



Oxford Cambridge and RSA

Thursday 15 October 2020 – Morning

AS Level Physics A

H156/02 Depth in physics

Time allowed: 1 hour 30 minutes

You must have:

- the Data, Formulae and Relationships Booklet

You can use:

- a scientific or graphical calculator
- a ruler (cm/mm)



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

Last name

StemUp Model Solution

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION

- The total mark for this paper is **70**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

ADVICE

- Read each question carefully before you start your answer.

Answer **all** the questions.

1 (a) A sound wave is an example of a longitudinal wave.

(i) State what is meant by the term **longitudinal** wave.

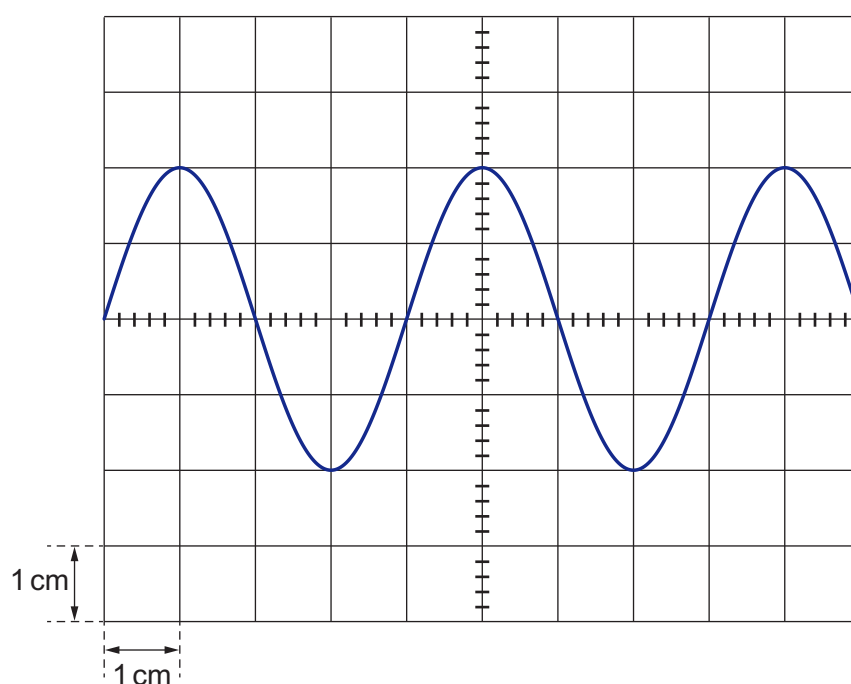
The particles (air molecules) vibrate (oscillate) parallel to the direction in which the wave travels (direction of energy transfer). [1]

(ii) A microphone is connected to an oscilloscope. Sound of frequency 500 Hz is incident on the microphone.

The oscilloscope time-base is set to 0.5 ms cm^{-1} and the y-gain set to 1.0 mV cm^{-1} .

The signal displayed on the oscilloscope screen has an amplitude of 2.0 mV.

The oscilloscope grid is shown below.



Sketch the oscilloscope trace on the grid above.

[2]

$$T = 1 / f = 1 / 500 = 2.0 \text{ ms, so one wavelength} = 2.0 / 0.5 = 4.0 \text{ cm}$$

$$\text{amplitude} = 2.0 \text{ mV} / 1.0 \text{ mV cm}^{-1} = 2.0 \text{ cm above and below the centre}$$

(b) Microwaves and X-rays are examples of electromagnetic waves.

(i) The following are possible wavelengths of electromagnetic waves.

0.2 km 2 m 2 cm 0.2 mm 2 μ m 200 nm 200 pm

Select from the list above a typical wavelength of a microwave and an X-ray.

microwave 2 cm

X-ray 200 pm

[2]

(ii) One property of electromagnetic waves is that they are transverse waves.

State **two** other properties.

1. can be reflected, refracted, diffracted and show interference

(they can also be polarised)

2. can all travel through a vacuum (at the same speed, ...

the speed of light, $3.00 \times 10^8 \text{ m s}^{-1}$)

[2]

- 2 (a) The table shows the refractive index n of air and glass for blue light. It also shows the speed v and the wavelength λ of blue light in air.

	air	glass
refractive index n	1.00	1.53
speed of light v/ms^{-1}	3.00×10^8	1.96×10^8
wavelength λ/m	4.69×10^{-7}	3.07×10^{-7}

- (i) Show that the frequency f of blue light in air is $6.40 \times 10^{14} \text{ Hz}$.

$$v = f\lambda, \text{ so } f = v / \lambda$$

$$f = 3.00 \times 10^8 / 4.69 \times 10^{-7}$$

$$f = 6.397 \times 10^{14} \text{ Hz} \approx 6.40 \times 10^{14} \text{ Hz}$$

[1]

- (ii) Complete the table by determining the missing values for v and λ for glass. Write your answers to 3 significant figures.

$$v = c / n = 3.00 \times 10^8 / 1.53 = 1.96 \times 10^8 \text{ m s}^{-1}$$

$$\lambda = v / f = 1.96 \times 10^8 / 6.40 \times 10^{14} = 3.07 \times 10^{-7} \text{ m}$$

[2]

(b) A semi-circular block of glass is placed in air.

Fig. 2.1 shows the path of blue light through the air and the semi-circular glass block.

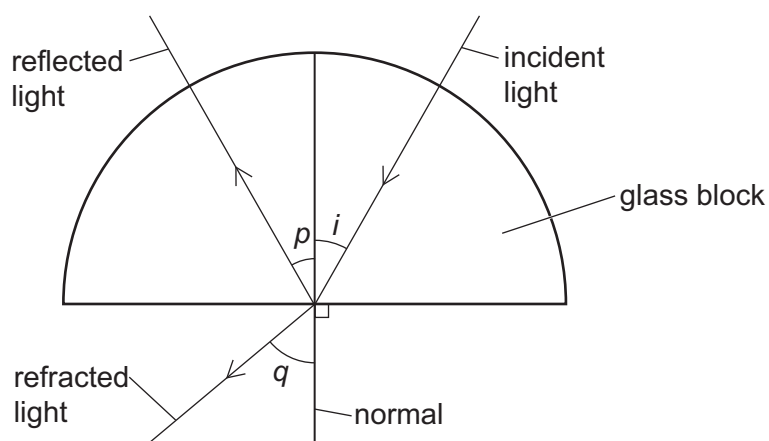


Fig. 2.1 (not to scale)

(i) The angle i is 30° .

1. Determine angle p .

angle of reflection = angle of incidence

$$p = \dots\dots\dots 30 \dots\dots\dots^\circ \text{ [1]}$$

2. Determine angle q , using the information from the table in (a).

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$1.53 \times \sin 30^\circ = 1.00 \times \sin q$$

$$\sin q = 1.53 \times 0.5 = 0.765$$

$$q = \sin^{-1} 0.765 = 49.9^\circ$$

$$q = \dots\dots\dots 50 \dots\dots\dots^\circ \text{ [2]}$$

- (ii) The angle i is increased from 30° to 60° . Describe and explain how angles p and q will change. In your answer, include the term **critical angle**.

p always equals i (law of reflection), so p increases from 30° to 60° .

As i increases, q increases (the refracted ray bends further from the normal) until i equals the critical angle, when $q = 90^\circ$.

Critical angle: $\sin C = 1 / 1.53$, so $C = 41^\circ$.

At $i = 60^\circ$, i is greater than the critical angle, so total internal reflection occurs: there is no refracted ray, so no angle q . [4]

- (c) Fig. 2.2 shows the same semi-circular glass block with the blue light replaced by red light.

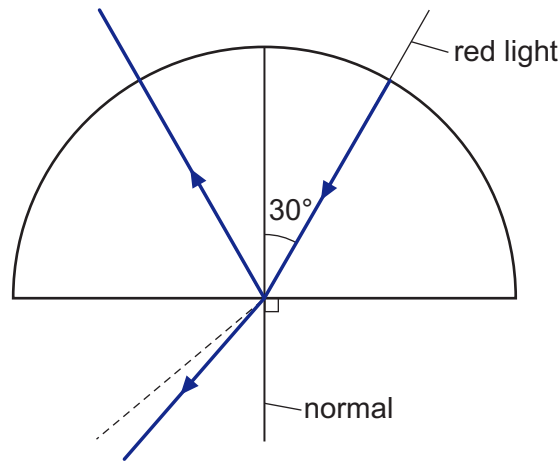


Fig. 2.2 (not to scale)

The dashed lines show the original paths of the blue light.

Draw on Fig. 2.2 the path of the red light in the glass block and out of the glass block. [2]

- 3 **Fig. 3.1** shows an experiment to investigate the extension of two identical springs connected side by side. A student uses a 30cm ruler to measure the length L_0 of the two-spring combination without a load attached.

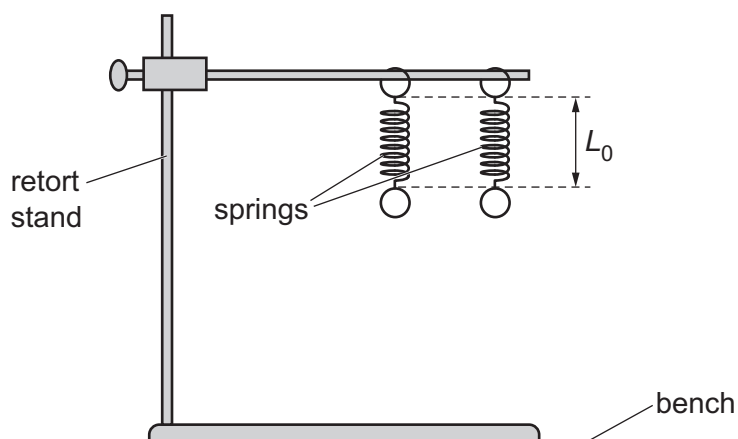


Fig. 3.1

The student then adds a rod and a mass M to the spring combination as shown in **Fig. 3.2**.

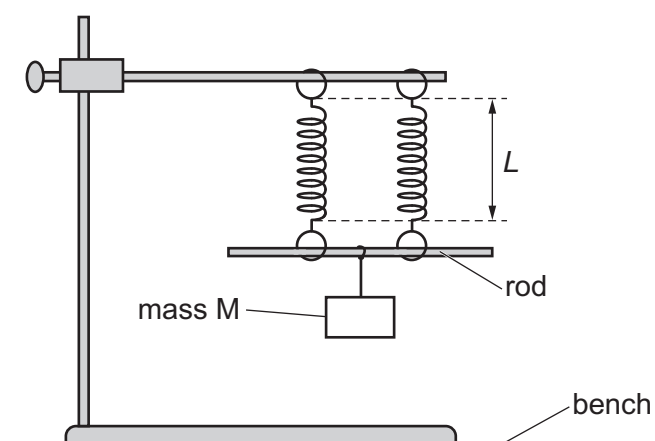
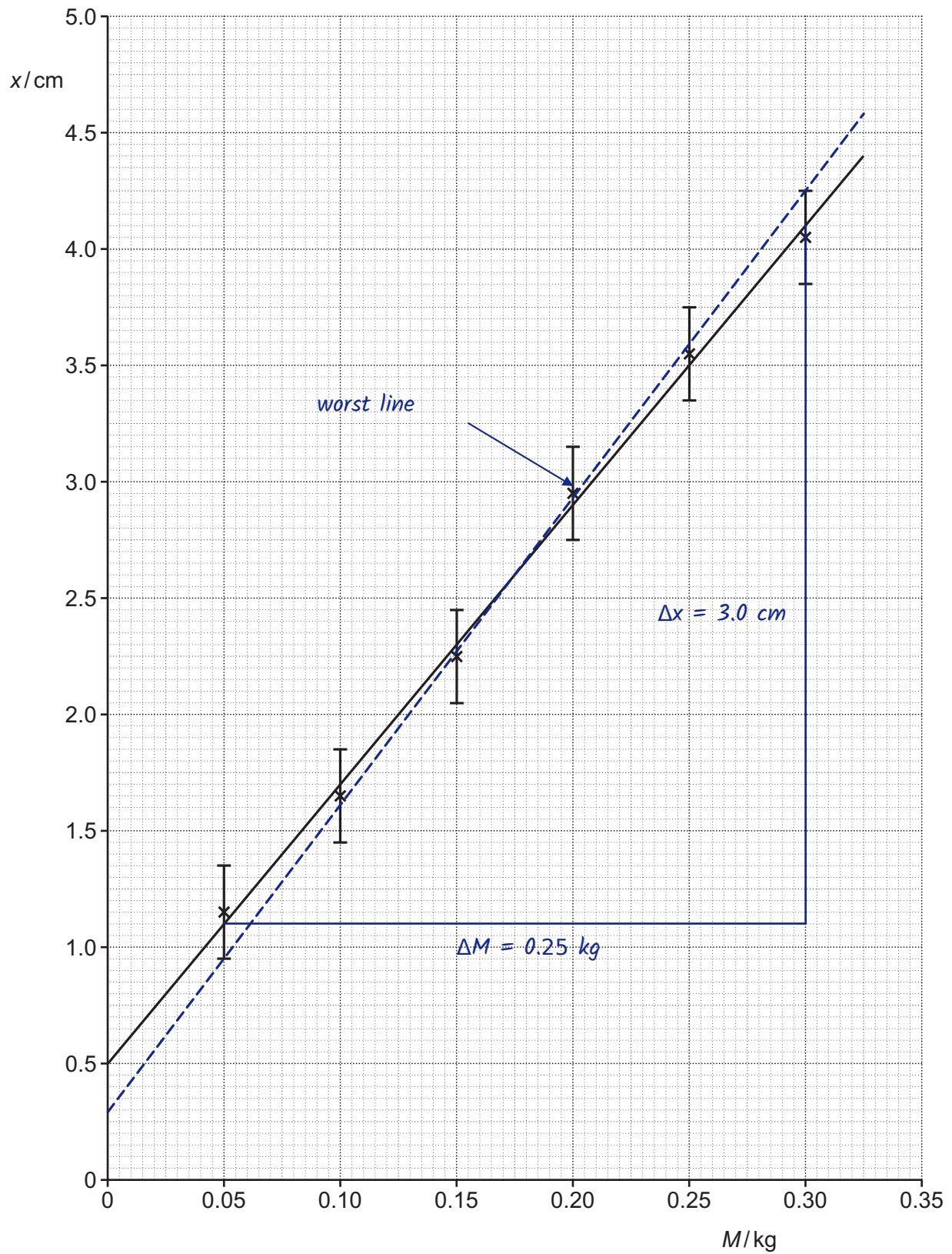


Fig. 3.2

The student then repeats the experiment for different values of M . For each value of M , the student determines the extension x of the spring combination and the absolute uncertainty in x .

The student plots a graph of extension x (y-axis) against mass M (x-axis) including error bars in x . The straight line of best fit is drawn.



It is suggested that the relationship between x and M is

$$x = \frac{Mg}{k} + R$$

where k is the force constant of the spring combination, g is the acceleration of free fall and R is a constant.

- (a) (i) Show that the gradient of the straight line of best fit is about 0.12 m kg^{-1} .

$$\begin{aligned} \text{gradient} &= \Delta x / \Delta M = (4.10 - 1.10) \times 10^{-2} / (0.30 - 0.05) \\ &= 0.030 / 0.25 = 0.12 \text{ m kg}^{-1} \end{aligned} \quad [2]$$

- (ii) Using the gradient, determine a value for k .
Give your answer to an appropriate number of significant figures and include an appropriate unit.

$$\begin{aligned} \text{gradient} &= g / k, \text{ so } k = g / \text{gradient} \\ k &= 9.81 / 0.12 = 81.75 \end{aligned}$$

$$k = \dots\dots\dots 82 \dots\dots\dots \text{unit } N \text{ m}^{-1} \quad [2]$$

- (b) (i) Draw a worst acceptable straight line. [1]

- (ii) Determine the gradient of your worst acceptable line.

$$\begin{aligned} \text{gradient} &= (4.25 - 0.95) \times 10^{-2} / (0.30 - 0.05) \\ &= 0.033 / 0.25 = 0.132 \text{ m kg}^{-1} \end{aligned}$$

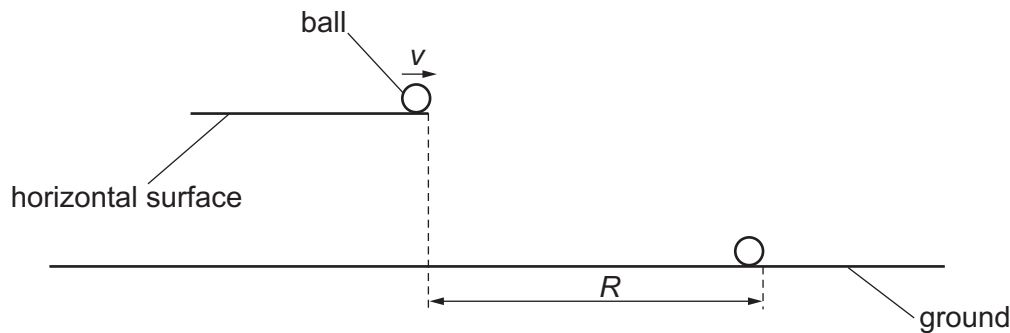
$$\text{gradient of worst acceptable line} = \dots\dots\dots 0.13 \dots\dots\dots \text{m kg}^{-1} \quad [1]$$

- (iii) Determine the percentage uncertainty in k .

$$\begin{aligned} \Delta \text{gradient} &= 0.13 - 0.12 = 0.01 \text{ m kg}^{-1} \\ \% \text{ uncertainty in } k &= \% \text{ uncertainty in gradient} = (0.01 / 0.12) \times 100 \end{aligned}$$

$$\text{percentage uncertainty} = \dots\dots\dots 8.3 \dots\dots\dots \% \quad [2]$$

- 4* A metal ball leaves a horizontal surface with velocity v .
A student investigates the horizontal distance R that the ball travels before it hits the ground.

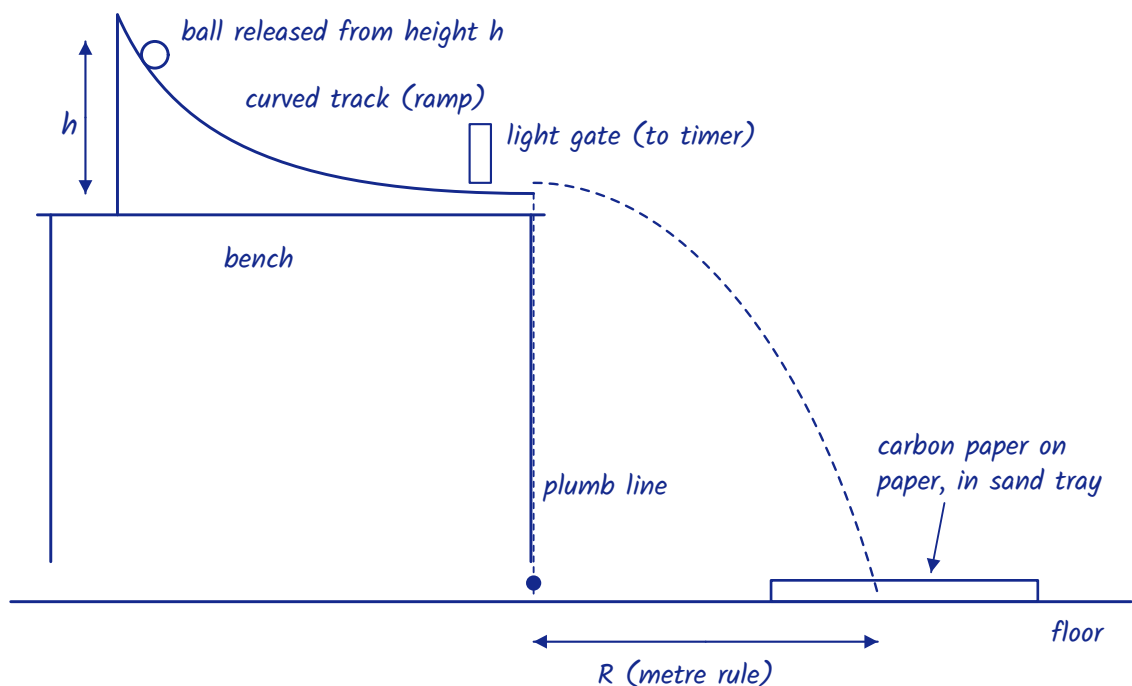


It is suggested that the relationship between R and v is given by

$$R = v\sqrt{\frac{Q}{g}}$$

where g is the acceleration of free fall and Q is a constant.

Describe with the aid of a suitable diagram how an experiment can be safely conducted, and how the data can be analysed, to determine Q . [6]



A ball rolls down a curved track clamped on a bench so it leaves the edge horizontally. A light gate at the edge, connected to a timer, records the time t for the ball to pass; measure the ball's diameter d with vernier calipers, so $v = d/t$ (or use $mgh = \frac{1}{2}mv^2$, $v = \sqrt{2gh}$).
The ball lands on carbon paper on white paper, which marks where it hits the

floor. Measure R with a metre rule from the point below the edge (found with a plumb line) to the mark.

Release the ball from rest from different heights h on the track to change v .

Repeat each height three times and average R and t .

Safety: place the paper in a tray of sand so the ball does not roll on the floor and cause someone to slip; keep feet clear of the landing area.

Analysis: $R = v\sqrt{Q/g}$, so plot a graph of R against v . A straight line through the origin confirms the relationship.

Gradient = $\sqrt{Q/g}$, so $Q = g \times \text{gradient}^2$ (or plot R^2 against v^2 , gradient = Q/g ,

$Q = g \times \text{gradient}$).

Additional answer space if required

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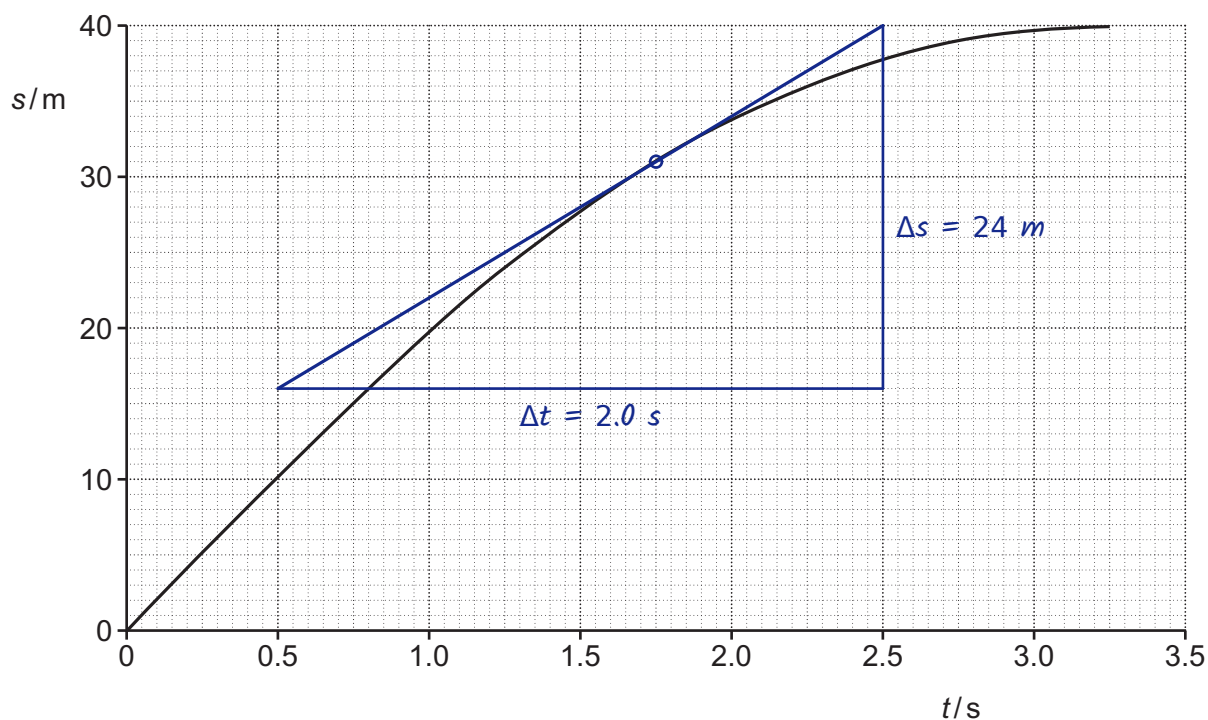
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- 5 A car is travelling at a constant speed of 20 m s^{-1} along a straight road. The driver sees a hazard ahead in the road, applies the brakes and brings the car to a stop. The graph below shows the displacement s against time t for the car from the time that the driver sees the hazard to when the car stops.



The braking force F acting on the car is constant.
 The mass of the car is 950 kg .
 The reaction time of the driver is 0.75 s .

- (a) State the gradient of the graph when $t = 0$.

gradient = ...20..... m s^{-1} [1]

- (b) Explain how you can deduce from the graph that the brakes are applied at time $t = 0.75$ s.

After 0.75 s the gradient of the graph decreases with time (the line starts to curve), showing the velocity is decreasing, so the car decelerates.

[2]

- (c) Draw a tangent to the graph at time $t = 1.75$ s.
Use this tangent to show that the speed of the car at $t = 1.75$ s is about 12 ms^{-1} .

$$\begin{aligned} \text{speed} &= \text{gradient of tangent} = \Delta s / \Delta t = (40 - 16) / (2.5 - 0.5) \\ &= 24 / 2.0 = 12 \text{ m s}^{-1} \end{aligned}$$

[2]

- (d) Determine the braking force F .
You may use information from (c) or from the graph.

$$\begin{aligned} a &= \Delta v / \Delta t = (20 - 12) / (1.75 - 0.75) = 8.0 \text{ m s}^{-2} \\ (\text{check: from } 0.75 \text{ s to } 3.25 \text{ s, } a &= 20 / 2.5 = 8.0 \text{ m s}^{-2}) \\ F &= ma = 950 \times 8.0 \\ F &= 7600 \text{ N} \end{aligned}$$

$$F = \dots\dots\dots 7600 \dots\dots\dots \text{ N [3]}$$

- (e) Describe and explain the variation of the displacement with time when the same driver applies the brakes in the same car when the initial speed of the car is 10 ms^{-1} .

The thinking time is the same (0.75 s), so the car travels at constant speed for half the distance: $10 \times 0.75 = 7.5 \text{ m}$ (straight line, half the gradient).

The deceleration is the same, so the braking time is halved to 1.25 s and the braking distance is a quarter, 6.25 m.

Total time is 2.0 s and total displacement is 13.75 m.

[3]

- 6 **Fig. 6.1** shows a uniform metal cylinder of weight 7.0 N. The cylinder has length 100 mm and diameter 32 mm.

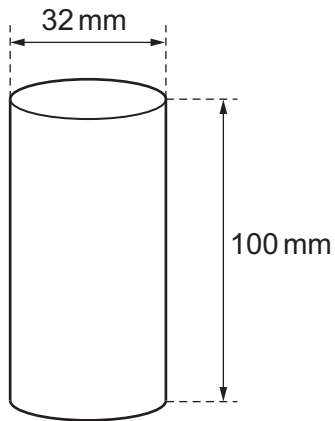


Fig. 6.1 (not to scale)

- (a) Calculate the density ρ of the metal.

$$V = \pi r^2 L = \pi \times (16 \times 10^{-3})^2 \times 100 \times 10^{-3} = 8.04 \times 10^{-5} \text{ m}^3$$

$$m = W / g = 7.0 / 9.81 = 0.714 \text{ kg}$$

$$\rho = m / V = 0.714 / 8.04 \times 10^{-5} = 8880 \text{ kg m}^{-3}$$

$$\rho = \dots\dots\dots 8900 \dots\dots\dots \text{ kg m}^{-3} \text{ [3]}$$

- (b) The cylinder is suspended by two cords **A** and **B**, attached to the centre of the top surface, as shown in **Fig. 6.2**.

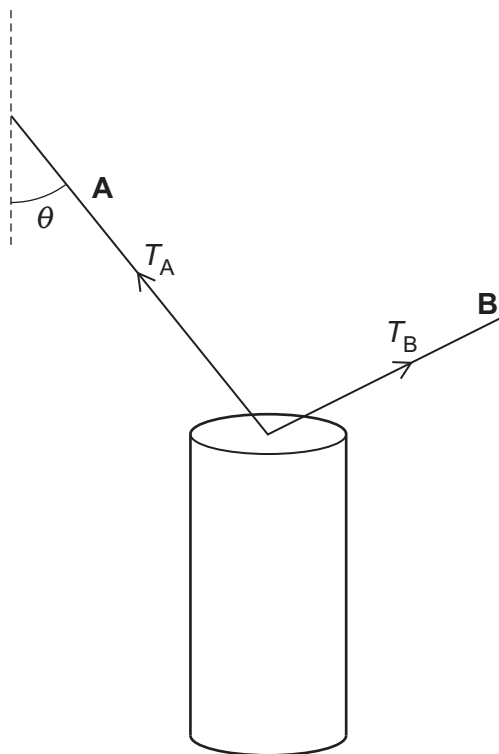


Fig. 6.2 (not to scale)

The tensions in each of the cords are T_A and T_B .

Fig. 6.3 shows T_B drawn to scale on graph paper.

Scale 1.0 cm represents 2.0 N.

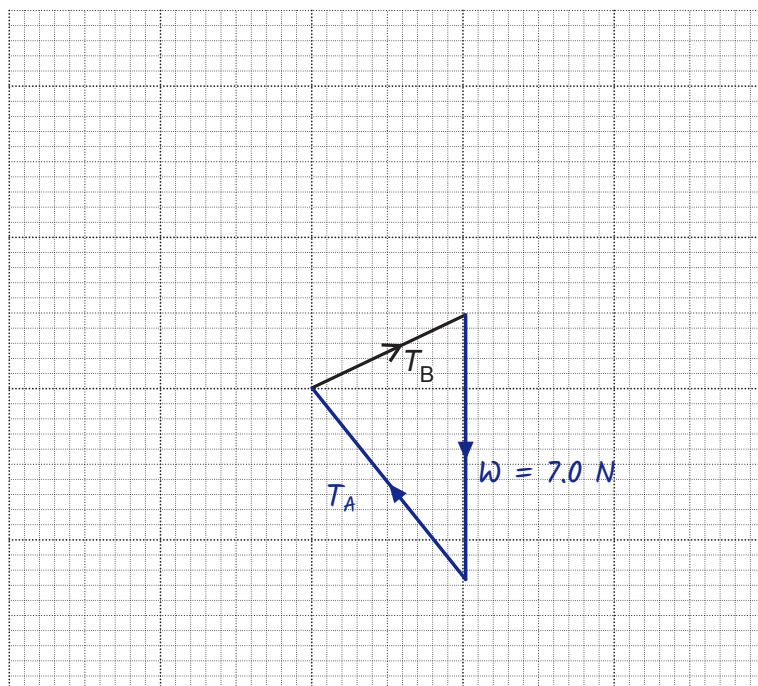


Fig. 6.3

- (i) Determine the magnitude of T_B .

$$T_B = \dots\dots\dots 4.5 \dots\dots\dots \text{ N [1]}$$

- (ii) Draw a triangle of forces on **Fig. 6.3** to represent the forces acting on the cylinder. Determine the magnitude of T_A .

$$T_B \text{ line} = 2.25 \text{ cm, so } T_B = 2.25 \times 2.0 = 4.5 \text{ N}$$

weight drawn as 3.5 cm vertical line; T_A closes the triangle

$$T_A \text{ line} = 3.25 \text{ cm, so } T_A = 3.25 \times 2.0 = 6.5 \text{ N}$$

$$T_A = \dots\dots\dots 6.5 \dots\dots\dots \text{ N [3]}$$

- (iii) Determine the angle θ in **Fig. 6.2**.

$\theta = \text{angle between } T_A \text{ and the vertical (protractor)}$

$$\theta = \dots\dots\dots 39 \dots\dots\dots ^\circ \text{ [1]}$$

Question 6 continues on page 16

Turn over

- (c) **Fig. 6.4** shows the same cylinder at rest on a bench.
A horizontal force F is applied to the cylinder so that it can rotate about point **X**.

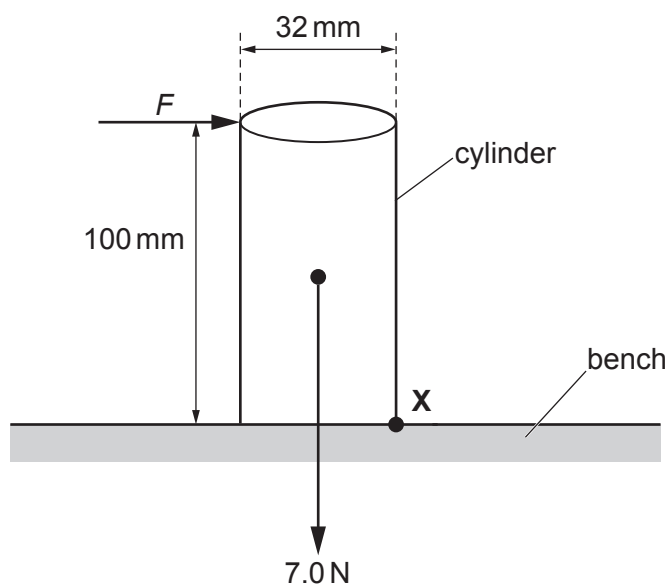


Fig. 6.4 (not to scale)

Calculate the minimum value of F to just topple the cylinder about **X**.

moments about X: clockwise moment = anticlockwise moment

$$F \times 100 \times 10^{-3} = 7.0 \times 16 \times 10^{-3}$$

$$F = (7.0 \times 16) / 100 = 1.12 \text{ N}$$

$F = \dots\dots\dots 1.1 \dots\dots\dots \text{ N [2]}$

17
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Question 7 is on page 18

- 7 A 150 W heater constructed from nichrome wire is switched on for 5.0 hours.

The wire has a cross-sectional area of $4.1 \times 10^{-9} \text{ m}^2$.

The current in the wire is 1.5 A.

The number density of charge carriers in nichrome is $7.9 \times 10^{28} \text{ m}^{-3}$.

(a) Calculate

- (i) the resistance R of the heater

$$P = I^2 R, \text{ so } R = P / I^2 = 150 / 1.5^2$$

$$R = 66.7 \, \Omega$$

$$R = \dots\dots\dots 67 \dots\dots\dots \Omega \text{ [2]}$$

- (ii) the number N of electrons passing through the heater in 5.0 hours

$$Q = It = 1.5 \times 5.0 \times 60 \times 60 = 27000 \text{ C}$$

$$N = Q / e = 27000 / 1.60 \times 10^{-19} = 1.69 \times 10^{23}$$

$$N = \dots\dots\dots 1.7 \times 10^{23} \dots\dots\dots \text{ [2]}$$

- (iii) the mean drift velocity v of the electrons (charge carriers) in the heater.

$$I = nAve, \text{ so } v = I / nAe$$

$$v = 1.5 / (7.9 \times 10^{28} \times 4.1 \times 10^{-9} \times 1.60 \times 10^{-19})$$

$$v = 0.0289 \text{ m s}^{-1}$$

$$v = \dots\dots\dots 0.029 \dots\dots\dots \text{ ms}^{-1} \text{ [2]}$$

- (b) The cost of 1 kWh of energy is 16p.
Calculate the cost of using the heater for 5.0 hours.

$$\text{energy} = 0.150 \text{ kW} \times 5.0 \text{ h} = 0.75 \text{ kWh}$$

$$\text{cost} = 0.75 \times 16$$

$$\text{cost} = \dots\dots\dots 12 \dots\dots\dots \text{ p [2]}$$

- (c) Nichrome is a metal. Silicon is a semiconductor.

State how the number density of charge carriers n and the resistivity ρ of silicon compare with that of nichrome.

n *Silicon has a much smaller number density of charge carriers than nichrome.*

.....

.....

ρ *Silicon has a much larger (greater) resistivity than nichrome.*

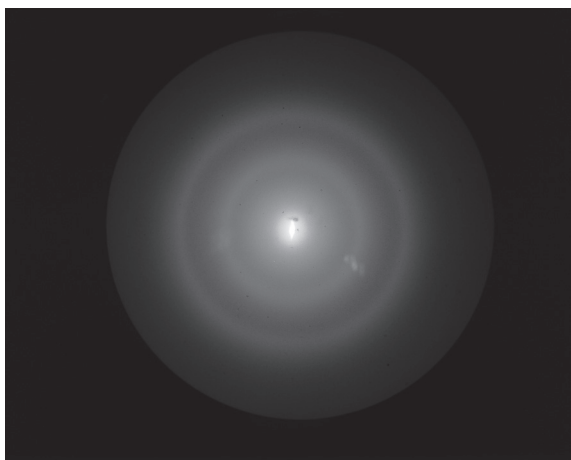
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[2]

Question 8 is on page 20

- 8* A student is investigating electron diffraction. A beam of electrons is directed towards a thin slice of graphite in an evacuated tube. The electrons are accelerated by a potential difference of 2000V. The diagram below shows the pattern formed on the fluorescent screen of the evacuated tube.



Describe and explain how the pattern changes as the potential difference is increased. Include how the de Broglie wavelength λ of the electron is related to the potential difference V . [6]

As V increases the rings become closer together (smaller radius, closer spacing) and the rings become brighter.

The electrons gain more kinetic energy: $eV = \frac{1}{2}mv^2$, so $v^2 \propto V$. They have a greater speed and a greater momentum $p = mv$.

de Broglie wavelength $\lambda = h / p$, so $\lambda = h / \sqrt{2meV}$ and $\lambda \propto 1/\sqrt{V}$: a larger V gives a smaller wavelength.

The graphite atom spacing stays the same, so a smaller wavelength means less diffraction (smaller diffraction angles).

A shorter wavelength also gives shorter path differences between areas of constructive and destructive interference, so the bright rings form closer to the centre.

Each electron hits the screen with more energy, so the rings are brighter. For example, doubling V reduces λ by a factor of $\sqrt{2}$.

Additional answer space if required

END OF QUESTION PAPER

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