AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

# A-level PHYSICS

Paper 3
Section A

Monday 3 June 2019 Afternoon

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.

**Materials**
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet.

**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.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- 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).
- Show all your working.

| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| **TOTAL** | |

**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.

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## Section A

Answer **all** questions in this section.

**0 1** **Figure 1** shows a sealed radioactive source used in schools and colleges.

**Figure 1**

**0 1 . 1** State **two** safety procedures to reduce risk when using this type of source.

**[2 marks]**

Safety procedure 1 _____

Safety procedure 2 _____

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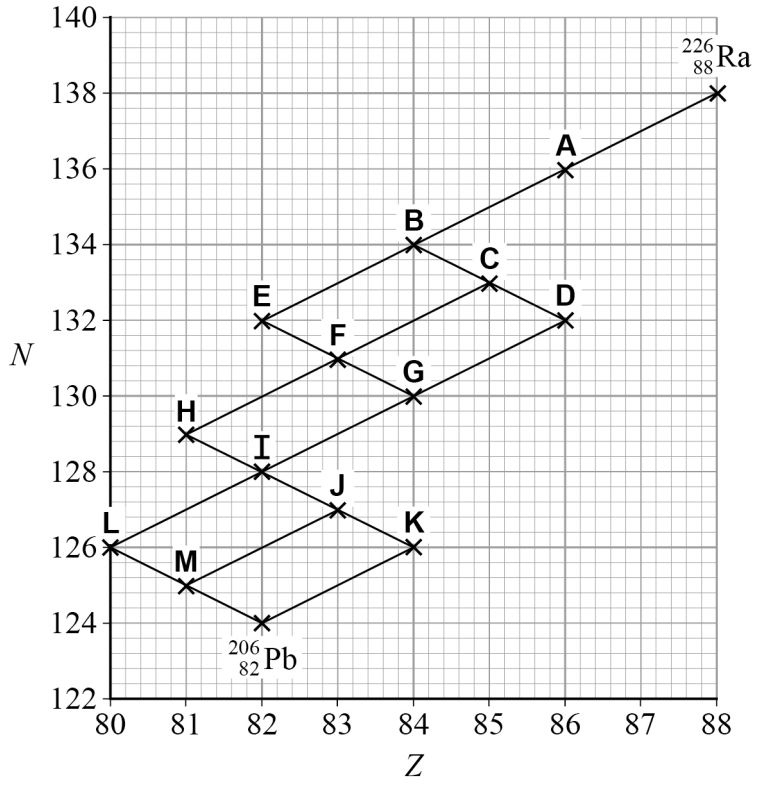
**0 1 . 2** A sealed source contains radium-226 ( $^{226}_{88}\mathrm{Ra}$ ).

$^{226}_{88}\mathrm{Ra}$ decays by emitting $\alpha$ and $\beta^-$ particles to produce $^{206}_{82}\mathrm{Pb}$ which is stable.

**Figure 2** is a graph of neutron number $N$ against proton number $Z$, showing the different ways that $^{226}_{88}\mathrm{Ra}$ can decay into $^{206}_{82}\mathrm{Pb}$.

Points **A** to **M** represent all the unstable nuclei that may be formed as $^{226}_{88}\mathrm{Ra}$ decays into $^{206}_{82}\mathrm{Pb}$.

**Figure 2**




Determine the number of routes by which **B** can change into **K**.

**[1 mark]**

**0 1 . 3** Identify which of the nuclei **A** to **M** are common to all the possible ways that $^{226}_{88}\mathrm{Ra}$ decays into $^{206}_{82}\mathrm{Pb}$.

**[3 marks]**

**Question 1 continues on the next page**

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**0 1 . 4** The sealed source emits $\gamma$ radiation in addition to $\alpha$ and $\beta^-$ particles.
A student uses the sealed source to investigate the inverse-square law for $\gamma$ radiation.
The student begins by making measurements to find the count rate $A_b$ for the background radiation.

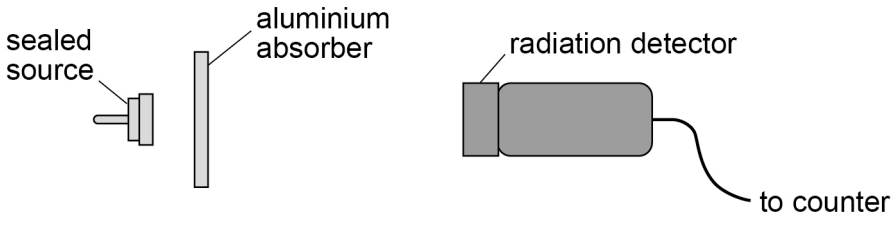
State and explain procedures

- to eliminate systematic error in the measurements used to find $A_b$
- to reduce the percentage uncertainty in $A_b$.

**[3 marks]**

**0 1 . 5** **Figure 3** shows an aluminium absorber placed between the sealed source and a radiation detector. This is to make sure that only $\gamma$ radiation from the source reaches the detector.

**Figure 3**



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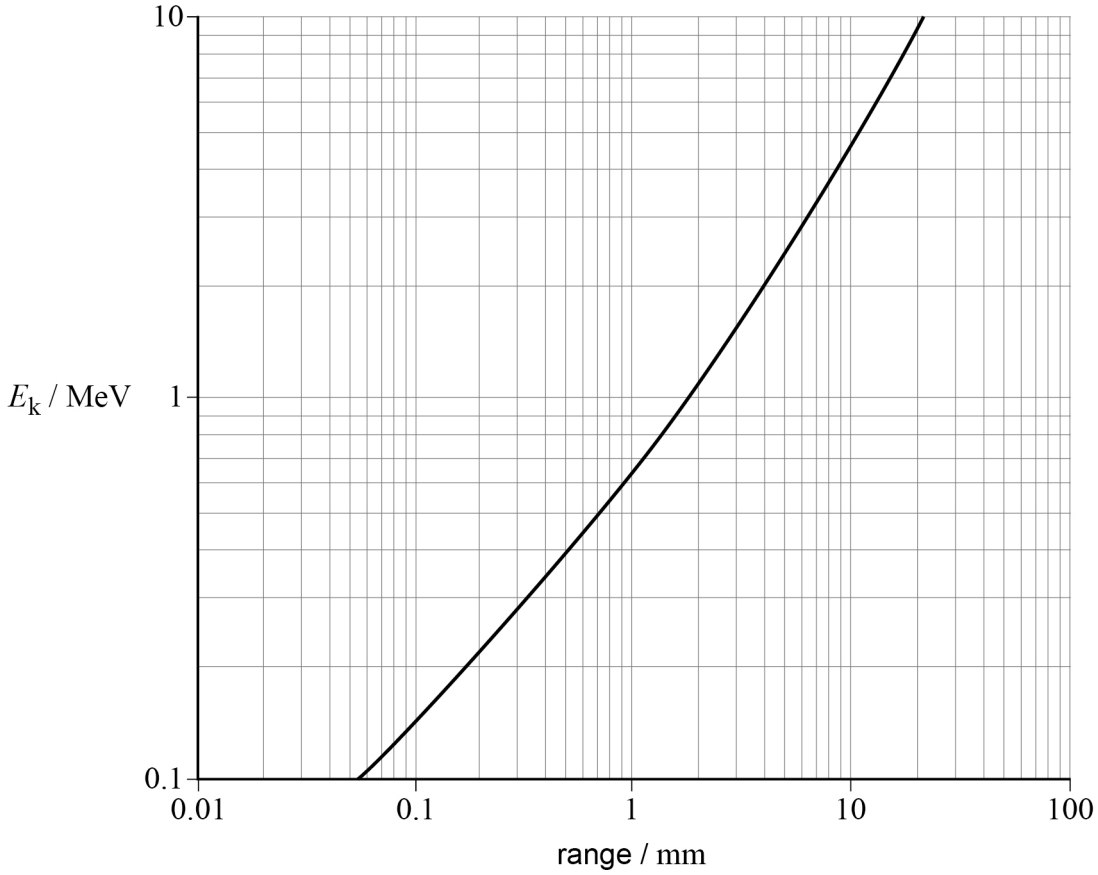
The sealed source emits:

- $\alpha$ particles with energy $E_k$ between $3.8$ MeV and $7.8$ MeV
- $\beta^-$ particles with energy $E_k$ between zero and $5.5$ MeV.

**Figure 4** shows how the range of $\beta^-$ particles in aluminium depends on $E_k$.

**Figure 4**




Deduce the minimum thickness of the aluminium absorber that should be used in the experiment.

**[3 marks]**

minimum thickness = _____ mm

**Question 1 continues on the next page**

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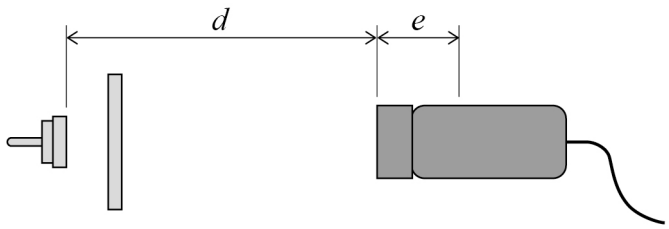
**0 1 . 6** Ionisation takes place inside the detector. The effective distance travelled by γ radiation from the source is $(d + e)$.
The distance $e$, shown in **Figure 5**, cannot be measured directly.

**Figure 5**




From the inverse-square law for γ radiation, it can be shown that

$$(d + e) = \sqrt{\frac{k}{A}}$$

where $A$ is the count rate, corrected for background radiation
$k$ is a constant.

The student plots the graph of $d$ against $\frac{1}{\sqrt{A}}$ shown in **Figure 6**.

Deduce $k$ using **Figure 6**.
Explain your reasoning.
Give a suitable unit for your result.

**[5 marks]**

$k$ = _____ unit _____

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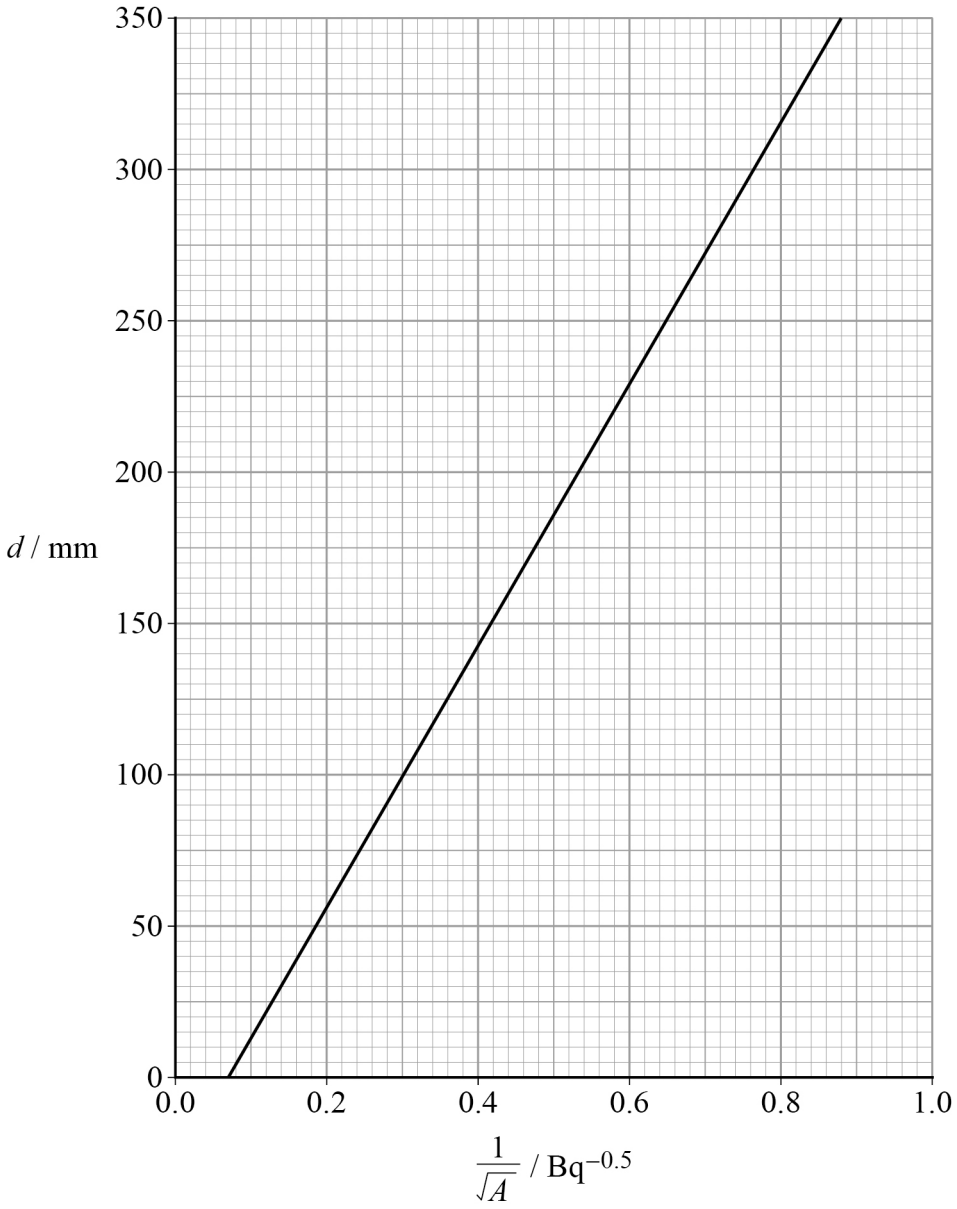
**Figure 6**




**0 1 . 7** Determine $e$ using **Figure 6**.

**[2 marks]**

$e$ = _____ mm

**19**

**Turn over ►**

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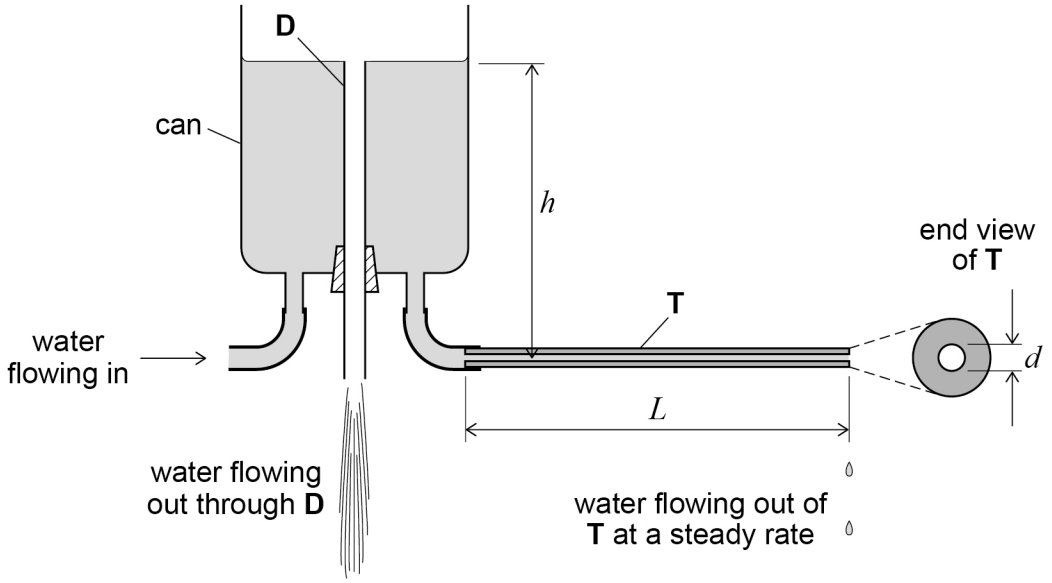
**0 2** **Figure 7** shows apparatus used to investigate the rate at which water flows through a horizontal cylindrical tube **T** of internal diameter $d$ and length $L$.

**Figure 7**




The apparatus ensures that the water level in the can is at a constant height $h$ above the centre of **T**.

Water flows out of **T** at a steady rate.

**0 2 . 1** The volume flow rate through **T** is $Q$, where $Q$ is in $\mathrm{m^3\,s^{-1}}$.
A student wants to measure $Q$ as water flows through **T**.

Outline a procedure the student should follow to measure $Q$.
Include in your answer

- the measuring instruments used
- how uncertainty in the measurements can be reduced.

**[4 marks]**

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

$$Q = \frac{\pi \rho g h d^4}{128 L \eta}$$

where $\rho$ is the density of water
$g$ is the gravitational field strength
$\eta$ is a property of the water called the coefficient of viscosity.

What is the SI unit for $\eta$?
Tick (✓) **one** box.

**[1 mark]**

$\text{N m}^{-1}\text{ s}$ ☐

$\text{N m}^{-2}\text{ s}$ ☐

$\text{N m}^{-1}\text{ s}^{-1}$ ☐

$\text{N m}^{-2}\text{ s}^{-1}$ ☐

**Question 2 continues on the next page**

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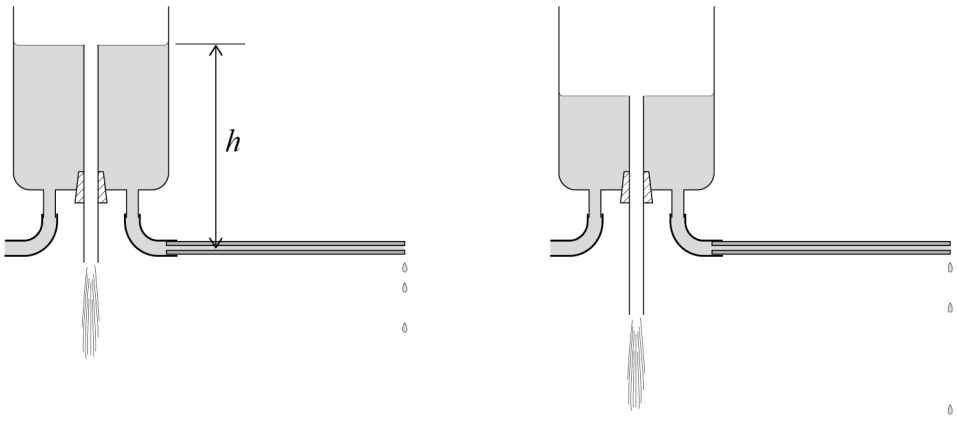
**0 2 . 3** An experiment is carried out to determine $\eta$ by a graphical method.
The rate at which water flows out of **T** is varied by adjusting the height of the drain tube as shown in **Figure 8**.

**Figure 8**




During the experiment the temperature is kept constant.
$Q$ is found for different values of $h$ and a graph of these data is plotted, with $Q$ on the vertical axis.
The percentage uncertainty in the gradient of the graph is $6.4\%$.

The dimensions of tube **T** are measured and the uncertainties in these data are calculated.

The percentage uncertainty
- in $d$ is $2.9\%$
- in $L$ is $1.8\%$.

The percentage uncertainties in $\rho$ and $g$ are negligible.

Deduce the percentage uncertainty in the result for $\eta$.

**[2 marks]**

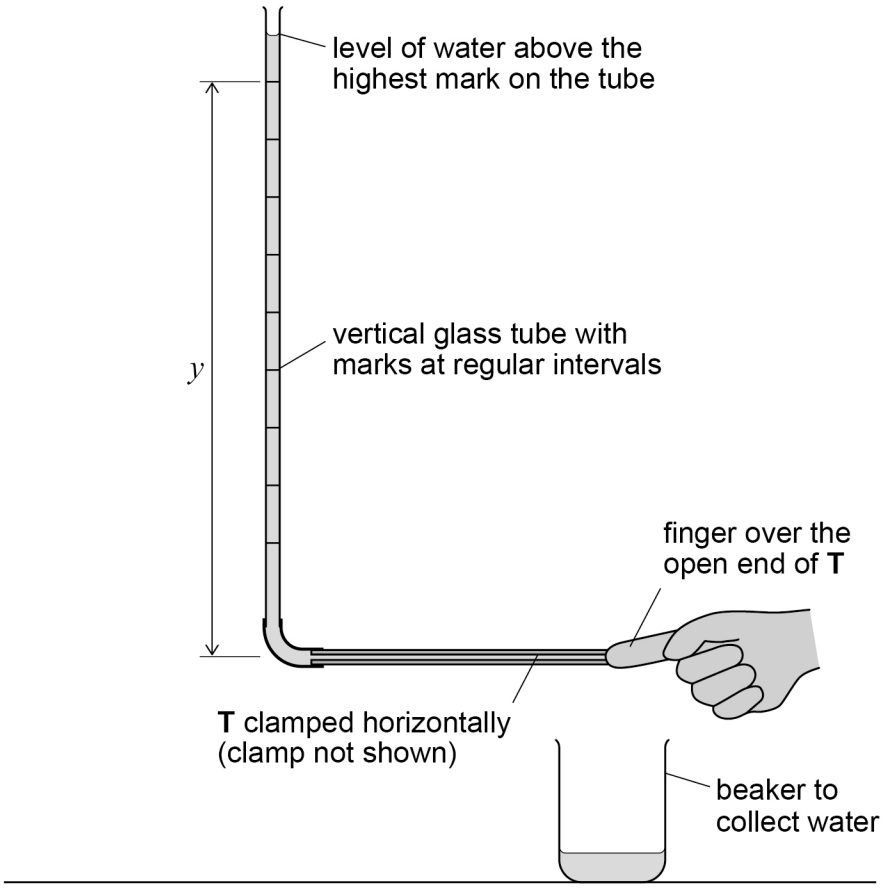
percentage uncertainty in $\eta$ = _____

*Do not write outside the box*

**0 2 . 4** In a different experiment, the horizontal tube **T** is connected to a vertical glass tube. Marks have been made at regular intervals on the glass tube.
The student measures and records the vertical distance $y$ between each of the marks and the centre of **T**.

She seals the open end of **T** and fills the glass tube with water, as shown in **Figure 9**.

**Figure 9**




**T** is opened and water flows into a beaker.
When the water level falls to the highest mark on the tube, she starts a stopwatch.
She records the time $t$ for the water to reach each of the other marks.

Explain how the student could check that the glass tube was vertical.
You may wish to add detail to **Figure 9** to illustrate your answer.

**[1 mark]**

**Question 2 continues on the next page**

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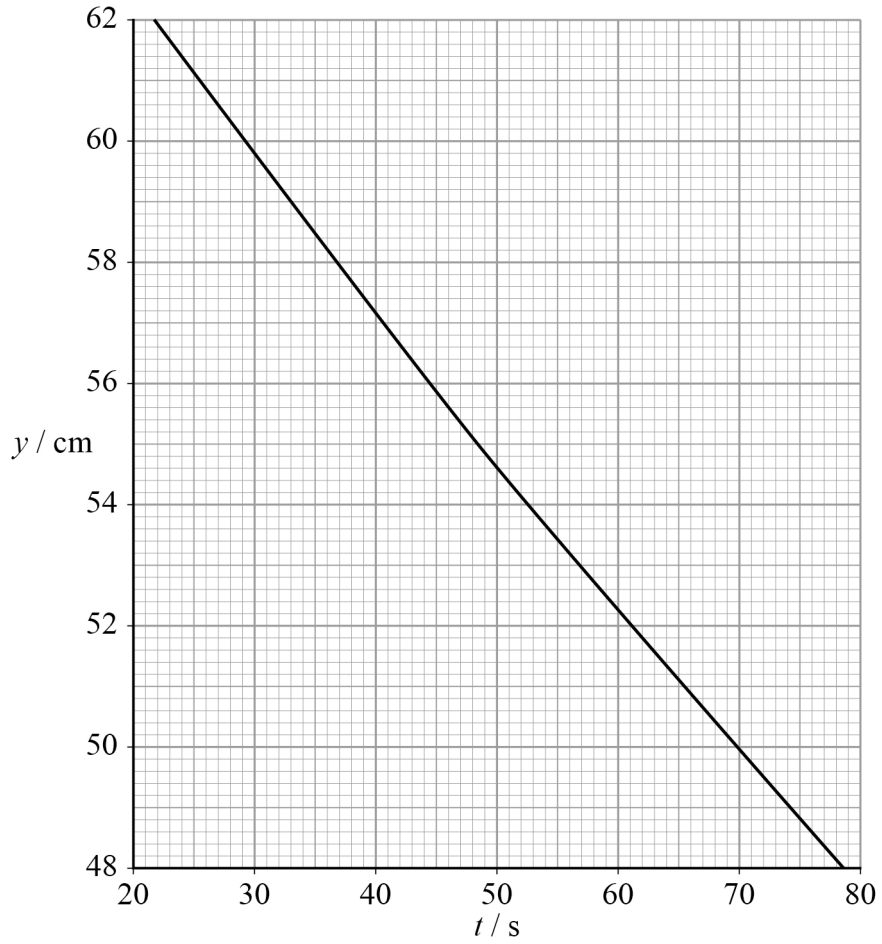
**0 2 . 5** **Figure 10** shows part of the graph drawn from the student's data.

**Figure 10**




It can be shown that $y$ decreases exponentially with $t$.

Show that $\lambda$, the decay constant for this process, is about $4.5 \times 10^{-3}$ $s^{-1}$.

**[2 marks]**

$\lambda$ = _____ $s^{-1}$

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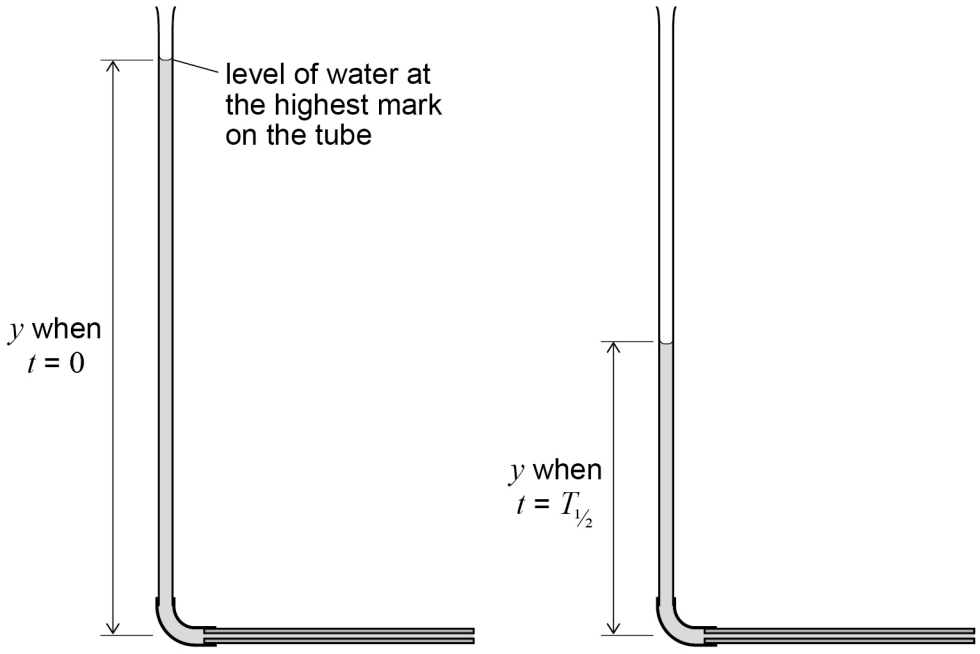
**0 2 . 6** $T_{1/2}$ is the time for $y$ to decrease by $50\%$, as shown in **Figure 11**.

**Figure 11**




Determine $T_{1/2}$.

**[1 mark]**

$T_{1/2}$ = _____ s

**Question 2 continues on the next page**

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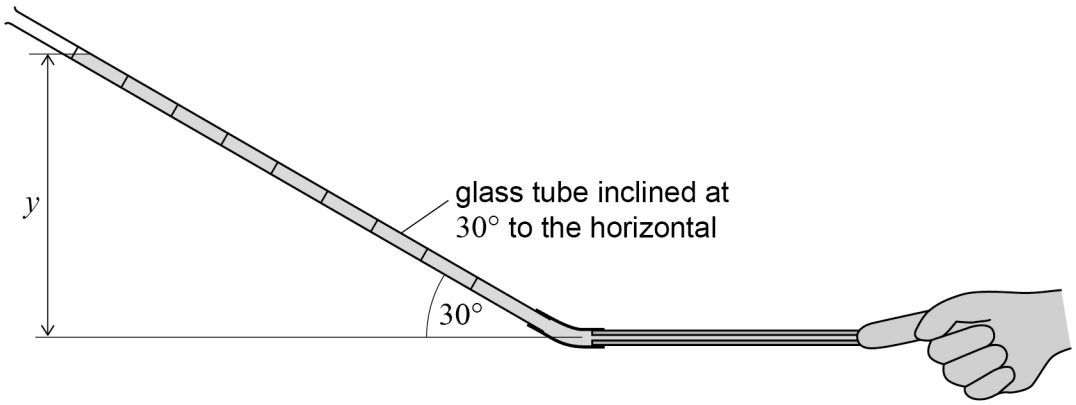
**0 2 . 7** The apparatus is adjusted so that the glass tube is inclined at $30°$ to the horizontal tube **T**, as shown in **Figure 12**.

**Figure 12**




The student measures and records the new values of $y$, the mean vertical distance between each of the marks and the centre of **T**.
She then carries out the experiment as before, recording new values of $t$ corresponding to each new value of $y$.

Draw a line on **Figure 13** to show the graph produced using the modified apparatus. The dashed line is the original graph when the glass tube was vertical as shown in **Figure 9**.

**[2 marks]**

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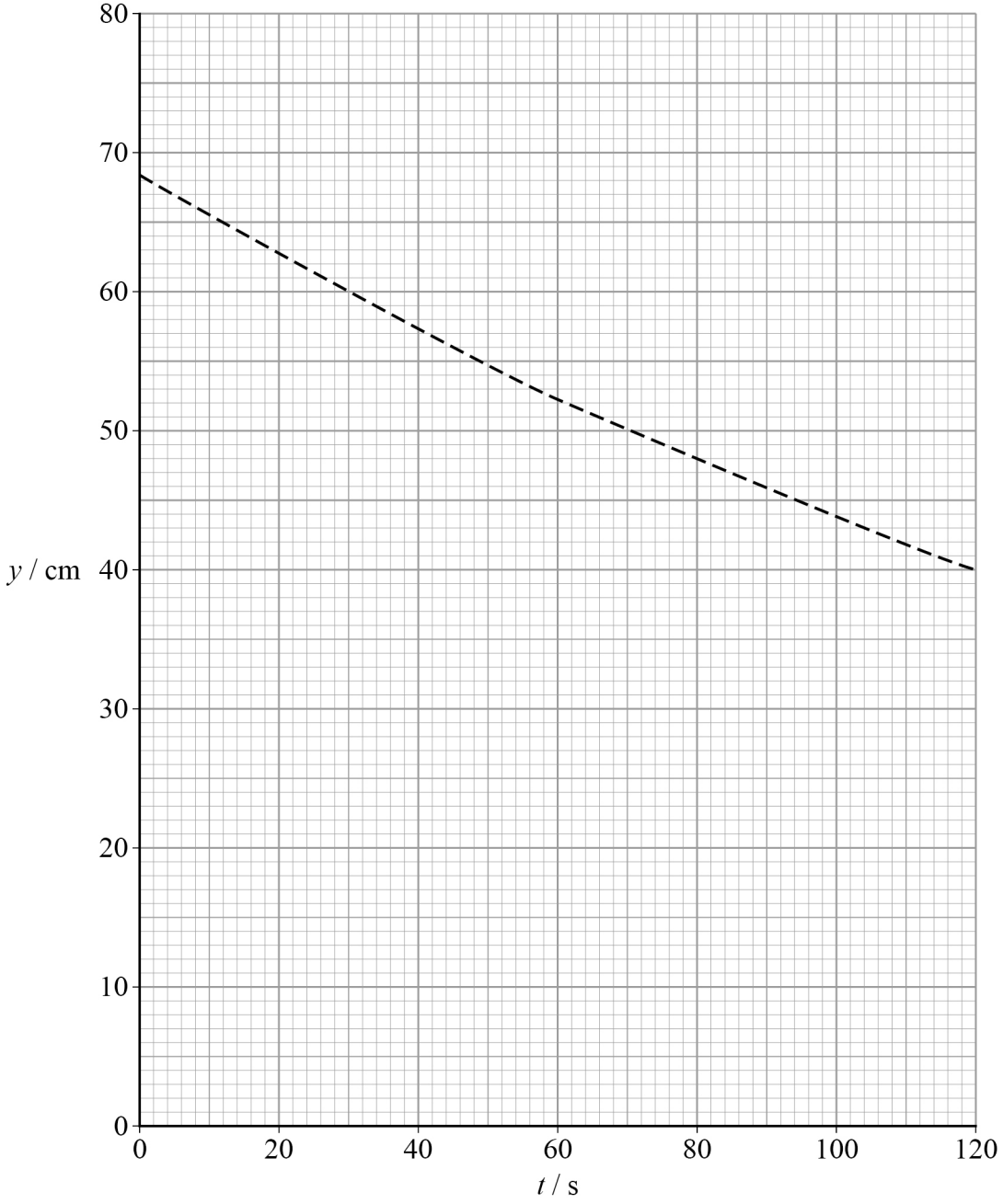
**Figure 13**



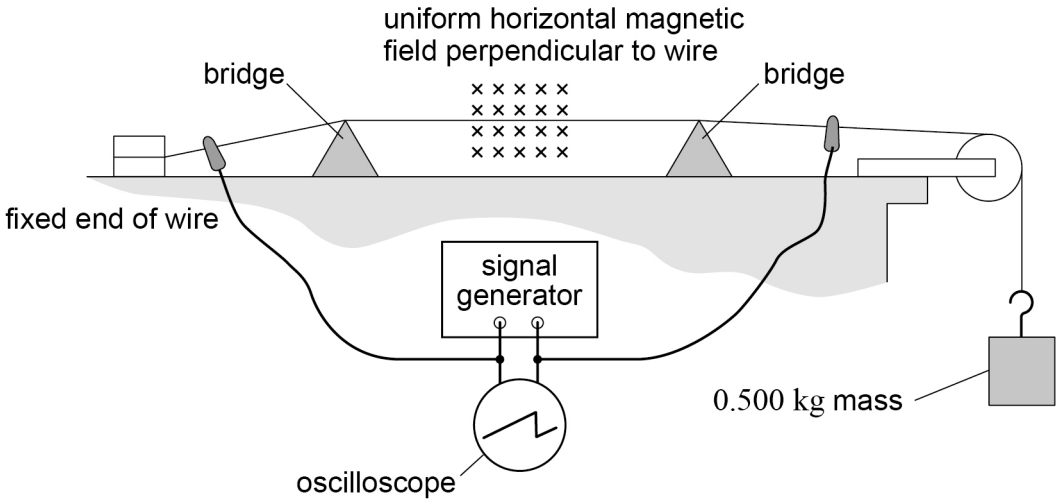

13

**Turn over for the next question**

**0 3** A stationary wave is formed on a stretched wire.

**Figure 14** shows the wire, fixed at one end, supported by two bridges and passing over a pulley.

**Figure 14**

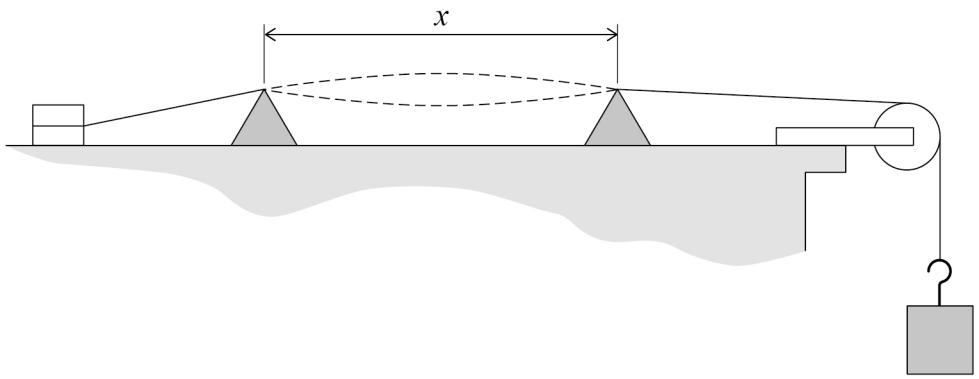



A $0.500\ \text{kg}$ mass is attached to the free end of the wire.
A uniform horizontal magnetic field is applied perpendicular to the wire between the bridges.
A signal generator is connected to each end of the wire.

The oscilloscope shown is used to determine the frequency of the output of the signal generator. The wire oscillates because the alternating current in the wire interacts with the magnetic field.

**Figure 15** shows the first harmonic stationary wave produced when the distance $x$ between the bridges is adjusted.

**Figure 15**



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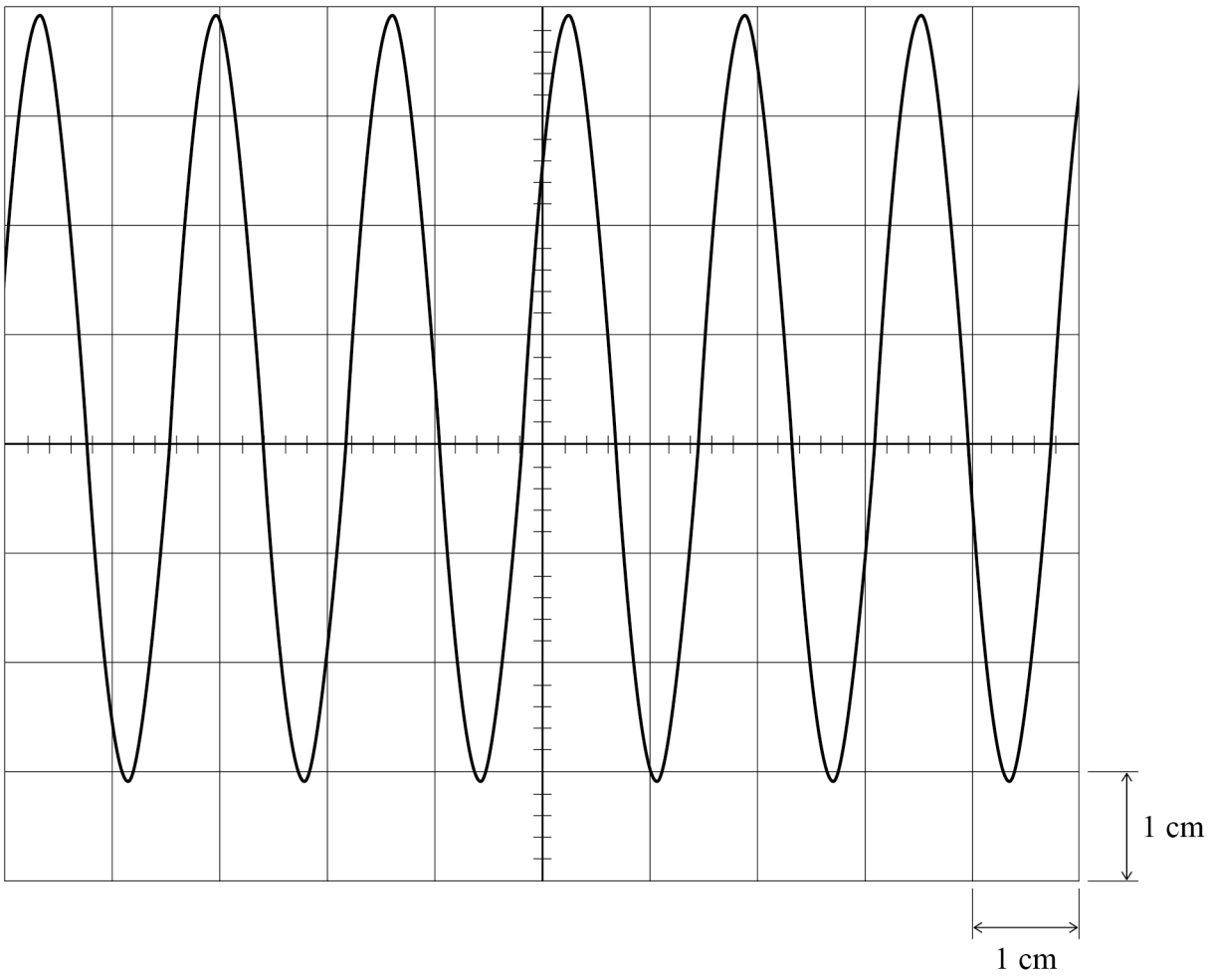
**0 3 . 1** The output potential difference (pd) of the signal generator is displayed on the oscilloscope, as shown in **Figure 16**.

**Figure 16**




The time-base setting of the oscilloscope is $10\ \text{ms cm}^{-1}$.

Determine $f$, the frequency of the alternating pd.

**[2 marks]**

$f$ = _____ Hz

**Question 3 continues on the next page**

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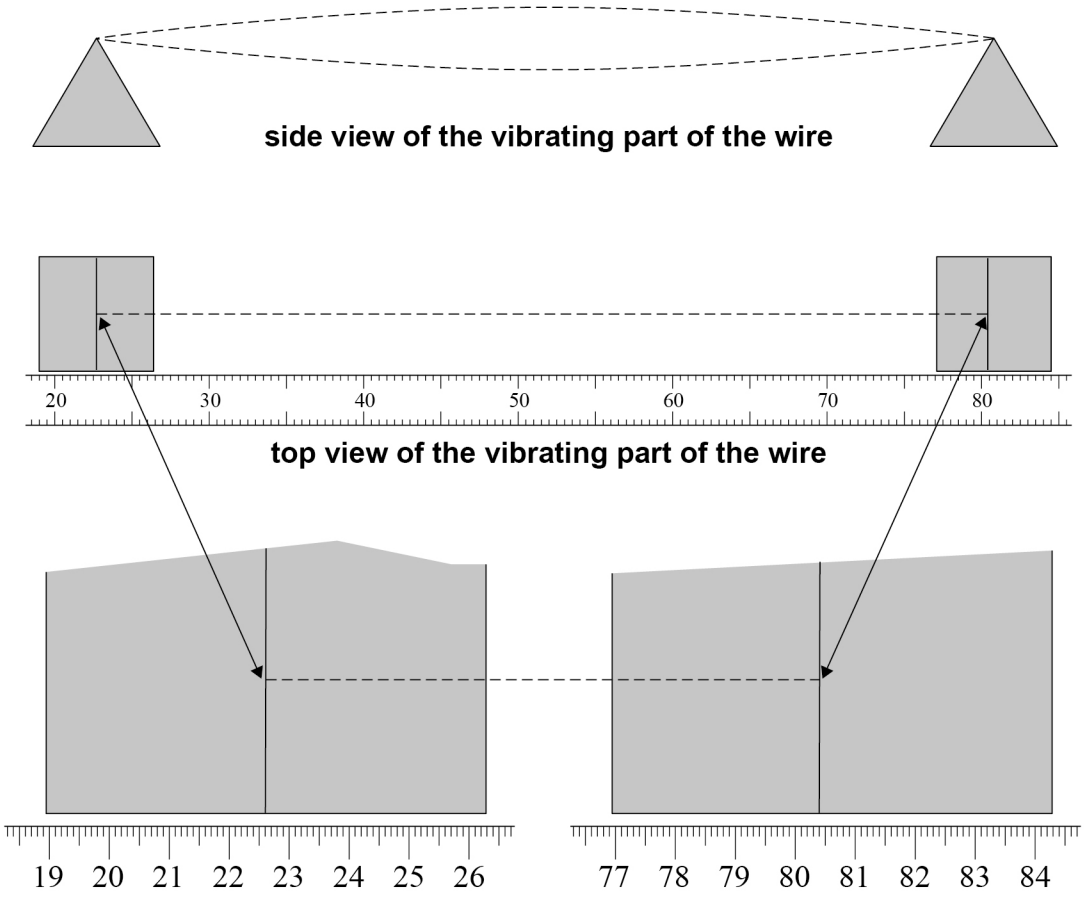
**0 3 . 2** A metre ruler is placed next to the bridges supporting the wire, as shown in **Figure 17**.

**Figure 17**




**enlarged view of the scale on the metre ruler near each bridge**

Determine the wavelength $\lambda$ of the stationary wave shown in **Figure 17**.

**[2 marks]**

$\lambda$ = _____ m

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**0 3 . 3** The stationary wave is formed by two waves of frequency $f$ and wavelength $\lambda$ travelling with speed $c$ in opposite directions.

Determine $c$.

**[1 mark]**

$c$ = _____ $\mathrm{m\ s^{-1}}$

**0 3 . 4** Determine, in $\mathrm{kg\ m^{-1}}$, the mass per unit length of the wire.

**[2 marks]**

mass per unit length = _____ $\mathrm{kg\ m^{-1}}$

**Question 3 continues on the next page**

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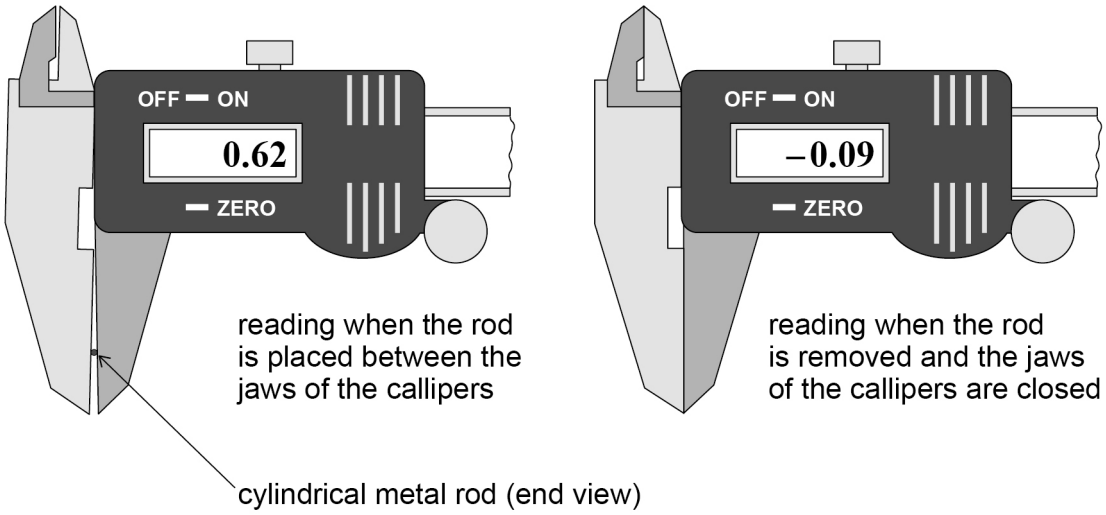
**0 3 . 5** A student uses digital vernier callipers to measure the diameter of a cylindrical metal rod. The student places the rod between the jaws of the callipers and records the reading indicated. Without pressing the zero button, the student removes the rod and closes the jaws.

**Figure 18** shows the calliper readings in millimetres, before and after the jaws are closed.

**Figure 18**




Calculate the diameter $d$ of the rod.

**[1 mark]**

$d$ = _____ mm

**0 3 . 6** Describe relevant procedures to limit the effect of random error in the result for $d$.

**[2 marks]**

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**0 3 . 7** Determine the density of the rod.
The mass per unit length of the rod is $3.54 \times 10^{-3}$ kg m$^{-1}$.

**[3 marks]**

density = _____ kg m$^{-3}$

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**END OF QUESTIONS**

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**ANSWER IN THE SPACES PROVIDED**

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