

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level PHYSICS

Paper 3 Section A

Materials

For this paper you must have:

- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions

- Use **black ink** or **black ball-point pen**.
- **Fill** in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do **all** rough work in this book. Cross through any work you do not want to be marked.
- Show **all** your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 45.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 70 minutes on this section.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
TOTAL	



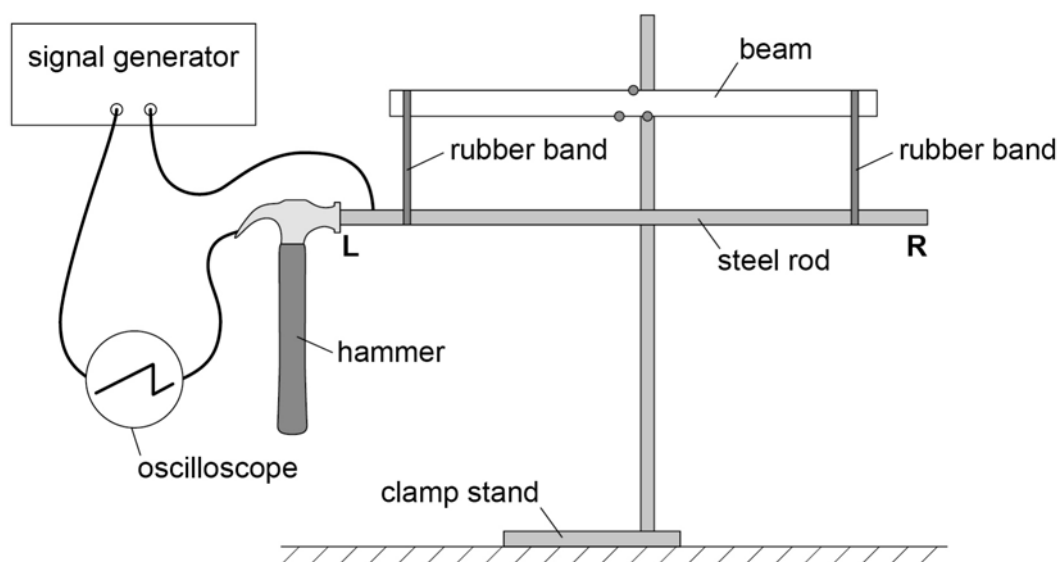
Section A

Answer **all** questions in this section.

0	1
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Figure 1 shows apparatus used to measure the speed of sound in a steel rod.

Figure 1

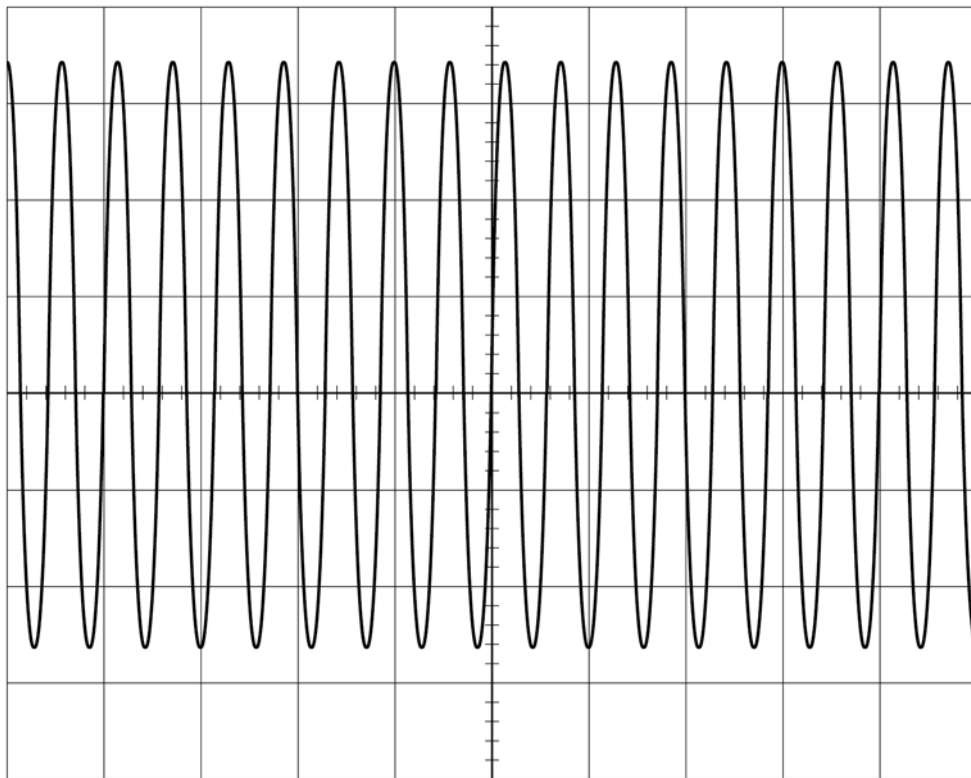


The steel rod is suspended from a beam using rubber bands. When the hammer is in contact with the end **L** of the steel rod, a circuit is completed and the signal generator is connected to the oscilloscope.

Figure 2 shows the waveform then displayed on the oscilloscope.



Figure 2



0 1 . 1

Which control on the oscilloscope should be used to centre the trace vertically on the screen?

Tick (✓) **one** box.

[1 mark]

X-shift

☐

Y-gain

☐

Y-shift

☒

Question 1 continues on the next page

Turn over ►



When the hammer hits end **L**, a sound wave travels along the steel rod and is reflected at end **R**.

When the wave returns to **L** the rod bounces away from the hammer and the circuit is broken.

Figure 3 shows the waveform produced by the brief contact between the hammer and **L**.

Note that the waveform has now been centred vertically.

Figure 3

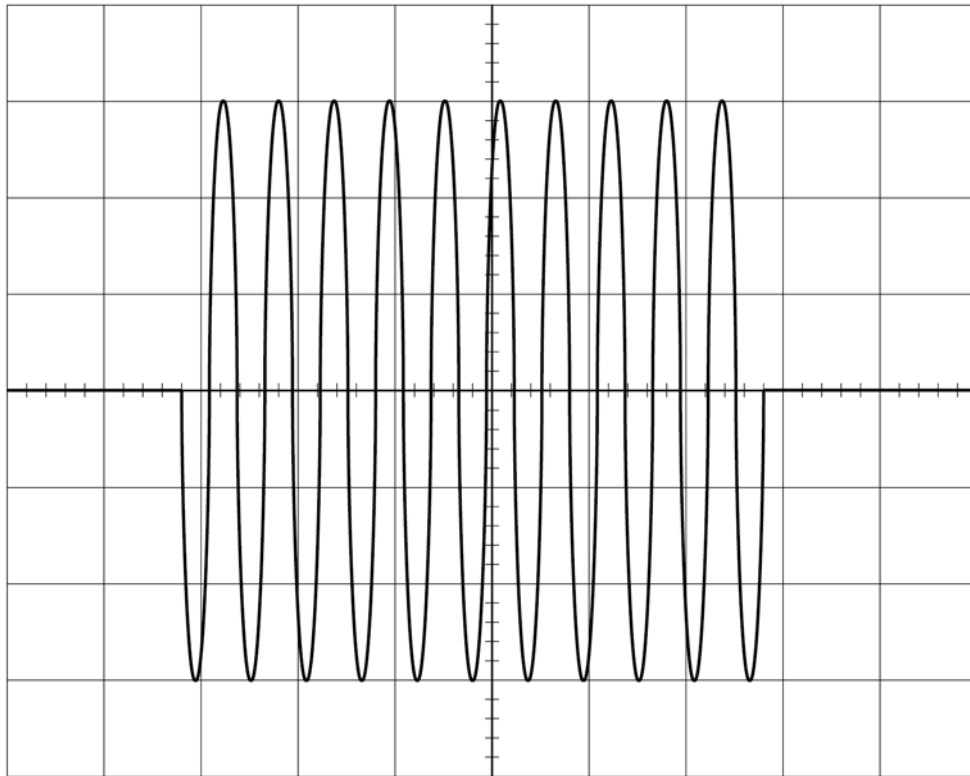
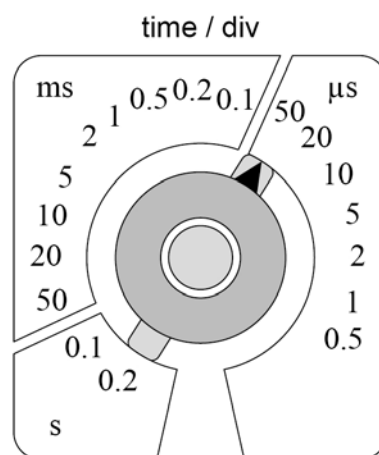


Figure 4 shows the time-base setting of the oscilloscope.

Figure 4



0 1 . 2

The distance between **L** and **R** in **Figure 1** is 0.870 m.

Deduce the speed of sound in the steel rod.

[3 marks]

$$\text{Contact time} = 6.0 \text{ divisions} \times 50 \mu\text{s div}^{-1} = 300 \mu\text{s} = 3.0 \times 10^{-4} \text{ s}$$

$$\text{Distance travelled} = \text{there and back} = 2 \times 0.870 = 1.74 \text{ m}$$

$$\text{speed} = \text{distance} \div \text{time} = 1.74 \div 3.0 \times 10^{-4}$$

$$\text{speed of sound} = \underline{\hspace{2cm} 5800 \hspace{2cm}} \text{ m s}^{-1}$$

0 1 . 3

A student repeats the experiment using a steel rod of twice the length.

Explain:

- how using the longer rod affects the waveform displayed
- any changes needed to get an accurate result for the speed.

You should include numerical detail.

[4 marks]

The sound now travels $2 \times 1.74 = 3.48 \text{ m}$, so the contact time is doubled; from $300 \mu\text{s}$ to $600 \mu\text{s}$ ($6.0 \times 10^{-4} \text{ s}$).

The waveform would be twice as long; double the number of cycles (about 20 instead of 10) is produced, which would need 12 divisions at $50 \mu\text{s div}^{-1}$.

The screen is only 10 divisions wide, so the waveform would extend beyond the screen and could not be fully displayed or measured.

So the time-base control must be adjusted to 0.1 ms div^{-1} ; the waveform then covers 6 divisions and fits on the screen.

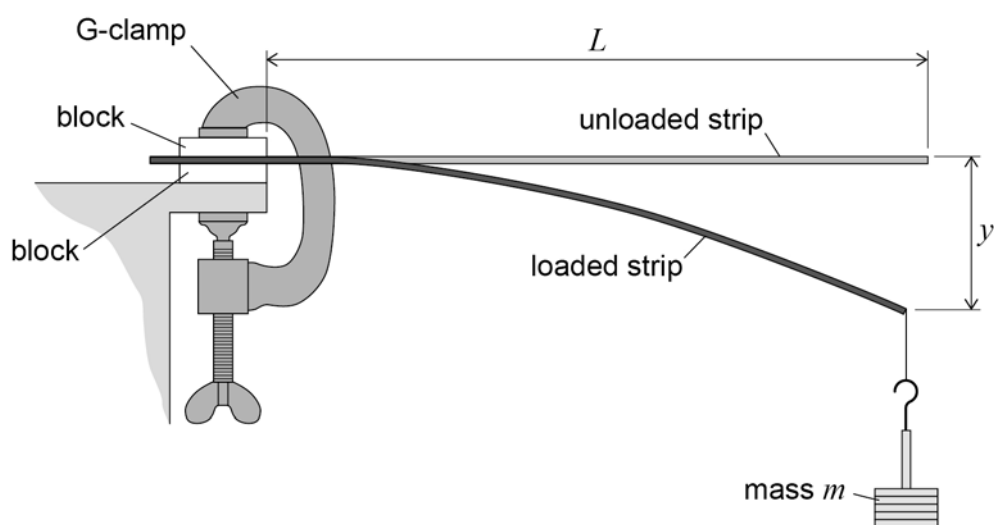
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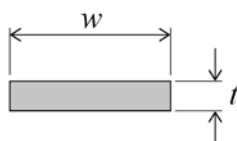
0 2

Figure 5 shows a strip of steel of rectangular cross-section clamped at one end. The strip extends horizontally over the edge of a bench.

Figure 5



end view of unloaded steel strip



0 2 . 1

A mass m is suspended from the free end of the strip.

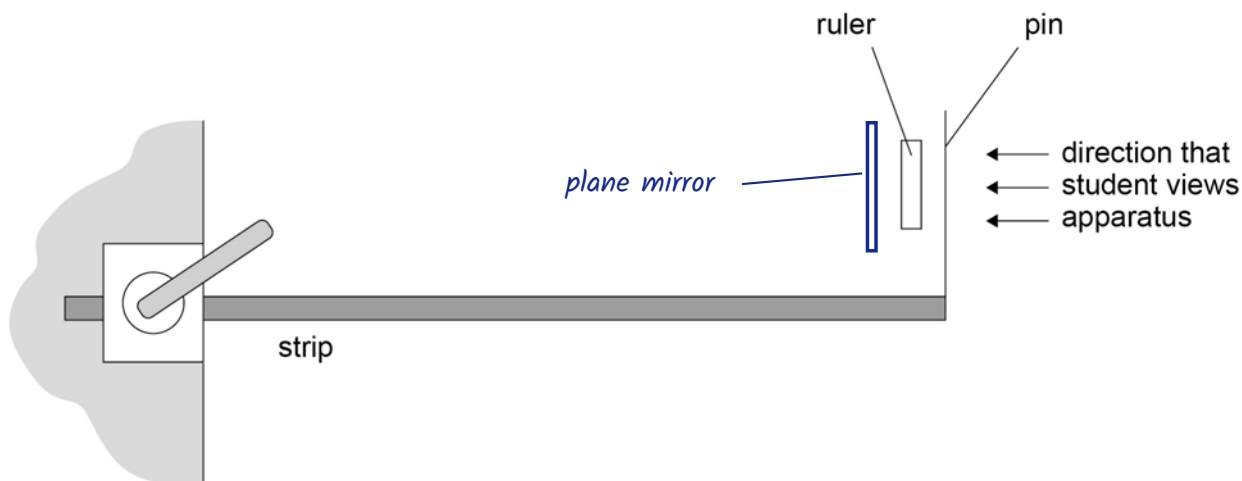
This produces a vertical displacement y .

A student intends to measure y with the aid of a horizontal pin fixed to the free end of the steel strip.

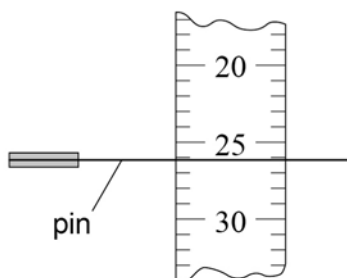
She positions a clamped vertical ruler behind the pin, as shown in **Figure 6**.

Figure 6

plan view



view seen by student



Explain a procedure to avoid parallax error when judging the reading indicated by the position of the pin on the ruler.

You may add detail to **Figure 6** to illustrate your answer.

[2 marks]

Place a (plane) mirror behind the ruler, next to the scale, so that the pin is reflected in it.

Move my eye (head) up or down until the pin hides / lines up exactly with its own reflection (image) in the mirror, then my line of sight is horizontal and perpendicular to the ruler, so read the scale at the pin.

Question 2 continues on the next page

Turn over ►



0 2 . 2 It can be shown that

$$y = \frac{4mgL^3}{Ewt^3}$$

where:

L is the distance between the free end of the **unloaded** strip and the blocks
 w is the width of the strip and is approximately 1 cm
 t is the thickness of the strip and is approximately 1 mm
 E is the Young modulus of the steel.

A student is asked to determine E using the arrangement shown in **Figure 5** with the following restrictions:

- only one steel strip of approximate length 30 cm is available
- m must be made using a 50 g mass hanger and up to four additional 50 g slotted masses
- the experimental procedure must involve only **one** independent variable
- a graphical method must be used to get the result for E .

Explain what the student must do to determine E .

[5 marks]

Keep the mass constant: use the 50 g hanger and all four 50 g slotted masses so $m = 250$ g (0.250 kg) throughout. The width w and thickness t are also constant as only one strip is used, so the only independent variable is the length L .

Measure the width w with vernier callipers and the thickness t with a micrometer (screw gauge), taking readings at several places along the strip and finding the mean.

Clamp the strip between the blocks with the G-clamp. Measure L , the distance from the blocks to the free end of the unloaded strip, with a metre ruler. Record the reading of the pin on the vertical ruler with no load (using the mirror to avoid parallax).

Hang the 250 g mass on the free end and record the new pin reading.

The vertical displacement y (the dependent variable) is the difference between the loaded and unloaded readings.



Remove the mass, slide the strip through the clamp to change L , re-tighten, and repeat for at least 6 values of L between about 10 cm and 25 cm (the strip is only 30 cm long). Repeat each reading and take a mean y .

Analysis: since $y = 4mgL^3 \div Ewt^3$, plot a graph of y (on the y-axis) against L^3 (on the x-axis). This should be a straight line through the origin.

The gradient = $4mg \div Ewt^3$, so $E = 4mg \div (wt^3 \times \text{gradient}) = (4 \times 0.250 \times 9.81) \div (wt^3 \times \text{gradient})$, using the measured w and t in metres.

Turn over for the next question

Turn over ►



0 3

Conductive putty can easily be formed into different shapes to investigate the effect of shape on electrical resistance.

0 3 . 1

A student uses vernier callipers to measure the diameter d of a uniform cylinder made of the putty.

Suggest **one** problem with using callipers to make this measurement.

[1 mark]

The callipers may squash (deform) the soft putty when closed on it, so the reading of the diameter would be reduced (too small).

0 3 . 2

Table 1 shows the calliper measurements made by a student.

Table 1

d_1 / mm	d_2 / mm	d_3 / mm	d_4 / mm	d_5 / mm
34.5	34.2	32.9	33.4	34.0

Show that the percentage uncertainty in d is about 2.4%.
Assume that all the data are valid.

[2 marks]

$$\text{mean } d = (34.5 + 34.2 + 32.9 + 33.4 + 34.0) \div 5 = 33.80 \text{ mm}$$

$$\text{uncertainty in } d = \text{half range} = \frac{1}{2} \times (34.5 - 32.9) = 0.80 \text{ mm}$$

$$\% \text{ uncertainty} = 0.80 \div 33.80 \times 100 = 2.37 \% \approx 2.4 \%$$



0 3 . 3 The length of the cylinder is 71 ± 2 mm.

Determine the uncertainty, in mm^3 , in the volume of the cylinder.

[4 marks]

$$\% \text{ uncertainty in } L = 2 \div 71 \times 100 = 2.82 \%$$

$$V = \pi d^2 L \div 4, \text{ so } \% \text{ uncertainty in } V = 2 \times 2.37 + 2.82 = 7.56 \%$$

$$V = \pi \times 33.8^2 \times 71 \div 4 = 6.37 \times 10^4 \text{ mm}^3$$

$$\Delta V = 0.0756 \times 6.37 \times 10^4 = 4.8 \times 10^3 \text{ mm}^3$$

uncertainty = 4.8×10^3 mm^3

Question 3 continues on the next page

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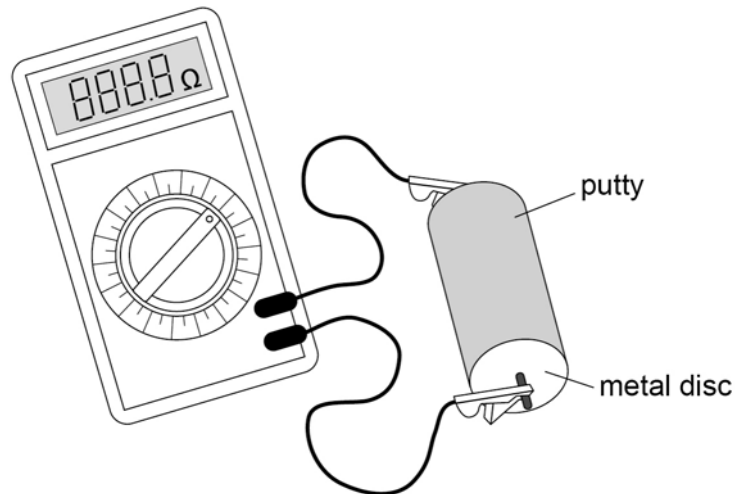
0 3 . 4

A student is given some putty to form into cylinders.

To find the resistance of a cylinder, metal discs are placed in contact with the ends of the cylinder and connected to a resistance meter.

Figure 7 shows the apparatus.

Figure 7



The student forms the putty into cylinders of different lengths, each of volume $5.83 \times 10^{-5} \text{ m}^3$.

The length L and resistance R are measured for each cylinder.

It can be shown that $R = \frac{\rho L^2}{5.83 \times 10^{-5}}$ where ρ is the resistivity of the conductive putty.

The student plots the graph shown in Figure 8.

Determine ρ .

State an appropriate SI unit for your answer.

[4 marks]

Ruled line of best fit through origin (Figure 8): gradient = $\Delta R \div \Delta L^2$

gradient = $(32.4 - 0) \div ((50 - 0) \times 10^{-3}) = 648 \text{ } \Omega \text{ m}^{-2}$

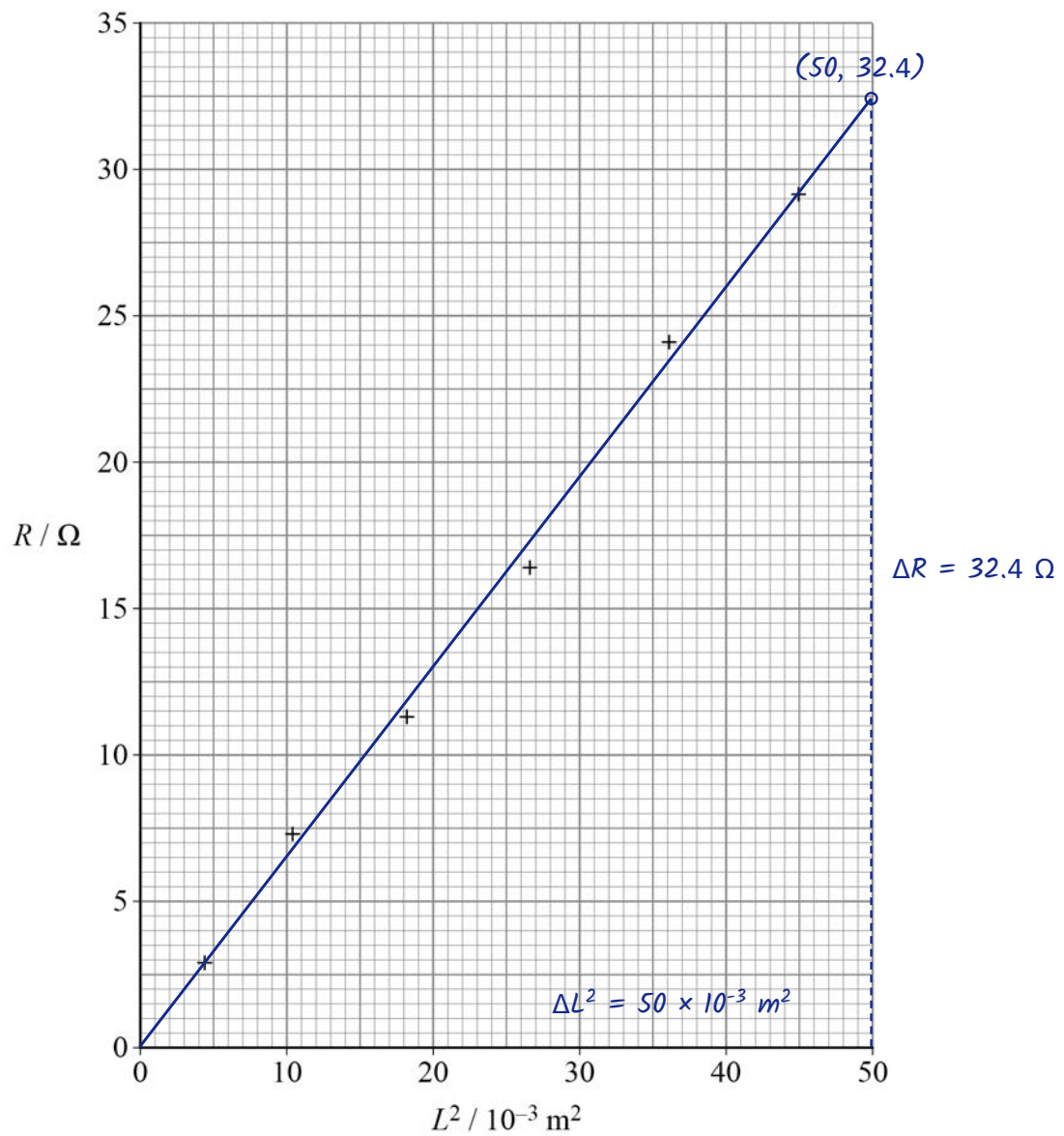
$R = \rho L^2 \div 5.83 \times 10^{-5}$, so gradient = $\rho \div 5.83 \times 10^{-5}$

$\rho = 648 \times 5.83 \times 10^{-5} = 3.78 \times 10^{-2} \text{ } \Omega \text{ m}$

$\rho =$ 3.78×10^{-2} unit = $\Omega \text{ m}$



Figure 8



Turn over for the next question

Turn over ►



0 4

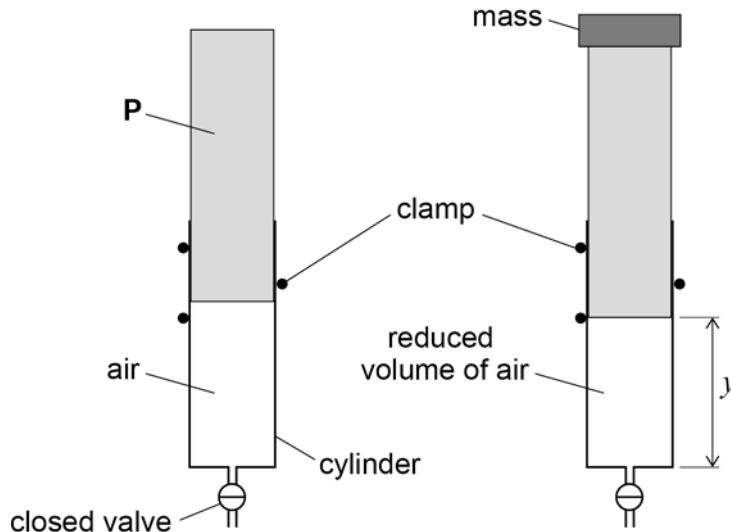
Figure 9 shows air trapped in a vertical cylinder by a valve and a piston **P**. The valve remains closed throughout the experiment.

A mass is placed on top of **P**.

P moves downwards and the volume of the trapped air decreases.

There are no air leaks and there is no friction between the cylinder and **P**.

Figure 9



The vertical distance y between the end of **P** and the closed end of the cylinder is measured.

Additional masses are used to find out how y depends on the total mass M placed on top of **P**.

Figure 10 shows a graph of these data.

0 4 . 1

Show that y is **not** inversely proportional to M .

Use data points from **Figure 10**.

[2 marks]

If $y \propto 1/M$, then $M \times y$ would be constant.

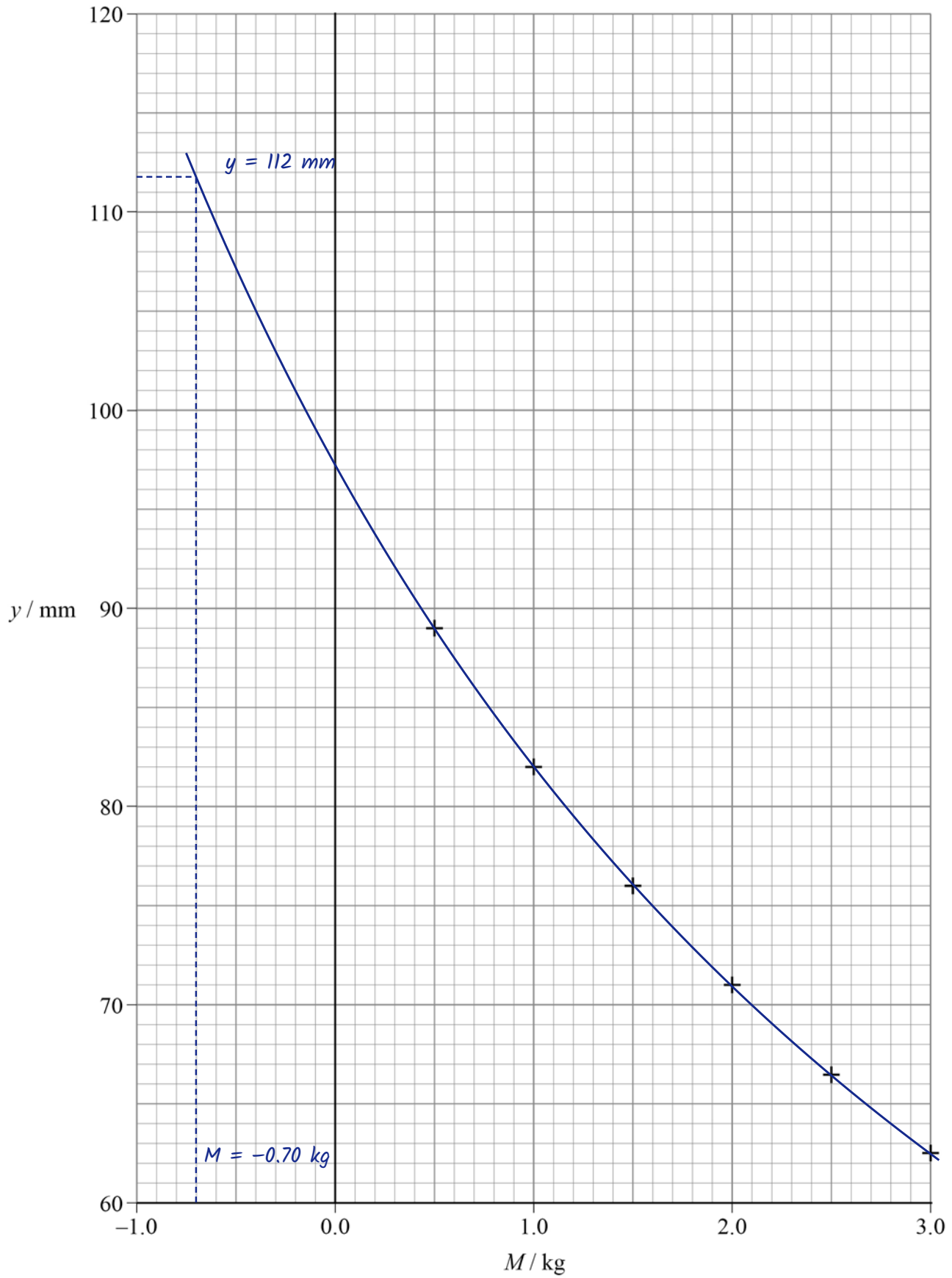
$$M = 0.5 \text{ kg}, y = 89.0 \text{ mm: } My = 0.5 \times 89.0 = 44.5 \text{ kg mm}$$

$$M = 3.0 \text{ kg}, y = 62.5 \text{ mm: } My = 3.0 \times 62.5 = 187.5 \text{ kg mm}$$

44.5 and 187.5 are very different, so My is not constant and y is not inversely proportional to M . (Also, when M doubles from 1.0 to 2.0 kg, y only falls from 82 mm to 71 mm; it does not halve to 41 mm.)



Figure 10



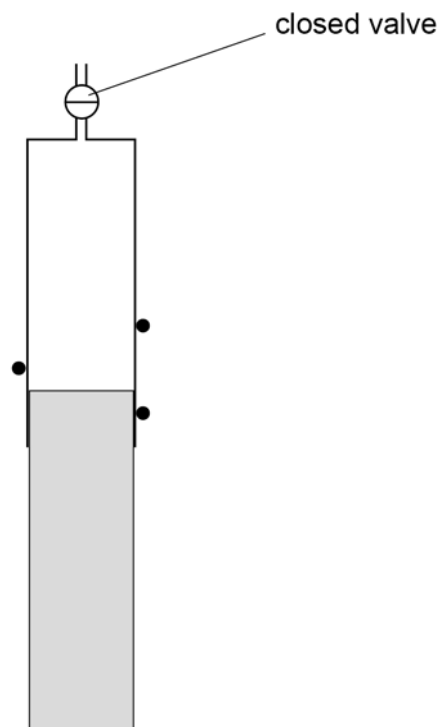
Question 4 continues on the next page

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0 4 . 2

The masses are removed and the cylinder is inverted.
P moves downwards without friction before coming to rest, as shown in **Figure 11**.

Figure 11

Explain why **P** does not fall out of the cylinder unless the valve is opened.

[3 marks]

As P moves down, the trapped air expands, so its pressure is reduced to below atmospheric pressure.

This pressure difference across $P \times \text{area of } P$ gives an upwards force that balances the weight of P, so P is in equilibrium.

When the valve is opened, air enters, the external and internal pressures equalise, and P falls.



0 4 . 3

The mass of **P** is 0.350 kg.

Deduce y when the cylinder is in the inverted position shown in **Figure 11**.

Draw a line of best fit on **Figure 10** to arrive at your answer.

[4 marks]

Upright, the weight of P (0.350 kg) adds to the load M on the air.

Inverted, the weight of P acts in the opposite direction (pulls P out),

so this is equivalent to $M = 0 - 2 \times 0.350 = -0.70$ kg on Figure 10.

Smooth curve through all six points extrapolated back to $M = -0.70$ kg

gives $y = 112$ mm

$y =$ 112 mm

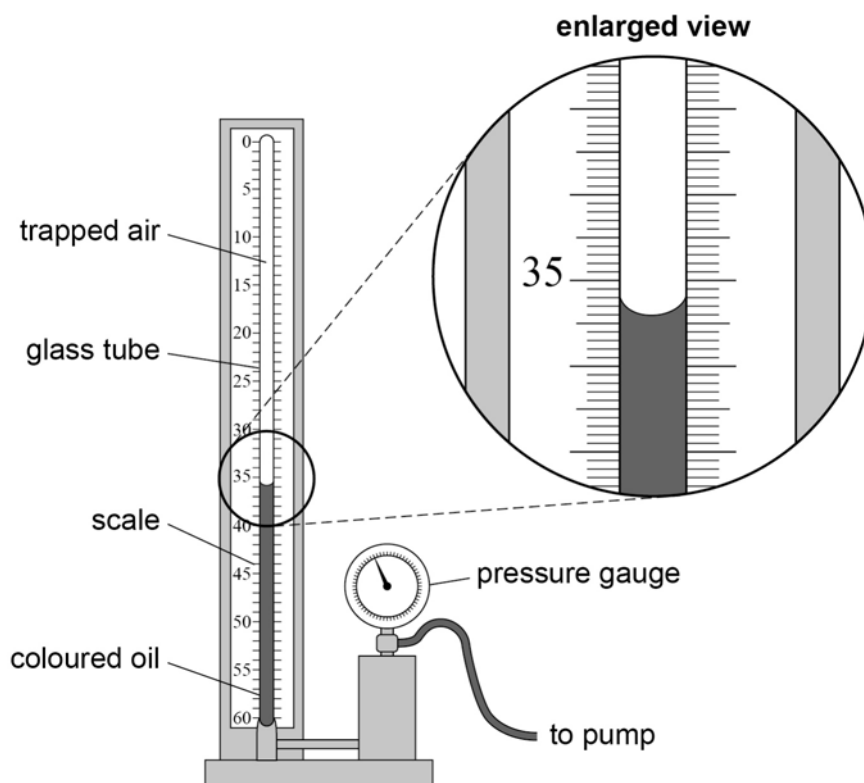
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Figure 12 shows apparatus used in schools to investigate Boyle's law.

Figure 12



A fixed mass of air is trapped above some coloured oil inside a glass tube, closed at the top.

A pump applies pressure to the oil and the air.

The trapped air is compressed and its pressure p is read from the pressure gauge.

0 4 . 4

A scale, marked in 0.2 cm^3 intervals, is used to measure the volume V of the air. A student says that the reading for V shown in **Figure 12** is 35.4 cm^3 .

State:

- the error the student has made
- the correct reading, in cm^3 , of the volume.

[2 marks]

The student has read the scale at the top of the meniscus (the top of the coloured oil) instead of at the bottom (lowest point) of the meniscus.

volume = 35.8 cm^3

Question 4 continues on the next page

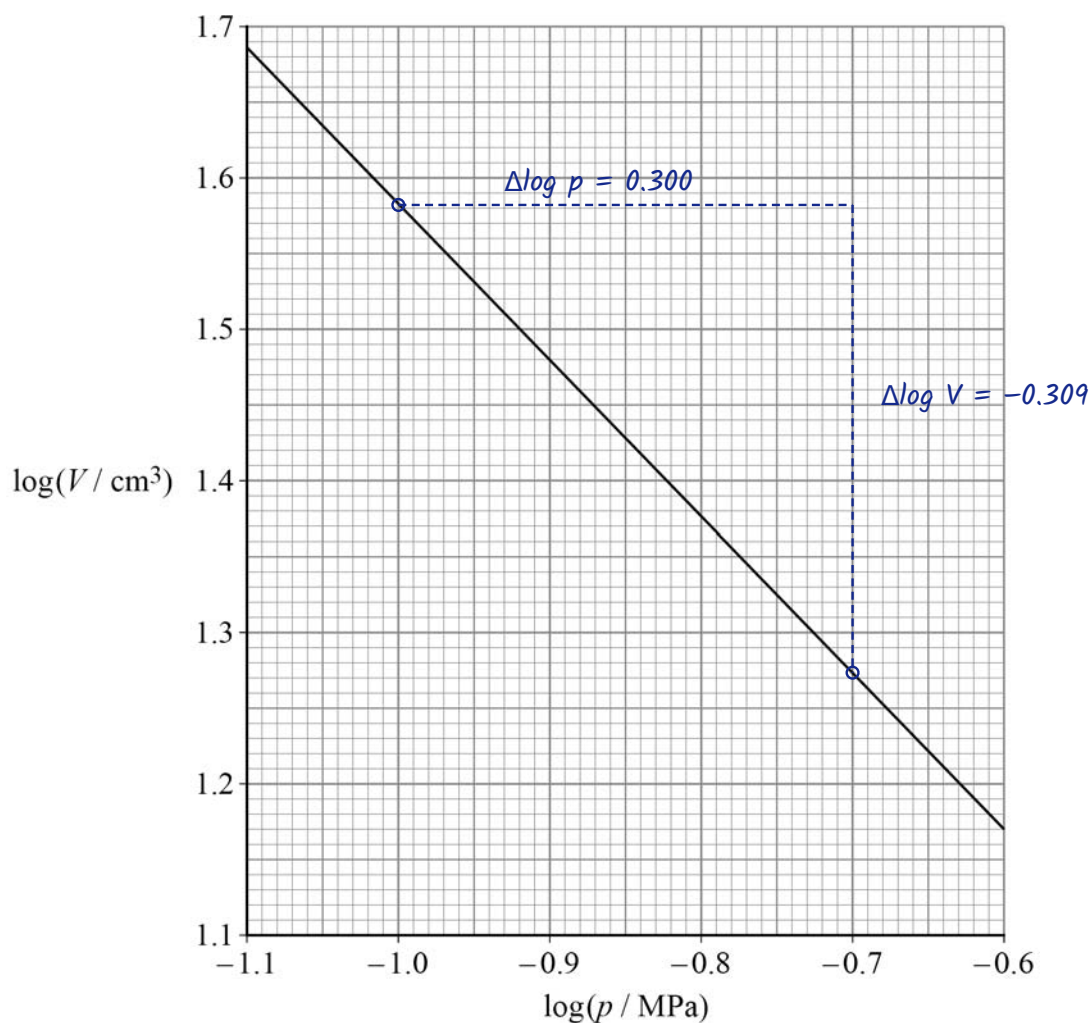
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0 4 . 5

Figure 13 shows data obtained using the apparatus in Figure 12.

Figure 13



Explain why the gradient of the graph in **Figure 13** confirms that the air obeys Boyle's law.

[3 marks]

$$\begin{aligned} \text{gradient} &= \Delta \log V \div \Delta \log p = (1.273 - 1.582) \div (-0.700 - (-1.000)) \\ &= -0.309 \div 0.300 = -1.03 \end{aligned}$$

Boyle's law: $pV = k$, so $\log V = -\log p + \log k$; compare with $y = mx + c$
so $\log V$ against $\log p$ should be a straight line of gradient -1 .

The gradient is $-1.03 \approx -1$, so $V \propto 1/p$ (V is inversely proportional to p)
and pV is constant: the air obeys Boyle's law.



0 4 . 6

The largest pressure that can be read from the pressure gauge is 3.4×10^5 Pa.

Determine, using **Figure 13**, the volume V corresponding to this pressure.

[3 marks]

$$p = 3.4 \times 10^5 \text{ Pa} = 0.34 \text{ MPa, so } \log(p/\text{MPa}) = \log 0.34 = -0.469$$

Read from line in Figure 13: at $\log p = -0.600$, $\log V = 1.170$

Gradient = -1.03 , so $\log V = 1.170 + (-1.03) \times (-0.469 - (-0.600))$

$$\log V = 1.170 - 1.03 \times 0.131 = 1.170 - 0.135 = 1.035$$

$$V = 10^{1.035} = 10.8 \text{ cm}^3$$

$$V = \underline{\quad 10.8 \quad} \text{ cm}^3$$

0 4 . 7

State **one** property of the air that must not change during the experiment.
Go on to suggest how this can be achieved.

[2 marks]

The temperature of the air must not change.

Change the pressure slowly, and wait after each change until the oil level stabilises before taking the reading, so the air returns to room temperature.

END OF QUESTIONS



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