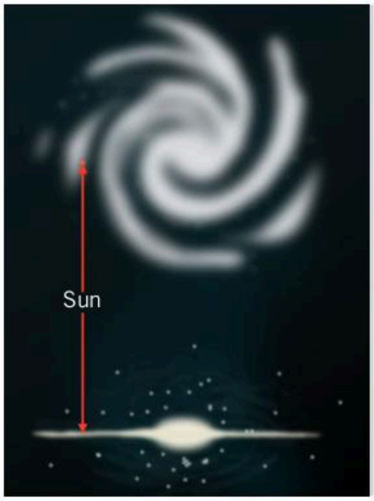
Meteors are bits of dust or rock that burn up as they move through the Earth's atmosphere and produce streaks of light. Any meteor that makes it to the ground is called a **meteorite**.

C Describe how the appearance of a comet is different to the appearance of a meteor.

Lights in the sky

Most of the dots of light that we see are **stars** in our **galaxy**, the **Milky Way**. A galaxy is a collection of stars and there are billions of stars in the Milky Way.

Light takes about eight minutes to get to us from the Sun, our nearest star. Our next nearest star is over four light-years away.



This shows our Sun in our galaxy, the Milky Way.

Some of the dots of light in the night sky are other galaxies. A galaxy contains billions of stars. The Milky Way is just one of billions of galaxies that make up the **Universe**. Our nearest large galaxy is Andromeda, which you can see with the naked eye. Light from Andromeda takes 2 million years to get to Earth.

The Andromeda galaxy is the nearest large galaxy to us.

D State what is meant by a 'galaxy'.

How do we know?

Astronomers have learned about the objects that we see in the night sky from the observations they have made. You cannot do experiments in astronomy. Astronomers use models to work out what makes up the Solar System, the Milky Way, and the Universe.

Comet Hale–Bopp was visible in the night sky in 1997.

Fantastic Fact!

All the elements that you are made of were made in the centre of stars in galaxies.

Summary Questions

1. Copy the sentences below, choosing the correct bold words.

   There are thousands of satellites in orbit around the **Sun/Earth**. The Moon is a natural satellite of the **Sun/Earth**. Comets are huge snowballs that orbit the **Sun/Earth**. Planets orbit the **Sun/Earth**.

   (4 marks)

2. Describe the difference between a meteor and a meteorite.

   (2 marks)

3. When you look up at the night sky you see dots of light that don't appear to move. List what the dots of light could be.

   (2 marks)

4. Compare the time it takes light to reach us from the different objects that you can see in the night sky.

   (6 marks QWC)

4.2 The Solar System

Learning objectives

After this topic you will be able to:

- name the objects in the Solar System
- describe some similarities and differences between the planets of the Solar System.

No-one has ever seen all of the Solar System at once because it is too big. Scientists have used observations to build a model of the Solar System.

What's in our Solar System?

Starting from the Sun and moving outwards the Solar System contains four inner planets and four outer planets. All of the planets orbit the Sun. Each orbit is a slightly squashed circle called an **ellipse**. Between the orbits of Mars and Jupiter there is an **asteroid** belt.

▲ These are NASA images of the planets of the Solar System.

A State the number of planets in the Solar System.

The planets

The inner planets, **Mercury**, **Venus**, Earth, and **Mars**, are all **terrestrial** planets; they are made of rock. The conditions on the planets are very different. Mercury does not have an atmosphere. At night the temperature drops to –170 °C and during the day it can reach 430 °C. Venus has an atmosphere of carbon dioxide that traps energy from the Sun.

Remember that order!

Before Pluto was renamed a dwarf planet, people used to remember the order of the planets using this mnemonic:
My Very Easy Method Just Speeds Up Naming Planets. A mnemonic uses first letters to make up a sentence. Make up your own mnemonic for the planets as they are now: M, V, E, M, J, S, U, N.

◀ The Curiosity rover on Mars takes a picture of itself.

The outer planets are called **gas giants**; they are made mainly of gases such as hydrogen and helium. All of the gas giants are very cold and are much bigger than the inner planets.

Many of the planets have moons in orbit around them. Saturn has 60 moons but Earth has only one.

Key Words

ellipse, asteroid, Mercury, Venus, Mars, terrestrial, gas giant, dwarf planet, gravity

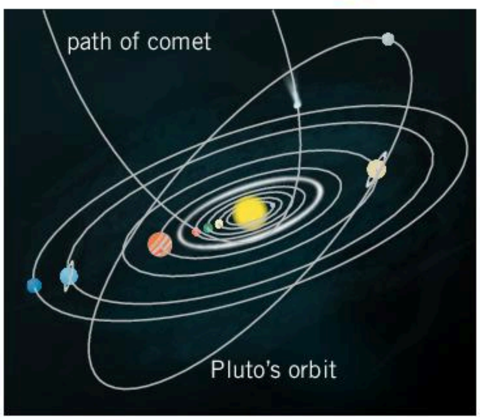
Planet	Diameter (km)	Distance from Sun (million km)	Distance from Sun	Temperature (°C)
Sun	1 391 000	–	–	–
Mercury	4879	58	3.2 light-minutes	–180 to 430
Venus	12 104	108	6.0 light-minutes	465
Earth	12 756	150	8.3 light-minutes	–89 to 58
Mars	6787	228	12.7 light-minutes	–82 to 0
Jupiter	142 800	778	43.3 light-minutes	–150
Saturn	120 660	1427	1 light-hour 19 light-minutes	–170
Uranus	51 118	2871	2 light-hours 39 light-minutes	–200
Neptune	49 528	4498	4 light-hours 10 light-minutes	–210

B List the planets in size order, starting with the smallest.

The asteroid belt

There are thousands of pieces of rock in the asteroid belt. Some are tiny specs of dust but one is large enough to be called a **dwarf planet**. Ceres is the only dwarf planet inside the orbit of Neptune.

Outside the Solar System



This diagram shows how the orbits of Pluto and a comet are different to the orbits of the planets.

Pluto used to be called a planet but in 2006 it was renamed a dwarf planet. Beyond Pluto's orbit is a region called the Kuiper Belt. Astronomers think that most comets come from outside our Solar System in a region called the Oort Cloud, beyond the Kuiper Belt.

How did our Solar System form?

Scientists think that **gravity** pulled the gas and dust together to form our Sun about 5 billion years ago. They think planets formed from a disc of gas and dust surrounding the Sun. Astronomers are looking for evidence from observations of other clouds of gas and dust to see if they can detect planets forming.

Fantastic Fact!

Venus spins in the opposite direction to all the other planets in the Solar System.

Summary Questions

1 Copy and complete the sentences below.

There are ______ inner and ______ outer planets in the Solar System. The band of dust and rocks between Jupiter and Mars is called the ______ ______. Pluto is a ______ planet. Scientists think that most comets come from a region outside the Solar System called the ______ ______.

(5 marks)

2 State one similarity and one difference between the inner and outer planets.

(2 marks)

3 Compare planets and asteroids.

(2 marks)

4 Describe and explain the link between distance from the Sun and temperature of the planets. Explain why Venus is the odd planet out.

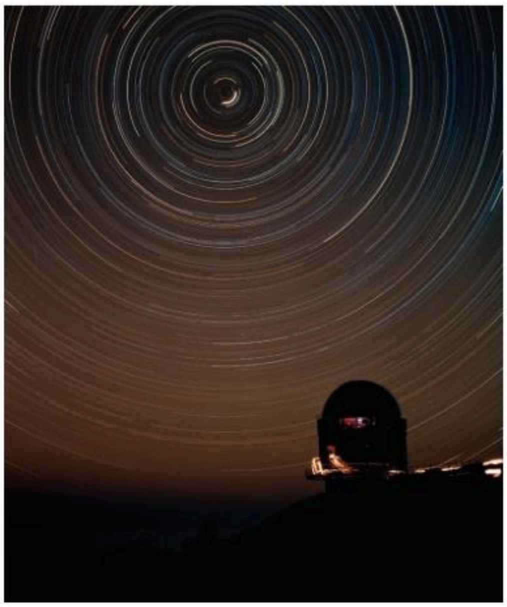
(6 marks QWC)

4.3 The Earth

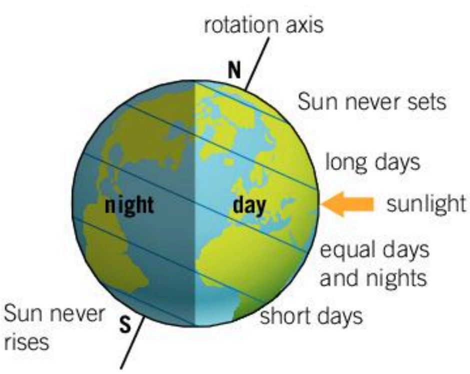
Learning objectives

After this topic you will be able to:

- explain the motion of the Sun, stars, and Moon across the sky
- explain why seasonal changes happen



▲ This photograph of the night sky was taken over 10.5 hours.



▲ When the Earth spins, half the Earth is in the light and half is in the dark.

Is the Earth special? Astronomers have discovered hundreds of planets orbiting other stars. They call these exoplanets. So far Earth is the only planet known to contain life.

The spinning Earth

The Earth spins on its **axis**. If you take a photograph over a long time the stars appear to move in circles. This shows that the Earth is spinning.

A Describe how you can demonstrate that the Earth is spinning.

There is **day** and **night** on Earth because Earth spins on its axis. It takes 24 hours to complete one full spin.

The Sun rises in the east each morning, reaches its highest point at noon, and then sets in the west in the evening. The Sun isn't moving. You are.

B State the direction in which the Sun rises.

The orbiting Earth

The Earth moves around the Sun once each **year**. The Earth takes 365.2422 days to orbit the Sun. There is an extra day in a leap year every four years.

Spin and orbit

Write the shortest sentence that you can to explain day length and year length using these words:

spin, day, night, orbit, year

Over the year the height of the Sun at noon, average daily temperature, and stars that you see at night all change during the different **seasons**.

The Earth's axis is tilted by 23.4°.

It is hotter in the summer than the winter because the tilt of the Earth's axis means that the Sun's rays spread over a smaller area and the days are longer.

In the summer in the North Pole the tilt of the axis means that the Sun doesn't set. This is called the 'Land of the Midnight Sun'. In the winter the Sun does not rise, giving a 'polar night'. This also happens at the South Pole.

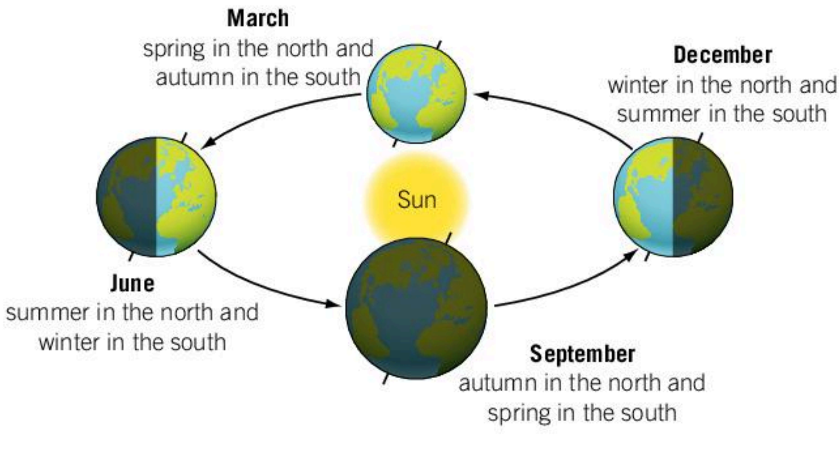
Key Words

exoplanet, axis, day, night, year, season, constellation

▲ The Sun never sets – this shows the Sun in the Arctic over a 24-hour period in the summer.

February 29th?
It takes 21 600 seconds longer to orbit the Sun than just the 365 days you use for one year. Show that in 4 years these extra seconds add up to one whole day.

The groups of stars, or **constellations**, that we see in the summer at night are different to the stars that we see in the winter. This is because the Earth is moving around the Sun. The side of the Earth that has night is facing different stars at different times of the year.



▲ The Sun's light is spread out over a bigger area in the winter.

Summary Questions

1 Copy the sentences below, choosing the correct bold word.

You see the Sun rise in the **east/west** and set in the **east/west** because the Earth **spins/orbits**. A **month/year** lasts approximately 365 days. This is the time that it takes the Earth to **orbit the Sun/spin once**. The days are **longer/shorter** in the summer and the Sun is **higher/lower** in the sky at noon.

(7 marks)

2

a Explain why it is hotter in the summer than it is in the winter. *(2 marks)*

b Explain why the shadow of a fence post is longer in the winter than in the summer. *(1 mark)*

3 Explain in detail what you would experience throughout the year if the axis of the Earth was not tilted.

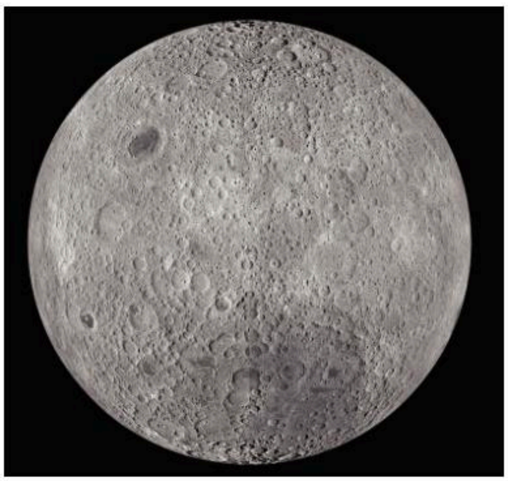
(6 marks QWC)

4.4 The Moon

Learning objectives

After this topic you will be able to:

- describe the phases of the Moon
- explain why you see phases of the Moon
- explain why eclipses happen.

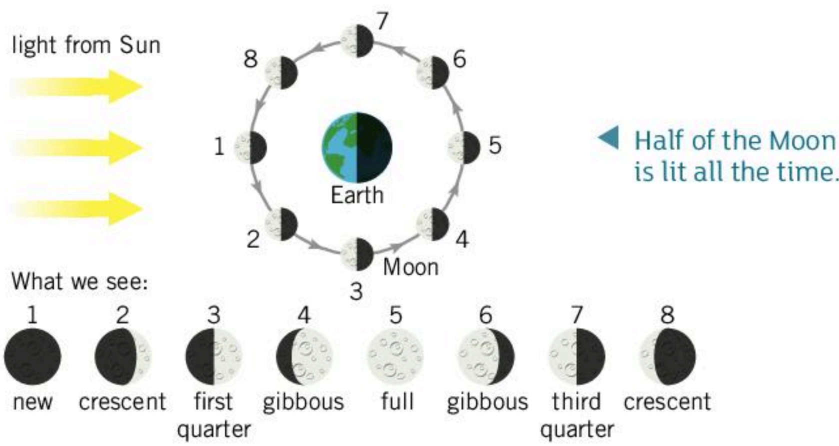


▲ There is a side of the Moon that you never see from Earth.

Many years ago, people used to have different ideas about space. The Ancient Chinese thought a solar eclipse was a demon eating the Sun. In other civilisations, people linked the changing appearance of the Moon with strange changes in behaviour.

Why does the Moon look different?

The Moon takes 27 days and 7 hours to orbit the Earth once.



◀ Half of the Moon is lit all the time.

A List the phases of the Moon, starting with a full moon.

Half the Moon is lit up by the Sun all the time. As the Moon moves around the Earth it looks different from the Earth. The changing shapes are called **phases of the Moon**. When the Moon is in position 1 you see a 'new' moon. You see the side of the Moon that is in shadow. The Moon moves around the Earth to position 2 and you see a crescent moon. In position 5, the Sun lights up the whole of the side that you can see from the Earth and you see a full moon.

A lunar month is the period of time from one new moon to the next new moon.

B State how much of the Moon's surface is lit up by the Sun during a new moon.

Farewell, Moon

The Moon is 38 000 000 000 cm away and is moving away from the Earth at a rate of about 3.8 cm per year. Work out how much closer to the Earth it was when you were born.

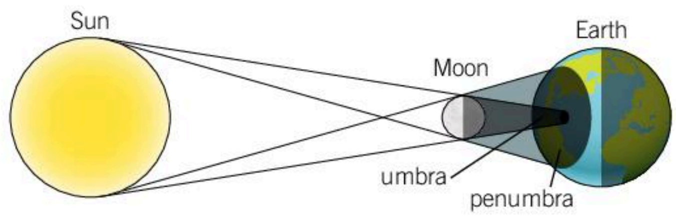
Fantastic Fact!

A 'blue' moon happens when there are two full moons in one calendar month. It happens quite often, about once every three years.

Why do we see eclipses?

Solar eclipses

When the Moon comes between the Sun and the Earth it makes a shadow on the Earth's surface. If you are standing in the **umbra**, the Moon completely blocks the light from the Sun and you see a **total solar eclipse**. If you are standing where only part of the Sun's light is blocked (the **penumbra**) you will see a **partial solar eclipse**.

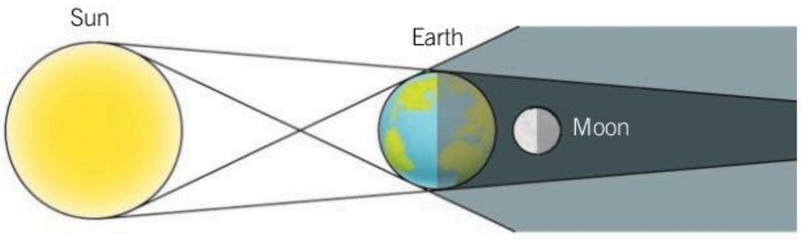


▲ A solar eclipse happens when the Moon blocks the light from the Sun.

C State the name of the deep shadow that produces a total solar eclipse.

Lunar eclipses

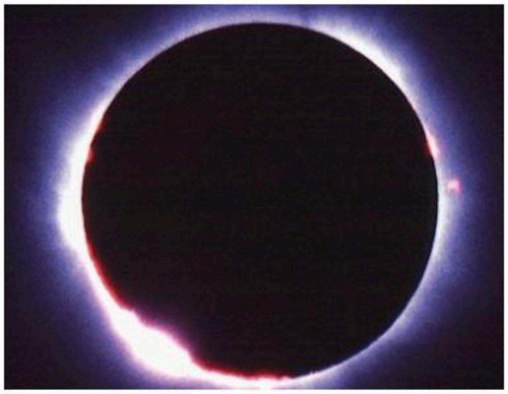
A **lunar eclipse** happens when the Earth comes between the Sun and the Moon.



Far side of the Moon

The Moon spins on its axis but the time it takes to spin all the way around is the same time that it takes to orbit the Earth. This means that the same side of the Moon always faces the Earth. There is a side that you never see.

This doesn't mean there is a side of the Moon that is always in the dark. When you are looking at a new moon the Sun is lighting up the side of the Moon that you can't see.



▲ You can see a total eclipse of the Sun.

Key Words

phases of the Moon, umbra, total solar eclipse, penumbra, partial solar eclipse, lunar eclipse

Summary Questions

1 Copy and complete the sentences below.

You see a ______ moon when the Sun lights up the whole of the side that you can see. When the side of the Moon that you can see is in shadow you see a ______ moon. A solar eclipse happens when the ______ comes between the Sun and the ______. A lunar eclipse happens when the ______ comes between the Sun and the ______.

(6 marks)

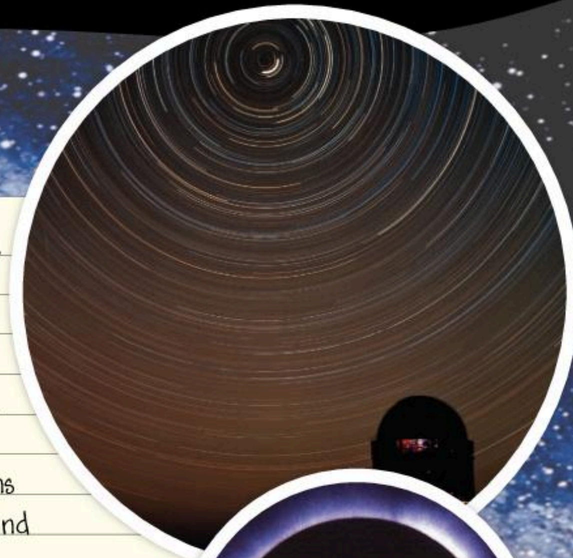
2 Explain why you would see an eclipse on some of the planets in the Solar System but not others.

(1 mark)

3 Describe how you could use a torch, a beach ball, and a tennis ball to demonstrate the difference between a solar eclipse and a lunar eclipse.

(6 marks QWC)

P1 Chapter 4 Summary



Key Points

- You can see satellites, the International Space Station, the Moon, comets, meteors, planets, stars, and galaxies in the night sky.
- The distances to objects in the night sky can be measured in light-time (light-seconds, light-minutes, light-hours, and light-years).
- The natural objects that you see are made of mixtures of gas, dust, rock, and ice.
- The Universe consists of millions of galaxies. Each galaxy contains billions of stars. Each star may have planets, asteroids, and comets in orbit around them. Each planet may have moons in orbit around them.
- There are four rocky inner planets (Mercury, Venus, Earth, and Mars), an asteroid belt, and four outer planets (Jupiter, Saturn, Uranus, and Neptune), made of gas.
- Planets further from the Sun are colder. Venus is hotter than Mercury, even though it is further from the Sun. This is because Mercury does not have an atmosphere to trap energy.
- The Earth spins on its axis once a day. This is why we have day and night, and why the Sun and stars appear to move across the sky.
- The Earth orbits the Sun in one year. The axis of the Earth is tilted and this explains the height of the Sun at noon, day length, temperature, and constellations that you see change during the year.
- You see phases of the Moon because the Moon is orbiting the Earth. Half of the Moon is always lit by the Sun.
- A solar eclipse happens when the Moon is between the Sun and the Earth. A lunar eclipse happens when the Earth is between the Sun and the Moon.

Key Words

star, artificial satellite, orbit, Earth, Moon, natural satellite, planet, Sun, Solar System, comet, meteor, meteorite, star, galaxy, Milky Way, Universe, astronomer, ellipse, asteroid, Mercury, Venus, Mars, terrestrial, gas giant, dwarf planet, gravity, exoplanet, axis, day, night, year, season, constellation, phases of the Moon, umbra, total solar eclipse, penumbra, partial solar eclipse, lunar eclipse

BIG Write

A new Earth...?

The table shows some information about the planet Pegasi b and Earth.

	51 Pegasi b	Earth
Distance from the star (million km)	7.7	150
Time to orbit the Sun (days)	4	365
Time to spin once on its axis (days)	4	1
Tilt of the axis (degrees)	79	23.5

Task

Write a guide to the new planet, comparing it to Earth and other planets in the Solar System.

Tips

- Could there be life on Pegasi b?

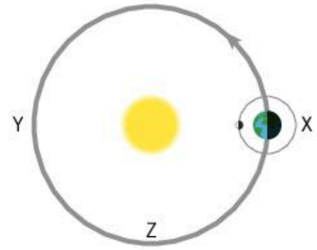
End-of-chapter questions

1 Here is a list of objects that you can see in the night sky. Sort the objects into those that are in orbit around the Sun and those that are in orbit around the Earth.

comet planet Moon satellite asteroid International Space Station

(*2 marks*)

2 The diagram shows the Earth in orbit around the Sun:



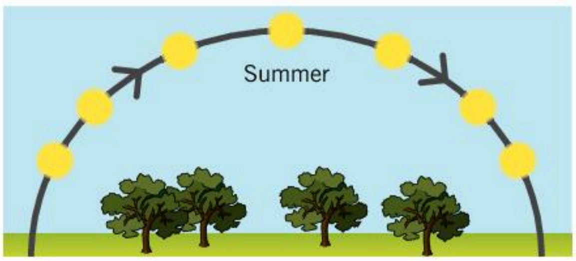
a Copy the diagram and label the Sun, the Earth, and the Moon. *(3 marks)*

b It is summer in the southern hemisphere when the Earth is at position X. State which season it would be when the Earth is at position Y. *(1 mark)*

c State how many months it would take the Earth to move between X and Z. *(1 mark)*

(*5 marks*)

3 This diagram shows how the Sun moves across the sky during the day in summer:



a Copy the diagram and add these labels: east, west, sunrise, sunset, noon

(2 marks)

b On the diagram sketch the path of the Sun in winter. *(2 marks)*

c Explain why the path of the Sun in the sky is different in autumn and in winter.

(2 marks)

(*6 marks*)

4 Here are some objects in the Universe:

Sun inner planet outer planet galaxy our nearest star Moon

a State which object or objects are a distance of light-seconds away and which are light-years away. *(2 marks)*

b Describe a problem with communicating with people on a spacecraft travelling through the Solar System. *(2 marks)*

(*4 marks*)

5 The table below shows the angle of tilt of the axes of all the planets in the Solar System.

Use the information in the table and your scientific knowledge to describe the seasonal changes on each of the planets and compare them to conditions on Earth.

(*6 marks QWC*)

Planet	Angle of tilt (°)	Planet	Angle of tilt (°)
Mercury	0	Jupiter	3
Venus	177	Saturn	27
Earth	23.5	Uranus	98
Mars	25	Neptune	30

Physics 2

It's hard to imagine a world without electricity. In this unit you will discover how circuits work and how the electricity in your house is generated. You will learn why it is important to insulate a house and what you pay for when you pay your electricity bill. You will also find out how to use graphs to tell a story, and how forces explain gas and air pressure.

You already know

- Lots of appliances run on electricity.
- You need a complete loop for an electric circuit to work.
- Some materials, like metals, are good conductors of electricity.
- You can change the volume of a buzzer or the brightness of a lamp by changing the number of cells.
- Switches can control lamps and buzzers.
- Forces can be transferred using gears, pulleys, levers, and springs.
- Light travels as a wave and can be reflected, refracted, or absorbed.
- Unbalanced forces can change the speed of an object.
- Magnets have two poles and attract or repel, depending which poles are facing each other.
- Some metals are magnetic. The Earth is a giant magnet.

Q

What happens to the brightness of a lamp if you use more cells?

BIG Questions

- What happens in an electric circuit?
- What happens in a power station?
- Why are aircraft cabins pressurised?

Picture Puzzler
Key Words

Can you solve this Picture Puzzler?

The first letter of each of these images spells out a science word that you will come across in this unit.

Picture Puzzler
Close Up

Can you tell what this zoomed-in picture is?

***Clue**: You will need one to make an electromagnet.*

Making connections

In **P1** you learnt about waves.

In **P2** you will learn how waves transfer energy.

In **P3** you will learn about the application of waves in communication, medicine, and detection techniques.

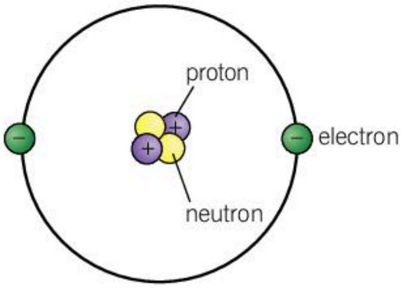
1.1 Charging up

Learning objectives

After this topic you will be able to:

- explain how objects can become charged
- describe how charged objects interact
- describe what is meant by an electric field.

▲ You can bend a stream of water with static electricity.



▲ An atom contains three types of particle.

Link

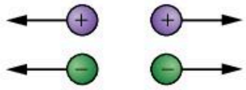
You can learn more about atoms in C1 2.2 Atoms

Because of static electricity you can stick a balloon to a wall or bend a stream of water. Static electricity produces lightning. What is static electricity, and where does it come from?

Attracting and repelling

There are two types of **electric charge**: **positive** charge (+) and **negative** charge (–). Charges **attract** or **repel** each other, like magnets do.

- **Positive** charges *repel* **positive** charges.
- **Negative** charges *repel* **negative** charges.
- **Positive** charges *attract* **negative** charges.



▲ Repelling.

▲ Attracting.

Memory jogger

Remember it like this: 'Like charges repel, unlike charges attract.'

A State the two types of electric charge.

Where does the charge come from?

Everything is made of particles called **atoms**.

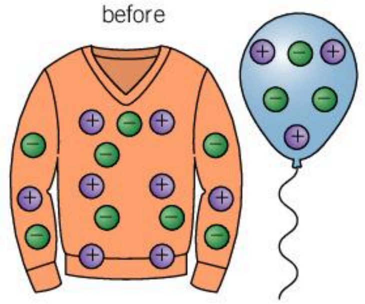
Atoms in turn are made of three types of smaller particle:

- **protons**, which have a positive charge
- **electrons**, which have a negative charge
- **neutrons**, which have no charge.

Charge is a property of a particle or object, just like mass.

Atoms contain equal numbers of protons and electrons. Overall an atom has no charge: it is **neutral**.

When you rub a balloon on your jumper some electrons are transferred from the jumper to the balloon. The balloon now has an overall negative charge. Your jumper has an overall positive charge. They will attract.



▲ Rubbing a balloon transfers electrons from your jumper to the balloon.

The balloon is made of rubber. The electrons stay on the balloon.

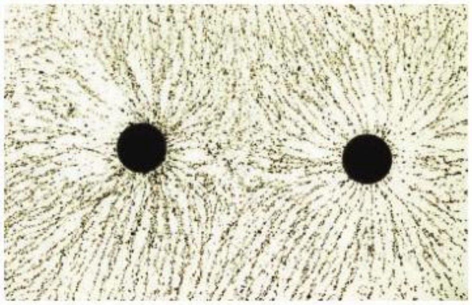
B State the charge on an electron, a proton, and a neutron.

Lightning

In a thundercloud air moves around, producing regions that have a positive or a negative charge. Electrons jump from one charged area to another and this produces a big **current**, which quickly heats the air. You see **lightning** and hear thunder.

What is an electric field?

There is an **electric field** around a charge, just as there is a gravitational field around a mass. If you put a charged object in an electric field, a force will act on it.



◀ Pepper grains line up in an electric field. This shows the electric field between two charges that are repelling.

Atomic puzzle

Unscramble the words below and pair them up. Explain why you have chosen to pair them that way.

notpro oneturn iviespot gianteve laterun centrelo

Key Words

electric charge, positive, negative, attract, repel, atom, proton, electron, neutron, neutral, current, lightning, electric field

▲ Lightning can strike a plane.

Fantastic Fact

Since you took your last breath lightning has struck the Earth 100 times. On average, airliners will get struck by lightning once a year.

Summary Questions

1 Copy and complete the sentences below.

There are two types of electric charge: ______ charge and ______ charge. When you rub a polythene rod with a cloth you transfer ______ from the cloth to the rod. Two polythene rods would ______ if you brought them close together. A polythene rod would ______ a rod that had a positive charge.

(5 marks)

2 A student rubs a balloon on his jumper and sticks it to the wall. Explain in terms of electrons why the balloon sticks to the wall.

(3 marks)

3 Compare a gravitational field and an electric field.

(6 marks QWC)

1.2 Circuits and current

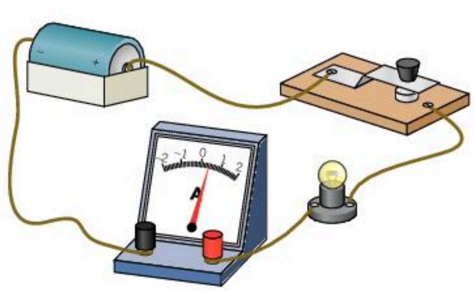
Learning objectives

After this topic you will be able to:

- describe what is meant by current
- describe how to measure current.

▲ A baby is kept warm using electric circuits.

▲ Divers need a torch to explore underwater caves.



▲ You connect an ammeter in a circuit to measure current.

Doctors use an incubator to help keep a premature baby alive. An electric current flows through a heater that keeps the baby warm.

What is current?

- When you complete a circuit, charged particles or charges move in the metal wires.
- The **current** is the amount of charge flowing per second.

When you press the **switch** on a torch the light comes on. The switch opens and closes a gap in the circuit. You need to close the gap and make a complete circuit for a current to flow.

When people talk about 'electricity' they usually mean 'electric current'.

A Describe what a current is.

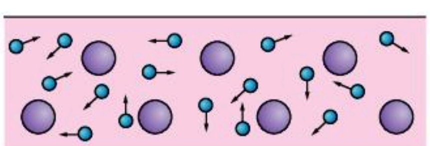
You can measure the current with an **ammeter**.

- Current is measured in amperes or **amps**.
- The symbol for amps is A. For example, the current in the circuit opposite is 0.4 A.

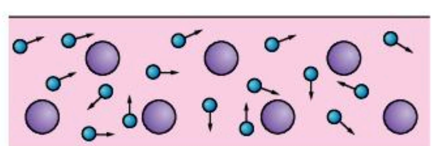
B Name the meter that you use to measure current.

Where do the charges come from?

The **cell** or **battery** pushes charges around the circuit. The battery does not produce the charges that move. They were already there in the wires. In a metal the charged particles that move are electrons.



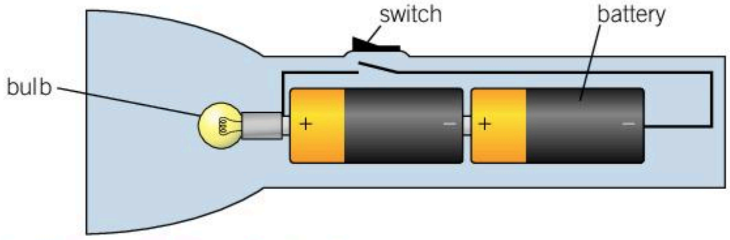
▲ The electrons are already in the wire.



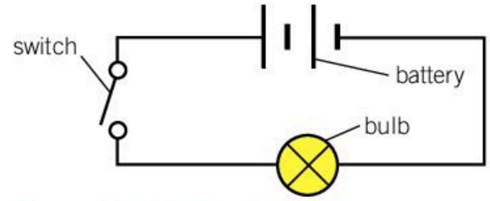
▲ The electrons move when you connect the battery.

Using circuit symbols

You can build circuits using components such as batteries, bulbs, and **motors**. It would take a long time to draw a picture of each circuit so you can use circuit symbols instead.



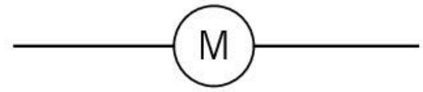
▲ This is a picture of a torch...



▲ ...and this is the circuit diagram.

In the torch diagram there are two cells. Cells used together like this are called a battery. People often use the word 'battery' for a single cell, but in physics we call it a cell.

You must make sure that you connect cells the right way round or they will not work.

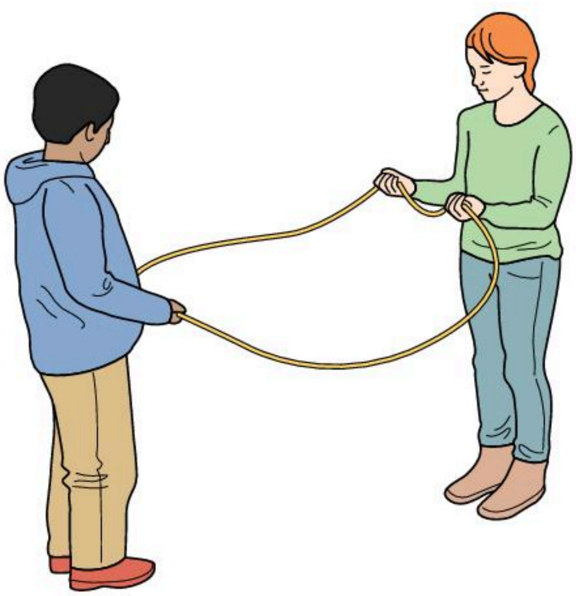


▲ Circuit symbols make it simpler to draw circuits.

Modelling electric circuits – part 1

You cannot see what happens in the wires when a current flows. Scientists use models such as the rope model to show what is happening. One person pulls the rope, and another person grips the rope lightly. The rope moves around. In this model:

- The rope represents the charges in the circuit.
- The amount of rope moving past a point per second is the current.



◀ A rope model can help you to understand circuits.

Confusing words?

For each of these words write one sentence using the word with its correct scientific meaning. Write a second sentence where it has a different, everyday meaning.

- charge
- current
- cell

Key Words

current, switch, ammeter, amps, cell, battery, motor

Summary Questions

1 Copy and complete the sentences below.

Current is the amount of ______ flowing per ______. In a metal wire charged particles called ______ move when you connect a battery. You can use a meter called an ______ to measure current. Current is measured in ______, which has the symbol ______.

(6 marks)

2

a Draw a circuit diagram to show how you could use a switch to turn a battery-powered motor on and off. *(2 marks)*

b Describe what happens in the wires when you close the switch. *(1 mark)*

3 Explain how you would use equipment and models to teach a primary-school student that the charges do not originate in the battery.

(6 marks QWC)

1.3 Potential difference

Learning objectives

After this topic you will be able to:

- describe what is meant by potential difference
- describe how to measure potential difference
- describe what is meant by the rating of a battery or bulb.

A doctor can use a defibrillator to start someone's heart if it stops. Defibrillators produce a large potential difference (sometimes called a voltage), much bigger than a battery can produce.

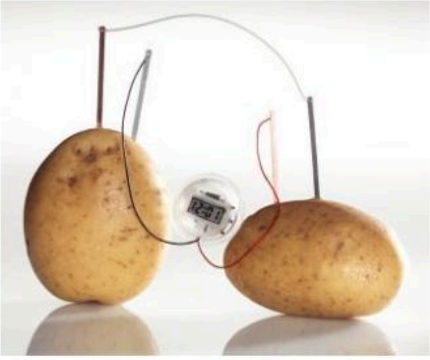
▲ You can save someone's life with a big potential difference.

What is potential difference?

The cell or battery provides the push to make charges move. The push is called a **potential difference**, or p.d. for short.

- The potential difference across a cell tells you about the size of the force on the charges.
- The potential difference also tells you how much energy can be transferred to the components in the circuit by the charges.

▲ Batteries come in different shapes and sizes.



▲ In a potato cell a chemical reaction between the metals and the potato produces a potential difference.

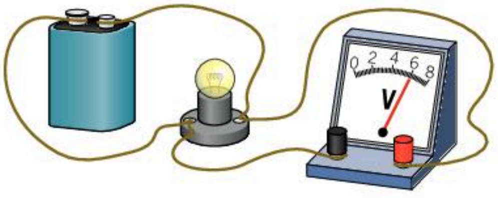
Measuring potential difference

You measure potential difference using a **voltmeter**.

- Potential difference is measured in **volts**.
- The symbol for volts is V. For example, the potential difference across the cell opposite is 6 V.

You can measure the potential difference of a cell by connecting a voltmeter across it. This is also called the **rating**.

A Name the meter that you use to measure potential difference.



▲ You connect a voltmeter either side of the component.

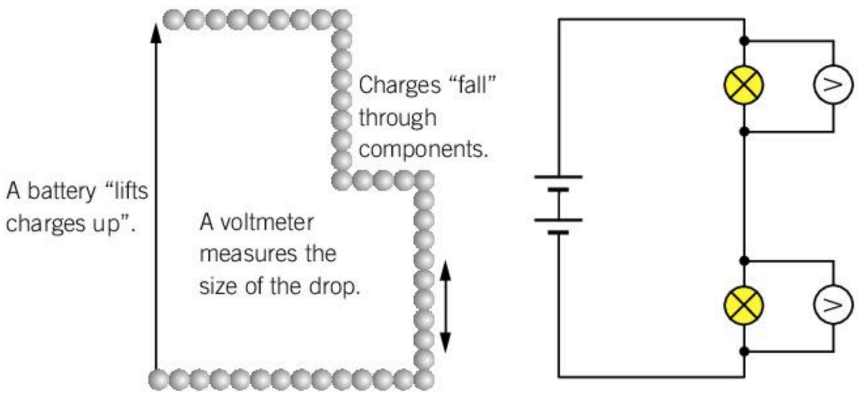
You can measure the potential difference across a component in a circuit using a voltmeter.

B State the unit of potential difference.

Circuit components such as bulbs also have a rating. The bulb in the circuit on the opposite page has a rating of 6 V. It is designed to work at a potential difference of 6 V, and no higher.

'Potential difference' or 'voltage'?

Sometimes people talk about the '**voltage**' of a cell or battery. It is better to talk about potential difference. You can think of a circuit as being a bit like this:



▲ You can think of the battery 'lifting' up the charges. In the circuit above the voltmeters would read the same.

Modelling electric circuits – part 2

You can use the rope model when you are thinking about potential difference. In the rope model:

- The person pulling the rope is like the battery.
- A bigger potential difference across the cell would come from the 'battery' person pulling harder.

Are bigger batteries better?

A student wants to collect some data about the size of batteries and the potential difference across each one. Write a plan that they could use to collect the data.

Key Words

potential difference, voltmeter, volts, rating, voltage

Foul Fact

Mary Shelley wrote *Frankenstein* after finding out that Louis Galvani made dead frogs' legs move using a battery in 1818.

Summary Questions

1 Copy and complete the sentences below.

The potential difference of a cell or battery tells you the size of the ______, and how much ______ can be transferred by the charges. You measure potential difference or p.d. with a ______. The ______ of a battery tells you the p.d across it, and the ______ on a bulb tells you the p.d. at which it is designed to work.

(5 marks)

2 A student connects a circuit with a cell, an ammeter, and a buzzer and listens to the buzzer. She adds another cell.

a Describe and explain what happens to the current. *(2 marks)*

b Describe and explain what happens if she turns one of the cells around. *(2 marks)*

3 A lot of people get current and potential difference (or voltage) mixed up. Use a model to explain the difference in detail.

(6 marks QWC)

1.4 Series and parallel

Learning objectives

After this topic you will be able to:

- describe the difference between series and parallel circuits
- describe how current and potential difference vary in series and parallel circuits.

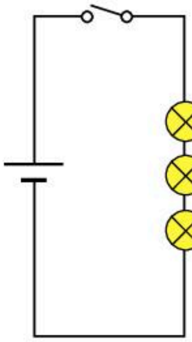
▲ Modern Christmas lights stay on if one bulb blows.

Christmas lights make a great display. In old sets of lights, if one of the bulbs broke they would all go out.

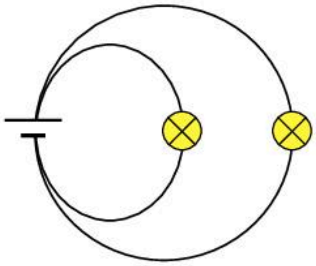
Two types of circuit

The old type of Christmas lights were connected in **series**. All the bulbs formed one loop, including the battery and the switch.

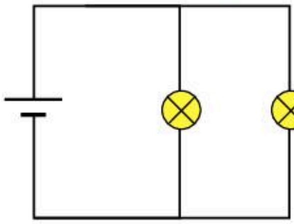
There is another type of circuit called a **parallel** circuit. In a parallel circuit there is more than one loop or branch. Parallel circuits are sometimes called 'branching circuits'.



▲ In a series circuit there is only one loop.



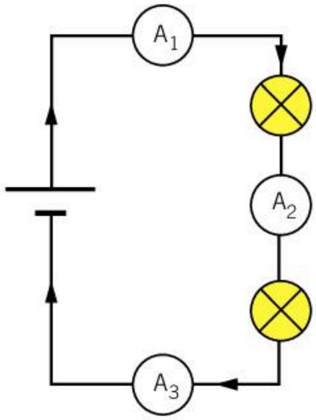
▲ This is a parallel circuit because there is more than one loop...



▲ ...which you can also draw like this.

Parallel circuits are very useful because if one bulb breaks, the other lights stay on. You can control each lamp separately in a parallel circuit by adding a switch to each branch. Each bulb is independent of the others.

A State two differences between series and parallel circuits.



▲ In a series circuit, the reading on all the ammeters is the same.

What happens to the current?

Series circuits

In the circuit opposite, the ammeters A_1, A_2, and A_3 all show the same reading. In a series circuit the current is the same everywhere.

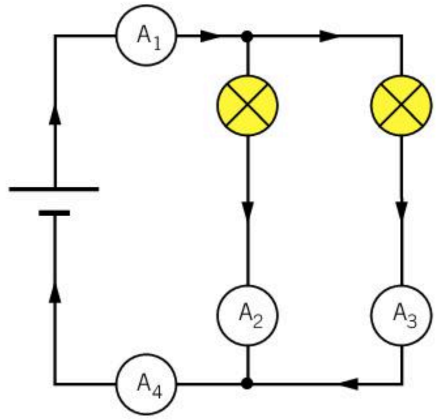
If you add components to a series circuit the current will get smaller.

Parallel circuits

A parallel circuit has more than one loop. In the circuit at the top of the next page, the current in each branch is the same. The ammeters A_2 and A_3 show the same reading.

The ammeters A_1 and A_4 measure the total current. The currents in all the branches of a parallel circuit add together to make the total current. Here the total current is double the current in each branch.

If you add another branch to a parallel circuit the current in the other branches stays the same but the total current increases.



▲ In a parallel circuit, the current in all the branches adds to the total current.

B State what happens to the total current as you add more branches in a parallel circuit.

Modelling circuits – part 3

You can use the rope model when you are thinking about different types of circuit. In the rope model:

Series circuits

- The rope moves at the same speed everywhere.
- As more people hold the rope, the rope moves more slowly.

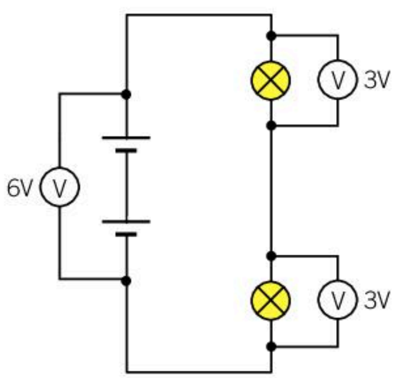
Parallel circuits

- There are more loops of rope.
- All the loops are driven by the same 'battery' person.

What happens to the potential difference?

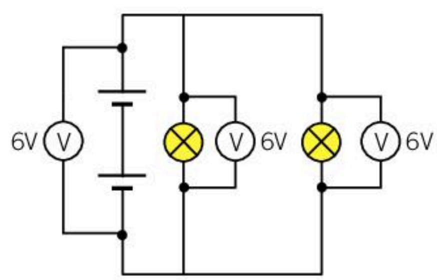
Series circuits

The potential difference across each component *adds up to* the potential difference across the battery.



Parallel circuits

The potential difference across each component *is the same as* the potential difference across the battery.



Current issues

In a circuit with a single cell and a single bulb, the current is 0.2 A. Calculate the current if you add another bulb in series with the first bulb. Explain your answer.

Key Words

series, parallel

Fantastic Fact

A family in Australia holds the world record for Christmas tree lights. Their display contained over 330 000 separate lights.

Summary Questions

1 Copy the sentences below, choosing the correct **bold** words.

A series circuit has **more than one**/**one** loop. A parallel circuit has **more than one**/**one** loop. If a bulb in a **parallel**/**series** circuit breaks the rest of the bulbs stay on. If a bulb in a **parallel**/**series** circuit breaks the rest of the bulbs go out.

(4 marks)

2 State what happens to the total current as you add more bulbs in a parallel circuit.

(1 mark)

3 Compare the readings on ammeters and voltmeters when you connect them in series and parallel circuits.

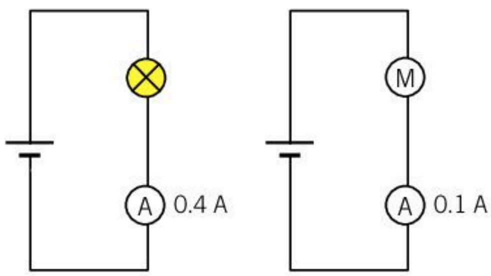
(6 marks QWC)

1.5 Resistance

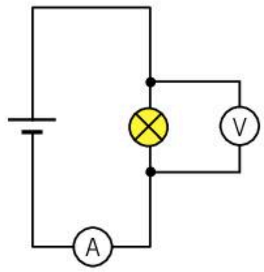
Learning objectives

After this topic you will be able to:

- describe what is meant by resistance
- calculate the resistance of a component and of a circuit
- describe the difference between conductors and insulators in terms of resistance.



▲ The currents in these circuits are different, even though the cells are the same.



▲ You can use an ammeter and a voltmeter to find the resistance of a lamp.

What's the resistance?

A bulb in a circuit has a current of 0.6 A through it and a potential difference of 12 V across it. Calculate the resistance of the bulb.

The current in the wires connected to a television is much smaller than the current in the wires to a microwave. The reason for this is to do with resistance.

◀ Electrical devices have different currents through them.

Different components, different current

Components do different jobs in an electric circuit.

Each circuit component has a different **resistance**. This tells you how easy or difficult it is for the charges to pass through the component. Resistance is measured in **ohms**, which has the symbol **Ω**. **Ω** is a letter from the Greek alphabet.

The current depends on the push of the battery and also the resistance of the component. You can calculate the current using this equation:

$$\text{current (A)} = \frac{\text{potential difference (V)}}{\text{resistance } (\Omega)}$$

You can use the idea of resistance to explain why the current decreases as you add more bulbs in a series circuit. Adding more bulbs increases the resistance, so the current is less.

A State what is meant by resistance.

Measuring resistance

You can use an equation to calculate the resistance of a component.

Here is the equation to calculate resistance:

$$\text{resistance } (\Omega) = \frac{\text{potential difference (V)}}{\text{current (A)}}$$

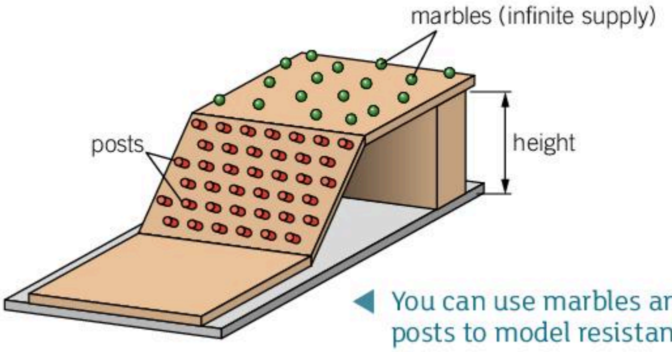
B State the unit of resistance.

For example, if you found that the current through a bulb was 0.2 A when the voltage across it was 6 V, you could work out the resistance:

$$\text{resistance} = \frac{\text{potential difference}}{\text{current}} = \frac{6\ \text{V}}{0.2\ \text{A}} = 30\ \Omega$$

What happens inside a wire?

You can use a model with marbles to show what happens inside a wire when a current flows. The charges that move in a wire are electrons.



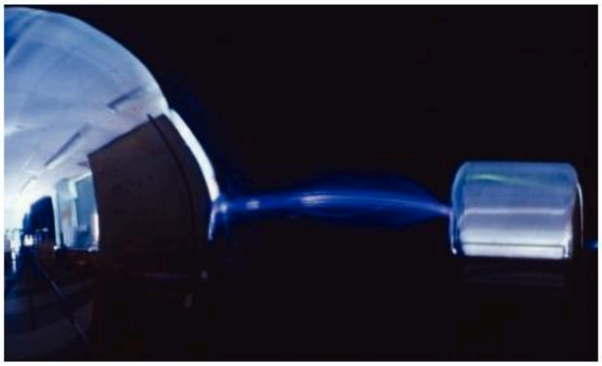
You can use marbles and posts to model resistance.

The marbles behave like electrons. As they fall down the slope they collide with the posts. Inside a wire the moving electrons collide with the atoms of the wire. They transfer energy, and the wire gets hot.

Conductors and insulators

Metals are good **conductors.** They have a very low resistance because they contain lots of electrons that can move. The resistance of a 10-m piece of copper wire is about 0.2 Ω.

Other materials such as plastics do not have many electrons that are free to move. The resistance of plastic objects is very high, over a thousand million million ohms. The air is usually an **insulator** but it can conduct if the potential difference is big enough. Insulators have a high resistance.



A spark happens when the air conducts electricity.

Fantastic Fact

Many people think that Thomas Edison invented the lightbulb. What he invented was the first lightbulb with a filament that didn't burn out when a current flowed in it.

Key Words

resistance, ohms, conductor, insulator

Summary Questions

1. Copy and complete the sentences below.

   The current in a circuit depends on the _______ and the _______. The current will be bigger if the _______ is smaller. Inside a metal wire _______ collide with atoms and transfer _______ to them. _______ are materials that contain lots of charges that are free to move. _______ contain fewer charges that can move.

   (7 marks)

2. In the circuit diagrams on the opposite page the cell has a potential difference of 3 V. Calculate the resistance of the motor and the lamp.

   (4 marks)

3. Compare the resistance of conductors and insulators.

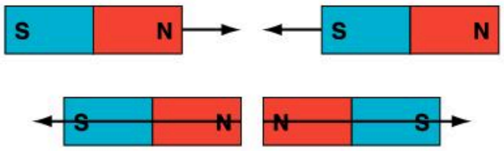
   (6 marks QWC)

1.6 Magnets and magnetic fields

Learning objectives

After this topic you will be able to:

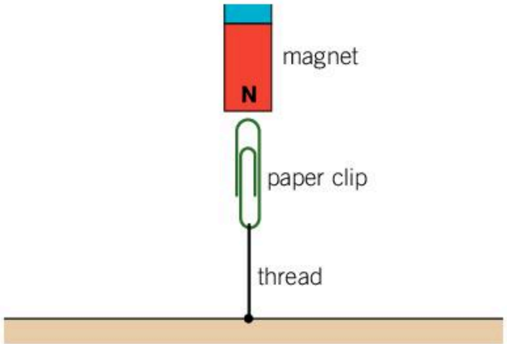
- describe how magnets interact
- describe how to represent magnetic fields
- describe the Earth's magnetic field.



▲ Magnets can attract or repel other magnets.

Memory jogger

Remember it like this: 'Like poles repel, unlike poles attract.'



▲ There is a force on a steel paper clip in a magnetic field.

Fantastic Fact

The Earth's magnetic field keeps flipping. About 500 000 years ago the magnetic north pole was actually the south pole.

With a magnet you can make something move without even touching it.

◀ Ferrofluid is a special liquid that is magnetic.

Attracting and repelling

A **magnet** has a **north pole** and a **south pole**.

- **North poles** *repel* **north poles**.
- **South poles** *repel* **south poles**.
- **North poles** *attract* **south poles**.

A Name the two poles of a magnet.

Only certain materials are attracted to a magnet. They are called **magnetic materials**. Iron is a magnetic material, and so is steel because steel contains iron. Cobalt and nickel are also magnetic.

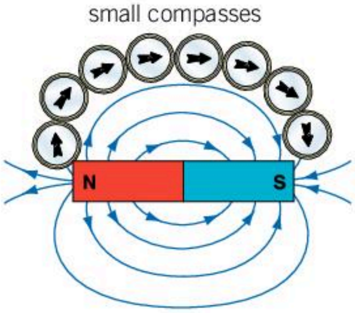
◀ Information on a credit card is stored in a magnetic strip.

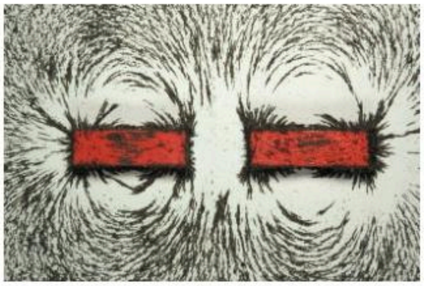
What is a magnetic field?

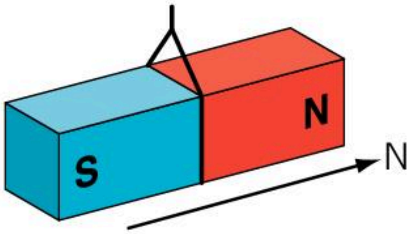
In an electric field there is a force on a charge. In a **magnetic field** there is a force on a magnet or a magnetic material.

You can find out the shape of a magnetic field in two ways:

- using plotting compasses
- using iron filings







▲ A magnet lines up with the Earth's magnetic field.

The needle of a compass lines up with the magnetic field. So do the iron filings. You can draw lines called **magnetic field lines** to represent the field. The lines go from the north pole to the south pole of the magnet, with arrows pointing from the north to the south pole.

- If the magnetic field lines are closer together this shows that the magnetic field is stronger.
- A permanent magnet is a magnet that has its own magnetic field.

How strong?

A student wants to measure the strength of different types of magnet by holding up a paperclip as shown in the diagram on the opposite page. Draw a table for their results.

B State two ways that you can find out the shape of a magnetic field.

The Earth's magnetic field

If you hang a magnet up it will line up in a direction pointing north to south. This is because it is in the magnetic field of the Earth.

The Earth behaves as if there is a huge bar magnet inside it. There is not really a bar magnet, and physicists are not sure what produces the Earth's magnetic field.

◀ The Earth's magnetic field is the same as that of a big bar magnet with the south pole at the top of the planet.

Key Words

magnet, north pole, south pole, magnetic material, magnetic field, magnetic field line

Summary Questions

1 Copy and complete the sentences below.

Magnets have a ______ pole and a ______ pole. Two poles that are the same will ______ and two poles that are different will ______. The needle of a ______ lines up in the ______ ______ of a magnet.

(6 marks)

2 Explain why the needle of a compass always points in the same direction wherever you point it in a room.

(2 marks)

3 Design a game of skill that uses magnets. Write a list of instructions for how to play the game using the key words on this page, and describe the scoring system.

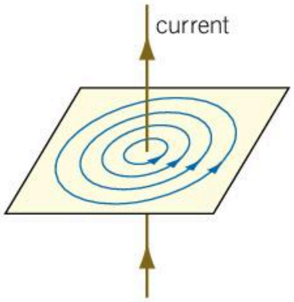
(6 marks)

1.7 Electromagnets

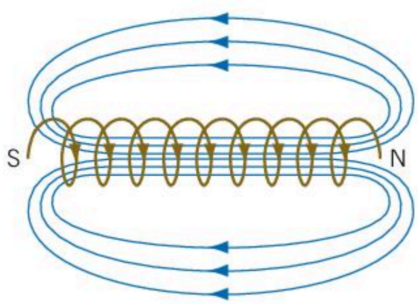
Learning objectives

After this topic you will be able to:

- describe how to make an electromagnet
- describe how to change the strength of an electromagnet.



▲ The magnetic field around a wire.



▲ The magnetic field around a coil of wire.

Foul Fact

Doctors in hospitals have used electromagnets to remove steel splinters from a patient's eye.

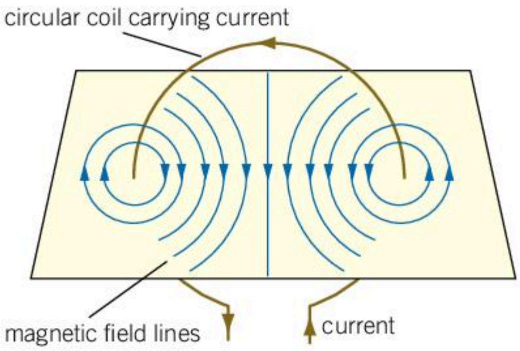
Permanent magnets are fun, but you can't turn them off.

The magnetic field around a wire

A wire with an electric current flowing through it has a magnetic field around it. You can investigate the field with a plotting compass. The field lines are circles.

Making an electromagnet

You can make a circular loop of wire and pass a current through it. The magnetic field lines at the centre of the loop are straight.



◀ The magnetic field around a loop of wire.

The magnetic field around a single loop isn't very strong. If you put lots of loops together to make a coil the field is much stronger. This is an **electromagnet**. The shape of the magnetic field is just like the shape of the magnetic field around a bar magnet.

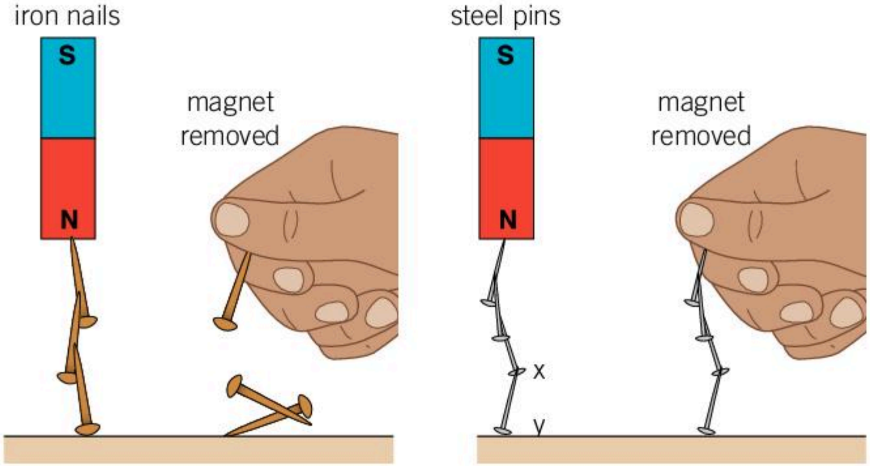
You can turn an electromagnet on and off by turning the current on and off. The magnetic field is only produced when the current is flowing in the wire.

Using a core

Electromagnets usually have a magnetic material in the centre of the coil, called a **core.** This makes the electromagnet much stronger. Most cores are made of iron. Iron is easy to **magnetise** but loses its magnetism easily.

Steel is hard to magnetise but keeps its magnetism. If you had a steel core in an electromagnet you could not turn the electromagnet off, because the steel would still be magnetic.

A State the type of material you can use for the core of an electromagnet.



▲ Steel stays magnetic when you remove the magnet.

How do I make an electromagnet stronger?

The strength of an electromagnet depends on:

- the number of turns, or loops, on the coil. More turns of wire will make a stronger electromagnet.
- the current flowing in the wire. More current flowing in the wire will make a stronger electromagnet.
- the type of core. Using a magnetic material in the core will make a stronger electromagnet.

B State three things that affect the strength of an electromagnet.

Permanent magnet or electromagnet?

Permanent magnets and electromagnets both have their uses. There are two main differences between permanent magnets and electromagnets.

- You can turn an electromagnet on and off.
- You can make electromagnets that are much stronger than permanent magnets.

Fantastic Fact

The strongest magnet is an electromagnet that produces a magnetic field 10 million times stronger than the Earth's magnetic field.

Key Words

electromagnet, core, magnetise

▲ The strength of an electromagnet depends on the number of turns on the coil, the current, and the core.

Summary Questions

1 Copy and complete the sentences below.

When a ______ flows in a wire it produces a ______ ______ around it. You can make an electromagnet using a ______ of wire with a ______ flowing in it. The shape of the ______ ______ around an electromagnet is the same as that around a bar magnet.

(5 marks)

2 Describe how to use a nail, a piece of wire, crocodile clips, leads, and a battery to make an electromagnet.

(2 marks)

3 Use the ideas on these pages to explain in detail why the number of coils, the current, and the type of core affect the strength of an electromagnet.

(6 marks QWC)

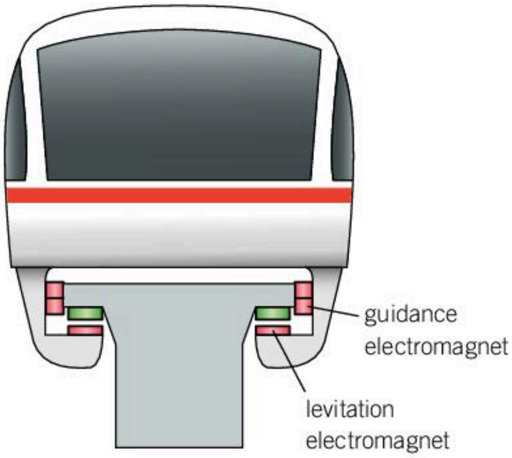
1.8 Using electromagnets

Learning objectives

After this topic you will be able to:

- describe some uses of electromagnets
- describe how a simple motor works.

▲ You can travel at over 200 mph on a maglev train.



▲ Electromagnets lift a maglev train and push it forward.

Have you ever travelled on a high-speed train? Trains that use electromagnets can go faster than a Formula 1 car. They don't have an engine. How do they work?

Lifting off

You have learned that magnets can repel each other. Engineers use this fact to build trains that use magnetic levitation. This means the train is lifted up using magnets.

Very powerful electromagnets on the track repel magnets on the train. There is no friction between the train and the track. This means the train can travel much faster than normal trains.

That's not all. The train is pushed forward by other electromagnets called guidance electromagnets. It does not need an engine.

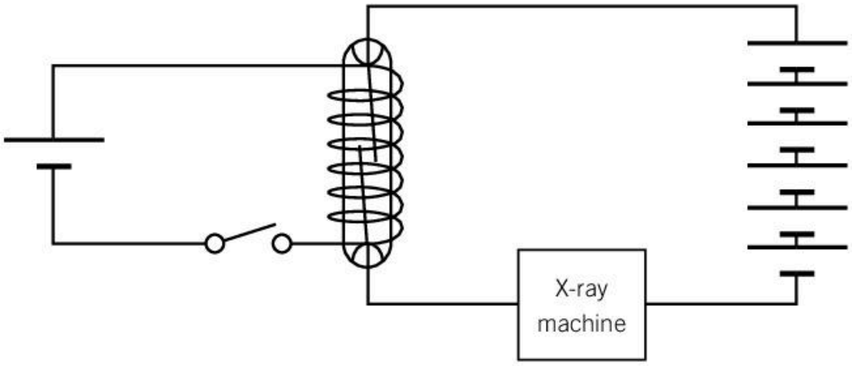
A State the type of magnet used to levitate a train.

Switching on

An X-ray machine can be very dangerous. It uses a very high potential difference. The radiographer using the machine uses a **relay** to turn the machine on, instead of a normal on/off switch.

What is a relay?

A relay uses a small current in one circuit to operate a switch in another circuit. When the switch is closed the coil becomes an electromagnet. The two pieces of iron inside are magnetised. They attract each other and turn on the X-ray machine.



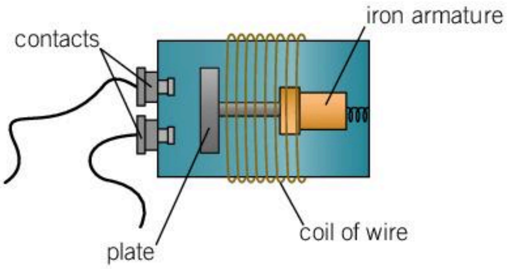
▲ A small current can turn on a much bigger current in a separate circuit.

Key Words

relay, motor

How do you start a car?

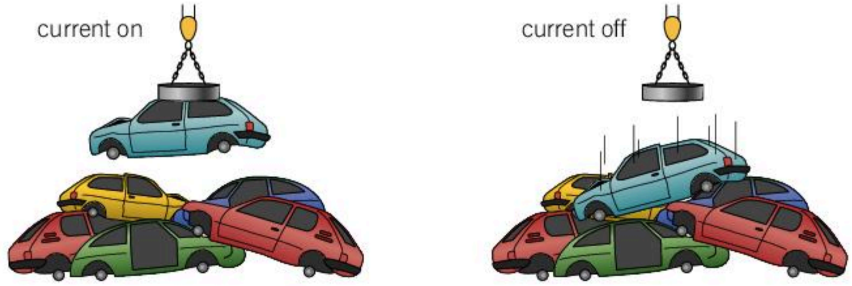
A car battery produces a large current that can be very dangerous. The driver switches on the circuit in the battery to start the car. They can do this safely using an electromagnet switch.



▲ A starter motor uses an electromagnetic switch.

How do you lift a car?

You can use an electromagnet to move large pieces of iron or steel in a factory, or to move cars in a scrap yard.



▲ Electromagnets can lift cars.

How do you sort metal?

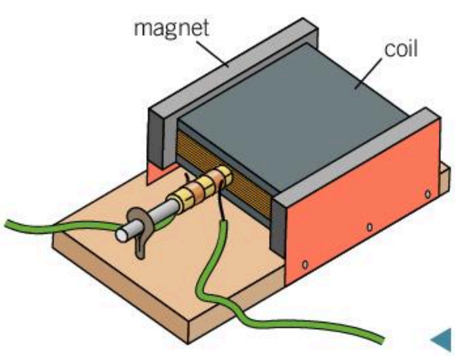
You can use an electromagnet to sort out scrap metal. Iron and steel will be attracted to the electromagnet. Other metals, such as aluminium, will not.

B, State one use of an electromagnet in a scrap yard.

Moving and spinning

The turntable in a microwave needs to turn so that your food cooks evenly. The **motor** that makes it move is just one of many motors in your home. You can make a simple motor using two magnets and a coil of wire.

When you connect the coil to a battery a current flows in the coil. The coil becomes an electromagnet. The forces between the coil and the permanent magnet make the coil spin.



◀ A simple motor.

Fantastic Fact

There are more than 50 electric motors in the average family home.

Recycle those cans!

Write a letter to the manager of your school's kitchen explaining how they could use electromagnets to sort the soft drinks cans for recycling.

Summary Questions

1 Copy and complete the sentences below.

Electromagnets can be used to levitate ______ and push them forward. A ______ acts like a switch to turn on circuits that can be dangerous. When a ______ flows in a coil of wire between two magnets then the coil ______. This is how an electric ______ works.

(5 marks)

2 State the parts of an electric motor and how a motor works.

(4 marks)

3 Design a system that uses electromagnets to hold open fire doors. The fire doors should close automatically when the fire alarm button is pressed. Explain in detail how your system works.

(6 marks QWC)

P2 Chapter 1 Summary

Key Points

- Objects can be charged positively or negatively by transferring electrons.
- Like charges repel and unlike charges attract.
- An electric field is a region where there is a force on charged particles or materials.
- Electric current is the amount of charge flowing per second. You measure current in amps (A) using an ammeter.
- The potential difference of a cell tells you the size of the push on the charges and how much energy can be transferred by them.
- You measure potential difference in volts (V) using a voltmeter. The rating of a cell or battery tells you the potential difference at which it operates.
- Series circuits contain only one loop, and the current is the same everywhere. Parallel circuits have branches and the currents in all the branches add up to make the total current.
- A component with a high resistance has a small current through it. Resistance is measured in ohms (Ω). You calculate the resistance using the potential difference across a component and the current through it. Insulators have a very high resistance and conductors have a very low resistance.
- Magnets have a north pole and a south pole. Like poles repel and unlike poles attract.
- Magnetic materials feel a force in the region around a magnet called a magnetic field. Magnetic field lines show the pattern of the magnetic field.
- A current flowing in a coil of wire wrapped around a magnetic material is an electromagnet. It behaves like a bar magnet but you can turn it on and off.
- Electromagnets are used in maglev trains, hospitals, and cars.

Key Words

electric charge, positive, negative, attract, repel, atom, proton, electron, neutron, neutral, current, lightning, electric field, switch, ammeter, amps, cell, battery, motor, potential difference, voltmeter, volts, rating, voltage, series, parallel, resistance, ohms, conductor, insulator, magnet, north pole, south pole, magnetic material, magnetic field, magnetic field lines, electromagnet, core, magnetise, relay, motor

Maths challenge

Mixed-up electromagnets

A student investigated the strength of electromagnets by seeing how many paperclips they will pick up. Here is his results table:

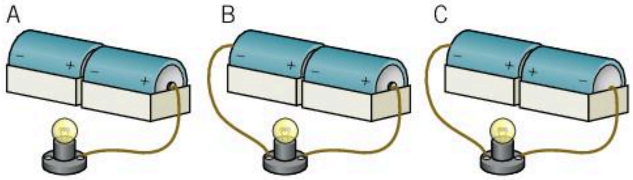
Number of coils	Potential difference	Type of core	Type of wire	Number of paperclips
10	1.5 V	iron	copper	4
10	3.0 V	iron	copper	8
10	4.5 V	iron	copper	12
10	6.0 V	iron	copper	16
40	3.0 V	iron	copper	20
30	3.0 V	iron	copper	16
20	3.0 V	iron	copper	12
10	3.0 V	steel	copper	10
10	3.0 V	aluminium	copper	0

Use the data to:

- make separate tables for each of the variables that he changed
- plot an appropriate graph for each variable.

End-of-chapter questions

1 Look at circuits A, B, and C.



a State the letter of the circuit or circuits in which the bulb is lit. *(1 mark)*

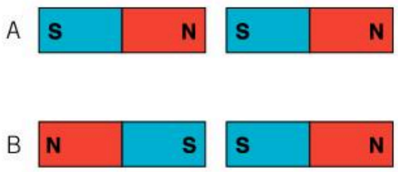
b Describe what you could do to make the bulb light in the other circuit or circuits. *(2 marks)*

(3 marks)

2

a Draw a diagram to show the magnetic field around a bar magnet. *(2 marks)*

b Describe what would happen to the magnets in the diagrams A and B below. *(2 marks)*



c State one difference between a permanent magnet and an electromagnet. *(1 marks)*

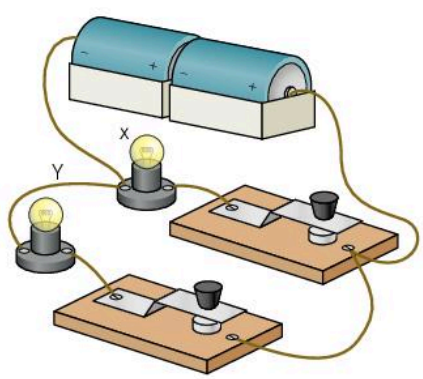
(5 marks)

3 Describe how a simple motor works.

(2 marks)

4

a Draw a circuit diagram for the circuit below. *(2 marks)*



b State whether this is a series or a parallel circuit. *(1 mark)*

c Copy and complete the table to show what would happen when you press the switches. *(3 marks)*

Switches closed	Bulbs lit
X	
Y	
X and Y	

d Describe how you could measure the current flowing in each bulb. *(2 marks)*

(8 marks)

5 A student connects one bulb, an ammeter, and a cell in series. He connects a voltmeter across the bulb.

a Draw a circuit diagram for this circuit. *(2 marks)*

The current through the bulb is 0.4 A. The potential difference across the bulb is 3 V.

b Explain what is meant by potential difference. *(1 mark)*

The bulb has a rating of 6 V.

c State what is meant by the rating of a lamp. *(1 mark)*

d Calculate the resistance of the lamp. *(2 marks)*

(6 marks)

6 The student adds another lamp in series to the circuit above.

a Describe and explain what happens to the reading on the ammeter. *(2 marks)*

b Describe and explain what happens to the reading on the voltmeter. *(2 marks)*

(4 marks)

7 A student rubs a rod with a cloth and uses the rod to pick up small pieces of paper. Explain in detail how this happens.

(6 marks QWC)

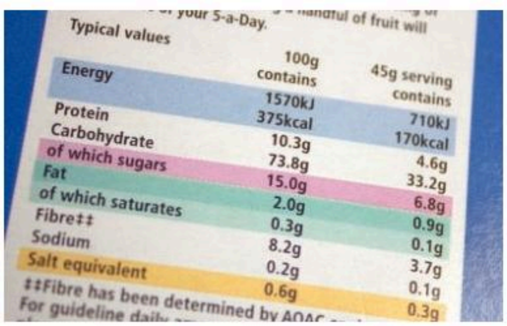
2.1 Food and fuels

Learning objectives

After this topic you will be able to:

- compare the energy values of foods and fuels
- compare the energy in foods and fuels with the energy needed for different activities.

▲ You need the energy stored in food.



▲ You can see the energy associated with food on the food label.

What did you have for breakfast? You need energy from food to do many things, including walking, breathing, and even reading this! Your brain needs energy to work.

How much energy?

Different foods are stores of different amounts of **energy**. Energy is measured in **joules** (J). One joule is a very small amount of energy, so we often use **kilojoules** (kJ). 1 kJ = 1000 J.

A State the unit of energy.

How much energy in food?

Food labels tell you how much energy is in the store associated with food.

The amount of energy stored in different foods varies greatly.

Food	Energy (kJ) per 100 g
apple	200
banana	340
peas	250
chips	1000
cooked beef	1000
chocolate	1500

When you choose which foods to eat you need to consider the nutritional value of the food as well as the energy that is in the store.

How much energy in fuels?

▲ The energy associated with this lump of coal is about 3000 kJ...

▲ ... which is the same amount as two bars of chocolate.

Coal and chocolate are both stores of energy. Oil, wood, and other fuels are stores too. You need oxygen to burn both food and fuels. People use the energy in fuels to heat their house or cook their food. Electrical appliances need an electric current to work. When you burn fuel in a power station it produces a current that makes your microwave or hair straighteners work.

Link

You can learn more about nutrition in B2 1.3 Unhealthy diet

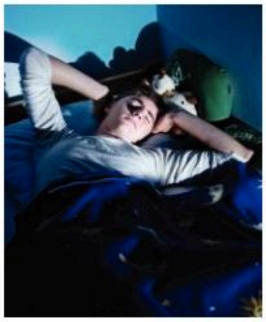
Key Words

energy, joule, kilojoule

B Name three fuels.

How much energy do you need each day?

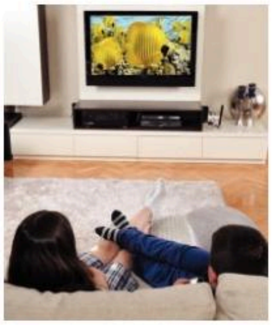
You need different amounts of energy depending on what you do each day.



▲ Sleeping: 300 kJ per hour.

▲ Working: 600 kJ per hour.

▲ Playing: 3600 kJ per hour.



▲ Relaxing: 360 kJ per hour.

There is an energy cost to everything that you do. You need energy to keep your body warm, to breathe, move, and talk. While you are growing you need energy for your bones, muscles, and brain to grow.

Activity	Energy (kJ) for each minute of activity
sitting	6
standing	7
washing, dressing	15
walking slowly	13
cycling	25
running	60
swimming	73

Sportsmen need a lot more energy than the average person. People who walk to the North or South Pole need even more energy because they need extra energy to keep warm.

Energy balance

An adult should just take in the energy they need for the activities that they do. If you take in more energy than you need your body stores it as fat to use in the future.

How far?

On average people can walk about 90 metres per minute, and run about 150 metres per minute.

Calculate how far you would need to run to burn off the energy in 50 g of chocolate.

Fantastic Fact

An adult man needs about 12 000 kJ per day. The same man walking to the North Pole would need about 27 000 kJ per day.

Summary Questions

1 Copy and complete the sentences below.

Energy is stored in ______ and ______. The amount of energy stored is measured in ______. When you are asleep your body needs energy for keeping warm and ______. Children need more energy than adults to grow bigger ______ and ______.

(6 marks)

2 Calculate the number of minutes you would need to cycle for to work off 200 g of chips.

(2 marks)

3 Use the information above to calculate the approximate energy cost of the activities that you do in one day. Compare the amount of fruit and vegetables with the amount of chips and chocolate that you would need to eat to give you this energy.

(6 marks)

2.2 Energy adds up

Learning objectives

After this topic you will be able to:

- describe energy before and after a change
- explain what brings about changes in energy.

◀ Energy is a bit like money.

▲ Camping gas is a chemical store.

Do you have some money in your pocket? If you know how much you left home with, and you didn't spend any on the way, then you know how much you have now.

Conservation of energy

Energy cannot just disappear, and you cannot end up with more than you had at the start. Energy cannot be created or destroyed, only transferred. This is the **law of conservation of energy**.

A State the law of conservation of energy.

Energy stores

There is energy associated with food and fuels (and oxygen). You can think of that energy as being in a **chemical store**. Energy is transferred from the store when you burn the fuel or respire. There are other types of **energy store**:

Energy to do with...	Type of store
food, fuels, batteries	chemical
hot objects	**thermal**
moving objects	**kinetic**
position in a gravitational field	**gravitational potential**
changing shape, stretching, or squashing	**elastic**

Before and after

A camping stove burns gas, which is a fuel.

	Before:	After:
What we have	unburnt fuel, more oxygen cold soup	less fuel, more carbon dioxide and water hot soup (and slightly hotter air)
Thinking about energy	more energy in the chemical store less energy in the thermal store	less energy in the chemical store more energy in the thermal store

If you could measure the energy in the chemical and thermal stores you would see that:

total energy before = total energy after

Fantastic Fact

If all the energy in the food that you eat was converted to energy in a thermal store you would glow like a light bulb.

Transferring energy

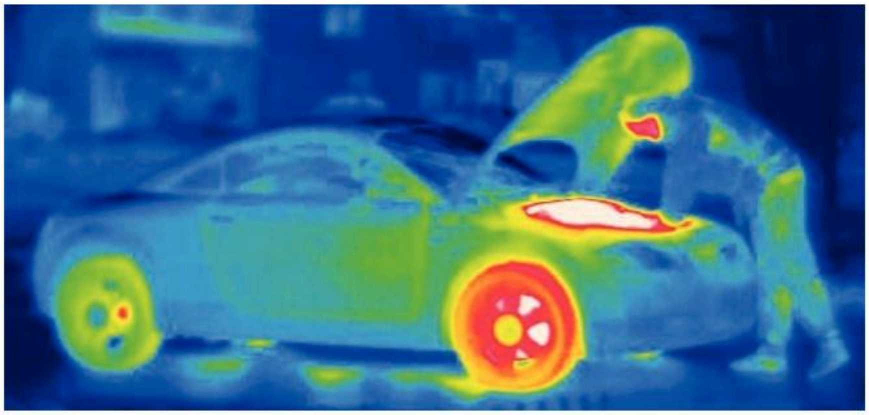
Electric current, light, and sound are ways of transferring energy between stores. After you use your phone, there is less energy in the chemical store and more energy in the thermal store of the surroundings.

B State three ways that energy is transferred between stores.

Wasting energy, saving energy

In a car you want the burning fuel to transfer energy to the store that you want (the kinetic store of the car), not to other stores that you don't want (such as a thermal store). You want the car to move, not heat up.

In many situations energy is transferred to the thermal store of the surroundings. Scientists say that the energy is **dissipated**.



▲ The energy in the thermal store is dissipated.

When we talk about 'saving energy', what we really mean is saving fuel. Energy is always conserved, but if we can transfer more of it to the useful store, we save fuel.

Why do things happen?

It is tempting to say that things happen *because* they have energy. Energy tells you what changes are possible, but it does not explain *why* things happen. Forces, not energy, explain why things move. For example, you can put fuel in a car but that does not make the car move. The force provided by the engine makes the car move.

Remember those stores!

Use the first letter of each of the stores in the table above to write a mnemonic to help you to remember them.

▲ The ski-lift increases the energy in the gravitational potential store.

Key Words

law of conservation of energy, chemical store, energy store, thermal, kinetic, gravitational potential, elastic, dissipated

Summary Questions

1 Copy and complete the sentences below, choosing the correct bold words.

The law of conservation of energy says that energy cannot be **created/dissipated** or **destroyed/transferred**. When you burn coal you transfer energy from a **chemical/thermal** store to a **chemical/thermal** store. You **can/cannot** explain why things happen using energy.

(5 marks)

2

a Describe where and how energy is stored in a torch. *(2 marks)*

b Explain what happens to the energy stored in the torch when it is switched on. *(2 marks)*

3 Use the ideas on these two pages to explain in detail what energy transfers happen when you cook sausages on a camp fire burning wood.

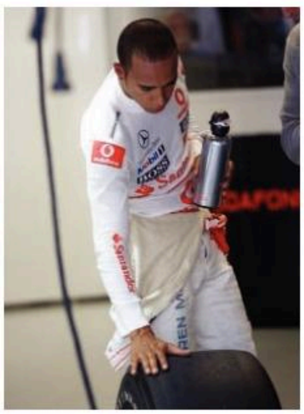
(6 marks QWC)

2.3 Energy and temperature

Learning objectives

After this topic you will be able to:

- state the difference between energy and temperature
- describe what happens when you heat up solids, liquids, and gases
- explain what is meant by equilibrium.



◀ Formula 1 teams heat up their tyres.

◀ Some thermometers use sensors to measure temperature.

▲ Sparks are hot, but they do not have much energy in the thermal store.

Hot tyres grip the road much better than cold tyres. Formula 1 drivers heat up their tyres.

What is temperature?

Something that is hotter than your skin will feel hot, and something that is colder than your skin will feel cold. You cannot measure **temperature** with your skin.

You use a **thermometer** to measure temperature. Some thermometers have a liquid inside a very thin glass tube that expands when it is heated. Other thermometers are digital.

We measure temperature in degrees Celsius (°C).

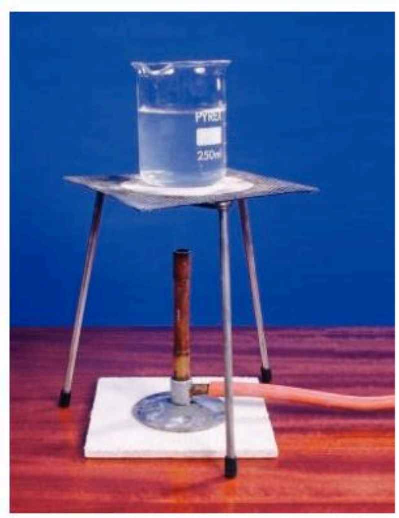
A State the unit of temperature and the unit of energy.

What's the difference?

There is a difference between energy and temperature. You can have a swimming pool and a beaker of water at exactly the same temperature.

Even though they are at the same temperature the swimming pool represents a much bigger thermal store of energy than the beaker of water.

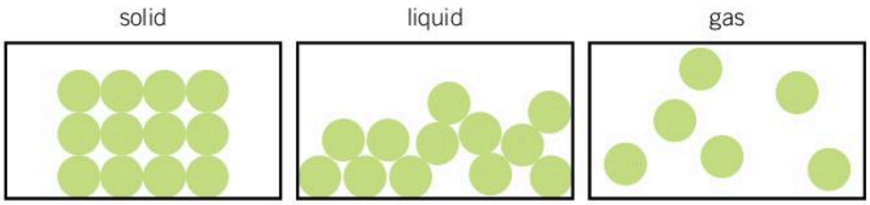
▲ There is a lot of energy in the thermal store of a heated swimming pool.



▲ There is less energy in the thermal store of a beaker of water at the same temperature than in the swimming pool's thermal store.

What happens when you heat things up?

Heating changes the movement of particles. If you heat a solid the particles vibrate more. If you heat a liquid or a gas the particles move faster and vibrate more.



▲ Particles in solids, liquids, and gases.

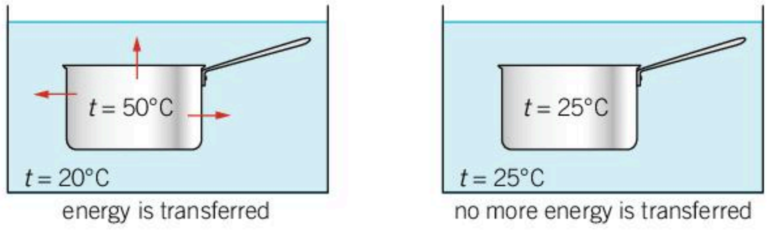
Individual particles in a solid, liquid, or gas get don't get hotter. They move or vibrate faster. The energy that you need to increase the temperature of a material depends on:

- the mass of material
- what the material is made of
- the temperature rise that you want.

B State what happens to the particles in a liquid when you heat it up.

Which way?

Hot objects cool down. Energy is never transferred from a cold object to a hot object, only from a hot object to a cooler object. The temperature difference is reduced and eventually both objects will end up at the same temperature. They will be in **equilibrium**. No more energy is transferred between their thermal stores.



C State what is meant by equilibrium.

Hot and cold

You might hear someone say "Shut the door, you'll let the cold in!"

Rewrite the statement so that it is scientifically correct and explain why it is now correct.

Link

You can learn more about particles in C1 1.1 The particle model

Key Words

temperature, thermometer, equilibrium

Summary Questions

1 Copy and complete the sentences below.

You measure _______ in degrees Celsius using a _______. _______ does not depend on the amount of material that you have, but the _______ stored does. The particles in a _______ vibrate more when you heat the solid. Energy moves from hotter objects to colder objects until they are in _______.

(6 marks)

2 Sort these things in order from least energy stored to most energy stored: a saucepan full of water at 50 °C, a cup of water at 30 °C, a saucepan full of water at 30 °C.

(1 mark)

3 You are cooking a pizza. You place your pizza on a metal tray at room temperature and put it in the oven. When the pizza is cooked you remove the tray from the oven. Eventually it reaches room temperature again. Describe and explain in detail what happens to the motion of the particles in the metal tray.

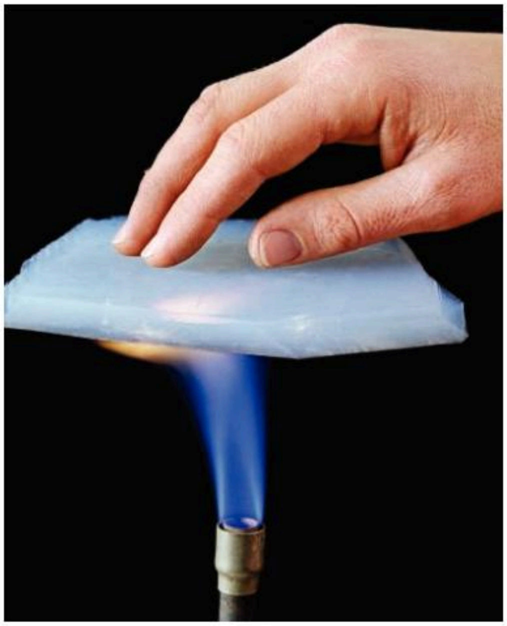
(6 marks QWC)

2.4 Energy transfer: particles

Learning objectives

After this topic you will be able to:

- describe how energy is transferred by particles in conduction and convection
- describe how an insulator can reduce energy transfer.



▲ This special material is called aerogel. Energy is transferred very slowly through it.

▲ The capsule that brought these astronauts back is insulated so that they do not burn up in the atmosphere.

Have you ever lit a wooden splint in a Bunsen burner flame? The end of the splint is at a temperature of about 1000 °C but you can still hold the other end.

What's the difference?

When you put the saucepan of soup on the stove, the soup heats up.

The bottom of the saucepan is made of metal. A metal is a good **conductor** of energy. Energy is transferred through it very quickly. This is **conduction.**

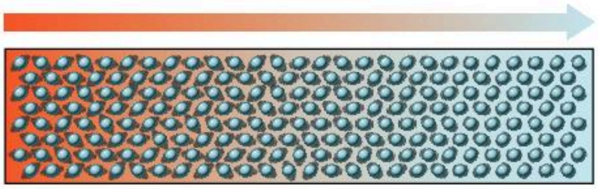
Energy can be transferred by conduction, **convection**, or **radiation**.

A Write a definition for the word 'conductor'.

Particles and conduction

In conduction particles transfer energy by colliding with other particles when they vibrate.

Energy transfer happens until the two surfaces are at the same temperature. If you keep one surface warm by heating it then you will maintain the temperature difference. The solid will continue to conduct.



Solid conductor, solid insulator?

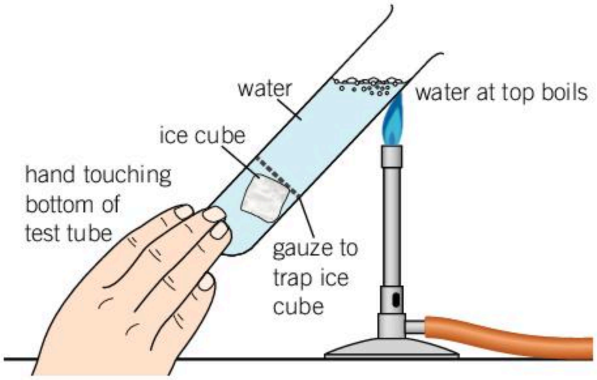
Energy is not transferred very easily through materials like wood. Wood and many non-metals are poor conductors. They are **insulators**. This does not mean that they do not conduct at all but that energy is transferred very slowly through them.

Insulating liquids and gases

Liquids are poor conductors. Divers wear wetsuits, which use a thin layer of water against the skin as an insulator to keep them warm.

Fantastic Fact

Engineers at NASA claim to have made the loudest noise ever. This is so loud that it can make holes in solid materials.



◀ A liquid is a very poor conductor of heat.

Gases do not conduct well at all because their particles are much further apart than the particles in a solid. Duvets and warm clothing are designed to trap small pockets of air, which is a good insulator.

B State what an insulator is.

Particles and convection

When you heat soup in a pan it all heats up, not just the layer in contact with the bottom of the saucepan. This is what happens:

- The soup that is in contact with the bottom of the pan gets hotter so the particles there move faster.
- The particles in the hotter soup move further apart, so the soup becomes less dense.
- The hotter soup rises (floats up) and cooler, denser soup takes its place.

This is called a **convection current**. Convection also happens in gases.

▲ A convection current in a saucepan of water heats all of the water up.

▲ Hurricanes are produced by convection currents in the atmosphere, and the spin of the Earth.

Particles and sound

When you play music, energy is transferred to the surroundings. The air and walls get a bit warmer. The particles in the air move a bit faster, and the particles in the walls vibrate more.

Key Words

conductor, conduction, convection, radiation, insulator, convection current

How fast?

A student wants to investigate how the temperature of a liquid affects how long it takes to cool down. Write a plan for the investigation, including a risk assessment.

Summary Questions

1 Copy and complete the sentences below.

Energy is transferred through a solid by ______ if there is a ______ ______ between the ends of it. Liquids and solids transfer energy by ______ because the particles can ______. Energy is transferred much more ______ through an insulator than it is through a conductor.

(6 marks)

2

a Explain in terms of particles why conduction happens in solids but not in liquids and gases. *(2 marks)*

b Explain in terms of particles why convection happens in liquids and gases but not in solids. *(2 marks)*

3 An electric kettle contains an element at the bottom that gets hot when you switch it on. Use the ideas on these pages to explain in detail how all the water in a kettle boils.

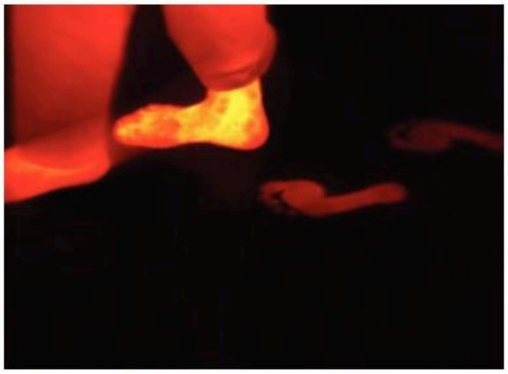
(6 marks QWC)

2.5 Energy transfer: radiation

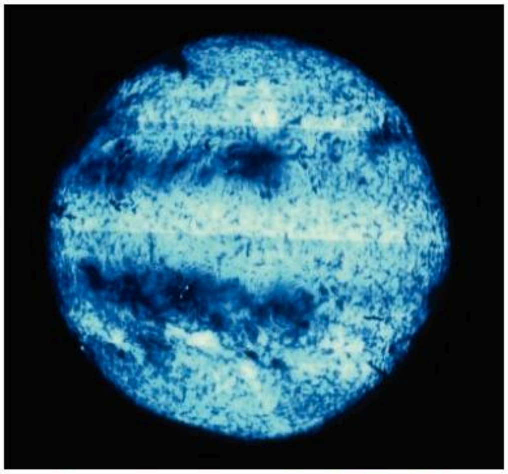
Learning objectives

After this topic you will be able to:

- describe some sources of infrared radiation
- explain how energy is transferred by radiation.



▲ A special camera detects these footprints.



▲ This is what the Sun looks like if you can only see infrared.

Link

You can learn more about the properties of light in P1 3.1 Light

You leave footprints on the floor when you walk across it in bare feet. You can't see them because your eyes detect visible light.

What is radiation?

Very hot things such as burning coal give out light as well as **infrared radiation**. Some people call infrared 'thermal radiation' or 'heat'. The Sun emits lots of different types of radiation, including light and infrared. Both light and infrared radiation travel as waves.

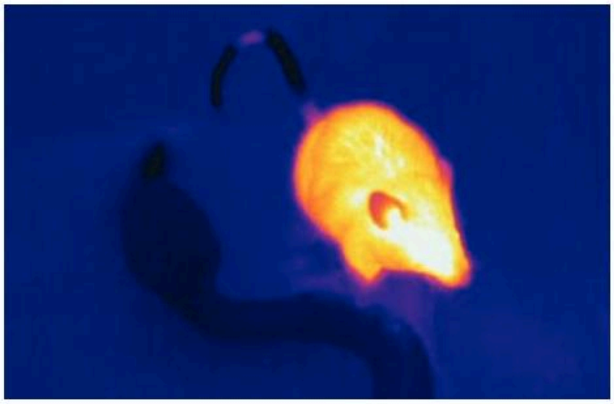
Transferring energy by radiation

You need particles to transfer energy by conduction and convection. You don't need particles to transfer energy by radiation. Light and infrared reach the Earth from the Sun by travelling through space. Space is a vacuum. There are no particles in a vacuum.

Emitting infrared

All objects (including you) give out, or emit, radiation.

- The type of radiation that they emit depends on their temperature.
- How much radiation they emit per second depends on the type of surface.
- Infrared can be transmitted, absorbed, or reflected, just like light.



◀ The mouse is warmer and emits a lot more infrared than the snake.

A Name two sources of infrared radiation.

Absorbing infrared

When the Sun is shining your skin feels hotter. Your skin detects the infrared when it absorbs it. Your skin is just one thing that detects infrared.

- A **thermal imaging camera** absorbs infrared and produces an image. The colours in the image are 'false'. The camera works out which areas are hotter and shows them redder in the image.
- A remote thermometer contains a sensor that detects infrared. It uses the radiation to work out the temperature.

You might feel hotter when you wear dark clothing. Dark colours absorb infrared, and light-coloured and shiny surfaces reflect infrared. If you hang clothes on a washing line the dark-coloured clothes will dry more quickly than the light-coloured ones.

▲ A thermal imaging camera produces a coloured image of the fire.

Reflecting infrared

At the end of a marathon, a runner's body temperature drops dramatically. Runners use foil to reflect the infrared back towards their bodies. This prevents their body temperature from falling too quickly.

◀ You can keep warm with a foil blanket.

B State what happens when infrared hits a shiny surface.

Cooling down

A student investigated the effect of the colour of a can on the time it takes hot water inside to cool down.

	Temperature drop (°C)			
Colour of can	1st measurement	2nd measurement	3rd measurement	Mean
shiny metal	12	15	16	
shiny white	5	18	14	
matt black	11	16	13	
shiny black	23	15	10	

a Identify the outlier or outliers.

b Calculate the mean temperature drop.

c Explain why it is not possible to make a conclusion from this experiment.

Key Words

infrared radiation, thermal imaging camera

Summary Questions

1 Copy and complete the sentences below.

The Sun and fire are examples of ______ of infrared. All objects emit ______ but the type of radiation depends on the ______. Infrared can be ______ from shiny surfaces, just like light. Dark-coloured surfaces ______ infrared better than light-coloured surfaces. Infrared does not need ______ to travel through. It can travel through empty space, or a ______.

(7 marks)

2 Explain why:

a houses are painted white in hot countries *(1 mark)*

b you can't find people in burning buildings with a thermal imaging camera. *(2 marks)*

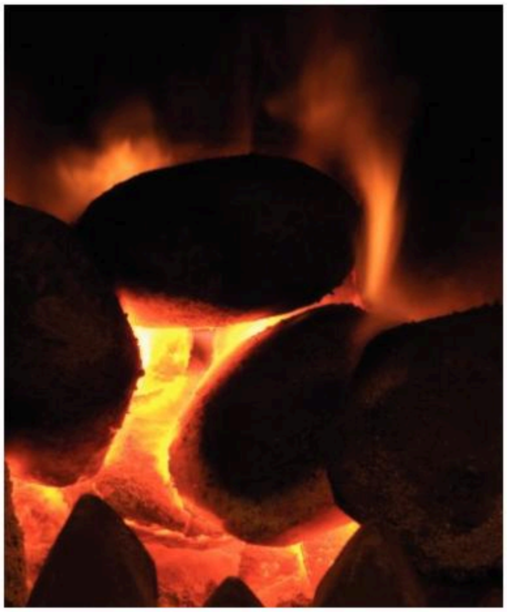
3 Draw a detailed visual summary about infrared radiation. *(6 marks)*

2.6 Energy resources

Learning objectives

After this topic you will be able to:

- describe the difference between a renewable and a non-renewable energy resource
- describe how electricity is generated in a power station.



▲ Coal is one of many energy resources.

Link

You can learn more about energy sources in P3 1.6 Your planet

Key Words

energy resource, fossil fuel, non-renewable, thermal power station, renewable, nuclear

Have you ever thought about where the fuels and electric current that you use in your house come from? The energy resources of the planet are used to heat homes, make electric appliances work, and move people around.

Fossil fuels

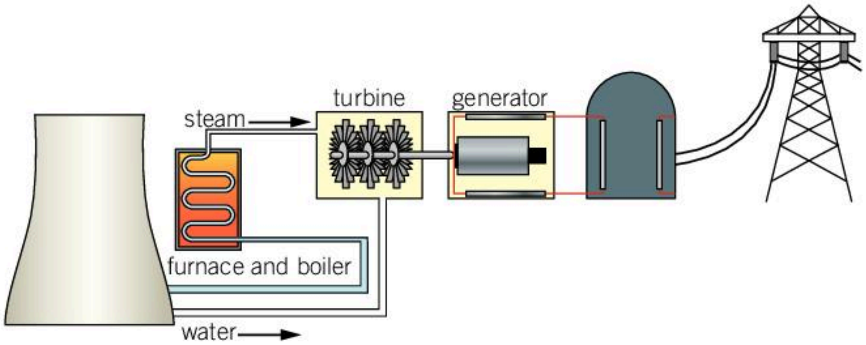
Coal, oil, and gas are **energy resources** that were formed millions of years ago. That is why they are called **fossil fuels**. Oil and gas are made from the fossilised remains of sea creatures. Coal is the fossilised remains of trees. The trees and sea creatures were compressed and heated over millions of years, and that produced coal, oil, and gas.

Coal, oil, and gas are **non-renewable**. That doesn't mean that you can't use them again. It means that you cannot easily get more of them when they run out.

A Name three fossil fuels.

What's in a power station?

Thermal power stations burn coal and gas. Oil is mainly used to produce petrol, plastics, and other useful materials.



▲ A power station burns fossil fuels to drive a generator.

A fuel burns to heat water and produce steam. The steam drives a turbine, which is a bit like a big fan. The turbine drives a generator. This provides the push that means a current flows in a kettle in your home. The current transfers energy from the chemical store of the fuel to the thermal store of the water in the kettle.

One problem with burning fossil fuels is that they produce a lot of carbon dioxide. Carbon dioxide is a greenhouse gas, so it can contribute to climate change.

Burning fossil fuels also produce pollutants such as sulfur dioxide, nitrogen oxides, and particulates.

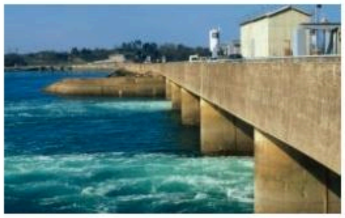
B Name the greenhouse gas that is produced when fossil fuels burn.

What's the alternative?

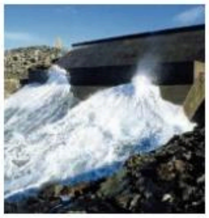
Scientists agree that it would be better if we did not burn so many fossil fuels. They have found some alternative methods to produce a current. These resources are **renewable** because they will not run out. Many renewable resources come from the **nuclear** store of energy of the Sun.

Renewable energy resources

▲ A wind turbine spins a generator directly.



▲ Tidal: water flows through turbines as the tide goes in and out.



▲ Waves turn a turbine.

▲ Biomass: you can burn plants instead of coal in a power station. The plants use carbon dioxide when they grow.

▲ Solar (photovoltaic) cells generate a potential difference from light.

▲ Hydroelectric: water falls down through turbines in the dam.

▲ Geothermal: hot rocks in the Earth heat water to form steam, which turns turbines.

C Name three renewable resources.

Renewable resources do not produce much carbon dioxide when they produce a current. They do produce carbon dioxide when they are being built.

Link

You can learn more about greenhouse gases in C2 4.6 Climate change

Chris the carbon atom

Write a children's story that follows the journey of Chris the carbon atom. Chris starts out in the trunk of a tree that is turned into coal and then used to generate electricity. At the end of the journey he is in a molecule of carbon dioxide.

Summary Questions

1 Copy and complete the sentences below.

Coal is a ______ resource because it will run out. It is called a ______ ______ because it took millions of years to form. Wind is a ______ resource because it won't run out.

(4 marks)

2 Explain how electricity is generated from coal.

(4 marks)

3 Design a board game that teaches the players about the advantages and disadvantages of using renewable and non-renewable energy resources.

(6 marks)

2.7 Energy and power

Learning objectives

After this topic you will be able to:

- explain the difference between energy and power
- describe the link between power, fuel use, and the cost of using domestic appliances.

Fantastic Fact

When you make popcorn you are boiling water. The water inside the popcorn kernel turns to steam and it explodes.

▲ The power rating of this heater is 2000 W.

▲ Some houses transfer more energy to the surroundings than others.

Some microwaves cook popcorn faster than others. Why is there a difference?

Powerful appliances

Microwave ovens have a **power rating** in **watts** (W). The power rating tells you how much energy is transferred *per second*, or the rate of transfer of energy.

You can calculate power using this equation:

$$\text{power (W)} = \frac{\text{energy (J)}}{\text{time (s)}}$$

The power of a microwave oven is about 800 W. A traditional oven has a power of about 12 000 W, or 12 **kilowatts**.

Kilowatts and kilojoules

12 000 W is the same as 12 kilowatts, or 12 kW. There are 1000 W in 1 kW. You divide by 1000 to convert watts to kilowatts.

An oven with a rating of 12 kW transfers energy at a rate of 12 000 J per second. This is the same as 12 kilojoules per second. There are 1000 J in 1 kJ.

A State the unit of power.

Keeping the temperature the same

All hot objects cool down. To keep a house at the *same* temperature you need to transfer energy to it at the *same* rate as energy is being transferred from it.

What are you paying for?

When you pay an electricity bill you are paying for a fuel such as coal to be burnt in a power station. The power station generates the potential difference that we call 'mains electricity'. You are charged for the number of hours that you use each appliance, and for the power of the appliance.

You can calculate energy use in **kilowatt hours** (kWh), or joules. This is the unit that electricity companies use to calculate your bill.

A kilowatt hour is calculated like this:. Suppose you use a 12 kW (12 000 W) oven for 1 hour (3600 seconds):

energy used in kWh = 12 kW × 1 hour
= 12 kWh

energy used in J = 12 000 J/s × 3600 s
= 43 200 000 J

B State the unit of energy that electricity companies use.

To reduce your energy bills you could use fewer appliances, or appliances that require less power to produce the same output. You can also use appliances for fewer hours. Insulation reduces the rate at which energy is transferred to the surroundings, so it reduces the rate at which you need to supply energy to heat the house.

▲ The electricity meter shows how much energy you have used in kWh.

▲ The bulbs are the same brightness but the one on the right has a much lower power.

What's the cost?

A shower has a power of 10 kW. A family uses the shower for 1 hour per day.

a Calculate how much energy, in kilowatt hours, they would have to pay for each week for using the shower.

b An electricity company charges 10p for each kWh. Calculate the cost in pounds.

Key Words

power rating, watt, kilowatt, kilowatt hour

Summary Questions

1 Copy and complete the sentences below.

Energy is measured in ______ and power is measured in ______. Power is the energy transferred per ______. You pay for the number of ______ that are transferred to your house by electricity. You could save money by using appliances with a ______ power rating, or by using them for ______ time.

(6 marks)

2 The potential difference across a bulb is 3 V and the current through it is 0.2 A.

a Calculate the power. *(2 marks)*

b Calculate the energy transferred by the bulb in 10 seconds. *(2 marks)*

3 Compare the cost of using a kettle with a power rating of 2 kW and a kettle rated 1.2 kW.

(6 marks QWC)

2.8 Work, energy, and machines

Learning objectives

After this topic you will be able to:

- calculate work done
- apply the conservation of energy to simple machines.

▲ Riding downhill is much easier than riding uphill.

Have you ever tried to ride your bike uphill in the same gear that you use to ride downhill? Choosing a lower gear makes it easier to go up hills.

Working out work

Not all energy transfers are to do with heating and cooling. You can transfer energy by doing **work**.

In physics the word 'work' has a special meaning.

- When you lift a book you do work against gravity.
- When you slide the book you do work against friction.

work done = force × distance
(J) (N) (m)

▲ Lifting a book.

work done = force × distance
= 2 N × 1 m
= 2 J

▲ Sliding a book.

work done = force ×distance
= 1 N × 0.2 m
= 0.2 J

A State the equation for calculating work.

Making life easier

A **simple machine** makes it easier to lift things, move things, or turn things. It reduces the force that you need to do a job, or increases the distance that something moves when you apply a force.

Levers

Most people use a **lever** to open a tin of paint. If you put a screwdriver between the lid and the rim of the tin, you can open the tin with a much smaller force.

The force applied to the lid by the lever is bigger than the force that you apply with just your hand. A lever is a force multiplier.

Fantastic Fact

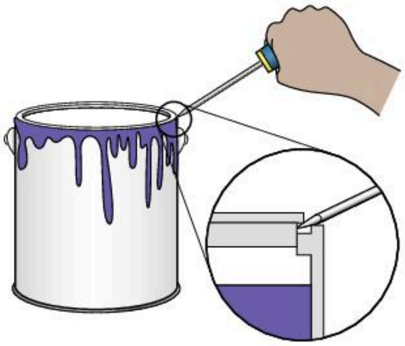
Using different size cogs on the front and back wheels of a bicycle can give you up to 34 gears.

Climb a mountain!

When you walk upstairs you are using a force to overcome your weight.

Your hand moves down and the other end of the lever moves up. Your hand moves much further than the other end of the lever.

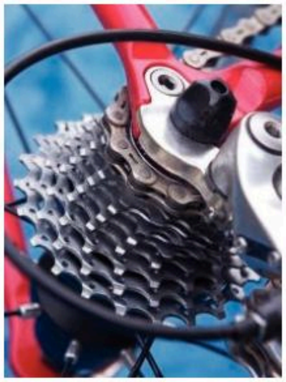
▲ A screwdriver applies a bigger force than you could apply with just your hand.



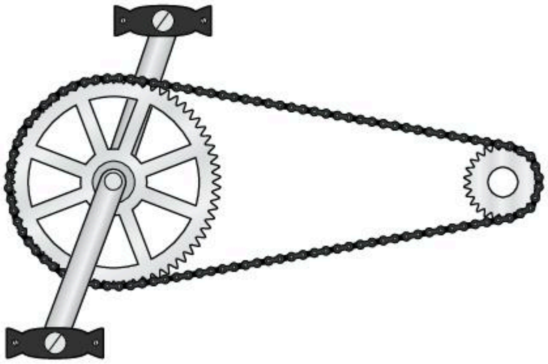
▲ The force may be bigger but the distance is smaller.

Gears

The **gear** system on a bicycle is a simple machine. Gears are a bit like levers that are rotating. You can use a gear system to increase the force, change direction, or go faster.



▲ You can select big or small cogs in bicycle gears.



▲ When the cog at the back is smaller, it takes less force to turn it. It is a force multiplier.

B Name two types of simple machine.

Getting something for nothing?

A small force acting over a big distance produces a big force. The big force can only move a small distance. You cannot get something for nothing.

The reason is the law of conservation of energy. If you increased the distance *as well* as the force then you would get more energy out than you put in. You cannot get out more than you put in.

Key Words

work, simple machine, lever, gear

Summary Questions

1 Copy and complete the sentences below.

You need to know the ______ and the ______ to calculate work done. A simple ______ like a ______ can be used to open a paint tin because it is a ______ multiplier. A ______ on a bicycle can make it easier to cycle uphill. All simple machines obey the law of ______ of energy. You cannot get more ______ out than you put in.

(8 marks)

2 You can use a stone under a plank of wood to lift a heavy rock.

a State the type of machine that you can make with this equipment. *(1 mark)*

b Calculate the work done by lifting a rock of weight 200 N a distance of 0.25 m. *(2 marks)*

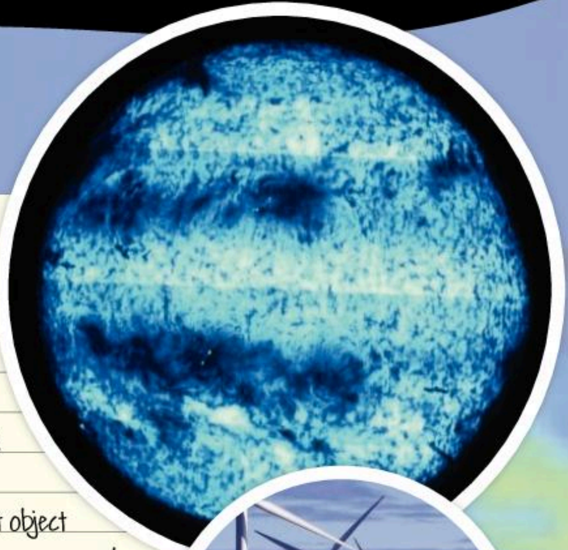
3 A person with a weight of 600 N climbs Mount Everest, a vertical height of 10 km. Compare the work done climbing Mount Everest and climbing 2.5 m upstairs to bed.

(4 marks)

4 Look at the diagram of the bicycle chain and cogs above. Explain in detail why you exert a force on the pedals, but you still obey the law of conservation of energy.

(6 marks QWC)

P2 Chapter 2 Summary



Key Points

- There is energy in the chemical stores associated with food and fuel. Energy is measured in joules. You need different amounts of energy for different activities.
- Energy cannot be created or destroyed; it can only be transferred between stores. This is the law of conservation of energy. Light, sound, and electricity are ways of transferring energy between stores.
- Temperature is measured using a thermometer. The temperature doesn't depend on the amount of material, but the amount of energy in the thermal store does.
- When a hot object is in contact with a colder one energy is transferred from the hot object to the colder one. Energy will be transferred, and the temperature difference will decrease, until the objects are in equilibrium.
- Energy is transferred by conduction in solids and by convection in liquids and gases.
- Energy is transferred by radiation, which does not need a medium to travel through. All objects emit radiation. Infrared radiation can be detected by your skin or a thermal imaging camera. If the energy transferred to an object is less than the energy transferred from it the object will cool down.
- Fossil fuels such as coal, oil, and gas were formed over millions of years and are non-renewable. They can be used to drive a generator in a thermal power station. Wind, wave, and solar sources are examples of renewable energy resources.
- Power = energy/time, and electrical power = potential difference × current. You can work out the energy transferred by appliances in your home using the unit of kilowatt hours.
- You calculate work by multiplying a force by a distance. Simple machines like levers and gears can make it easier to do work but you do not get more energy out than you put in.

Key Words

energy, joule, kilojoule, law of conservation of energy, chemical store, energy store, thermal, kinetic, gravitational potential, elastic, dissipated, temperature, thermometer, equilibrium, conductor, conduction, convection, radiation, insulator, convection current, infrared radiation, thermal imaging camera, energy resource, fossil fuel, non-renewable, thermal power station, renewable, power rating, watt, kilowatt, kilowatt hour, work, simple machine, lever, gear

BIG Write

Energy campaign

You are a local councillor who wants to raise awareness of the energy content of food and how that links to the energy needed for activities that people do.

Task

Design an energy diary that students could use to take a snapshot of their own energy use over a day or a week.

Tips

- Remember that you need energy for everything you do, even sleeping.
- Remind students that if they take in more energy than they need the body will store it as fat to use in the future.

End-of-chapter questions

1 Here are some energy resources. List the renewable energy resources.

wind solar oil coal geothermal gas

(1 mark)

2

a State which definition of power below is correct. *(1 mark)*

A the energy transferred per hour

B the energy transferred

C the energy transferred per second

D the force over a distance

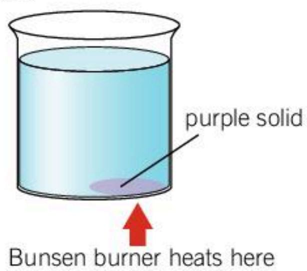
b Select all the units of power from this list:

kW J watts kilojoules kilowatts W joules kJ

(1 mark)

(2 marks)

3 Here is an experiment to demonstrate convection.



a Describe what will happen to the purple colour during heating. *(3 marks)*

b Explain why the purple colour forms a convection current. *(3 marks)*

(6 marks)

4

a Name a fossil fuel that can be burned in a power station. *(1 mark)*

b Explain why it is called a 'fossil' fuel. *(1 mark)*

c Use your answer to part b to explain why fossil fuels are non-renewable. *(2 marks)*

(4 marks)

5 A tennis ball has 10 J of energy when it is 1 m above the floor.

a Name the store associated with this energy. *(1 mark)*

b A student states that there will be 10 J of energy in the kinetic store just before it hits the ground.

i Explain why the student has made that statement. *(1 mark)*

ii Explain why the student might not be correct. *(1 mark)*

c Explain why the ball moves. *(2 marks)*

(5 marks)

6 Calculate the work done in each of the situations below:

a a car engine that uses a force of 500 N to move a car 200 m *(2 marks)*

b a shopkeeper who uses a force of 50 N to lift a box 1.5 m. *(2 marks)*

(4 marks)

7 You want to reduce your energy bills.

a Calculate the power of a lightbulb that transfers 6000 J every minute. *(2 marks)*

b Calculate the power of a different lightbulb that has a current of 0.05 A through it when there is a potential difference of 240 V across it. *(2 marks)*

c Both bulbs are equally bright. State and explain which lightbulb you should use.

(2 marks)

(6 marks)

8 Some double-glazing systems trap air between two panes of glass.

a Explain how energy is transferred through a double-glazed window from a hot room to the cold air outside. *(3 marks)*

b State and explain how the rate of energy transfer would change if you removed the air from the gap. *(3 marks)*

(6 marks)

9 Explain in detail why insulating your house will reduce your energy bills.

(6 marks QWC)

3.1 Speed

Learning objectives

After this topic you will be able to:

- calculate speed
- describe relative motion.

▲ A cheetah can travel faster than a car.

▲ A speed camera measures how long it takes a car to travel a certain distance by taking a photo at the start of the distance and another at the end. It can then calculate the car's speed.

It feels fast going downhill on a bike. Even going downhill you could not travel as fast as a cheetah.

How fast?

Speed is a measure of how far something travels in a particular time. In science you measure speed in **metres per second** (m/s). Car speed and speed limits are measured in miles per hour (m.p.h.) or kilometres per hour (km/h). A very fast car can move at over 300 km/h, but when you walk to school you are probably walking at 5 km/h or about 1 m/s.

A Write a definition of the word speed.

How do you calculate speed?

To find the speed of an object moving at a steady speed you need to measure the time it takes to travel between two points.

You work out the speed from the distance travelled divided by the time taken:

$$\text{speed (m/s)} = \frac{\text{distance travelled (m)}}{\text{time taken (s)}}$$

A long-distance runner runs part of his race at a steady speed. It takes him 20 seconds to run 100 m.

$$\text{speed} = \frac{100\text{ m}}{20\text{ s}} = 5\text{ m/s}$$

When you are using an equation to calculate speed it is helpful to write it out like this. If you write the units of distance and time in the equation then you will have the correct units for the speed.

	Speed (m/s)	Speed (km/h)	Speed (m.p.h.)
walking quickly	1.7	6.1	3.7
sprinting	10	36	22
typical speed limit	14	50	31
cheetah	33	119	75
aeroplane cruising speed	255	918	570
sound in air	330	1180	738
light in air	300 000 000	10 000 000 000	670 000 000

B State the unit of speed that you use in science.

Speed or average speed?

A marathon runner will take several hours to run the 26.2 miles (42.2 km) of a marathon. She does not run at exactly the same speed throughout the race.

▲ A marathon runner's speed changes during a race.

The speed that the runner is travelling at any time during the race is the **instantaneous speed**. This is the speed that you see on the speedometer in a car.

You can work out the **average speed** by dividing the *total* distance by the *total* time that it took to run the race. This average speed makes it easier to compare how fast different people, or boats, or cars, travel.

Marathon times

A marathon runner runs the marathon in 2 hours 30 minutes, or 2.5 hours. Calculate the average speed of the runner in km/h.

Relative motion

Have you ever looked out of the window of a stationary train in a station at a moving train and felt that your train is moving? This is an example of **relative motion**. Relative motion means how fast one thing is travelling compared to another. Being on a moving train looking at a stationary one feels the same as being on a stationary train looking at a moving one.

Speed is relative. If two cars are moving at the same speed in the same direction their relative speed is zero. If the cars are moving at 30 m.p.h. towards each other their relative speed is 60 m.p.h. The speed of 30 m.p.h. is relative to a stationary point.

C State what is meant by relative motion.

Foul Fact

You cough at 60 m.p.h. but your sneeze would break the motorway speed limit. You sneeze at over 100 m.p.h.

Key Words

speed, metres per second, instantaneous speed, average speed, relative motion

Summary Questions

1. Copy and complete the sentences below.
   To calculate speed you need to know the ______ and the ______. To calculate average speed you divide the ______ ______ by the ______ ______. You measure speed ______ to a stationary object.
   (5 marks)
2. A runner runs 100 m in 12.5 seconds. Calculate her average speed.
   (2 marks)
3. A car is travelling east at 50 km/h. On the same road another car is travelling west at 20 km/h. The cars are moving away from each other. Describe their relative motion.
   (2 marks)
4. Use the speed equation to explain how a speed camera calculates a car's speed.
   (6 marks QWC)

3.2 Motion graphs

Learning objectives

After this topic you will be able to:

- interpret distance–time graphs
- calculate speed using a distance–time graph.

Key Words

distance–time graph, acceleration

▲ The car and motorbike are travelling at different speeds.

Fantastic Fact

You might hear people talk about the time it takes a car to accelerate from 0 to 60 m.p.h. A very fast car can accelerate from 0 to 60 m.p.h. in 2.3 seconds.

Working it out

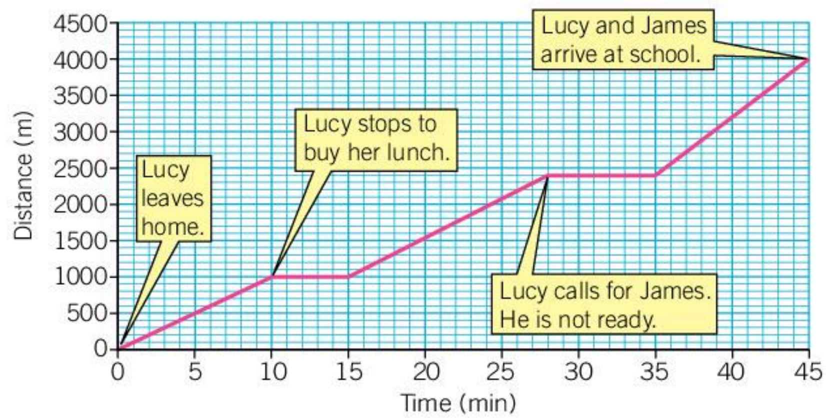
Look at the distance–time graph opposite for a constant speed. Calculate the speed using information on the graph.

How long does it take you to get to school? You can tell the story of a journey with a graph.

What is a distance–time graph?

A **distance–time graph** is a useful way of showing how something moves. It shows the distance that something travels over a certain time.

Here is a graph that shows Lucy's journey to school. The line shows how far she travelled each minute of the journey.

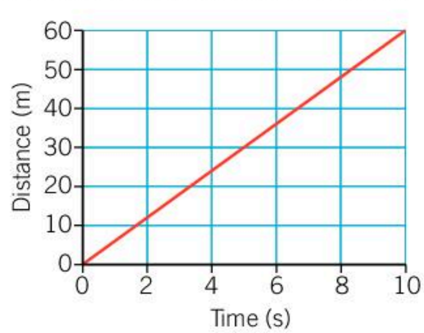


▲ A distance–time graph for Lucy's journey to school.

A State what a distance–time graph shows.

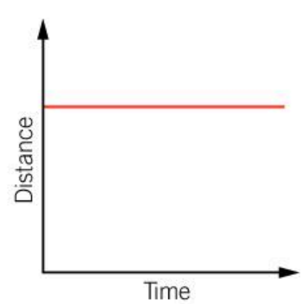
What does the graph tell us?

This is a very simple distance–time graph. The object moves the same distance each second.



▲ A distance–time graph for a constant speed.

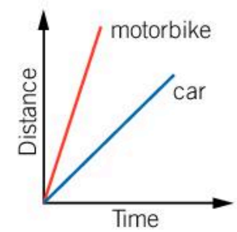
What happens if you stay still? The line on the distance–time graph is horizontal.



▲ A distance–time graph for a stationary object.

The slope of a distance–time graph tells you the speed. If the line is steep the object is moving fast. If it is not very steep then the object is moving more slowly.

B State what the slope of a distance–time graph shows you.



▲ A distance–time graph for two different speeds.

In the graph opposite, both the car and the motorbike are moving at a steady speed. The line for the motorbike shows a faster speed and the line for the car shows a slower speed.

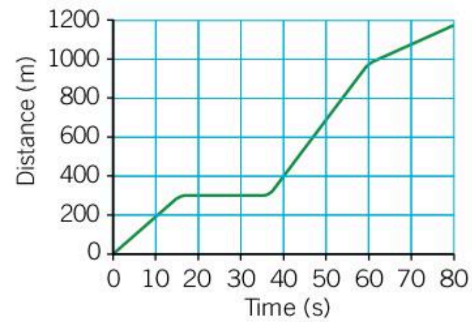
A more realistic graph

When you are travelling in a car your speed does not stay the same for the whole journey. The speed changes through the journey.

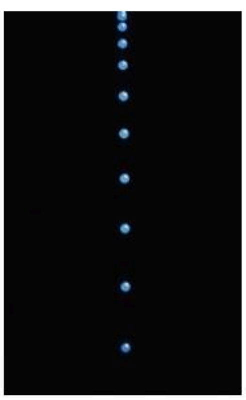
The changing speed is shown by the slope of the graph. The slope changes gradually, not suddenly.

If your speed is changing you are accelerating. **Acceleration** tells you how quickly your speed is changing.

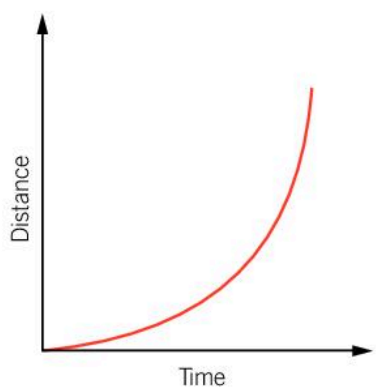
When you drop a ball it gets faster and faster. It accelerates towards Earth. The distance–time graph is curved. The distance–time graph is also curved if an object is slowing down.



▲ A more realistic distance–time graph.



▲ The distance a ball falls in one second increases as it accelerates.



▲ A distance–time graph for an accelerating object.

Working out speed from a distance–time graph

You can calculate speed from a distance–time graph. For example, in the first section of Lucy's graph she walks 1000 m in 10 minutes or 600 seconds.

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$= \frac{1000\text{ m}}{600\text{ s}}$$

$$= 1.7\text{ m/s}$$

Summary Questions

1 Copy and complete the sentences below.

A distance–time graph shows the ______ that an object travels in a certain ______. The ______ of the line tells you the speed. If the line is horizontal the object is ______. If the line is a curve the speed of the object is ______.

(5 marks)

2 Look at the graph for Lucy's journey to school.

a Calculate Lucy's speed for the final 10 minutes of the graph. *(4 marks)*

b State the value of the speed in the horizontal sections of the graph. *(1 mark)*

3 Imagine two students travelling 3 km to school. One walks and the other travels by car. Sketch a graph for each journey and compare the graphs that you have drawn.

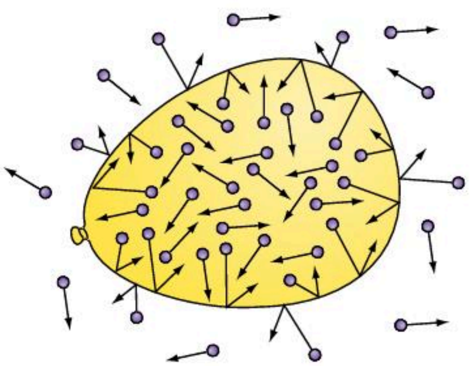
(6 marks QWC)

3.3 Pressure in gases

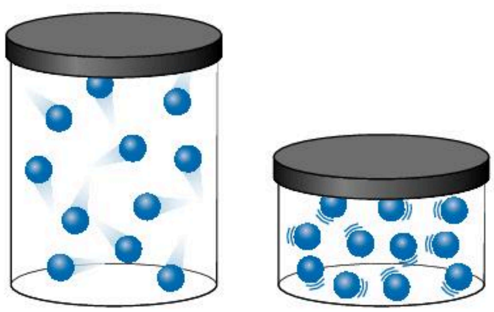
Learning objectives

After this topic you will be able to:

- describe the factors that affect gas pressure
- describe how atmospheric pressure changes with height.



▲ If there are more collisions on the inside than the outside the balloon gets bigger.



▲ In a smaller volume gas molecules will collide more often with the walls of the container.

Balloon pressure

A student wants to investigate how the volume of a fixed amount of air in a balloon changes with temperature. Write a plan for the investigation.

Have you ever blown a balloon up until it bursts?

◀ The moment when a balloon bursts.

What is gas pressure?

When you blow up a balloon there are millions of air molecules hitting the inside of the balloon.

The collisions between the air molecules and the balloon produce **gas pressure** (air pressure). Lots of collisions make a high gas pressure because there is a big force over a small area. Gas pressure is exerted in all directions.

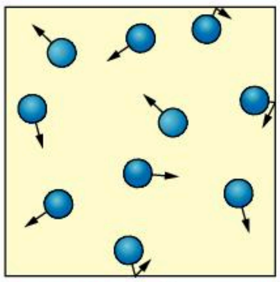
Changing volume

If you squash a gas into a smaller volume there will be more collisions between the gas molecules and the walls of the container. The pressure increases.

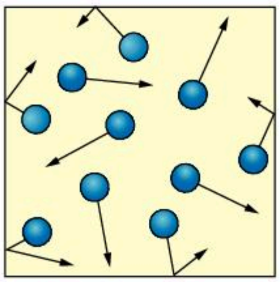
Changing temperature

When a gas cools down its molecules move more slowly. If the container doesn't change shape, then the pressure goes down. There are fewer collisions with the sides of the container.

A State what happens to the speed of gas molecules when the temperature goes down.



▲ Cool gas: fewer and less energetic collisions.



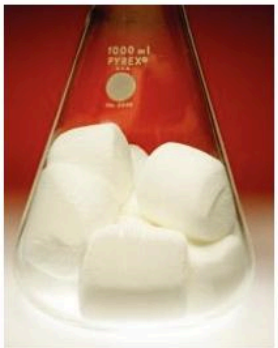
▲ Hot gas: more collisions that are more energetic.

Compressed gas

When you pump up a bicycle tyre you increase the gas pressure. As you pump more gas into a container the gas becomes **compressed**. There are more molecules in the same space, so there are more collisions. The pressure is bigger, so the force exerted by the gas over the area of the container is big. You need a strong container to hold a compressed gas.

Atmospheric pressure

There is air all around you. The air exerts a pressure on your body all the time called **atmospheric pressure**. You do not feel the pressure. It is cancelled out by the pressure of the gases and liquids in your body pushing out.



Marshmallows contain pockets of air that expand when you pump out the air around them.

Changing atmospheric pressure

The atmospheric pressure at sea level is bigger than the atmospheric pressure high up a mountain. Gravity pulls the air particles towards the Earth. Where the particles are closer there are more collisions. The pressure is higher.

The gas has a higher **density** at sea level. There is more mass of gas in a certain volume.

The smaller atmospheric pressure makes it hard for mountain climbers to breathe in enough oxygen. Mountaineers often take oxygen tanks when they climb high mountains such as Everest. The tanks contain oxygen gas that has been compressed into a small volume.

B State what happens to the atmospheric pressure as you go up a mountain.

Key Words

gas pressure, compressed, atmospheric pressure, density

Foul Fact

Think of your favourite famous person. When you breathe in you are breathing in at least 10 air molecules that they have breathed out.

Link

You can learn more about gas pressure in C1 1.7 Gas pressure

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

A gas exerts a pressure on the walls of its container because the particles **collide with/stick to** the walls. If the gas gets hotter the pressure will be **bigger/smaller**. If the volume gets bigger the pressure will be **bigger/smaller**. As you go up a mountain the air pressure is **bigger/smaller** because there are **fewer/more** gas particles.

(5 marks)

2 A climber climbs a mountain.

a Explain why he might take a cylinder of oxygen with him. *(2 marks)*

b Explain why the oxygen needs to be compressed. *(2 marks)*

3 A teacher heats some water in a drinks can until it is boiling and steam comes out of the can. She quickly turns the can over and puts it into some water. Explain in detail why the can collapses.

(6 marks QWC)

3.4 Pressure in liquids

Learning objectives

After this topic you will be able to:

- describe how liquid pressure changes with depth
- explain why some things float and some things sink.

How do you squash a polystyrene cup without touching it? Take it deep beneath the sea and the pressure in the water will do it for you.

▲ The cup on the left was taken down to a depth of 3000 m.

Liquid pressure

When you swim underwater the water exerts a pressure on you. The water molecules are pushing on each other and on surfaces, and this **liquid pressure** acts in all directions.

When you squeeze a bag with holes in it the water is pushed out of all the holes because of liquid pressure. The water comes straight out of each hole and then falls because of gravity.

▲ The water comes out in all directions.

▲ The water behind a dam exerts a pressure on the concrete.

If you put water in a syringe, cover the end, and try to compress the liquid you will find it impossible. Liquids are **incompressible**. This is because the particles in a liquid are touching each other and there is very little space between them. In a gas there is lots of space between the particles so gases can be compressed. Liquids pass on any pressure applied to them.

A Write down what incompressible means.

Why does it float?

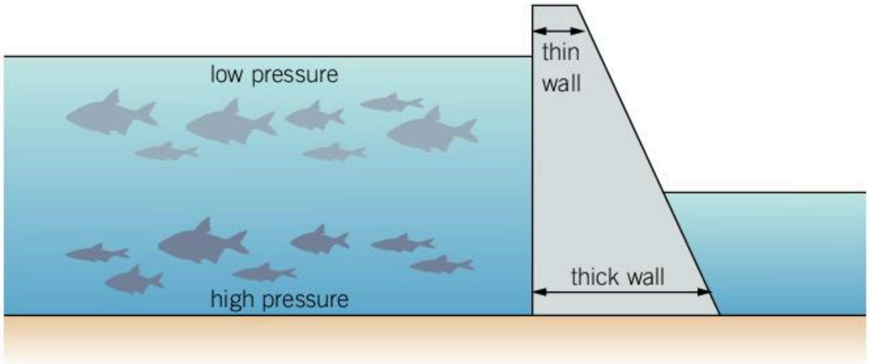
A primary-school student says that 'heavy things sink and light things float'.

Use the example of a ferry to explain to them why that is not the case.

Pressure and depth

The wall of a dam is not straight. It curves outwards at the bottom.

The pressure at the bottom of the lake is bigger than the pressure at the top. The pressure at a particular depth in a liquid depends on the weight of water above it.



▲ A dam is thicker at the bottom.

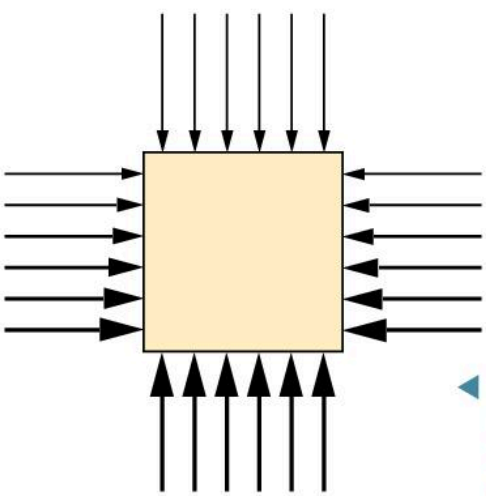
B State what happens to liquid pressure as you go deeper in a lake.

Floating and sinking

It is liquid pressure that produces upthrust, the force that keeps things afloat. If you push a balloon into a bucket of water you can feel the water pushing back. Upthrust acts on any object that is floating, or is submerged in a liquid.

It is easy to work out why a rubber duck floats. There are lots more water molecules hitting the bottom of the rubber duck than there are air molecules hitting the top. This produces the upthrust. The duck sinks until there is enough upthrust to balance the weight.

If the area in contact with the water is too small, there is not enough upthrust to make the object float.



◀ This object is submerged. The arrows show the forces acting on the object because of the pressure in the water.

When a submarine is underwater there is a difference in pressure between the top and bottom of the submarine. That produces a force that pushes the submarine up. This force is upthrust.

Fantastic Fact

The water pressure at the bottom of the Atlantic Ocean is equivalent to the weight of eight cars pushing on an area the size of your thumb.

Key Words

liquid pressure, incompressible

Link

You can learn more about upthrust in P1 1.1 Introduction to forces

Summary Questions

1 Copy and complete the sentences below.

The pressure in a liquid acts in ______ directions. The pressure ______ as you go deeper because the ______ of the water above you gets ______. The difference in pressure explains why there is a force called ______ on a floating object.

(5 marks)

2

a Explain in terms of pressure why a boat made of modelling clay floats. *(2 marks)*

b Explain why the same mass of modelling clay shaped into a ball sinks. *(2 marks)*

3 You push a ping pong ball to the bottom of a bucket of water. Explain in detail what happens to the ball when you let it go.

(6 marks QWC)

3.5 Pressure on solids

Learning objectives

After this topic you will be able to:

- calculate pressure
- apply ideas of pressure to different situations.

▲ There is no wind on the Moon to blow Neil Armstrong's footprints away.

▲ The tracks on the earthmover stop it sinking into the mud.

Key Words

pressure, newtons per metre squared

When Neil Armstrong walked on the Moon in 1969 he left footprints. The footprints are still there.

What is pressure?

When you stand on any surface you exert a force on it because of your weight. Your weight is spread out over the area of your foot. You are exerting a **pressure** on the ground. If you are standing on a soft surface such as mud the pressure might be big enough for you to sink.

An earthmover is very heavy. It has a weight of about a million newtons, the same as about 15 000 people! A single person standing on the same muddy ground might sink. The earthmover does not sink because its weight is spread out over a bigger area.

Pressure is a measure of how much force is applied over a certain area. The pressure acts in a direction that is at 90°, or normal, to the surface.

A State the direction that pressure acts.

How do you calculate pressure?

You calculate pressure using this equation:

$$\text{pressure (N/m}^2\text{)} = \frac{\text{force (N)}}{\text{area (m}^2\text{)}}$$

You measure force in newtons (N) and area in metres squared (m^2). Pressure is measured in **newtons per metre squared** (N/m^2).

Sometimes it is easier to measure smaller areas in centimetres squared (cm^2). If you measure the area in cm^2 then the pressure is measured in N/cm^2.

When you do calculations it is very important to look at the units of area. If you write them next to the number in your equation then you will see which unit of pressure you need to use.

B State the units of pressure.

Fantastic Fact

To produce the same pressure on the floor that you exert when you push in a drawing pin, you would need over 5000 people standing on your shoulders.

Big and small pressure

The studs on the bottom of a hockey or football boot have a small area compared with the area of the foot. This produces a bigger pressure. The studs sink into the ground and help the player to move quickly.

The weight of a hockey player is 600 N.

The area of her two feet is 200 cm².

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{600\ \text{N}}{200\ \text{cm}^2} = 3\ \text{N/cm}^2$$

The total area of the studs is 20 cm².

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{600\ \text{N}}{20\ \text{cm}^2} = 30\ \text{N/cm}^2$$

▲ The studs increase the grip on the ground.

▲ Snowshoes increase the area of your feet so the pressure is less.

Studs increase the pressure. At other times it is useful to make the pressure smaller, as with the earthmover.

If you need to walk over a soft surface such as snow, you need to increase the area of your feet in contact with the ground so that you do not sink.

Finding the force

Which of these is the correct equation for working out the force?

A force = pressure/area

B force = pressure × area

C force = area/pressure

▲ The pressure is bigger if your weight is concentrated over a smaller area, such as your hand.

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

Pressure is a measure of how much **force/pressure** there is on a certain **area/volume**. If you exert a **big/small** force on a **big/small** area the pressure will be large. Pressure is measured in **N/m²/Nm**.

(5 marks)

2 A gymnast has a weight of 600 N. The area of each hand is 150 cm². Calculate the pressure on the floor when he is doing a handstand.

(3 marks)

3 The point of a nail has an area of 0.25 cm², and an average person has a weight of 700 N. Explain in detail why it is possible to lie on a bed of 4000 nails, but not on a single nail.

(6 marks QWC)

3.6 Turning forces

Learning objectives

After this topic you will be able to:

- describe what is meant by a moment
- calculate the moment of a force.

▲ Tightrope walking over Niagara Falls.

▲ You need to apply a turning force to open a door.

Key Words

pivot, moment, newton metres, law of moments, centre of gravity, centre of mass

A tightrope walker uses a long pole to help him to balance.

A force that turns

Whenever you open a door you are using a turning force. A turning force acts a certain distance from a **pivot**.

The turning effect of a force is called a **moment**. The moment depends on the force being applied and how far it is from the pivot.

moment (Nm) = force (N) × perpendicular distance from the pivot (m)

You measure force in newtons (N) and distance in metres (m). You calculate a moment in **newton metres** (Nm).

A State the unit of a 'moment'.

The law of moments

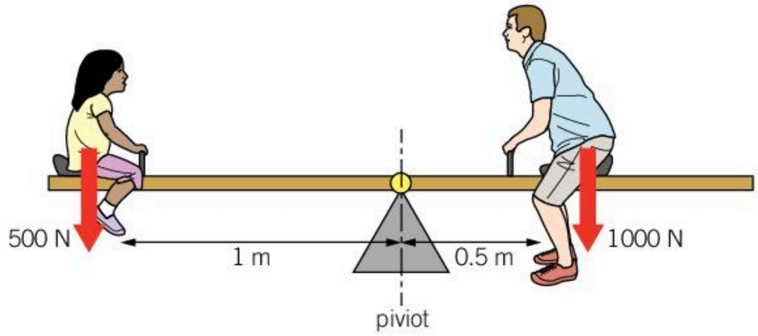
You sit on the left of a see-saw with your friend at the other end. It balances.

The moment of your weight acts anticlockwise. The moment of your friend's weight acts clockwise.

When an object is in equilibrium the sum of the clockwise moments is equal to the sum of the anticlockwise moments. This is the **law of moments**.

▲ These apples are in equilibrium because the clockwise moment equals the anticlockwise moment.

B State the law of moments.



▲ The see-saw doesn't turn if it is in equilibrium.

You can work out if a see-saw is going to be balanced by calculating the clockwise and the anticlockwise moments.

clockwise moment = force × distance on the right
= 1000 N × 0.5 m
= 500 Nm

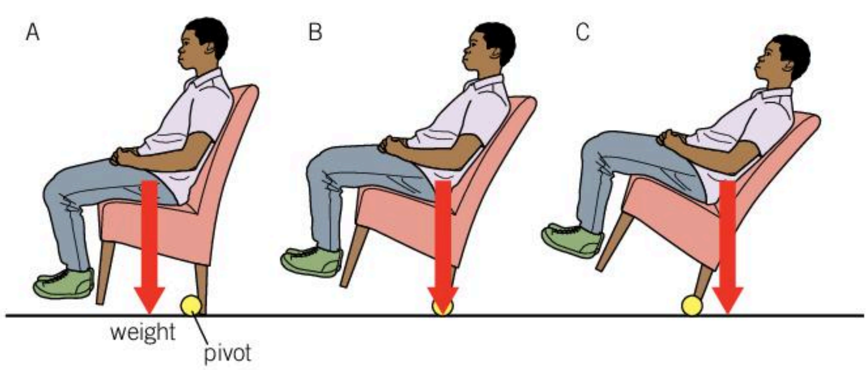
anticlockwise moment = force × distance on the left
= 500 N × 1 m
= 500 Nm

The moments are the same. The see-saw balances.

Falling over

When you lean back and tip your chair slightly, there is a turning force that brings your chair back. That turning force is your weight acting about the point where the legs touch the floor. If you lean back far enough you will topple over.

All the weight of an object seems to act through a point called the **centre of gravity** (or **centre of mass**). If the centre of gravity is above the pivot there is no turning force. If the centre of gravity is to the left or right of the pivot there will be a turning force.



▲ There is a turning force in A and C, but not in B.

C Describe what is meant by centre of gravity.

Fantastic Fact

The world's largest see-saw is in New York. It is just over 24 metres long. It lifts you higher than a house.

Sitting on a see-saw

A mother and daughter are on a see-saw 2 m long. The mother has a weight of 600 N and the child has a weight of 150 N.

Calculate where the mother must sit to balance the child who is sitting at the other end.

Summary Questions

1 Copy and complete the sentences below.

The ______ effect of a force is called a moment. You can calculate the moment of a force by multiplying the ______ by the ______. If the anticlockwise moments equal the clockwise moments the object will be in ______. This is the ______ of moments. The ______ of an object acts through a point called the centre of ______.

(7 marks)

2 A girl applies a force of 5 N to close a door. The handle is 0.75 m from the hinge. Calculate the moment of the force.

3 Design a balancing game that children can play. Explain in terms of the law of moments and centre of gravity how to play it.

(6 marks QWC)

P2 Chapter 3 Summary

Key Points

- Speed = distance/time, measured in metres per second (m/s). Average speed is the total distance travelled/total time taken.
- You can show what is happening to the position of an object on a distance–time graph. The slope of the distance–time graph is the speed.
- Gas pressure is due to the collisions of gas molecules with the sides of the container or object. If the gas is hotter, or compressed into a smaller volume, or if there are more gas molecules in the same space, there will be more collisions and the pressure will be greater.
- Atmospheric pressure is due to the collisions of air molecules with objects. Atmospheric pressure decreases with height because there are fewer air molecules higher up.
- Liquids are incompressible. The pressure at a particular depth in a liquid depends on the weight of water above it. Pressure increases with depth.
- Pressure = force/area, measured in N/m^2 or N/cm^2. The pressure tells you how the force is spread out over an area.
- The turning effect of a force is called a moment. You calculate a moment by multiplying the force by the distance from a pivot.
- If the clockwise moments acting on an object equal the anticlockwise moments the object will be in equilibrium. This is how see-saws balance.
- The centre of gravity is the point at which all the weight of the object appears to act.
- The weight of an object acting through the centre of mass can produce a turning force.

Case study

Alien landing

When NASA sent a probe to Cassini, one of the moons of Saturn, they did not know what would happen. They called it 'crash or splash'.

Imagine landing a spacecraft on an unknown planet.

Task

Tell the story of the journey of your spacecraft as it approaches and lands.

Tips

- Include the type of atmosphere on the planet, and how it changes close to the surface.
- Decide whether there are oceans, and what they are made of.
- Say whether your spacecraft would float or sink on any ocean.

Key Words

speed, metres per second, instantaneous speed, average speed, relative motion, distance–time graph, acceleration, gas pressure, compressed, atmospheric pressure, density, liquid pressure, incompressible, pressure, newtons per metre squared, pivot, moment, newton metres, law of moments, centre of gravity, centre of mass

End-of-chapter questions

1 Choose units of speed from the list below.

m/s m s h mph km/s km

(3 marks)

2 You can make a hole in a piece of wood if you bang in a nail with a hammer. If you hit the wood with the hammer it does not make a hole. Choose the best explanation for this from the statements below:

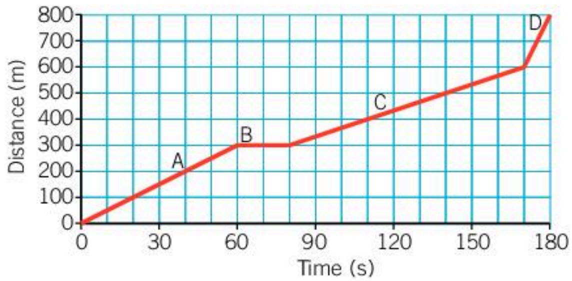
A The area of the nail is much smaller so the pressure is smaller.

B The area of the nail is much smaller so the pressure is bigger.

C The area of the hammer is bigger so the pressure is bigger.

(1 mark)

3 Here is a graph of a person riding his bike.



State the letter of the section where the student was:

a stationary *(1 mark)*

b moving fastest *(1 mark)*

c moving slowest. *(1 mark)*

(3 marks)

4

a Explain why it can hurt your hands when you carry heavy shopping in carrier bags. *(2 marks)*

b Explain why road bikes have narrow tyres but off-road bikes have wide tyres. *(2 marks)*

(4 marks)

5 A car is travelling at 70 mph and a lorry is travelling at 50 mph.

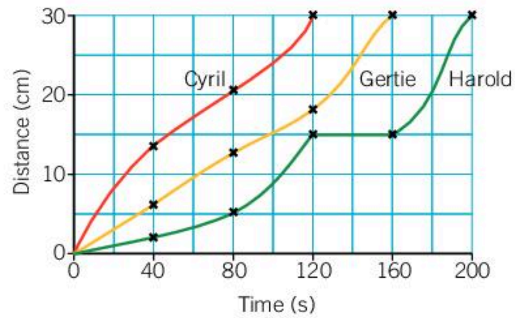
a Calculate the speed of the car relative to the lorry. *(2 marks)*

The car slows down to 50 mph.

b State the new speed of the car relative to the lorry. *(1 mark)*

(3 marks)

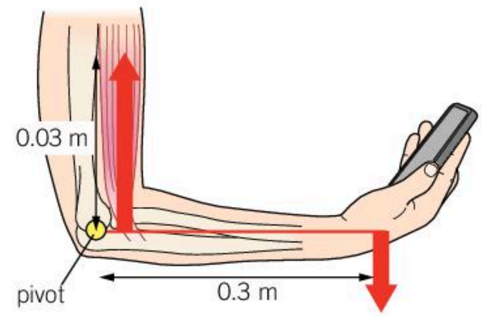
6 Here is a distance–time graph for three snails Cyril, Gertie, and Harold.



Compare the journeys of the three snails, and describe what happened to their speed during the journeys.

(6 marks)

7 Look at the diagram of an arm holding a phone. The phone has a weight of 1.5 N.



a Calculate the moment of the force exerted by the phone. *(2 marks)*

b Calculate the force that the muscle exerts to keep the phone in equilibrium. *(2 marks)*

c Explain why the force exerted by the muscle is much greater than the weight of the phone. *(2 marks)*

(6 marks)

8 You buy a bag of crisps in an airport. After take-off you take the crisps out of your rucksack. Explain in detail why the bag has expanded.

(6 marks QWC)

Physics 3

In this unit you will learn about how technology, from mobile phones to hospitals, has changed the way that we live our lives. You will learn how our ideas about the Universe have changed, and how people discovered electromagnetism and radioactivity. You will also learn about how scientists look for aliens, new particles, and how GPS works.

You already know

- Resistance = potential difference//current
- A microphone converts a sound wave to an electrical signal.
- Light waves and infrared radiation are waves.
- Waves can be reflected and refracted.
- Speed = distance/time.
- The Moon is in orbit around the Earth, which is in orbit around the Sun, which is one of billions of stars in the Universe.
- The Earth is one planet in the Solar System, which is part of the Milky Way galaxy.
- You can make an electromagnet from a coil of wire, battery, and nail.
- Electricity is generated in a power station.

Q

What is a light year?

BIG Questions

- How does your mobile phone work?
- How did the Universe begin?
- How would we know if there were aliens out there?

Picture Puzzler
Key Words

Can you solve this Picture Puzzler?

The first letter of each of these images spells out a science word that you will come across in this unit.

Picture Puzzler
Close Up

Can you tell what this zoomed-in picture is?
***Clue**: It glows in the dark.*

Making connections

In **P1** you learnt about non-contact forces.

In **P2** you learnt about electromagnets.

In **P3** you will learn about the electromagnetic spectrum and the use of the electromagnetic induction in electricity generation.

1.1 Your phone

Learning objectives

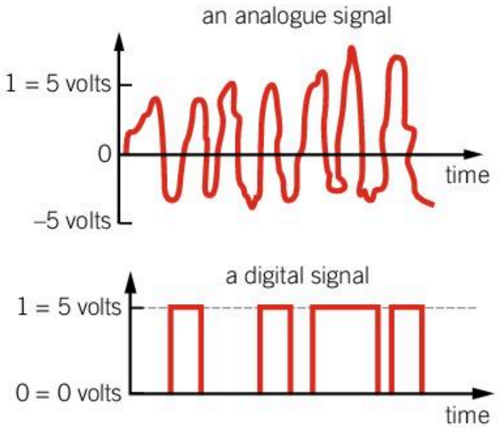
After this topic you will be able to:

- describe the difference between an analogue and a digital signal
- describe how waves can be used for communication.

▲ A microphone produces an analogue signal.

Link

You can learn more about how a microphone works in P1 2.4 Detecting sound



▲ An analogue signal can have any value, but a digital signal can have only two values.

These days we rely on smart phones and other devices that communicate. How do they work?

Your call

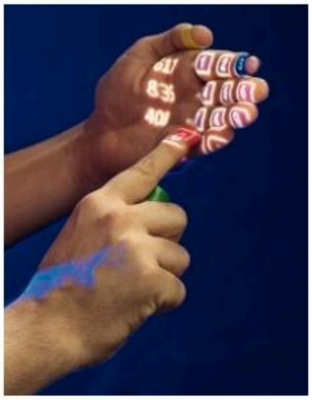
You speak into your phone, and a microphone detects what you say. It converts the sound into an electrical signal.

The electrical signal is an **analogue** signal. It can have any value. The wave on the screen on the left is an analogue signal.

The digital age

Your phone converts the analogue signal from the microphone into a **digital** signal. It takes the amplitude of the sound wave at different times and converts it to a **binary** number. A binary number uses only 1s and 0s. In binary the number 3 would be 11. You can see other binary numbers in the table opposite.

A signal made of 1s and 0s is a digital signal.



▲ You don't need a keyboard to operate this wearable computer.

Decimal number	Binary number (bit)
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010

A State the number of values that a digital signal can have.

Your friend's phone receives the digital signal and converts it back to an analogue wave. This is sent to a loudspeaker in the phone. She hears your voice.

Sending sounds as digital signals is a lot clearer than sending them as analogue signals.

Storing information

A 1 or a 0 is called a **bit** (short for **bi**nary digi**t**). If you put 8 bits together you get a byte. 1000 bytes = 1 kilobyte or 1 kB. 1 million bytes = 1 megabyte (1 MB), and 1 thousand million bytes = 1 gigabyte (1 GB).

When you store a song on your phone or laptop you store bits. Bits are stored like little pieces of magnetic material. If it is magnetised one way (say, N–S) it represents a 0. If it is magnetised the other way (S–N) it represents a 1.

B State the number of bits in a byte.

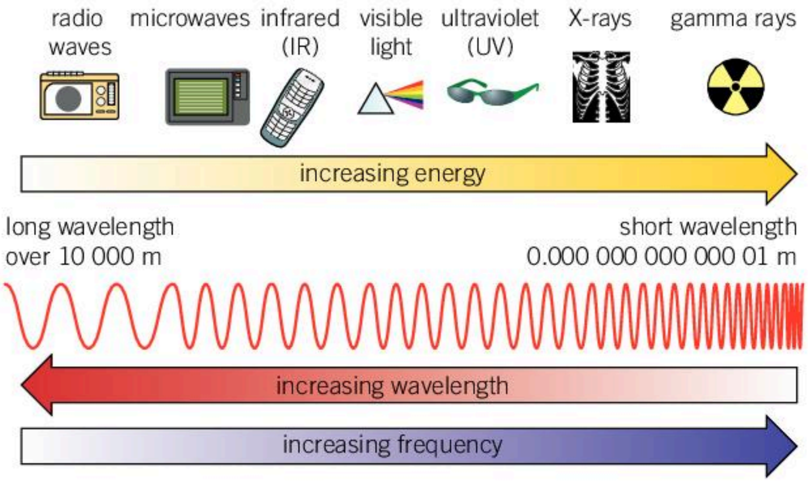
Sending and receiving

When you make a call or download a song you are transferring bits. That is why download speeds are calculated in bits per second. Information on CDs and DVDs is stored as a series of pits, which represent the bits.

▲ A CD stores bits.

Using waves

Most smart devices don't need wires to communicate. The bits are sent or received using waves with the 1s and 0s coded into them. The waves are waves of the **electromagnetic spectrum**.



Devices that communicate via Bluetooth and Wi-Fi use **microwaves**. Infrared communication uses infrared waves.

All electromagnetic waves travel at the same speed as light and can travel through a vacuum. **Radio waves** have the longest wavelength and the lowest frequency. They are used to send radio and television signals.

Fantastic Fact

There is more computing power in a birthday card that sings 'Happy Birthday' than there was in the entire world 50 years ago.

Key Words

analogue, digital, binary, bit, electromagnetic spectrum, microwave, radio wave

Remember those waves!
Make up a mnemonic so that you can remember the waves of the electromagnetic spectrum.

Summary Questions

1 Copy and complete the sentences below.

A smart phone uses a microphone to change sound to a signal that is ___________. This is converted to a ___________ signal made up of 1s and 0s. An ___________ wave transfers information to another phone. Waves such as radio, microwaves and ___________ are used for communication.

(4 marks)

2 Calculate how many songs of size 1 MB you can fit on a 500 GB hard drive.

(2 marks)

3 Compare analogue and digital signals and their uses.

(6 marks QWC)

1.2 Your house

Learning objectives

After this topic you will be able to:

- describe what is meant by efficiency
- describe how an LDR detects light.

▲ Lightbulbs have changed over the years.

Link

You can learn more about how power stations generate electricity in P2 2.6 Energy resources

▲ LEDs are much more efficient than incandescent lightbulbs.

Think what houses were like 150 years ago, before electricity was invented. Can you imagine not being able to just switch a light on? What do you think the lighting will be like in houses of the future?

Light it up

Old types of bulb

Fifty years ago everyone used incandescent lightbulbs. These contained a filament that got so hot that it gave out visible light. One big problem was that most of the energy transferred was dissipated. The lightbulbs were not very **efficient**. Lots of energy was being used to heat up the room, not light it.

If a device is efficient most of the energy transferred to it does what we want. We want the lightbulb to light up the room, not heat it.

You can work out efficiency as a percentage. Devices such as lightbulbs, hair straighteners, or televisions cannot be 100% efficient. Some energy always ends up heating the environment. The incandescent lightbulb was only 10% efficient. 90% of the energy heated up the air.

$$\text{efficiency (\%)} = \frac{\text{useful energy (or power) out} \times 100}{\text{total energy (or power) in}}$$

A State the efficiency of an incandescent lightbulb.

Better bulbs

Scientists worked to make lightbulbs more efficient. They invented a **light-emitting diode** or **LED**. LEDs are about 30% efficient. They are very versatile and can be fitted into clothing or phones, and made into impressive displays. Giant LED screens can display changing images during concerts.

Houses of the future will have LEDs that you can switch on and off, or make dimmer and brighter, by waving your hands or speaking.

Key Words

efficient, light-emitting diode (LED), light-dependent resistor (LDR), sensor, sensing circuit

How efficient?

LEDs of the future could be 45% efficient. For every 100 J that a future LED uses state:

- how much energy is used to light the room
- how much energy is used to heat it.

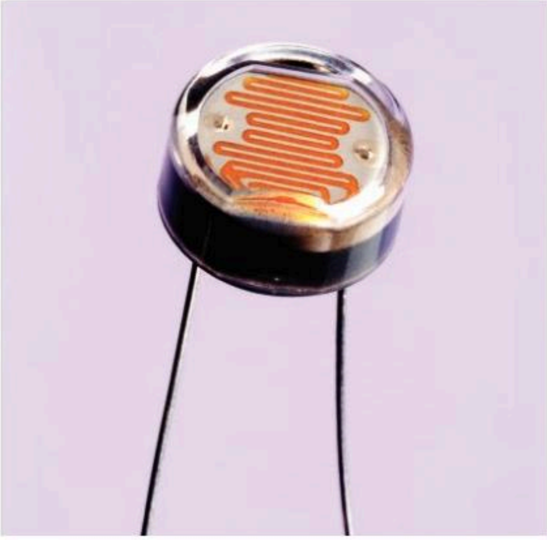
Detecting light

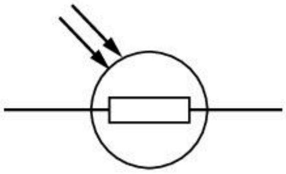
Have you ever gone to school and left the light in your bedroom on all day?

A house of the future could have circuits that detect if you are out, if it is daytime, and if the light is on – and then turn it off.

To detect light level you use a component called a **light-dependent resistor** or **LDR**. This is a **sensor**. It detects changes in its surroundings. The resistance of the LDR changes in different light levels.

B Name a component that can detect light level.





▲ An LDR and its circuit symbol.

If the light level is high the resistance of the LDR is low. To detect if it is daytime you need an LDR outside, and to detect if the light is on you need an LDR in the room. They would be part of a **sensing circuit**.

You can use a sensing circuit to control the light level in a house. It is possible to control circuits in your house by using your phone.

▲ LEDs can be built into clothing or footwear.

Fantastic Fact

If all the energy in your food heated you up you would glow like a 60 W lightbulb.

Summary Questions

1 Copy and complete these sentences.

A more efficient lightbulb is better at ___________ a room than a less efficient lightbulb. You can sense light level with an ___________. This could be used in a ___________ circuit to control the lights in a house.

(3 marks)

2 Compare LEDs and incandescent bulbs.

(2 marks)

3 Describe how an LDR detects light.

(2 marks)

4 Explain why LEDs could save money compared with incandescent bulbs. Use the efficiency equation to help.

(6 marks QWC)

1.3 Your hospital – intensive care

Learning objectives

After this topic you will be able to:

- describe how a thermistor detects changes in temperature
- describe how sensors can be used in hospitals.

▲ A sensor on the finger monitors pulse rate and oxygen levels.

Key Word

thermistor

Press release

Summarise how physics is used in an intensive care unit in under 100 words.

Many premature babies would not survive without an incubator. Their temperature needs to be kept constant. Equipment in intensive care keeps patients alive.

Monitoring the patient

How hot?

It is very important to keep the temperature inside an incubator high enough so that the baby is kept warm. You can monitor the temperature using a circuit component called a **thermistor**. The resistance of a thermistor changes with temperature. If the temperature increases the resistance decreases. If the temperature decreases the resistance increases.

▲ A thermistor and its circuit symbol.

If the temperature inside the incubator falls, the voltage across the resistor increases. This could be used in a sensing circuit to switch on a heater. The thermistor can also be used to make sure that the temperature does not rise too high.

A State the name of the component that detects temperature.

Pulse rate and oxygen

Your pulse rate shows how fast your heart is beating. Doctors and nurses can take your pulse by feeling with their fingers on your wrist or neck. But in hospital it is often important to monitor the pulse rate continuously, and also the oxygen in the blood.

If you hold a torch under your finger in the dark you will see that your finger is translucent. To monitor the pulse rate and oxygen levels, a sensor on the patient's finger emits visible light and infrared radiation. Blood with lots of oxygen absorbs the infrared more than the visible light. This is how they monitor the oxygen levels.

Heartbeat

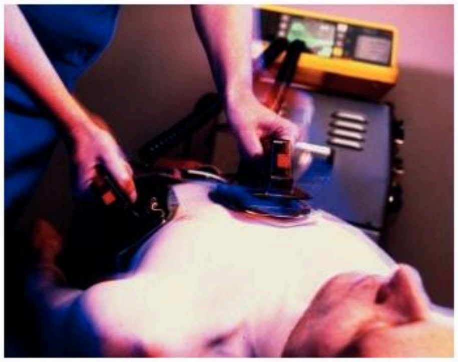
For heart patients it is important to monitor electrical changes in the heart, which happen every time the heart beats. Doctors attach electrodes to the patient's skin. These are gel pads that detect small changes in potential difference. The machine amplifies the potential difference and displays it on a screen. The information can be converted to a digital signal that is used by a computer.

B State what electrodes attached to the skin detect.

▲ The screen shows the changes in potential difference as the heart beats.

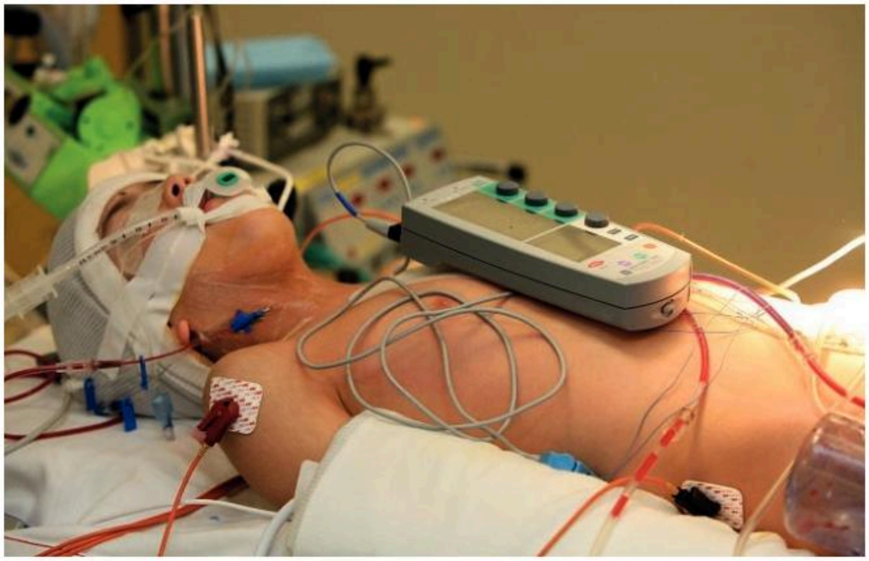
Keeping the patient alive

There are lots of pieces of equipment in an intensive care unit that use physics to help keep people alive.



▲ A defibrillator uses stored charge to produce a large potential difference. First aiders use this to start someone's heart when it has stopped beating.

▲ A ventilator uses an electric motor to move a piston up and down. This pumps air into the lungs of a patient who is struggling to breathe.



▲ A pacemaker can keep a patient's heart beating. It applies a potential difference at regular intervals to the heart muscles.

Foul Fact

When your heart beats it produces enough pressure to squirt blood 10 m.

Summary Questions

1 Copy and complete the sentences below.

You can use a __________ in a circuit to detect temperature. Doctors use visible light and __________ radiation to monitor a patient's pulse. Electrodes connected to a patient's chest can measure __________ __________. A __________ can keep a heart pumping, and a __________ can start a heart that has stopped.

(5 marks)

2 Describe how you can use a thermistor to monitor temperature in a circuit.

(3 marks)

3 Compare how pulse rate and heartbeat are monitored.

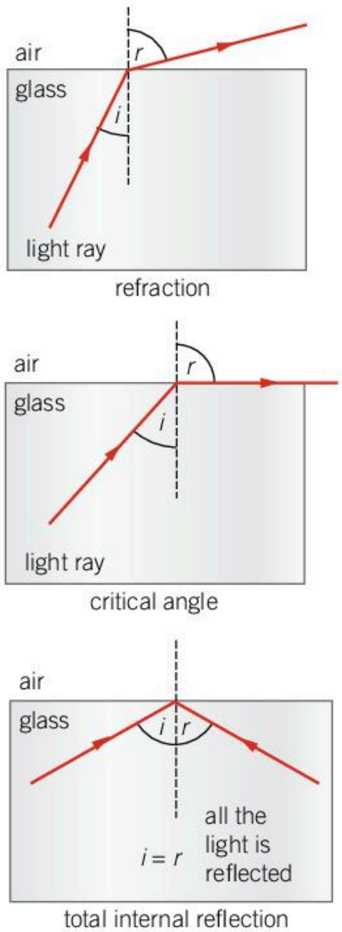
(6 marks QWC)

1.4 Your hospital – seeing inside

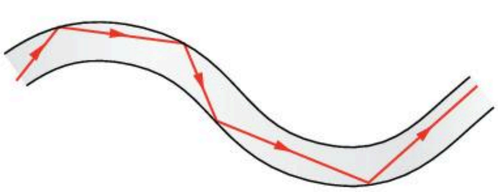
Learning objectives

After this topic you will be able to:

- describe how optical fibres work
- describe some techniques for seeing inside the human body.



▲ Light can be refracted or reflected inside a piece of glass.



▲ Light is totally internally reflected as it goes down an optical fibre.

You may have had an X-ray, or know someone who has. Before X-rays were used, the only way to find out what was happening inside was to cut a patient open. Today doctors have lots of ways of seeing inside the body.

Using waves of the electromagnetic spectrum

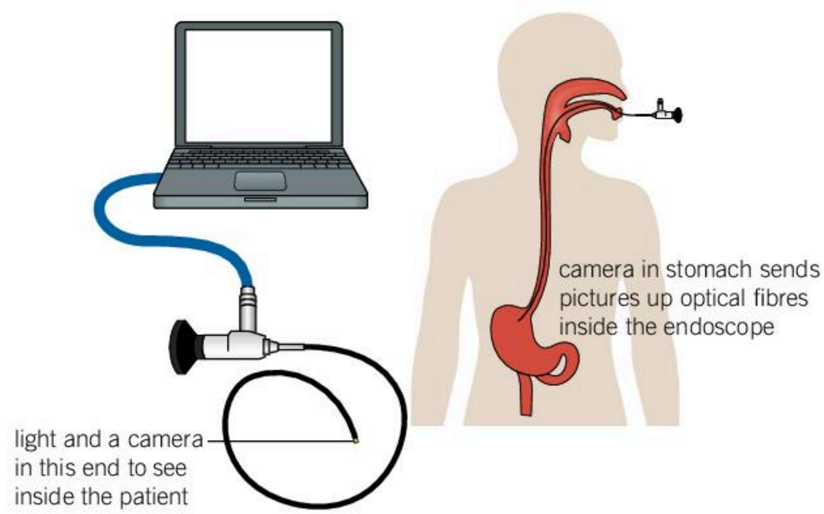
Visible light

One of the simplest ways of seeing inside someone is to use a 'light pipe' called an **endoscope**.

If light hits the boundary between glass and air at a shallow angle it refracts. If it hits at a very large angle it reflects. There is a special angle, called the **critical angle**, where the angle of refraction is 90°.

A State what is meant by critical angle.

This type of reflection, where the light reflects back and stays inside the glass, is called **total internal reflection**. It happens inside thin glass fibres called **optical fibres**.



▲ An endoscope contains optical fibres to see inside a patient.

X-rays

X-rays are waves of the electromagnetic spectrum. They have a much higher frequency, and higher energy, than light.

Bones absorb X-rays more than soft tissues such as muscles and internal organs. A machine emits X-rays that travel through your body to a detector. The amount of X-rays that pass straight through or are absorbed builds up a picture of what's inside the body.

Gamma rays

You can see how well someone's kidneys are functioning using **gamma rays**. A patient drinks a medical tracer, a special chemical that is taken in by their kidneys. A detector detects the gamma rays and forms an image. Gamma rays have the highest frequency and energy of all the waves of the electromagnetic spectrum.

B Name three waves of the electromagnetic spectrum that are used to see inside the human body.

Using sound and magnets

Ultrasound

Doctors can use an ultrasound transmitter and receiver on the end of an endoscope. This produces an image of internal organs that you cannot see very easily with X-rays or a normal endoscope.

Magnetic resonance imaging

Magnetic resonance imaging (**MRI**) scanners use very, very powerful electromagnets to make images of the inside of the body. They allow doctors to see how organs, including the brain, work. MRI scanners are very expensive and the patient has to lie very still in a small space while the scan is taken.

▲ A patient inside an MRI scanner.

Crossword clues

Make a crossword using the waves of the electromagnetic spectrum mentioned on these two pages, as well as ultrasound. Write clues for each type of wave.

Fantastic Fact

The magnetic field inside a hospital scanner is so strong it can levitate a frog. If a magnetic field was strong enough it could levitate a human.

Key Words

endoscope, critical angle, total internal reflection, optical fibre, X-ray, gamma ray, magnetic resonance imaging (MRI)

Summary Questions

1 Copy and complete the sentences below, choosing the correct bold words.

When light hits the inside of a glass fibre at an angle **bigger/smaller** than the critical angle it is **reflected/refracted**. This is used to see inside patients with an **endoscope/telescope**. Doctors can also use **X-rays/microwaves** and **gamma rays/ultraviolet** to see inside patients.

(5 marks)

2 Describe the conditions for light to be totally internally reflected.

(2 marks)

3 Describe how a doctor can investigate the functions of the following organs:

a the brain **b** the kidneys

(4 marks)

4 Compare the use of light, sound, and magnets to see inside the human body.

(6 marks QWC)

1.5 Your sports

Learning objectives

After this topic you will be able to:

- describe how technology is used in sport
- describe what is meant by reaction time.

▲ Some sports rely on technology.

Key Words

projectile motion, reaction time, uncertainty

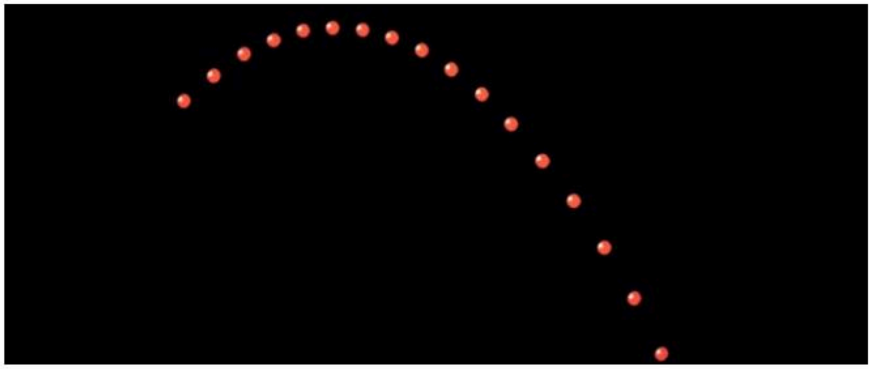
▲ It takes time for you to react to what you see or hear.

Sometimes a player challenges a call in a game of tennis. An animation on the big screen shows whether the ball was in or out. How does it work?

Spot the ball

If you hit a ball you can work out where it will go if you know the speed at the start, called the initial speed, and the angle at which you hit it. The way it moves is called **projectile motion**. While the ball is in contact with the racket there is a force on it. This changes the speed and direction of motion of the ball.

When the ball is not in contact with anything there are only two forces acting on it: air resistance and weight. The air resistance reduces the speed and the weight pulls it towards the Earth. The ball slows down and falls down.



▲ A ball follows a path that you can predict.

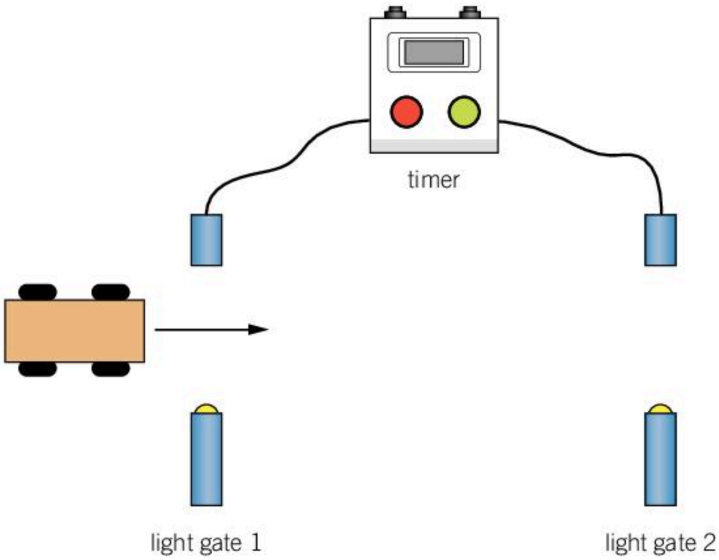
A camera can take photographs of the ball many times a second. From this a computer can work out the position of the ball each time and can predict where it will land.

A State the two things that you need to know to work out where a tennis ball will go when you hit it.

How fast can you react?

Think about measuring the time for the 100-m sprint on sports day. You listen for the sound that starts the race and start the stopwatch as soon as you can. It takes time for the signal from your ears to reach your brain, and the signal from your brain to reach your hand. This is called **reaction time**.

B State the name of the time that it takes you to react.



▲ Light gates produce more accurate and precise results than a stopwatch.

Your reaction time is about 0.2 seconds. You should take this into account when you consider the quality of your data in an investigation. There are more accurate ways of measuring time, such as light gates. In the diagram above, when the car crosses the beam of light at gate 1 the clock starts, and when it crosses the beam of light at gate 2 the clock stops.

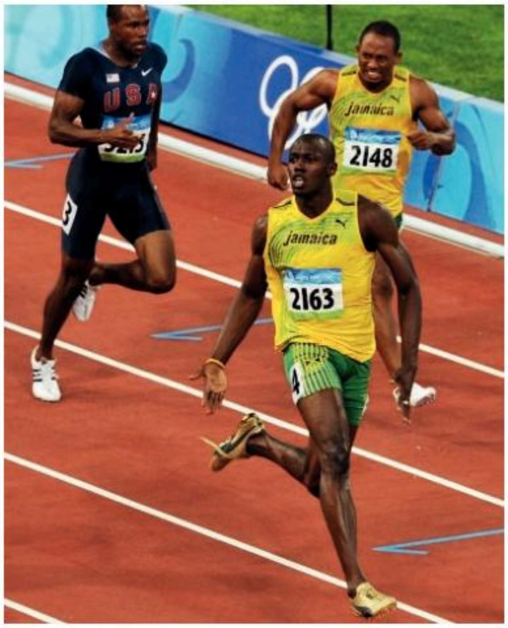
Keeping safe

Many sports can be dangerous. Formula 1 drivers wear helmets and their cars are designed to protect them from injury if there is an accident. Formula 1 and other cars have features to increase the time of contact in a collision. If you increase the time that it takes for the car to stop, you reduce the forces on the people inside. They are less likely to be injured.

Uncertainty

If you measure the time for the 100-m sprint your stopwatch might show 00:00:18.3258. This means 0 hours, 0 minutes, and 18.3258 seconds. You should round up to 18.5 seconds because of your reaction time.

There is an **uncertainty** in this result because of your reaction time. Most people's reaction time is about 0.2 seconds.



▲ Sporting events need to measure the time for the 100-m sprint accurately, without reaction times.

Summary Questions

1 Copy and complete the sentences below.

A computer can predict where a ball will land because it works out how forces change the __________ and direction of motion of an object. Measuring time with a stopwatch is affected by your __________ time. Racing cars are designed to increase the __________ of a collision to reduce the __________ on the driver.

(4 marks)

2 Describe what is meant by the term reaction time.

(2 marks)

3 Compare the use of a stopwatch and light gates to measure the time it takes a ball to reach the ground.

(4 marks)

4 Discuss the impact that technology has had on sport.

(6 marks QWC)

1.6 Your planet

Learning objectives

After this topic you will be able to:

- explain why demand for electricity is increasing
- describe how future demand for electricity could be met.

Link

You can learn more about kWh in P2 2.7 Energy and power

Key Words

nuclear fusion

Fantastic Fact

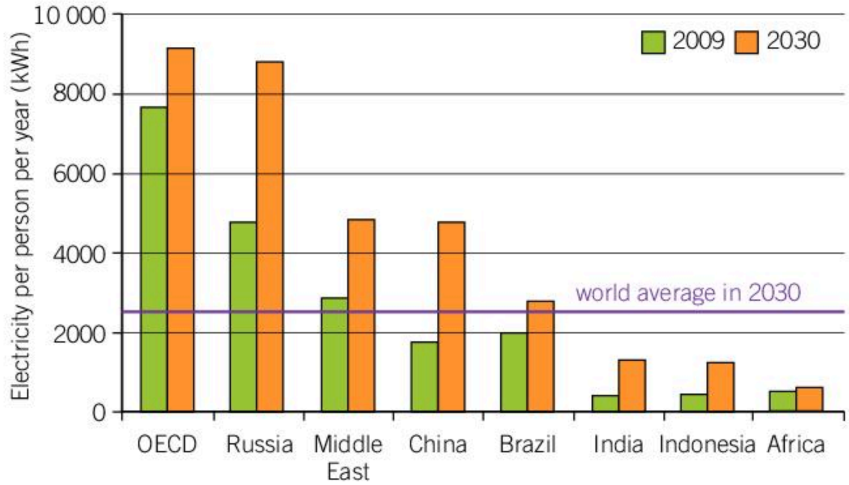
The Sun is getting less massive every day. The energy that it radiates is a result of converting mass to energy.

▲ The UK generates some electricity using wind turbines.

You may have heard people talk about saving energy, or the energy crisis.

What's the problem?

The global demand for electricity is increasing. The chart compares electricity demand between 2009 and 2030, in kWh per person per year. Computer models help scientists to make predictions.



▲ A computer model predicts electricity demand.

Demand could increase for several reasons, such as:

- We use a lot more electrical devices.
- The population of the planet is increasing.
- Countries that did not have a big demand for electricity now have a bigger demand.

There are many consequences of this increase, such as climate change, pollution of the air, water, and soil, and the environmental impact on water and land.

A State one reason why demand for electricity is increasing.

Possible solutions?

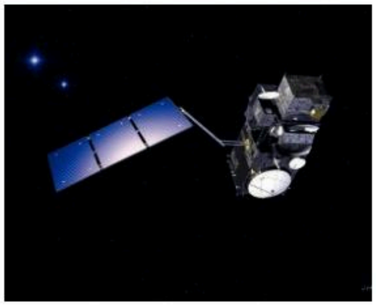
We can try to use methods of generating electricity that do not contribute to climate change or produce pollution.

Renewable resources such as wind turbines do not produce carbon dioxide when they are being used. They do produce carbon dioxide when they are being built. Biofuels produce carbon dioxide when they are burned.

Traditional power stations use fossil fuels to boil water to make steam to turn a turbine, which drives a generator. Wind, waves, tides, or falling water can turn a turbine instead. Geothermal energy pumps water underground to produce the steam.

B Name two renewable resources that can turn a turbine.

Solar cells do not need a generator. The cells absorb light from the Sun and produce a potential difference directly. Solar cells are getting more and more efficient. Carbon dioxide is produced when solar cells are made, but not when they are running. In the future solar cells in your clothes could power your phone or other mobile devices.

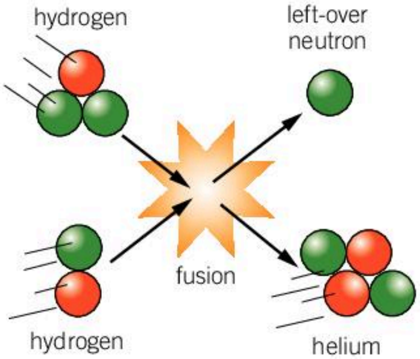


▲ Solar cells generate electricity in remote places.

Fusion

One of the most exciting projects produces energy from **nuclear fusion**. This is just the same as the process that provides energy in the Sun.

Hydrogen atoms join together to make helium and a lot of energy is produced. The reaction does not produce any greenhouse gases.



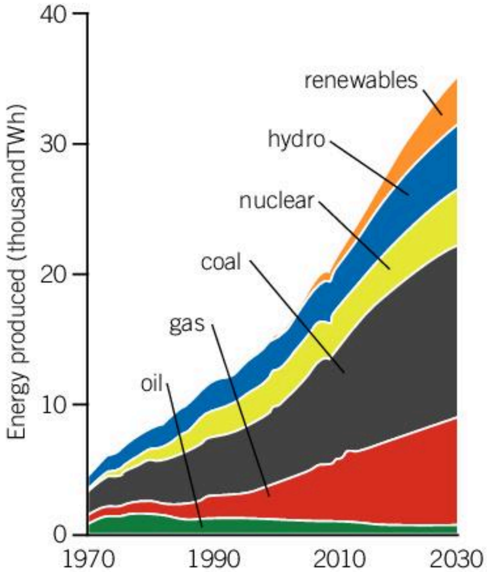
▲ A fusion reaction is not like a normal chemical reaction.

C Name the process that makes the Sun shine.

A fusion reactor needs to heat the hydrogen to a very high temperature. If scientists could make a working reactor then our energy problems could be solved.

How many?

Write an electricity journal for a day that lists everything electrical that you use.



▲ Different resources used worldwide to generate electricity.

Summary Questions

1 Copy the sentences below, choosing the correct bold words.

The demand for electricity is **decreasing/increasing** because the population is **decreasing/increasing**. Another reason is that the number of devices that need electricity is **decreasing/increasing.** We need to find alternatives that **do/don't** contribute to climate change.

(4 marks)

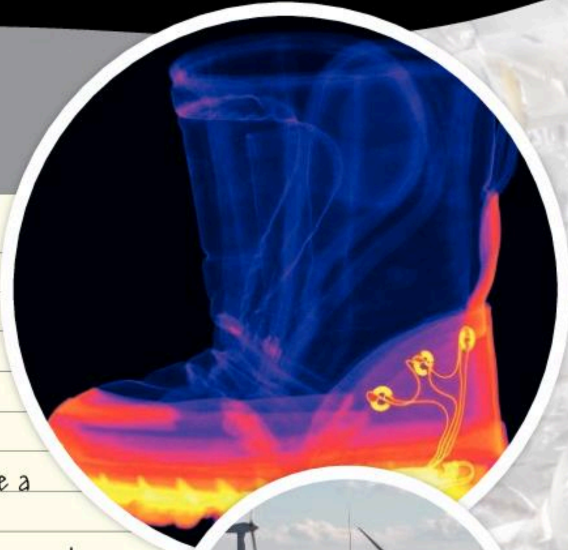
2 Suggest and explain two alternatives to fossil fuels that could generate electricity in the future.

(4 marks)

3 Design a game of snakes and ladders based on the pros and cons of different ways of generating electricity. Write an explanation on each snake or ladder.

(6 marks)

P3 Chapter 1 Summary



Key Points

- An analogue signal can have any value. A digital signal is a series of 1s and 0s.
- You can use radio waves, microwaves, infrared, and visible light for communication. These waves are part of the electromagnetic spectrum together with ultraviolet, X-rays, and gamma rays.
- A device is efficient if very little energy is wasted. Light-emitting diodes are more efficient than incandescent lightbulbs.
- You can use a light-dependent resistor to monitor light level. You can use a thermistor to monitor temperature.
- You can use sensors to monitor pulse rate and heart rate, and defibrillators and pacemakers to start and maintain a heartbeat.
- Light that hits the inside of a glass fibre at an angle bigger than the critical angle is totally internally reflected. This allows doctors to see inside people using an endoscope.
- Doctors use X-rays, ultrasound, and gamma rays to see inside the human body.
- You can use light gates to reduce the impact of reaction time in sporting events.
- Sports cars are designed to reduce the force on a driver in an accident by increasing the time the collision lasts.
- The demand for electricity is increasing because the population is getting bigger and we are using more electrical devices. In the future the demand will need to be met using a range of renewable and non-renewable resources, or new technology such as nuclear fusion.

Key Words

analogue, digital, binary, bit, electromagnetic spectrum, microwave, radio wave, efficient, light-emitting diode (LED), light-dependent resistor (LDR), sensor, sensing circuit, thermistor, endoscope, critical angle, total internal reflection, optical fibre, X-ray, gamma ray, magnetic resonance imaging (MRI), projectile motion, reaction time, uncertainty, nuclear fusion

Big Write

The big exhibition

Your local council wants to put on an exhibition in a shopping centre that shows the impact of technology on people's lives. They want to make big display boards to highlight how much we all rely on technology without realising it.

Task

Produce designs for at least four boards for the exhibition.

Tips

- Decide which areas of everyday life to include.
- Think about how to introduce the scientific ideas to the general public.
- Make the boards attractive so that people will stop and read them.

End-of-chapter questions

1 State which of the waves in the list below are waves of the electromagnetic spectrum.

radio waves	sound waves	visible light
X-rays	infrared	water waves

*(**4 marks**)*

2 Match the device to its correct definition.

Device	**Definition**
LDR	used to see inside people
thermistor	used to detect light
LED	used to detect temperature
endoscope	an efficient lightbulb

*(**4 marks**)*

3 State which of the following times is likely to be your reaction time.

2 seconds	0.02 seconds
0.2 seconds	20 seconds

*(**1 mark**)*

4

a Name **two** ways that doctors can use technology to see inside the human body without surgery. *(2 marks)*

b Name **two** ways that engineers can reduce the risk of injury to a car driver. *(2 marks)*

*(**4 marks**)*

5 A student is investigating solar cells. She puts a solar cell on the desk below a lamp and connects it to a voltmeter. She puts thin layers of clear plastic film on top of it to see if the output of the solar cell is affected by them.

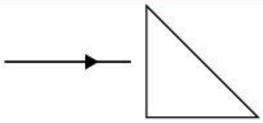
a State the question that she is investigating. *(1 mark)*

b Draw a table that she could use for her results. *(1 mark)*

c State and explain the type of graph that she could draw. *(2 marks)*

*(**4 marks**)*

6 The following diagram shows light going into a prism. The critical angle is 42°.



a Copy and complete the diagram to show what happens to the ray. Use a protractor to measure the angles. *(4 marks)*

b Explain why you have completed the diagram in the way that you have. *(2 marks)*

*(**6 marks**)*

7 Sketch and explain the shape of a graph of the resistance of a thermistor against temperature. *(**2 marks**)*

8 Copy and complete the sentences using the words 'digital' or 'analogue'.

a The signal produced by the microphone in your mobile phone is __________. *(1 mark)*

b The signal transmitted by your mobile phone is __________. *(1 mark)*

c The signal received by your friend's mobile phone is __________. *(1 mark)*

d The signal produced by the loudspeaker in your friend's mobile phone is __________. *(1 mark)*

*(**4 marks**)*

9 Look at the table below. It shows four different devices. Use the law of conservation of energy and the equation for efficiency to complete the table.

Device	Useful energy (J)	Wasted energy (J)	Total energy (J)	Efficiency
lightbulb	5		25	
kettle		500	2000	
television	2500	2500		
car	100		400	

*(**8 marks**)*

10 A gardener wants to use sensors to monitor the temperature in his greenhouse. Describe in detail how he could use thermistors and a heater to keep the temperature in his greenhouse constant.

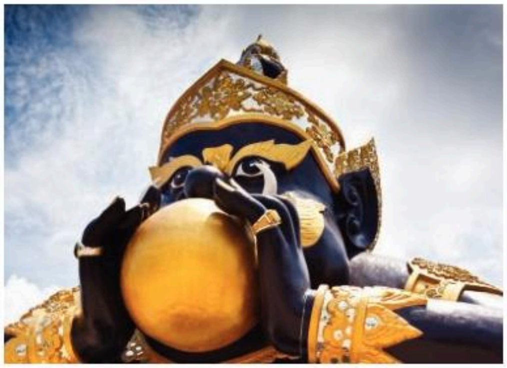
*(**6 marks QWC**)*

2.1 Discovering the Universe 1

Learning objectives

After this topic you will be able to:

- describe some ideas about the Universe that developed in different cultures
- describe the geocentric model of the Solar System.



▲ People in Thailand thought that solar eclipses happened when a god called Rahu swallowed the Sun.

What do scientists do?

Scientists use **evidence** from observations and measurements to develop explanations. They use the explanations to make **predictions** about what will happen in the future.

Link

You can learn more about lunar and solar eclipses in P1 4.4 The Moon

Key Words

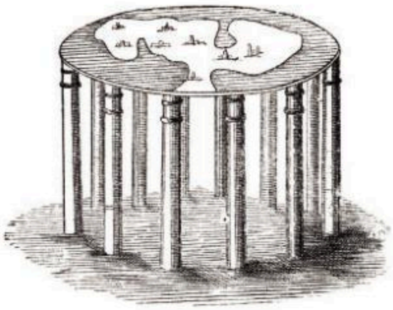
evidence, prediction, model, geocentric model

How have ideas about the Universe changed? What did people who lived thousands of years ago believe?

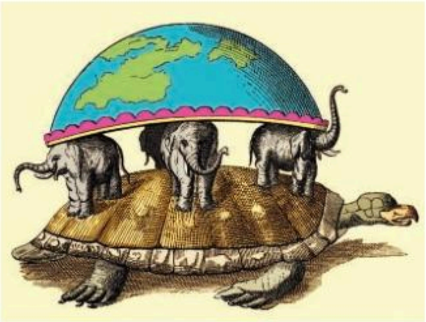
Telling stories

People used to tell stories about the Sun, Moon, and other objects in the sky. The stories explained why things happened, like the Sun rising and setting, and why eclipses happened. Some people thought that the Sun was eaten by monsters during a solar eclipse. Many of the ancient ideas about the Earth said that the Earth was flat.

Thousands of years ago there were people who thought that a flat Earth was supported by pillars, or surrounded by oceans. By 300 BC most people in Europe thought the Earth was a sphere, but the flat-Earth idea continued in China until about 1600.



▲ People in India thought that a flat Earth was supported by 12 pillars.



▲ There was another idea, that the Earth was supported on the back of a turtle.

The stories people used to tell were not scientific explanations.

A State two things that scientists do to collect evidence.

Making models

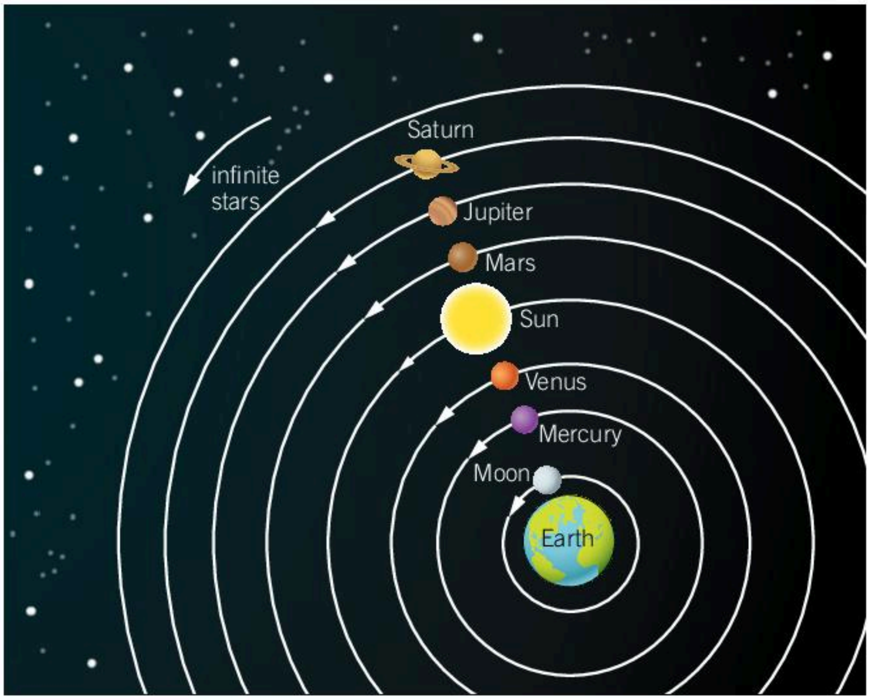
People couldn't look for patterns in their observations of the night sky until writing and numbers had been invented. They needed to make measurements and write them down.

When scientists noticed patterns, they tried to explain them by making **models**. A model can be something physical, or it can use equations. Models help us to explain what we see and to predict what will happen.

Early models of the Universe

Astronomers in India, China, and the Middle East had different ideas about the objects they could see in the sky. Some people believed that the Earth did not move. This was the **geocentric model**. In this model the Sun, Moon, planets, and stars moved around the Earth. They moved on crystal spheres that light could travel through.

Two Greek astronomers, Plato and Aristotle, wrote books explaining this model over 2000 years ago.



▲ The geocentric model of the Universe with the Earth at the centre.

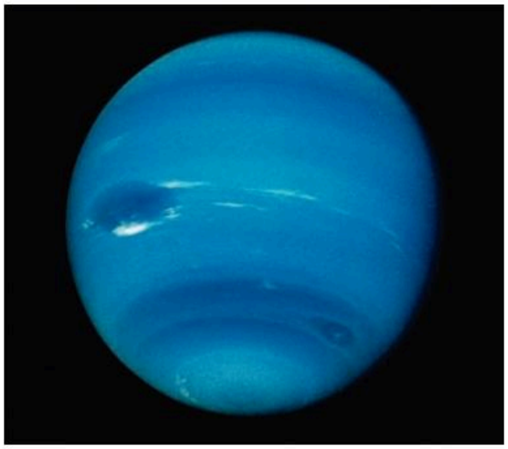
B Name the model of the Universe with the Earth at the centre.

Same idea, different place

Some ideas are not new.

An Indian mathematician and astronomer called Bhaskaracharya lived around 1000 years ago. He said that there was a force between all objects. This is the force that we call gravity. He worked out that the Earth attracted the Moon 500 years before Isaac Newton published his ideas about gravity.

Newton had the same idea as Bhaskaracharya but he used equations in his explanation. Astronomers used Newton's equations to predict that there was a planet beyond Uranus. Newton's idea was very powerful because you could use it to make predictions.



▲ The planet Neptune was where Newton predicted it would be.

Strange moon

Imagine you have gone back in time to ancient Thailand. Describe how you could show people how eclipses really happen.

Summary Questions

1 Match the model or story to the country it comes from.

the geocentric model	India
the Earth on the back of a tortoise	Thailand
the Sun is swallowed by a god during an eclipse	Greece

(3 marks)

2 Describe the geocentric model of the Universe.

(2 marks)

3 Think about the stories that people used to tell each other about stars and planets. Compare these with the geocentric model of Newton and Bhaskaracharya.

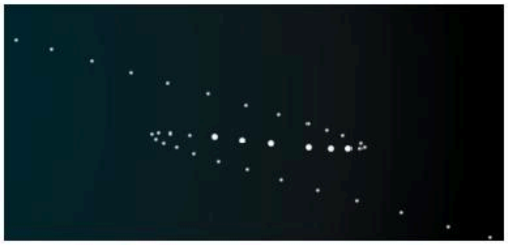
(6 marks QWC)

2.2 Discovering the Universe 2

Learning objectives

After this topic you will be able to:

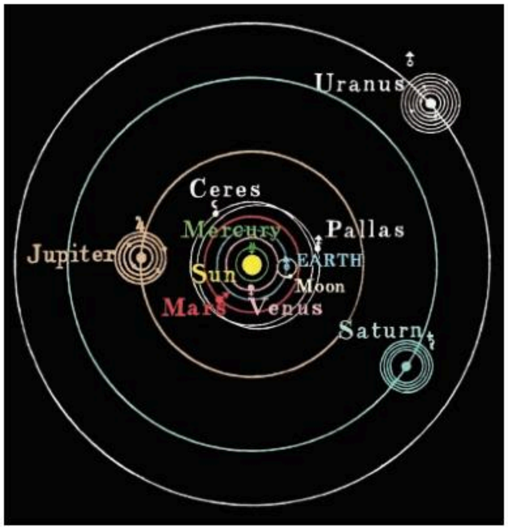
- describe how observations led to a different model of the Solar System
- describe the heliocentric model of the Solar System.



▲ Each dot shows the position of Mars every week for several months.

Key Words

retrograde motion, heliocentric model



▲ The heliocentric model.

You know that the Sun, not the Earth, is at the centre of the Solar System. How did astronomers work that out?

Our model doesn't work

The geocentric model was very popular. Aristotle was a very famous scientist and people trusted what he said. His ideas spread all over the world and people accepted the geocentric model. It explained lots of the observations that people saw every day.

- The ground did not seem to move.
- The Sun and Moon did appear to move.
- The stars also appeared to move.

There was a problem. Sometimes the planets appeared to go backwards. This is called **retrograde motion**. You do not notice it during one night, but if you make observations over several months you can see that the paths of the planets change direction.

A Name the type of motion where the planets appear to move backwards.

It was difficult to explain these observations using the geocentric model. Greek scientists at the time could have rejected the geocentric model and looked for a different model.

They didn't. A scientist called Ptolemy changed the model so that the planets went in complicated orbits. He published his ideas in about 140 AD.

Lots of astronomers all over the world accepted Ptolemy's changes.

A better model

The Greek astronomer Aristarchus had described a different model in around 200 BC. In this model the planets orbited the Sun. This is the **heliocentric model**, the model we use today.

In 1030 Indian astronomers such as Al-Biruni were discussing a heliocentric model.

It was not until 1543 that a book with this model was published. The author was Nicolaus Copernicus.

B Name the model of the Solar System with the Sun at the centre.

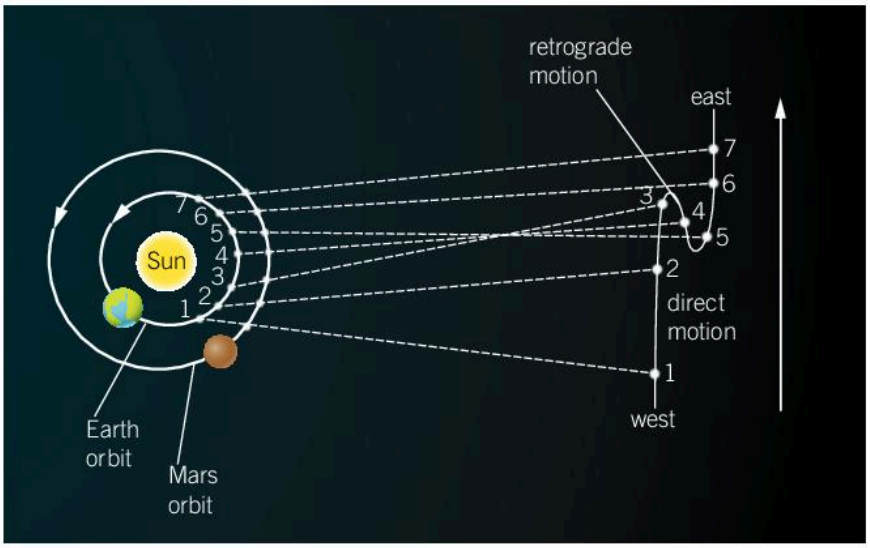
New technology

Galileo Galilei was an Italian physicist. In 1609 Galileo used a new invention called a telescope. He saw objects in orbit around Jupiter, not in orbit around the Earth. They were moons of Jupiter, and they are called the Galilean satellites after him.

This was evidence that not everything was in orbit around the Earth. This idea went against what the Church believed. Galileo's observations provided new evidence for the heliocentric model, but it took a long time for it to be accepted.

Link

You can learn more about telescopes in P3 3.1 Detecting planets



▲ It is easier to explain retrograde motion using the heliocentric model.

Keep it simple

The heliocentric model can explain retrograde motion more simply than the geocentric model. Simple explanations are important in science. If an explanation becomes too complicated scientists will start to look for a simpler explanation.

Date	Where	Idea
850 BC	India	The Earth is in motion around the Sun.
350 BC	Greece	Aristotle describes the geocentric model in a book.
200 BC	Greece	Aristarchus describes the heliocentric model in a book.
151	Greece	Ptolemy publishes his revised geocentric model.
1300	Baghdad	Ibn al-Shatir improves Ptolemy's model.
1543	Poland	Copernicus publishes the heliocentric model.

Foul Fact

You can see one of Galileo's fingers in a museum in Florence, Italy. They were cut off his body 95 years after his death and then lost for nearly 300 years.

Geo-?

'Geo' means 'Earth' in Greek, so 'geocentric' means 'with the Earth at the centre'. Try to work out what the other half of these 'geo' words mean: 'geography', 'geometry'. What do you think 'helio' means?

Summary Questions

1 Copy and complete the sentences below, choosing the correct bold words.

The geocentric model **did/did not** explain retrograde motion in a simple way. It took observations by **Galileo/Copernicus** to provide evidence for the heliocentric model.

(2 marks)

2 Explain why Galileo's observations could not be explained using the geocentric model.

(2 marks)

3 Describe the heliocentric model of the Universe.

(2 marks)

4 Draw a timeline to show and explain the development of the geocentric and heliocentric models of the Solar System.

(6 marks)

2.3 The Big Bang

Learning objectives

After this topic you will be able to:

- describe the timescale of the Universe
- describe what is meant by the Big Bang.

How did the Universe begin? When did it start?

Are we special?

When you observe other galaxies you find that they are all moving away from us. You might think that our planet, or our galaxy, is very special, and that we are at the centre of the Universe. This is not the case. If we lived in the Andromeda galaxy we would see exactly the same thing. The Milky Way would appear to be moving away from us.

Imagine that you are on the surface of a balloon that has dots on it. The dots are like galaxies. As you blow up the balloon each dot is moving away from every other dot.

An astronomer called Edwin Hubble made these observations about galaxies moving away from us in 1929. He also found out that galaxies that were further away were moving faster. The Hubble Space Telescope (HST) is named after him.

▲ You can make a model of the expanding Universe with a balloon.

The Big Bang

Most scientists think that the Universe began with the **Big Bang**. All of space and time expanded from something smaller than an atom. The Universe has been expanding ever since. The Big Bang theory explains why galaxies are moving apart and why the galaxies that are further away are moving faster.

▲ The HST is named after the person who coined the term 'Big Bang'.

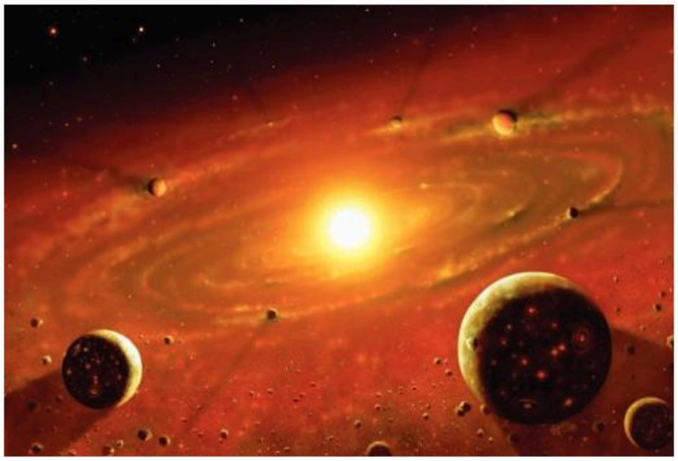
A Name the theory that scientists have for how the Universe started.

Just a theory?

Sometimes it is confusing when scientists use the word 'theory'. It doesn't mean that they are not sure. It means that it is the best explanation that scientists have for all of the evidence.

What happened after the Big Bang?

Scientists believe that the Big Bang happened about 14 billion years ago. After about 150 million years the first stars started to appear. Galaxies started to form after billions of years. It wasn't until 9 billion years after the Big Bang that our Solar System formed. That was 5 billion years ago.



Our Solar System formed from a disc of dust and gas.

Life on Earth probably started about 4 billion years ago. The dinosaurs lived between 200 million and 65 million years ago. Humans have existed for less than half a million years.

B State the age of the Solar System.

Modelling timescale

Sometimes it is very difficult to imagine things that are very big, like the timescale of the Universe. It is good to make a model, or an **analogy**, to make it easier to understand.

Imagine that the timescale of the Universe is compressed into a year. If the Big Bang happened on 1 January, the Solar System would form in August, and humans would appear at 11.30 p.m. on 31 December.

The big question

One question that seems very confusing is this one:

"If the Universe is infinite, and it is expanding, what is it expanding into?"

It is hard to think of what an infinite Universe means. It means that there is no edge to it. There is no 'outside' for the Universe to expand into.

Think of the whole of space filled with dough. The dough goes on and on for ever and never stops. Inside the dough are raisins, just like galaxies. The dough expands and the raisins get further apart. This is what is happening in our Universe. The space between galaxies is expanding.

Key Words

Big Bang, analogy

Fantastic Fact

Some scientists believe that microbes on asteroids or comets developed into life on Earth.

The expanding Universe is like expanding dough.

Summary Questions

1 Order these events, starting with the earliest.

first living things
formation of the Solar System
Big Bang
dinosaurs died out

(4 marks)

2 Compare the age of the Earth and the age of the Universe.

(2 marks)

3 Describe what is meant by the Big Bang.

(2 marks)

4 Draw a scaled timeline of the Universe until today. Include a suitable scale and include key events from these pages.

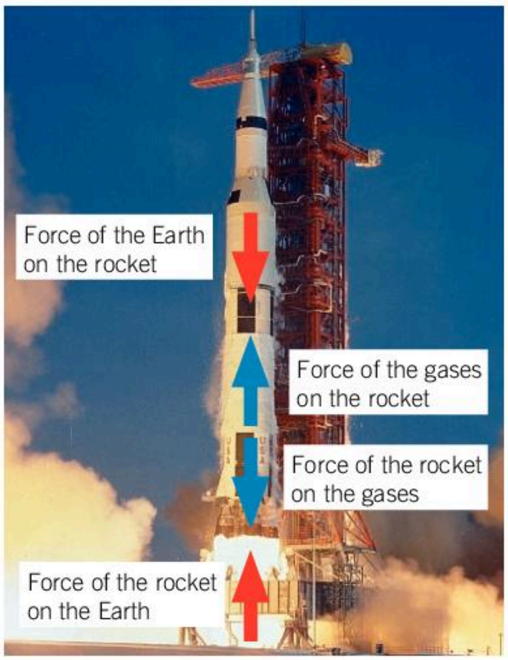
(6 marks)

2.4 Spacecraft and satellites

Learning objectives

After this topic you will be able to:

- describe how to get a satellite into orbit
- describe some uses of satellites.



▲ If you ignore drag, there are two forces acting on a rocket when it takes off.

▲ The Voyager missions sent spacecraft through the Solar System.

Fantastic Fact

Outer space starts 62 miles above the surface of the Earth. Higher than that the air is too thin for planes to fly.

The first living things to go to outer space were fruit flies. How do space scientists launch objects into space?

Into space

You have probably blown up a balloon and let it go. The balloon flies off. The force of the balloon on the air pushes the air backwards. The force of the air on the balloon pushes the balloon forwards. This is a bit like how scientists put a satellite into orbit.

They launch a satellite by attaching it to a rocket. Fuel burns inside the rocket and pushes the waste gases out of the bottom of it. This 'push' is one part of an interaction pair. There is the force of the rocket on the gases, and the force of the gases on the rocket.

There are also forces between the rocket and the Earth. When the force of the air on the rocket is bigger than the force of the Earth on the rocket, it will take off.

A Name the two forces shown in the image on the left that act on the rocket as it takes off.

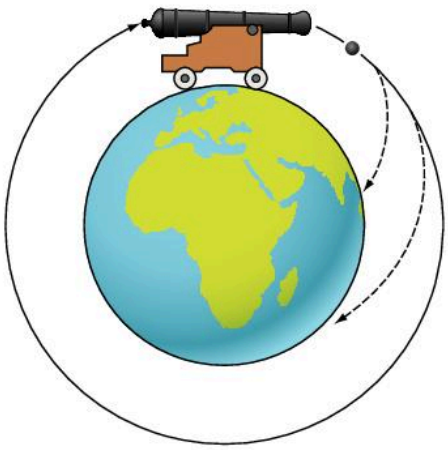
There have been more missions to the Moon than to any other object beyond the Earth. That is because the Moon is the closest object, and it only takes days to get there and back.

There have been missions to all the planets in the Solar System and to the Sun. The *New Horizons* spacecraft will take pictures of Pluto and the Kuiper Belt later this decade. Most satellites just take photographs, but missions to Mars have collected rocks and done experiments as well.

Into orbit

The Moon is the only natural satellite of the Earth. The first artificial satellite was *Sputnik 1*, launched by the Russians in 1957. It was a metal sphere about 50 cm in diameter. To get it into orbit the engineers needed to launch it to the right height and fire it at the right speed. The force of gravity kept it in orbit.

Satellites are used for communication, monitoring the weather, studying the Earth and space, and much more. Scientists need to put the satellite into the right type of orbit for the right job.



Isaac Newton said that you could launch a cannonball into orbit if you fired it at the right speed.

How many?

The International Space Station takes about 90 minutes to orbit the Earth. Calculate how many times it orbits the Earth each day.

Key Words

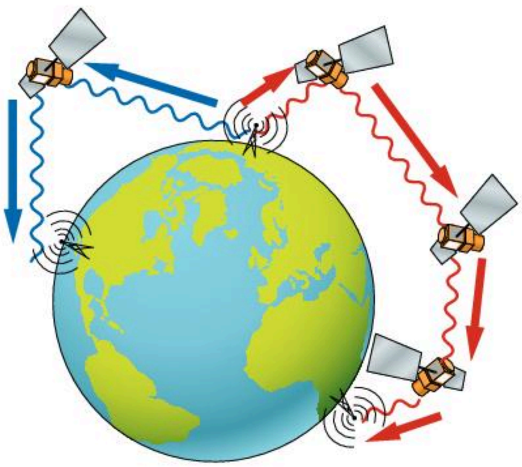
geostationary orbit, low Earth orbit (LEO), polar orbit

In the same place

Some satellites stay over the same position on the Earth all the time. They are in a **geostationary orbit**. It takes one day for a geostationary satellite to orbit the Earth. It is always above a spot on the Equator. A geostationary satellite is about 36 000 km from Earth.

A satellite in a geostationary orbit can broadcast television signals. A television company transmits a radio signal to the satellite. The satellite broadcasts it to lots of houses. If you walk down the street you will see that all the satellite dishes point in the same direction.

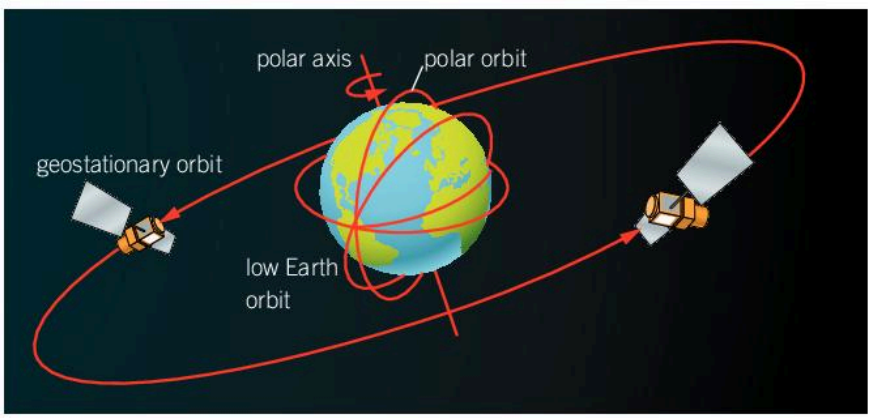
B Name the type of orbit in which the satellite stays in the same place over the Earth.



Satellites can relay signals around the world.

Lower orbits

There are lots of satellites, such as the International Space Station, in **low Earth orbit** (**LEO**). This is an orbit below 1000 km from Earth. Some LEO satellites go over the North Pole and the South Pole in a **polar orbit**. Polar orbit satellites are useful for mapping. You need a satellite in LEO if you want to see the whole of the Earth's surface.



Satellites have different orbits.

Summary Questions

1. Match each satellite to its use.

geostationary orbit	International Space Station
low Earth orbit	satellite television
polar orbit	mapping the Earth's surface

(3 marks)

2. Describe how satellites get into orbit.

(2 marks)

3. Compare geostationary satellites and satellites in low Earth orbit.

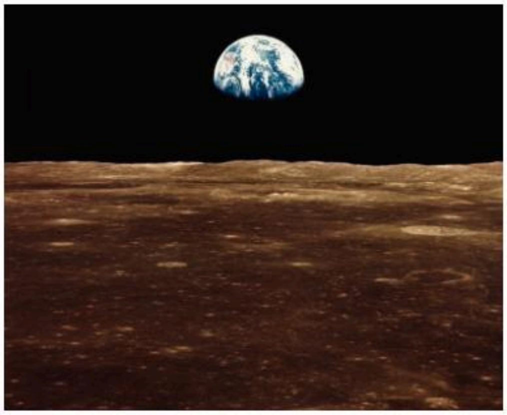
(6 marks QWC)

2.5 Mission to the Moon

Learning objectives

After this topic you will be able to:

- describe some of the risks and benefits of the space programme.



▲ Only 12 people have ever seen 'Earthrise' from the Moon.

▲ To land at a safe speed the astronauts needed a parachute to slow them down.

Fantastic Fact

If Buzz had shut the door behind him when he joined Neil on the Moon's surface they would both still be there. There was no handle on the outside of the lander.

It cost a lot of money to send Neil Armstrong and Buzz Aldrin to the Moon in 1969. Was it worth it?

One small step for man ...

The *Apollo* missions from 1961 to 1975 were designed to put people on the Moon. It was the most difficult engineering challenge that had ever been attempted. There are lots of **risks** when you go into space. Equipment can be damaged and people can be injured.

Risk assessment

There is a risk to any activity. It is not possible to make anything 100% safe. When you do a risk assessment you consider the probability that something will happen, and the consequences if it did. Then you do your best to reduce the probability or change the consequences.

In the *Apollo* missions the engineers and scientists tried to make all the equipment 99.9% reliable. There were two or even three back-up systems for each process.

99.9% reliable means that if there were 1000 missions, something would go wrong once. There were only going to be 20 *Apollo* missions to the Moon.

A State the two factors that you need to consider when you do a risk assessment.

A risky business

One of the most obvious risks is at take-off. When the astronauts took off they were lying on top of an enormous rocket that could have exploded. As they travelled back to Earth through the atmosphere the spacecraft got very, very hot due to friction. The outside of the spacecraft was designed to withstand temperatures hotter than the surface of the Sun. To land safely back on Earth they relied on parachutes to slow their descent.

There was danger from the Sun while they were travelling there and back. The Sun produces lots of radiation. Occasionally the Sun emits a **solar flare**. A huge amount of extra radiation is thrown out into space. In 1989 a solar flare wiped out the electricity system in Canada. A solar flare could stop all the on-board computers working.

... one giant leap for mankind

You probably have in your pocket or bag a product of the space programme. In 1963 half the computers in the world were developed for the Moon missions. We would not have smart phones and other computer-controlled gadgets without them. There were lots of other benefits.

The liquid-cooled suits used by racing-car drivers and fire-fighters are based on the *Apollo* astronauts' spacesuits.

The computer programs for swiping credit cards use software designed for the *Apollo* missions.

The shock-absorbing materials used in sports shoes were developed for spacesuits.

Water filters use technology designed to recycle astronauts' urine.

Baby-milk formulas are based on protein-rich drinks developed for astronauts.

One of the most important benefits of the space programme was not a gadget. Neil Armstrong could hold his thumb up and block out the Earth from view. He saw how fragile planet Earth looks from space. This made people think about looking after our planet.

What's the risk?

Suggest one way that a cyclist can reduce the probability of being in an accident.

Suggest one way that a cyclist can reduce the consequences if they are in an accident.

▲ The Sun can give off powerful solar flares.

Key Words

risk, solar flare

Summary Questions

1 Sort each word or words into risks and benefits of the Moon landings.

smart-phone technology

radiation

rocket exploding

baby milk

(4 marks)

2 The *Apollo* space program cost about as much as 5000 hospitals. Describe one benefit of the *Apollo* missions that would be useful in hospitals.

(2 marks)

3 Explain in detail the risks and benefits of the *Apollo* missions to the Moon.

(6 marks QWC)

2.6 Radioactivity 1

Learning objectives

After this topic you will be able to:

- describe what is meant by a radioactive material.

▲ Some toys glow in the dark after they have been in sunlight.

▲ Marie Curie.

Fantastic Fact

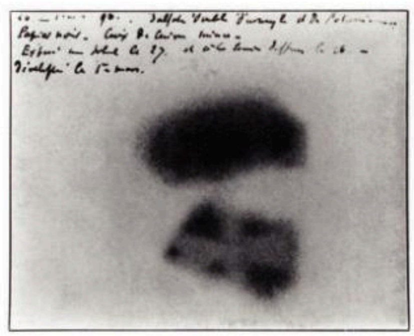
The cartoon 'The Simpsons' shows radioactive materials glowing green, just like radium.

What do toys that glow in the dark have to do with radioactivity?

Strange rays

In 1896 a French physicist called Henri Becquerel was interested in rocks that seemed to glow in the dark. You may have seen toys that glow at night after being in sunlight. Becquerel thought that rocks containing the element uranium did the same. He put the rocks in the light, then placed them near photographic plates. These photographic plates were used in cameras before the invention of film and digital cameras. When he developed the plates by processing them with chemicals, he found that the plates had gone dark where the rocks had been near them.

One day it was cloudy so Becquerel decided not to put the rocks in the sunshine. He left them in a drawer instead with some photographic plates. When he processed the plates they had gone dark again. The rocks didn't need to be in sunlight. He thought they must be giving out invisible rays, which he called 'Becquerel rays'.



▲ Becquerel's plates had dark patches.

New elements

Marie Curie was a Polish physicist. She was also interested in the rays that rocks seemed to give out. She noticed that some rocks seemed to give out more rays than others. She wondered why.

In 1898 she ground up 1000 kg of a rock called pitchblende. She kept refining it until she had one-tenth of a gram of a new element called **radium**. Radium glows green in the dark. She and her husband Pierre also discovered a new element called polonium.

Marie Curie named the production of invisible rays from some materials '**radioactivity**'. Now we describe these materials as **radioactive**. The mysterious rays are called **radiation**.

A Name the word used to describe a material that gives out radiation.

What are those rays?

You may have met the word 'radiation' in lots of different topics. The Sun gives out radiation. Energy is transferred by radiation. Now you are learning that radioactive materials give out radiation.

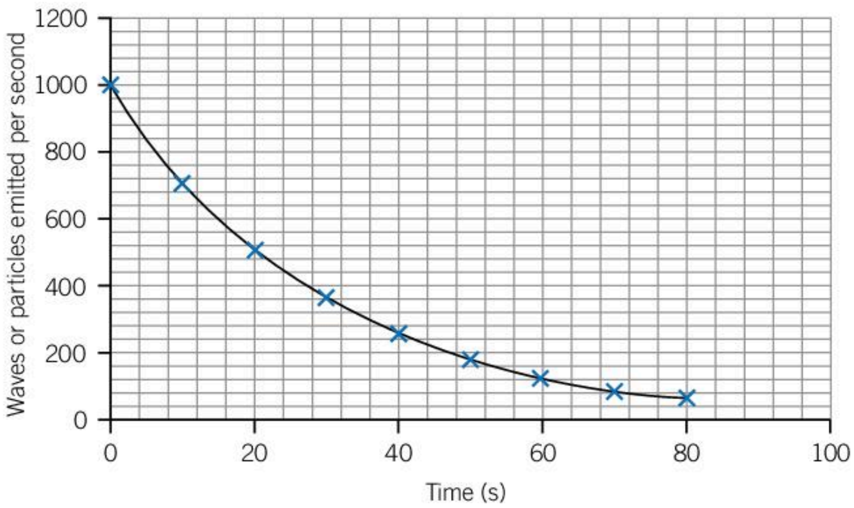
Radiation is anything emitted from a source. It can be in the form of a wave or particles. You have already met the waves of the electromagnetic spectrum such as radio waves or infrared radiation. Radiation can also be particles.

Alpha, beta, and gamma

Just a couple of years after Becquerel's discovery another physicist, Ernest Rutherford, worked out that there were three types of radiation emitted by the rocks. Rutherford called them **alpha**, **beta**, and **gamma**. These are the first three letters of the Greek alphabet.

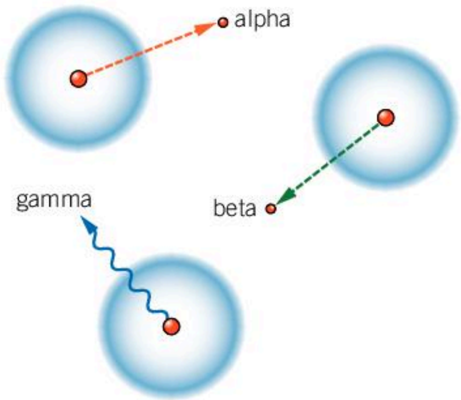
Rutherford and his team of physicists worked out that alpha radiation was made up of the nuclei of helium atoms. Beta radiation was electrons, and gamma radiation was waves of the electromagnetic spectrum.

B Name the three types of radiation given out by radioactive materials.



▲ A radioactive material becomes less radioactive over time.

Marie Curie noticed that after a few months her sample of polonium seemed to become less radioactive. All radioactive materials get less radioactive over time. The time it takes for the radiation that they give out per second to go down by half is called the **half-life**. The half-life of polonium is 4.5 months. The half-life of some radioactive materials is millions of years.



▲ An unstable atom can emit alpha, beta, or gamma radiation.

Half-life

A radioactive material emits 2000 alpha particles per second. If the half-life is 2 days, how much radiation will it emit per second after 4 days?

Key Words

radium, radioactivity, radioactive, radiation, alpha, beta, gamma, half-life

Summary Questions

1 Copy and complete the sentences below.

Alpha, beta, and gamma radiation is given out by anything that is __________. After a while these materials emit __________ radiation per second.

(2 marks)

2 Describe the difference between 'radiation' and 'radioactive'.

(2 marks)

3 Explain the shape of the graph on this page.

(6 marks QWC)

2.7 Radioactivity 2

Learning objectives

After this topic you will be able to:

- describe the risks of using radioactive materials
- describe some uses of radioactive materials.

How do you know if something is dangerous? If it causes damage that you can see immediately, it will be obvious. If it takes years to see the damage then it is much more difficult.

Miracle cure?

Marie Curie used to keep a small jar of radium by her bed. It glowed in the dark. Her husband carried a small sample in his pocket so that he could show people about the discoveries they had made. People were very excited about this miraculous material.

Very soon people started to sell things that contained radioactive materials, such as radium water and radium toothpaste. They claimed that the radiation could cure disease.

▲ Some people drank a small tube of radioactive water every day.

The bad news

Marie Curie and her husband became very ill. At times Pierre's legs were shaking so much he could hardly stand up. In 1932 a famous American golfer died of **cancer** after eating lots of radium for many years. Cancer is a disease caused by cells of the body growing out of control. People had begun to make the connection between radioactive materials and diseases such as cancer.

Key Words

cancer, mutation, sterilise, gamma camera, radiotherapy

A Name a disease that radiation can cause.

This did not stop people using radioactive materials in a wide range of places. During the Second World War a company that made watch dials employed women to paint radium onto the dials. Years later most of the women developed cancer in their mouths from licking the paintbrushes.

Now we understand the effects of radiation on cells. Radiation can cause changes called **mutations** in cells. These mutations can lead to cancer.

▲ The hands of this watch glow in the dark because they are painted with radium.

▲ All radioactive materials must be labelled and controlled.

The good news

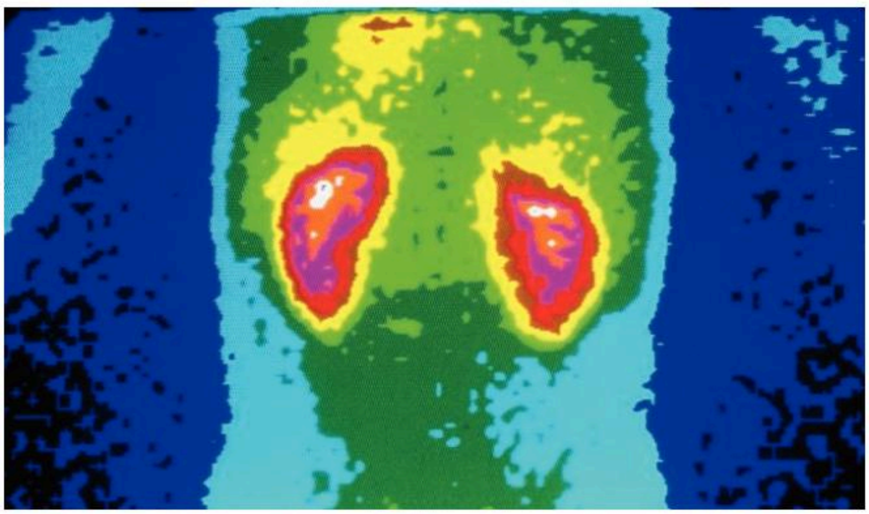
It is tempting to think that everything about radioactive materials is bad. That is not the case. Radiation can also kill cells such as harmful bacteria. We can use radiation to **sterilise** medical equipment and food.

Doctors also use radioactive materials to diagnose and treat disease.

B State two useful ways that radiation can be used.

Finding out what is wrong

Doctors can use a **gamma camera** to find out whether a patient's kidneys are working properly. The patient drinks a material that is radioactive. The radioactive material emits gamma rays. The material must have a short half-life. Doctors use different types of radioactive material to look at different organs of the body.



▲ A gamma camera detects radiation.

Treating cancer

You can also use radioactive materials to treat cancers. This might not seem logical because radiation can cause mutations that cause cancer. High doses of radiation can damage cells so badly that they die, and this is how doctors treat cancer cells. This is called **radiotherapy**.

Confusing?

Write a paragraph with as few words as possible that shows the correct use of these words: radioactive, radiation, radiotherapy.

▲ This symbol on food packaging shows that radiation has been used to kill bacteria on it.

Fantastic Fact

Some countries such as Japan still sell radium water.

Summary Questions

1 Copy and complete the sentences below.

People used to think that drinking radioactive water could __________ their diseases. Now we know that radiation can __________ diseases such as cancer. We can also use radioactive materials to cure cancer using __________.

(3 marks)

2 Describe one risk of using radioactive materials with a long half-life to diagnose disease.

(2 marks)

3 Compare the risks and benefits of radioactive materials.

(6 marks, QWC)

2.8 Electromagnetism 1

Learning objectives

After this topic you will be able to:

- describe how to generate electricity using electromagnetic induction.

▲ Oersted's experiment showed that electricity and magnetism were linked.

▲ Michael Faraday.

If you rub some materials they can pick up light objects. Some rocks can attract pieces of iron and certain other metals. What is the connection between electricity and magnetism?

A lucky discovery

In 1820 a Danish scientist called Hans Christian Oersted was giving a lecture to other scientists. He wanted to show them some experiments using an electric current to heat a wire. He also wanted to do some experiments with magnetism. He had a compass nearby ready to show the field around a magnet.

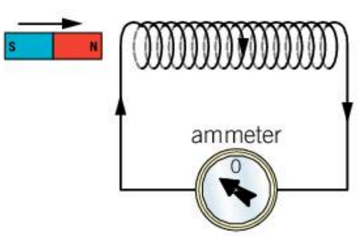
He set up the wire and switched the current on. The compass needle moved. He didn't tell the audience, but when they had gone he tried it again and the needle moved again. Oersted had produced a magnetic field around a current flowing in a wire. He had discovered **electromagnetism**.

An important discovery

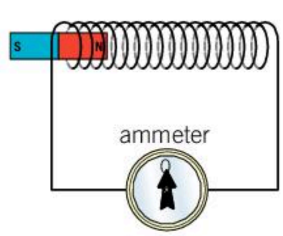
Michael Faraday was born in 1790 and grew up in London. He left school at the age of 13 and went to work for a person who made books. He started to read the books and learnt a lot of science. Eventually he became a scientist himself.

How do generators work?

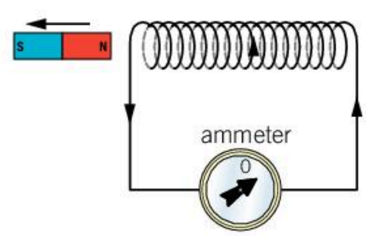
Faraday heard about Oersted's discovery and did some experiments himself. He found out that if you move a magnet inside a coil of wire then a potential difference is produced. This is called **electromagnetic induction**. If you connect a meter then a current flows because the circuit is complete.



If you move the magnet into the coil the needle moves to the left.



If the magnet and coil don't move the meter reads zero.



As you move the magnet out of the coil the needle moves to the right.

This is one of the most important discoveries in science. Electricity is generated in a power station by electromagnetic induction. The key thing is that the magnet needs to move relative to the coil of wire.

A Name the process used to generate electricity.

Another scientist, Joseph Henry, discovered electromagnetic induction at exactly the same time. Michael Faraday published his results first so he was given the credit. Scientists publish their results in journals so that other scientists can read them. Before they can be published other scientists check their results. This is called **peer review**.

Backwards and forwards

There is another way to generate an electric current. Instead of using a moving magnet you can use a coil with a current that is changing. This is called **alternating current** and it produces a changing magnetic field. If there is another coil or a piece of metal close by then a current will flow in it.

You can check whether a pan is magnetic with a magnet.

You might have seen a special cooker called an induction hob. There is a coil of copper below the glass hob. It produces a changing magnetic field using alternating current. This generates a current in the bottom of the metal pan, which gets hot and cooks the food. The pan needs to be made of a magnetic material such as steel to work.

Peer review

Describe why it is important for scientists to publish their results in journals, and why peer review is important.

Fantastic Fact

You have used one of Michael Faraday's inventions. He invented an early form of the Bunsen burner.

Key Words

electromagnetism, electromagnetic induction, peer review, alternating current

A wind-up torch contains a magnet and a coil.

Summary Questions

1 Copy and complete the sentences below, choosing the correct bold words.

You can generate a potential difference in a coil of wire by **holding/moving** a magnet in it. If you keep the magnet **moving/stationary** then no potential difference is generated.

(2 marks)

2 Describe how a wind-up torch works in terms of electromagnet induction.

(3 marks)

3 Explain how electricity can be generated in a coil of wire.

(6 marks QWC)

2.9 Electromagnetism 2

Learning objectives

After this topic you will be able to:

- describe how electromagnetic waves are used for communication.

How do people communicate with submarines, or with satellites? They cannot use wires. The communication must be wireless.

▲ You cannot use wires to communicate with a submarine.

From wires to waves

About 150 years ago it took 10 days to send a message from Europe to the United States by ship. Then in 1866 engineers connected the two continents with a transatlantic cable. This meant people could send messages using an electrical signal. The messages were sent as Morse code. This is a series of dots and dashes that represented letters. It was much quicker than a ship, but they could only send 8 words per minute.

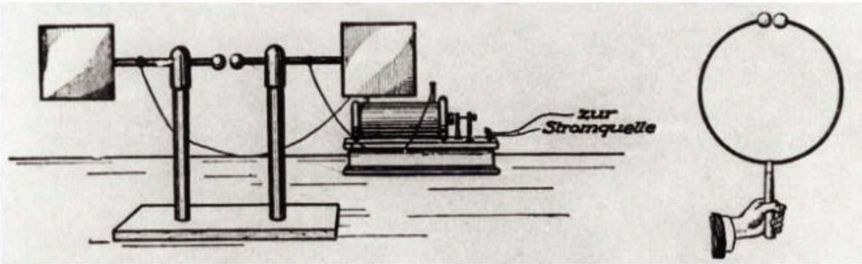
▲ This machine was used to tap out a message in Morse code.

There should be waves ...

In 1873 a Scottish scientist called James Clerk Maxwell used ideas from electromagnetism to make a prediction. He said that when electric charges move backwards and forwards such as in an alternating current, it should generate waves. This is a good example of a scientific explanation producing a prediction that you can test. If Maxwell's theory was correct scientists should be able to generate and detect electromagnetic waves.

... and there are

Eight years after Maxwell's prediction, Heinrich Hertz designed some apparatus to test it. His **transmitter** was a circuit with an alternating current that produced a spark. It made radio waves. His detector was a loop of wire. He showed that the waves could travel several metres through the air.



▲ Hertz was the first person to send and receive radio waves.

You may have seen a loop **aerial** coming out of the back of an old radio or television set. That is how radio waves used to be detected.

Fantastic Fact

When someone asked Hertz what his discovery meant for society he said, 'Nothing, I guess'. Little did he know it would lead to WiFi and mobile phones!

▲ Television signals use electromagnetic waves too.

A Name the piece of equipment that detects radio waves for a radio or television.

Different waves for different uses

How many different wireless devices can you think of? They all work using the electromagnetic waves that Hertz discovered. Waves of different frequencies have different uses. The frequency is the frequency of a radio wave called the carrier wave that the device sends out or receives. Devices add signals that represent sound or images to the carrier waves to send them. An aerial detects the wave and we can see the images and hear the sound.

Frequency range	Example uses
30–300 Hz	communication with submarines
300–3000 Hz	communication within mines
3–30 kHz	navigation, time signals, wireless heart rate monitors
30–300 kHz	AM long-wave broadcasting, amateur radio
300–3000 kHz	AM (medium-wave) radio broadcasts, avalanche beacons
3–30 MHz	citizens' band radio
30–300 MHz	FM radio, television broadcasts
300–3000 MHz	microwave ovens, microwave devices/communications, radio astronomy, mobile phones, WiFi, Bluetooth, GPS
3–30 GHz	radar, communications satellites, satellite television broadcasting

Just a minute ...

Calculate how long it would take to send one verse of 'Happy Birthday' along a wire by Morse code.

Link

You can learn more about AM and FM in P3 3.4 Detecting messages

Key Words

wireless, transmitter, aerial

Summary Questions

1 Copy and complete the sentences below.

A __________ wave is a radio wave that carries information such as sound or images. You need __________ communication to talk to people on submarines and aircraft. A device called a __________ produces the waves and an __________ receives them.

(4 marks)

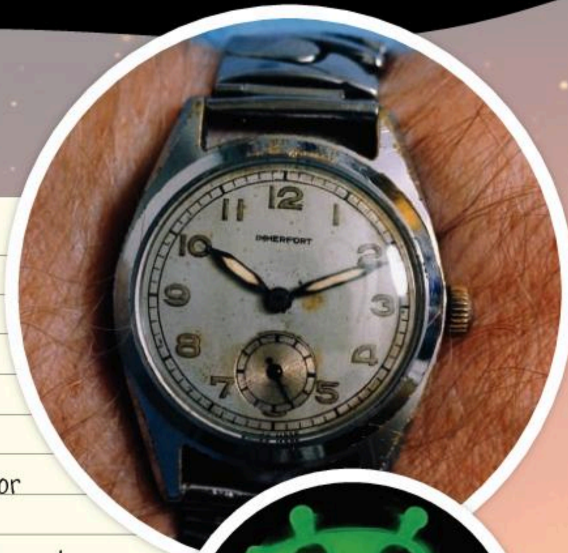
2 Describe how electromagnetic waves are used in communication. Give examples in your answer.

(4 marks)

3 Design a poster to illustrate the information in the table on this page.

(6 marks)

P3 Chapter 2 Summary



Key Points

- Different cultures have developed different ideas about observations of stars and planets.
- The geocentric model was replaced with the heliocentric model as new evidence became available.
- The accepted model for the way the Universe started is the Big Bang.
- Rockets move satellites into orbits that are geostationary orbits, polar orbits, or low Earth orbits. Satellites have a wide range of uses such as for communication and monitoring the weather.
- It was very risky to send people to the Moon but there were many benefits such as advances in computing.
- Some materials give out alpha, beta, and gamma radiation. They are radioactive.
- Radiation can damage cells and cause cancer. It can also be used to sterilise objects and treat cancer in radiotherapy.
- You can generate electricity using electromagnetic induction. A potential difference will be produced if you have a wire in a changing magnetic field.
- Changing electric currents can produce electromagnetic waves. Wireless communication uses different frequencies of electromagnetic radiation.

Key Words

evidence, prediction, model, geocentric model, retrograde motion, heliocentric model, Big Bang, analogy, geostationary orbit, low Earth orbit (LEO), polar orbit, risk, solar flare, radium, radioactivity, radioactive, radiation, alpha, beta, gamma, half-life, cancer, mutation, sterilise, gamma camera, radiotherapy, electromagnetism, electromagnetic induction, peer review, alternating current, wireless, transmitter, aerial

Big Write

The 20th century

There were lots of new discoveries between 1900 and 2000.

Task

Construct a timeline that shows the different discoveries. Use this to write an illustrated story for children.

Tips

- Include what the discoveries were and when they happened.
- Describe how they changed how people lived, or how they thought about the Universe and our place in it.

End-of-chapter questions

1 Match each model to its definition.

geocentric model	The Universe began when all of space and time expanded.
heliocentric model	The Earth is at the centre of the Universe.
Big Bang theory	The Sun is at the centre of the Universe.

(***3 marks***)

2 State which of these is the approximate age of the Universe in billions of years:

5 14 8 65

(***1 mark***)

3 From the list below, name the different types of radiation given out by a radioactive material.

alpha microwaves sound
gamma radio waves beta

(***1 mark***)

4 Copy and complete these sentences.

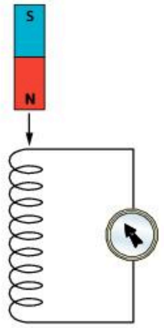
a If a satellite is always over the same place it is in _____________ orbit. *(1 mark)*

b A satellite that goes over the North Pole is in a _____________ orbit. *(1 mark)*

c The International Space Station is in _______________ orbit. *(1 mark)*

(***3 marks***)

5 A student moves a magnet into a coil and the needle on the ammeter in the circuit moves to the left.



a Describe what she would see if she moved the magnet out of the coil. *(1 mark)*

b Describe what she would see if she held the magnet stationary inside the coil. *(1 mark)*

She wants to investigate how the number of turns on the coil affects the size of the current.

c Describe **two** control variables in this experiment. *(2 marks)*

d Describe and explain the graph that she could draw using her results. *(2 marks)*

(***6 marks***)

6

a Explain how you can use radiation to sterilise needles in hospitals. *(2 marks)*

b Explain why doctors use materials with a short half-life to diagnose disease. *(2 marks)*

(***4 marks***)

7 Describe how you can communicate with a submarine when it is underwater.

(***2 marks***)

8 Describe one piece of evidence that the Universe started with the Big Bang.

(***1 mark***)

9 You have two pieces of radioactive material. They both give out 400 waves or particles per second.

Sample A has a half-life of 2 days, and Sample B has a half-life of 5 days. Compare how the radiation emitted per second by each sample changes over 10 days.

(***4 marks***)

10 Explain why doctors need to balance risk and benefit when they use a gamma camera.

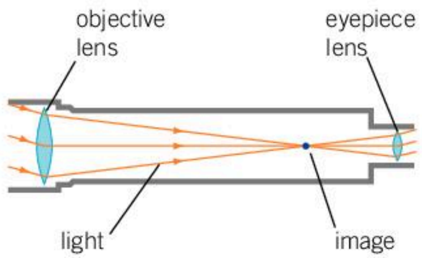
(***6 marks QWC***)

3.1 Detecting planets

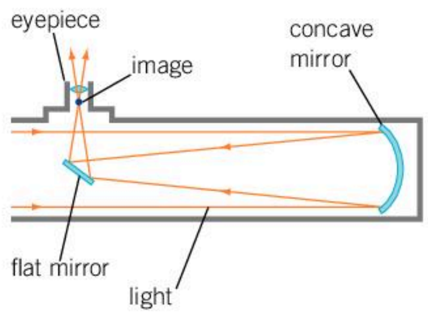
Learning objectives

After this topic you will be able to:

- describe how astronomers use telescopes
- describe two types of telescope.



▲ A refracting telescope uses lenses to refract light.



▲ A reflecting telescope uses a concave mirror to reflect light.

Link

You can learn more about lenses in P1 3.3 Refraction

Key Words

refracting telescope, objective, eyepiece, magnify, reflecting telescope, Hubble Space Telescope (HST), exoplanet, intensity

You can see the planets Mercury, Venus, Mars, Jupiter, and Saturn with the naked eye. How do astronomers find planets around stars other than the Sun?

Telescopes

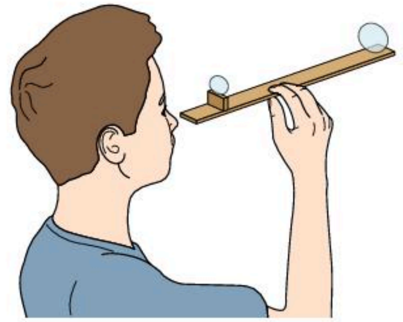
Some of the most important observations in the history of science have been made with the telescope.

Galileo's telescope

Galileo used a telescope with two lenses. This is called a **refracting telescope**. The **objective** lens produces a real image of a distant object. The **eyepiece** lens **magnifies** the image of the object. This is how Galileo could observe the moons in orbit around Jupiter. Before that most people thought that the Earth was at the centre of the Solar System.

A Name the two types of lens that Galileo used in his telescope.

Astronomers observed Neptune for the first time in 1846. They were looking for it because of a prediction from Newton's law of gravitation. This discovery made scientists more confident that Newton was correct.



▲ You can use two lenses to make a telescope.

▲ A satellite dish focuses radiation.

Using curved mirrors

There are problems with Galileo's telescope. For example, different colours of light are refracted by different amounts. So the image of an object that emits different colours might not be clear. Instead of using lenses, it is better to produce an image with a curved mirror. This is called a **reflecting telescope**.

Curved reflectors can be used to focus light or other radiation. This is how a TV satellite dish detects microwave radiation from a satellite.

The Hubble Space Telescope

Curved mirrors can be big, such as the 2.4 m mirror in the **Hubble Space Telescope** (**HST**). It would be difficult to make a lens that big, and it would be too heavy to send into space.

The HST takes stunning images of objects in our Solar System, showing stars being born and stars dying. It has even produced images of planets around other stars, called **exoplanets**.

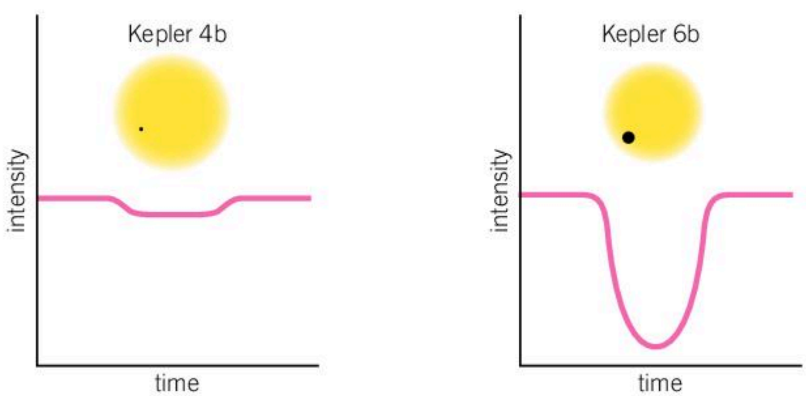
The light reflected from an exoplanet is very faint. It is difficult to see against the star's light. Astronomers have found thousands of exoplanets. They saw only a few of them with a telescope that uses visible light. They used other methods to find the rest.

B Name the type of planet around a star that is not our Sun.

Kepler

In 2009 the *Kepler* space observatory was launched. It has a telescope with a 95 megapixel camera, the largest launched into space. Its large mirror has detected thousands of exoplanets.

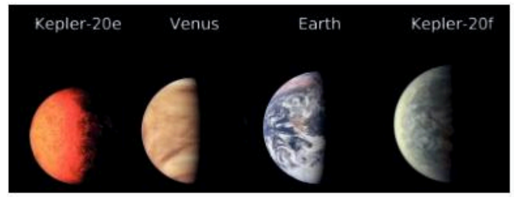
Kepler was launched to try to find planets in other solar systems that might support life. *Kepler* looks at the same part of the sky all the time. If a planet moves in front of a star it will block out some radiation. *Kepler's* camera can detect the change in the **intensity**, and work out the size of the planet passing in front of the star. The intensity tells you the energy per second transferred as light radiation.



▲ The graphs show the drop in light intensity as a planet moves in front of a star.

Front-page news

Write a headline and paragraph that you might have read in a newspaper when the first exoplanet was discovered in 1992.



▲ Some of the planets that Kepler has discovered are the same size as Earth.

▲ Cat's Eye Nebula image from the HST.

Fantastic Fact

The *Kepler* telescope can detect a change in intensity equivalent to that of a fly in front of a car headlamp on full beam.

Summary Questions

1 Copy and complete the sentences below.

You can make a telescope with two lenses. The lens near the object is the __________ lens and the lens that you look into is the __________ lens. Astronomers look for planets around other stars, called __________, by detecting changes in the __________ of the light from the star.

(4 marks)

2 Describe one similarity and one difference between reflecting and refracting telescopes.

(2 marks)

3 Compare the HST and the *Kepler* space observatory.

(6 marks QWC)

3.2 Detecting alien life

Learning objectives

After this topic you will be able to:

- describe how astronomers search for life on other planets.

▲ The Aricebo radio telescope looks for radio signals from aliens.

Link

You can learn more about the spectrum of white light in P1 3.5 Colour

▲ Mars is in the habitable zone. The *Curiosity* rover has found evidence that water flowed on the red planet.

Some people think there is life on other planets. Could there be life, and how would we know?

Is there anyone out there?

There are billions of stars in the billions of galaxies that make up the Universe. Astronomers have detected exoplanets around lots of stars. This makes some astronomers think there may be life on other planets. They estimate that there could be millions or even billions of Earth-like planets in the Milky Way alone.

Scientists use **mathematical models**. These are very useful when you cannot do experiments to collect data. In 1961 the astronomer Frank Drake wanted to show people how scientists work. He wrote an equation for working out how many planets are likely to have life on them. The search for alien life continues.

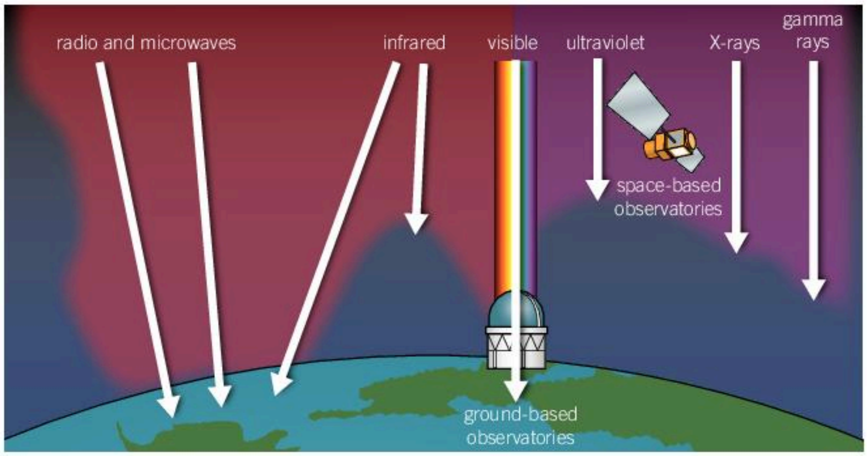
SETI

SETI is the **Search for Extra-Terrestrial Intelligence**. Astronomers on the SETI project use radio telescopes, like the one at Aricebo in Puerto Rico, to detect radio signals from space.

Most radio waves, visible light, and some infrared and ultraviolet radiation reach the surface of the Earth. The rest are absorbed by the atmosphere.

Astronomers have put telescopes that detect the other waves of the electromagnetic spectrum in orbit around the Earth.

A State what SETI stands for.



▲ The atmosphere absorbs some waves of the electromagnetic spectrum.

Conditions for life

Astronomers use computers to estimate the '**habitable zone**' around other stars. This is the region where an exoplanet would be at a suitable temperature. For there to be life on a planet like Earth there needs to be liquid water, so it cannot be too hot or too cold.

B State what is meant by a habitable zone.

You need an atmosphere with oxygen for life like the life on Earth. Astronomers can work out what stars are made of by looking at the light that they emit. There are black lines, a bit like a barcode, in the spectrum of light. The barcode is called a **line spectrum**. It shows that some frequencies are missing.

▲ The spectrum of the Sun has some frequencies of light missing.

Scientists can do experiments with gases on Earth and work out what the barcodes mean. The lines show which elements are present in the gas that the light has travelled through. That is how we know that the Sun is made mainly of hydrogen and helium.

Astronomers can look at the barcodes in light that has travelled through the atmosphere of an exoplanet as it passes in front of a star.

Can we talk to them?

In 1936 the first radio signal went out into space. If there was a planet with alien life on it around our nearest star, Proxima Centauri, then the aliens would have received the signal in 1940. Proxima Centauri is about 4 light-years away.

Astronomers have sent messages out into space. In 1974 they beamed a message from the Aricebo telescope. It was made of lots of 1s and 0s (bits) that make an image when put together. The image shows numbers, elements, DNA, people, and our place in the Solar System. It was beamed at a star cluster 25 000 light-years away. It will be over 50 000 years before we could get a reply.

▲ The message sent from Aricebo.

Fantastic Fact

Helium was first detected by looking at light from the Sun, not by finding it on Earth.

Key Words

mathematical models, SETI (Search for Extra-Terrestrial Intelligence), habitable zone, line spectrum

How long?

Estimate how long it would take to send a message that is two minutes long to someone on a planet orbiting Proxima Centauri.

Summary Questions

1 Copy and complete the sentences below.

When they look for alien life astronomers detect __________ waves from space using telescopes on the ground. They look for planets that might have liquid __________ or __________ gas needed for life like the life on Earth.

(3 marks)

2 Explain why astronomers might not receive signals that aliens send using X-rays.

(1 mark)

3 Explain three techniques that astronomers use to identify an exoplanet that has the conditions needed for life.

(6 marks QWC)

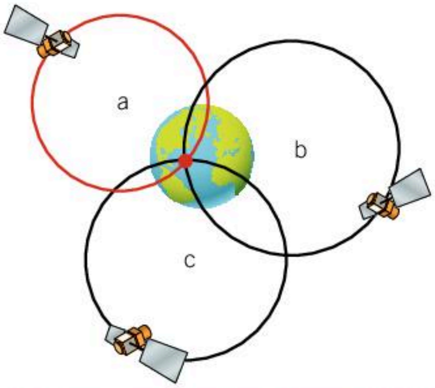
3.3 Detecting position

Learning objectives

After this topic you will be able to:

- describe how GPS works
- describe how you can find the distance to planets and stars.

▲ Scientists use GPS to track animals such as giant turtles.



▲ A GPS receiver uses three satellites to work out position.

▲ It is very important to be able to detect the position of a plane.

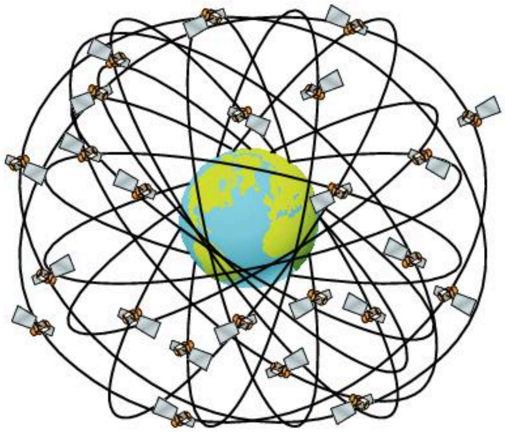
A smart phone can pinpoint its position to within about 10 m. How does it do this?

Using radio waves

You can communicate using radio waves. Your television or radio receives information via radio waves. The **Global Positioning System** (**GPS**) uses 24 satellites in orbit around the Earth. They transmit radio waves.

A State what GPS stands for.

GPS calculates distance from a measurement of time. Radio waves travel at the speed of light, 300 000 000 m/s. If you know the time the waves have taken to travel, and their speed, you can work out the distance they have travelled. This is how GPS works.



◀ There are GPS satellites that can be used wherever you are on Earth.

A GPS receiver detects signals from three satellites. It works out the distance to each one. From these distances it can work out your position. It may check using a fourth satellite.

GPS signals need **line of sight** to the satellite. There needs to be a direct line from your receiver to the satellite.

Radar

Other systems use radio waves such as **radar** (**RA**dio **D**etection **A**nd **R**anging). Radio waves bounce off metal objects, just as light reflects off a mirror. Radar is similar to sonar. You can find the distance using the time the reflected radio wave takes to travel. For radio waves you need to use the speed of light, not the speed of sound.

Different frequencies have different uses. Air-traffic controllers use radio waves with a frequency of about 3000 MHz to monitor planes. 1 MHz = 1 million Hz. A GPS signal from a satellite has a frequency of about 1575 MHz.

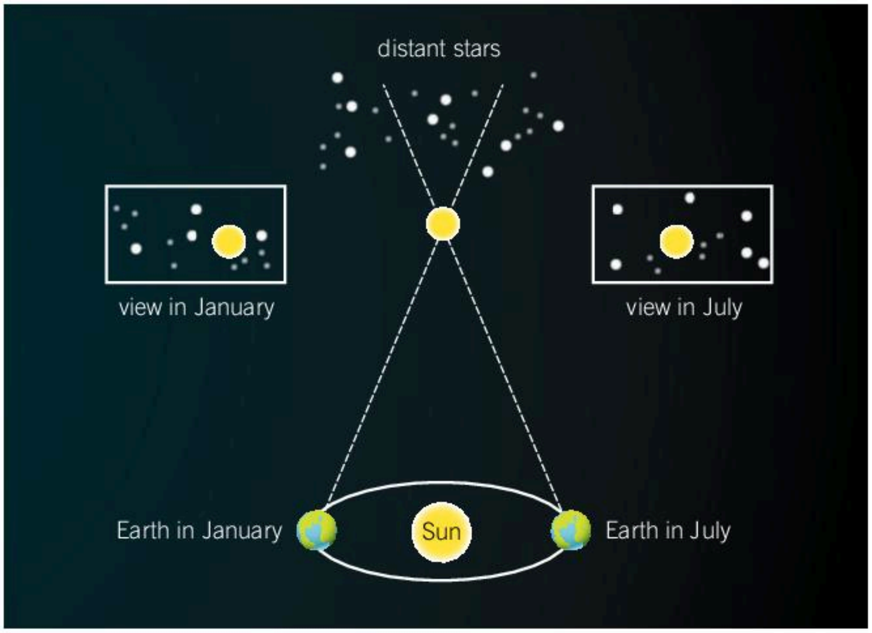
B State what type of waves are used in a radar system.

How do we know?

'How do we know?' is one of the most important questions that you can ask. How do we know the distance to the Moon, or to Mars?

Astronomers find distances to objects in the Solar System using radar. A pulse of radio waves will take about 2.5 seconds to reflect back from the Moon, and over 5.5 hours from Pluto.

Astronomers need a different technique for objects outside the Solar System. This method is called **parallax**. It works because a star such as Proxima Centauri appears to be in a different place in July and in December. Knowing the distance from the Earth to the Sun, astronomers use mathematics to work out the distance to the star.



▲ You can use parallax to find the distance to a star.

Fantastic Fact

The clocks on satellites run faster than clocks on the ground. This is an effect predicted by Einstein's theories of relativity. This means that your head is older than your feet!

Link

You can learn more about using different frequencies to broadcast signals in P3 2.9 Electromagnetism 2

How close?

When radio waves travel from a GPS satellite to a receiver the uncertainty in the time is about 0.000 000 03 seconds. Work out the uncertainty in the position using distance = speed x time. (The speed of light is an accurate value.)

Key Words

Global Positioning System (GPS), line of sight, radar, parallax

Summary Questions

1. Copy and complete the sentences below.

   GPS measures the __________ for a signal to reach you from three satellites and works out __________. You can work out the distance to objects in the Solar System using __________. You use a method called __________ to work out the distance to other stars. *(4 marks)*

2. Describe how GPS works. *(4 marks)*

3. Compare the use of radar and parallax for measuring distance. *(6 marks QWC)*

3.4 Detecting messages

Learning objectives

After this topic you will be able to:

- describe how a radio wave carries a signal.

▲ A microphone converts speech into an electrical signal.

Link

You can learn more about digital and analogue signals in P3 1.1 Your phone

Key Words

carrier wave, modulation, diffraction

The air is full of waves carrying information. How do devices like radios and mobile phones get the information from the correct wave?

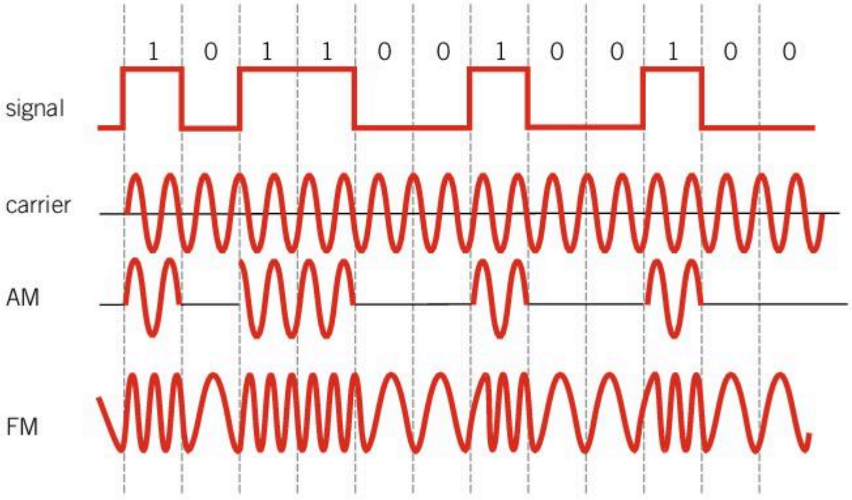
Sending information

Phones, televisions, and radios use waves of the electromagnetic spectrum. Radio waves, microwaves, and infrared are all used as **carrier waves**. The sound that you hear when you listen to a radio station is transmitted using a carrier wave of a particular frequency.

AM and FM radio

When a radio presenter speaks the sound is converted to an electrical signal by the microphone. This electrical signal can then be converted into a digital signal of 1s and 0s.

A radio transmitter adds the digital signal of the sound to the carrier wave. It can change either the amplitude or the frequency of the carrier wave. This is called **modulation**. It produces an AM (amplitude modulated) wave or an FM (frequency modulated) wave.



▲ A signal changes either the amplitude or the frequency of a carrier wave.

A Name the two types of modulated wave.

The radio transmitter emits the AM or FM carrier wave, and the receiver (your radio) detects the signal. It decodes the signal to get back to sound.

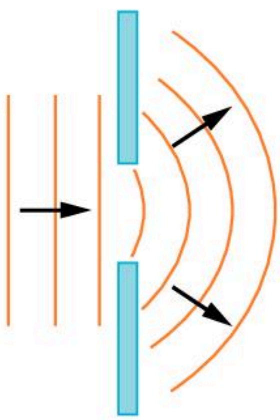
Different radio stations broadcast at different frequencies. The frequency is the frequency of the carrier wave they use. This is the wave that you tune into to listen to your chosen radio station. For Radio 1 it is 99.1 MHz. There are 1000 Hz in 1 kHz, and 1 000 000 Hz in 1 MHz.

Receiving information

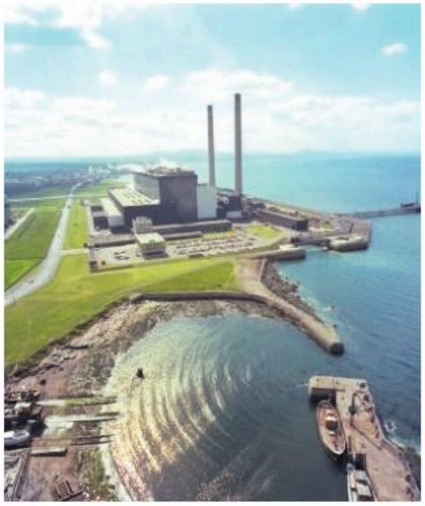
Radio waves spread around obstacles like buildings or hills. This is called **diffraction**. All waves can be diffracted.

Diffraction happens when waves go through a gap or around an obstacle. You can see diffracton happening with water waves. They spread out when they go into harbours.

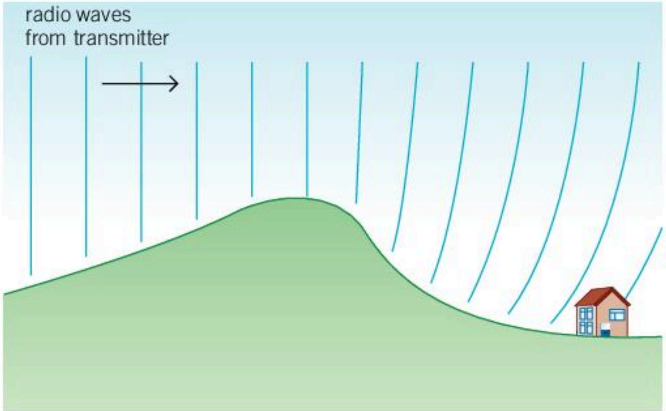
You notice diffraction whenever you can hear someone through a doorway but you cannot see them. The sound waves are diffracted by the doorway but the light waves are not diffracted very much at all.



▲ Waves spread out as they go through a gap or round an obstacle.



▲ Water waves diffract as they go into a harbour.



▲ Radio waves diffract around hills.

Link

You can learn more about using different frequencies to broadcast signals in P3 2.9 Electromagnetism 2

How many hertz?

Convert the frequency of Radio 1 to Hz, and to kHz.

Fantastic Fact

Radio waves are the fastest way of sending information because they travel at the speed of light, and nothing travels faster than this.

Summary Questions

1 Match each word to its definition.

diffraction	the radio wave that carries a signal
carrier wave	the spreading out of waves around an obstacle
modulating	changing the amplitude or frequency of a wave

(3 marks)

2 Describe the difference between AM and FM.

(2 marks)

3 Describe in detail how the sound of a Radio 1 presenter travels from the microphone to your radio.

(6 marks QWC)

3.5 Detecting particles

Learning objectives

After this topic you will be able to:

- describe how physicists investigate what the Universe is made of
- describe how particles can be detected.

We are made up of tiny particles called atoms. Inside atoms are protons, neutrons, and electrons. What's inside a proton?

Clouds and bubbles

In the past physicists have used cloud chambers or bubble chambers to detect particles that came from space. These detectors produce tracks when particles pass through them, just like the trails made by aircraft in the sky. Physicists could work out the type of particle from the type of track it made. This helps them to work out what the Universe is made of.

In 1936 two American physicists were experimenting with a cloud chamber. They detected a particle that was just like an electron, only more massive. It was a muon. It did not fit with the idea that you needed just protons, neutrons, and electrons to make everything in the Universe. They needed a new model. In the new model there were smaller particles inside protons and neutrons.

▲ Particles make tracks in cloud chambers just like these tracks.

A Name one type of detector that produces a particle track.

Link

You can learn more about about the structure of the atom in C3 2.2 Looking into atoms

A smashing time

For over 100 years scientists have smashed things into each other. They have accelerated small particles and fired them into matter. By looking at what came out of the collisions between the particles and the matter, they worked out what is inside matter. This is how Ernest Rutherford worked out that there is a very tiny, massive nucleus at the centre of an atom. This is also how physicists worked out what is inside protons.

New detectors

Physicists accelerate particles such as protons or electrons in a huge machine called an **accelerator**, such as the **Large Hadron Collider (LHC)**. There is a very, very strong electric field inside an accelerator. Protons and electrons move in a field because they are charged particles. This is just like the electrons moving in a wire when you connect up a battery. Connecting the battery produces an electric field. Physicists can accelerate particles in an accelerator to close to the speed of light.

▲ At the LHC beams are accelerated inside tubes 27 km long in tunnels.

Today physicists don't often use cloud chambers or bubble chambers. The detectors at the LHC are made of **semiconductors** that detect the mass of a particle, and its charge. A semiconductor is half-way between a conductor and an insulator.

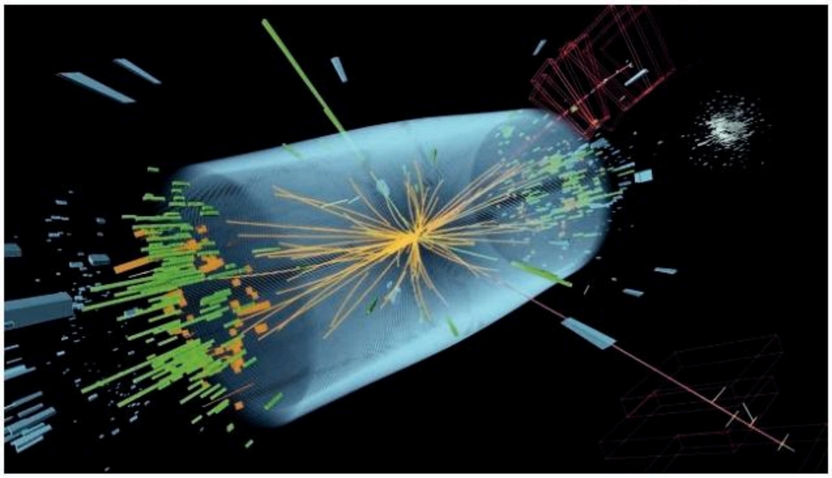
B Name the type of material used in particle detectors.

A particle zoo

When physicists smashed beams of protons and electrons together they detected the electrons bouncing off particles much smaller than a proton. This is just like the alpha particles bouncing off the nucleus of an atom. Inside protons (and neutrons) are even tinier particles called **quarks**.

Physicists have detected lots of other types of particle, just as the new model predicted they would. Sometimes the particles that they detect are more massive than the particles that they smash together. This is a bit like smashing an apple and an orange together and getting a watermelon.

The model predicted that there should be a particle called the **Higgs boson**. It was finally discovered at the LHC in 2012, and is one of the last pieces of the jigsaw. The Higgs boson is the particle that gives everything mass.



▲ Computers analyse data from the LHC detectors.

Tiny, massive, heavy?

When physicists say that something is massive they do not mean that it is big. They mean that it has mass. Having mass does not mean that something is heavy. Weight is not the same as mass.

▲ A physicist stands in front of one of the huge detectors at the LHC.

Key Words

accelerator, Large Hadron Collider (LHC), semiconductor, quark, Higgs boson

Fantastic Fact

The extra mass made in some collisions comes from the energy of the particles. It is a result of one of the most famous equations in physics: $E = mc^2$. E is energy, m is mass, and c is the speed of light.

Summary Questions

1. Copy and complete the sentences below.

   Physicists used to detect particles from the ___________ that they left in cloud chambers. They work out what everything is made of by ___________ beams of particles and smashing them together.

   (2 marks)

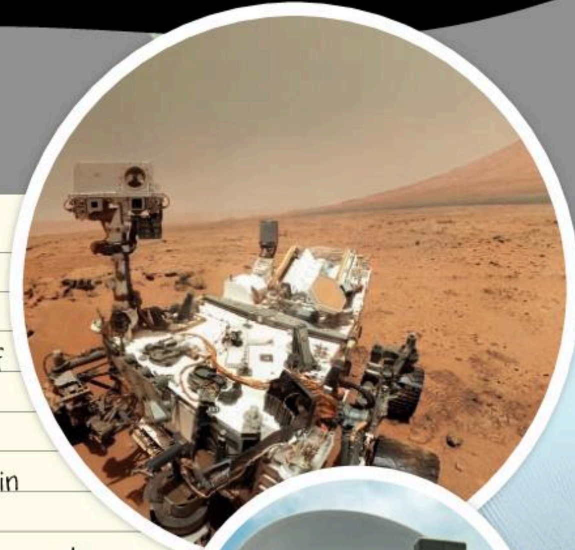
2. Compare particle detectors used now and in the past.

   (4 marks)

3. Explain in detail the link between the muon, the LHC, and the Higgs boson.

   (6 marks QWC)

P3 Chapter 3 Summary



Key Points

- The first telescope contained an objective lens and an eyepiece lens. Most telescopes are made with curved mirrors.
- Physicists can detect exoplanets by looking at how the intensity of the light radiation from a star changes when the exoplanet passes in front of it.
- We can detect radio signals from space using telescopes on the ground. The Search for Extra-Terrestrial Intelligence (SETI) looks for messages in the signals.
- Physicists can work out which planets are likely to have liquid water. They use the light that has passed through the atmosphere of exoplanets to work out if they contain oxygen.
- The Global Positioning System (GPS) uses the time taken for a radio signal to reach you from different satellites to work out your position.
- Physicists use radar to work out the distance from the time, and this is how they can find the distance to objects in the Solar System.
- Radio waves can carry information such as speech. The sound is converted to a digital signal that is used to modulate a carrier wave (radio wave). Radio waves can be detected behind hills because they diffract around objects and through gaps.
- Physicists accelerate charged particles and smash them together in accelerators like the Large Hadron Collider (LHC). This has helped them to work out that protons and neutrons contain smaller particles called quarks.
- They detect particles from the tracks in cloud chambers or bubble chambers, or by using semiconductors.

Key Words

refracting telescope, objective, eyepiece, magnify, reflecting telescope, Hubble Space Telescope (HST), exoplanet, intensity, mathematical model, SETI (Search for Extra-Terrestrial Intelligence), habitable zone, line spectrum, Global Positioning System (GPS), line of sight, radar, parallax, carrier wave, modulation, diffraction, accelerator, Large Hadron Collider (LHC), semiconductor, quark, Higgs boson

Big Write

Cosmic detective

You can see some things that are far away, like planets, with a telescope. You can see things that are really small, like cells, with a microscope, but you can't use a microscope to 'see' tiny particles like protons.

Task

You are a writer for a publishing company. Design a four-page children's leaflet that explains how physicists see things that are far away or very small.

Tips

- Remember to explain clearly each key word you use.
- Include images to make the science interesting for your audience.

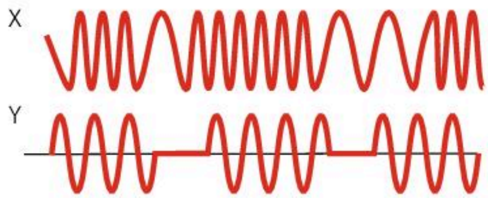
End-of-chapter questions

1 Match the object being detected to the method of detection.

exoplanet	radar
Higgs boson	Kepler Space Telescope
position of a plane	Large Hadron Collider

*(**3 marks**)*

2 Look at the diagrams below.



a State the letter of the diagram that shows an AM wave. *(1 mark)*

b State what the letter A in AM stands for. *(1 mark)*

*(**2 marks**)*

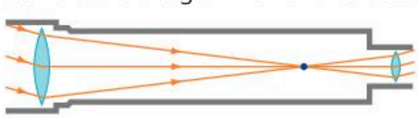
3 List these objects in order of size, starting with the smallest.

proton quark atom molecule

*(**1 mark**)*

4 Describe the difference between a planet and an exoplanet. *(**2 marks**)*

5 Look at the diagram of the telescope.



a Label the eyepiece and the objective lenses. *(1 mark)*

b State **two** reasons why telescopes in space use mirrors, not lenses. *(2 marks)*

*(**3 marks**)*

6 A radio station broadcasts at a frequency of 93.2 MHz.

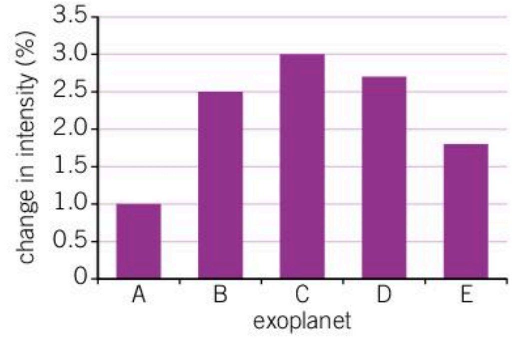
a Convert the frequency to Hz. *(1 mark)*

b Describe the difference between a sound wave and a carrier wave. *(2 marks)*

*(**3 marks**)*

7 Describe the difference between the detector used to discover the muon and the detector that found the Higgs boson. *(**4 marks**)*

8 Here is some data about five exoplanets that show the percentage change in the intensity of radiation detected by the *Kepler* observatory as each moves across a star.



a List the stars in order starting with the biggest. *(1 mark)*

b Explain why you have put the planets in the order that you have chosen. *(2 marks)*

*(**3 marks**)*

9 The Chandra telescope detects X-rays, not visible light. Explain why it was sent into space, rather than used on the ground. *(**2 marks**)*

10

a A radar system detects a plane 3 km away. Calculate how long it takes the radio signal to hit the plane and come back. The speed of light is 300 000 000 m/s. *(3 marks)*

b It takes 2.5 seconds to detect a radio signal reflected from the Moon. Calculate the distance to the Moon. *(3 marks)*

c State **two** reasons why there is a limit to the distances you can measure using radar. *(2 marks)*

*(**8 marks**)*

11 You are an alien astronomer living on an exoplanet. Explain in detail how you could work out that there was life on Earth.

*(**6 marks QWC**)*

Glossary

absorb Taken into a material.
acceleration The amount by which speed increases in one second.
accelerator A machine that uses electric fields to make charged particles travel very fast.
accurate Close to the true value of what you are measuring.
aerial A piece of metal used to detect electromagnetic waves.
air resistance The force on an object moving through the air that causes it to slow down (also known as drag).
amplifier A device for making a sound louder.
amplify To increase the amplitude of a sound so that it sounds louder.
amplitude The distance from the middle to the top or bottom of a wave.
alpha (radiation) A type of radiation given out by radioactive material; alpha radiation is helium nuclei.
alternating current Current carried by charges moving backwards and forwards.
ammeter A device for measuring electric current in a circuit.
amps Units of measurement of electric current, symbol A.
analogue Can have any value.
analogy A comparison between two things that helps you to explain what one of them is.
analyse The process of looking at data and writing about what you have found out.
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.
artificial satellite A manmade spacecraft.
asteroid Lumps of rock orbiting the Sun left over from when the Solar System formed.
astronomer A scientist who studies space.
atom A neutral particle; everything is made of atoms.
attract Be pulled together, for example, opposite poles of a magnet attract and positive and negative charges attract.
audible range The range of frequencies that you can hear.
auditory canal The passage in the ear from the outer ear to the eardrum.
auditory nerve An electrical signal travels along the auditory nerve to the brain.
average speed The total distance travelled in the total time taken for a complete journey.
axis (Earth) The imaginary line that the Earth spins around.

balanced (forces) Forces acting on an object that are the same size but act in opposite directions.
battery Two or more electrical cells joined together.
bar chart A way of presenting data when one variable is discrete or categoric and the other is continuous.
beta (radiation) A type of radiation given out by radioactive material; beta radiation is electrons.
Big Bang The expansion of space, which scientists believe is how the Universe started.
binary Can only have two values, 0 or 1.
biofuel A fuel made from plants or from animal waste.
bit A 1 or a 0, from 'binary digit'.
brain The organ in the human body that processes signals from receptors

categoric A variable that has values that are words.
carrier wave A wave, such as a radio wave, that carries information from a transmitter to a receiver.
cell A chemical store of energy, which provides the push that moves charge around a circuit.
centre of gravity The point in an object where the force of gravity seems to act.
centre of mass The point in an object where the mass of an object seems to act.
charge-coupled device (CCD) A grid of pixels at the back of a digital camera that absorbs light and produces an image.
chemical store Energy stored in food and fuels.
cochlea Snail-shaped tube in the inner ear with the sensory cells that detect sound.
collide To bump into, or hit, a particle or surface.
comet Dust particles frozen in ice that orbit the Sun.
compress To squash into a smaller space.
compressed Squashed into a smaller space.
compression The part of a longitudinal wave where the air particles are close together.

conclusion What you write down to say what you have found out during an investigation.
conduction The way in which energy is transferred through solids, and to a much lesser extent in liquids and gases.
conductor A material that conducts charge or energy well, such as a metal or graphite.
confidence (in a conclusion) How sure you are of your conclusion based on the data.
constellation A collection of stars that make a pattern in the sky.
contact force A force that acts when an object is in contact with a surface, air, or water.
continuous A variable that has values that can be any number.
control variable A variable that you have to keep the same in an investigation.
convection The transfer of energy by the movement of gases or liquids.
convection current The movement of heated liquids or gasses.
converging (lens) Bringing rays of light together.
convex (lens) A lens that produces converging rays of light.
core A rod of a magnetic material placed inside a coil to make the magnetic field of an electromagnet stronger.
cornea The transparent layer at the front of the eye.
crest The top of a wave.
critical angle The angle of incidence for which the angle of refraction is 90°.
current The flow of electrical charge (electrons) around a complete circuit per second.

data Words or numbers that you obtain when you make observations or measurements.
day The time it takes a planet to make one full spin on its axis.
decibel A commonly used unit of sound intensity or loudness (dB).
deform To change shape.
density The mass of a material in a certain volume.
dependent variable A variable that changes when you change the independent variable.
diaphragm (microphone) The part of the microphone that vibrates when a sound wave hits it.
diffraction Spreading out of waves around obstacles.
diffuse reflection Reflection from a rough surface.
digital Can only have a high or a low value.
discrete A variable that can only have whole-number values.
dispersion The splitting up of a ray of light of mixed wavelengths by refraction into its components.
dissipated Energy that has become spread out or 'wasted' by heating the environment.
distance–time graph A graph that shows how far an object moves each second.
drag force The force acting on an object moving through air or water that causes it to slow down.
driving force The force that is pushing or pulling something.
dwarf planet A small lump of rock in orbit around the Sun.

ear The organ of the body that detects sound.
eardrum A membrane that transmits sound vibrations from the outer ear to the middle ear.
Earth A rocky inner planet, third from the Sun in the Solar System.
echo A reflection of a sound wave by an object.
efficient Does not waste much energy.
elastic limit The point beyond which a spring will not return to its original length when the force is removed.
elastic store Energy stored when objects change shape.
electric charge A property of a material or particle that can be positive or negative.
electric field A region where a charged material or particle experiences a force.
electromagnet A temporary magnet produced using an electric current.
electron A negatively charged particle found in atoms. Electrons flow through a wire when a current flows.
electrostatic force The force acting between two charged objects.
electromagnetic induction The process of generating electricity using a changing magnetic field and a wire.
electromagnetic spectrum The range of wavelengths of radiation produced by the Sun and other sources.
electromagnetism The interaction of magnetism and electricity.
ellipse A squashed circle or oval shape.
emit To give out.
endoscope A medical instrument for seeing inside the human body using total internal reflection.

energy A quantity that shows whether a process can or cannot happen. Energy is needed for work to be done.
energy resources Materials or mechanisms for heating or generating electricity.
energy store Something such as a food or hot object that enables you to account for the energy at the start and end of a transfer.
equilibrium When the forces in a system are balanced. See also *thermal equilibrium*.
evaluate To discuss the quality of data collected during an investigation and suggest improvements to the method.
evidence Measurements or observations that scientists use to develop or check theories.
exoplanet A planet in orbit around a star other than our Sun.
extension The amount by which an object gets longer when a force is applied.
eye Organ of sight, which focuses and detects light.
eyepiece (lens) The lens that magnifies the image in a refracting telescope.

fossil fuel Coal, oil, and gas made from the remains of trees and sea creatures over millions of years.
field A region where something feels a force.
filter A piece of material that allows some radiation (colours) through but absorbs the rest.
focal point The point at which the rays refracted by a convex lens cross over.
focus Another name for the focal point.
freezing The change of state from liquid to solid.
frequency The number of complete waves or vibrations produced in one second (measured in hertz).
friction The force that resists movement because of contact between surfaces.
fuel A material that burns to transfer useful energy.

galaxy A number of stars and the solar systems around them grouped together.
gamma camera A camera that detects gamma radiation.
gamma (radiation) A type of radiation given out by radioactive material; gamma radiation is an electromagnetic wave.
gamma ray Wave with the highest frequency in the electromagnetic spectrum.
gas giant An outer planet in the Solar System, made mainly from gas.
gas pressure The force exerted by gas particles per unit area of a surface.
gear A rotating lever that reduces the force required to do work.
geocentric model A model of the Solar System with the Earth at the centre.
geostationary orbit A satellite in this orbit stays over the same place on the Earth's surface.
Global Positioning System (GPS) The system that uses radio waves from satellites to pinpoint your position.
gravity A non-contact force that acts between two masses.
gravitational potential store Energy due to the position of an object in a gravitational field.

habitable zone The distances from a star where a planet could have conditions for life.
half-life The time it takes for the amount of radiation per second emitted by a radioactive material to go down by half.
hazard A possible source of danger.
heliocentric model A model of the Solar System with the Sun at the centre.
hertz The unit of frequency (Hz).
Higgs boson The particle that gives everything mass.
Hooke's Law A law that says that if you double the force on an object the extension will double.
Hubble Space Telescope (HST) A telescope in orbit around the Earth.
hypothesis An idea that is a way of explaining scientists' observations.

image The point from which rays of light entering the eye appear to have originated.
incident ray The ray coming from a source of light.
incident wave The wave coming from a source.
incompressible Cannot be compressed (squashed).

independent variable A variable you change that changes the dependent variable.
infrared radiation Radiation given off by the Sun and other objects that brings about energy transfer.
infrasound Sound below a frequency of 20 Hz.
inner ear The semi-circular canals that help you to balance, and your cochlea.
instantaneous speed The speed at a particular moment.
insulator A material that does not conduct electricity or transfer energy well.
intensity (of light) Energy transferred per second as light.
interaction pair When two objects interact there is a force on each one that is the same size but in opposing directions.
inverted Upside down.
investigation An experiment or set of experiments designed to produce data to answer a scientific question or test a theory.
iris The coloured part of your eye.

joules The unit of energy, symbol J.

kilogram "A unit of mass, symbol kg.
kilohertz 1 kilohertz (kHz) = 1000 hertz (Hz)
kilojoules 1 kilojoule = 1000 J, symbol kJ.
kilowatt hours The unit of energy used by electricity companies, symbol kWh.
kilowatts 1 kilowatt = 1000 W, symbol kW.
kinetic store Energy of moving objects.

Large Hadron Collider (LHC) The particle accelerator that detected the Higgs boson.
law of conservation of energy Energy cannot be created or destroyed, only transferred.
law of moments An object is in equilibrium if the clockwise moments equal the anticlockwise moments.
law of reflection The angle of incidence is equal to the angle of reflection.
lens A device made of shaped glass that focuses light rays from objects to form an image.
lever A simple machine that multiplies the force.
light-dependent resistor (LDR) A device that has a resistance that changes with light level.
light-emitting diode (LED) An efficient component that gives out light.
light-time Distance measured in terms of how far light travels in a given time.
lightning A current through the air that produces light and sound.
line graph A way of presenting results when there are two numerical variables.
line of best fit A smooth line on a graph that travels through or very close to as many of the points plotted as possible.
line of sight A direct line between a source and a detector.
line spectrum A spectrum of light that has some frequencies of light missing.
liquid pressure The pressure produced by collisions of particles in a liquid.
longitudinal A wave where the vibrations are in the same direction as the direction the wave moves.
loudness How loud you perceive a sound of a certain intensity to be.
low Earth orbit (LEO) An orbit of about 1000 km above the Earth's surface.
lubrication A substance that reduces friction between surfaces when they rub together.
luminous Gives out light.
lunar eclipse An eclipse that happens when the Earth comes between the Sun and the Moon.

magnetic field A region where there is a force on a magnet or magnetic material.
magnetic field lines Imaginary lines that show the direction of the force on magnetic material.
magnetic force The force between two magnets, or a magnet and a magnetic material.
magnetic material A material that is attracted to a magnet, such as iron, steel, nickel, or cobalt.
magnetic resonance imaging (MRI) A technique for producing images of the inside of the human body using magnetism.
magnetise Make into a magnet.
magnification How many times bigger the image appears compared to the object.
magnify To make something appear bigger.
Mars A rocky inner planet, fourth from the Sun in the Solar System.
mass The amount of matter (stuff) a thing is made up of.
mathematical model A set of rules using maths, usually using a computer, that helps you predict what could happen.

mean An average of a set of data, found by adding together all the values in the set and dividing by the number of values in the set.
medium The material that affects light or sound by slowing it down or transferring the wave.
Mercury A rocky inner planet, closest to the Sun in the Solar System.
meteor A piece of rock or dust that makes a streak of light in the night sky.
meteorite A stony or metallic object that has fallen to Earth from outer space.
metres per second A unit of speed.
microphone A device for converting sound into an electrical signal.
microscope An optical instrument used to magnify objects, so small details can be seen clearly.
microwave Wave of the electromagnetic spectrum used for heating and for communicating.
middle ear The ossicles (small bones) that transfer vibrations from the outer ear to the inner ear.
Milky Way The galaxy containing our Sun and Solar System.
model Objects, equations, or images that help to explain what we see.
modulation A process of adding information to a carrier wave.
moment A measure of the ability of a force to rotate an object about a pivot.
Moon A rocky body orbiting Earth; it is Earth's only natural satellite.
motor A component or machine that spins when a current flows through it.

natural satellite A moon in orbit around a planet.
nuclear fusion A process that produces energy by combining light nuclei to form heavier nuclei.
negative The charge on an electron, or on an object that has had electrons transferred to it.
neutral Describes an object or particle that has no charge, or in which positive and negative charges cancel out, giving no charge overall.
neutron A neutral particle found in atoms.
newton The unit of force, symbol N.
newton metre The unit of moment.
newtonmeter A piece of equipment used to measure weight in newtons.
newtons per metre squared A unit of pressure.
night The period on one section of the Earth or other planet when it is facing away from the Sun.
non-contact force A magnetic, electrostatic, or gravitational force that acts between objects not in contact.
non-luminous Objects that produce no light.
non-renewable Energy resources that have a limited supply.
normal An imaginary line at right angles to a surface where a light ray strikes it.
north pole The pole of a magnet that points towards the north.

observation Carefully looking at an object or process.
ohms The units of resistance, symbol Ω.
objective (lens) The lens in a telescope that focuses light from an object.
optical fibre Very fine tube of plastic or glass that can transmit light using total internal reflection.
opaque Objects that absorb, scatter, or reflect light and do not allow any light to pass through.
optic nerve A paired sensory nerve that runs from each eye to the brain.
orbit The path taken by one body in space around another.
oscillation Something that moves backwards and forwards.
oscilloscope A device that enables you to see electrical signals, like those made by a microphone.
ossicles The small bones of the middle ear (hammer, anvil, and stirrup) that transfer vibrations from the eardrum to the oval window.
outer ear The pinna, auditory canal, and eardrum.
outlier A result that is very different from the other measurements in a data set.
oval window The membrane that connects the ossicles to the cochlea.

parallax A method of working out the distance to stars outside the Solar System.

parallel A circuit in which there are two or more paths or branches for the current.
partial eclipse A solar eclipse where only part of the Sun is covered by the Moon.
particle The tiny things that materials are made from.
peak The top of a wave.
peer review The evaluation of a scientist's work by another scientist.
penumbra The area of blurred or fuzzy shadow around the edges of the umbra.
phases of the Moon Shape of the Moon as we see it from Earth.
photoreceptor A specialised cell that is sensitive to light.
pie chart A way of presenting data when one variable is discrete or categoric and the other is continuous.
pinhole camera A simple camera made of a box with a small hole at the front and a screen at the back.
pinna The outside part of the ear that we can see.
pitch A property of sound determined by its frequency.
pivot The point about which a lever or see-saw balances.
pixel A picture element found at the back of a digital camera.
plan A description of how you will use equipment to collect valid data to answer a scientific question.
plane A mirror with a flat, reflective surface.
planet Any large body that orbits a star in a Solar System.
polar orbit A satellite in this orbit goes over the North and South Poles.
positive The charge on a proton, or on an object that has had electrons transferred from it.
potential difference A measure of the push of a cell or battery, or the energy that the cell or battery can supply.
power rating The number in watts or kilowatts that tells you the rate at which an appliance transfers energy.
precise This describes a set of repeat measurements that are close together.
prediction A statement that says what you think will happen.
pressure The force exerted on a certain area.
primary colour The colours red, blue, and green.
prism A triangular-shaped piece of glass used to produce a spectrum of light.
projectile motion Motion that can be predicted from the speed and direction of an object thrown into the air.
proton A positively charged particle found in atoms.
pull A type of force.
pupil The hole in the front of your eye where light goes in.
push A type of force.

quark A tiny particle that protons, neutrons and other particles are made of.

radar RAdio Detection And Ranging, a method of working out distance from the time of reflection.
radiation The transfer of energy as waves or particles from a source (which could be radioactive.
radioactive Giving out alpha, beta, or gamma radiation.
radioactivity The name of the process of producing radiation invented by Marie Curie.
radiotherapy A type of therapy that uses radioactive material to kill cancer cells.
radio waves Waves with the lowest frequency in the electromagnetic spectrum, used for communicating.
radium A radioactive element discovered by Marie Curie.
random (error) A error that causes there to be a random difference between a measurement and the true value each time you measure it.
range The difference between the lowest and highest values a variable can have.
rarefaction The part of a longitudinal wave where the air particles are spread out.
rating The value of potential difference at which a cell or bulb operates.
reaction The support force provided by a solid surface like a floor.
reaction time The time the brain takes to process information and act.
real (image) An image that you can put on a screen; the image formed in your eyes.
receiver The device that absorbs the sound waves.
reflect Bounce off.
reflected ray The ray that is reflected from a surface.
reflected wave The wave that is reflected from a surface.
reflecting telescope A telescope that uses mirrors to produce an image.

refracting telescope A telescope that uses lenses to produce an image.
reflection The change in direction of a ray or wave after it hits a surface and bounces off.
refraction The change in direction of a ray or wave as a result of its change in speed.
relative motion The difference between the speeds of two moving objects, or of a moving and a stationary object.
relay Electrical device that uses current flowing through it in one circuit to switch on and off a current in a second circuit.
renewable A fuel that is easily replaced.
repeatable (results) When you repeat measurements in an investigation and get similar results they are repeatable.
repel Be pushed away from each other, for example, like magnetic poles repel or like electric charges repel.
reproducible (results) When other people carry out an investigation and get similar results to the orginal investigation the results are repeatable.
resistance How difficult it is for current to flow through a component in a circuit.
resistive force Any force that acts to slow down a moving object.
resolution How clearly a microscope can distinguish two separate points.
retina The layer of light sensitive cells at the back of the eye.
retrograde motion The motion of a planet that looks as if it is moving backwards.
reverberation The persistence of a sound for a longer period than normal.
risk The probability of something happening that could cause damage or injury.
risk assessment A description of how you will make it less likely that people will be injured, or equipment damaged, and what to do if this happens.

safety Making sure that something is safe and that hazards and risks are minimal.
scientific journal A collection of articles written by scientists about their research.
season Changes in the temperature during the year as the Earth moves around its orbit.
secondary colour Colours that can be obtained by mixing two primary colours.
semiconductor A material that is halfway between a conductor and an insulator, used to detect particles.
sensing circuit A circuit that uses components such as LDRs and thermistors to detect changes in the environment, such as light or temperature changes.
sensor An electrical component that produces a voltage or changes its resistance when it detects something in the environment, such as a change in temperature.
series A circuit in which components are joined in a single loop.
SETI (Search for Extra-Terrestrial Intelligence) The programme of searching radio signals from space to find evidence of life on other planets.
simple machine Lever or gear that reduces the force required to do something, but increases the distance.
solar eclipse An eclipse where the Moon comes between the Sun and the Earth.
solar flare A process that produces a large amount of radiation emitted by the Sun.
Solar System The Sun and the planets and other bodies in orbit around it.
sound A series of compressions and rarefactions that move through a medium.
source (light or sound) Things that emit (give out) light or sound.
south pole The pole of a magnet that points towards the south.
spectrum A band of colours produced when light is spread out by a prism.
specular reflection Reflection from a smooth surface.
speed A measure of how far something travels in a given time.
speed of light The distance light travels in one second (300 million m/s).
speed of sound The distance sound travels in one second (330 m/s).
spread The difference between the highest and lowest measurements of a set of repeat measurements.
star A body in space that gives out its own light.
switch A component that controls the current by making or breaking the circuit.

streamlined Shaped to reduce resistance to motion from air or water.
stretch An object can be stretched if you exert a force on it.
Sun The star at the centre of our Solar System.
superpose When waves join together so that they add up or cancel out.
systematic (error) An error that causes there to be the same difference between a measurement and the true value each time you measure it.
switch A component that controls the current by making or breaking the circuit.

temperature A measure of how hot or cold something is, measured in degrees Celsius.
tension A stretching force.
tertiary colour A colour made by mixing three primary colours.
thermal equilibrium Objects are at thermal equilibrium when they are at the same temperature.
thermal imaging camera A camera that absorbs infrared and produces a (false-colour) image.
thermal power station A power station that uses fossil fuels to generate electricity.
thermal store Energy in objects as a result of the motion of their particles.
thermistor A device that has a resistance that changes with temperature.
thermometer Instrument used to measure temperature.
total eclipse An eclipse where all of the Sun is covered by the Moon.
total internal reflection The complete reflection of light at a boundary between two media.
translucent Objects that transmit light but diffusing (scattering) the light as it passes through.
transmit When light or other radiation passes through an object.
transmitter (light or sound) A device that gives out light or sound.
transparent Objects that transmit light and you can see through them.
transverse The vibrations are at right angles to the direction the wave moves.
trough The bottom of a wave.

ultrasound Sound at a frequency greater than 20 000 Hz, beyond the range of human hearing.
umbra The area of total shadow behind an opaque object where no light has reached.
unbalanced (forces) Opposing forces on an object that are unequal.
uncertainty The amount by which you cannot be sure of the value of your measurement because of your measuring instruments or methods.
Universe Everything that exists.
uplift Uplift happens when huge forces from inside the Earth push rocks upwards.
upthrust The force on an object in a liquid or gas that pushes it up.

vacuum A space in which there is no matter.
variable A quantity that can change, for example, time, temperature, length, mass.
Venus A rocky inner planet, second from the Sun in the our Solar System.
vibration Backwards and forwards motion of the parts of a liquid or solid.
virtual An image that cannot be focused onto a screen.
vocal chords The pieces of skin that vibrate to produce sound.
voltage A measure of the strength of a cell or battery used to send a current around a circuit.
voltmeter A device for measuring voltage.
volt Unit of measurement of voltage, symbol V.

water resistance The force on an object moving through water that causes it to slow down (also known as drag).
watt The unit of power, symbol W.
wave A vibration that transfers energy.
wavelength The distance between two identical points on the wave.
weight The force of the Earth on an object due to its mass.
wireless The process of transmitting information using electromagnetic waves rather than wires.
work A way of transferring energy that does not involve heating.

X-ray Wave of the electromagnetic spectrum used for producing images of bones and tissue.

year The length of time it takes for a planet to orbit the Sun.

Index

absorption
- infrared 88, 89
- light 38

acceleration 100, 101
accelerators 156
accuracy 4
additive colours 46
aerials 144
air pressure *see* gas pressure
air resistance 14, 18, 22
alien life detection 150, 151
alpha radiation 139
alternating current 143
AM (amplitude modulation) 154
ammeters 64
amplification, ears 32
amplifiers, microphones 33
amplitude, waves 26, 30
amplitude modulation (AM) 154
amps 64
analogies 133
analogue signals 114
analyses, data 8, 9
Andromeda 51
angle of incidence 40
angle of reflection 40
animals, sound 31
Apollo missions 136, 137
Aricebo radio telescope 150
Aristotle 129–131
artificial satellites 50, 134, 135, 152
asteroid belt 52, 53
atmospheric pressure 103
atoms 62, 156, 157
attraction
- electric charge 62
- magnets 72

audible range 31
auditory canal/nerve 32
average speed 99
axis (Earth) 54, 55

balanced forces 22, 23
bar charts 7
batteries 64–67
Baumgartner, Felix 29
Becquerel, Henri 138
beta radiation 139
Bhaskaracharya 129
Big Bang 132, 133
binary, digital signals 114
biomass 91
bits 114, 115
brain, eyes and 44
bubble chamber particle detection 156
bytes 114

cameras 44, 45, 89
cancer 140
carbon dioxide 90
carrier waves, radio 154, 155
categoric data 5
CCD (charge-coupled device) 45
cells, electric charge 64, 65
centre of gravity/mass 109
charge, electricity 62–65
charge-coupled device (CCD) 45
charts 7, 8
chemical stores, energy 82
circuits 64, 65
- potential difference 67
- sensing circuits 117
- series/parallel 68, 69
- symbols 64, 65

climate change 90
cloud chamber particle detection 156
cochlea, ears 32
coils, electromagnets 74, 75
collecting data 2, 6
collision, gas pressure 102
colour 46, 47
comets 50, 51
communication 144, 145, 154, 155
compressed gas 103
compression 16, 27, 103
computers, development 137
conclusions 8–10
conduction 86
conductors 71, 86
cones, retina 44
confidence in conclusions 10
conservation of energy 82
constellations 55
contact force 14
continuous data 5
continuous spectrum 46
control variables 3
convection 86, 87
convection currents 87
converging lens 43
convex lens 43
cores, electromagnets 74, 75
cornea 44
crest of wave 26
critical angle, electromagnetic spectrum 120
Curie, Marie 138–140
current 64, 65
- alternating 143
- convection currents 87
- different components 70
- electromagnets 74
- lightning 63
- series/parallel circuits 68, 69

curved mirrors, telescopes 148, 149

data
- accurate/precise 4
- analysing 8, 9
- collecting 2, 6
- evaluating 10, 11
- recording 6, 7
- types 5

day 54
decibels (dB) 33
defibrillators 119
deformation, forces 16
density, gas pressure 103
dependent variables 3
depth, liquid pressure 104
detection 148–159
- alien life 150, 151
- light 117
- messages 154, 155
- particles 156, 157
- planets 148, 149
- position 152, 153
- sound 32, 33

diaphragm, microphones 33
diffraction 155
diffuse scattering 41
digital signals 114
diodes, LEDs 116, 117
direction change
- light 42, 43
- projectile motion 122
- unbalanced forces 23

discrete data 5
discrete variables 7
dispersion, colour 46
dissipation, energy 83, 116
distances
- measuring with echoes 34
- to stars 153

distance–time graphs 100, 101
drag forces 18, 19
driving force 22
dwarf planets 52, 53

eardrum 32
ears 32
Earth 54, 55
- looking after 137
- magnetic field 73
- satellites 50

echoes 34, 35
eclipses 57
Edison, Thomas 71
efficiency, lightbulbs 116
elastic limit, springs 17
elastic stores, energy 82
electric charge 62–65
electric fields 63
electricity 62–71
- circuits/current 64, 65
- demand increases 124, 125
- magnetism and 74–77, 142–145
- paying for 92, 93
- potential difference 66, 67
- resistance 70, 71
- series/parallel circuits 68, 69

electromagnetic induction 142, 143
electromagnetic spectrum 115, 120, 121
electromagnetism 74–77, 142–145
electrons 62, 71
electrostatic force 20
elliptical orbits 52
emitting infrared 88
emitting light 38
endoscopes 120
energy 80–97
- adding up 82, 83
- balance 81
- conservation law 82
- crisis 124, 125
- food/fuels 80, 81
- power and 92, 93
- resources 90, 91
- stores 82–85
- temperature and 84, 85, 92
- transfer 28, 29, 83, 85–89
- waves 26
- work/machines 94, 95

equilibrium 22, 85, 108, 109
errors 11
evaluations, data 10, 11
evidence, scientific 128
exoplanets 149
extension, stretching 16
eyepiece lens, telescopes 148
eyes 38, 44, 45

falling over 109
Faraday, Michael 142, 143
field, force fields 20
filters, light 47
floating 105
FM (frequency modulation) 154
focal point/focus, lenses 43
food 80, 81
force fields 20
forces 14–25
- at a distance 20, 21
- balanced forces 22, 23
- describing 14
- drag forces 18, 19
- driving force 22
- liquid pressure 105
- magnetic fields 72
- measuring 15, 21
- spacecraft 134
- turning forces 108, 109
- types 14
- unbalanced forces 22, 23
- *see also* pressure

fossil fuels 90, 91
frequency
- audible range 31
- light 46
- ultrasound 35
- waves 26, 145

frequency modulation (FM) 154
friction 14, 18, 19
fuels 80, 81, 90, 91
fusion, nuclear 125

galaxies 51
Galilei, Galileo 131, 148
gamma cameras 141
gamma radiation 139
gamma rays 115, 121
gas giants 52
gas pressure 102, 103
gases
energy transfer 85–87
pressure in 102, 103
gears 95
generators, electricity 142
geocentric models 129, 130
geostationary orbits 135
geothermal energy 91
Global Positioning System (GPS) 152, 153
graphs 7, 8, 17, 100, 101
gravitational field strength 21
gravitational potential stores, energy 82
gravity 14, 20, 129
centre of 109
Solar System formation 53
greenhouse gases 90

habitable zone, life 151
half-life, radioactive materials 139
hearing *see* ears
heartbeat monitoring 119
heating, energy 85
heliocentric models 130, 131
helium 151
Henry, Joseph 143
Hertz, Heinrich 144
hertz (Hz), pitch of sound 30
Higgs boson particle 157
Hooke's Law 17
hospitals, new technology 118–121
houses, new technology 116, 117
Hubble Space Telescope (HST) 132, 149
hydroelectric energy 91
Hz *see* hertz

ideas, developing into questions 2
images
inverted 44
real images 45
reflection 40
incandescent lightbulbs 116
incidence, angle of 40
incident rays 40
incident waves 27
incompressibility, liquids 104
independent variables 3
induction, electromagnetic 142, 143
induction hob cooker 143
information storage 114, 115
infrared radiation 88, 89
infrared waves 115
infrasound 31
inner ear 32
instantaneous speed 99
insulators 71, 86
intensity of light 149
intensive care 118, 119
interaction pairs, forces 15
International Space Station (ISS) 50, 135
inverted images, eyes 44
investigations 2, 4, 5
iris of eye 44
iron 72, 74
ISS *see* International Space Station

joules (J) 80
Jupiter 50

Kepler space observatory 149
kg *see* kilograms
kHz *see* kilohertz
kilograms (kg) 21
kilohertz (kHz) 30
kilojoules (kJ) 80, 92
kilowatt hours (kWh) 92, 93
kilowatts (kW) 92
kinetic stores, energy 82
kJ *see* kilojoules
kW (kilowatts) 92
kWh *see* kilowatt hours

Large Hadron Collider (LHC) 156, 157
law of conservation of energy 82
law of moments 108
law of reflection 40, 41
LDRs (light-dependent resistors) 117
LEDs *see* light-emitting diodes
lenses 43, 148
LEO (low Earth orbit) 135
levers 94, 95
LHC *see* Large Hadron Collider
life detection 150, 151
lifting, electromagnets 76, 77
light 38–49
colour 46, 47
intensity of 149
new technology 116, 117
refraction 42, 43
source 38
speed of 29, 39
stars 151
travelling 38, 39, 42
waves 27, 39, 115, 120
light-dependent resistors (LDRs) 117
light-emitting diodes (LEDs) 116, 117
light gates, reaction time 123
light-time 39
lightbulbs 116, 117
lightning 63
line of best fit 8
line graphs 7, 8, 17
line of sight, GPS 152
line spectrum, stars 151
liquids
energy transfer 85, 86
pressure in 104, 105
see also water
longitudinal waves 26, 27
loudness 30, 31, 33
low Earth orbit (LEO) 135
lubrication 18
luminous objects 38
lunar eclipses 57

m/s (metres per second) 98
machines, energy 94, 95
magnetic field lines 73
magnetic fields 72–74
magnetic force 20
magnetic materials 72
magnetic resonance imaging (MRI) 121
magnets/magnetism 72–77, 121, 142–145
magnification, telescopes 148
Mars 50, 52
mass
centre of 109
particle detection 157
weight difference 21
mathematical models, alien life 150
Maxwell, James Clerk 144
mean (average) 6
measurements
distances 34
forces 15, 21
loudness 33
potential difference 66, 67
range of 5, 11
resistance 70, 71
spread of 4, 10
see also data
media
light travel 42
sound travel 28
Mercury 50, 52
message detection 154, 155
see also communication
metal-sorting, electromagnets 77
meteorites 50
meteors 50
metres per second (m/s) 98
microphones 30, 33, 114
microwaves 92, 115
middle ear 32
Milky Way 51
mirrors 40, 41, 148, 149
mobile phones *see* phones
models
alien life 150
electric circuits 65, 67, 69
Universe 128–131, 133
modulation, radio 154
moments, law of 108
Moon 50, 56, 57
missions to 134, 136, 137
phases of 56
motion 98–111
planets 130
projectile motion 122
see also speed
motion graphs 100, 101
motors 64, 77
MRI *see* magnetic resonance imaging
mutations, radioactive materials 140

N *see* newtons
N/m2 (newtons per metre squared) 106
natural satellites 50
see also Moon
negative charge 62
neutral objects, atoms 62
neutrons 62
new technology 114–127
Newton, Isaac 129
newton metres (Nm) 108
newtonmeters 15
newtons (N) 15, 21
newtons per metre squared (N/m2) 106
night 54
night sky 50, 51
Nm (newton metres) 108
non-contact force 14
non-luminous objects 38
non-renewable energy 90
normal line, mirrors 40
north pole, magnets 72
nuclear energy 91, 125
nuclear fusion 125

objective lens, telescopes 148
observations 2
Oersted, Hans Christian 142
ohms, resistance 70, 71
opaque objects 38
optic nerve 44
optical fibres 120
optical illusions 42
orbits
Earth 54, 55
planets 52
satellites 50, 134, 135
oscillation 26, 27
oscilloscopes 30
ossicles, ears 32
outer ear 32
outliers (results) 6
oval window, ears 32
oxygen, monitoring patients 118

pacemakers 119
parallax 153
parallel circuits 68, 69
partial eclipses 57
particles
detecting 156, 157
energy transfer 85–87
patients, monitoring 118, 119
peak of wave *see* crest of wave
peer reviews 143
penumbra, solar eclipses 57
phases of the Moon 56
phones 114, 115
photoreceptors, retina 44
pie charts 7
pinhole cameras 45
pinna of ear 32
pitch 30, 31
pivot, turning forces 108, 109
pixels, cameras 45
plane, mirrors 40
planets 50, 52, 53
detecting 148, 149
retrograde motion 130, 131
plans 4, 5

Plato 129
polar orbits 135
poles, magnets 72
polonium 138, 139
position, detecting 152, 153
positive charge 62
potential difference 66, 67, 69
  see also voltage
power, energy and 92, 93
power rating, appliances 92
power stations 90, 92, 143
precision, data 4
predictions 3, 9, 128, 129
pressure
  gases 102, 103
  liquids 104, 105
  solids 106, 107
primary colours 46
prisms 46
projectile motion 122
protons 62, 156, 157
Ptolemy 130
pull force 14, 15
pulse rate monitoring 118
pupil of eye 44
push force 14

quarks 157

radar 152, 153
radiation 86, 88, 89, 138, 139
radio telescopes 150
radio waves 115, 144, 145, 152–155
radioactivity 138–141
radiotherapy 141
radium 138, 141
random errors 11
range, measurements 5, 11
rarefaction, waves 27
rating potential difference 66
reaction force 16
reaction time 122, 123
real images 45
receivers, ultrasound 35
receiving information 115
recording data 6, 7
reflected rays 40
reflected waves 27
reflecting telescopes 148
reflection 38, 40, 41
  angle of 40
  infrared 89
  law of 40, 41
  optical fibres 120
  waves 27
refracting telescopes 148
refraction 42, 43, 120, 148
  dispersion 46
relative motion 99
relays, electromagnets 76
renewable energy 91, 124, 125
repeatability 5, 6
repelling
  electric charge 62
  magnets 72
reproducibility 5
resistance 117
  air 14, 18, 22
  electricity 70, 71
  water 18, 19
retina of eye 44
retrograde motion, planets 130, 131
reverberations 34
risk, spacecraft missions 136, 137
risk assessment 5, 136
rods, retina 44

safety 5, 123
satellites 50, 134, 135, 152
  see also Moon
Saturn 50
scientific questions 2, 3
scientific work 2–11, 128
Search for Extra-Terrestrial
  Intelligence (SETI) 150
seasons 54
secondary colours 46
see-saws 109
semiconductors, LHC 157
sending information 115
sensing circuits 117
sensors, light detection 117
series circuits 68, 69
SETI (Search for Extra-Terrestrial
  Intelligence) 150
simple machines 94, 95
sinking 105
smart devices 114, 115
solar eclipses 57
solar energy 91, 125
solar flares 136, 137
Solar System 50, 52, 53
  detecting distances 153
  formation 53, 133
  models 130
solids
  energy transfer 85, 86
  pressure on 106, 107
sonar 35
sound 26–37
  detecting 32, 33
  hospital equipment 121
  speed of 28–39
  transfer 28, 29
  waves 26–28, 30
source of light 38
south pole, magnets 72
space 21, 134–137, 148–151, 153
spacecraft 134–137
spectrum, electromagnetic 115,
  120, 121
spectrum of light 46, 151
specular reflection 41
speed 98–101
  calculating 98, 101
  of light 29, 39
  projectile motion 122
  of sound 28–39
  unbalanced forces 23
sports, new technology 122, 123
spread of measurements 4, 10
springs 17
squashing 16, 17
stars 51, 55, 151, 153
  see also galaxies; Sun
static electricity 62
steel 72, 74, 75
sterilisation materials 141
storing information 114, 115
story-telling 128
straight-line graphs 17
streamlining 19
stretching 16, 17
subtractive colours 46, 47
Sun 50, 88, 125, 136, 137
  see also solar...
superposed waves 27
switches 64, 76, 77
symbols, circuits 64, 65
systematic errors 11

telescopes 131, 148–150
television 145
temperature
  energy and 84, 85, 92
  gas pressure 102
  intensive care 118
tension 17
terrestrial planets 52
theories 132
thermal imaging cameras 89
thermal power stations 90
thermal stores, energy 82, 84, 85
thermistors 118
thermometers 84
tidal energy 91
time
  distance–time graphs 100, 101
  Universe and 133
total eclipses 57
total internal reflection, optical
  fibres 120
trains 76
translucence 38
transmission of light 38
transmitters
  radio waves 144
  ultrasound 35
transparent objects 38
transverse waves 26, 27
trough of wave 26
turbines *see* wind turbines
turning forces 108, 109
turning points in physics 128–147

ultrasound 31, 35
ultraviolet (UV) waves 115
umbra, solar eclipses 57
unbalanced forces 22, 23
uncertainty 5, 11, 123
undulation 26
Universe 51, 128–133
upthrust 15, 105
uranium 138
UV (ultraviolet) waves 115

vacuums
  light and 39
  sound and 28
variables 2, 3, 7
ventilators 119
Venus 50, 52, 53
vibrations 26, 28, 32
virtual images 40
visible light 115, 120
voltage 66, 67
  see also potential difference
voltmeters 66, 67
volts 66
volume changes, gas pressure 102

W (watts) 92
water
  light refraction 42
  resistance 18, 19
  see also liquid...
watts (W) 92
wavelengths 26
waves 26–28, 30, 39
  communication 144, 145
  crest of wave 26
  diffraction 155
  features 26
  hospital equipment 120
  infrared waves 115
  smart devices 115
  superposed 27
  trough of wave 26
  see also radio waves
weight
  forces 21
  pressure 106, 107
white light splitting 46
wind turbines 91, 124, 125
wireless devices 144, 145
wires
  communication 144
  electrons 71
  magnetic fields 74
work as energy 94, 95

X-rays 76, 115, 120

OXFORD
UNIVERSITY PRESS

Great Clarendon Street, Oxford, OX2 6DP, United Kingdom

Oxford University Press is a department of the University of Oxford. It furthers the University's objective of excellence in research, scholarship, and education by publishing worldwide. Oxford is a registered trade mark of Oxford University Press in the UK and in certain other countries

First published in 2014

British Library Cataloguing in Publication Data
Data available

978-0-19-830717-4

10 9 8 7 6 5 4

Paper used in the production of this book is a natural, recyclable product made from wood grown in sustainable forests. The manufacturing process conforms to the environmental regulations of the country of origin.

Printed in India by Manipal Technologies Ltd

Acknowledgements
The publisher and the authors would like to thank the following for permissions to use their photographs:

Cover image: Ase/Shutterstock; p2: Rido/Shutterstock; p2: Rex Features; p10: Arcady/Shutterstock; p12: 262276/Shutterstock; p12: ProfStocker/Shutterstock; p12-13: Diego Cervo/Shutterstock; p13: Elke Meitzel/Science Photo Library; p13: Michael Dunning/Photographer's Choice/Getty Images; p13: svetlana55/ Shutterstock; p13: bkindler/iStockphoto; p13: Tish1/Shutterstock; p13: Susumu Nishinaga/Science Photo Library; p14: Terry Renna/AP Images; p15: ProfStocker/ Shutterstock; p15: MichaelHitoshi/Photodisc/Getty Images; p16: Brave Rabbit/ Shutterstock; p17: Elina/Shutterstock; p18: Velychko/Shutterstock; p19: Gallo Images/Vetta/Getty Images; p20: Tommounsey/iStockphoto; p20: 262276/ Shutterstock; p22: Diego Cervo/Shutterstock; p22: Yousef Allan/AP images; p23: Racefotos2008/Shutterstock; p24-25: Brave Rabbit/Shutterstock; p24: Racefotos2008/Shutterstock; p24: Velychko/Shutterstock; p26: Andrew Lambert Photography/Science Photo Library; p27: science photos/alamy; p28: Steve Allen/ Science Photo Library; p28: Stuart Westmorland/Corbis; p29: Jay Nemeth/ Red Bull/Associated Press; p30: Andrew Lambert Photography/Science Photo Library; p30: Image Source/Getty Images; p31: Elke Meitzel/Science Photo Library; p32: Steve Gschmeissner/Science Photo Library; p34: Henrik Sorensen/ The Image Bank/Henrik Sorensen; p35: Thierry Berrod, Mona Lisa Production/ Science Photo Library; p36: Jay Nemeth/Red Bull/Associated Press; p36: Steve Allen/ Science Photo Library; p36-37: Stuart Westmorland/Corbis; p38: Efired/ Shutterstock; p38: auremar/Shutterstock; p40: gabczi/Shutterstock; p42: Martyn F. Chillmaid/Science Photo Library; p44: Tatiana Makotra/Shutterstock; p45: Paul Parker/Science Photo Library; p46: Atlantide Phototravel/Corbis; p46: Andrzej Wojcick/Science Photo Library; p48: Tatiana Makotra/Shutterstock; p48: Paul Parker/Science Photo Library; p48: auremar/Shutterstock; p50: NASA/ Science Photo Library; p51: Marcel Clemens/Shutterstock; p51: Celestial Image Picture Co./Science Photo Library; p52: Marcel Clemens/Shutterstock; p52: NASA/Science Photo Library; p54: David Parker/Science Photo Library; p55: Dr Juerg Alean/Science Photo Library; p56: NASA/Science Photo Library; p57: bkindler/iStockphoto; p58: David Parker/Science Photo Library; p58: bkindler/ iStockphoto; p58-59: Celestial Image Picture Co./Science Photo Library; p61a: Martyn F Chillmaid/Science Photo Library; p61b: Marcel Clemens/Shutterstock; p61c: Triff/Shutterstock; p61d: Science Source/Science photo Library; p62: Charles D Winters/Science Photo library; p63a: Erik Simonsen/Getty Images; p63b: Ted Kinsman/Science Photo Library; p64a: Peter Ryan/Science Photo Library; p64b: Matthew Oldfield/Science Photo Library; p66a: Michael Donne/ Science photo Library; p66b: Martyn F Chillmaid/Science Photo Library; p66c: Tek Image/Science Photo Library; p68: Romakoma/Shutterstock; p70: Pincasso/ Shutterstock; p71: Andrew Lambert/Science Photo Library; p72a: Oliver Hoffman/Shutterstock; p72b: JJ Studio/Shutterstock; p73: Mark Garlick/Science Photo Library; p75: Clive Streeter/Dorling Kindersley/Getty Images; p76: Martin Bond/Science Photo Library; p80a: Graf Vision/Shutterstock; p80b: Anglian Art/ Shutterstock; p80c: Danymages/Shutterstock; p80d: Volosina/Shutterstock; p81a: Ajan Alen/Shutterstock; p81b: Michael Jung/Shutterstock; p81c: CLS Design/Shutterstock; p81d: Levent Konuk; p82a: Art Allianz/Shutterstock; p82b: Liane M/Shutterstock; p83a: Peter Gudella/Shutterstock; p83b: Edward Kinsman/Science Photo Library; p84a: Alberto Pellaschiar/Associated Press; p84b: Lebazele/Getty Images; p84c: Mehau Kulyk and Victor De Schwanberg/ Science Photo Library; p84d: Bikerriderlondon/Shutterstock; p84e: Andrew Lambert photography/Science Photo Library; p86a: Nrel/US Department of Energy/Science Photo Library; p86b: Qin Xianan/Color China Photo/Associated Press; p87a: Blue Ring Media/Shutterstock; p87b: Jeff Schmaltz, Lance/Eosdis Modis Rapid Response Team/NASA/Science Photo Library; p88a: GIP Photosstock/Science Photo Library; p88b: Noao/Science Photo Library; p88c: Edward Kinsman/Science Photo Library; p89: Dario Sabljak/Shutterstock; p89b: Jason Hetherington/Getty Images; p90: Tim Burrett/Shutterstock; p91a: Irina Belousa/iStock; p91b: Kshishtof/iStock; p91c: Skynavin/Shutterstock; p91d: Tides Stream; p91e: Martin Bond/Science Photo library; p91f: iStock; p91g: gprentice/iStock; p92: Tony McConnell/Science Photo Library; p93a: Cecile Degremont/Look at Sciences; p93b: Sheila Terry/Science Photo Library; p94: Antonov Roman/Shutterstock; p95a: Science Source/Science Photo library; p95b: Kkgas/iStock; p98a: Frans Lanting/Mint Images/Science Photo Library; p98b: Joe Gough/Shutterstock; p99: Ostill/Shutterstock; p100: Christian Mueller/ Shutterstock; p102: Ted Kinsman/Science Photo Library; p103a: Charles D Winters/Science Photo Library; p103b: Charles D Winters/Science Photo Library; p104a: Dr Ken MacDonald/Science Photo Library; p104b: David Parker/Science Photo Library; p106a: NASA/Science Photo Library; p106b: Jeremy Bishop/ Science Photo Library; p107a: Warren Goldswain/Shutterstock; p107b: Racheal Grazias; p107c: Bigchen/Shutterstock; p108a: Frank Gunn/The Canadian Press/ Associated Press; p108b: Benedektibor/Shutterstock p112: (background) Nasa/ Esa/Stsci/Science Photo Library, (t) Arno Massee/Science Photo Library, (m) Soho/ ESA/NASA/Science Photo Library; p123: (tl1) NASA/Science Photo Library, (tl2) Pyshnyy Maxim Vjacheslavovich /Shutterstock, (tc1) Fuse/Getty Images, (tc2) NASA/Science Photo Library, (tr1) NASA/Science Photo Library, (tr2) Ted Kinsman/Science Photo Library, (b) Klaus Guldbrandsen/Science Picture Library; p114: (tl) Jeremy Horner/Corbis, (tr) Sam Ogden/Science Photo Library; p115: Claus Lunau/Science Photo Library; p116: (t) Jiri Hera/Shutterstock, (b) janda75/ iStockphoto; p117: (t) Edward Kinsman/Science Photo Library; p118: (l) AJ photo/hop. Americain/Science Photo Library; p119: (t) Dr P. Marazzi/Science Photo Library, (ml) Michael Donne/Science Photo Library, (mr) Deep Light Productions/Science Photo Library, (b) LISSAC/Science Photo Library; p121: Arno Massee/Science Photo Library; p122: (tl) lev radin/Shutterstock, (tr) Kenneth Eward/Science Photo Library, (bl) Howard Kingsnorth/Science Photo Library; p123: Pedro Ugarte/AFP/Getty images; p124: Jesus Keller/Shutterstock; p125: European Space Agency/J. Huart/Science Photo Library; p126: (background) janda75/iStockphoto, (tr) Edward Kinsman/Science Photo Library, (mr) Jesus Keller/Shutterstock; p128: (l) Yuttasak Jannarong / Shutterstock, (c) Royal Astronomical Society/Science Photo Library /Science Photo Library, (r) Sheila Terry/Science Photo Library; p129: (r) NASA/Science Photo Library; p130: (b) Sheila Terry/Science Photo Library; p132: (l) Victor De Schwanberg/Science Photo Library, (r) Stocktrek/Photodisc/Getty Images; p133: (l) Mark Garlick/ Science Photo Library, (r) MaraZe/Shutterstock; p134: (b) Julian Baum/Science Photo Library; p136: (t) NASA/Science Photo Library, (b) NASA/Science Photo Library; p137: (tr) Soho/ESA/NASA/Science Photo Library, (tl) Pyshnyy Maxim Vjacheslavovich /Shutterstock, (tc) Photobac/Shutterstock, (ml) YanLev/ Shutterstock, (bl) FamVeld /Shutterstock, (bc) Tomislav Pinter/Shutterstock; p138: (tl) Martyn F. Chillmaid/Science Photo Library, (bl) W. F. Meggers Collection/American Institute of Physics/Science Photo Library, (r) Science Photo Library; p140: (tl) Public Health England/Science Photo Library, (bl) Public Health England/Science Photo Library, (br) Kaspri/Shutterstock; p141: (tr) Lack-O'Keen/Shutterstock; p142: (t) Giphotostock/Science Photo Library, (b) British Library/Science Photo Library; p143: (tr) Awe Inspiring Images/ Shutterstock, (bl) Sheila Terry/Science Photo Library; p144: (tl) Iurii/ Shutterstock, (bl) Christopher Wood/Shutterstock, (br) NYPL/Science Source/ Science Photo Library; p145: Fuse/Getty Images; p146: (background) Mark Garlick/Science Photo Library, (tr)Public Health England/Science Photo Library, (mr) Martyn F. Chillmaid/Science Photo Library; p148: Amy Walters/ Shutterstock; p149: (tr) NASA/Ames/JPL-Caltech/Wikipedia, (mr) Nasa/Esa/Stsci/ Science Photo Library; p150: (t) David Parker/Science Photo Library, (b) NASA/ Science Photo Library; p151: Science Photo Library; p152: (t) Ted Kinsman/ Science Photo Library, (b) Ed Young/Science Photo Library; p154: DmitriMaruta/ Shutterstock; p156: (t) Galina Barskaya/Shutterstock, (b) Adam Hart-Davis/ Science Photo Library; p157: (t) CERN/Science Photo Library, (b) Thomas Mccauley, Lucas Taylor/Cern/Science Photo Library; p158: (background) Thomas Mccauley, Lucas Taylor/Cern/Science Photo Library, (tr) NASA/Science Photo Library, (mr) Amy Walters/Shutterstock.

Activate

Question • Progress • Succeed

Physics

Activate is a Key Stage 3 Physics course designed to support every student on their journey through Key Stage 3 to Key Stage 4 success.

The ***Activate*** suite of resources is tailored to the 2014 Programme of Study and offers a comprehensive and flexible solution for effective differentiation and assessment.

Activate offers:

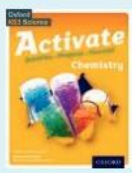
- **a clear route through Key Stage 3 Physics** for students following a triple-science Key Stage 3
- **inquisitive and engaging science**, with Big Questions, investigations, and question-led lessons
- **maths, literacy, and working scientifically progression** developed and supported throughout the course
- **carefully designed and differentiated questions**, motivating every student to improve and progress
- **reliable and effective assessment resources**, quality assured by an expert assessment editor
- **preparation for Key Stage 4**, with development of QWC, working scientifically, and problem-solving question skills.

What's on the cover?

The cover shows a computer-generated electric lightning effect.

kerboodle

Kerboodle provides digital Lessons, Resources, and Assessment for your classroom, plus a Kerboodle Online Student Book available for separate access by teachers and students.

Student Books	  	Packed full of activities, questions, and interesting facts to engage and inspire students.
Teacher Handbooks	  	Page-by-page match to the Student Book, with lesson plans, differentiation, and assessment.
Kerboodle: Lessons, Resources, and Assessment	kerboodle kerboodle kerboodle	A flexible bank of resources, including lessons and automarked tests.
Kerboodle Books	kerboodle kerboodle kerboodle	Online access to the Student Book, accessible on a wide range of devices both in school and at home.

Prefer combined sciences?

All components in ***Activate*** are also available as *Activate 1*, *Activate 2*, and *Activate 3* versions.

OXFORD
UNIVERSITY PRESS

How to get in touch:
web www.oxfordsecondary.co.uk
email schools.enquiries.uk@oup.com
tel 01536 452620
fax 01865 313472

ISBN 978-0-19-830717-4