

GCSE PHYSICS

(8463)

Required practical handbook

The methods provided in this Required practical handbook are suggested examples, designed to help your students fulfil the apparatus and techniques requirements outlined in the specifications. Written papers will include questions requiring knowledge gained from carrying out the specified practicals.

Please note: it is the Apparatus and techniques requirements which are compulsory and must be fulfilled. Teachers are encouraged to adapt or develop activities, resources and contexts to suit their equipment and to provide the appropriate level of engagement and challenge for their own students.

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Introduction

The purpose of this handbook

The required practical activities listed in the GCSE Physics specification (8463) have been written to ensure that students have the opportunity to experience all of the Apparatus and Techniques (AT) criteria required by Ofqual.

In this guide we **suggest** methods for carrying out the required practical activities to give ideas and guidance to help you plan the best experience for your students. **None of these methods are compulsory.** However, you must ensure that you carry out a sufficient variety of practical work to give your students the opportunity to experience all aspects of the AT criteria required by Ofqual. The methods we have suggested will enable you to do this, but we strongly encourage you to adapt them to fit the needs of your students and the resources you have available.

The methods we suggest are deliberately familiar, using apparatus and techniques that are readily available in most schools. All of the methods suggested have been written by practising teachers and trialled by specialist lab technicians, who have included sample results when appropriate.

Covering the AT criteria

Students must be given the opportunity to experience all of the physics AT criteria during their GCSE science course, regardless of the awarding body whose specification they study.

Individual practical activities will not necessarily cover all aspects of an AT statement, ie it is only by doing all of the required practical activities that all aspects of each AT statement will be covered. The teacher and technician notes indicate which aspects of an AT statement the method we suggest covers.

We are keen to encourage teachers to use alternative methods that support students to develop their understanding of the AT statements. More detailed advice, additional activities and alternative methods can be found on the [CLEAPSS website](#).

Whichever method you use, it is your responsibility to check that you have covered all of the aspects of the AT statements.

The GCSE practical science statement

There is no practical skills endorsement at GCSE level, unlike that at A-level. Instead, the head of each school or college will need to sign the AQA practical science statement to confirm that reasonable opportunities have been given to ensure that each student has:

- completed the required practical activities detailed in the specification
- made a contemporaneous record of such work undertaken during the activities and the knowledge, skills and understanding derived from those activities.

The head of centre will need to return the signed statement to us by the date we will publish on our website. We will also contact schools and colleges directly with the deadline date and send timely reminders if we don't receive the form. Failure to send this form counts as malpractice/maladministration and may result in formal action or warning for the school or college.

Teachers should agree with their head of school what evidence he or she requires to be confident in signing the declaration.

If a student is absent from a required practical activity and doesn't catch up with the work they have missed, it may compromise their overall grade as 15% of the available examination marks are practical work related.

Risk assessment

Schools and colleges are responsible for ensuring that appropriate safety procedures are followed, and should undertake full risk assessments.

Comprehensive information on safe use of practical apparatus, techniques and associated chemicals etc is available on the [CLEAPSS website](#).

Suggested websites to support with practical work

[Association for science education](#)

[Getting practical](#)

[IOP](#)

[Practical Physics](#)

[STEM](#)

Student worksheets

Within the student worksheets we have included a number of tasks which will challenge students to think about their practical work and/or related theory. The questions are **not** example examination questions and are expected to be edited and expanded on by teachers.

Required practical activities per specification

The below table shows which required practical activities must be covered by each of the five GCSE science specifications.

Required practical activity	Synergy	Trilogy	Biology	Chemistry	Physics
Microscopy	✓	✓	✓		
Osmosis	✓	✓	✓		
Enzymes	✓	✓	✓		
Food tests	✓	✓	✓		
Photosynthesis	✓	✓	✓		
Reaction time	✓	✓	✓		
Field investigations	✓	✓	✓		
Plant responses			✓		
Decay			✓		
Microbiology			✓		
Making salts	✓	✓		✓	
Temperature changes	✓	✓		✓	
Rates of reaction	✓	✓		✓	
Chromatography	✓	✓		✓	
Water purification	✓	✓		✓	
Electrolysis	✓	✓		✓	
Neutralisation				✓	
Identifying ions				✓	
Specific heat capacity	✓	✓			✓
Resistance	✓	✓			✓
I-V characteristics	✓	✓			✓
Density	✓	✓			✓

Force and extension	✓	✓			✓
Acceleration	✓	✓			✓
Waves	✓	✓			✓
Radiation and absorption	✓	✓			✓
Thermal insulation					✓
Light					✓

Teacher and technician notes

Specific heat capacity

An investigation to determine the specific heat capacity of one or more materials.

The investigation will involve linking the decrease of one energy store (or work done) to the increase in temperature and subsequent increase in thermal energy stored.

	Trilogy	Synergy	Physics
RPA	14	2	1
Specification reference	6.1.1.3	4.1.1.4	4.1.1.3

By using this method your students will have the opportunity to develop the following aspects of the physics AT skills	
AT 1	use of appropriate apparatus to measure mass, time and temperature accurately
AT 5	use in a safe manner appropriate apparatus to measure energy changes/transfers and associated values such as work done

Materials

Each student should have:

For the basic method

- 1 kg copper, iron and aluminium metal blocks, each with two holes – one for the heater and one for the thermometer
- thermometer
- pipette to put water in the thermometer hole
- 30 W heater
- 12 V power supply
- insulation to wrap around the blocks
- ammeter and voltmeter
- 4 mm leads
- stopwatch or stopclock
- balance (capable of measuring more than 1 kg) to determine the mass of the blocks
- heatproof mat.

Technical information

The method involves using an electric heater to raise the temperature of the blocks. You may have blocks made for this experiment. The blocks usually have a mass of 1 kg and have holes that fit the heater and the thermometer. The heaters fit snugly but there is usually an air gap around the thermometer. A drop of water provides a better thermal contact. The blocks should be lagged to reduce heat loss to the surroundings.

Please refer to the GCSE Physics required practicals presentation on the [GCSE Practicals page](#) for examples of DIY equipment and tips.

The students will switch on the power supply and measure the current and potential difference. This is to obtain the power of the heater (power = potential difference x current), which should remain constant. Typical heaters are rated at anything from 30 W to 110 W. The students can be told the power of the heater rather than measure it if preferred. The students measure and record the temperature of the block every minute for about 10 minutes. They then plot a graph of temperature against work done by the heater. There is some thermal inertia as the block warms up so the beginning of the student's graphs will not be linear if they start timing from when they switch on.

Additional information

The heat capacity of a substance is the work done raising the temperature of the substance by 1 °C. Heat capacity depends upon the mass of substance. If it is measured for unit mass (ie 1 kg), it is called the specific heat capacity.

$$\text{specific heat capacity} = \frac{\text{energy transferred}}{\text{mass} \times \text{temperature rise}}$$

The students obtain values for current and potential difference (to work out the power), time and temperature. From the power and time they can work out the energy supplied, or work done by the heater. A graph of temperature against work done should be a straight line once the block has warmed a bit. Students use the gradient of this line and the mass of the block to work out the specific heat capacity. Having blocks of different materials allows students to see that specific heat capacities vary significantly, even between metals.

Metal	Copper	Aluminium	Iron	Lead	Steel	Brass
Specific heat capacity in J/kg °C	385	913	500	126	452	380

Using a 30 W heater for 10 minutes provides $10 \times 60 \times 30 = 18\,000$ J

This would be sufficient to raise the temperature of 1 kg of copper from room temperature to about 70 °C, aluminium to about 40 °C and iron to 55 °C. This supports the idea that 10 minutes is an adequate length of time for the experiment.

Thermal insulation

Investigate the effectiveness of different materials as thermal insulators and the factors that may affect the thermal insulation properties of a material.

	Physics
RPA	2
Specification reference	4.1.2.1

By using this method your students will have the opportunity to develop the following aspects of the physics AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately, including time, volume and temperature
AT 5	safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associate values such as work done

There are two parts to this practical:

1. Investigating the effectiveness of different materials as thermal insulators.
In this part of the experiment students will measure the rate of cooling of a beaker of hot water when insulated with different materials.
2. Investigating factors that may affect the thermal insulation properties of a material.
In this part of the experiment students will measure the rate of cooling of a beaker of hot water when insulated with different thicknesses of the same materials.

Materials

For the basic method

- five 100 cm³ beakers
- five 250 cm³ beakers
- five thermometers
- kettle to heat water
- piece of cardboard
- scissors
- stopwatch
- insulating material (eg newspaper, corrugated cardboard, bubble wrap, polystyrene balls, cotton wool)
- rubber bands.

AQA technician data

Time mins	Material used for insulation			
	No insulation	Bubble wrap	Newspaper	Tin foil
	Temperature °C			
0	85	86	86	84
3	78	81	81	77
6	71	76	77	70
9	64	69	70	65
12	60	65	66	61
15	57	61	63	58
Change in temperature °C				

Time mins	Material used for insulation			
	0 layers of newspaper	2 layers of newspaper	4 layers of newspaper	6 layers of newspaper
	Temperature °C			
0	85	86	86	86
3	78	81	82	83
6	71	76	77	78
9	64	68	70	71
12	60	65	67	68
15	57	62	65	66
Change in temperature °C				

Resistance

Use circuit diagrams to set up and check appropriate circuits to investigate the factors that affect the resistance of an electrical circuit.

This should include

- the length of a wire at constant temperature
- combinations of resistors in series and parallel.

	Trilogy	Synergy	Physics
RPA	15	15	3
Specification reference	6.2.1.3	4.7.2.2	4.2.1.3

By using this method your students will have the opportunity to develop the following aspects of the physics AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including length
AT 6	use of appropriate apparatus to measure current, potential difference (voltage) and resistance and to explore the characteristics of a variety of circuit elements
AT 7	use circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements

There are two parts to this practical:

1. Investigating how the resistance of a wire depends on its length.
2. Investigating resistance in series and parallel circuits.

Materials

Each student should have:

For the basic method

- a battery or suitable power supply
- ammeter
- voltmeter
- crocodile clips
- resistance wire
- metre rule
- connecting leads
- wire-wound resistors, eg $10\ \Omega$.

Technical information

This practical requires the students to make a circuit by looking at a circuit diagram, measure current and potential difference and calculate the resistance.

Activity 1

Attach a length of resistance wire (eg constantan or nichrome 22swg) to a metre ruler using short pieces of tape. Attach a crocodile clip to one end (the zero end) of the wire. Attach the other crocodile clip to the wire at a first specified length. The students vary the length of wire by moving this crocodile clip and record the length of wire, current and potential difference.



Additional information

The resistance of the wire is proportional to its length. A graph of resistance against length should be a straight line through the origin.

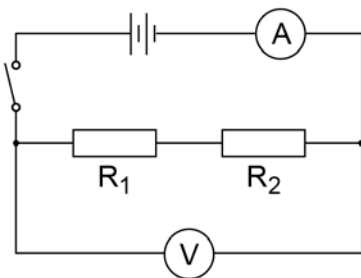
This experiment is a good one to use to discuss zero error as it is hard to attach the crocodile precisely to the zero end of the wire, and there will be some contact resistance.

The potential difference will not vary very much during the experiment. Use a low value of potential difference particularly for the short length of wire as the current will increase significantly and the wire can get quite hot. The wire should be fairly thin to give decent values of resistance.

Activity 2

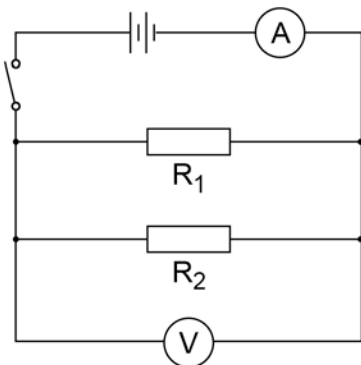
For the second activity, any suitable value of resistors may be used as long as you have two resistors of the same value. Using wire-wound resistors should alleviate any potential problems with overheating.

Give students two resistors of the same value and ask them to connect them into the two circuits shown below. By measuring the voltage across the resistors and the current through them (placing the meters in the positions shown in the circuit diagrams) they can calculate the total resistance of the circuit.



Technician Adviser results

0.22A
4.45V
 $R_1=R_2$



Technician Adviser results

Current 0.79A
Potential difference 3.94V
 $R_1=R_2$

Students compare the total resistance in the circuit when they connect the resistors in series and in parallel.

I–V characteristics

Use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements including a filament lamp, a resistor and a diode at constant temperature.

	Trilogy	Synergy	Physics
RPA	16	15	4
Specification reference	6.2.1.4	4.7.2.2	4.2.1.4

In this practical, students set up circuits involving different elements to investigate how the current changes as with the potential difference.

There are three parts to this investigation:

- characteristics of a lamp
- characteristics of a resistor
- characteristics of a diode.

By using this method students will have the opportunity to develop the following aspects of the physics AT skills	
AT 6	use appropriate apparatus to measure current and potential difference and to explore the characteristics of a variety of circuit elements
AT 7	use circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements

Materials

For the basic method

- ammeter
- milliammeter (for working with the diode)
- voltmeter
- 12 V, 24 W filament lamp (eg a ray box lamp)
- Resistor (eg 100 Ω , 1 W)
- diode and protective resistor (eg 10 Ω)
- variable resistor (eg 10 Ω , 5 A)
- connecting leads.

Technical information

There are many different electricity kits available and the students should use what is familiar to them. When using the diode, the students will need to use a protective resistor. They should still be able to connect the voltmeter across the diode (ie the resistor and diode should not be soldered together). This resistor should be labelled 'P' to distinguish it from the other resistor.

If a lab pack is used for the power supply this can remove the need for the rheostat as the potential difference can be varied directly. The voltage should not be allowed to get so high as to damage the components, check the rating of the components you plan to suggest your students use.

Additional information

There are three separate experiments, ideally to be run during the same lesson in the order written.

The diode will need to be protected to prevent the current through it getting too big. It also behaves differently depending on the polarity of the supply. Due to the low currents through it, a milliammeter will need to be used in this circuit.

The students will record the current through each component for different values of potential difference. This method uses a variable resistor to vary the potential difference, although a variable power supply may be used instead.

The students will plot a graph of current against potential difference. The shape of this specific graph is what is meant by a characteristic of a component. There is a tendency for some to think that the gradient of this graph is the resistance. In fact the resistance at any point on the graph is the inverse of the gradient of a line from that point to the origin.

Density

Use appropriate apparatus to make and record the measurements needed to determine the densities of regular and irregular solid objects and liquids.

Volume should be determined from the dimensions of regularly shaped objects and by a displacement technique for irregularly shaped objects.

	Trilogy	Synergy	Physics
RPA	17	1	5
Specification reference	6.3.1.1	4.1.1.2	4.3.1.1

There are three parts to this investigation:

- calculating the density of a regularly shaped object
- calculating the density of an irregularly shaped object
- calculating the density of a liquid.

By using this method students will have the opportunity to develop the following aspects of the physics AT skills	
AT 1	use appropriate apparatus to make and record a range of measurements accurately including length, mass and volume. Use of such measurements to determine densities of solid and liquid objects

Materials

For the basic method

- various regular shaped objects
- various irregular shaped objects
- a suitable liquid (eg sugar solution)
- a 30 cm ruler marked off in millimetres
- a digital balance
- a displacement can
- a variety of measuring cylinders
- two 250 cm³ beakers
- paper towels.

Technical information

The experiments may be best done as part of a circus – so that everyone uses the different density measuring techniques. You may want to code the solid objects for easy identification.

The displacement can spout is likely to be too low to fit a measuring cylinder underneath it; you will need to hold a beaker underneath and wipe up any spills.

Additional information

There are three separate experiments. The density of regular objects focuses on the use of a millimetre scale ruler and the calculations of volume and density. Students could use their value of density to identify the material of the object being measured.

The density of liquid experiment does not make use of specific gravity bottles. It is a basic technique and students could identify a liquid from its density.

The experiments provide data in g and cm^3 . Students should be able to calculate density in g/cm^3 and kg/m^3 .

Suggested alternative approaches from teachers and technicians

If a displacement can is not available, students could measure the volume by displacement in a sufficiently large measuring cylinder and noting the change in reading. Students should choose an appropriate measuring cylinder and justify their choice.

Force and extension

Investigate the relationship between force and extension of a spring.

	Trilogy	Synergy	Physics
RPA	18	13	6
Specification reference	6.5.3	4.6.1.6	4.5.3

In the practical, students place known masses on a spring, measure the total resultant length of the spring and calculate its extension.

By using this method students will have the opportunity to develop the following aspects of the physics AT skills	
AT 1	use appropriate apparatus to make and record a range of measurements accurately including length
AT 2	use appropriate apparatus to measure and observe the effect of forces including the extension of springs

Materials

For the basic method

- a suitable spring capable of extending more than 1 cm under a load of 1 N with loops at each end
- metre ruler
- suitable pointer (eg splint and tape)
- weight stack appropriate for the spring (eg 10 N in steps of 1 N)
- clamp stand
- two clamps and bosses
- G-clamp or weight to prevent the apparatus tipping over the edge.

Technical information

The pointer should be attached so that it doesn't slip or change angle. It is probably best attached to the bottom of the spring. Students will calculate the extension ie the increase in length. Many are likely to think that this is the incremental increase – in fact it is the total increase (ie from the original length). The students align the top of the ruler with the top of the spring – this isn't essential but it may help to emphasise this point about the extension.

Students may need to be told how to convert the mass (in grams) written on the weight stack into a weight in newtons. (Using the equation weight (N) = mass (kg) x gravitational field strength (N/kg). This practical can be used to emphasise the difference between mass and weight.

Additional information

The proportional relationship between force and extension is known as Hooke's Law.

The students will record the reading on the metre ruler (which will be the length of the spring if set up that way) as the weights are added. They will then calculate the extension (ie the increase from the original reading). The extension should increase in proportion to the weight. A graph of extension against weight will be a straight line through the origin. The gradient of the line is 1/stiffness or 1/spring constant (ie the graph for a stiffer spring will have a lower gradient).

Acceleration

Investigate

- the effect of varying the force on the acceleration of an object of constant mass
- the effect of varying the mass of an object on the acceleration produced by a constant force.

	Trilogy	Synergy	Physics
RPA	19	14	7
Specification reference	6.5.4.2.2	4.7.1.6	4.5.6.2

This investigation can be done with simple equipment (stopwatches and toy cars) or using a linear air track and light gates. However, if the latter method is used, students will not have the opportunity to complete physics AT 1 measurement of mass and time.

By using this method students will have the opportunity to develop the following aspects of the physics AT skills	
AT 1	use appropriate apparatus to make and record a range of measurements accurately including length, mass and time
AT 2	use appropriate apparatus to measure and observe the effect of forces
AT 3	use appropriate apparatus and techniques to measure motion, including determination of speed and rate of change of speed (acceleration/deceleration)

Materials

For the basic method

- a 1 m ruler
- toy car
- bench pulley, string and small weight stack (eg 1 N in steps of 0.2 N)
- two clamp stands, clamps and bosses
- Blu-Tac or similar to attach weights to the car.

Basic method using cars and stopwatches

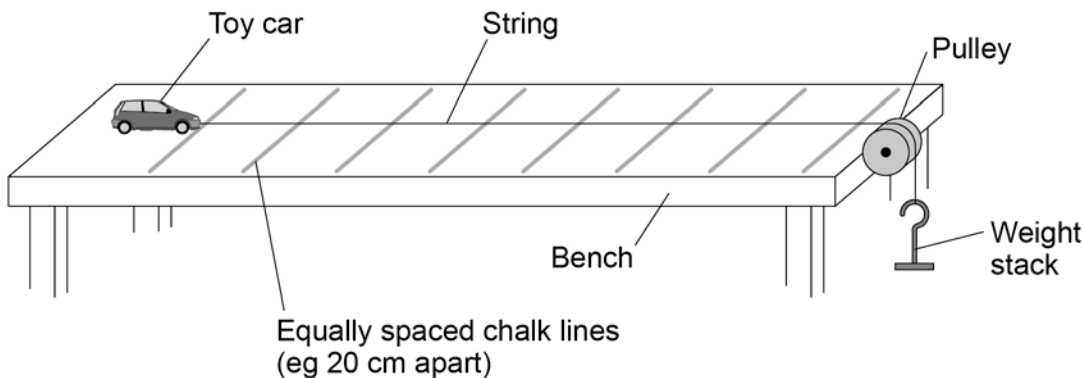
Students draw straight lines in chalk onto the bench at equally measured intervals to allow the time to travel set distances to be easily recorded.

The force is provided by the weight stack, string and pulley. Attach the pulley to the bench at the far end of the track. Hang the weight stack on the string, pass it over the pulley and attach it to the toy car.

Select weights that, when added to the end of the string through the pulley will just accelerate the car along the bench.

To investigate the effect of force on acceleration with constant mass, repeat the experiment with different masses on the end of the string placing the mass removed from the hanger on the top of the car so that the total mass of the car and hanger is constant. To investigate the effect of mass on acceleration with constant force, use the same mass on the string and add different masses to the top of the car.

Our technician used a car of mass 460 g. Using a smart phone to video the sequence will provide more reliable data.



Waves

Make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves

- in a ripple tank
- in a solid.

	Trilogy	Synergy	Physics
RPA	20	5	8
Specification reference	6.6.1.2	4.7.1.6	4.6.1.2

The investigation is split into two parts:

- observing water waves in a ripple tank
- observing waves on a stretched string or elastic cord.

By using this method students will have the opportunity to develop the following aspects of the physics AT skills	
AT 4	make observations of waves in fluids and solids to identify the suitability of apparatus to measure speed, frequency and wavelength

Materials

For the basic methods

Activity 1

- ripple tank and accessories
- suitable low-voltage supply
- metre rule.

Activity 2

- vibration generator
- 5 or 6 watt power signal generator
- string or elasticated cord
- set of 100 g masses and hanger
- set of 10 g masses and hanger
- wooden bridge
- pulley on a clamp.

Activity 1

Technical information

The design of ripple tanks varies slightly from one manufacturer to another. The following is given for general guidance.

The depth of water in the ripple tank should be about 5 mm.

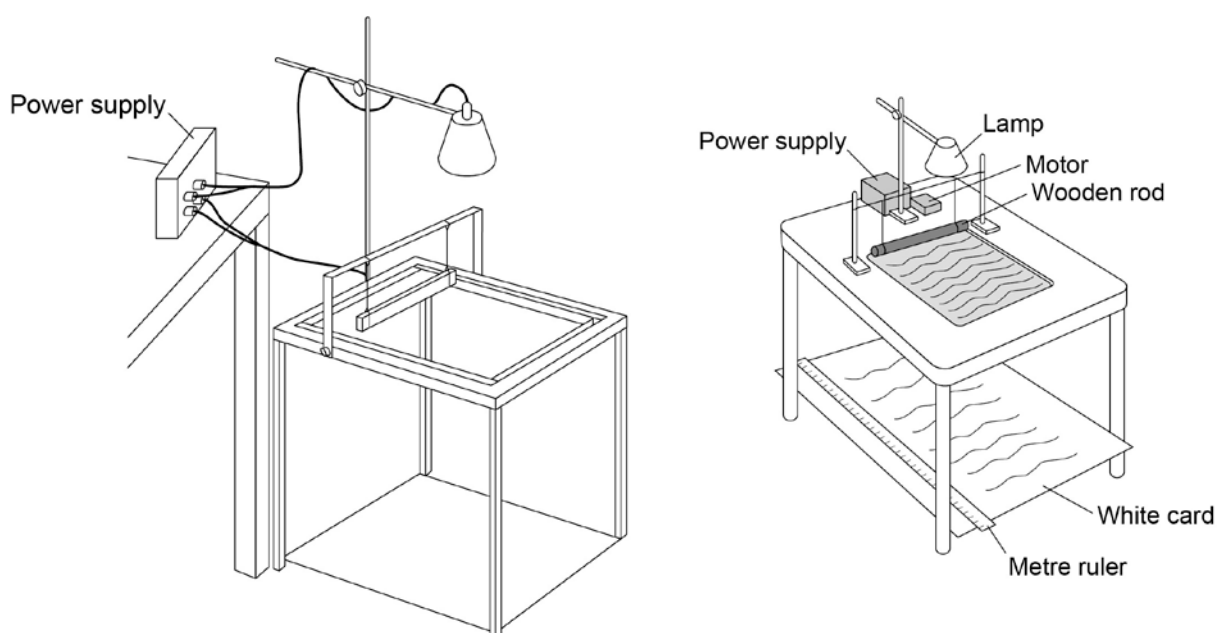
To produce plain (straight) waves, a wooden rod should be used (usually one of the accessories supplied with the ripple tank). When stationary, the wooden rod should just touch the water surface.

A single low-voltage power supply may be used for both the motor attached to the wooden rod and the lamp (usually a power supply designed specifically for use with a ripple tank). Alternatively, a fixed power supply can be used for the lamp and a single 1.5 V cell with a variable resistor (in series) as a variable supply to the motor.

The ripple pattern can be viewed either on a large sheet of white card placed on the floor directly below the ripple tank or on the ceiling. To view the floor, have the lamp above the ripple tank. To view the ceiling, have the lamp below the ripple tank. If viewing the pattern on the floor students should look from the side directly at the card and not look from above through the water in the ripple tank. The position of the lamp should be adjusted to give a clear image. Some ripple tanks are designed to sit on top of an overhead projector. If one of these is used the students will be able to view a large image projected onto a wall.

You can use a strobe light to make waves stationary and read the frequency on the strobe. Please check that your students will not be affected by strobe lights if you do choose to use one.

Please refer to the GCSE Physics required practicals presentation on the [GCSE Practicals page](#) for examples of DIY equipment and tips.



Additional information

A darkened laboratory may make it easier to observe the wave pattern.

Students should observe the wave pattern and then decide how the wavelength, frequency and speed should be measured.

Wavelength – it is likely that a metre ruler positioned at right angles to the projected wave fronts will be used. Measure across as many waves as possible then divide the total length by the number of waves.

Frequency – it is likely that no apparatus will be used. If the motor is rotating slowly so the frequency is low it should be possible to count the number of waves passing a point in the pattern over a given time (say 10 seconds). Then divide the number of waves counted by 10. If this is a demonstration experiment have several students count the waves and then calculate the mean value.

Obtaining a clear pattern from a ripple tank is not easy. It is advisable to trial the experiment and if possible have the ripple tank set up and ready for use before the class starts. It might be a good idea to use a smart phone to film the ripples for easier counting or to use a strobe light. There are numerous apps and YouTube clips to reinforce this learning.

Possible data:

Ripple tank		
Frequency in Hz	Wavelength in m	Speed in m/s
4.545	0.025	0.114

Activity 2

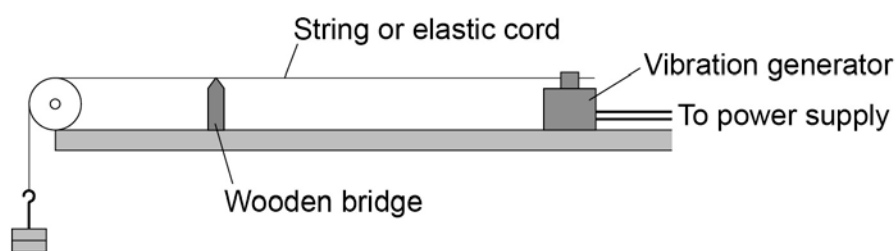
Technical information

This method uses resonance to set up a standing wave on a vibrating string. The theory of resonance and standing waves does not need to be covered, but links to music should be stressed. Students who play stringed instruments will be able to talk about this in some detail.

The practical should be trialled before use with students to ensure a standing wave can be set up and seen.

To achieve the conditions necessary for resonance the following can be adjusted:

- the frequency at which the generator vibrates (adjust the frequency of the signal generator)
- the length of string allowed to vibrate (move the wooden bridge)
- the tension in the string (add or remove masses).



For a quick demonstration use an elasticated cord attached to the vibration generator. Then simply stretch the cord until it resonates and a standing wave pattern is seen.

Students should observe the wave pattern and then decide how the wavelength, frequency and speed should be measured.

- Wavelength – it is likely that a metre ruler will be used to measure across as many half wavelengths as possible. Then divide the total length by the number of half waves. Multiplying this number by two will give the wavelength.
- Frequency – it is likely that no apparatus will be used. The frequency will be the frequency of the power supply. It may be suggested that a stroboscope is used. This will ‘freeze’ the pattern to show a transverse wave. The frequency of the stroboscope is then the frequency of the waves.
- Speed – this will be calculated using the equation:

$$\text{wave speed} = \text{frequency} \times \text{wavelength}$$

100g mass hanger tension		
Frequency in Hz	Wavelength in m	Speed in m/s
5.0	3.38	16.90
10.0	1.68	16.80
15.0	1.12	16.80

Light

Investigate the reflection of light by different types of surface and the refraction of light by different substances.

	Physics
RPA	9
Specification reference	4.6.1.3

By using this method your students will have the opportunity to develop the following aspects of the physics AT skills	
AT 4	make observations of the effects of the interaction of electromagnetic waves with matter
AT 8	make observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter

Materials

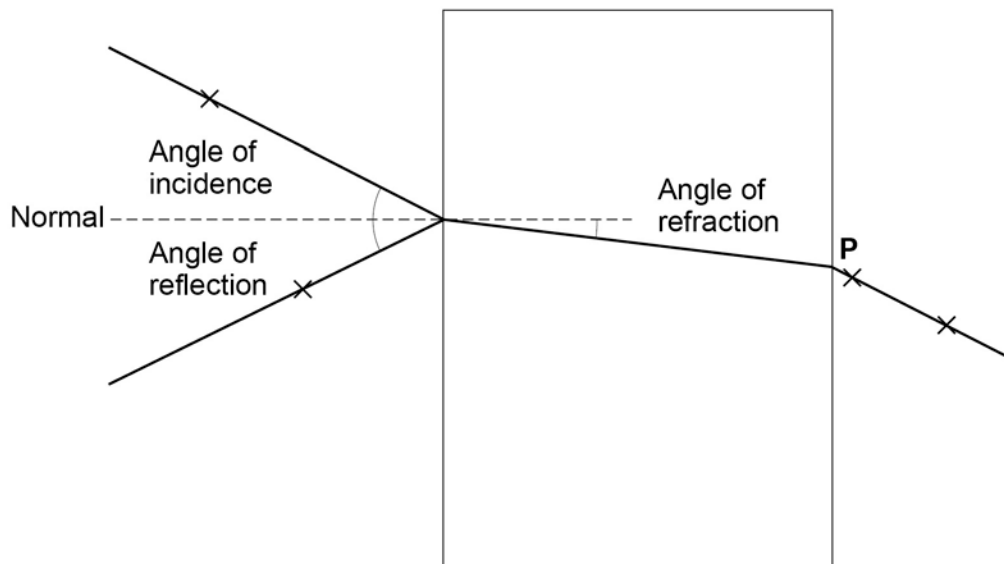
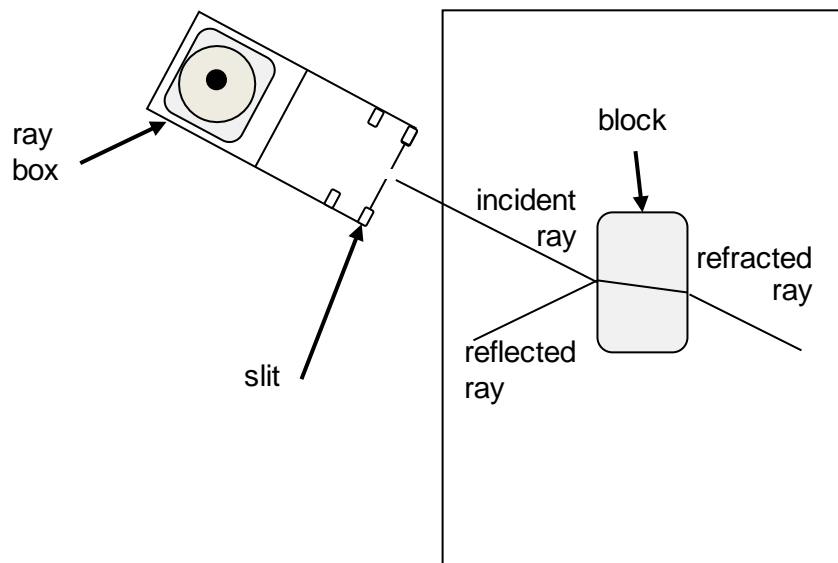
For the basic method to fulfil the ATs

- ray box and suitable power supply
- collimating slit and lens
- rectangular transparent blocks – preferably of different materials eg glass, perspex, plastic
- 30 cm ruler
- protractor
- sheets of plain A3 paper.

Technical information

In this experiment, students trace the path of light reflected from and refracted through blocks of different materials. They will use a ray box to produce a narrow ray of light. They will compare the light reflected and refracted for the two materials.

The reflected and refracted rays from the ray box will be faint. The experiment will have to be carried out in low light conditions.



This is the pattern of rays to expect students to draw.

Suggested alternative approaches from teachers and technicians

- Demonstrate the refraction of light using a glass and an arrow drawn on paper behind it. As you fill the glass with water the arrow reverses. The same can be done with a coin underneath the glass.
- Students will also be able to obtain measurements using the virtual practical available at phet.colorado.edu/en/simulation/bending-light.

AQA Technician results

Angle of incidence in degrees	First block - GLASS	
	Angle of reflection in degrees	Angle of refraction in degrees
25.0	25.0	17.0

Angle of incidence in degrees	Second block - PERSPEX	
	Angle of reflection in degrees	Angle of refraction in degrees
25.0	25.0	16.0

Radiation and absorption

Investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.

	Trilogy	Synergy	Physics
RPA	21	6	10
Specification reference	6.6.2.2	4.1.4.3	4.6.2.2

By using this method students will have the opportunity to develop the following aspects of the physics AT skills	
AT 1	use appropriate apparatus to make and record a range of measurements accurately including temperature
AT 4	make observations of the effects of the interaction of electromagnetic waves with matter

Materials

For the basic method

- Leslie cube
- kettle
- infrared detector
- heatproof mat.

Technical information

The detector may be an infrared detector with a suitable meter, an infrared thermometer or a liquid-in-glass thermometer with the bulb painted matt black. The last option is likely to have the least resolution.

Suggested alternative approaches from teachers and technicians

If a Leslie cube is not available or a class set is required then a simple 'home-made' version could be made.

Student worksheets

Specific heat capacity

Investigating the specific heat capacity of different metals.

In this practical you will:

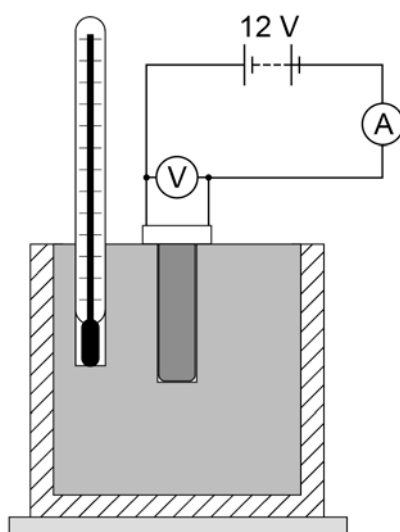
- heat up blocks of different metals using an electric heater
- measure the mass and temperature of the block
- calculate the work done by the heater
- plot a graph of temperature change against work done and use the gradient to calculate the specific heat capacity of the metal.

Apparatus

- three metal blocks, one copper, one iron and one aluminium, each with two holes for a thermometer and heater
some insulation material to wrap around the blocks
- a thermometer
- a pipette to put water in the thermometer hole
- a 12 V immersion heater (30 – 110W)
- a 12 V power supply
- an ammeter and a voltmeter
- five connecting leads
- a stopwatch or stopclock
- a balance.

Method

1. Measure and record the mass of the copper block in kg.
2. Wrap the insulation around the block.
3. Place the heater in the larger hole in the block.
4. Connect the ammeter, power pack and heater in series.
5. Connect the voltmeter across the heater.



6. Use the pipette to put a small amount of water in the other hole.
7. Put the thermometer in this hole.
8. Set the power pack to 12 V. Switch on the power pack to turn on the heater.
9. Record the ammeter and voltmeter readings. These shouldn't change during the experiment.

Mass of copper block in kg	
Current reading on the ammeter in amps	
Potential difference reading on the voltmeter in volts	
Power (Power = IV)	

10. Measure the temperature and start the stopclock.

11. Record the temperature every minute for 10 minutes.

Record your results in the table below.

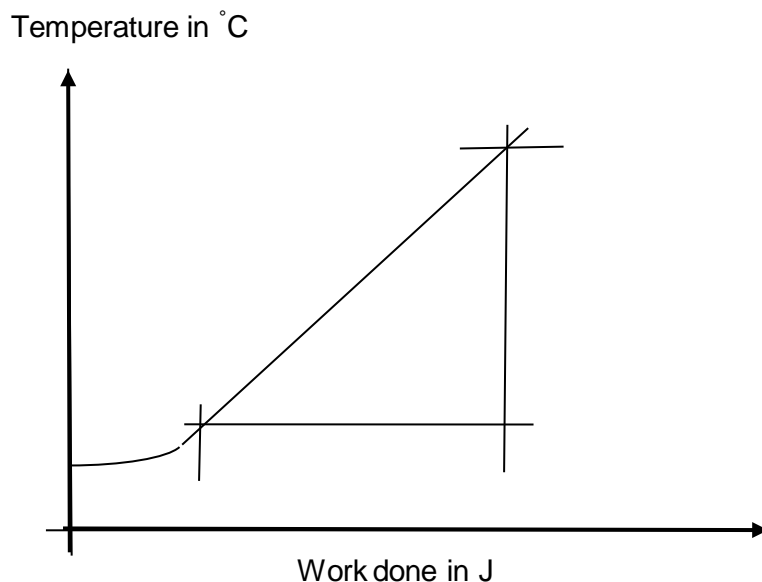
Time in seconds	Temperature in °C	Work done in J (time x power of the heater)
0		0
60		
120		
180		
240		
300		
360		
420		
480		
540		
600		

12. Calculate the power of the heater in watts.

Power in watts = potential difference in volts x current in amps

13. Calculate the energy transferred (work done) by the heater. To do this, multiply the time in seconds by the power of the heater. Record these values in your table.

14. Plot a graph of the temperature in °C against work done in J.



15. Draw a line of best fit.

Take care as the beginning of the graph may be curved.

16. Calculate the gradient of the straight part of your graph.

The gradient = change in temperature rise in °C/change in work done in J

17. The **heat capacity** of the copper block is calculated using the formula:

$$\frac{1}{\text{gradient}}$$

It is the amount of heat energy in J needed to increase the temperature by 1°C.

18. The **specific heat capacity** of copper is the amount of heat energy in J needed to increase the temperature of 1kg of copper by 1°C.

Calculate the specific heat capacity of the copper block using the equation:

Change in thermal energy in J = mass in kg x specific heat capacity in J/kg/ °C x temperature change.

19. Repeat the experiment for the blocks made from aluminium and iron.

Type of metal block	Specific heat capacity in J/kg/°C
Copper	
Aluminium	
Iron	

Conclusion

Look at the following hypothesis:

'William thinks that denser materials have higher specific heat capacities. Using the density values of the metals below and the values of specific heat capacity that you have calculated, do you agree with him?' Write a short paragraph to explain your reasoning.

Type of metal block	Density in g/cm ³
Copper	8.96
Aluminium	2.70
Iron	7.87

Thermal insulation

Investigate the effectiveness of different materials as thermal insulators and the factors that may affect the thermal insulation properties of a material.

In this practical you will:

- measure the rate of cooling of a beaker of hot water that is insulated with different materials
- use your results to plot cooling curves to determine which is the best thermal insulator
- measure the rate of cooling of a beaker of hot water that is insulated with different thicknesses of the same material
- use your results to plot cooling curves to determine the effect of changing the thickness of the insulator.

Activity 1: Comparing the effectiveness of different materials as thermal insulators

Apparatus

- a large beaker
- a small beaker
- a thermometer
- a kettle to heat water
- a piece of cardboard with hole in as a lid
- scissors
- a stopclock
- a selection of insulating materials.

Method

1. Put the small beaker inside the larger beaker.
2. Use the kettle to boil water. Put 80 cm³ of this hot water into the small beaker.
3. Use a piece of cardboard as a lid for the large beaker. The cardboard must have a hole for the thermometer.
4. Put the thermometer through the hole in the cardboard lid so that its bulb is in the hot water.
5. Record the temperature of the water and start the stopwatch.
6. Record the temperature of the water every 3 minutes for 15 minutes.

7. Record your results in a table like this one:

Time mins	Material used for insulation			
	No insulation			
	Temperature °C			
0				
3				
6				
9				
12				
15				
Change in temperature °C				

8. Repeat steps 1–6 using different materials each time to fill the space between the small and large beaker.

Make sure you use the same volume of water each time.

Analysis of results

- Use your results to plot a graph to show the cooling curve for each material.
- Use your graph to determine which material is the best insulator.
- Why do you think this material was a particularly good insulator?

Activity 2: How thickness of material affects the thermal insulation

Apparatus

- a 100 cm³ beaker
- a thermometer
- a kettle to heat water
- a piece of cardboard with hole in as a lid
- scissors
- stopwatch
- insulating material
- rubber bands.

Method

1. Wrap **two layers** of insulating material around the beaker, holding it in place with a rubber band. Do not add insulating material to the bottom of the beaker.
2. Put 80 cm³ of hot water into the beaker.
3. Add a lid to the beaker.
4. Insert the thermometer through the hole in the lid so that its bulb is in the hot water.
5. Record the temperature of the water and start the stopwatch.
6. Record the temperature of the water every 3 minutes for 15 minutes.
7. Record your results in a table like this one. You can use the '**no insulation**' results from activity 1 for '**0 layers**' in this results table to save time.

Time mins	Material used for insulation			
	0 layers of newspaper	2 layers of newspaper	4 layers of newspaper	6 layers of newspaper
	Temperature °C			
0				
3				
6				
9				
12				
15				
Change in temperature °C				

8. Repeat steps 2–6 **adding 2 more layers of insulation each time.**

Analysis of results

Use your results to plot a graph to show the cooling curve for each different numbers of layers of insulation.

Use your graph to state the relationship between the numbers of layers of insulation and the overall change in temperature over the 15 minutes period.

Using the principles from both investigations, explain how these are applied in home construction to build energy efficient houses.

Resistance

Factors that affect the resistance of electrical circuits:

- length of a wire at constant temperature
- combination of resistors in series and parallel.

In this practical you will:

Activity 1:

- set up a circuit which can measure the potential difference and current across a wire at different lengths along the wire
- calculate the resistance for different lengths of wire and state the relationship between resistance and length.

Activity 2:

- use circuit diagrams to construct circuits with resistors in series and in parallel
- measure the potential difference and current in circuits with resistors in series and then in parallel.

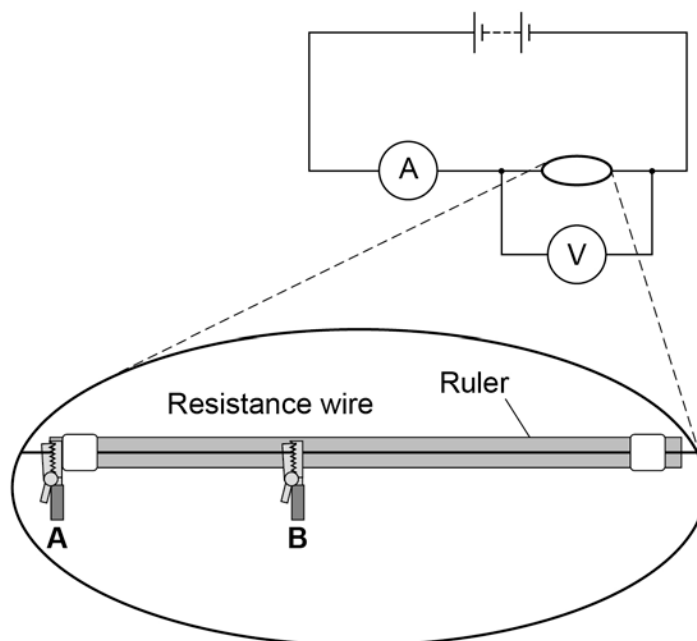
Activity 1: How does the length of the wire affect the resistance at a constant temperature?

Apparatus

- a battery or suitable power supply
- ammeter
- voltmeter
- crocodile clips
- resistance wire attached to a metre ruler
- connecting leads.

Method

1. Use the circuit diagram to set up and connect the circuit.



2. Connect a lead from the negative side of the ammeter to the crocodile clip at the zero end of the ruler. Connect a lead from the other crocodile clip to the negative side of the battery. Use this lead as a switch to disconnect the battery between readings.
3. Decide the interval distance (eg 10cm) you will investigate and connect the first distance to be tested between crocodile clips A and B.
4. Measure the readings on the voltmeter and ammeter at this distance.

5. Record your results in a table like this:

Length of wire in cm	Potential difference in volts	Current in amps	Resistance in ohms
10			

6. Move crocodile clip B and record the readings for the different lengths of wire eg 20cm, 30cm etc.

7. Calculate the resistance for each length of wire using the equation:

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

8. Plot a graph of resistance against length of wire.

9. You should be able to draw a straight line of best fit although it may not go through the origin.

Why might this be the case?

What type of relationship is there between resistance and length?

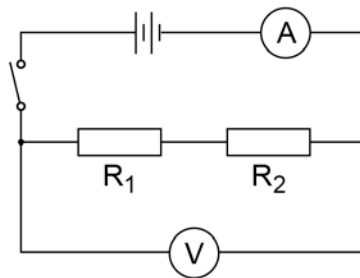
Activity 2: How does the arrangement of resistors in series and in parallel affect resistance?

Apparatus

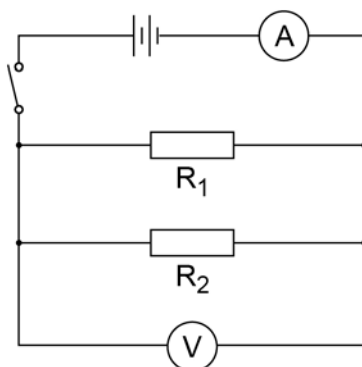
- a battery or suitable power supply
- a switch
- ammeter
- voltmeter
- crocodile clips
- two $10\ \Omega$ resistors
- connecting leads.

Method

1. Use the circuit diagram to set up and connect the circuit for two resistors in series $R_1=R_2$



2. Switch on and record the readings of the ammeter and the voltmeter.
3. Calculate the total resistance of the series circuit.
4. Set up the circuit for two resistors in parallel. Use the circuit diagram below. $R_1=R_2$



-
5. Switch on and record the readings of the ammeter and the voltmeter.

 6. Calculate the total resistance of the parallel circuit.

 7. What conclusions can you make about the effect of adding resistors
 - in series
 - In parallel.

 8. How could you check the value of the resistance of R_1 and R_2 in either circuit?

I-V characteristics

Investigating the I-V characteristics of circuit components.

What happens to the current through a component when the potential difference across it changes?

For some circuit components, the value of resistance can change as the current changes. You can use the graph of current against potential difference to help identify the component in a circuit.

In this practical you will:

- construct circuits and draw circuit diagrams
- measure the current across a component as you change the potential difference
- plot graphs of current against potential difference for each component.

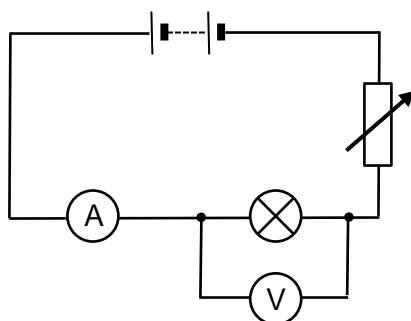
Activity 1: The characteristic of a filament lamp

Apparatus

- a digital ammeter
- a digital voltmeter
- element holders
- a variable resistor
- connecting leads
- a filament lamp
- a battery or suitable power supply.

Method

1. Use the circuit diagram as below to set up your circuit.



2. Record the readings on the ammeter and voltmeter in a suitable table.
3. Adjust the variable resistor and record the new readings on the ammeter and voltmeter.
4. Repeat this to obtain several pairs of readings.

- Swap the connections on the battery/power supply. The ammeter is now connected to the negative terminal and variable resistor to the positive terminal. The readings on the ammeter and voltmeter should now be negative.
- Continue to record pairs of readings of current and potential difference with the battery reversed.
- Plot a graph of current against potential difference. As the readings include negative values the origin of your graph will be in the middle of the graph paper.

You should be able to draw a line of best fit through the origin. **This is the characteristic of a filament lamp.**

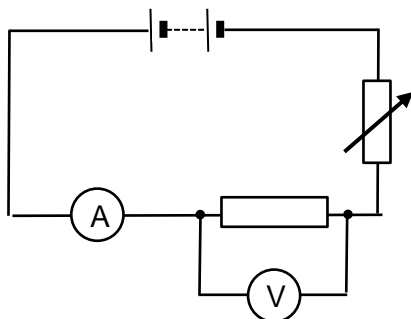
Activity 2: The characteristic of a resistor

Apparatus

- the circuit that you set up in activity 1
- a resistor.

Method

- Swap the leads on the battery/power supply back to their original positions.



- Replace the filament lamp with the resistor.
- Record the readings on the ammeter and voltmeter in a suitable table.
- Adjust the variable resistor and record the new ammeter and voltmeter readings. Repeat this to obtain several pairs of readings.
- Swap the connections on the battery/power supply. Now the ammeter is connected to the negative terminal and variable resistor to the positive terminal.

The readings on the ammeter and voltmeter should now be negative.

- Continue to record pairs of readings of current and potential difference with the battery reversed.
- Plot a graph of current against potential difference. As the readings include negative values the origin of your graph will be in the middle of the graph paper.

You should be able to draw a straight line of best fit through the origin. **This is the characteristic of a resistor.**

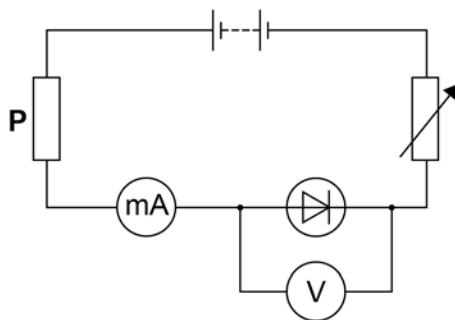
Activity 3: The characteristic of a diode

Apparatus

- the circuit you set up in activity 1
- a milliammeter
- a diode
- an extra resistor labelled P.

Method

1. Swap the leads on the battery/power supply back to their original positions.
2. If you can, reduce the battery/power supply potential difference to less than 5 V.
3. Connect the extra resistor labelled P.
4. Replace the ammeter with a milliammeter.
5. Replace the resistor used in activity 2 with the diode.



6. Record the readings on the milliammeter and voltmeter in a suitable table.
7. Adjust the variable resistor and record the new milliammeter and voltmeter readings.
8. Repeat this to obtain several pairs of readings.
9. Swap the connections on the battery/power supply. Now the milliammeter is connected to the negative terminal and variable resistor to the positive terminal. The readings on the milliammeter and voltmeter should now be negative.
10. Continue to record pairs of readings of current and potential difference with the battery reversed.
11. Plot a graph of current against potential difference. As the readings include negative values the origin of your graph will be in the middle of the graph paper.

You should be able to draw a line of best fit through the origin. **This is the characteristic of a diode.**

Density

Investigating density of regularly and irregularly shaped solids and liquids using a range of appropriate apparatus.

In this practical you will:

- use a ruler and a balance to determine the density of a regularly shaped object
- use a displacement method to determine the density of an irregularly shaped object
- use measurements of volume and mass to determine the density of a liquid.

Activity 1: Determine the density of a regularly shaped object

Apparatus

- 30 cm ruler marked off in mm
- digital balance
- a selection of regularly shaped objects.

Method

1. For each of your selected objects measure and record the:
 - length
 - width
 - height.
2. Calculate the volume of each object.
3. Record your results in a table like this:

Regular shaped object	Length in cm	Width in cm	Height in cm	Volume in cm ³	Mass in g	Density in g/cm ³

4. Measure the mass of each object using the digital balance. Record the results in your table.
5. Calculate and record the density of each object using:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

6. Standard units of density are kg/m³. Use the data above to calculate the density of the object in these units.

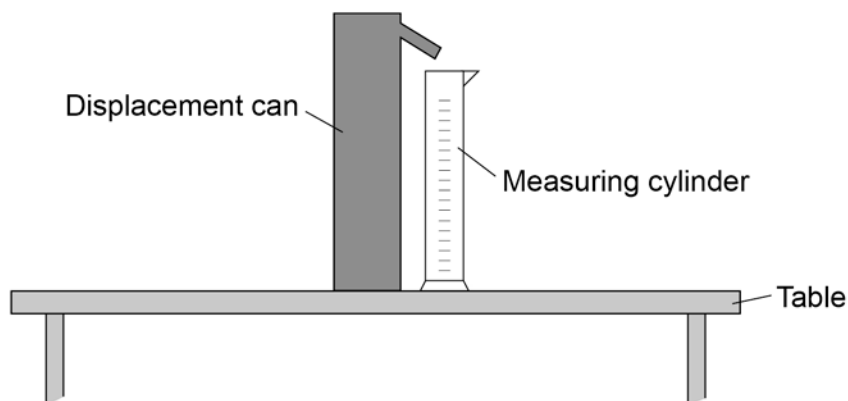
Activity 2: Determining the density of an irregularly shaped object

Apparatus

- a digital balance
- a displacement can
- various measuring cylinders
- a beaker of water and an extra empty beaker
- paper towels
- a selection of irregularly shaped objects.

Method

1. Measure the mass of one of the irregular shaped objects.
2. Record your results in a simple table.
3. Put the displacement can on your desk. Put an empty beaker under the spout and fill the can with water. Water should be dripping from the spout and you should wait until you see this stop.
4. Then put a measuring cylinder that you think will give the most accurate reading under the spout instead of the beaker.



5. Very carefully lower the object into the displacement can so that it is completely submerged. Collect all of the water that comes out of the spout in the measuring cylinder.
6. Measure the volume of the collected water. This volume is equal to the volume of the object.
7. Calculate and record the density of the object.
8. Repeat the activity for some other objects.
Remember to refill the can with water each time.

Activity 3: Determining the density of a liquid

Apparatus

- a digital balance
- a 100 cm³ measuring cylinder
- a sugar solution of unknown concentration.

Method

1. Measure the mass of the empty measuring cylinder.
2. Record your results in a table like this:

Mass of the empty cylinder in g	Volume of liquid in cm ³	Mass of cylinder plus liquid in g	Mass of liquid in g	Density of liquid in g/cm ³

3. Pour **about** 100 cm³ of the sugar solution into the measuring cylinder.
Record the volume accurately.
4. Measure and record the mass of the measuring cylinder and liquid. From this calculate and record the mass of just the liquid.
5. Calculate the density of the liquid.
6. Standard units of density are kg/m³. Use the data above to calculate the density of the liquid in these units.

Task

- a) Write a paragraph to describe and explain the differences in density you have seen between solids and liquids. You might consider how particles are arranged in the different states of matter.
- b) Use the table below to identify some of the samples of regular shaped object you used in activity 1.

Substance	Aluminium	Zinc	Iron	Copper	Gold
Density in g/cm ³	2.7	7.1	7.9	8.9	19.3

- c) Using your results from activity 3, determine the mass of sugar per cm³ dissolved in the water.
The density of water is 1 g/cm³. Assume the sugar does not affect the volume of the water.

Force and extension

Investigate the relationship between force and extension of a spring.

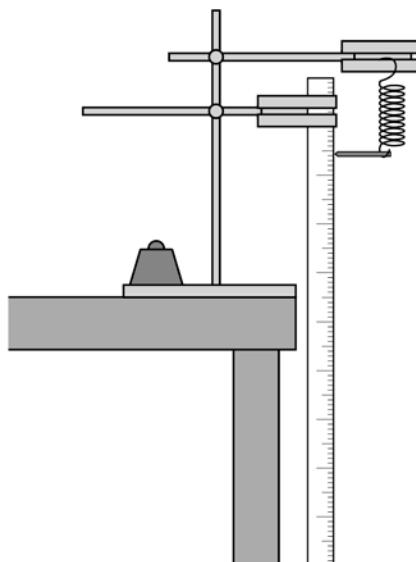
In this practical you will:

- hang different masses from a spring and measure the extension of the spring for each mass used
- convert mass into weight
- use your results to plot a graph of extension against weight.

Apparatus

- a spring
- a metre ruler
- a splint and tape to act as a pointer
- a 10 N weight stack
- a clamp stand
- two clamps and bosses
- a heavy weight or G-clamp to prevent the apparatus tipping over
- safety goggles.

Method



1. Set up your apparatus as in the diagram making sure that:
 - the ruler is vertical. The zero on the scale needs to be at the same height as the top of the spring
 - the splint is **attached securely to the bottom of the spring**. Make sure that the splint is horizontal and that it rests against the scale of the ruler.

2. Take a reading on the ruler – this is the length of the unstretched spring. Record this reading in your results table.

Weight in N	Length of spring in cm	Extension of spring in cm
0.0 (No weight stack added)		0
1.0 (weight stack added)		
2.0		

3. Carefully hook the base of the weight stack onto the bottom of the spring. This weighs 1.0 newton (1.0 N). Don't forget that the mass added will have to be converted to newtons.
4. Take a reading on the ruler – this is the length of the spring when a force of 1.0 N is applied to it.
5. Add further weights. Measure and record the length of the spring each time.
6. Calculate the extension for each weight and record it on the table.

Analysis of results

Use your results to plot a graph with:

- 'extension of spring in cm' on the y-axis.
 - 'weight in N' on the x-axis.
- a) State the relationship between force and extension of a wire.
 - b) Calculate the spring constant (force = spring constant x extension).

A force that stretches or compresses a spring does work and elastic potential energy is stored in the spring. Providing that the spring is not inelastically deformed **the work done on the spring and the elastic potential energy stored are equal.**

- c) Calculate the work done in stretching your spring using the equation:

$$\text{Elastic potential energy} = 0.5 \times \text{spring constant} \times (\text{extension})^2$$

- d) Hang an unknown object on the spring. Measure the extension and use your graph to determine the object's weight. Check it with a newton meter.

Acceleration

How are force, mass and acceleration related?

In this practical you will:

- time how long it takes for a toy car or trolley of constant mass to move a distance when different forces are applied to it
- time how long it takes for a toy car or trolley to move a distance if the force applied is constant but the mass of the toy car or trolley is varied
- calculate the acceleration of the toy car or trolley in each case.

Activity 1: Measuring the effect of force on acceleration at constant mass

Apparatus

- a toy car (or trolley)
- a metre ruler
- pencil, chalk or masking tape to mark the intervals
- a bench pulley
- string
- a small weight stack
- a stopwatch
- Blu-tac.

Method

1. Use the ruler to measure intervals on the bench and draw straight lines or place tape across the bench at these intervals.
2. Attach the bench pulley to the end of the bench.
3. Tie a length of string to the toy car or trolley. Pass the string over the pulley and attach the weight stack to the other end of the string.
4. Make sure the string is horizontal and is in line with the toy car or trolley.
5. Hold the toy car or trolley at the start point.
6. Attach the full weight stack (1.0 N) to the end of the string.
7. Release the toy car or trolley at the same time as you start the stopwatch, press the stop watch (lap mode) at each measured interval on the bench and for the final time at 100 cm.
8. Record the results in the table.
9. Repeat steps 5–8 for decreasing weights on the stack for example, 0.8 N, 0.6 N, 0.4 N, 0.2 N. Make sure you place the masses that you remove from the weight stack onto the top of the car each time you decrease the weight.

Distance travelled in cm	1.0 N	0.8 N	0.6 N	0.4 N	0.2 N
	Time in s	Time in s	Time in s	Time in s	Time in s
20					
40					
60					
80					
100					

Activity 2: Measuring the effect of mass on acceleration with a constant force

Apparatus

The same apparatus as you used in activity 1.

Method

1. Setup the bench, pulley, weight stack and car as in steps 1-5 of activity 1.
2. Use your results from activity 1 to select a weight for the weight stack that will just accelerate the car along the bench.
3. Put a 200g mass on the car.
4. Hold the car at the start point.
5. Attach your chosen weight stack to the end of the string.
6. Release the car at the same time as you start the stopwatch, press the stopwatch (lap mode) at each measured interval on the bench and for the final time at 100 cm.
7. Record the results in the table outline below.
8. Repeat steps 5–8 for increasing more masses on the car.

	Change in mass of the toy car				
Distance travelled in cm					
20					
40					
60					
80					
100					

Conclusion

- Write a sentence to state the relationship that you have seen in both activities. Do the results of your activities reflect Newton's Second Law?
- Identify and classify the sources of error in this investigation.
- How could you change the method or the apparatus used to improve the accuracy and reproducibility of your results?

Waves

Observing the properties of waves in liquids and solids.

In this practical you will:

- use a ripple tank to set up waves
- measure the wavelength and frequency of the water waves and use your measurements to calculate the wave speed
- use a vibration generator to set up a stationary wave in a string
- measure the wavelength and frequency of the waves in the string and use your measurements to calculate the wave speed.

Activity 1: Observing water waves in a ripple tank

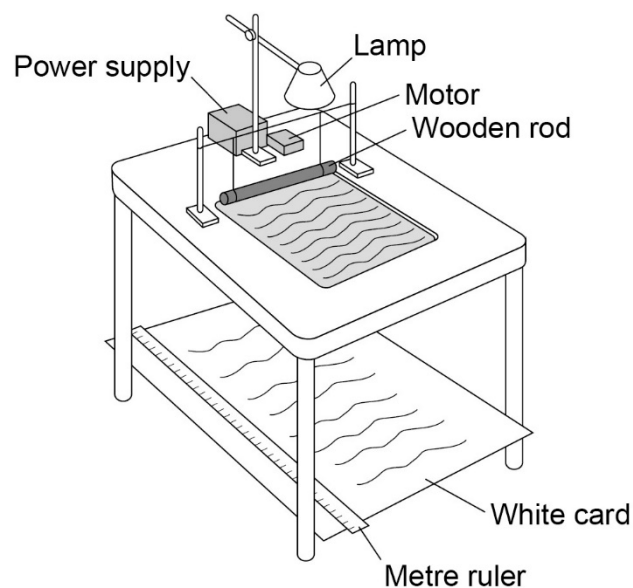
Apparatus

- a ripple tank plus accessories
- a low-voltage power supply
- a lamp
- a metre ruler.

Method

1. Set up the ripple tank as shown in the diagram.

Make sure that there is a large sheet of white card or paper on the floor under the tank.



2. Pour water to a depth of about 5 mm into the tank.
3. Adjust the height of the wooden rod so that it **just** touches the surface of the water.
4. Switch on the overhead lamp and the electric motor.
5. Adjust the speed of the motor to produce low frequency water waves.
6. Adjust the height of the lamp so that the pattern of the waves can be clearly seen on the white card.
7. Place a metre ruler at right angles to the waves shown in the pattern on the card.
Measure across as many waves as you can. Then divide that length by the number of waves. This gives the **wavelength** of the waves. Record this value in the table below.
8. Count the number of waves passing a point in the pattern over a given time (say 10 seconds).
Then divide the number of waves counted by 10. This gives the **frequency** of the waves. Record this value in the table below.
9. Calculate the speed of the waves using the equation:

$$\text{wave speed} = \text{frequency} \times \text{wavelength}$$

10. Record this value in the table below.

Waves in a liquid		
Frequency in Hz	Wavelength in m	Speed in m/s

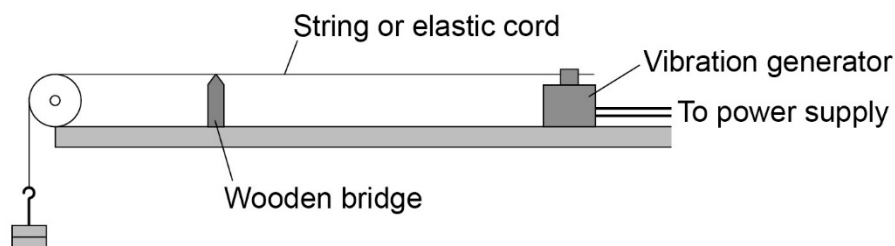
Activity 2: Observing waves in a solid

Apparatus

- a vibration generator
- 5 or 6 watt signal generator (power supply)
- a string or piece of elasticated cord
- a set of 100 g masses and hanger
- a set of 10 g masses and hanger
- a wooden bridge
- a pulley on a clamp.

Method

1. Set up the apparatus as shown in the diagram.



2. Switch on the vibration generator. The string (or elasticated cord) should start to vibrate.
3. To see a clear wave pattern, adjust the tension in the string or move the wooden bridge to adjust the length of the string.

The waves should look like they are not moving.

4. Use a metre ruler to measure across as many half wavelengths as possible (a half wavelength is one loop).

Then divide the total length by the number of half waves. Multiplying this number by two will give the **wavelength**.

5. The **frequency** of the wave is the frequency of the signal generator (power supply).
6. Calculate the speed of the wave using the equation:

$$\text{wave speed} = \text{frequency} \times \text{wavelength}$$

7. Repeat steps 2-6 for different frequencies.

Waves in a solid		
Frequency in Hz	Wavelength in m	Speed in m/s

Evaluation

1. State the relationship between the variables measured in activities 1 and 2.
2. Comment on the accuracy of your results in both activity 1 and 2.
3. How suitable was the apparatus that you used in both activities? How might you change the apparatus to provide more accurate results?

Light

Investigate the reflection of light by different types of surface and the refraction of light by different substances.

In this practical you will:

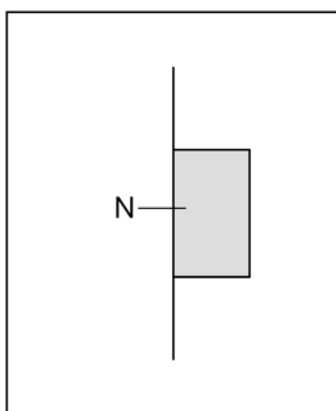
- use a ray box to direct a ray of light onto the surface of a transparent block
- mark the path of the ray that is reflected from the surface of the block
- mark the path of the ray that passes through the block
- use different materials and compare the results.

Apparatus

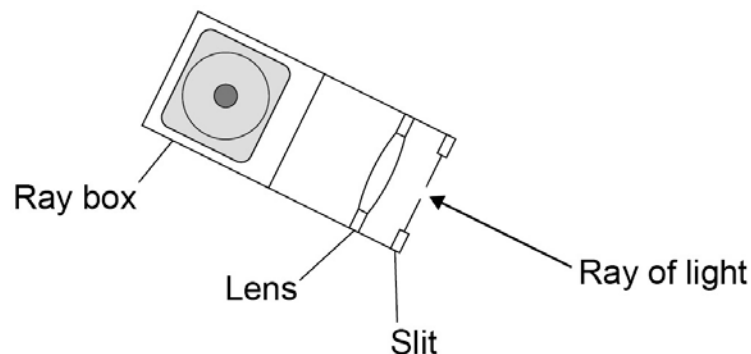
- ray box
- suitable power supply
- a slit that fits the ray box and can be used to make a narrow ray
- two rectangular transparent blocks of different materials eg glass, Perspex
- 30 cm ruler
- protractor
- sheets of plain A3 paper.

Method

1. Place the ruler near the middle of the A3 paper and draw a straight line.
2. Use the protractor to draw a second line at right angles to this line.
3. Label this line with an 'N' for 'normal'.
4. Place your block onto the paper so that it is lined up with the ruler line and draw around it as in the diagram below.

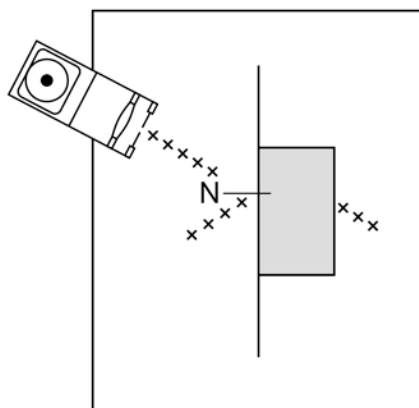


5. Set up the ray box and slit so that a narrow ray of light is produced.



Care: The ray box will get hot – be careful when you move it. Switch it off when you don't need it.

6. Use the ray box to direct a ray of light at the point where the normal meets the block. The ray box needs to be at an angle as in the diagram below.



7. Mark the path of the incoming and outgoing rays with crosses.
8. Switch on the room lights. Switch off the ray box and remove the block and join up your crosses with solid lines to show the pathway of the three different rays.
9. Label the rays with their scientific names.
10. Use the protractor to measure:
 - a. the angle of incidence
 - b. the angle of reflection
 - c. the angle of refraction.

Record your measurements in a table like this one:

Angle of incidence in degrees	First block	
	Angle of reflection in degrees	Angle of refraction in degrees

11. Now repeat the method steps again on the reverse side of A3 paper for the other transparent block.

Angle of incidence in degrees	Second block	
	Angle of reflection in degrees	Angle of refraction in degrees

Conclusion

Physics theory suggests that the angles of incidence and reflection should be the same for a material, but the angles of refraction for that material should be different.

How well do **your results** support this theory for the two different materials that you have tested?

Evaluation

Consider the apparatus and method that you used. Are there any improvements that you could make to improve the accuracy of the angles you measured if you were to repeat this experiment?

Radiation and absorption

Investigating the amount of infrared radiation radiated from different surfaces.

In this practical you will:

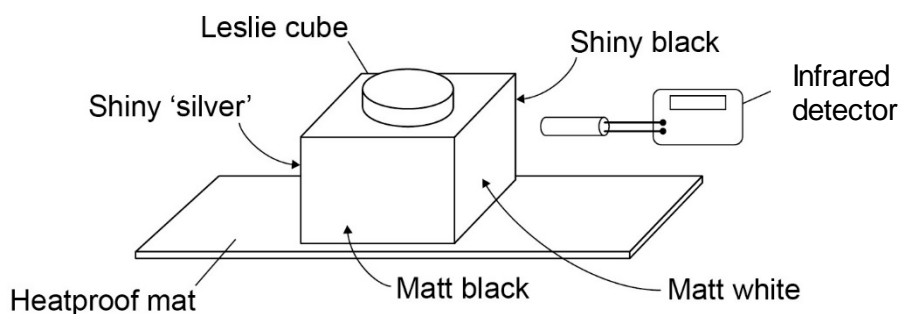
use a Leslie cube and infrared detector to compare the amount of infrared radiated from different surfaces: shiny black, matt black, shiny silver and matt white.

Apparatus

- a Leslie cube
- a kettle
- an infrared detector
- a heat-proof mat.

Method

1. Put the Leslie cube onto the heat-proof mat.
2. Fill the cube with very hot water and put the lid on the cube. Your apparatus should look like this:



3. Use the detector to measure the amount of infrared radiated from each surface.
Make sure that the detector is the same distance from each surface.

Task

Plot an appropriate chart to show the amount of infrared radiated by each type of surface and write a conclusion.

Get help and support

Visit our website for information, guidance, support and resources at [aqa.org.uk/8463](https://www.aqa.org.uk/8463)

You can talk directly to the science subject team

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