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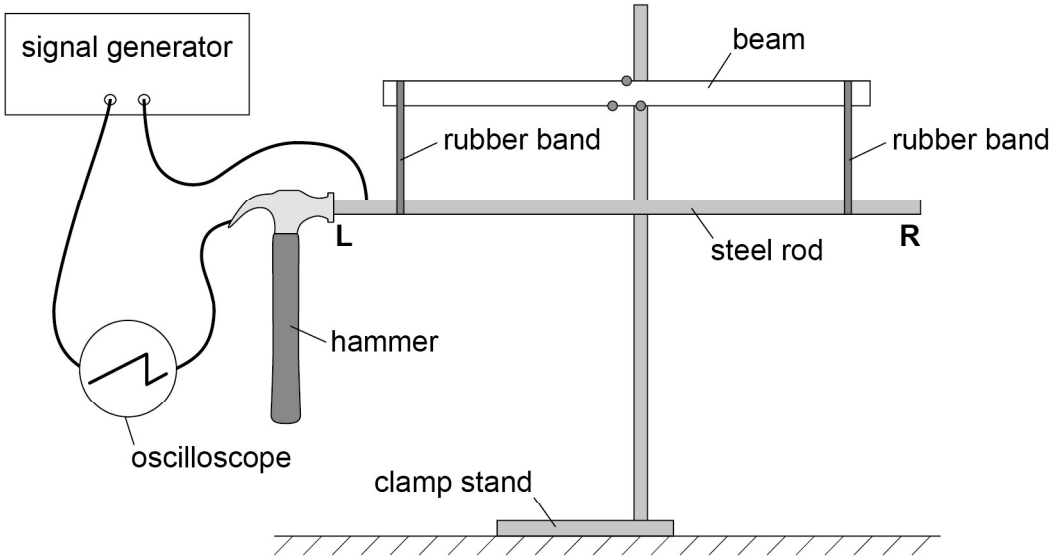
## Section A

Answer **all** questions in this section.

**0 1** **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.

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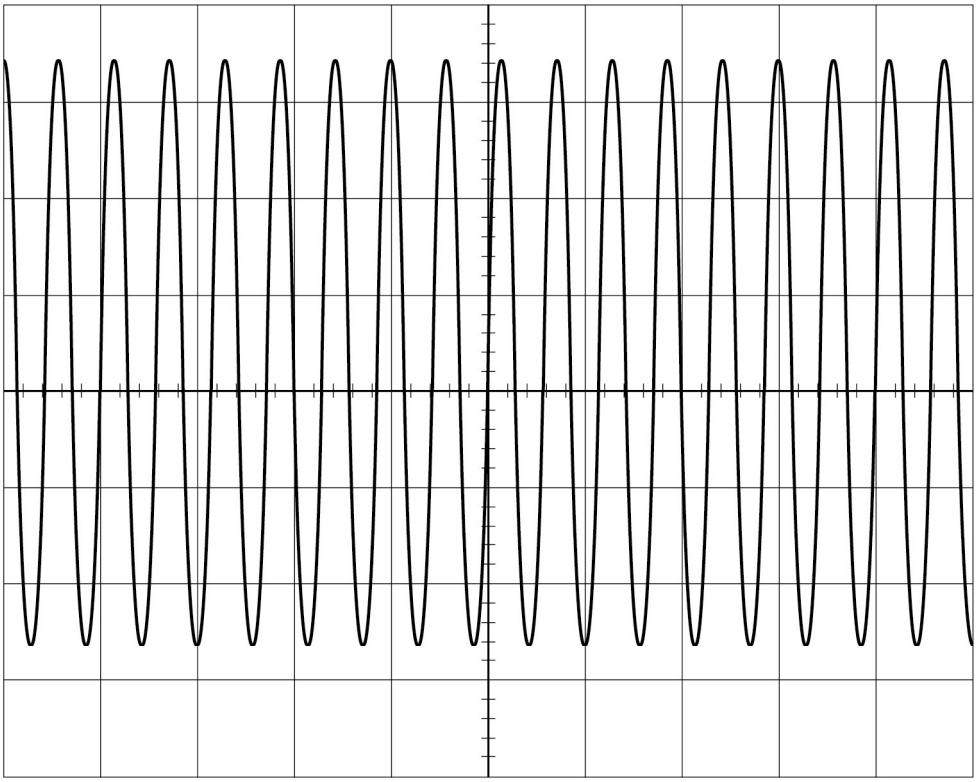
**Figure 2**



**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**

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**

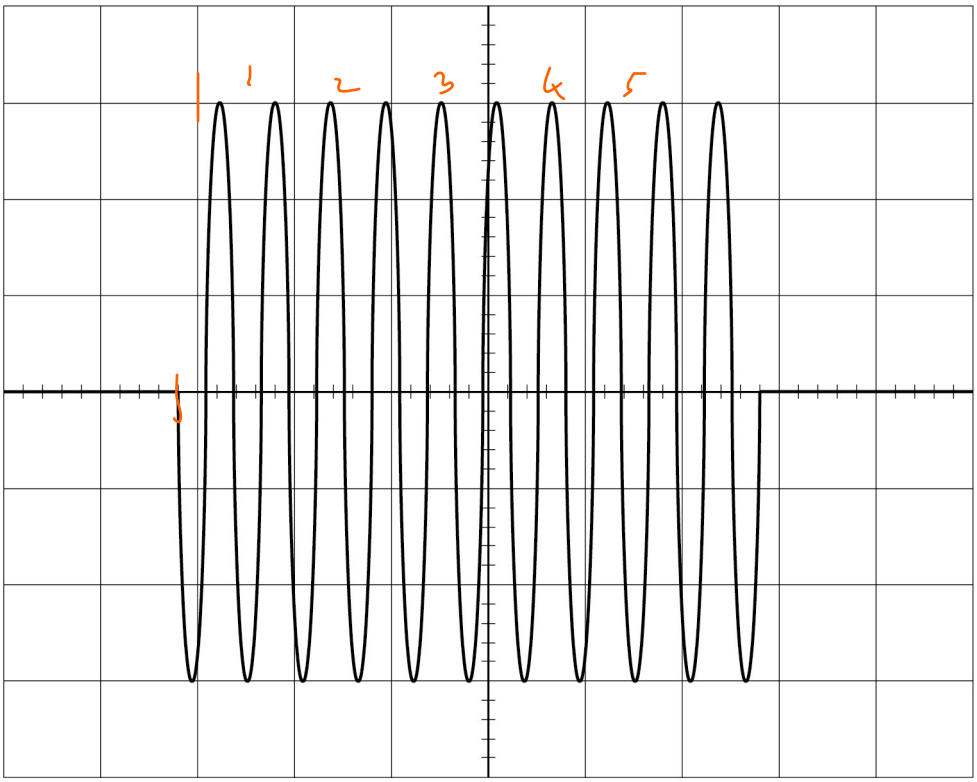
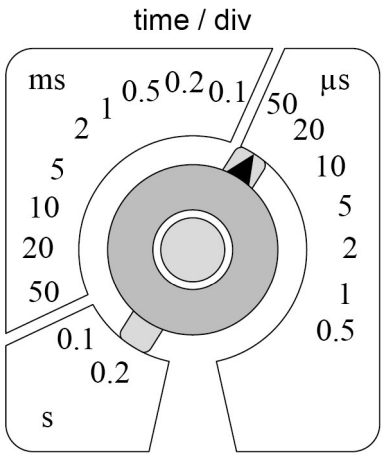



**Figure 4** shows the time-base setting of the oscilloscope.

**Figure 4**



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**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]**

Distance = 2 × 0.87

Contact time = 6 div at 50 μs/div

$\therefore s = \frac{d}{t} = \frac{2 \times 0.87}{6 \times 50 \times 10^{-6}} = 5800$ m/s

speed of sound = _____ 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 time to travel will be twice as long which will be 12 divisions in the x direction

The waveform will go off the screen

therefore need to reduce the time base to 0.1 ms, so the 'dot' moves slower and the waveform fits on the screen again.

note - they refer to it as 'waveform' and penalise 'trace' for some reason

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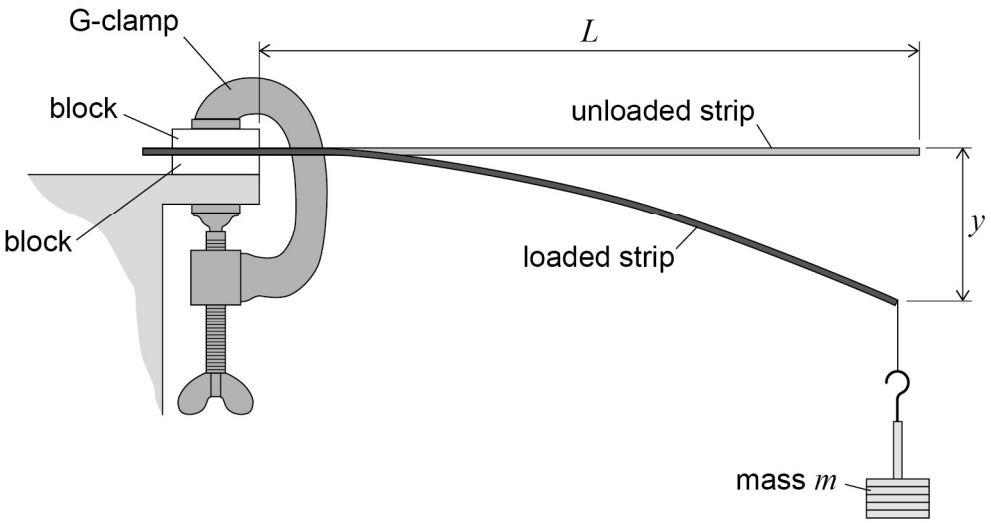
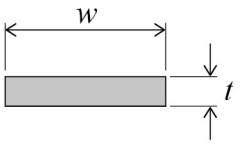
**0 2** **Figure 5** shows a strip of steel of rectangular cross-section clamped at one end. The strip extends horizontally over the edge of a bench.

**Figure 5**




end view of unloaded steel strip



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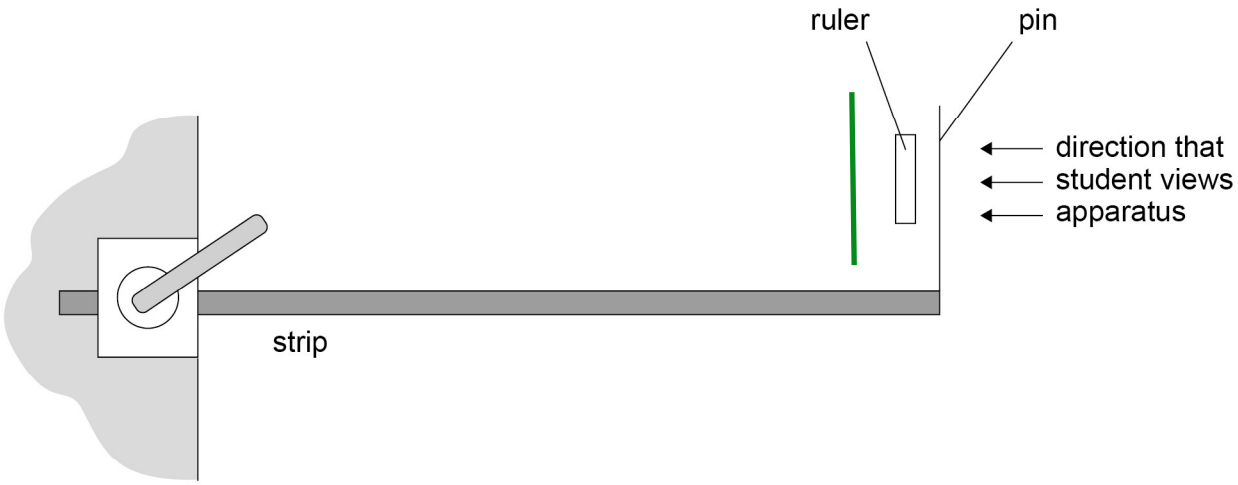
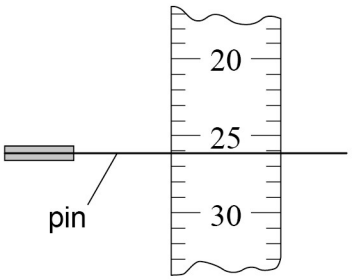
**0 2 . 1** A mass $m$ is suspended from the free end of the strip.
This produces a vertical displacement $y$.
A student intends to measure $y$ with the aid of a horizontal pin fixed to the free end of the steel strip.
She positions a clamped vertical ruler behind the pin, as shown in **Figure 6**.

**Figure 6**

**plan view**




**view seen by student**

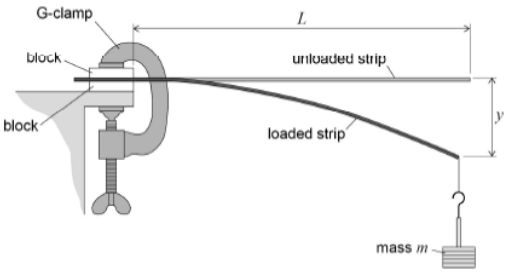



Explain a procedure to avoid parallax error when judging the reading indicated by the position of the pin on the ruler.
You may add detail to **Figure 6** to illustrate your answer.

**[2 marks]**

put a mirror brhind the rular. You can then move your head so the pin and its reflection line up

**Question 2 continues on the next page**

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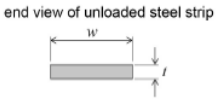
**0 2 . 2** It can be shown that

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




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 $1\ \text{cm}$
$t$ is the thickness of the strip and is approximately $1\ \text{mm}$
$E$ 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 $30\ \text{cm}$ is available
- $m$ must be made using a $50\ \text{g}$ mass hanger and up to four additional $50\ \text{g}$ 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]**

m is independent variable, y is dependent

controls are L, W& t

vary mass in steps of 50g & measure y. Repeat & get averages

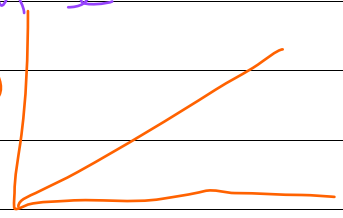
use a ruler for L & micrometer for w & t.

could vary L & keep m constant

$y = \frac{4mgL^3}{EwL^3}$ $\frac{4gL^3}{EwL^3}$ is cont

$y = mx$

So




$\text{grad} = \frac{4gL^3}{EwL^3}$

$\therefore E = \frac{4gL^3}{\text{grad}\, wL^3}$

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7

**Turn over for the next question**

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**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 putty is easily deformed by the callipers

**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]**

av $d$ = 33.8 mm

range = $\frac{34.5 - 32.9}{2}$ = 0.8 mm

$\therefore$ % = $\frac{0.8}{33.8} \times 100$ = 2.37%

3 sf

≈ 2.4%

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**0 3 . 3** The length of the cylinder is $71 \pm 2$ mm.

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

**[4 marks]**

$d = 33.8 \pm 2.37\%$ $\quad \frac{2}{71} \times 100 = 2.82\%$

$V = \pi \left(\frac{d}{2}\right)^2 L = 6.37 \times 10^5$

uncert $= 2 \times 2.37 + 2.82 = 7.56\%$

$\therefore \Delta b = \frac{7.56}{100} \times 6.37 \times 10^5$

uncertainty = $4.81 \times 10^3$ $mm^3$

**Question 3 continues on the next page**

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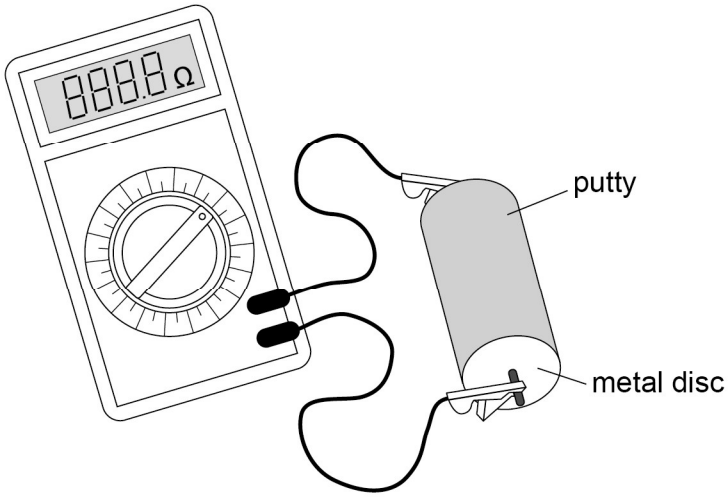
**0 3 . 4** A student is given some putty to form into cylinders.

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 $R = \dfrac{\rho L^2}{5.83 \times 10^{-5}}$ where $\rho$ is the resistivity of the conductive putty.

The student plots the graph shown in **Figure 8**.

Determine $\rho$.
State an appropriate SI unit for your answer.

**[4 marks]**

$\rho$ = _____ unit = _____

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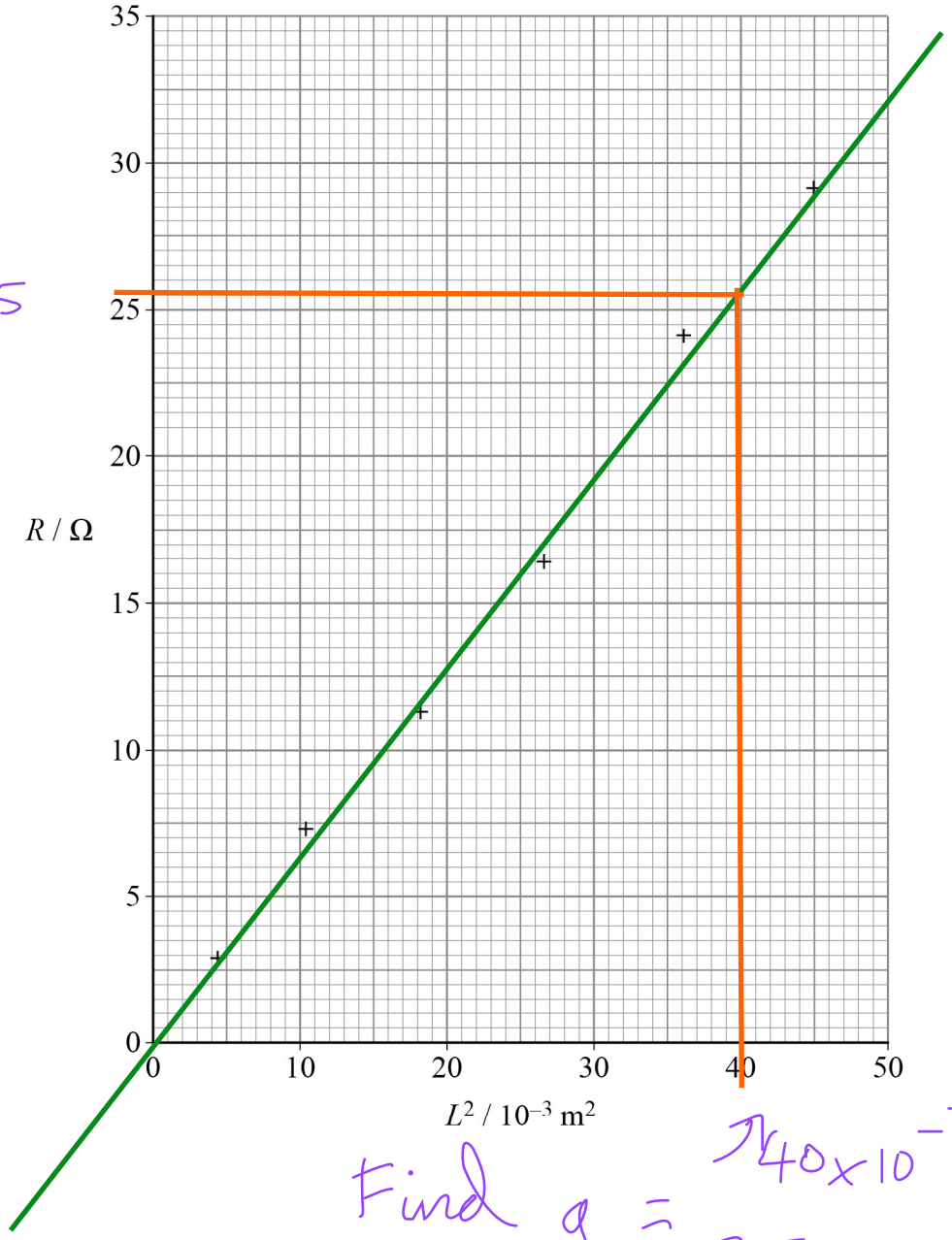
**Figure 8**




25.5

Find $g = \frac{25.5}{40 \times 10^{-3}} = 637.5$

11

**Turn over for the next question**

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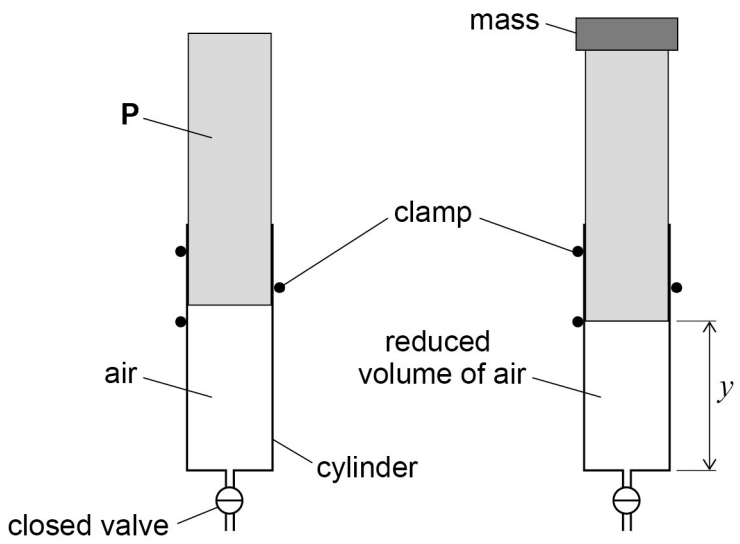
**0 4** **Figure 9** shows air trapped in a vertical cylinder by a valve and a piston **P**.
The valve remains closed throughout the experiment.

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]**

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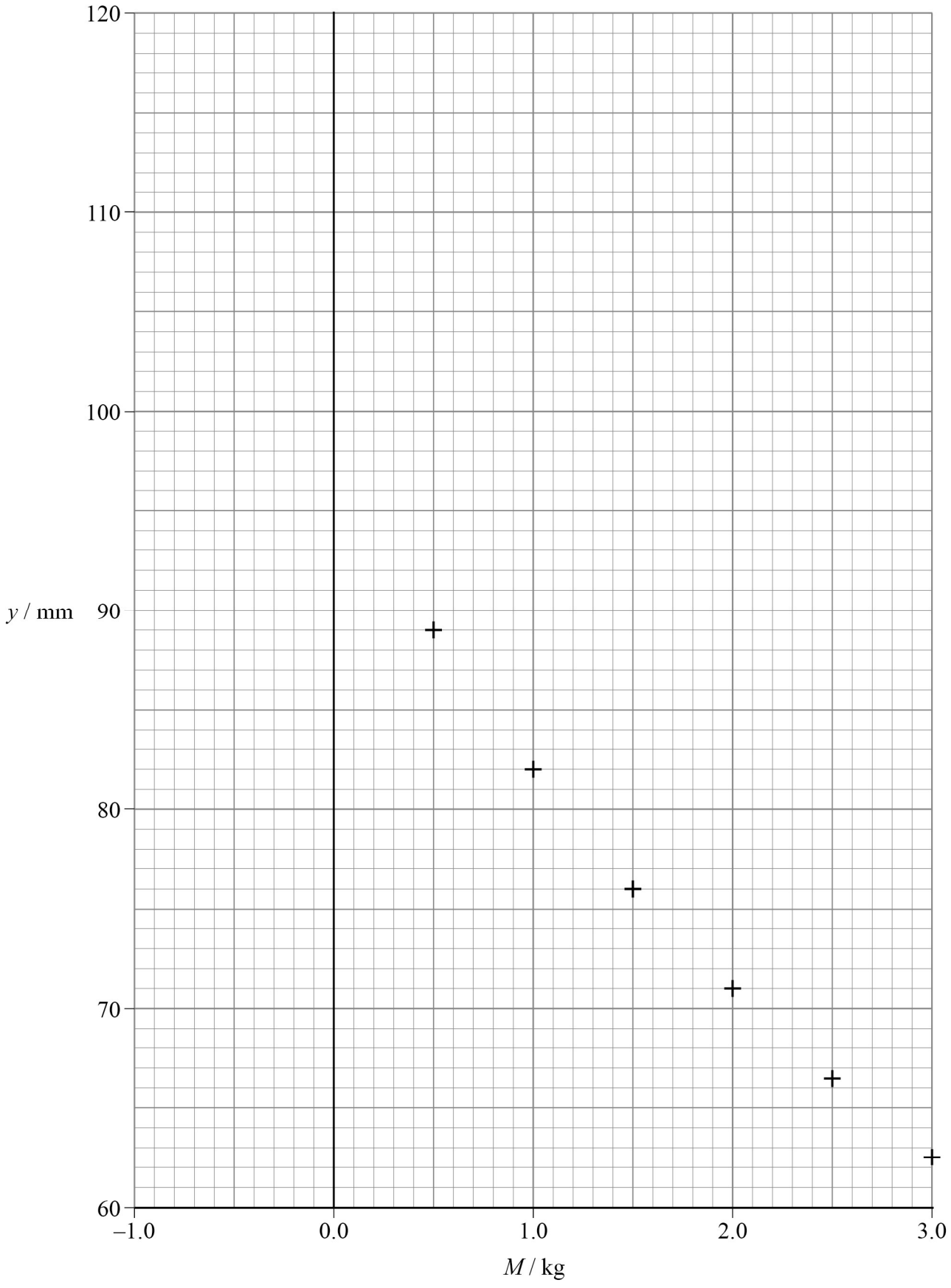
**Figure 10**




**Question 4 continues on the next page**

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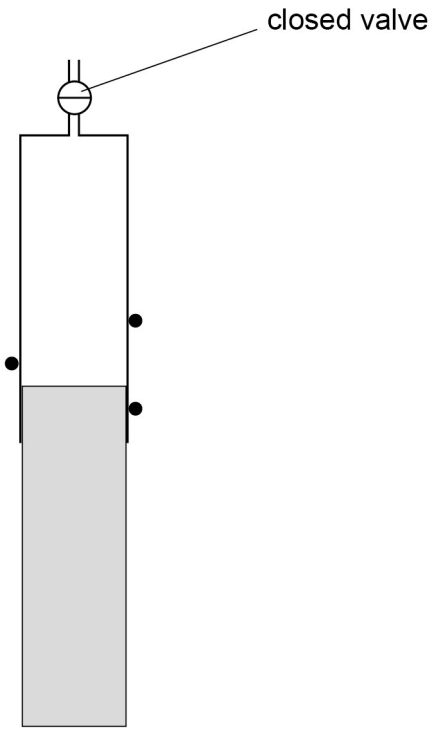
**0 4 . 2** The masses are removed and the cylinder is inverted.
**P** moves downwards without friction before coming to rest, as shown in **Figure 11**.

**Figure 11**




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

**[3 marks]**

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**0 4 . 3** The mass of **P** is $0.350\ \text{kg}$.

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]**

$y =$ _____ mm

**Question 4 continues on the next page**

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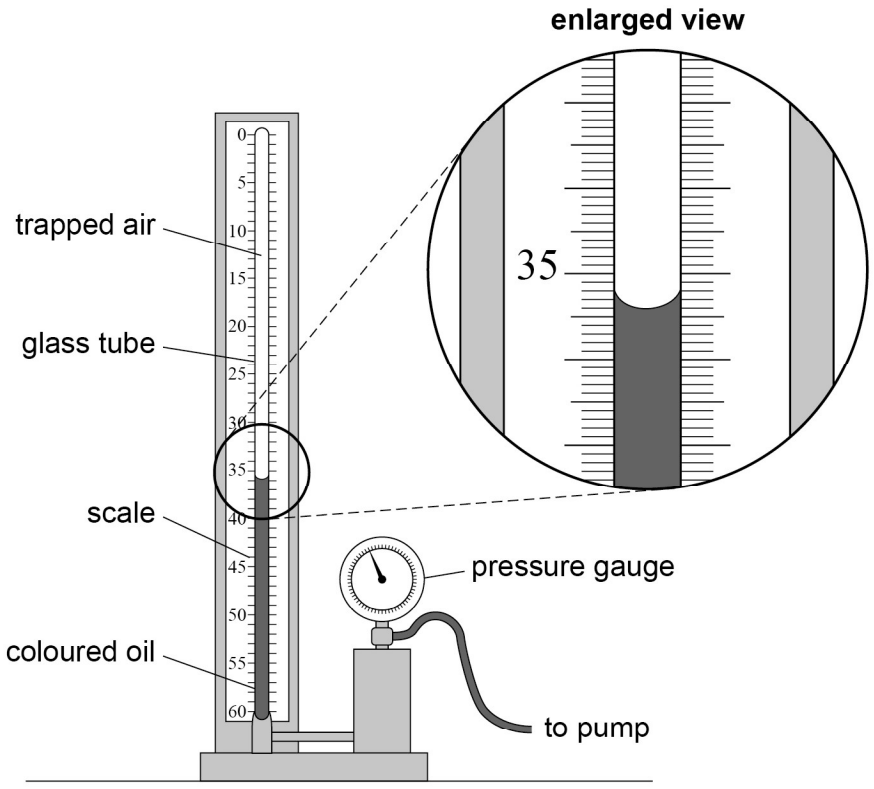
**Figure 12** shows apparatus used in schools to investigate Boyle's law.

**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.

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**0 4 . 4** A scale, marked in $0.2\ \text{cm}^3$ intervals, is used to measure the volume $V$ of the air.
A student says that the reading for $V$ shown in **Figure 12** is $35.4\ \text{cm}^3$.

State:

- the error the student has made
- the correct reading, in $\text{cm}^3$, of the volume.

**[2 marks]**

volume = _____ $\text{cm}^3$

**Question 4 continues on the next page**

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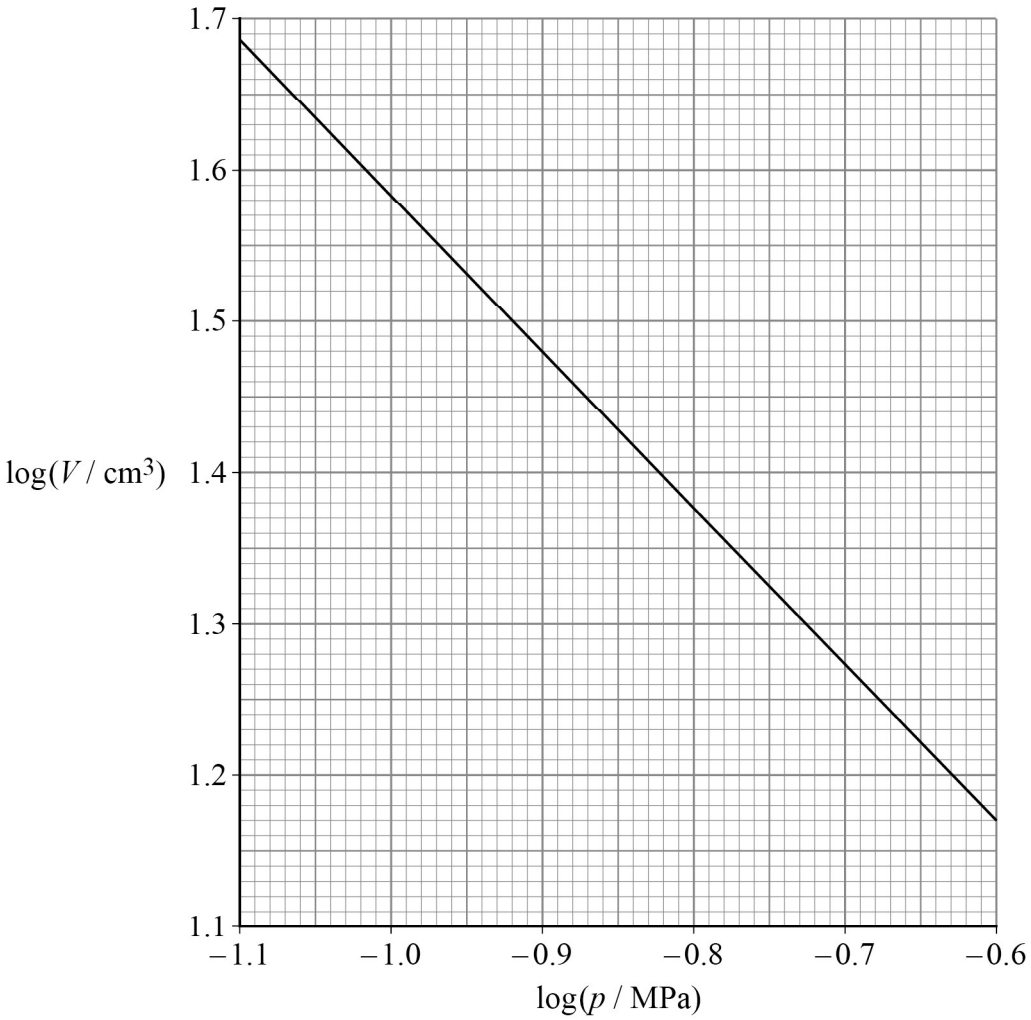
**0 4 . 5** **Figure 13** shows data obtained using the apparatus in **Figure 12**.

**Figure 13**




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

**[3 marks]**

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**0 4 . 6** The largest pressure that can be read from the pressure gauge is $3.4 \times 10^5$ Pa.

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

**[3 marks]**

$V =$ _____ $\text{cm}^3$

**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]**

_____

_____

_____

_____

_____

_____

19

**END OF QUESTIONS**

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**ANSWER IN THE SPACES PROVIDED**

the time to travel will be twice as long which will be 12 divisions in the x direction

The trace will go off the screen

therefore need to reduce the time base contro0.1ms

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| Question number | **Additional page, if required.**<br>**Write the question numbers in the left-hand margin.** |
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