Answers to Cambridge IGCSE® Physics Laboratory Practical Book

Experimental skills and abilities

Skills for scientific enquiry

1 **(a)** measuring cylinder
(b) digital balance
(c) metre rule
(d) micrometer screw gauge
(e) liquid in glass thermometer
(f) stopwatch
(g) voltmeter
(h) digital timer
(i) protractor
(j) ammeter
(k) ruler

2 **(a)** Measure the thickness of at least 20 pages with a micrometer screw gauge and divide the value by 20 to obtain the average thickness of one page.
(b) Time at least 10 oscillations with a stopwatch and divide the result by 10 to obtain the average time for one oscillation.
(c) Weigh at least 20 pins on a balance and divide the result by 20 to obtain the average mass of one pin.

3

Device	Accuracy
metre rule	1 mm
vernier scale	0.1 mm
micrometer screw gauge	0.01 mm
stopwatch	0.5 s
digital timer	1 ms
digital balance	typically 1 g or 0.1 g
liquid in glass thermometer	1 °C
100 ml measuring cylinder	1 ml or 1 cm^3

4 **(a)** 9.75 **(b)** 9.8 **(c)** 1×10^1

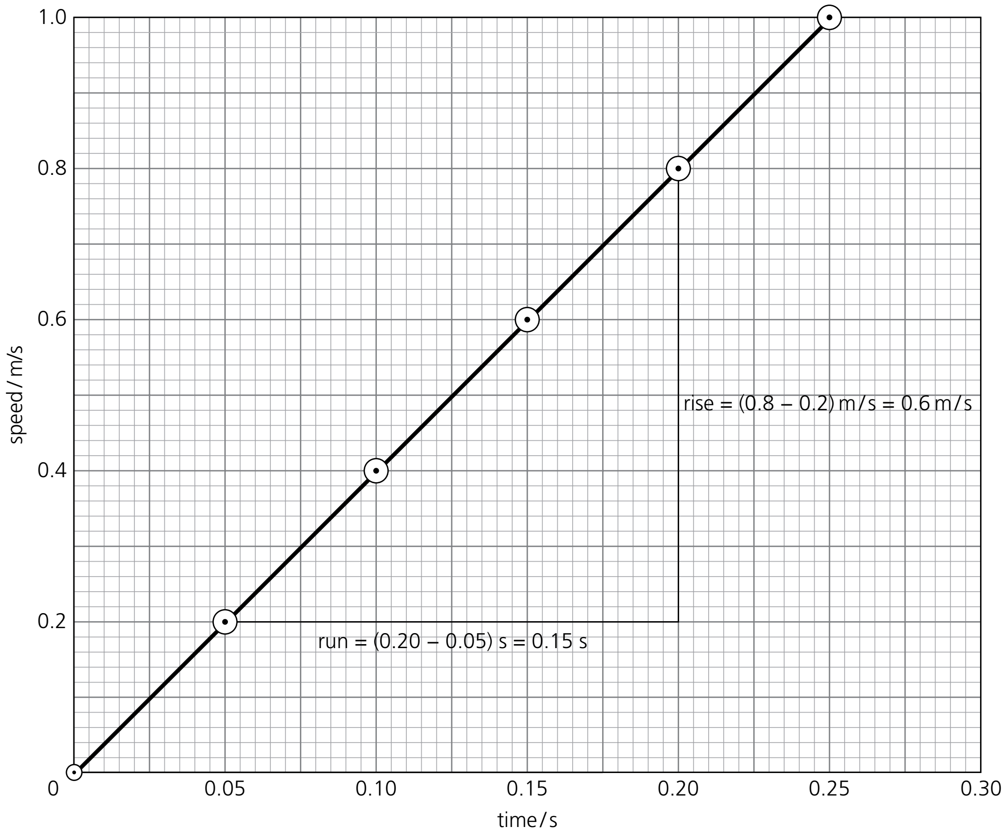
5 **(a)** $P = IV = 250 \times 10^{-3} \times 8.0 = 2.0$ J/s
(b) $I = \frac{P}{V} = \frac{60}{12} = 5.0$ A

6 true current = (26 – 2) mA = 24 mA

7 **(a)** **(i)** speed, time **(ii)** mass, acceleration
(iii)

Manipulated (independent) variable	Fixed variable	Responding (dependent) variable
time	mass, acceleration	speed

(b)



(c) gradient = $\frac{0.6\,\text{m/s}}{0.15\,\text{s}} = 4.0\,\text{m/s}^2$

(d) Speed is proportional to time (duration) of fall.

1 General physics

1.1 Simple pendulum

Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
length	mass	period
mass	length	period

Method

The length of the pendulum was measured from *the point of support* to *the centre of the bob* with *a metre rule.*

Timing ten oscillations, rather than one, improves the degree of accuracy of the measurement because the timing is over a longer period.

For example, if the timing measurement is accurate to 0.5 s and the time measured is 2 s the degree of accuracy is 0.5 parts in 2 or 25 parts in 100. However, if the time measured is 20 s, the degree of accuracy is 0.5 parts in 20 or 2.5 parts in 100.

Conclusions

1 The period of a simple pendulum increases when the length of the pendulum increases.
2 The period of a simple pendulum does not change when the mass of the pendulum changes.

To summarise: the period of a simple pendulum varies with the length and not the mass of the pendulum.

Evaluation

Reliability of results could be improved by:

- timing a greater number of oscillations
- investigating a larger range of pendulum lengths and masses
- determining the length of the pendulum more accurately (by measuring the diameter of the bob with vernier callipers).

Extension

$g = 9.8\,\text{m/s}^2$

1.2 Density

Method

The dimensions of the blocks A and B were measured with: *a ruler to an accuracy of 1 mm.*

The diameter of the wire C was measured: *several times with a micrometer screw gauge to an accuracy of 0.01 mm.*

The diameter of the ball D can be obtained *by setting it between two smooth vertical surfaces (blocks A and B could be used if they are as high as the ball's diameter) and measuring the distance between the surfaces with a ruler.*

The volume of object E was obtained by: *recording the water level in a measuring cylinder before and after it was submerged.*

Mass was measured with a balance of accuracy: *e.g. 1 g.*

Results and calculations

Regularly shaped solids

1 Volume of a block = length × width × height.
2 Volume of a wire = length × π × (diameter)^2/4
= length × π × (radius)^2

Tables should be completed with correct units, measurements and calculations; density values should be given to two significant figures.

Table 1

Object	Length/cm	Width/cm	Height/cm	Volume/cm^3	Mass/g	Density / g/cm^3
A						
B						

Table 2

Object	Length/ cm	First measurement of diameter/mm	Second measurement of diameter/mm	Average diameter/cm	Volume/ cm^3	Mass/ g	Density / g/cm^3
C							
D							

Liquid

Table 3

Mass of empty cylinder/g	Mass of cylinder + water/g	Mass of water/g	Volume of water/ cm^3	Density of water / g/cm^3

Irregularly shaped solid

Table 4

Mass of E/g	Volume of water/cm^3	Volume of water + E/cm^3	Volume of E/cm^3	Density of E/ g/cm^3

Conclusions

Materials A, B, C, D and E should be identified correctly.

Typical density values are:

wood (teak) = 0.8 g/cm^3

aluminium = 2.7 g/cm^3

polythene = 0.90 g/cm^3

rubber = 0.9–1.2 g/cm^3

iron = 7.9 g/cm^3

gold = 19.3 g/cm^3

silver = 10.5 g/cm^3

Evaluation

Reliability of results could be improved by:
- using a more accurate measuring cylinder
- making dimension and mass measurements on a larger sample of each material.

Extension

Measure the density of the teaspoon using the method for an irregularly shaped solid and compare the result with expected values for silver and steel.

1.3 Motion

Method

State that the tickertape timer produces a dot or 'tick' on a tape every $\frac{1}{50}$ s when the tape is pulled through the timer, allowing measurement of both distance and time to be recorded simultaneously. Mention should be made of any difficulties encountered in the operation of the timer and any precautions taken to achieve good results.

Results and calculations

Distance/time

1 Vertical axis should be labelled as distance/cm, horizontal axis as time/s.
Each tape corresponds to a time of 0.2 s if the time of a tick is $\frac{1}{50}$ s.
Larger dot spacing indicates faster motion; fast and slow regions should be labelled.

2 The speed is fastest when the dots are furthest apart.

3 When the dots are equally spaced the speed is constant.
If N dots occupy a length L of the tape, then:
speed = distance/time

$$= \frac{L}{(N \times \frac{1}{50})} \text{ cm/s}$$

when L is in cm.

Velocity/time

1 Vertical axis should be labelled as distance/cm, horizontal axis as time/s.

2 v_1 and v_2 should be calculated as in *Distance/time*, part **3**, above.

3 acceleration $= \frac{(v_2 - v_1)}{t}$

$$= \frac{(v_2 - v_1)}{\frac{N}{50}}$$

$$= 5(v_2 - v_1) \text{ if } N = 10$$

4 The acceleration is constant if the size of the steps between tapes is constant.

Conclusions

Values obtained for velocity and acceleration in the experiment should be stated.

Evaluation

The experiment could be improved by timing over longer distances and times.

Extension

1 zero

2 air resistance and the force due to the Earth's gravitational field

1.4 Hooke's law

Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
force	spring constant	extension

Method

For example: the apparatus was set up as shown in the diagram with the metre rule held vertically by taping it to the bench. The position of the bottom of the spring on the scale, l_s, was recorded without the mass holder. The length of the mass holder, l_o, was measured and it was then suspended from the spring; the position the bottom of the mass holder reached on the scale was recorded, l. The extension produced by the mass holder was calculated by subtracting ($l_o + l_s$) from l. A 100 g mass was then loaded onto the holder, the new scale reading recorded and the extension again calculated. This procedure was repeated for increasing loads up to 600 g.

Results and calculations

1 Measurements should be recorded and force and extensions correctly calculated.

2

Table 2

Mass/g	Stretching force/N	Scale reading/mm	Extension/mm
100	1		
200	2		
300	3		
400	4		
500	5		
600	6		

3 On the graph, axes should be labelled with Extension/mm vertically and Stretching force/N horizontally. An easy-to-read/plot scale should have been chosen to use as much of graph paper as possible and the six data points should be correctly plotted. The best straight line should be drawn through the points. The line should go through the origin; it will be offset from the origin if a systematic error exists in the measurements.

Summary of results

The gradient of the line extension/stretching force should be calculated from as long a length of line as possible.

Conclusions

If the graph is a straight line through the origin this indicates that the extension is proportional to the stretching force, as predicted by Hooke's law.

Evaluation

Experiment could be improved by increasing loads at 50 g intervals and repeating the readings as the spring was unloaded.

A fixed vertical scale and a pointer on the base of the holder could also increase accuracy.

Extension

The spring constant, *k*, is equal to the inverse of the gradient of the graph and it should be stated in units of N/m or N/mm to no more than two significant figures.

Note: 200 N/m = 0.2 N/mm

1.5 Balancing a beam

Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
distance	mass	moment

Method

For example: we first tested that the ruler swung freely about the pivot and then balanced it by adding a small piece of blu-tack close to the fulcrum. A mass was then hung from the ruler on the left-hand side of the pivot; a small piece of blu-tack was used to hold it in place. A second mass was then hung from the right-hand side of the pivot and moved along the beam until it was balanced. The moment of the force exerted by each mass was found by multiplying the weight of the mass, *F*, by its distance along the ruler from the pivot, *d*. The procedure was repeated for different mass positions and sizes. Although it was easier to balance the beam with the weights near to the fulcrum, the degree of accuracy of the measurements for *d*, and hence the moments, were less, because the distance measured was smaller.

Results and calculations

Table 2 Theoretical values

m_1/g	F_1/N	Position on ruler/cm	d_1/cm	$F_1 \times d_1$/ N cm	m_2/g	F_2/N	Position on ruler/cm	d_2/cm	$F_2 \times d_2$/ N cm	Net moment/ N cm
30	0.30	5.0	20.0	6.0	40	0.40	40.0	15.0	6.0	0
30	0.30	10.0	15.0	4.5	40	0.40	36.2	11.2	4.5	0
30	0.30	15.0	10.0	3.0	40	0.40	32.5	7.5	3.0	0
50	0.50	5.0	20.0	10	60	0.60	41.7	16.7	10	0
50	0.50	10.0	15.0	7.5	60	0.60	37.5	12.5	7.5	0
50	0.50	15.0	10.0	5.0	60	0.60	33.3	8.3	5.0	0

Forces, distances and moments should be correctly calculated. In each case the sum of the anticlockwise moments should have a similar value to the sum of the clockwise moments, so that the net moment is close to zero.

Table 3

	Mass/g	*F*/N	Position on ruler/cm	*d*/cm	$F \times d$/N cm	Anticlockwise moment/N cm	Clockwise moment/N cm
M_1	30	0.30					
M_2	40	0.40					
M_3	50	0.50					

Conclusions

1. Within experimental accuracy: sum of anticlockwise moments = sum of clockwise moments
2. There is no net moment when the beam is balanced.

Evaluation

Higher accuracy and sensitivity could be achieved in the experiment by:

- using a longer beam
- taking the mass and turning effect of the blu-tack into account.

Extension

Find distances (d_1 and d_2) from the fulcrum at which a known mass (m_1) and the unknown mass (m_2) can be hung to balance the beam. Equate the anticlockwise and clockwise moments:

$$m_1gd_1 = m_2gd_2$$

Solve the equation to find m_2.

1.6 Centre of mass

Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
point of suspension	position of centre of mass	orientation

Method

For example: a cardboard lamina was suspended from a nail held in a retort stand. It was first checked that the lamina could swing freely about the nail. A plumb line was then suspended from the nail and the position of the vertical line marked on the lamina. The lamina was then suspended from two additional points and the position of the plumb line marked in each case. The centre of mass occurred at the point of intersection of the three lines. The procedure was repeated for variously shaped laminae.

Results and calculations

In each case it should be found that the vertical lines drawn through three different points of suspension of a lamina intersect at a point – the centre of mass of the lamina.

Conclusions

When a body is *suspended* from a point, its centre *of mass* lies *vertically* below the point of suspension. By drawing in the vertical lines on a lamina below *two* different points of *suspension* the place where the two lines *intersect* marks the position of the *centre* of mass. The vertical line drawn from any other *point* of suspension passes through the centre of mass.

Evaluation

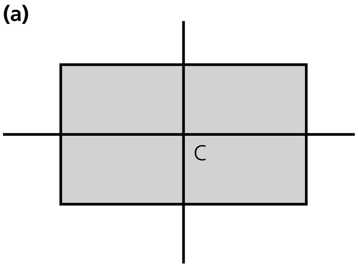
The experiment could be improved by:

- reducing friction at the pivot
- testing a larger variety of lamina shapes
- increasing the number of points of suspension.

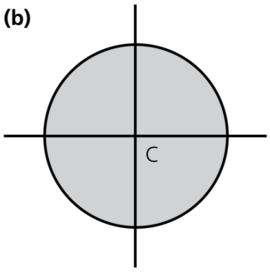
Extension

1

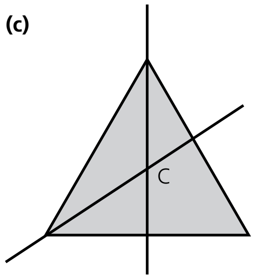
(a)



(b)



(c)



2 A rectangle will be more stable if it rests on its long side. This is because it can be tilted through a larger angle before the vertical line from its centre of gravity lies outside the base. Its centre of gravity is lower and its base is larger than when it rests on its short side.

1.7 Pressure

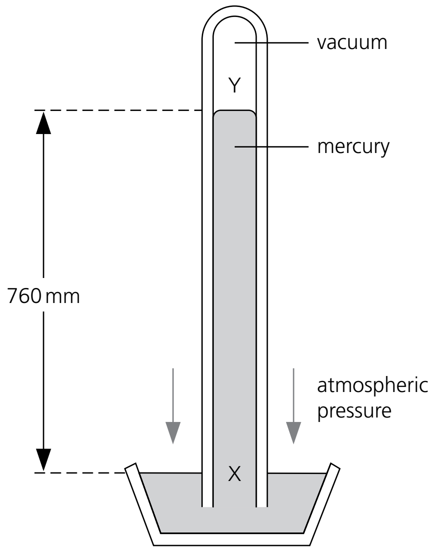
Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
pressure	density	height

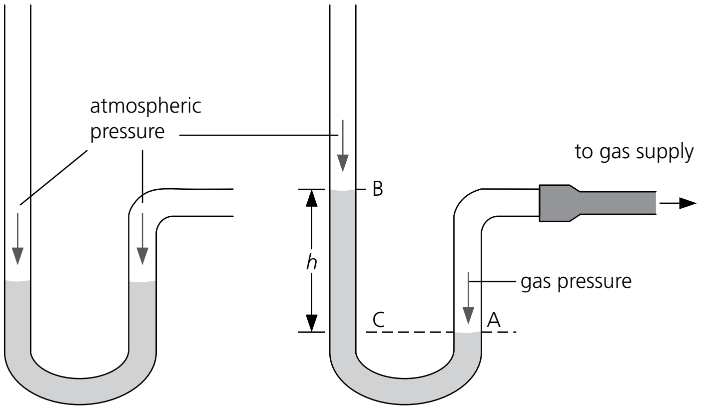
Method

Atmospheric pressure



Atmospheric pressure is given by the height of the mercury column *XY*.

Manometer



(a) **(b)**

Results and calculations

Atmospheric pressure

For example, atmospheric pressure = 760 mmHg = 760×10^{-3} mHg

In Pa, atmospheric pressure = $h \times \rho \times g$

$= (760 \times 10^{-3})\,\text{m} \times 13\,600\,\text{kg/m}^3 \times 10\,\text{N/kg}$

$= 1.03 \times 10^5\,\text{N/m}^2$

$= 1.03 \times 10^5\,\text{Pa}$

Manometer

Density of water = $1000\,\text{kg/m}^3$.

In Table 2, gas pressure = atmospheric pressure + $h\rho g$, where ρ is the density of the liquid in the manometer.

Conclusions

A value for the atmospheric pressure in Pa should be stated.

The range of gas pressures measured with the manometer should be given in Pa.

Evaluation

Reliability of results could be improved by:
- using a more consistent gas pressure in the manometer
- using more accurate values for g and the atmospheric pressure in the laboratory in the calculation

Extension

1 Pressure = $h\rho g$. Since the pressure remains constant and so do ρ and g, there is no change in the vertical height of the column if the tube is narrower or wider.

2 If the column is tilted, the *vertical* height of the column will be unchanged, but the mercury will reach further along the tube, increasing the scale reading and the apparent air pressure.

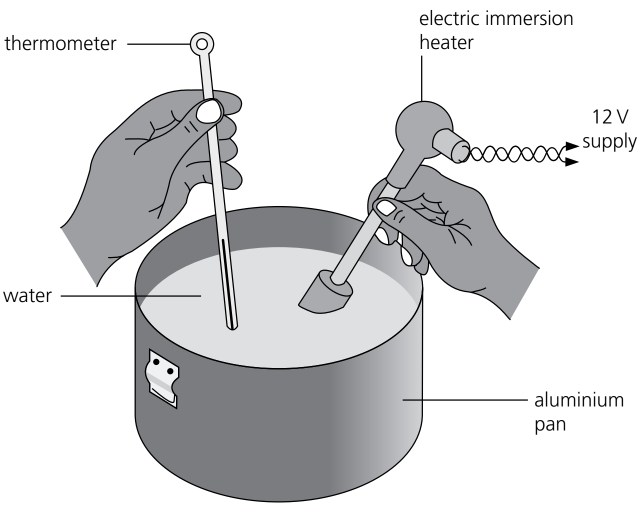
2 Thermal physics

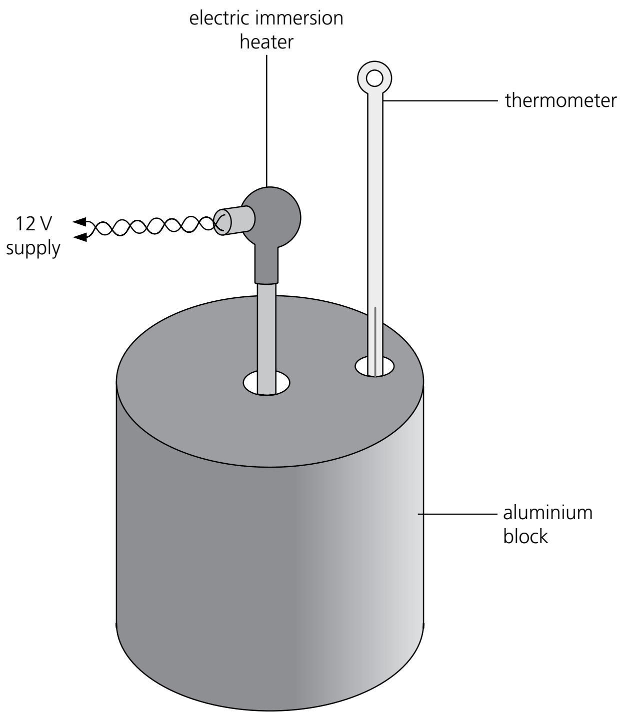
2.1 Specific heat capacity

Method

The diagrams should be labelled.

Mention should be made that the thermometer was used to take readings of the initial temperature and the highest temperature reached after the heater was switched off; also that the time for which the heater was switched on was recorded.





Mention the need to stir the water to ensure it all reaches the same temperature. Precautions could be taken to shield apparatus from draughts and to use insulation to reduce loss of heat; it is difficult to reduce heat loss from the liquid surface.

Results and calculations

Liquid

1 Readings should be recorded for power of heater, *P*, in W (J/s), and for mass of water, *m*, in kg.

Table 1

Initial temperature, T_1/°C	**Highest temperature, T_2/°C**	**Change in temperature, ΔT/°C**	**Heating time, *t*/s**	**Heat supplied, $Q = Pt$ / J**
			300	

2 A value for the specific heat capacity of water, *c*, should be given in J/(kg °C), calculated using the formula:

$$c = \frac{Q}{m \times \Delta T}$$

Solid

1 Readings should be recorded for power of heater, *P*, in W (J/s), and for mass of metal cylinder, *M*, in kg.

Table 12.2

Initial temperature, T_1/°C	Highest temperature, T_2/°C	Change in temperature, ΔT/°C	Heating time, *t*/s	Heat supplied, $Q = Pt$ / J
			300	

2 A value for the specific heat capacity of the metal cyclinder, *c*, should be given in J/(kg °C), calculated using the formula:

$$c = \frac{Q}{M \times \Delta T}$$

Conclusions

Higher values than those given below will be obtained due to heat losses in the experiment; values should be given two or three significant figures.

- specific heat capacity of water = 4200 J/(kg °C)
- specific heat capacity of aluminium = 910 J/(kg °C)
- specific heat capacity of copper = 385 J/(kg °C)
- specific heat capacity of steel = 450 J/(kg °C)

Evaluation

Results are affected by heat lost to the surroundings.

Experimental results could be improved by insulating the water container and the cylinder more effectively.

Extension

thermal capacity = mass × specific heat capacity

1 thermal capacity of water = 1 kg × 4200 J/kg °C
= 4200 J/°C

2 A value for the thermal capacity of the metal cylinder should be given in J/°C, calculated using the formula:

thermal capacity of metal = mass of metal × c_{metal}

2.2 Specific latent heat

Method

1 **(a)** To ensure heat is not used to bring the ice up to a temperature of 0 °C.
(b) To measure amount of ice being melted due to heat coming from the surroundings; the melted ice is collected for the same time as the heater will be on.

2 **(a)** Bubbles appear throughout the water.
(b) 100 °C

Results and calculations

Specific latent heat of fusion of ice

1 Values should be recorded for:

(a) power of immersion heater, P, in W (J/s)

(b) heat supplied by immersion heater in 4 minutes, Q, in J – calculated using:

$Q = P \times$ time in seconds

(c) mass of ice melted by heat from surroundings, m_1, in g

(d) mass of ice melted by heater and surroundings, m_2, in g

(e) mass of ice melted by heater, m, in g – calculated using:

$m = (m_2 - m_1)$

2 A value should be recorded for the specific latent heat of fusion of ice, l_f, in J/kg – calculated using:

$$l_f = \frac{Q}{m}$$

Specific latent heat of vaporisation of steam

1 Values should be recorded for:

(a) power of immersion heater, P, in W (J/s)

(b) heat supplied by immersion heater in 5 minutes, Q, in J – calculated using:

$Q = P \times$ time in seconds

(c) mass of (mat + beaker + water), m_3, in g

(d) mass of (mat + beaker + water after boiling for 5 minutes), m_4, in g

(e) mass of water changed to steam , m, in g – calculated using:

$m = (m_3 - m_4)$

2 A value should be recorded for the specific latent heat of vaporisation of steam, l_v in J/kg – calculated using:

$$l_v = \frac{Q}{m}$$

Conclusions

- specific latent heat of fusion of ice = 3.4×10^5 J/kg
- specific latent heat of vaporisation of steam = 2.3×10^6 J/kg

(answers to two significant figures)

Results will differ from the given values due to unaccounted for heat gains/losses from/to the surroundings.

Evaluation

Experimental results could be improved by insulating further the funnel and the beaker.

Extension

The potential energy of the molecules increases but their kinetic energy is unchanged (the temperature remains constant during melting).

2.3 Conduction and radiation

Method

Conduction

Heat is transferred along the rods by conduction.

Radiation

1 To ensure both thermometers start cooling at the same temperature above the surroundings; bodies cool faster when their temperature difference with their surroundings is greater.
2 To ensure the cooling environment for each thermometer is the same; bodies cool faster in a draught.

Results and calculations

Conduction

Table 1 should be completed and units for the time measurement stated.

Radiation

1 The room temperature should be noted.
The temperature of each thermometer should be recorded in Table 2 every 30 seconds during cooling; temperatures should be read to 1 °C.
2 A cooling curve should be plotted for each thermometer.
On the graph, axes should be labelled with temperature/°C vertically and time/s (or minutes) horizontally. An easy-to-read/plot scale should have been chosen to use as much of graph paper as possible and the data points should be clear and correctly plotted; the temperature of each thermometer should decrease with time.

Conclusions

1 **(a)** Wax takes the shortest time to melt on the best conductor of heat.
(b) Conductors should be listed in order of increasing times for the melting of the wax.
2 **(a)** The thermometer with the dull black bulb cools down faster than the one with the shiny bulb.
(b) A dull black surface emits radiation *better/faster than* a shiny surface.

Evaluation

1 To improve the conduction experiment, ensure the amount of wax on each rod is the same and the same amount of heat is applied to each rod.
2 The radiation experiment could be improved by ensuring that the surrounding conditions for each thermometer are the same (stir the water to ensure it has the same temperature throughout; ensure that there are no draughts, the room temperature is constant and the thermometers are kept away from direct sunlight). The temperature of each thermometer should be the same at the time they both start to cool.

Extension

Radiators should be painted black because black bodies are better emitters of radiation than white ones.

3 Properties of waves

3.1 Law of reflection

Method

1 It is important to align the reflecting surface of the mirror exactly along line *AOB* to: *ensure that the normal ON is at 90° to the reflecting surface of the mirror / ensure that the light beam strikes the mirror at the marked angle of incidence.*
2 The accuracy of measurements taken with a protractor is: *1°*.

Results and calculations

A sharp pencil should be used to draw in the lines in Figure 2 at the angles given in the table.

Table 1

Angle of incidence, i/°	Angle of reflection, r/°
15	15
30	30
45	45
60	60
75	75

The perpendicular distance of P_O from mirror should equal the perpendicular distance of P_I from the mirror.

Conclusions

1 My results *are in agreement with* the law of reflection, within experimental *error.*

2 The image in a plane mirror is formed at a position that is: *the same distance behind the mirror as the object is in front; the line joining the object and the image is perpendicular to the mirror.*

3 The image formed in a plane mirror has the following characteristics: *it is upright, the same size as the object, laterally inverted and virtual.*

Evaluation

Results could be improved by any of the following:

- using a larger and more accurate protractor
- using a narrower beam of light
- making sure the mirror and pins are vertical; align the bases of the pin and its image
- using a thinner mirror (to reduce the effects of refraction in the glass).

Extension

1 An image is laterally inverted when right and left are interchanged.

2 Check by looking at yourself in a plane mirror; close your right eye and notice that it is the left eye of your image that closes.

3.2 Refraction of light

Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
angle of incidence	refractive index	angle of refraction

Method

1 The angle in degrees between the normal and the surface (*AOB)* of the glass block is: *90°.*

2 The paths of the refracted and emergent rays were determined by marking: *the position of the refracted ray where it emerges from the glass block and a few points along the path of the emergent beam.*

Results and calculations

1 A sharp pencil should be used to draw the ray paths in Figure 1. A normal should be drawn at the point the ray exits the glass block. The same value for *n* should be obtained for 30° and 60° angles of incidence in Table 2. When the angle of incidence is 0°, *n* cannot be determined.

2 A sharp pencil should be used to draw the ray paths in Figure 2. A normal should be drawn at the point the ray exits the glass block. The same value for *n* should be obtained for 30° and 60° angles of incidence in Table 3; note that at an angle of incidence of 60°, total internal reflection may occur within the glass block.

3 An average value of refractive index is obtained by adding all the values of *n* obtained and dividing by the number of readings; the value should be given to two significant figures.

Conclusions

1 A typical value for the refractive index of glass is $n = 1.5$.

2 **(a)** A light ray is refracted *towards* the normal when it enters the glass block and *away from* the normal when it leaves the block.

(b) A ray incident normally on a glass block is not refracted but passes *straight through* the block.

(c) When a light ray strikes the glass/air boundary at a large angle, total internal reflection of the light occurs. If a light ray does not undergo *total internal reflection* in the block, the ray emerges *parallel* to the incident ray, since $i = \theta$ within the accuracy of the experiment.

Evaluation

Reliability of results could be improved by either of the following:

- using a larger and more accurate protractor
- using a narrower beam of light.

Extension

1 When light is incident on a boundary with a less dense medium, total internal reflection of the light occurs for angles of incidence greater than a critical angle, *c*. (If the less dense medium is air, the critical angle is given by: $\sin c = \frac{1}{n}$.)

2 For glass of refractive index, $n = 1.5$, $\sin c = \frac{1}{1.5} = 0.6667$ so $c = 41.8°$.

3.3 Lenses

Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
object distance	focal length of lens	image distance

Method

1 We found the height of the image by: *marking the top and bottom of the image on the card and then measuring the distance with a ruler / other appropriate method.*

2 We determined if the image was inverted or not by: *holding the point of a pen at the top of the object and locating the tip of the pen in the image / sticking a marker at the top of the object and locating it in the image / other appropriate method.*

Results and calculations

Focal length of lens

For a distant object, the image distance from the lens equals the focal length of the lens.

Magnification

The height of the object should be stated.

Table 2

Torch position	Object distance, *u*/cm	Image distance, *v*/cm	Height of image/cm	Linear magnification	Upright or inverted
beyond 2*F*				<1	inverted
at 2*F*				1	inverted
between 2*F* and *F*				>1	inverted
between *F* and lens				>1	upright

Conclusions

1 The focal length of the lens should be stated to three significant figures.

2 When the object is beyond 2*F* the image lies on the opposite side of the lens to the object, between *F* and 2*F*; it is diminished and inverted.

As the object is moved towards the lens, the diminished and inverted image moves away from the lens and becomes larger.

At 2*F* the object and inverted image are the same size.

When the object lies between 2*F* and *F*, the magnification increases further and the image is magnified and inverted.

For an object between *F* and the lens, the image is on the same side of the lens as the object, magnified and upright.

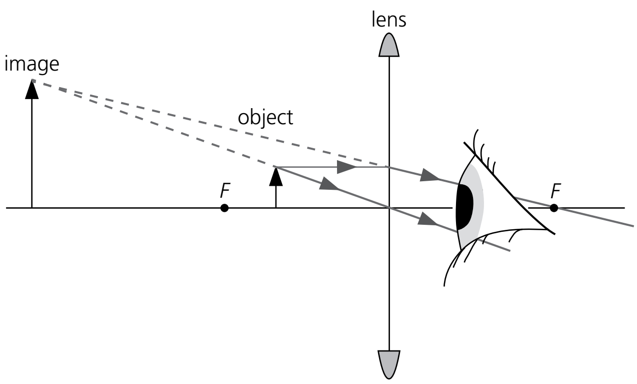
Evaluation

The experiment could be improved by using more rigid holders for the torch, lens and screen; making sure they are all set perpendicular to the ruler.

Extension

1 A real image can be formed on a screen but a virtual image cannot.

2



3.4 Speed of sound

Variables

Table 1

Manipulated (independent)	Fixed	Responding (dependent)
distance	speed	time

Method

The distance *d* was measured with *a metre rule* and had an accuracy of about *5 mm.*

Distance, *d*, was difficult to determine exactly because: *the precise position in the microphone at which the electronic signal was triggered was not known / we measured from centre to centre of the microphones / other appropriate response.*

To ensure sounds from neighbouring experiments did not trigger our timer we: *arranged to do our timings at different moments / other appropriate response.*

Results and calculations

Five sets of measurements for different microphone separations should be taken.

1 On the graph, axes should be labelled with *d*/cm vertically and *t*/ms horizontally, an easy-to-read/plot scale should be chosen to use as much of graph paper as possible and the data points should be correctly plotted.
The best straight line should be drawn through the points with a sharp pencil. The line may be displaced from going through the origin if there is a systematic error in determining *d.*

2 The gradient of the line *d/t* should be calculated from as long a length of line as possible, using the triangle method; it should be clear how the value was obtained.

(a) gradient of graph = 33 cm/ms (given to two significant figures)

(b) speed of sound in air $= \frac{d}{t}$
= gradient of graph
= 33 cm/ms
= 330 m/s

Conclusions

Speed of sound in air = 330 m/s at 0 °C; the speed varies with air temperature.

Differences from this value will result from the room temperature being above 0 °C and the experimental accuracy obtainable for the time and distance measurements.

Evaluation

The experiment could be improved by taking measurements using a longer distance between the two microphones; and by using a more sensitive timer.

Extension

Speed of sound in iron $= \frac{d}{t}$

$$= \frac{0.3\,\text{m}}{(50 \times 10^{-6})\,\text{s}}$$

= 6000 m/s

4 Electricity and magnetism

4.1 Electric charges and currents

Method

For example:
Ensure that the suspended rod is stationary before bringing up the charged rod or strip. Check the components in the circuit are correctly connected before the power is switched on; make sure the lamps are on when the current readings are being taken.

Results and calculations

Positive and negative charges

Table 1 results should show that like charges repel and unlike charges attract.

Electric currents

1 The current value (I) recorded will depend on the resistance (R) of the lamp and the terminal p.d. (V) of the cell used. Note that $I = \frac{V}{R}$.
2 The currents measured with the ammeter at positions A, B, C and D should all have the same value.
3 The currents measured with the ammeter at positions S and R should have the same value. If the lamps have the same resistance, the current measured with the ammeter at positions P and Q should be the same and be half the value measured when the ammeter is at position S or R.

Conclusions

1 Like charges *repel*, unlike charges *attract.*
2 **(a)** The current is *the same* at all points in a series circuit.
(b) The sum of the currents in the branches of a parallel circuit *equals* the current entering *or leaving* the parallel section.

Evaluation

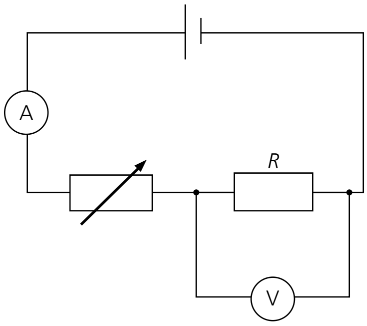
State that the current readings agree with theory within experimental error. More accurate results could be obtained by ensuring that the terminal p.d. of the cell has the same value when each current reading is taken.

Extension

1 Electrostatic induction occurs when a charged rod is brought near an insulated metal object. If the rod is negatively charged, electrons are repelled from the part of the metal closest to the rod, leaving that area with a net positive charge; an attractive force results between the rod and the metal.
(If the rod is positively charged, electrons are attracted to the rod and the area closest to it will have a net negative charge. Again there is an attractive force between the rod and the metal.)
2 Small pieces of aluminium foil would be attracted to a charged rod through electrostatic induction.

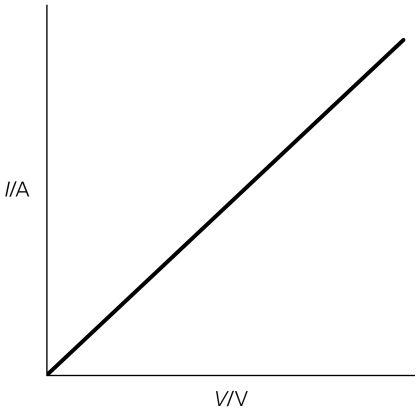
4.2 Resistance

Method



Results and calculations

1 Six measurements for *I* and *V* should be recorded in Table 1.
Values calculated for *R* should be the same within experimental error.



2 On the graph, axes should be labelled with *I*/A vertically and *V*/V horizontally. An easy-to-read/plot scale should have been chosen to use as much of graph paper as possible and the data points should be clear and correctly plotted. The best straight line should be drawn through the points. The line should go through the origin; it will be offset from the origin if a systematic error exists in the measurements.

3 The gradient of the line, *I*/*V*, should be calculated from as long a length of line as possible.
The average resistance of the wire should be calculated from 1/(gradient of graph).
The resistance of 1 m of SWG 34 constantan wire is 11.7 Ω.
The resistance of 1 m of SWG 28 constantan wire is 4.5 Ω.

4 Table 2 should be completed.
For a fixed diameter wire, *R* should increase as the length of wire increases.
For a fixed length of wire, *R* should decrease as the diameter becomes larger.

Conclusions

1 Within experimental accuracy, the resistance of the constantan wire remains constant when *I* is increased; the inverse of the gradient of the graph of *I* versus *V* is equal to the average resistance of the wire.

2 The resistance increases when the length of wire increases.
The resistance decreases when the diameter of the wire increases.

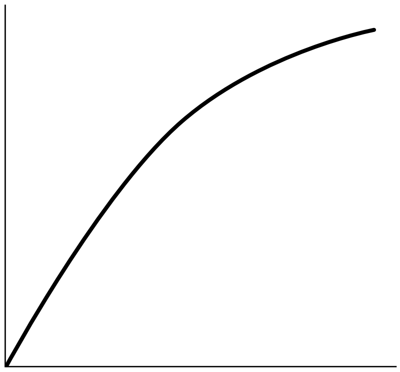
Evaluation

The experiment could be improved by taking more readings and using a more sensitive ammeter and voltmeter.

Extension

1 The filament heats up.

2



4.3 Potential divider

Method

For example: the circuit was set up as in Figure 1 and measurements made of I, V_1 and V_2 for three different thermistor temperatures. The thermistor cooled quickly after it was heated with a match and it was difficult to record all three values at the same instant of time; we each read a meter on a countdown to try to improve the accuracy of these readings.

Results and calculations

1 Values of I, V_1 and V_2 should be recorded in Table 1 for three different thermistor temperatures. $R_2 = \frac{V_2}{I}$ should be correctly calculated and the ratios V_1/V_2 and R_1/R_2 for each temperature should be equal, within the accuracy of the experimental measurements.

2 **(a)** increase
(b) increase
(c) decrease
(d) decrease

3 Calibrate V_1 with temperature.

Conclusions

Within experimental accuracy, the potential divider equation $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ holds.

When the temperature of the thermistor rises its resistance decreases.

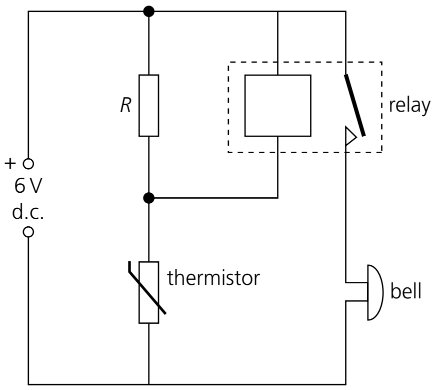
Evaluation

The experiment could be improved by controlling temperature of thermistor and taking more measurements at different temperatures.

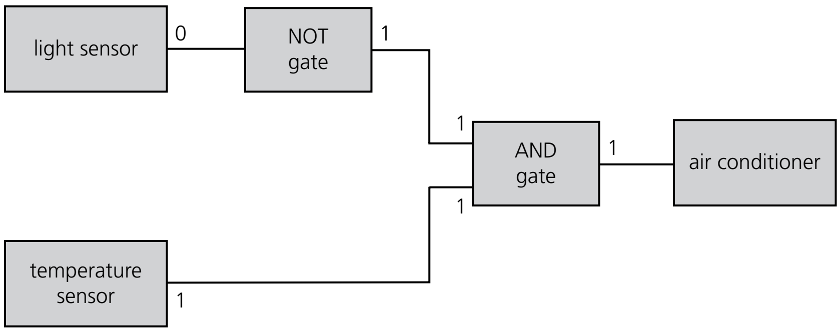
Extension

High temperature alarm

Correct symbols should be used for the components in the circuit.



Control system



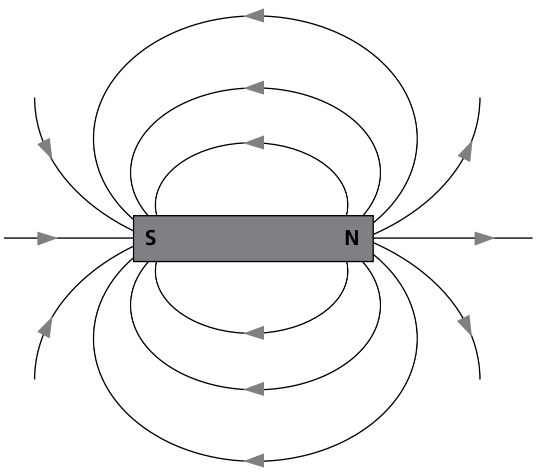
4.4 Magnetism

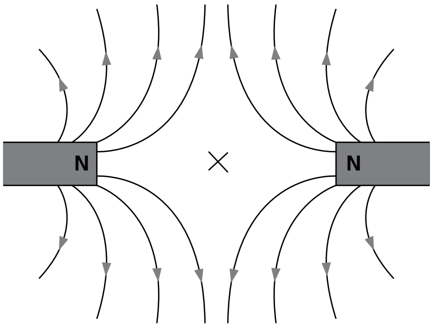
Method

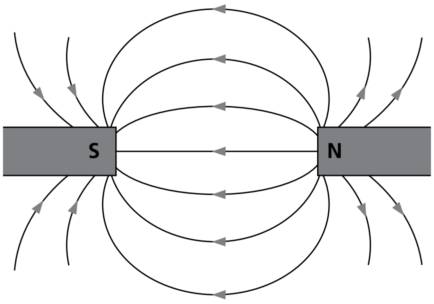
1 Since like poles repel, the north pole of the compass points away from the north pole of the magnet.
2 The north pole of a compass points in the direction of the magnetic field at that point.
3 Iron filings become magnetised in a magnetic field and line up along magnetic field lines.

Results

Field lines should be drawn as shown.







Conclusions

1 The magnetic field around a bar magnet is *strongest* near the ends/poles as is shown by the *higher density* of magnetic field lines in this region.

2 Magnetic field lines are directed from the *north* pole of a magnet to the *south* pole.

Evaluation

The experiments could be improved by using a smaller compass, a sharper pencil, finer iron filings.

Extension

A steel bar can be magnetised by any of the following methods:

- Insert the steel bar in a solenoid and increase the d.c. current through the solenoid.
- Stroke the bar with another magnet.
- Hammer the bar in a magnetic field.

4.5 Electromagnetism

Method

1 Iron is easily magnetised and strengthens the magnetic field that is produced by the electromagnet.

2 The direction of the induced current changes depending on whether the magnet is moved towards or away from the coil.

Results and calculations

Electromagnet

1 Table 1: number of paper clips supported increases as the current through the coil increases.
Table 2: at a current of 1 A, the number of paper clips supported increases as the number of turns increases.

2 The polarity of the top of the coil will depend on which way it is wound. The value obtained should agree with that given by the right hand-grip rule.

Electromagnetic induction

Table 3

Direction of movement of north pole	Speed of movement of magnet	Maximum current, *I*/A	Direction of current	Polarity of coil end facing magnet
towards coil	fast		+	N
towards coil	slow		+	N
away from coil	fast		–	S
away from coil	slow		–	S

Table 4

Direction of movement coil	Speed of movement of coil	Maximum current, *I*/A	Direction of current	Polarity of coil end facing magnet
towards N pole of magnet	fast		+	N
away from N pole of magnet	fast		–	S

Conclusions

1 Strength of the electromagnet increases as the current increases and as the number of turns increases.

2 **(a)** Yes, if a larger current is induced in the coil when the magnet is moved quickly.

(b) Yes, if the current induced in the coil produces a magnetic field that opposes the movement of the magnet.

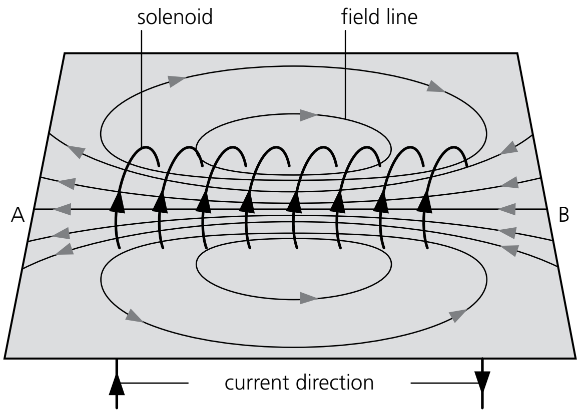
Evaluation

The experiments could be improved by:

- testing coils with a larger number of turns
- using a stronger magnet/more sensitive meter.

Extension

1



2 Current flows left to right.

4.6 Electric motor

Method

A d.c. electric motor is used to raise different masses through 0.5 m. The voltage and current in the motor should be recorded and the power input calculated. The time taken for each mass to be raised should also be recorded to enable the power output and hence the efficiency of the motor to be calculated. Precautions taken could include: the mass tended to sway initially, so we waited until it was rising smoothly before we timed a rise. To ensure the rule was vertical we taped it to a leg of the bench and put paper arrows on the scale to mark the position of the bottom of the mass at which we started and stopped the timer. We noticed that the motor became warm when it was being used.

Results and calculations

Readings for raising four different masses should be recorded in Tables 1 and 2 and the power input, output and efficiency of the motor correctly calculated for each to two significant figures.

Conclusions

The efficiency of the motor is less than 100%.

Efficiency and speed may vary with the size of the load.

Energy is lost as heat in the motor.

Evaluation

The experiment could be improved by:

- reshaping the axle so that the string winds up more smoothly
- using an electronic timer to record *t*
- taking more readings.

Extension

1 The wire moves downwards.

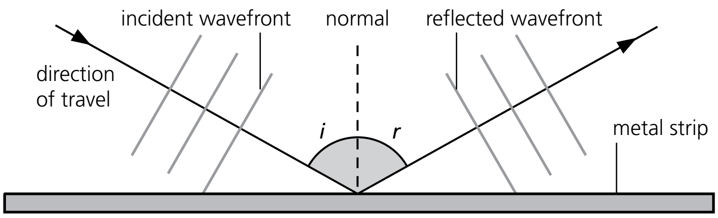
2 The current through the motor; the number of turns on the coil of the motor and the strength of the magnetic field in which the coil turns.

More experiments

Ripple tank experiments

Reflection

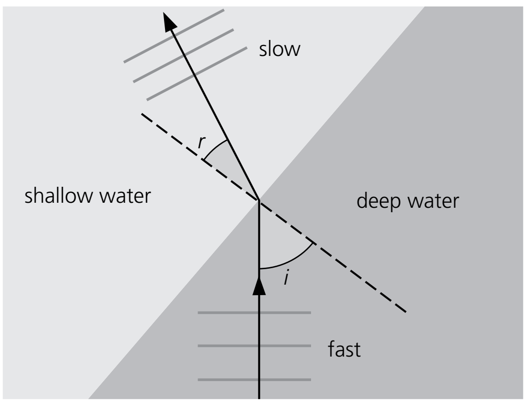
2



3 • Yes, law of reflection is obeyed: $i = r$ within the limits of experimental accuracy.

Refraction

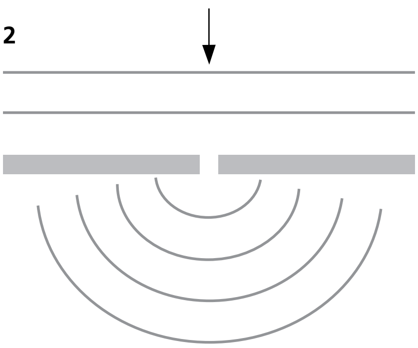
2



3 • Wavelength is shorter in the shallow region as the wave crests are closer together.
• Waves travel faster in deep water than in shallow water.
• The waves bend towards the normal in the shallow water; refraction occurs.

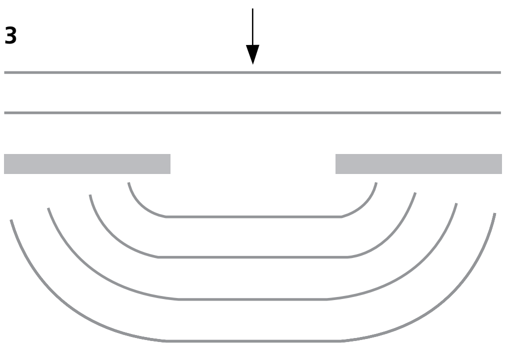
Diffraction

2



• Diffraction occurs; the waves passing through the gap are circular and spread in all directions.

3



• Straight waves pass through the gap and there is less spreading of the waves round the obstacle.

Rate of cooling

• The water cools faster in the beaker with the larger diameter because the surface area in that beaker is larger.

Gold-leaf electroscope

Polythene rods and acetate strips are charged by rubbing with a cloth.

In this experiment a gold-leaf electroscope is used to detect charge and to distinguish between good and bad conductors.

4 **(a)** When a charged polythene rod is brought near the electroscope cap the gold leaf *rises*.
(b) When the charged polythene rod is then moved away from the electroscope cap the gold leaf *falls*.
(c) When a charged cellulose acetate strip is brought near the electroscope cap the gold leaf *rises*.
(d) When the charged acetate strip is then moved away from the electroscope cap the gold leaf *falls*.
(e) When a charged polythene rod is drawn across the edge of the electroscope cap the gold leaf *rises* and the electroscope *charges*.
(f) When you touch the charged electroscope cap with a finger, the gold leaf *falls* and the electroscope *discharges*.

Table 2 should be completed; if the gold leaf falls quickly the material is a good conductor.

5 **(a)** The gold leaf of an electroscope rises when a charged object is brought close to the cap or when charge is transferred to it.
(b) The gold leaf of a charged electroscope falls quickly when it is discharged through a good conductor and slowly or not at all when it is discharged through a bad conductor or insulator.

6 Good conductors: aluminium foil, wire, metal objects, etc.
Bad conductors: paper, wood, plastic, glass, etc.

Maltese cross

1 The cathode rays cast a shadow of the Maltese cross on the fluorescent screen.
2 The cathode rays behave like a conventional current (positive charge flow) travelling from the anode to the cathode. Since they clearly flow from cathode to anode, the cathode rays must be negatively charged.
3 Downwards

Cathode ray oscilloscope

A CRO is used to display and measure the amplitude and frequency of waveforms.

Two different tuning forks are used to produce sound which is converted into an electrical signal by a microphone attached to the Y-input of the CRO. Alternatively, waveforms of different amplitude and frequency produced by a signal generator can be connected directly to the Y-input of the CRO.

For each tuning fork a sine wave of different frequency should be drawn; the peaks of the wave should be closer together for the note of higher frequency. The louder the sound, the larger the amplitude of the sound wave; the amplitude reduces as the sound from the tuning fork dies away.

Practical test past exam questions

1 Equipment required:

- thermometer (–10 to 110 °C)
- beaker (250 cm^3)
- hot water (80 to 100 °C)
- metre rule
- retort stand with boss and clamp
- stopwatch.

(a) (i) Temperature of the hot water, θ_h, should be recorded. [1]

(iv) Table 1.1 should be completed:

Table 1.1

t/s	Position A, *θ*/°C	Position B, *θ*/°C
30		
60		
90		
120		
150		
180		

(b) Measurements for *t* should be in s, *θ* in °C. [1]

Values for *t* should be 30, 60, 90, 120, 150, 180 as shown. [1]

Temperatures should be measured to an accuracy of 1 °C. [1]

Temperature decreases with time in position A. [1]

Temperature decreases with time in position B. [1]

(c) Temperature of the hot water, θ_h, should be recorded. [1]

(e) Statement should match and be justified by the readings.

e.g. The thermometer bulb cools more quickly in position B. We know this because after 180 s the temperature recorded in position B is lower than in position A. [1]

(f) Any two from:

- The starting temperature, θ_h, at which the bulbs start cooling should be the same.
- Room temperature should be constant.
- The thermometer should be kept away from draughts, and out of direct sunlight.
- The same time intervals should be monitored. [2]

[Total: 10]

2 Equipment required:

- a biconvex lens of focal length about 15 cm
- a plane mirror (with dimensions larger than that of the lens)
- a lamp in holder – a 24 W car headlamp powered by a low voltage supply is suitable
- an illuminated object in holder – a card with a triangular-shaped hole in it, covered with translucent paper
- a metre rule
- two vertical flat surfaces, e.g. two blocks of wood

The centre of the object hole, the lamp filament and the centre of the lens should all be at the same height above the bench and aligned along a straight line.

(c) A value for *f* (cm) should be recorded. [2]

(d) An average value for *d* (cm) should be calculated. [3]

(e) A value for *t* (cm) should be recorded. [1]

(f) Sketch should show more than half of the lens being enclosed by the blocks; the ruler should be shown touching the blocks. [2]

(g) (i) A value for f (cm) should be calculated. [1]

(ii) Answer should be justified by results – for example: no, values disagree by an amount too much to be accounted for by the inaccuracy of the experimental results. [1]

[Total: 10]

3 Equipment required:

- a metre rule
- pivot
- masses 30–70 g
- load X of about 30 g
- tape

(a) Table 3.1 should be completed with d in cm (less than 50 cm) and $1/d$ correctly calculated. [2]

(b) On the graph the axes should be labelled with m/g vertically and $\frac{1}{d} / \frac{1}{\text{cm}}$ horizontally and an easy-to-read/plot scale should have been chosen to use as much of graph paper as possible. [1]

The data points should be clear and correctly plotted to half a small square. [1]

The best straight line should be drawn through the points. [1]

It should be a single thin line. [1]

(c) The gradient of the graph, G, should be calculated from as long a length of line as possible (more than half) using the triangle method. [1]

It should be clear how the value was obtained. [1]

(d) Value for z is 0.5 cm – 5 cm. [1]

Two or three significant figures should be given. [1]

[Total: 10]

4 Equipment required:

- 2 V power supply
- switch
- ammeter (0–1 A) with a minimum resolution of 0.05 A
- voltmeter (0–5 V) with a minimum resolution of 0.1 V
- three 4.7 Ω resistors with a power rating of at least 2 W
- connecting leads

(a) Values for I_A, I_B, I_C and I_D should be recorded to two decimal places [1]

current unit specified as amps (A) [1]

I_A and I_D should both be greater than I_B and I_C [1]

$I_A = (I_B + I_c)$ to one decimal place [1]

(b) (i) The correct value for $(I_B + I_c)$ should be given. [1]

(ii) The statement should match current readings [1]

justified by reference to current readings. [1]

(c) Value for V (less than 2.5 V) given to at least 1 decimal place. [1]

Combined R = 7.05 Ω (value given to 2 or 3 significant figures). [1]

(d) Voltmeter should be shown connected between A and D with correct symbol used. [1]

[Total: 10]

Alternatives to practical past exam questions

1 **(a)** two from: length, diameter, number of coils of spring [2]
one from: mass of spring, range of loads [1]
(b) show l_0 consistent with l [1]
(c) Fix a card vertically next to the spring; mark on original and extended lengths, then measure the distance between marks. [1]
[Total: 5]

2 **(a)** On the graph, axes should be labelled with *F*/N vertically and *a*/ m/s^2 horizontally and an easy-to-read/plot scale should have been chosen to use as much of graph paper as possible. [1]
The data points should be clear and correctly plotted to half a small square. [2]
The best straight line should be drawn through the points. [1]
It should be a single thin line. [1]
(b) Statement true [1]
if graph is a straight line through the origin. [1]
(c) The gradient of the graph should be calculated from as long a length of line as possible (more than hal(f) using the triangle method. [1]
It should be clear how the value was obtained. [1]
Value of *m* should be in the range 1.39–1.45 kg. [1]
[Total: 10]

3 **(a)** **(i)** P_3 and P_4 positions should be marked on emergent ray at least 5 cm apart. [1]
(ii) Line should be drawn neatly through **A** at 90° to the surface of the block. [1]
(b) **(i)** $r = 20° \pm 2°$ [1]
(ii) $i = 32° \pm 2°$ [1]
(c) Match P_3 and P_4 positions to base of P_1 and P_2/view pins at a low angle/view pins from a position close to the table. [1]
[Total: 5]

4 **(a)** **(i)** *l*/m [1]
V/V, *I*/A, *R*/Ω [1]
(ii) 1.69 Ω, 3.44 Ω, 5.03 Ω (*R* values should be given to 2 or more significant figures) [2]
(b) *R*/*l* values consistent (6.75, 6.88, 6.71; average value = 6.78 Ω/m) [1]
relationship: *R* directly proportional to *l* [1]
justification: *R*/*l* values are constant within limits of experimental accuracy [1]
(c) $R = 6.8 \times l = 6.78 \times 1.50 = 10.2$ (value should be in the range 10 to 10.35) [2]
(d) Two from: wire heats up/burns out, resistance of wire increases, meter readings increase/readings off scale, meters damaged, power source cuts out/fuse burns out, wire expands and becomes floppy. [2]
[Total: 11]