

GCSE COMBINED SCIENCE

(8464) (8465)

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 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 Combined Science specifications (8464 and 8465) 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 combined science 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 apparatus and techniques statements. More detailed advice, additional activities and alternative methods can be found on the CLEAPSS website:

- [Biology](#)
- [Chemistry](#)
- [Physics](#)

Whichever method you use, it is your responsibility to check that you have covered all aspects of the apparatus and techniques criteria.

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](#)

[Field studies council](#)

[Getting practical](#)

[IOP](#)

[Practical Biology](#)

[Practical Chemistry](#)

[Practical Physics](#)

[RSC](#)

[Society of Biology](#)

[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: Biology

Microscopy

Use a light microscope to observe, draw and label biological specimens.

	Trilogy	Synergy	Biology
RPA	1	3	1
Specification reference	4.1.1.2	4.1.3.2	4.1.1.2

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 7	use of appropriate apparatus, techniques and magnification, including microscopes to make observations of biological specimens and producing labelled scientific drawings

Materials

For the basic method

- a microscope
- prepared slides of plant and animal cells.

Students should make clear, labelled diagrams of the cells they observe and include the magnification.

Osmosis

Investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.

	Trilogy	Synergy	Biology
RPA	2	4	3
Specification reference	4.1.3.2	4.1.3.3	4.1.3.2

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to measure and record a range of measurements accurately including length, mass and volume of liquid
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 5	measurement of rate of reaction by a variety of methods including an uptake of water

Materials

For the basic method

In addition to standard laboratory equipment:

- a potato
- a cork borer
- a ruler with mm scale
- labels or a permanent marker
- paper towels
- a sharp knife or scalpel
- a top-pan balance accurate to at least 0.01 g
- a range of sugar or sodium chloride solutions (0.25–1.0 M)
- distilled water.

The class will need to collect results from solutions of at least five different concentrations if students wish to be able to plot a graph and calculate the rate of uptake of water. A balance measuring to 0.01 g is necessary to get a measurable change in a short time. The length of time that the potato cylinders are left in the sugar or salt solutions can be adjusted to suit lesson timings.

If a water bath is included and tubes left for 30 minutes at 30°C it will give measurable changes in mass and length whilst allowing students experience of controlling temperature.

The method has been worked through using sugar solutions by our Technician Advisor. The table below shows the data obtained, which can be used as examples or for students to use to gain further practice in the calculation and graph plotting.

	1.0 M sugar solution	0.75 M sugar solution	0.5 M sugar solution	0.25 M sugar solution	Distilled water
Initial mass in g	6.08	5.97	6.10	5.92	5.98
Final mass in g	4.05	3.82	4.00	4.45	6.48
Change in mass in g	-2.03	-2.15	-2.10	-1.47	+0.05
Percentage change in mass	-33.4	-36.0	-34.4	-24.8	+8.3
Initial length in cm	3.2	3.3	3.3	3.1	3.2
Final length in cm	2.5	2.7	2.8	3.2	3.7
Change in length in cm	-0.7	-0.6	-0.5	+0.1	+0.5
Percentage change in length	-22.0	-17.0	-1.4	+2.0	+16.0

Technical information – to make up sugar solutions of various concentrations

Make up a 1.0 M sucrose solution by adding distilled water to 342.4 g of sugar (dissolve by heating) and making up to 1 litre in a volumetric flask. Dilute this appropriately to produce a range of solutions from 1.0 to 0.25 M. This should provide enough of each solution for a class as each student needs 10 cm³ of each, in addition to 10 cm³ of distilled water.

Ensure that potato cylinders do not have any skin on them as this affects the movement of water molecules.

Food tests

Use qualitative reagents to test for a range of carbohydrates, lipids and proteins. To include: Benedict's test for sugars, iodine test for starch and Biuret reagent for protein.

	Trilogy	Synergy	Biology
RPA	3	7	4
Specification reference	4.2.2.1	4.2.1.5	4.2.2.1

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 2	safe use of appropriate heating devices and techniques including the use of a bunsen burner and a water bath

Materials

For the basic method

In addition to standard laboratory equipment:

- a sample of food to be tested
- pestle and mortar
- stirring rod
- filter funnel and filter paper
- five 100 cm³ beakers
- a conical flask
- distilled water
- four test tubes
- labels or marker pen
- water bath (electric or beaker of water and Bunsen burner*)
- Benedict's solution
- iodine solution (0.01 M)
- ethanol
- Biuret solution.

* use of the Bunsen burner to satisfy AT2

This is usually carried out as a circus activity. There is a range of different ways of approaching this. You may choose to use specific foods to show positive test outcomes or to use a range of foods that are tested with all reagents to allow a more investigative approach. This will depend on the experiences of the students at Key Stage 3.

The basic student worksheet will describe how to carry out each of the separate food tests but this can be adapted as appropriate to ensure students are challenged.

Technical information

Benedict's qualitative reagent

Benedict's solution or DNSA (see CLEAPSS) should be used to test for reducing sugars. Benedict's solution can also be purchased from suppliers and is very stable when stored.

Glucose, lactose and maltose are reducing sugars and give a positive test. Sucrose is a non-reducing sugar and does not give a positive result.

No hazard warning symbol is required on the bottle as the concentrations of each of the constituents are low.

Qualitative Biuret reagent

This is best made up as Biuret A and Biuret B, which are quite stable, and add as a two-stage test. See CLEAPSS.

Iodine solution

A 0.01 M solution is suitable as a test reagent for starch. It may be purchased ready-made or made up following the instructions on CLEAPSS.

Ethanol solution

Please note that there are alternative approaches to testing for lipids including the simple rubbing of the sample onto filter paper which will show a positive test if the paper goes transparent.

Suggested foods for testing

- **Carbohydrates:** potato, bread, rice, cooked noodles, biscuits, sugar, apples, flour, corn starch.
- **Lipids:** olive oil, sesame seed oil, grape seed oil, margarine, butter, lard, milk (full fat, semi-skimmed, skimmed), egg white solution, egg yolk solution.
- **Proteins:** whole cheese, meat, tofu, apple, potato, cooked beans, eggs, yeast, milk, yogurt.

Note: grated cheese that you can buy in prepared packs from a supermarket often contains starch, which can confuse students if you test foods for a range of things.

Enzymes

Investigate the effect of pH on the rate of reaction of amylase enzyme.

	Trilogy	Synergy	Biology
RPA	4	20	5
Specification reference	4.2.2.1	4.7.4.7	4.2.2.1

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including time, temperature, volume of liquids and pH
AT 2	safe use of appropriate heating devices and techniques including use of a Bunsen burner and water bath or electric heater
AT 5	measurement of rates of reaction by a variety of methods including using colour change of an indicator

Materials

For the basic method

In addition to standard laboratory equipment:

- 10 test tubes
- a test tube rack
- water bath (electrical or Bunsen burner and beaker) at 35°C
- a spotting tile
- a 5 cm³ measuring cylinder
- pasteur pipettes, syringes or 5 cm³ measuring cylinders
- a glass rod
- a stopwatch or stopclock
- starch solution (1%)
- fungal amylase solution (0.1%)
- labelled buffered solutions at a range of pH values
- labels
- iodine solution (0.01 M)
- a thermometer.

This is one example of how enzyme activity can be measured. As amylase often generates unreliable data you could use this enzyme as a demonstration and students could then use suitable alternatives eg catalase. Amylase activity should be tested before using in class to ensure that results can be obtained in a reasonable time.

A 0.1% solution of amylase gives good results, but this can be diluted further if the reaction is still too fast.

The method suggested has been trialled with several classes, and all were able to obtain results. The method was trialled using 0.1% fungal amylase, 1% starch and with pH5, 6, 7 and 8 prepared buffers (CLEAPSS) and buffers purchased from suppliers. There was no noticeable difference between results. The following results were obtained.

pH of solution	Time for amylase to completely break down the starch in seconds (at 35°C)
5	29
6	46
7	160
8	>300

The amount of amylase can be reduced to 1 cm³ to increase the time taken for the starch to be broken down.

Technical information

Amylase will slowly lose activity so it is best to make up a fresh batch, using the powdered enzyme, for each lesson. Otherwise any results collected on different days will not be comparable.

Starch suspension should also be made fresh. This can be done by making a cream of 5g of soluble starch in cold water and pouring into 500 cm³ of boiling water. Stir well and boil until you have a clear solution.

A 0.01 M iodine solution is suitable as a test reagent for starch. It may be purchased ready-made or made up following the instructions on CLEAPSS.

Buffered solutions should be made using CLEAPSS (*The Universal Buffer: Recipe 1*). The optimum pH for amylase is pH 6. A range of buffered solutions between pH 5 and pH 8 would be appropriate. Buffers can be purchased from suppliers but ensure they do not contain any dye.

It is best to check that the amylase breaks down the starch at an appropriate rate before students do this experiment. At around the optimum pH, the end point should be reached within 1–2 minutes, but this will depend on the amylase used.

Some amylases used in detergents are not denatured even at temperatures close to boiling water. Some amylases are also inhibited by buffers. Fungal amylase is quite reliable.

Photosynthesis

Investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.

	Trilogy	Synergy	Biology
RPA	5	10	6
Specification reference	4.4.1.2	4.2.2.6	4.4.1.2

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately, including time and volume of a gas
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 4	safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment
AT 5	measurement of rates of reaction by a variety of methods including the production of gas

Materials

For the basic method

- a beaker
- filter funnel
- a 1cm³ or 10 cm³ measuring cylinder
- freshly cut 10 cm piece of pondweed
- a light source
- a metre rule
- a stopwatch.

This practical is difficult to achieve measurable volumes of oxygen within routine time but is useful to demonstrate to students the principles of photosynthesis. It might be helpful to support students understanding of the rate of photosynthesis with the use of a simulation or similar resources.

Technical information

Native species of *Cabomba* are no longer available to schools because it is classed as an invasive species and has been removed from sale. Other varieties of pondweed such as *Elodea* could be used in this investigation which can be bought from tropical fish shops and some large garden centres. If *Elodea* is used, place the plant in a beaker of water in front of a lamp for 2–3 hours before starting the investigation.

High-intensity light sources (at least 1000 lumens) need to be used for the practical. Low energy light bulbs should not be used as the light intensity may be too low to promote measurable photosynthesis.

If the pondweed tubes are placed in a beaker of water (at least 250ml) then the use of a heat shield is usually unnecessary. Temperature of the water can be monitored with a thermometer to ensure no temperature rise.

If no bubbles appear from the cut end of the pondweed when placed closest to the light source, cut a few millimetres off the end or, if necessary, use a new freshly cut piece.

Reaction time

Plan and carry out an investigation into the effect of a factor on human reaction time.

	Trilogy	Synergy	Biology
RPA	6	8	7
Specification reference	4.5.2	4.2.1.6	4.5.2.1

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including length
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 4	safe and ethical use of a living organisms (plants or animals) to measure physiological functions and responses to the environment

Materials

Students work in pairs for this investigation. Each pair should have:

For the basic method

- a metre rule
- a chair
- a table.

Technical information

This method investigates the effect of practising an event on reaction time.

Ruler measurements can be converted to reaction times using the conversion table on page 22.

Additional information

Students can use the conversion table on page 20 to calculate reaction time from their measurements. Pre-converted strips can be taped to metre rulers to save time.

This method has been trialled with students and the following results obtained.

Drop test attempt	Ruler measurements in cm		Reaction times in seconds	
	Person 1	Person 2	Person 1	Person 2
1	48	32	0.31	0.26
2	44	30	0.30	0.25
3	37	27	0.28	0.23
2	29	28	0.24	0.24
5	26	25	0.23	0.23
6	34	21	0.26	0.21
7	34	26	0.26	0.23
8	20	25	0.21	0.23
9	32	29	0.26	0.24
10	19	27	0.20	0.23

Conversion table

Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)
1	0.05	21	0.21	41	0.29	61	0.35	81	0.41		
2	0.06	22	0.22	42	0.29	62	0.36	82	0.41		
3	0.08	23	0.22	43	0.30	63	0.36	83	0.41		
4	0.09	24	0.22	44	0.30	64	0.36	84	0.41		
5	0.10	25	0.23	45	0.30	65	0.36	85	0.42		
6	0.11	26	0.23	46	0.31	66	0.37	86	0.42		
7	0.12	27	0.23	47	0.31	67	0.37	87	0.42		
8	0.13	28	0.24	48	0.31	68	0.37	88	0.42		
9	0.14	29	0.24	49	0.32	69	0.38	89	0.43		
10	0.14	30	0.25	50	0.32	70	0.38	90	0.43		
11	0.15	31	0.25	51	0.32	71	0.38	91	0.43		
12	0.16	32	0.26	52	0.33	72	0.38	92	0.43		
13	0.16	33	0.26	53	0.33	73	0.39	93	0.44		
14	0.17	34	0.26	54	0.33	74	0.39	94	0.44		
15	0.18	35	0.27	55	0.34	75	0.39	95	0.44		
16	0.18	36	0.27	56	0.34	76	0.39	96	0.44		
17	0.19	37	0.28	57	0.34	77	0.40	97	0.45		
18	0.19	38	0.28	58	0.34	78	0.40	98	0.45		
19	0.20	39	0.28	59	0.35	79	0.40	99	0.45		
20	0.21	40	0.29	60	0.35	80	0.40	100	0.45		

Field investigations

Measure the population size of a common species in a habitat. Use sampling techniques to investigate the effect of a factor on the distribution of this species.

	Trilogy	Synergy	Biology
RPA	7	12	9
Specification reference	4.7.2.1	4.4.2.4	4.7.2.1

There are two parts to this investigation:

1. Investigating the population size of a plant species using random sampling.
2. Investigating the effect of a factor on plant distribution using a transect line.

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including length and area
AT 4	safe and ethical use of a living organism to measure physiological responses to the environment
AT 6	application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field

Materials

For the basic method

- a quadrat (25 × 25 cm or 50 × 50cm)
- a 30m tape measure
- a light meter
- a clipboard.

Technical information

1. Investigating the population size of a plant species using random sampling

Choose an area of grass with sufficient space to carry out this survey. You will need at least 400 m² to accommodate a class.

Help students to identify the species being investigated.

Lay out two tape measures (or marked strings) 20 m in length so that they form right angles. These two tape measures represent the two sides of a 20 m × 20 m square. Place two bags containing numbers at the point where the two tape measures meet.

Organise the students into groups of three. One student will select a number from one of the bags and move that distance along the tape. A second student will select a number from the other bag and move that distance along the other tape. The third student with the quadrat uses the other two students as markers in order to place the quadrat on the ground. The group then return their numbers to the bags. The group then return to their quadrat to count and record the number of different plant species in the quadrat.

Get students to repeat this process in order to count the number of plant species in a chosen number of quadrats. Students can then use this data to estimate the population of the survey area.

For example, in a case where 50 daisies were counted in ten samples, the total population can be estimated using this equation:

$$\text{Estimated population size} = \frac{\text{total area}}{\text{area sampled}} \times \text{number of daisies counted}$$

The area sampled from 10 quadrats is 0.25 m × 0.25 m = 10 × 0.0625 m² = 0.625 m²

The total area of the survey = 20 m × 20 m = 400 m²

$$\text{Estimated population} = \frac{400}{0.625} \times 50 = 32,000$$

2. Investigating the effect of a factor on plant distribution using a transect line

A transect line from a tree to an open area can be used to record the change in the number of a particular species as light intensity changes. Students can record either percentage grass cover or the number of daisies in each quadrat. Students need to lay out a tape measure in a straight line so that a quadrat can be placed at regular intervals.

In this method, students should use a light meter to measure the light intensity at each quadrat. This will allow students to plot a graph of distribution against light intensity. You will need to demonstrate how to use a light meter. You could access a light meter via a phone app.

A shorter transect line could be used if space is limited and quadrats could be placed closer together.

Suggested alternative approaches from teachers and technicians

- Alternative investigations may be possible using micro-habitats such as trees, pathways, hedges, walls, grave stones, ponds, soil, etc.
- Students could investigate the distribution of lichens on tree trunks or walls at different distances from a main road.
- Students could also investigate the distribution of woodlice in relation to soil water content, light intensity or temperature.

Teacher and technician notes: Chemistry

Making salts

Preparation of a pure, dry sample of a soluble salt from an insoluble oxide or carbonate using a Bunsen burner to heat dilute acid and a water bath or electric heater to evaporate the solution.

	Trilogy	Synergy	Chemistry
RPA	8	17	1
Specification reference	5.4.2.3	4.7.3.2	4.4.2.3

By using this method your students will have the opportunity to develop the following aspects of the chemistry AT skills	
AT 2	safe use of appropriate heating devices and techniques including the use of a Bunsen burner and water bath or electric heater
AT 4	safe use of a range of equipment to purify and/or separate a chemical mixture including evaporation, filtration and crystallisation
AT 6	safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products

Materials

For the basic method

- 1.0 M dilute sulfuric acid
- copper (II) oxide powder
- a spatula
- a glass rod
- a measuring cylinder
- two beakers: one 100 cm³ and one 250 cm³
- Bunsen burner
- tripod
- gauze
- heatproof mat
- filter funnel and paper
- a small conical flask
- an evaporating basin
- a crystallising dish.

Technical information

To prepare 1.0 M dilute sulfuric acid, consult CLEAPSS.

40cm³ of dilute acid will react with approximately 3.2g copper (II) oxide powder, but more than this will be used due to the excess added.

Additional information

The waste crystals can be recycled to make up new copper (II) sulfate stock solutions.

Electrolysis

Investigate what happens when aqueous solutions are electrolysed using inert electrodes.

	Trilogy	Synergy	Chemistry
RPA	9	21	3
Specification reference	5.4.3.4	4.7.5.3	4.4.3.4

By using this method your students will have the opportunity to develop the following aspects of the chemistry AT skills	
AT 3	use of appropriate apparatus and techniques for conducting and monitoring chemical reactions including appropriate reagents and/or techniques for the measurement of pH in different situations
AT 7	use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds

Materials

For the basic method

- 0.5 M copper (II) chloride solution
- 0.5 M sodium chloride solution
- a Petri dish lid with bored holes
- two carbon rod electrodes with support bungs
- two crocodile/4mm plug leads
- low voltage power supply
- blue litmus paper
- forceps

Technical information

To prepare 0.5 M copper (II) chloride solution and 0.5 M sodium chloride solution, consult CLEAPSS.

Small petri dish lids fit 100 cm³ beakers well and can be drilled out at 180° spacing to take the two electrodes. If the carbon rods are then fitted with holed bungs that are positioned to rest on the lid above the holes, the rods will be stabilised well and the risk of short circuits will be much reduced.

Proprietary electrolysis cells are available, and can be substituted if available.

Solution	Positive electrode (anode)			Negative electrode (cathode)		
	Observations	Element formed	State	Observations	Element formed	State
Copper (II) chloride	Bubbles of gas Bleaches blue litmus white	Chlorine	gas	Brown/red solid coating on rod	Copper	solid
Sodium chloride	Bubbles of gas Bleaches blue litmus white	Chlorine	gas	Bubbles of gas (more rapid production)	Hydrogen	gas

Additional information

This practical activity could involve developing a hypothesis to reinforce working scientifically, so students could work individually or in groups to devise a hypothesis about the products that will be formed at the electrodes.

Chlorine is produced during the first two electrolyses. Students should be warned not to inhale it, and the laboratory should be well ventilated. Limiting the potential difference to 4 V and the electrolysis times to 5 minutes will minimize the risk of chlorine exposure.

Suggested alternative approaches from teachers and technicians

- A simpler version can be carried out in a Petri dish:
 - place approximately 5ml of copper(II) chloride solution in the Petri dish
 - connect two carbon fibre electrodes to a 4 V power source
 - chlorine is produced at the anode and copper at the cathode
 - if a drop of potassium iodide is also placed in the covered Petri dish it will darken as the electrolysis progresses. This is because the chlorine is displacing the iodine.
- You can watch the CLEAPSS version of this on YouTube at [youtube.com/watch?v=KvW-q1FQV9E](https://www.youtube.com/watch?v=KvW-q1FQV9E)

Temperature changes

Investigate the variables that affect temperature change in chemical reactions eg acid plus alkali.

	Trilogy	Synergy	Chemistry
RPA	10	18	4
Specification reference	5.5.1.1	4.7.3.3	4.5.1.1

By using this method your students will have the opportunity to develop the following aspects of the chemistry AT skills	
AT1	use of appropriate apparatus to make and record a range of measurements accurately, including mass, temperature and volume of liquids
AT 5	making and recording appropriate observations during chemical reactions including changes in temperature
AT 6	safe and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products

Materials

For the basic method

- 2 M hydrochloric acid
- 2 M sodium hydroxide solution
- expanded polystyrene cups and lids with thermometer holes
- thermometers.

Technical information

To prepare 2 M hydrochloric acid, consult CLEAPSS.

To prepare 2 M sodium hydroxide solution, consult CLEAPSS.

Additional information

Additional guidance may need to be provided to students regarding the drawing of the two lines of best fit so that they intersect.

The solutions used are fairly concentrated in order to produce reasonable temperature changes.

2 M sodium hydroxide is particularly hazardous to the eyes.

Results from our technician adviser trials

Total volume of sodium hydroxide added in cm ³	Maximum temperature in °C		
	First trial	Second trial	Mean
0	20.0	21.0	
5	24.0	24.6	
10	26.8	27.6	
15	28.6	29.6	
20	30.8	31.3	
25	31.8	32.8	
30	32.0	32.6	
35	31.6	31.8	
40	30.6	31.0	

Rates of reaction

Investigate how changes in concentration affect the rates of reactions by both measuring the volume of a gas produced and monitoring a change in colour or turbidity.

	Trilogy	Synergy	Chemistry
RPA	11	19	5
Specification reference	5.6.1.2	4.7.4.3	4.6.1.2

By using this method your students will have the opportunity to develop the following aspects of the chemistry AT skills	
AT1	use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature and volumes of liquids and gases
AT 3	use of appropriate apparatus and techniques for conducting and monitoring chemical reactions
AT 5	making and recording appropriate observations during chemical reactions including the measurement of rates of reaction by a variety of methods such as production of gas and colour change
AT 6	safe and careful handling of liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes

Activity 1: investigating measurement of rate of reaction using volume of gas produced

Materials

For the basic method

- magnesium ribbon cut into 3 cm lengths
- dilute hydrochloric acid, 1.0 M and 1.5 M
- safety goggles
- conical flask (100 cm³)
- single-holed rubber bung and delivery tube to fit conical flask
- water trough
- two measuring cylinders (100 cm³)
- clamp stand, boss and clamp
- stopclock.

Technical information

The magnesium ribbon needs to be cleaned by rubbing lengths of the ribbon with fine sandpaper to remove the layer of oxidation. Gas syringes can be used instead of troughs of water and measuring cylinders.

To prepare hydrochloric acid, see CLEAPSS.

The AQA technician adviser results are below:

Time in seconds	Volume of gas produced (cm ³)	
	1.0 M	1.5 M
10	4.0	12.0
20	9.0	25.0
30	16.0	36.0
40	23.0	49.0
50	31.0	56.0
60	39.0	56.0
70	44.0	56.0
80	50.0	56.0
90	50.0	56.0
100	50.0	56.0

Activity 2: investigating measurement of rate of reaction using colour change or turbidity

Materials

For the basic method

- 40 g/dm³ sodium thiosulfate solution
- 1.0 M dilute hydrochloric acid
- a conical flask (100 cm³)
- a printed black paper cross
- a stopclock.

Technical information

To prepare 40 g/dm³ sodium thiosulfate solution, consult CLEAPSS. The concentration is specified in g/dm³ rather than mol/dm³ to simplify graph plotting for students.

To prepare 1.0 M dilute hydrochloric acid, consult CLEAPSS.

Printed crosses may give a greater likelihood of students obtaining reproducible results between groups.

Additional information

Sulfur dioxide gas is released during the reaction, which can exacerbate breathing difficulties in people with conditions such as asthma. The laboratory should be well ventilated and it might be appropriate to cover the neck of the conical flask with cling film for example.

Consult CLEAPSS guide for additional safety information and for safe disposal instructions.

Concentration of sodium thiosulfate in g/dm ³	Time taken for cross to disappear in seconds			
	First trial	Second trial	Third trial	Mean
8	137	138	156	
16	76	75	77	
24	46	47	46	
32	37	40	37	
40	27	25	27	

Chromatography

Investigate how paper chromatography can be used to separate and tell the difference between coloured substances. Students should calculate R_f values.

	Trilogy	Synergy	Chemistry
RPA	12	9	6
Specification reference	5.8.1.3	4.2.2.4	4.8.1.3

In this practical students use paper chromatography to separate and identify a mixture of food colourings.

By using this method students will have the opportunity to develop the following aspects of the chemistry AT skills	
AT 4	safe use of a range of equipment to purify and/or separate chemical mixtures including chromatography

Materials

For the basic method

- a 250 cm³ beaker
- a wooden spill or pencil to support the chromatography paper
- paper clip
- a ruler
- a pencil
- distilled water
- four known food colourings labelled A–D
- unknown food colouring labelled U
- rectangle of chromatography paper
- five glass capillary melting point tubes.

Technical information

There are several brands of food colouring available. It will be necessary to experiment to obtain a type that gives good results. The unknown mixture **U** should contain two of the known food colourings and a third colour **not** from **A–D**. Best results will be obtained if **A–D** are single dyes and not mixtures themselves.

Additional information

Chromatography paper should be pre-cut for student use so that it will not touch the beaker walls (if it does, capillary rise at the edges will distort the solvent front). Melting point tubes take up food dye by capillary action and are a convenient way of making small, concentrated, reproducible spots.

Wet chromatography paper is difficult to take measurements from. Because of the drying time involved it may be necessary to take measurements and do calculations during the following lesson. Hairdryers might be used to speed up drying time.

Students should be reminded not to move or touch the beaker once the experiment is under way.

A lid is sometimes suggested for good results, especially when the solvent is volatile, but is not essential with water. If desired, a Petri dish makes a suitable lid.

Water purification

Analysis and purification of water samples from different sources.

To include pH measurement, removal of dissolved solids and distillation.

	Trilogy	Synergy	Chemistry
RPA	13	11	8
Specification reference	5.10.1.2	4.4.1.8	4.10.1.2

This practical involves several activities.

- Students demonstrate that a sample of water is impure by:
 - measuring the pH and comparing it with the pH of pure water
 - demonstrating that the sample contains dissolved solids by evaporating it and revealing dissolved solids. They can extend the analysis by calculating the mass of dissolved solids present.
- Students then distil the water. They then re-test the distillate to show that the water has been purified.

This can be delivered in a range of different contexts to suite the ability of your students eg accessing drinking water on a cruise ship or on a desert island.

By using this method students will have the opportunity to develop the following aspects of the chemistry AT skills	
AT1	use of appropriate apparatus to make and record a range of measurements accurately including mass
AT 2	safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater
AT 3	use of appropriate apparatus and techniques for the measurement of pH in different situations
AT 4	safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, distillation

Materials

For the basic method

pH tests

- safety goggles
- pure distilled water
- samples of water at different pH values
- universal indicator solution or paper.

Dissolved solids

- sample of a prepared salt solution or mineral bottled water (concentration unimportant but should give good crystal formation when evaporated)
- Bunsen burner
- tripod
- gauze
- heatproof mat
- evaporating basin
- weighing balance.

Distillation

- conical flask with delivery tube with bung
- a boiling tube
- ice bath
- cobalt chloride paper (optional).

Additional information

In the **distillation experiment** students will need to be cautioned to remove the heat source if it seems likely the salt water will boil over through the delivery tube. They should also be told to keep the delivery tube at least 2cm from the bottom of the collecting test tube; otherwise the distillate level may rise above it, creating the possibility of suck-back when heating is discontinued.

Teacher and technician notes: Physics

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.

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.

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.

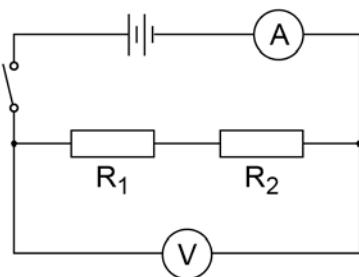
This experiment is a good one to use to discuss zero error as it is hard to attach the crocodile precisely to the zero end of the wire, and there will be some contact resistance.

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.

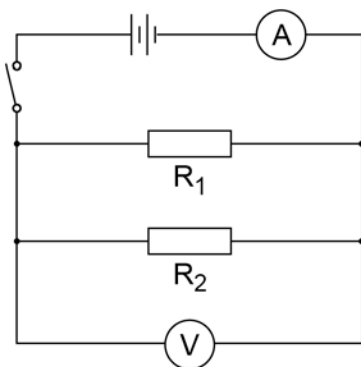


Technician Adviser results

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 $1/\text{stiffness}$ or $1/\text{spring constant}$. (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 1m 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

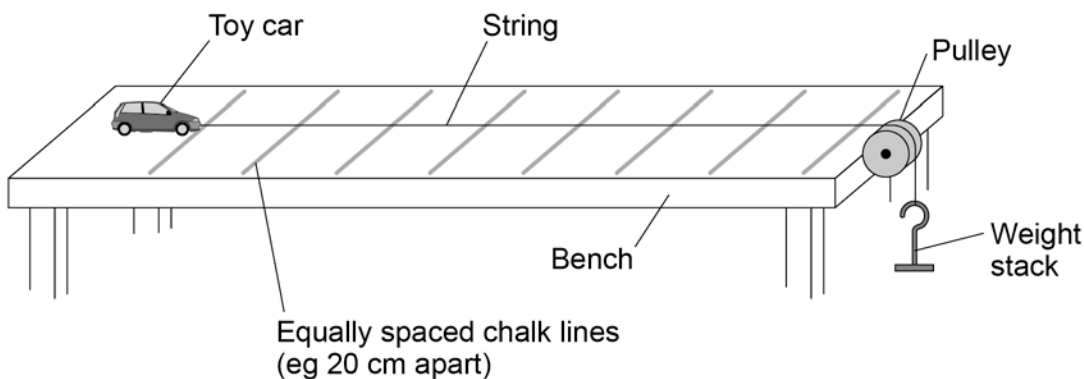
Students draw straight lines in chalk onto the bench at equally measured intervals to allow the time to travel set distances to be easily recorded.

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. 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 460g. 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.

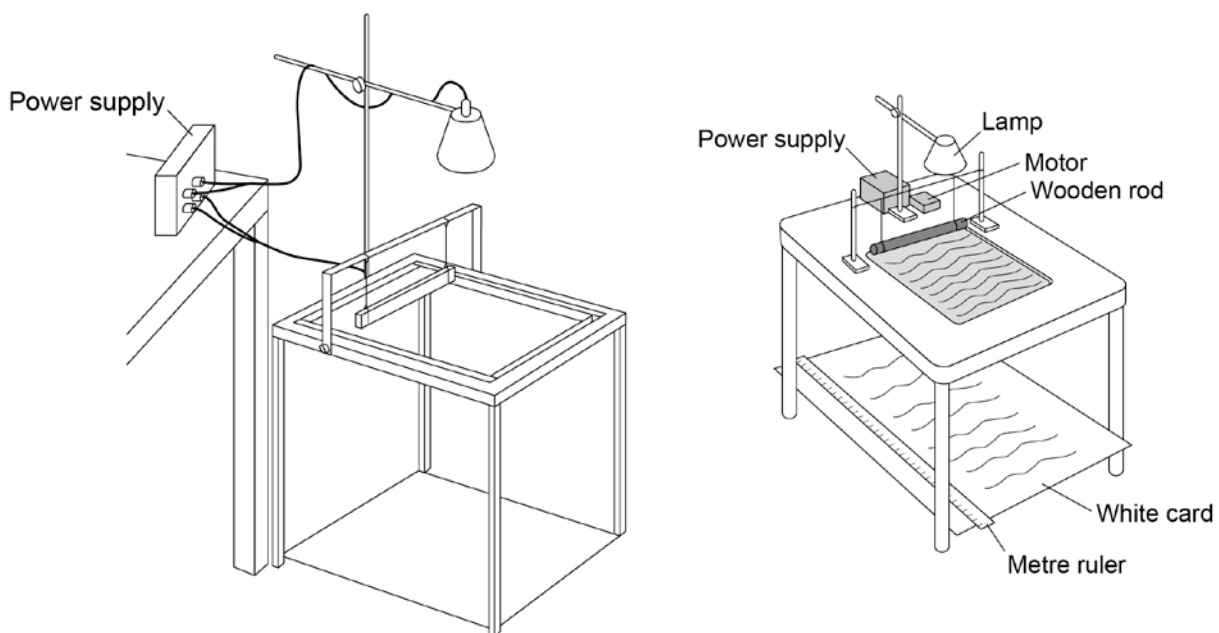
The depth of water in the ripple tank should be about 5 mm.

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.



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

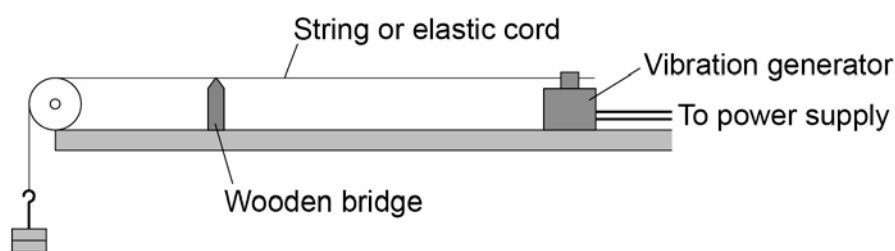
Technical information

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

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: Biology

Microscopy

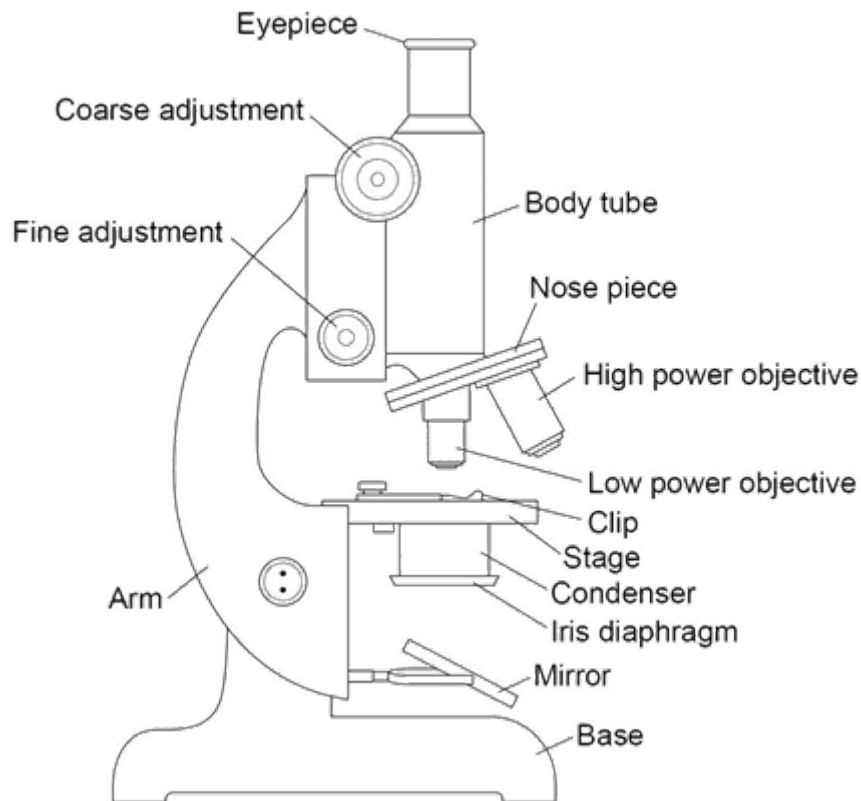
Use a light microscope to observe, draw and label biological specimens

In this practical you will:

- use an optical microscope to look at and draw the cells on your microscope slide
- identify structures within the cells
- make a note of the magnification used.

Using a microscope to look at animal and plant cells

The diagram shows a typical microscope.



Some microscopes have a built-in light instead of a mirror.

Apparatus

- a microscope
- prepared slides of plant and animal cells.

Method

1. Put the slide on the microscope stage.
2. Turn the nose piece to select the lowest power objective lens (this is usually $\times 4$ objective lens). The end of the objective lens needs to **almost** touch the slide.
3. Turn the coarse adjustment knob to move the lens towards the slide. Look from the side (**not** through the eyepiece) when you are adjusting the lens.
4. Now look through the eyepiece. Slowly turn the coarse adjustment knob in the direction to increase the distance between the objective lens and the slide. Do this until the cells come into focus.
5. Slightly turn the fine adjustment knob to bring the cells into a clear focus. Use the low power objective lens (totalling $\times 40$ magnification) to look at the cells.
6. When you have found some cells, turn the nose piece to switch to a higher power lens ($\times 100$ or $\times 400$ magnification).
7. You will have to use the fine adjustment knob again to bring the cells back into focus.
8. Make a clear, labelled drawing of some of the cells. Make sure that you draw and label any component parts of the cell. Use a pencil to draw the cells.
9. Write the magnification underneath your drawing. Remember to multiply the objective magnification by the eyepiece magnification.

Cell drawings and magnification

Animal cell	Plant cell

Task

Write down the names of the parts of both the animal and plant cell that you cannot see in the light microscope field of view. Write a sentence to explain the function of these parts.

Osmosis

Investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.

In this practical you will:

- prepare samples of potato and place them in different concentrations of sugar or sodium chloride (salt) solution
- make measurements of mass and length of your samples before and after soaking them in the solutions.

Apparatus

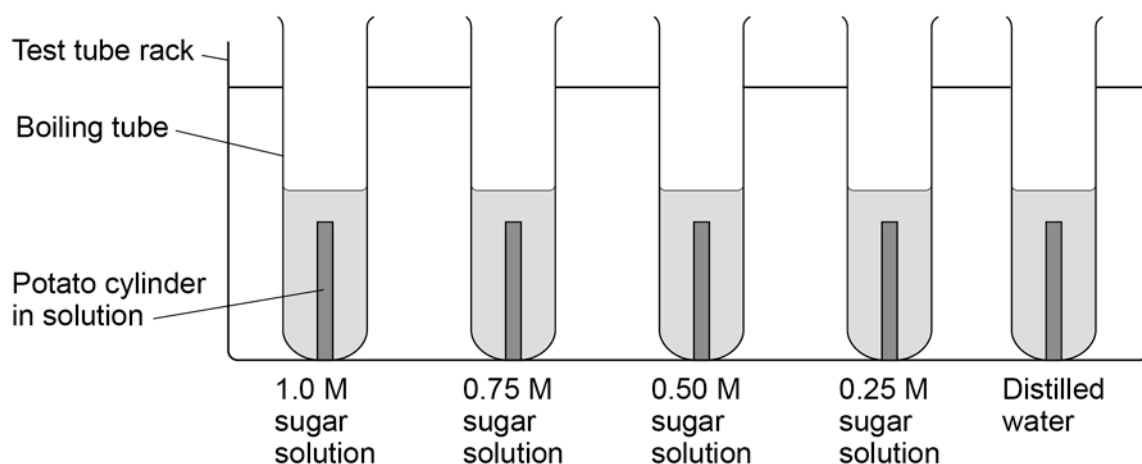
- a potato
- a cork borer
- a ruler
- a 10 cm³ measuring cylinder
- labels
- five boiling tubes
- a test tube rack
- paper towels
- a sharp knife or scalpel
- a white tile
- a range of sugar or salt solutions
- distilled water
- a top-pan balance accurate to at least 0.01 g.

Method

1. Use a cork borer to cut five potato cylinders of the same diameter.
2. Use the knife to trim off any potato skin on each potato cylinder. Then trim each potato cylinder so that they are all the same length.
3. Accurately measure the mass of each potato cylinder.
4. Accurately measure the length of each cylinder.
5. Record your measurements in a table like the one shown over the page.

	1.0 M sugar solution	0.75 M sugar solution	0.5 M sugar solution	0.25 M sugar solution	Distilled water
Initial mass in g					
Final mass in g					
Change in mass in g					
Percentage change in mass %					
Initial length in cm					
Final length in cm					
Change in length in cm					
Percentage change in length %					

- Measure 10 cm³ of each concentration of sugar or salt solution and put into boiling tubes. Label each boiling tube clearly.
- Measure 10 cm³ of the distilled water and put into the fifth boiling tube. Label the boiling tube clearly.
- Add one potato cylinder to each boiling tube.



-
9. Leave the potato cylinders in the boiling tubes for a chosen amount of time.
 10. Remove the potato cylinders from the boiling tubes and carefully blot them dry with the paper towels.
 11. Measure the new mass and length of each potato cylinder again. Record your measurements for each concentration in your table.

Analysis of your results

- Calculate the change in mass and length of each potato cylinder. Record your results in your table.
- Calculate the percentage change in mass and length of each potato cylinder and record your results in your table.
- Write a paragraph to state what has happened and how this relates to the theory of osmosis in cells.

Food tests

Use qualitative reagents to test for a range of carbohydrates, lipids and proteins. To include: Benedict's test for sugars, Iodine test for starch and Biuret reagent for protein.

In this practical you will:

use qualitative reagents to test for the presence of carbohydrates, lipids and proteins in a range of foods.

Test for carbohydrates

The Benedict's test for sugars

Apparatus

- food sample
- a test tube
- Benedict's solution
- traditional water bath to include Bunsen burner use
- thermometer
- pipettes.

Method

1. Set up your traditional water bath set up using a Bunsen burner.
2. Put some of the food sample into a test tube.
3. Add a few drops of Benedict's solution to the sample in the test tube.
4. Put the test tube in the water bath at a minimum of 80 °C for about 5 minutes.
5. Note down any colour change in your table of results.

The Iodine test for starch

Apparatus

- food sample
- a test tube
- iodine solution
- pipettes.

Method

1. Put some of the food sample into a test tube.
2. Add a few drops of Iodine solution.
3. Note down any colour change in your table of results.

Test for lipids

Apparatus

- food sample
- a test tube
- ethanol
- distilled water.

Method

1. Put some of the food sample into a test tube.
2. Add a few drops of distilled water.
3. Add a few drops of ethanol.

Care: Ethanol is highly flammable. Keep the solution away from any flames.

4. Shake the solution gently.
5. Note what you see in your table of results.

Test for protein

Apparatus

- a test tube
- a 10 cm³ measuring cylinder
- Biuret solution A and Biuret solution B.

Method

1. Put some of the food sample into a test tube.
2. Add 1 cm³ of Biuret solution A and 1 cm³ of Biuret solution B to the test tube.

Care: Biuret solution contains copper sulphate, which is poisonous, and sodium hydroxide, which is corrosive. Handle the solution with care. Wash immediately if you spill it on your skin, and wipe up any spills.

3. Shake the tube gently to mix.
4. Note any colour change in your table of results.

Recording data

Record your results in the table below.

Name of food tested	Colour produced with Benedict's solution	Colour produced with iodine solution	Cloudy layer produced with ethanol	Colour produced with Biuret solution

Write a conclusion to state which food groups are present one of the food samples you tested and an explanation of how you know this.

Enzymes

Investigate the effect of pH on the rate of reaction of amylase enzyme.

In this practical you will:

- use the enzyme amylase to break down starch at different pH values
- measure the pH of different solutions
- use a water bath to keep reacting solutions at a constant temperature
- use a continuous sampling technique
- use iodine solution as an indicator of the breakdown of starch into sugars.

Apparatus

- 10 test tubes
- a test tube rack
- a water bath
- a thermometer
- a spotting tile
- a 5 cm³ measuring cylinder
- pasteur pipettes
- a glass rod
- a stopclock
- starch solution
- amylase solution
- iodine solution
- labelled buffered solutions at a range of pH values
- labels.

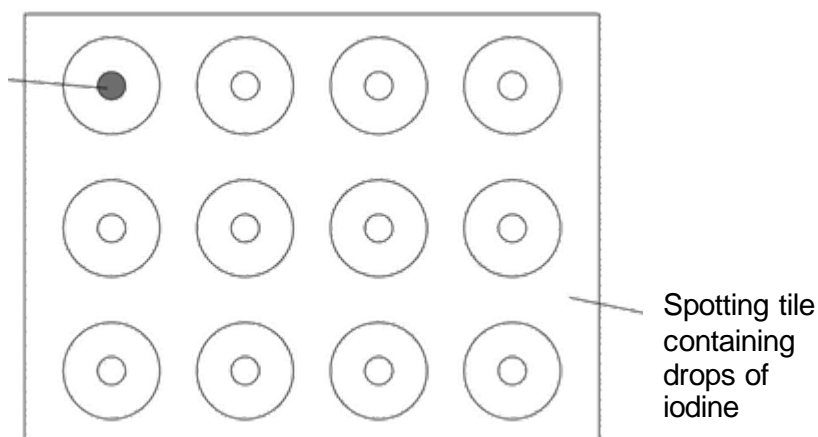
Method

1. Heat your water bath to 35°C.
2. Put 2 cm³ of each buffered solution into individual, separate test tubes. Label each tube with the pH of the solution.
3. Label 5 test tubes 'Starch' and add 4 cm³ of starch solution into each tube.
4. Put a thermometer in one of the starch test tubes to monitor the temperature. Leave the thermometer in this tube throughout the experiment.
5. Add 10 cm³ of Amylase solution into another test tube. Label the tube 'amylase'.
6. Put all the test tubes into the water bath.
7. Allow the solutions to reach 35 °C.
8. While the solutions are reaching the required temperature, put one drop of Iodine solution into each depression on your spotting tile.

Put a drop of starch solution in the first depression of the tile. This is your 'zero time' mixture. You will use this as a comparison of colour for your test buffers. Starch gives a blue-black colour with iodine, and the iodine stays brown if all the starch has broken down to glucose.

9. When all the tubes have reached 35 °C take one of the tubes of starch from the water bath and add the 2cm³ of your first pH buffered solution. Stir the mixture with a glass rod.
10. Use the pipette to add 2 cm³ of amylase solution to the mixture. Start the stopclock as soon as you add the amylase. Keep stirring the mixture with the glass rod.
11. After 10 seconds, remove one drop of the mixture with a glass rod.
12. Put this drop on the second depression of your spotting tile.

Drop of starch solution added at zero time



13. Rinse the glass rod with water.
14. Every 10 seconds, use the glass rod to remove one drop of the mixture. Put each drop onto the iodine solution in the next depression on the spotting tile. Remember to rinse the glass rod with water after putting each drop on the spotting tile.
15. Keep sampling every 10 seconds until the iodine does not change colour.
16. Record your results in a table like this one:

pH of solution	Time for amylase to completely break down the starch in seconds

Repeat steps 10–17 with both of your other pH buffered solutions.

Task

Enzymes are **biological catalysts**. Explain what happens to the starch when the amylase is added.

Photosynthesis

Investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.

In this practical you will:

measure the volume of oxygen produced by the pondweed as the light intensity changes as the light source is moved.

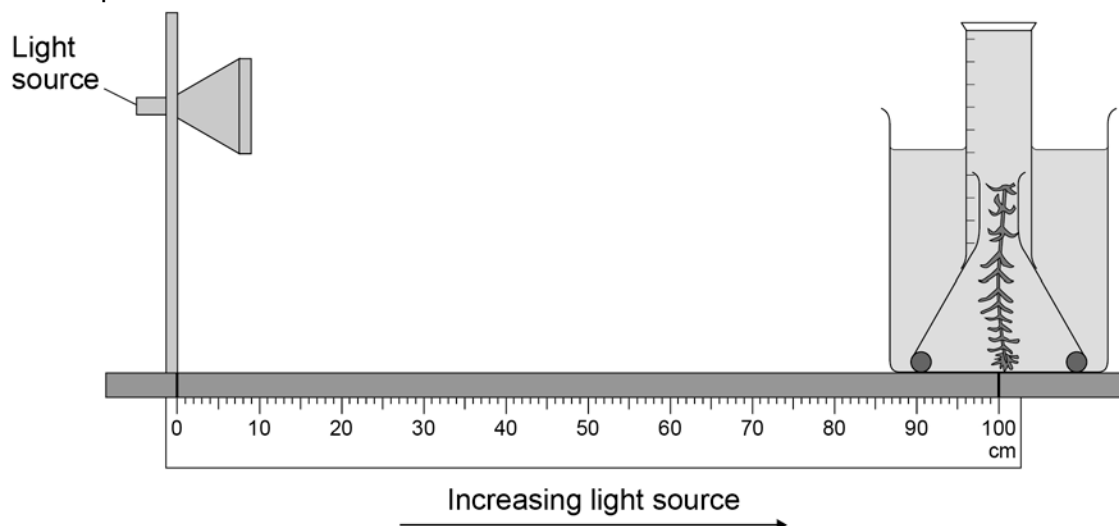
Apparatus

- a beaker
- a filter funnel
- plasticine
- a measuring cylinder (1 or 10cm³)
- a 10 cm piece of pondweed
- a light source
- a metre rule
- a stopwatch.

Method

1. Put your 10cm piece of pond weed (cut edge at the top) into a beaker of water.
2. Cover the pondweed with an inverted filter funnel – raised off the bottom of the beaker with plasticine.
3. Fill the measuring cylinder with water and gently position as in the diagram.
4. Use the ruler to position the beaker of pondweed 1 metre away from the light source.

Your experiment should look like this:



5. Start the stopwatch and:
 - a. count and record the number of bubbles released in three minutes
 - b. record the volume of gas produced and collected in the measuring cylinder in the same three minutes.
6. Record your results in a table like this one:

Increasing light intensity					
	100cm	80cm	60cm	40cm	20cm
Number of gas bubbles					
Volume of gas cm ³					

7. Move the light source so that the pondweed beaker is 80 cm away.
8. Refill the measuring cylinder with water and gently position as in the diagram.
Then repeat steps 5 and 6.
9. Repeat for distances of 60, 40 and 20 cm.

Evaluation

Which method of recording gas collection was most accurate and why?

Reaction time

Plan and carry out an investigation into the effect of a factor on human reaction time.

In this practical you will:

- decide which factor you want to investigate that will have an effect on human reaction time
- work with a partner to use the ruler drop test
- use your results to calculate your reaction time before and after you made the change.

Apparatus

- a metre ruler
- a chair
- a table
- any further equipment needed depending on the factor you are changing.

Investigation

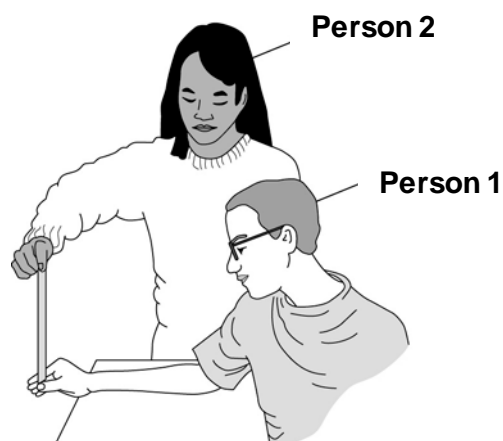
What factor have I decided to change?

How will I change it?

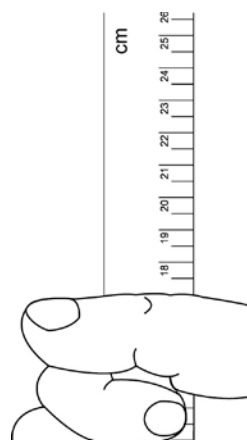
What affect do I think it will have on human reaction time?

Method for standard human reaction time test

1. Work with a partner to do this test. Choose who will be person 1 and who will be person 2.
2. Each of you should use your dominant hand to do this experiment. If you are right handed then your dominant hand is your right hand.
3. Person 1 sits down on the chair, with good upright posture and eyes looking across the room.
4. Person 1 puts the forearm of their dominant arm across the table with their hand overhanging the edge.
5. Person 2 holds a ruler vertically with the bottom end (the end with the 0 cm mark) in between person 1's thumb and first finger. They will tell person 1 to prepare to catch the ruler.



6. Person 1 catches the ruler with their thumb and first finger as quickly as possible when it drops.
7. Record the number on the ruler that is level with the top of person 1's thumb.



8. Have a short rest, then repeat the test several times.

9. Record your results on a table.

Drop test attempt	Ruler measurements in cm				Reaction times in seconds			
	Person 1 Before	Person 2 Before	Person 1 After	Person 2 After	Person 1 Before	Person 2 Before	Person 1 After	Person 2 After
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

10. Repeat the test with Person 2 catching the ruler and Person 1 dropping it.

11. Record Person 2's results on the table.

12. Use a conversion table to convert your ruler measurements into reaction times.

13. Make the change that you are investigating to change human reaction time.

14. Repeat steps 1-9 for each person and record the results in your data table.

Analysing the data

Do your results reflect your hypothesis? Did the factor you changed have any effect on your reaction time?

Consider your own and your partners results. Are your reaction times similar? If not, can you explain why?

What type of errors might have happened to affect your results?

Field investigations

Measure the population size of a common species in a habitat. Use sampling techniques to investigate the effect of a factor on the distribution of this species.

In this practical you will:

- work in a group to use a quadrat to estimate the population size of a plant species in a survey area
- use a transect line and a quadrat to investigate the effect of light intensity on the number of plants in a survey area.

Investigating the population size of a plant species using random sampling

Apparatus

A quadrat.

Method

Your teacher will have prepared a survey area for you and will show you how to identify the plants (eg plantain) you are surveying. You will need to work in groups of three.

1. Collect two numbers, one from each bag.
2. Use the numbers and the tape measures to locate the first position for your quadrat.
3. Lay the quadrat on the ground.
4. Replace the numbers in the bags.
5. Count and record the number of the chosen plant species inside the quadrat.
6. Repeat steps 1–5 until you have recorded the numbers of chosen plant species in ten quadrats.
7. Your teacher will show you how to estimate the population of plantain using the equation

$$\text{estimated population size} = \frac{\text{total area}}{\text{area sampled}} \times \text{number of plantain counted}$$

Task

Design a results table and record the number of each type of chosen species you could see in each of your ten quadrats.

Investigating the effect of light intensity on plant distribution using a transect line

Apparatus

- a quadrat
- a 30 m tape measure
- a light meter.

Method

Your teacher will help you choose a species of plant to identify.

1. Put the 30 m tape measure in a line from the base of a tree to an open area of ground.
2. Put the quadrat against the transect line. One corner of the quadrat should touch the 0 m mark on the tape measure.
3. Count the number of plants inside the quadrat.
4. Use the light meter to measure the light intensity at this position.
5. Record your results in a table like this:

Distance along the transect line in m	Number of plants in quadrat	Light intensity
0		
5		
10		
15		
20		
25		
30		

-
5. Move the quadrat 5 m up the transect line and count the number of plants again. Measure the light intensity at this position. Record your results in your table.
 6. Continue to place the quadrat at 5 m intervals up the transect line. Count the number of plants and measure the light intensity in each quadrat.

Task

Plot and draw appropriate graphs, selecting appropriate scales for the axes.

Write a sentence to describe the relationship you see in your graphs.

Student worksheets: Chemistry

Making salts

Making soluble salts: preparation of pure dry copper sulfate crystals.

In this practical you will:

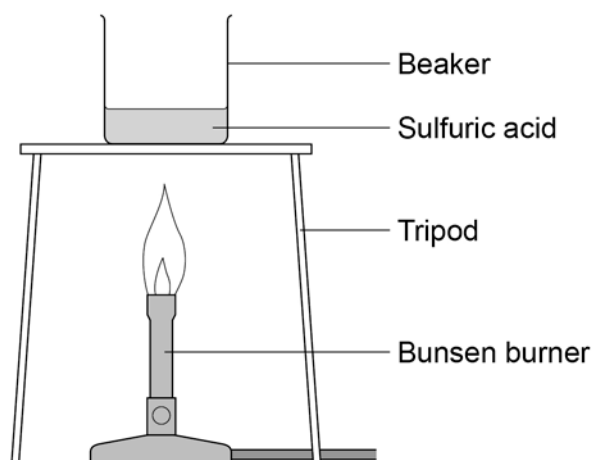
- react sulfuric acid with insoluble copper (II) oxide to prepare an aqueous solution of the salt copper sulfate
- separate out unreacted copper (II) oxide by filtration
- prepare pure dry crystals of copper sulfate from the solution.

Apparatus

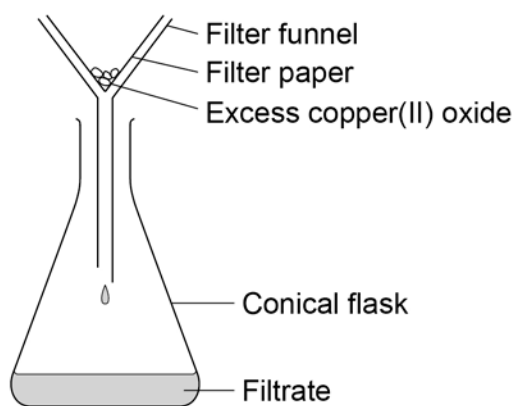
- dilute sulfuric acid
- a measuring cylinder
- copper(II) oxide powder
- a spatula
- a glass rod
- a 100 cm³ beaker
- a 250 cm³ beaker
- a Bunsen burner
- a tripod
- gauze
- a heatproof mat
- a filter funnel and paper
- a small conical flask
- an evaporating basin
- a crystallising dish.

Method

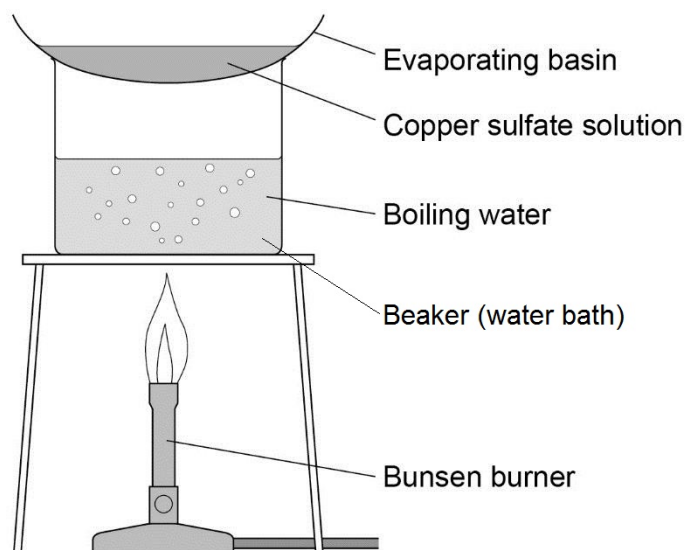
1. Measure 40 cm³ sulfuric acid and put it into the 100 cm³ beaker.
2. Set up the Bunsen burner, tripod, gauze and heatproof mat. Put the beaker on the gauze and heat the acid **gently** until it is almost boiling. **Turn off the Bunsen burner.**



3. Remove the glass beaker from the tripod. Use the spatula to add a **small** amount of copper (II) oxide powder to the hot acid. Stir with the glass rod. The copper (II) oxide will disappear and the solution will turn clear blue.
4. Add some more copper (II) oxide and stir again.
5. Keep adding the copper (II) oxide until some of it remains after stirring.
6. Allow the apparatus to cool completely.
7. Set up the filter funnel and paper over the conical flask. Filter the contents of the beaker.



8. Pour the filtrate from the conical flask into the evaporating basin.
9. Set up a water bath using the 250 cm³ beaker on the tripod and gauze.
10. Evaporate the filtrate gently using the water bath.



11. When crystals start to form, stop heating the water bath.
12. Pour the remaining solution into the crystallising dish.
13. Leave the crystallising dish in a cool place for at least 24 hours.
14. Remove the crystals from the concentrated solution with a spatula.
Gently pat the crystals dry between two pieces of filter paper.

Task

Write a word and a symbol equation for the chemical reaction you have carried out in the space below.

Electrolysis

Investigate what happens when two different aqueous solutions are electrolysed using inert electrodes.

In this practical you will:

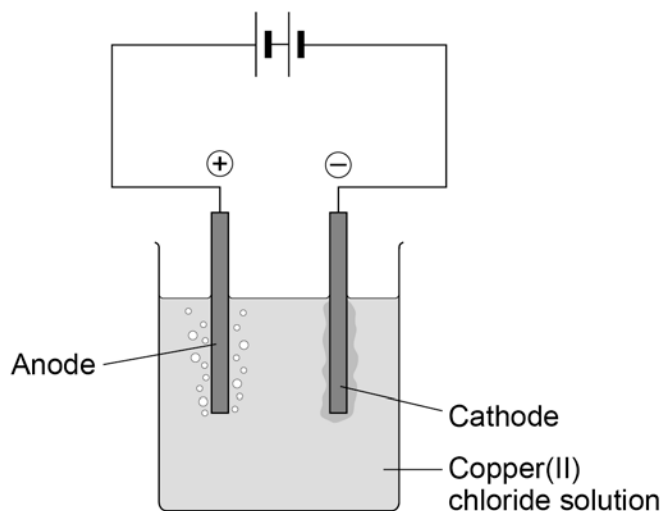
- use a low voltage power supply and carbon rod electrodes to pass a current through two different salt solutions.
- identify the element formed at the positive and negative electrodes for each solution.
- add extra detail to the basic electrochemical diagram provided.

Apparatus

- copper(II) chloride solution
- sodium chloride solution
- 100 cm³ beaker
- petri dish lid
- two carbon rod electrodes
- two crocodile / 4 mm plug leads
- low voltage power supply
- blue litmus paper
- forceps.

Method

1. Pour approximately 50cm³ copper (II) chloride solution into the beaker.
2. Add the petri dish lid and insert the carbon rods through the holes. **The rods must not touch each other.**
3. Attach crocodile leads to the rods. Connect the rods to the dc (red and black) terminals of a low voltage power supply.



4. Select 4 V on the power supply and switch on.
5. Look at both electrodes and record your initial observations in the table below.
6. Use forceps to hold a piece of blue litmus paper in the solution next to the anode (positive electrode) and identify the element?

Write all your observations in a table like this one.

Solution	Positive electrode (anode)			Negative electrode (cathode)		
	Observations	Element formed	State	Observations	Element formed	State
Copper (II) chloride						
Sodium chloride						

Care - switch off the power supply after 5 minutes.

-
7. Rinse the electrochemical cell apparatus and collect a new set of electrodes.

Repeat steps 1–8 using the other solution sodium chloride and complete the following tasks to show your understanding of the chemistry of electrolysis.

- a. Draw a fully labelled diagram of your electrochemical cell.

- b. What is the third main product of this electrolysis reaction that could be detected with the use of red litmus?

Electrolysis is also used to extract metals from their ore. Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite using carbon as the positive electrode.

To support with your revision:

- a. Explain why a mixture is used as the electrolyte.

- b. Explain why the positive electrode must be continuously replaced.

- c. Write half equations for the chemical reactions happening at both electrodes (HT only).

Temperature changes

Investigate the variables that affect temperature change in chemical reactions eg acid plus alkali.

In this practical you will:

- react sodium hydroxide solution with hydrochloric acid
- measure the temperature changes during the reaction
- plot a graph of your results and record the temperature change.

Apparatus

- dilute hydrochloric acid
- dilute sodium hydroxide solution
- an expanded polystyrene cup and lid
- 250 cm³ beaker
- 10 cm³ measuring cylinder
- 50 cm³ measuring cylinder
- a thermometer.

Method

1. Measure 30 cm³ dilute hydrochloric acid and put it into the polystyrene cup.
2. Stand the cup inside the beaker. This will make it more stable.

3. Use the thermometer to measure the temperature of the acid. Record your result in a table like this.

Total volume of sodium hydroxide added in cm ³	Maximum temperature in °C		
	First trial	Second trial	Mean
0			
5			
10			
15			
20			
25			
30			
35			
40			

4. Measure 5 cm³ sodium hydroxide solution.
5. Pour the sodium hydroxide into the polystyrene cup. Fit the lid and gently stir the solution with the thermometer through the hole.
6. Look carefully at the temperature rise on the thermometer.
7. When the reading on the thermometer **stops changing**, record the highest temperature reached in the table.
8. Repeat steps 4–7 to add further 5 cm³ amounts of sodium hydroxide to the cup each time, recording your temperature reading in the results table.
9. Repeat until a maximum of 40cm³ of sodium hydroxide has been added.
10. Wash out all the equipment and repeat the experiment for your second trial.

Analysis and conclusion

- a. Calculate the **mean** maximum temperature reached for each volume of sodium hydroxide. Record these means in your table.
- b. Plot a graph from your results and draw two straight lines of best fit.
- c. From the graph read off the maximum temperature change.
- d. This is an example of an **exothermic** reaction, when heat is given out. Can you explain why the results you recorded show that the temperature started to fall after a certain volume of sodium hydroxide had been added?
- e. Can you explain what is happening to the chemical bonds in the reactants and the products when an exothermic reaction is taking place?

Rates of reaction

How does the concentration of an acid affect the rate of reaction?

Activity 1 – by measuring the volume of gas produced

In this practical you will:

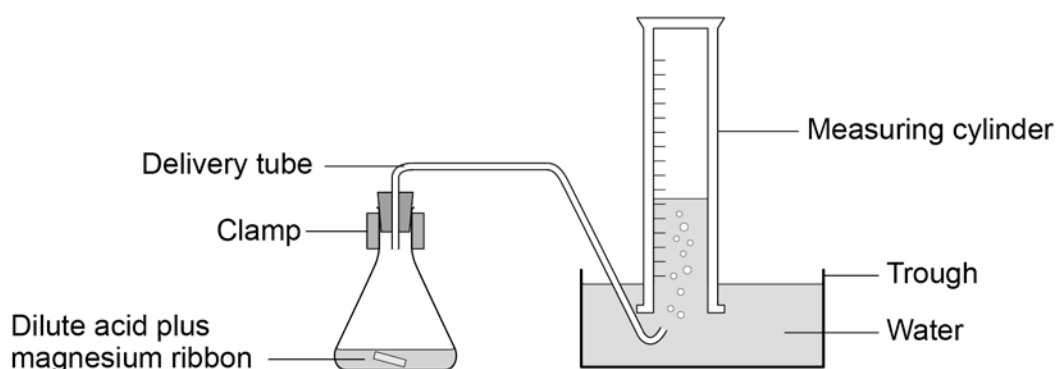
- react magnesium ribbon with different concentrations of hydrochloric acid
- measure the volume of gas produced for each concentration.
- use your results to work out how the rate of reaction is affected by the concentration of the acid.

Apparatus

- safety goggles
- a 100 cm³ conical flask
- a single-holed rubber bung and delivery tube to fit conical flask
- a water trough
- two 100 cm³ measuring cylinders
- a clamp stand, boss and clamp
- a stop clock
- magnesium ribbon cut into 3 cm lengths
- two different concentrations of dilute hydrochloric acid, 1.0 M, and 1.5 M.

Method

1. Measure 50 cm³ of 1.0 M hydrochloric acid using one of the measuring cylinders. Pour the acid into the 100 cm³ conical flask.
2. Fit the bung and delivery tube to the top of the flask.
3. Half fill the trough or bowl with water.
4. Fill the other measuring cylinder with water. Make sure it stays filled with water when you invert it into the water trough and that the delivery tube is positioned correctly.



5. Add a single 3 cm strip of magnesium ribbon to the flask, put the bung back into the flask as quickly as you can, and start the stopclock.
6. Record the volume of hydrogen gas given off at suitable intervals (eg 10 seconds) in a table like this:

Time in seconds	Volume of gas produced cm ³	
	1.0 M	1.5 M
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		

Continue timing until the volume of gas does not change.

7. Repeat steps **1–6** using 1.5 M hydrochloric acid.

Analysis, conclusion and evaluation

- a. Plot a graph of your results.
- b. Draw a line of best fit. The results should generate a curve not a straight line.
- c. Plot the curve for both 1.0 M and 1.5 M hydrochloric acid on the same graph.
- d. Use your graph to compare the rates of reaction with different concentrations of hydrochloric acid with magnesium.
- e. Use kinetic theory to explain your findings.

How does the concentration of sodium thiosulphate affect the rate of reaction?

Activity 2 – investigating measurement of rate of reaction using colour change or turbidity

In this practical you will:

- react different concentrations of sodium thiosulfate with hydrochloric acid
- use a stop clock to time how long it takes for the mixture to become cloudy for each concentration
- use your results to work out how the rate of reaction changes as the concentration of the sodium thiosulfate changes.

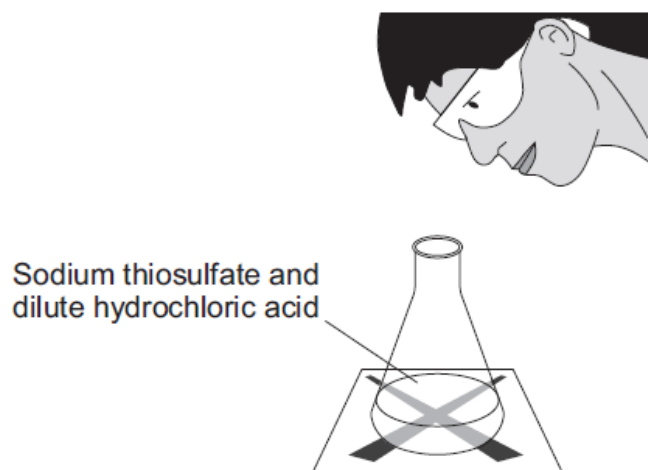
Apparatus

- 40 g/dm³ sodium thiosulfate solution
- dilute hydrochloric acid
- 10 cm³ measuring cylinder
- 100 cm³ measuring cylinder
- 100 cm³ conical flask
- printed black paper cross
- stopclock.

Method

1. Measure 10 cm³ sodium thiosulfate solution and put it into the conical flask.
2. Measure 40 cm³ of water. Add the water to the conical flask.
3. This dilutes the sodium thiosulfate solution to a concentration of 8 g/dm³.
4. Put the conical flask on the black cross.
5. Measure 10 cm³ of dilute hydrochloric acid.
6. Put this acid into the flask. At the same time swirl the flask gently and start the stopclock.

7. Look down through the top of the flask. Stop the clock when you can no longer see the cross.
Take care to avoid breathing in any sulfur dioxide fumes.



8. Record the time it takes for the cross to disappear in the table below. Record the time in **seconds**.

Concentration of sodium thiosulfate in g/dm ³	Time taken for cross to disappear in seconds			
	First trial	Second trial	Third trial	Mean
8				
16				
24				
32				
40				

9. Repeat steps **1–7** changing the concentration of sodium thiosulphate each time as below
- 20 cm³ sodium thiosulfate + 30 cm³ water (concentration 16 g/dm³)
 - 30 cm³ sodium thiosulfate + 20 cm³ water (concentration 24 g/dm³)
 - 40 cm³ sodium thiosulfate + 10 cm³ water (concentration 32 g/dm³)
 - 50 cm³ sodium thiosulfate + no water (concentration 40 g/dm³).

Analysis, conclusion and evaluation

- a. Share results with two other groups. Record these results in the second and third blank columns of your table.
- b. Calculate the **mean** time for each of the sodium thiosulfate concentrations. Leave out anomalous values from your calculations.
- c. Plot a graph and draw a smooth curved line of best fit.
- d. Describe the relationship between the independent variable and the dependent variable? What were your control variables?
- e. Compare your results with those of others in the class. Is there evidence that this investigation is reproducible?
- f. Evaluate the two methods that you have used to investigate the effect of concentration on rate of reaction.

Chromatography

Investigate how paper chromatography can be used to separate and identify a mixture of food colourings.

In this practical you will:

- use paper chromatography to separate a mixture of food colourings.
- calculate the R_f value for each pure food colouring in the solvent water.
- use your R_f values to identify which colourings are in the unknown mixture, U.

Apparatus

- a 250 cm³ beaker
- a wooden spill
- a rectangle of chromatography paper
- four known food colourings labelled A–D
- an unknown mixture of food colourings labelled U
- five glass capillary tubes
- a paper clip
- a ruler
- a pencil.

Method

1. Use a ruler to draw a horizontal pencil line 2 cm from the bottom short edge of the chromatography paper. This is your **origin line**.
2. Mark five pencil spots at equal intervals across the origin line. Make sure you keep at least 0.5 cm away from each edge of the paper.
3. Use a glass capillary tube to put a small spot of each colouring **A**, **B**, **C** and **D** on four of the pencil spots. Use a different tube for each colouring. Use the fifth tube to put a small spot of the unknown mixture **U** on the fifth pencil spot.

Try to make sure each spot is no more than 2-3 mm in diameter.

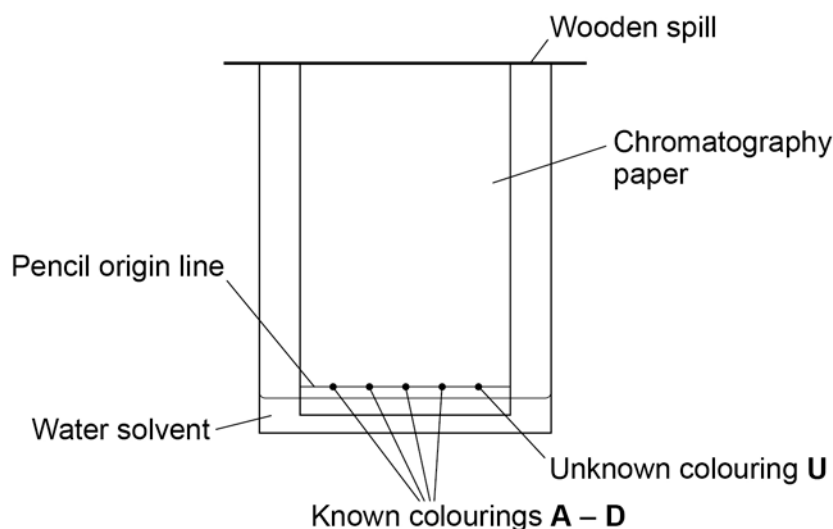
Label each spot **in pencil**.

4. Pour water into the beaker to a depth of **no more than 1 cm**.
5. Clip the top short edge of the chromatography paper to the wooden spill. The top end is the end furthest from the spots.
6. Carefully rest the wooden spill on the top edge of the beaker. The bottom edge of the paper should dip into the water solvent.

Make sure that:

- the pencil start line is above the water surface
- the sides of the paper do not touch the beaker wall.

Your apparatus should look like this:



7. Wait for the water solvent to travel at least three quarters of the way up the paper. **Do not disturb the beaker during this time.**
8. Carefully remove the paper from the beaker. Draw another pencil line on the dry part of the paper as close to the wet edge as possible. This is called the **solvent front line**.
9. Hang the paper up to dry thoroughly.
10. Measure the distance in mm between the two pencil lines. This is the distance travelled by the water solvent.
11. For each of food colour A, B, C and D measure the distance in mm from the start line to the middle of the spot.

12. Record your measurements in the table below:

Food colouring	Distance travelled in mm		R _f value
	Solvent	Spot	
A			
B			
C			
D			

Analysis, conclusion and evaluation

a. Calculate the R_f value for each of the known colours. Use the equation:

$$R_f = \frac{\text{distance moved by solute}}{\text{distance moved by solvent}}$$

b. Observe the spots made by food colouring mixture **U**.

c. What conclusions can you draw from your results?

d. Are there any other colourings in mixture **U** which do **not** match **A–D**?

e. How do you know that a chemical is pure from chromatography results? Are there any other ways that chemists use to ensure that a substance is a pure substance?

Water purification

Analysing and purifying a sample of water and making it safe to drink.

In this practical you will:

- Analyse a sample of water
- purify a water sample by distillation.

Activity 1: Analysing a sample of water

Apparatus

- 10 cm³ of each of the water samples to be tested
- universal indicator paper or solution.

Method

1. Use the universal indicator paper to measure the pH of the water sample.
2. Accurately weigh an empty evaporating basin and record to two decimal places.
3. Pour 10 cm³ of water sample 1 into the evaporating basin.
4. Heat the evaporating basin on a tripod and gauze using a Bunsen burner until the solids start to form and the majority of water has evaporated.
5. Weigh the cooled evaporating basin again and calculate the mass of the solids that were dissolved in the water.
6. Record your results in a table:

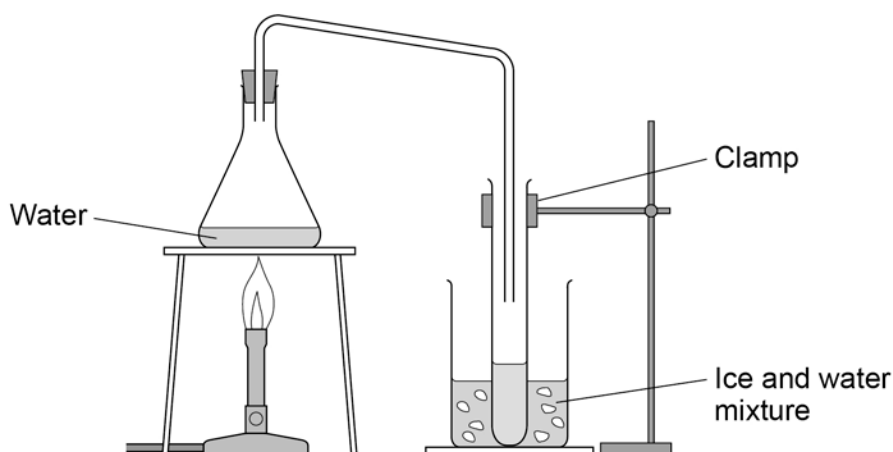
	pH	Mass of solids dissolved in 10 cm ³
Water sample 1		
Water sample 2		
Water sample 3		

Activity 2: Purifying a sample of water by distillation

Apparatus

- 10 cm³ of water sample 1
- a Bunsen burner
- a tripod
- gauze
- a heatproof mat
- clamp and clamp stand
- conical flask with delivery tube and bung
- a boiling tube
- ice bath
- cobalt chloride paper.

1. Place the water sample in the conical flask. Set up the apparatus for distillation as shown in the diagram.



2. Heat the water using the Bunsen burner until it boils. Then reduce the heat so that the water boils gently.
3. The distilled water will collect in the cooled test tube. Collect about 1 cm depth of water in this way, then stop heating.
4. Analyse the water you have distilled with cobalt chloride paper.

Task

Use the following key words to write a paragraph to explain how you have collected a sample of pure water

- evaporation
- condensation
- steam
- gas
- liquid
- boiling
- temperature
- cool surface.

What is the difference between **pure** water and **potable** water?

Student worksheets: Physics

Specific heat capacity

Investigating the specific heat capacity of different metals.

In this practical you will:

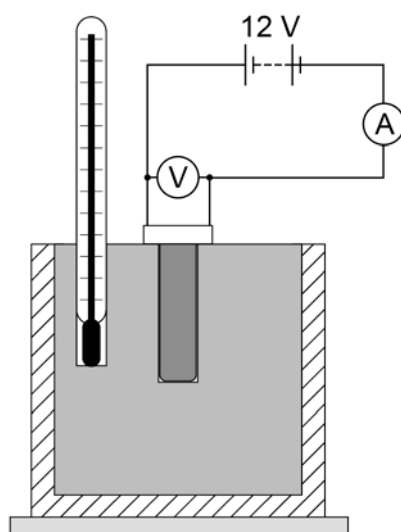
- Heat up blocks of different metals using an electric heater.
- Measure the mass and temperature of the block.
- Calculate the work done by the heater.
- Plot a graph of temperature change against work done and use the gradient to calculate the specific heat capacity of the metal.

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.

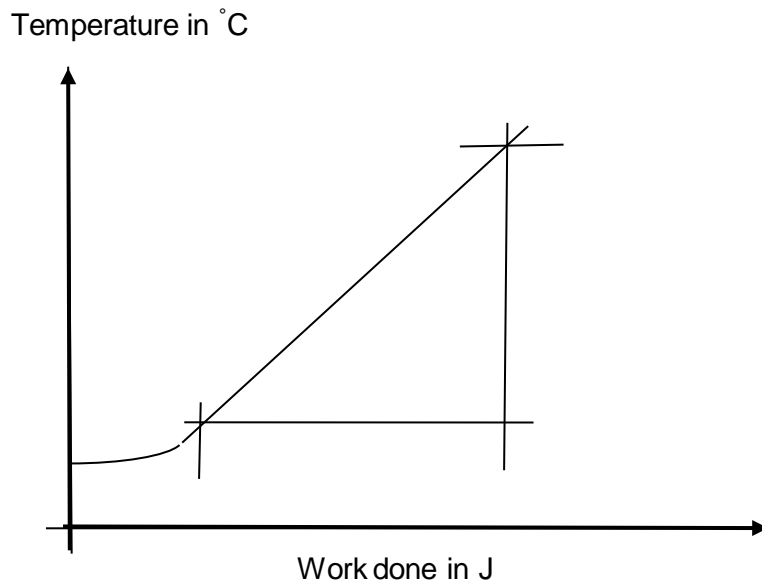
Time in seconds	Temperature in °C	Work done in J (time x power of the heater)
0		0
60		
120		
180		
240		
300		
360		
420		
480		
540		
600		

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

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.

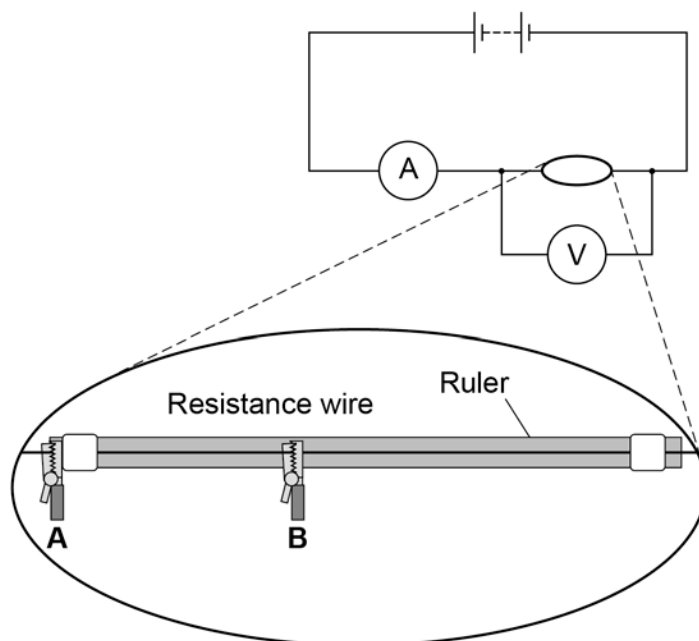
Activity 1: How does the length of the wire affect the resistance at a constant temperature?

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?

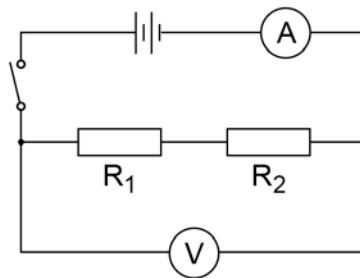
Activity 2: How does the arrangement of resistors in series and in parallel affect resistance?

Apparatus

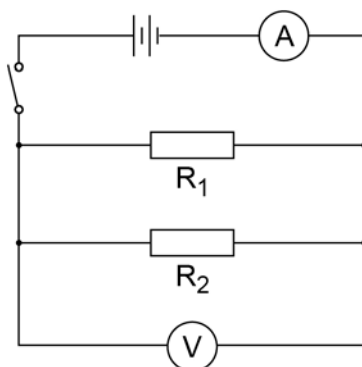
- a battery or suitable power supply
- a switch
- ammeter
- voltmeter
- crocodile clips
- two $10\ \Omega$ resistors
- connecting leads.

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.

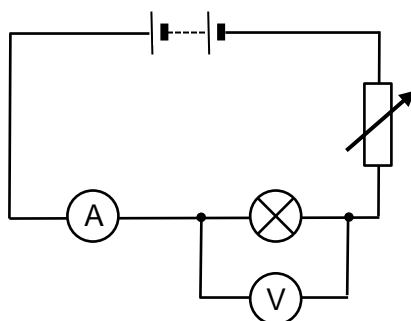
Activity 1: The characteristic of a filament lamp

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.**

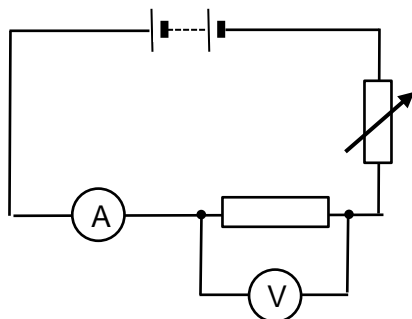
Activity 2: The characteristic of a resistor

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.**

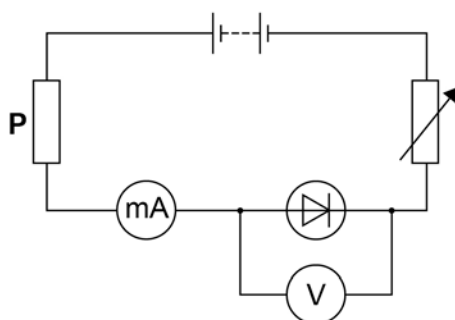
Activity 3: The characteristic of a diode

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 objects in these units.

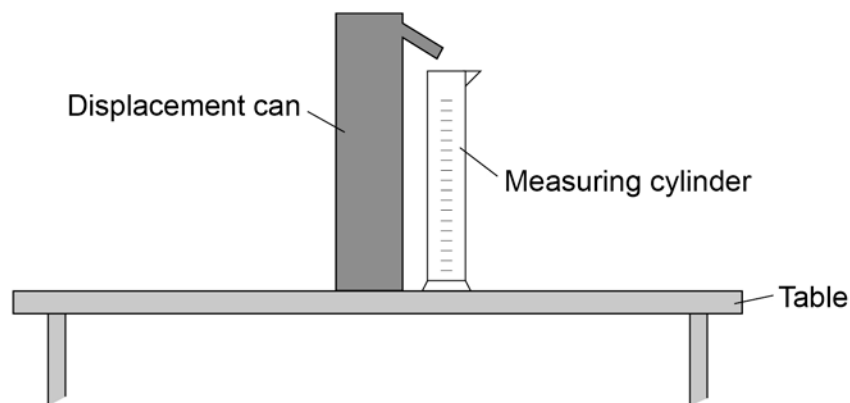
Activity 2: Determining the density of an irregularly shaped object

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.

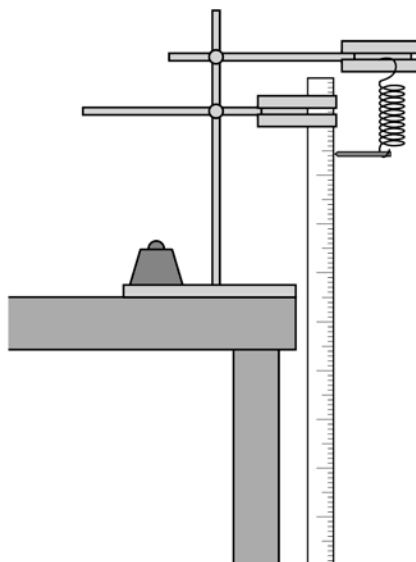
In this practical you will:

- 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 elastically 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.

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

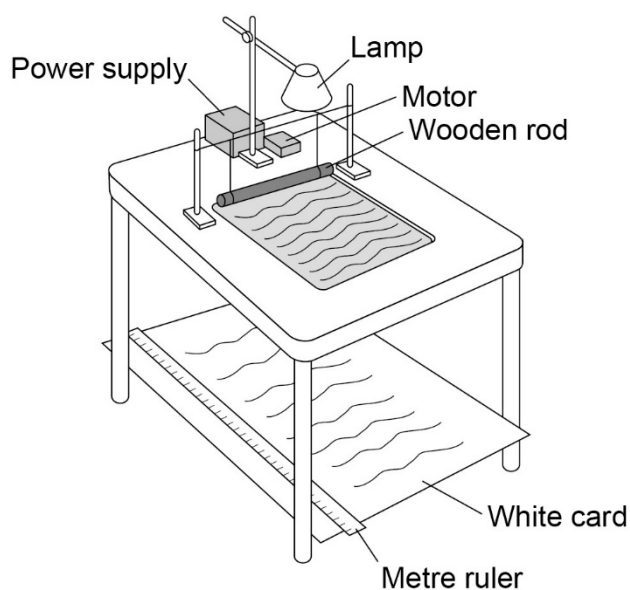
Apparatus

- 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

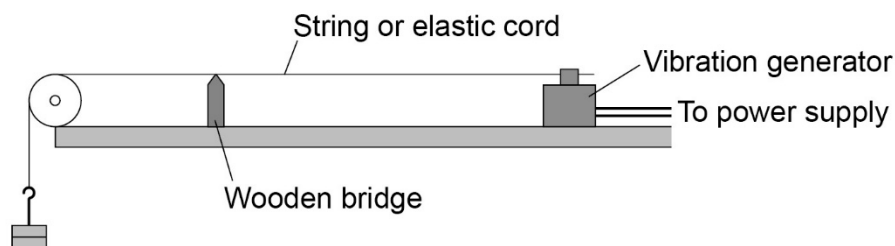
Activity 2: Observing waves in a solid

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?

Radiation and absorption

Investigating the amount of infrared radiation radiated from different surfaces.

In this practical you will:

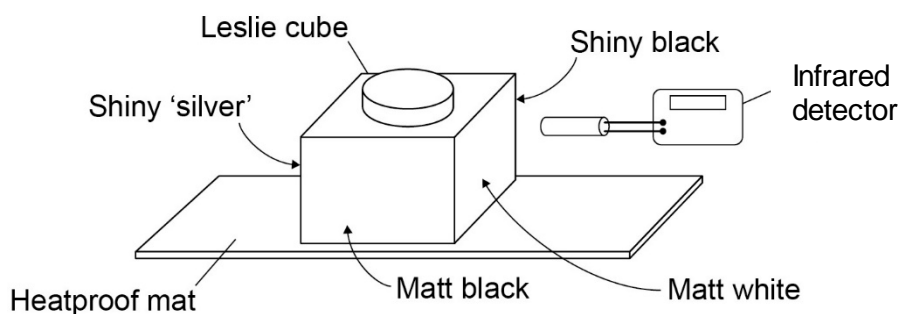
use a Leslie cube and infrared detector to compare the amount of infrared radiated from different surfaces: shiny black, matt black, shiny silver and matt white.

Apparatus

- a Leslie cube
- a kettle
- an infrared detector
- a heatproof 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/8464 and aqa.org.uk/8465

You can talk directly to the science subject team

E: gcsescience@aqa.org.uk

T: 01483 477 756