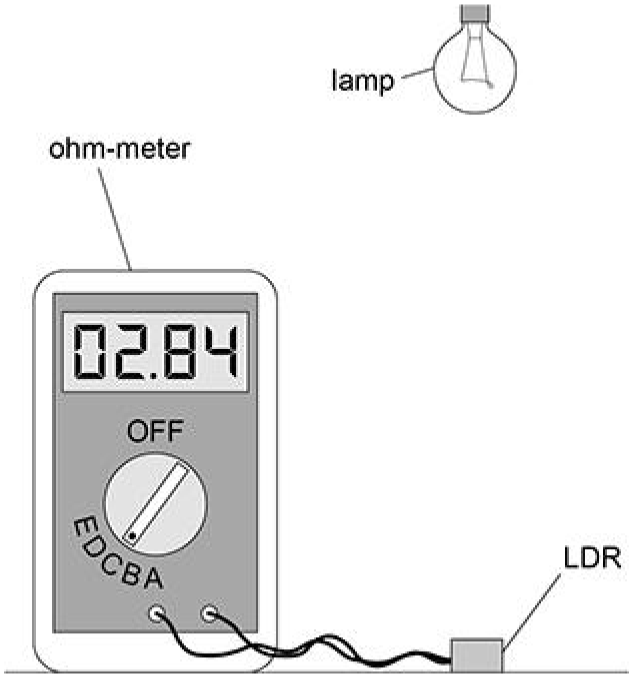
Q1.

Figure 1 shows apparatus used to investigate how the resistance R of a light-dependent resistor (LDR) varies with illumination.

Figure 1



The ohm-meter

- **always** displays a four-digit reading of R
- can be set to the different ranges **A** to **E** shown in **Table 1**.

Table 1

Setting	Maximum reading displayed	Minimum (non-zero) reading displayed	Unit
range **A**	199.9	000.1	Ω
range **B**	1999	0001	Ω
range **C**	19.99	00.01	kΩ
range **D**	199.9	000.1	kΩ
range **E**	1.999	0.001	MΩ

(a) Explain why the reading displayed in **Figure 1** shows that the ohm-meter is set to range **C**.

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(1)

(b) The quantity E_V is a measure of the intensity of the light incident on the LDR.
The SI unit of E_V is the lux (lx).

The resistance R of the LDR is given by

$$\log(R / \Omega) = -0.772 \log(E_V / \text{lx}) + 5.09$$

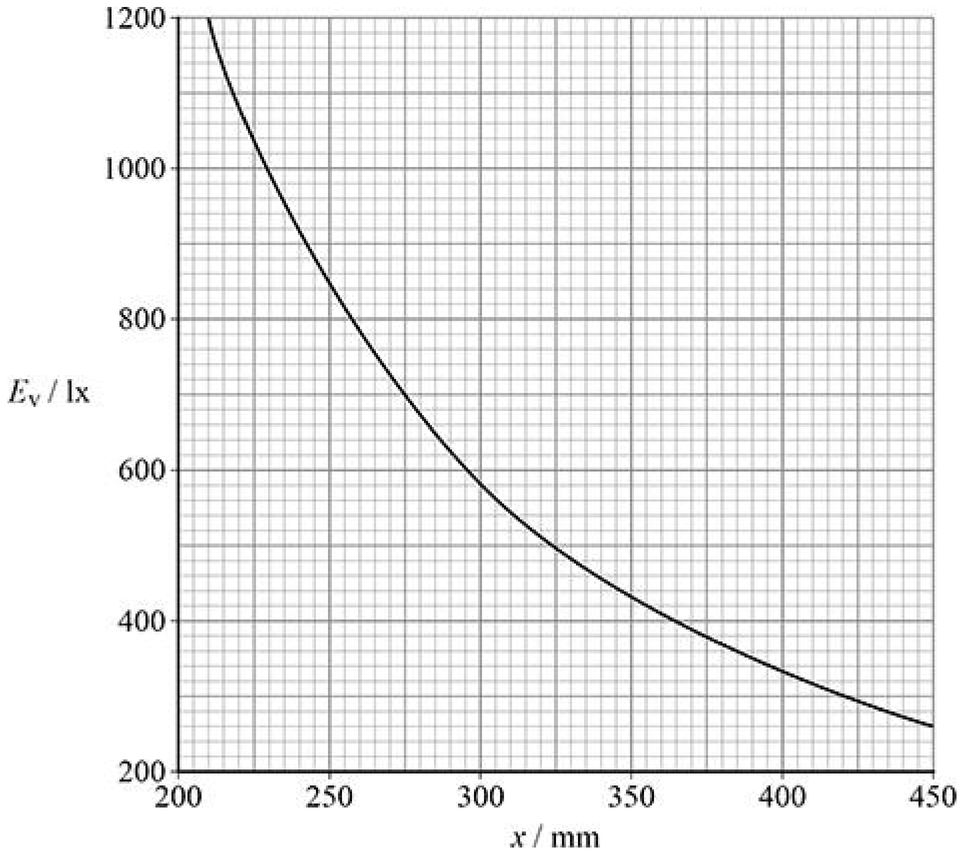
Show that E_V for the arrangement shown in **Figure 1** is about 130 lx.

(2)

R is recorded for different values of the vertical distance x between the lamp and the LDR.
E_V is calculated for each value of R.

Figure 2 shows how E_V varies with x.

Figure 2



It can be shown that $E_V \propto \frac{1}{x^2}$

(c) Describe a method to show that **Figure 2** confirms this relationship.
You do not need to show any calculations.

(2)

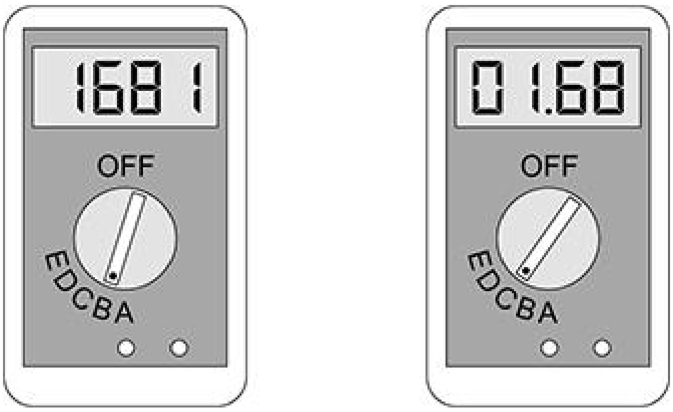
(d) Deduce the value of x when E_V = 130 lx.

x = ____________________ mm

(2)

(e) R is measured when x = 450 mm.
Figure 3 shows how the ohm-meter displays the values of R when set to range **B** and when set to range **C**.

Figure 3



The uncertainty of the reading on the ohm-meter is ±2% of the displayed reading plus ±2 in the least significant digit.

This means that:

- using range **B** the **maximum** value of R is 1.02 × 1681 + 2 = 1717 Ω
- using range **C** the **minimum** value of R is 0.98 × 1.68 – 0.02 = 1.63 kΩ.

Complete **Table 2**.
Go on to explain whether range **B** or range **C** should be used to measure R.

Table 2

Setting	Minimum R	Maximum R
range **B**	____________ Ω	1717 Ω
range **C**	1.63 kΩ	____________ kΩ

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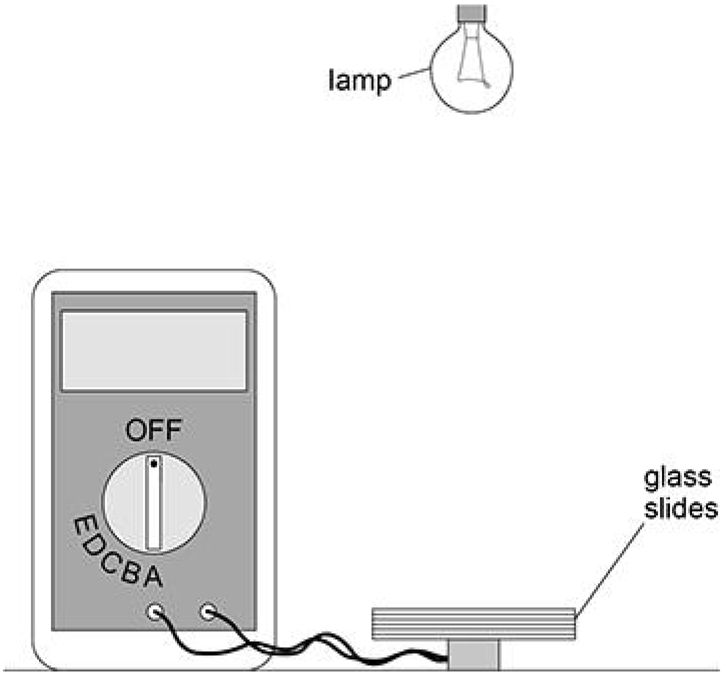
(2)

Figure 4 shows the LDR being used to investigate the transmission of light through glass slides.

Figure 4



The lamp and ohm-meter are switched on.
R is recorded with different numbers of slides placed on the LDR.
E_V is calculated for each value of R.

(f) The positions of the lamp and the LDR are not changed during the experiment.

Identify **two** other control variables.

1. ____

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2. ____

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(2)

(g) For the arrangement in **Figure 4** it can be shown that

$$E_V = 400\ e^{-\mu N}$$

where N is the number of slides

μ is a constant.

Explain how μ can be determined from a linear graph.

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(2)

(h) In an experiment $\mu = 9.0 \times 10^{-2}$

Deduce the minimum number of slides needed to reduce E_V by 50%.

number of slides = ______________________

(2)

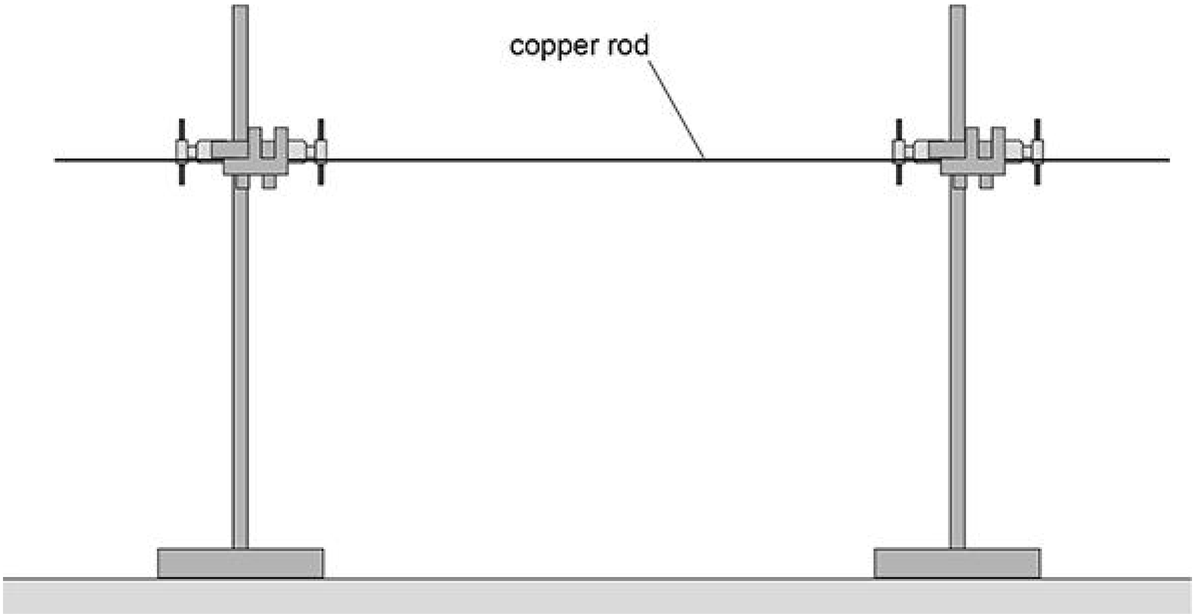
(Total 15 marks)

Q2.

This question is about a method to investigate how the force on a conductor varies with flux density and current (required practical activity 10).

Figure 1 shows a copper rod clamped above a horizontal bench.

Figure 1



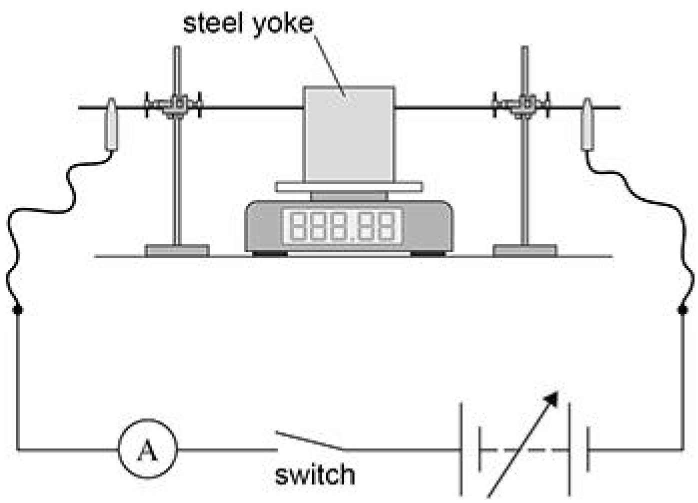
(a) Describe a method to show that the copper rod is horizontal.
Your method must include the use of a metre ruler.
You may annotate **Figure 1**.

(3)

Figure 2 shows the copper rod positioned above a digital balance.

Two identical magnets are mounted on a steel yoke with their opposite poles facing each other.
The balance is zeroed.
The yoke is then placed on the balance so that a horizontal uniform magnetic field is applied perpendicular to the copper rod.
The ends of the rod are connected as shown.

Figure 2



(b) When the switch is open, the reading on the balance shows the mass of the yoke and the two magnets.
When the switch is closed, the reading on the balance decreases.

Explain, with reference to **Figure 2**, the direction of the horizontal magnetic field.

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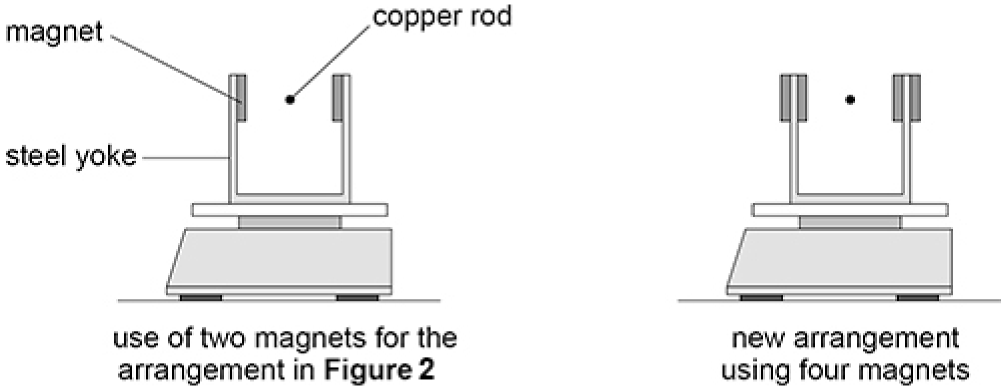
(3)

The current I in the rod is varied.
The balance reading M_1 is recorded for different values of I.

The switch is now opened.
Two additional magnets, identical to those used before, are attached to the yoke.

Figure 3 shows how this new arrangement compares with the arrangement in **Figure 2**.

Figure 3

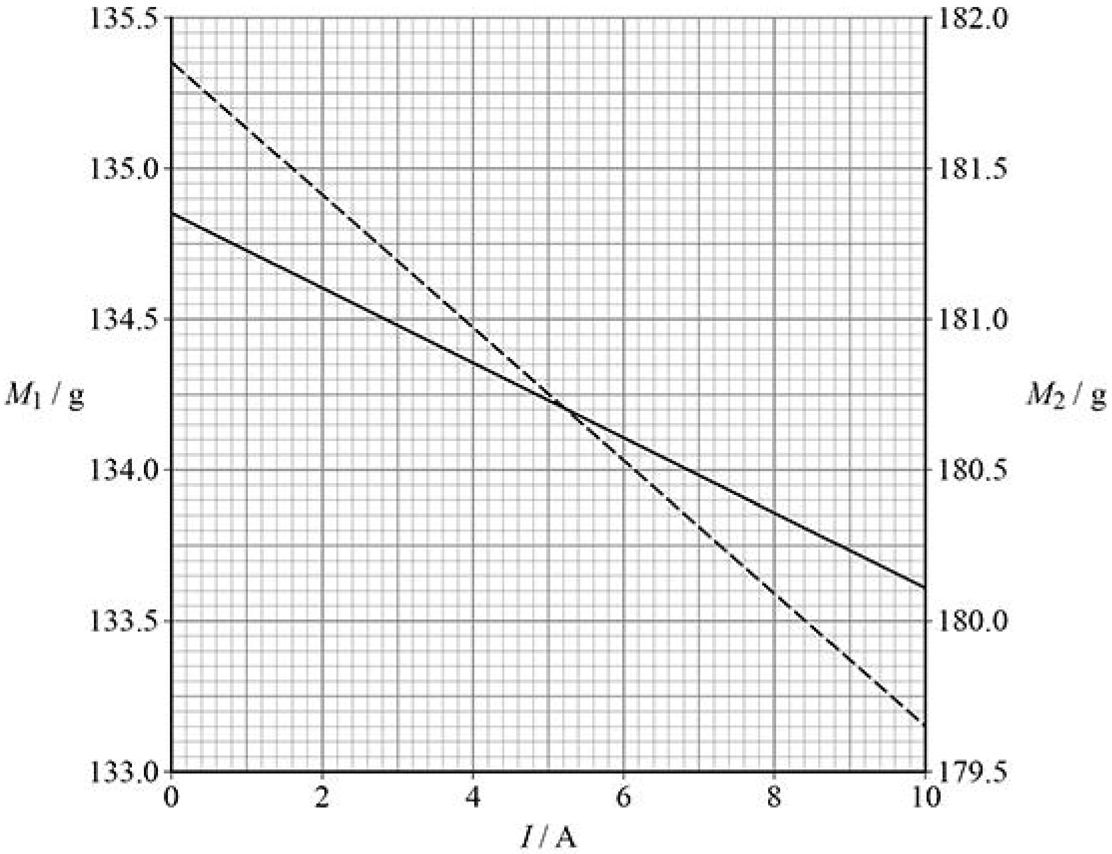


The balance reading with four magnets attached to the yoke is M_2.
With the switch open, M_2 is the mass of the yoke and the four magnets.

The switch is now closed.
M_2 is recorded for different values of I.

Figure 4 shows data from both experiments.
Values of M_1 and M_2 are plotted using different vertical axes.

Figure 4



The solid line ——— shows the variation of M_1 with I

The dashed line ----- shows the variation of M_2 with I

It can be shown that

$$M = kBI + nZ + Y$$

where

M = balance reading when the current is I
B = magnetic flux density of the horizontal uniform magnetic field
n = number of magnets attached to the yoke
Z = mass, in g, of each magnet
Y = mass, in g, of the yoke
k is a constant.

(c) Deduce the fundamental base units for k.

fundamental base units = ____________________

(3)

(d) Determine Y.

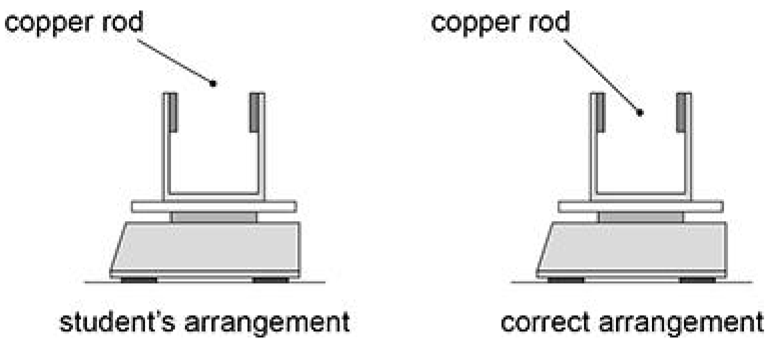
Y = ____________________ g

(3)

(e) A student sets up the apparatus with the copper rod positioned incorrectly.

Figure 5 shows how the student's arrangement compares with the correct arrangement.

Figure 5



The student produces a graph of M_1 against I.

Compare the student's graph with the graph of M_1 against I (the solid line) in **Figure 4**.
Explain your answer.

(3)
(Total 15 marks)

Q3.

A stroboscope emits bright flashes of white light.
The duration of each flash and the frequency of the flashes can be varied.

The table below shows information about the stroboscope.

	Minimum	**Maximum**
Duration of each flash / μs	60	300
Frequency of flashes / Hz	1	150

The duration of each flash is T_1.
The time from the start of a flash to the start of the next flash is T_2.

The duty cycle of a stroboscope is defined as $\frac{T_1}{T_2}$.

(a) What is the maximum duty cycle of the stroboscope?

Tick ✓ **one** box.

6.0×10^{-5} ☐

3.0×10^{-4} ☐

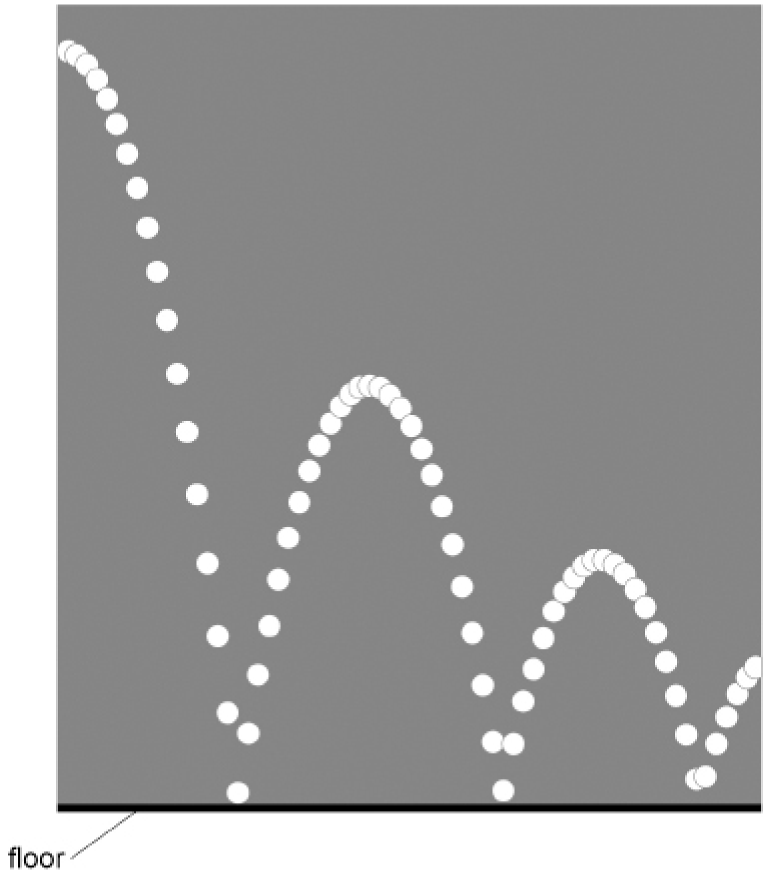
9.0×10^{-3} ☐

4.5×10^{-2} ☐

(1)

(b) **Figure 1** shows images produced in an experiment in which a bouncing ball is illuminated by a stroboscope.
The stroboscope flashes at a constant frequency.

Figure 1



Suggest why T_1 must be very short for this experiment.

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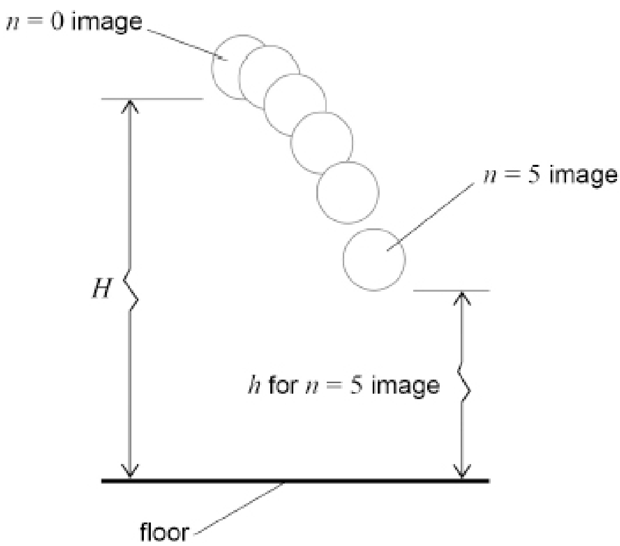
(1)

Figure 2 shows the first six images starting with n = 0, where n is the image number.

Figure 2



The images are used to determine:

H, the vertical distance from the bottom of the ball to the floor when n = 0
h, the vertical distance from the bottom of the ball to the floor for each non-zero value of n.

The n = N image is produced at the instant that the ball hits the floor for the first time. For n between 0 and N it can be shown that

$$H - h = \frac{u_0 n}{f} + \frac{g}{2}\left(\frac{n}{f}\right)^2$$

where

u_0 is the vertical velocity of the ball when n = 0
g is the acceleration due to gravity
f is the frequency of the flashes.

(c) In order to find g, a graph is plotted with values of $\frac{H-h}{n}$ on the y-axis.

Suggest what is plotted on the x-axis.
Go on to explain how g is determined from this graph.

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The following data are recorded.

H = 1550 mm
f = 31.0 Hz

The graphical analysis of data from **Figure 1** gives g as 9.79 m s^{-2}.

(3)

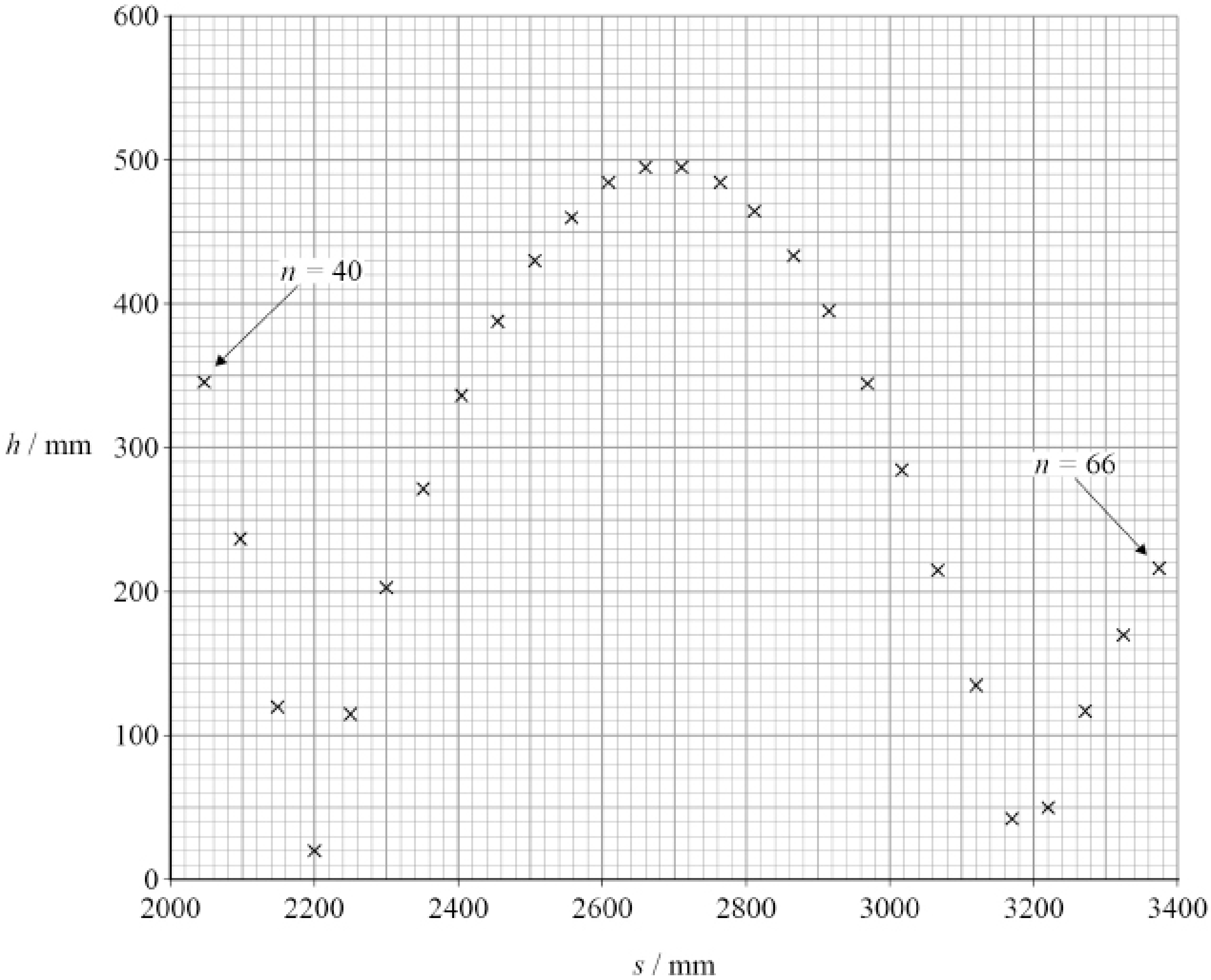
(d) Determine u_0.

u_0 = ____________________ m s^{-1}

(3)

Figure 3 shows positions of the bottom of the ball for n = 40 to n = 66
In this range of positions, the ball makes contact with the floor for the second and third times.
Values of h, the vertical distance from the bottom of the ball to the floor, are plotted on the y-axis.
Values of s, the horizontal displacement from a point on the floor below the centre of the n = 0 image, are plotted on the x-axis.

Figure 3



(e) Determine, in mm s^{-1}, the horizontal velocity of the ball between the second and third contacts of the ball with the floor.

horizontal velocity = ____________________ mm s^{-1}

(2)

(f) Determine the time between the second and third contacts.
Annotate **Figure 3** to show your method.

time = ____________________ s

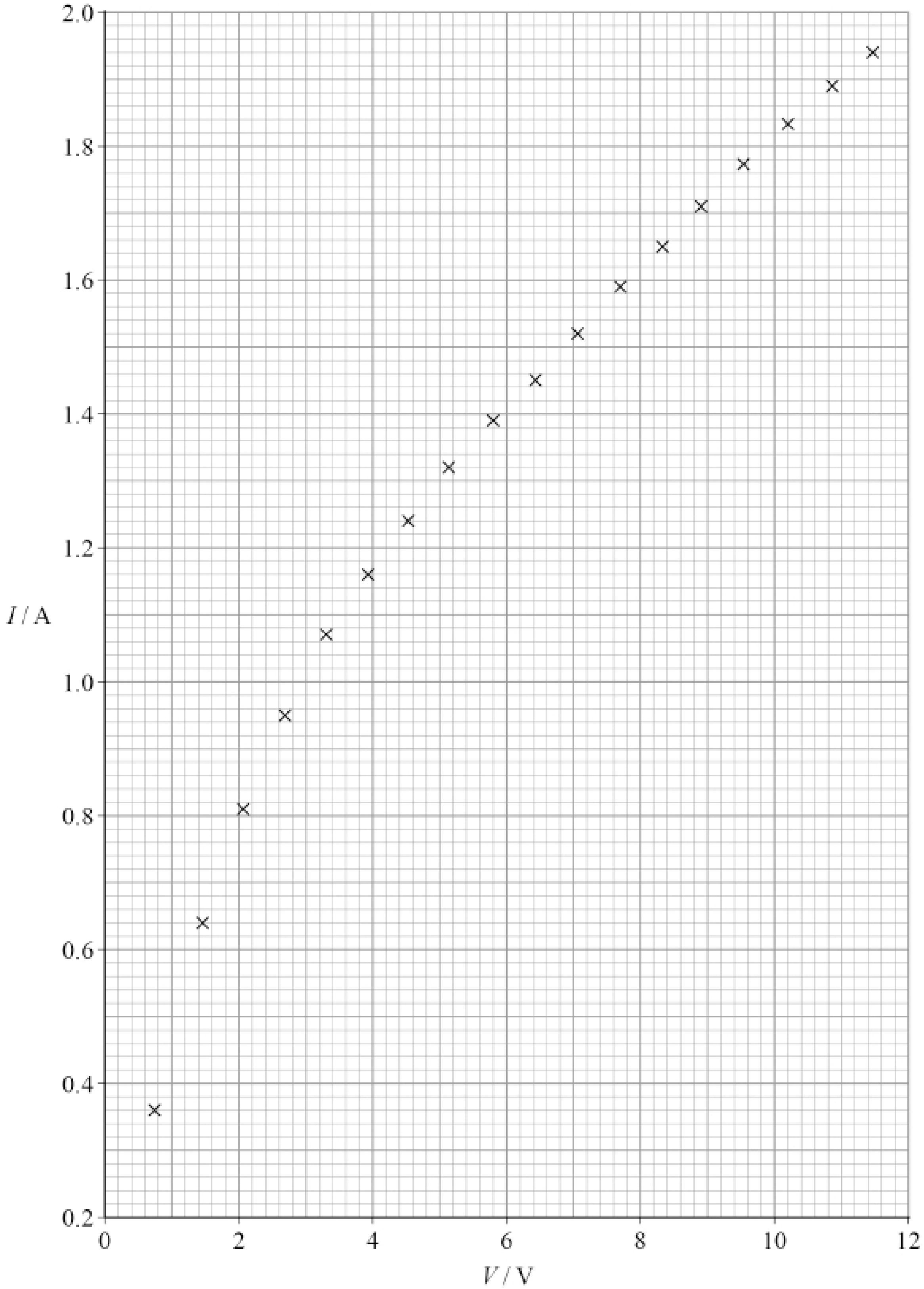
(3)

(Total 13 marks)

Q4.

Figure 1 is a plot of current–voltage data for a filament lamp **L**.

Figure 1



The current I was measured as the voltage V across **L** was increased at a steady rate.
These data were obtained using a current sensor and a voltage sensor connected to a data logger.
The logger recorded data at a rate of 2.5 Hz.

(a) Determine, in $V s^{-1}$, the rate of increase of V.

rate of increase of V = ____________________ $V s^{-1}$

(2)

(b) State **two** advantages of using data logging for this experiment.

1 ____

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2 ____

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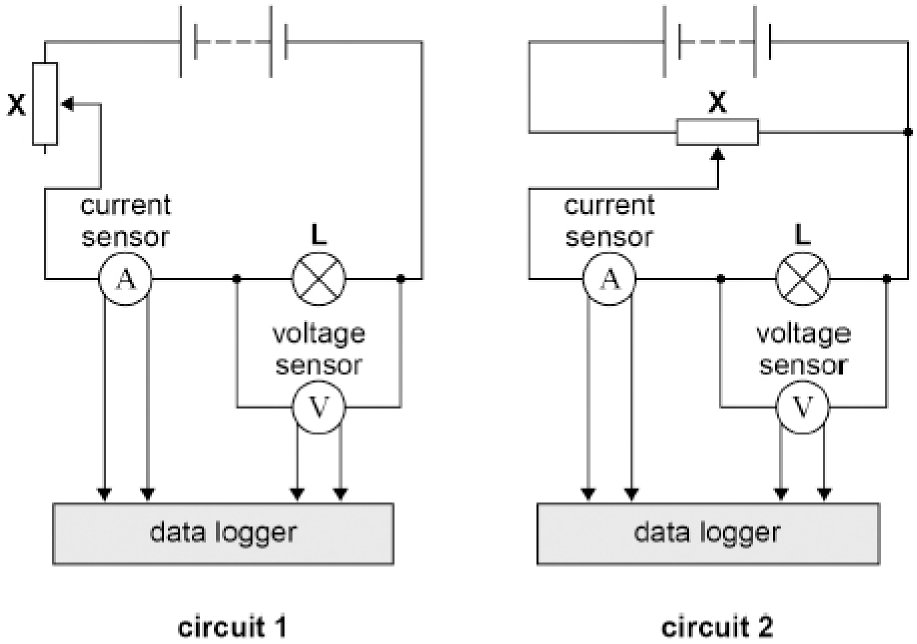
(2)

(c) **Figure 2** shows two circuits that can be used to collect current–voltage data.

Figure 2



The dc supply has an emf of 12 V and negligible internal resistance.
The current sensor and the voltage sensor behave as ideal meters.

In circuit **1**:

- **X** is used as a variable resistor with a maximum resistance of 14.9 Ω
- when **X** is set to maximum resistance, the resistance of **L** is 2.3 Ω.

In circuit **2**, **X** is used as a potential divider.

Discuss, with reference to circuit **1 and** circuit **2**, whether either circuit can produce all the data shown in **Figure 1**.
Support your answer with a calculation.

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(4)

The table below shows some values of V that are plotted on **Figure 1** and corresponding results for I and for the power P dissipated in **L**.

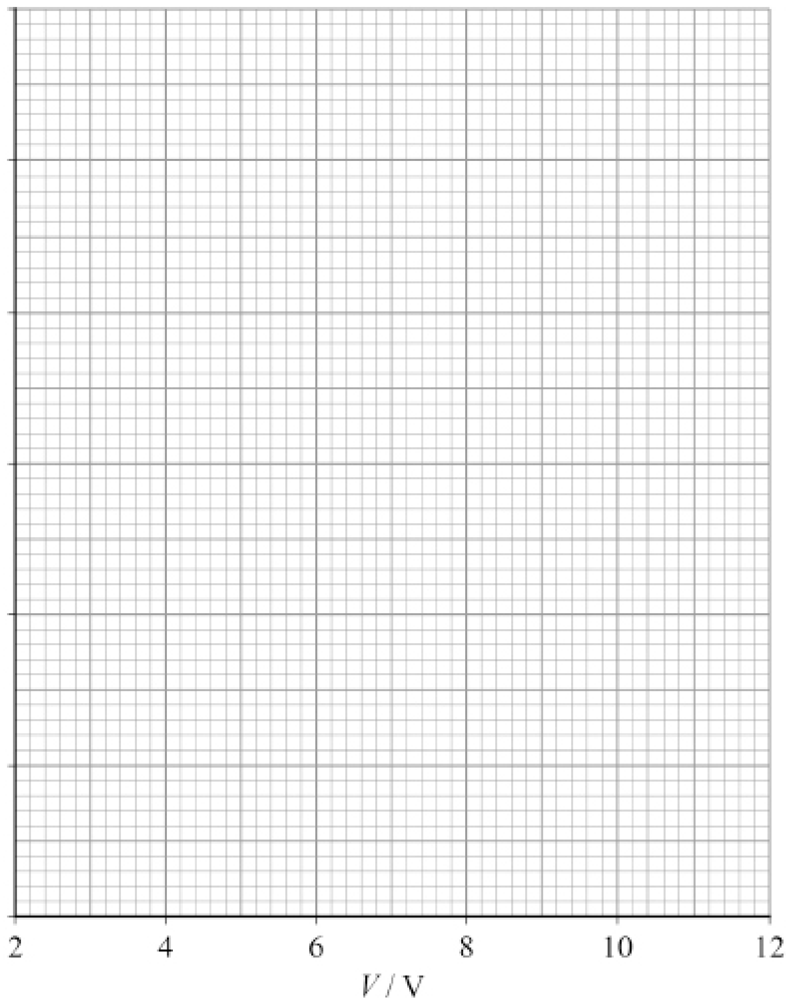
V / V	I / A	P / W
3.30	1.07	3.53
5.17	1.32	
7.69	1.59	12.2
9.58		
11.47	1.94	22.3

(d) Complete the table below above.

(3)

(e) Plot on **Figure 3** a graph of P against V.
You should use only the data in your completed table.

Figure 3



(3)

(f) **L** is connected to a 12 V power supply of negligible internal resistance. **L** then dissipates its rated power P_r .

A second lamp, identical to **L**, is now connected in series with **L**.

Determine the percentage of P_r that is dissipated in this circuit.

percentage = ____________________ %

(2)

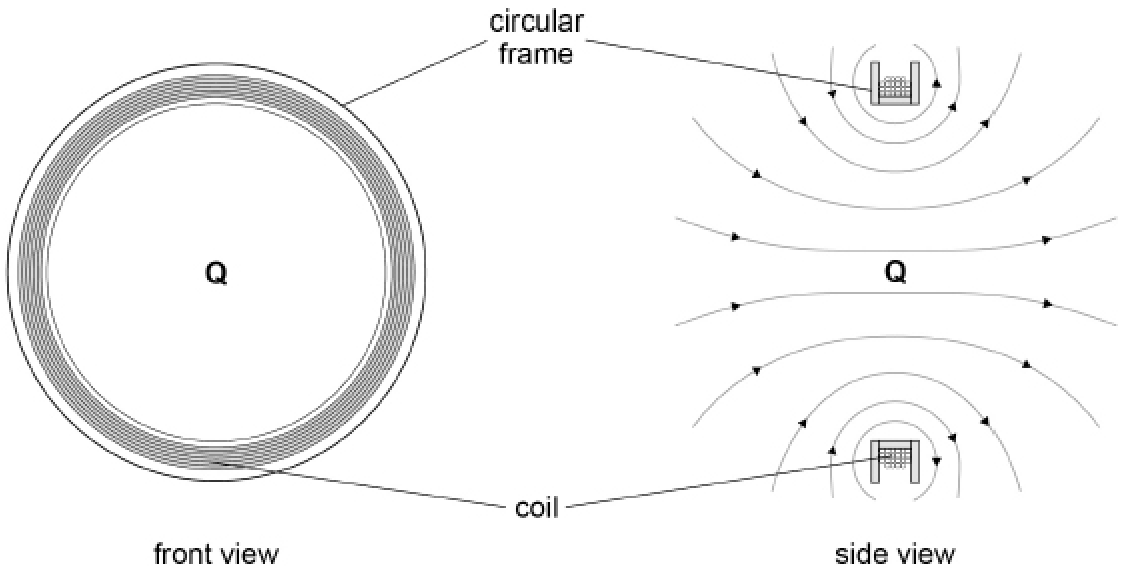
(Total 16 marks)

Q5.

Figure 1 shows the front view of a vertical coil mounted on a circular frame.

Figure 1 is a side view showing a section through the frame and coil.
A constant direct current in the coil produces magnetic flux represented by the magnetic field lines on this diagram.

Figure 1a **Figure 1b**



Point **Q** is at the centre of the coil.

A sensor placed at **Q** detects B_H, the horizontal component of the magnetic flux density.

The effect of the Earth's magnetic field at **Q** is negligible.

(a) Discuss whether a search coil is a suitable sensor to detect B_H.

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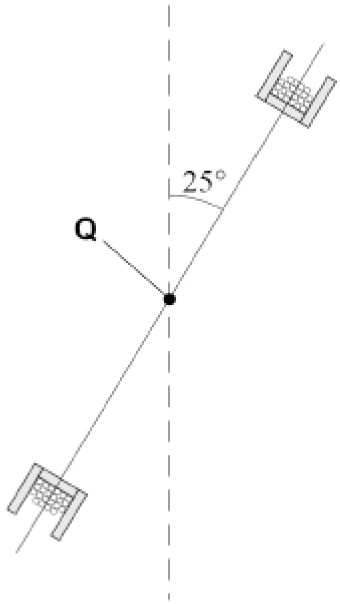
(2)

B_H is measured at **Q** with the coil vertical.

The coil is now rotated about **Q** through 25° as shown in **Figure 2**.
The current in the coil does not change.

Figure 2



A new measurement of B_H is made with the coil fixed in this new position.

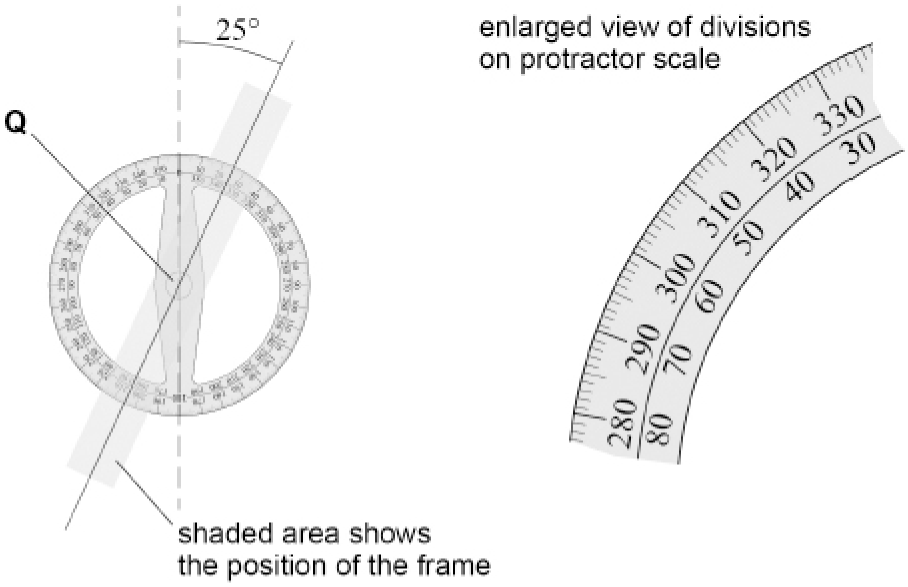
(b) Determine the percentage change in B_H produced by this rotation of the coil.
Show your working.

percentage change = ____________________ %

(2)

(c) **Figure 3** shows a protractor being used to measure the angle through which the coil is rotated.

Figure 3



Estimate the percentage uncertainty in this result.
Justify your answer.

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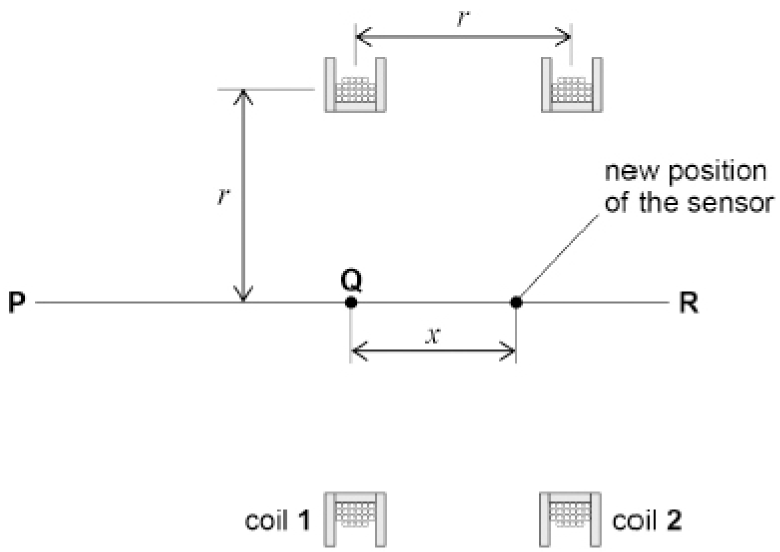
percentage uncertainty = ____________________ %

(3)

Figure 4 shows an arrangement of two vertical coils.
Four experiments are done using this arrangement.

Figure 4



Coil **1** and coil **2** are identical and have a radius r.
The coils are separated by a distance r and have a common axis **PR**.
Q is at the centre of coil **1**.

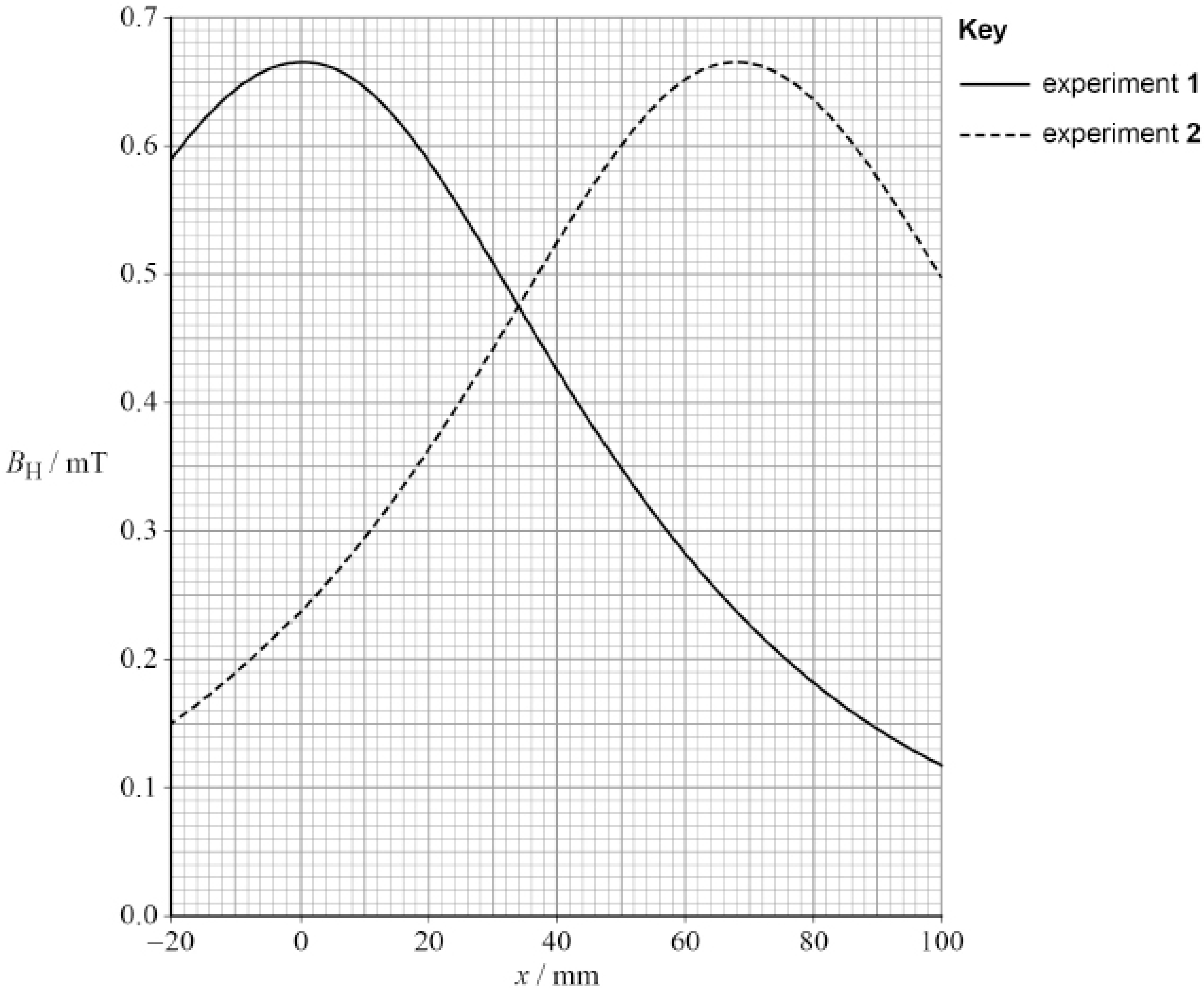
The four different experiments investigate how B_H varies with x, the displacement of the sensor from **Q** along **PR**.

In experiment **1**, the current in coil **1** is 225 mA and the current in coil **2** is zero.

In experiment **2**, the current in coil **1** is zero and the current in coil **2** is 225 mA.

Figure 5 shows the results of experiment **1** and experiment **2**.

Figure 5



(d) During experiment **1**, B_H is measured with the sensor at **Q**.
The sensor is then moved along **PR** until the value of B_H is halved.
The distance from **Q** to the sensor is $x_{0.5}$

Determine $\frac{x_{0.5}}{r}$

$\frac{x_{0.5}}{r}$ = ____________________

(2)

In experiment **3**, the current in both coils is 225 mA so that the magnetic fields produced by coil **1** and coil **2** are combined.

The resultant B_H has a constant maximum value in the region between $x = \frac{r}{4}$ and $x = \frac{3r}{4}$

(e) Deduce, in mT, the value of B_H in this region.

B_H = ____________________ mT

(2)

(f) State **two** characteristics of the magnetic field lines in this region.

1 ____

____

____

2 ____

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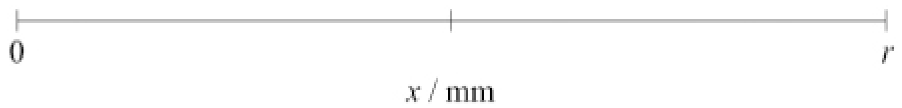
____

(2)

(g) In experiment **4**, the current in coil **2** is reversed so that the direction of the magnetic field produced by coil **2** is also reversed.
The magnitudes of the currents in coil **1** and coil **2** are still 225 mA.

Sketch a graph to show how B_H varies between $x = 0$ and $x = r$.
The x-axis has been provided for you.

Your graph should include numerical values on your B_H axis that correspond to $x = 0$ and $x = r$.

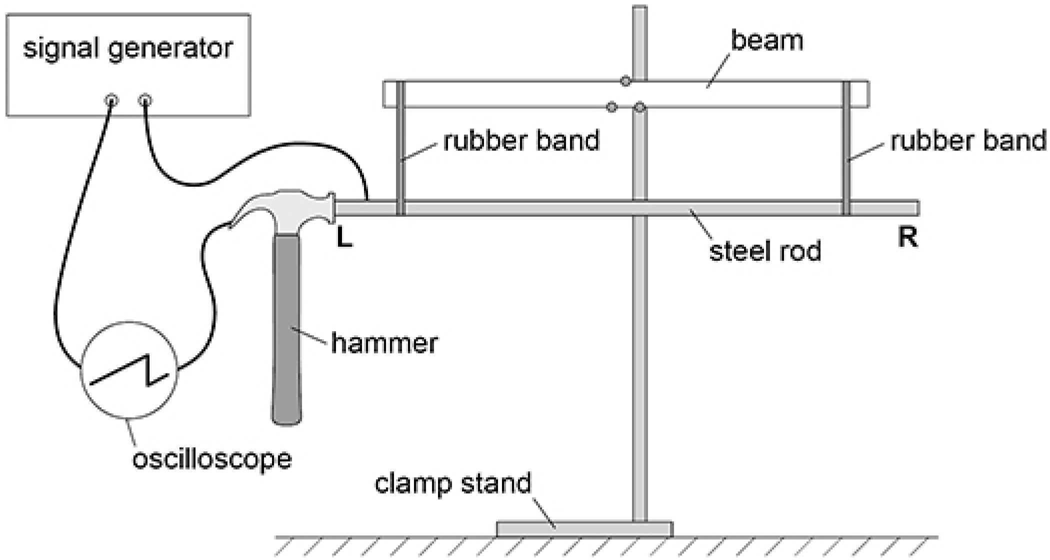


(3)
(Total 16 marks)

Q6.

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

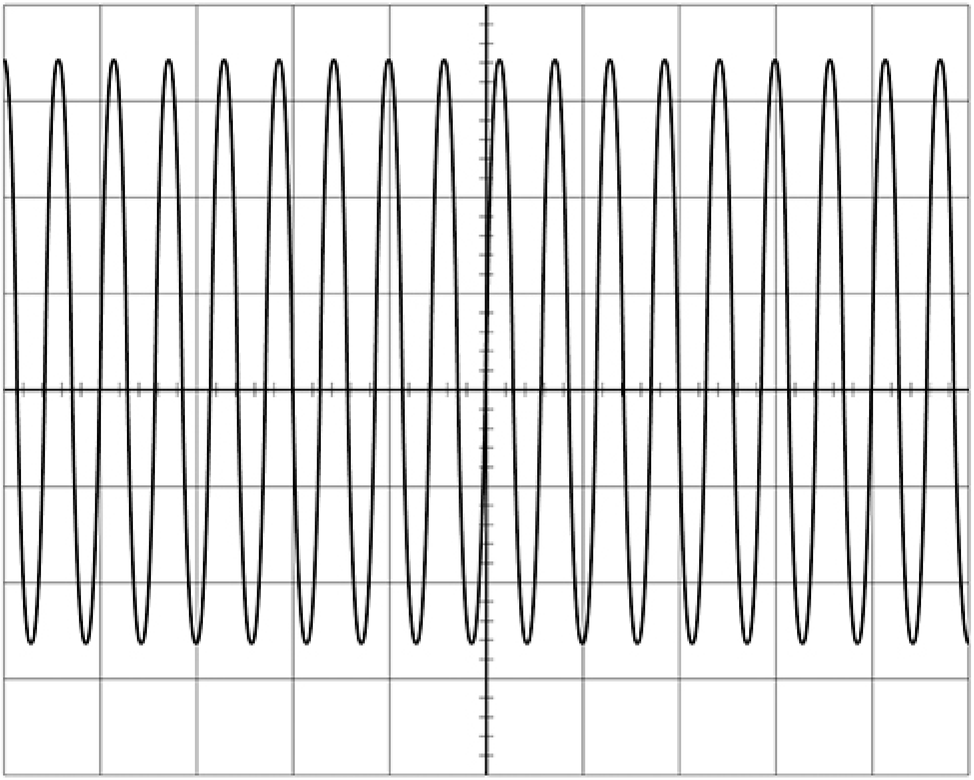
Figure 1



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



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

Tick (✓) **one** box.

X-shift ☐

Y-gain ☐

Y-shift ☐

(1)

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

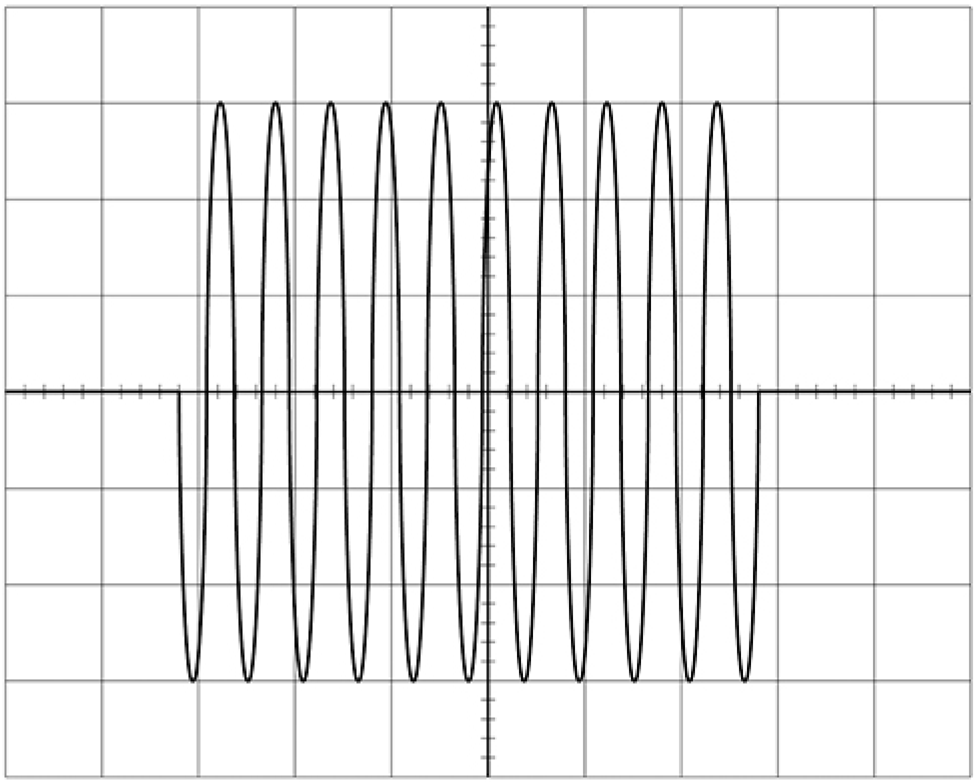
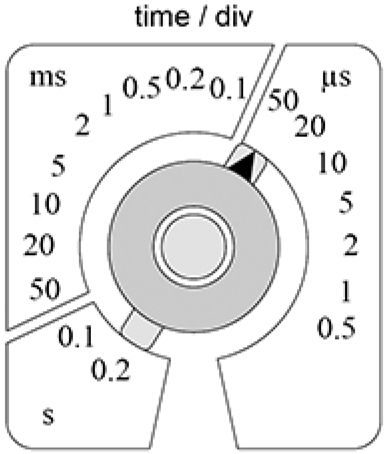


Figure 4 shows the time-base setting of the oscilloscope.

Figure 4



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

Deduce the speed of sound in the steel rod.

speed of sound = _______________ $m\ s^{-1}$

(3)

(c) 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.

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(4)

(Total 8 marks)

Q7.

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

(a) 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)

(b) The table below shows the calliper measurements made by a student.

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)

(c) The length of the cylinder is 71 ± 2 mm.

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

uncertainty = ____________________ mm^3

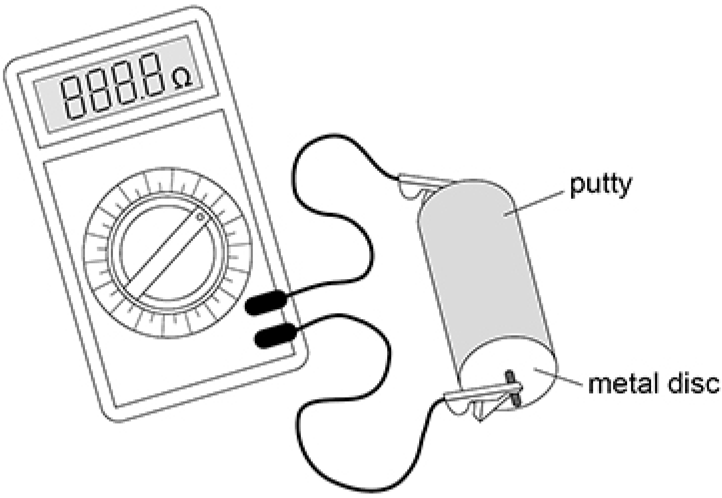
(4)

(d) 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 1 shows the apparatus.

Figure 1

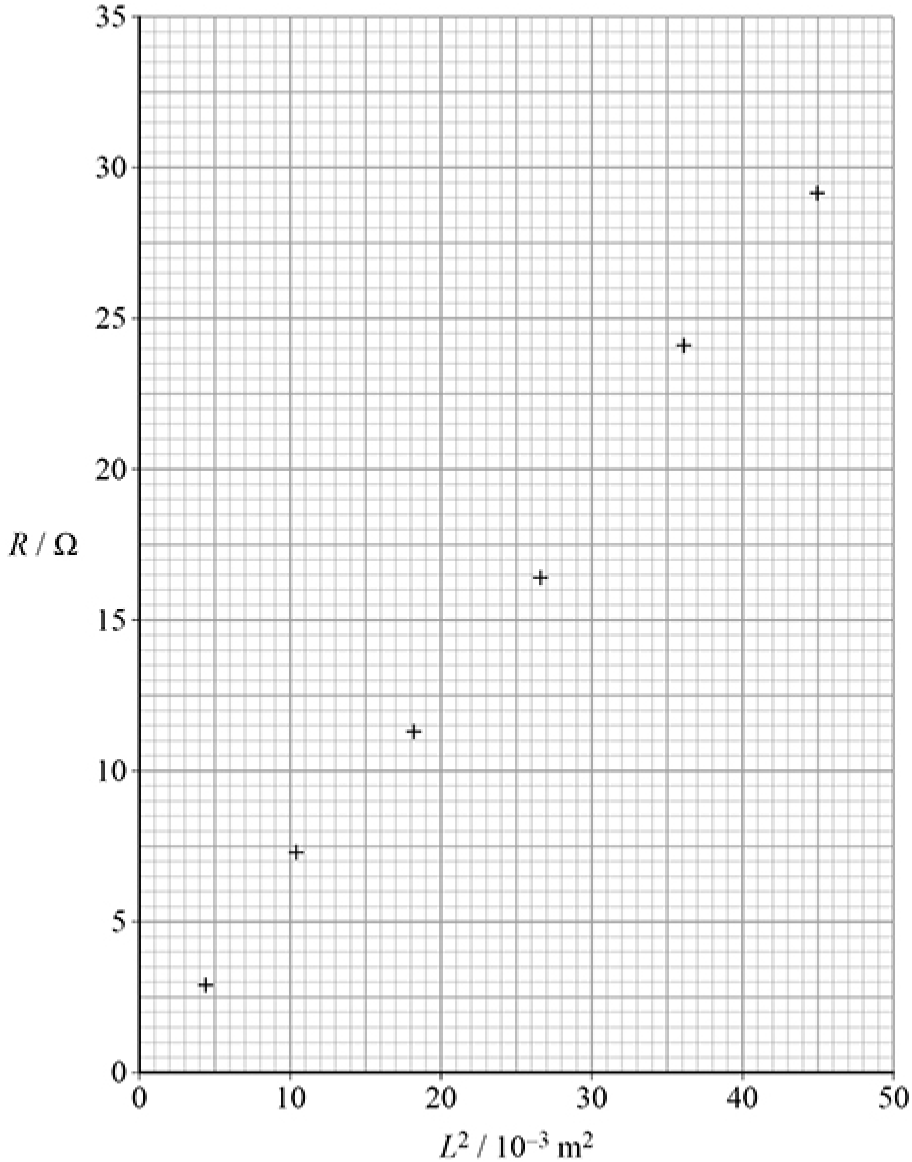


The student forms the putty into cylinders of different lengths, each of volume 5.83×10^{-5} m^3.
The length L and resistance R are measured for each cylinder.

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

The student plots the graph shown in **Figure 2**.

Figure 2



Determine ρ.
State an appropriate SI unit for your answer.

ρ = ________________ unit = ________________

(4)

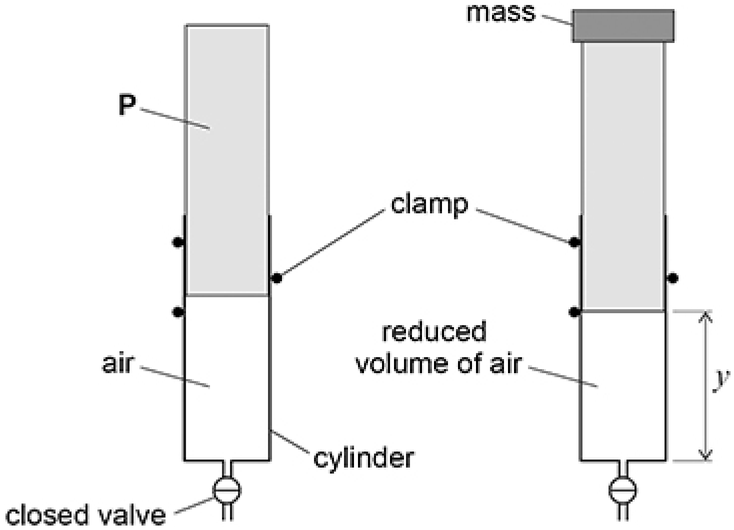
(Total 11 marks)

Q8.

Figure 1 shows air trapped in a vertical cylinder by a valve and a piston **P**.
The valve remains closed throughout the experiment.

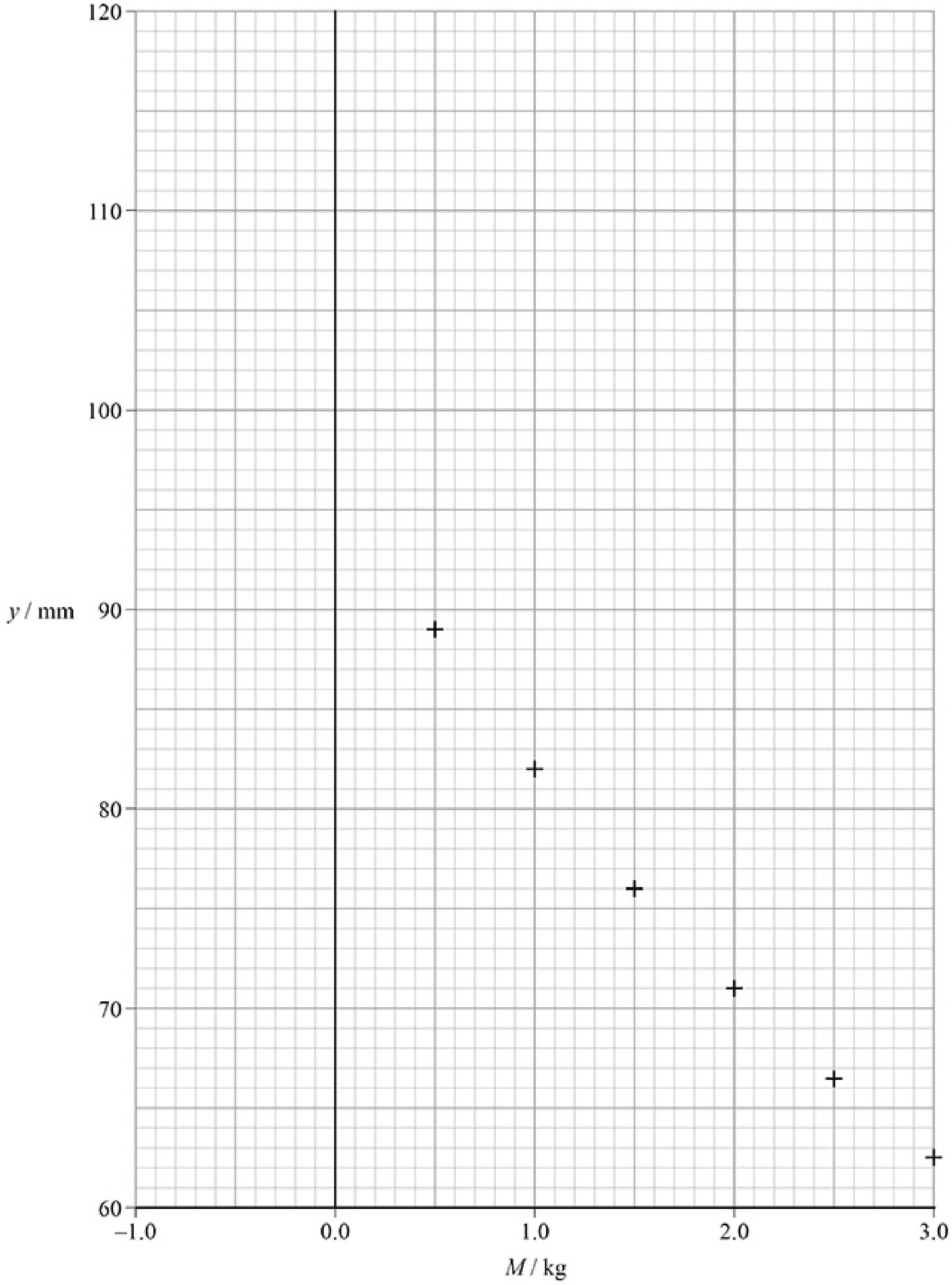
A mass is placed on top of **P**.
P moves downwards and the volume of the trapped air decreases.
There are no air leaks and there is no friction between the cylinder and **P**.

Figure 1



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 2 shows a graph of these data.

Figure 2

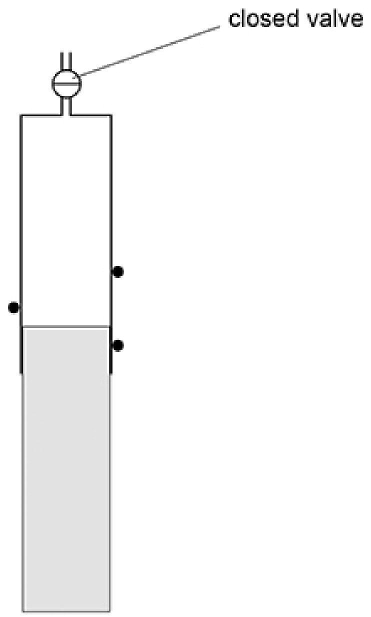


(a) Show that y is **not** inversely proportional to M.
Use data points from **Figure 2**.

(2)

(b) The masses are removed and the cylinder is inverted.
P moves downwards without friction before coming to rest, as shown in **Figure 3**.

Figure 3



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

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(3)

(c) The mass of **P** is 0.350 kg.

Deduce y when the cylinder is in the inverted position shown in **Figure 3**.

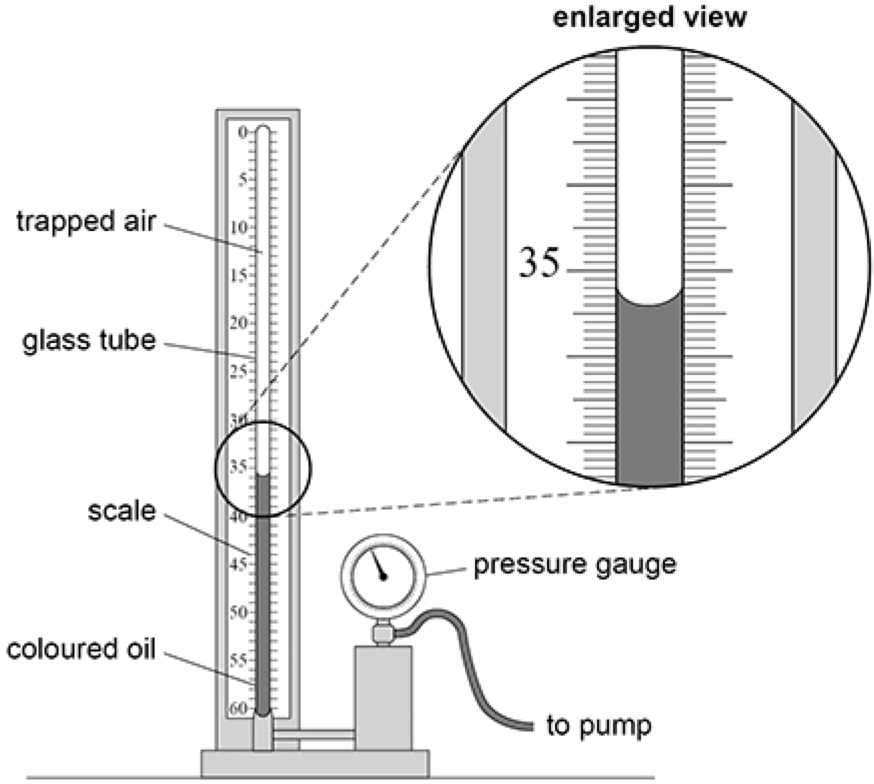
Draw a line of best fit on **Figure 2** to arrive at your answer.

y = _______________ mm

(4)

Figure 4 shows apparatus used in schools to investigate Boyle's law.

Figure 4



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.

(d) 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 4** is $35.4\ \text{cm}^3$.

State:

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

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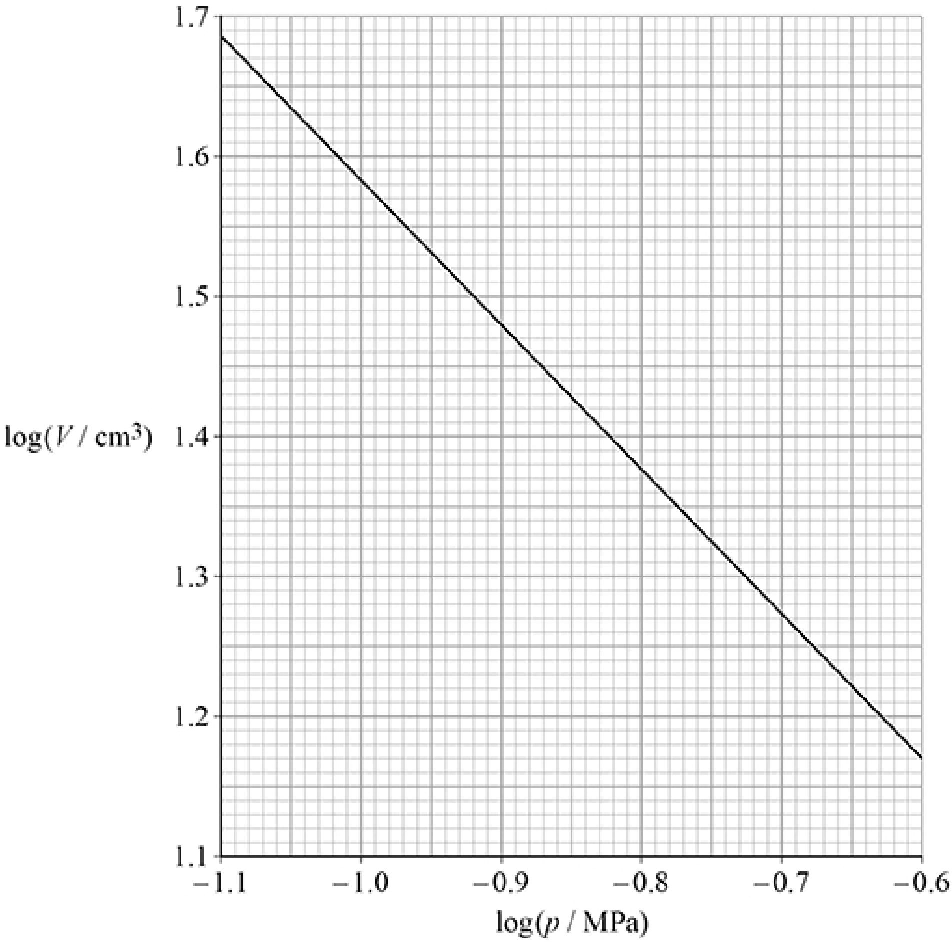
volume = _______________ cm^3

(2)

(e) **Figure 5** shows data obtained using the apparatus in **Figure 4**.

Figure 5



Explain why the gradient of the graph in **Figure 5** confirms that the air obeys Boyle's law.

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(3)

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

Determine, using **Figure 5**, the volume *V* corresponding to this pressure.

V = _______________ cm^3

(3)

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

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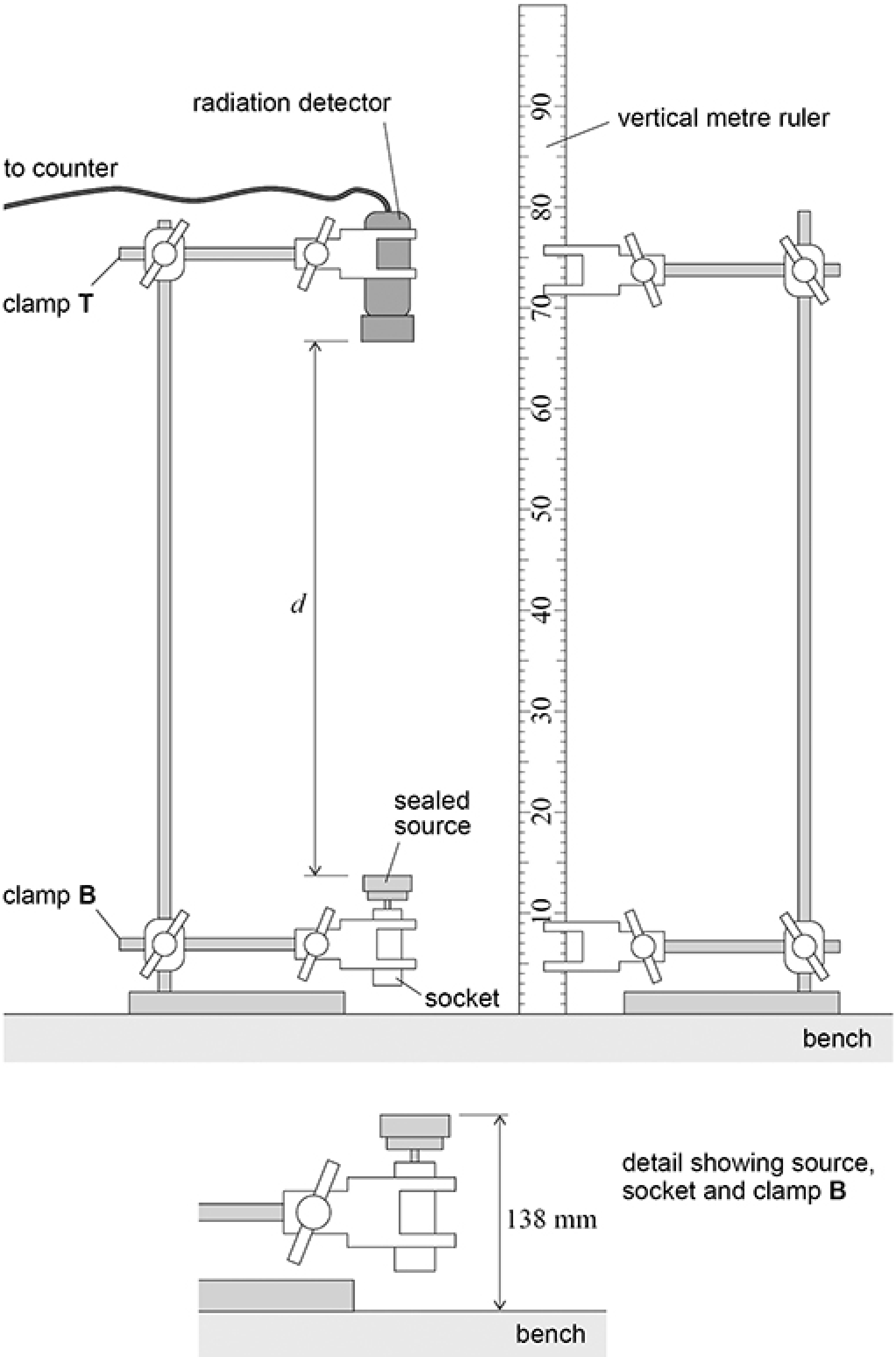
(2)

(Total 19 marks)

Q9.

Figure 1 shows apparatus used to investigate the inverse-square law for gamma radiation.

Figure 1



A sealed source that emits gamma radiation is held in a socket attached to clamp **B**. The vertical distance between the open end of the source and the bench is 138 mm. A radiation detector, positioned vertically above the source, is attached to clamp **T**.

A student is told **not** to move the stands closer together.

(a) Describe a procedure for the student to find the value of d, the vertical distance between the open end of the source and the radiation detector.

In your answer, annotate above the figure to show how a set-square can be used in this procedure.

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(2)

(b) Before the source was brought into the room, a background count C_b was recorded.

C_b = 630 counts in 15 minutes

With the source and detector in the positions shown in the figure above, d = 530 mm. Separate counts C_1, C_2 and C_3 are recorded.

C_1 = 90 counts in 100 s
C_2 = 117 counts in 100 s
C_3 = 102 counts in 100 s

R_C is the mean count rate corrected for background radiation.

Show that when d = 530 mm, R_C is about 0.3 s^{-1}.

(2)

(c) The apparatus is adjusted so that d = 380 mm.
Counts are made that show R_C = 0.76 s^{-1}.

The student predicts that:

$$R_C = \frac{k}{d^2}$$

where k is a constant.

Explain whether the values of R_C in parts (b) and (c) support the student's prediction.

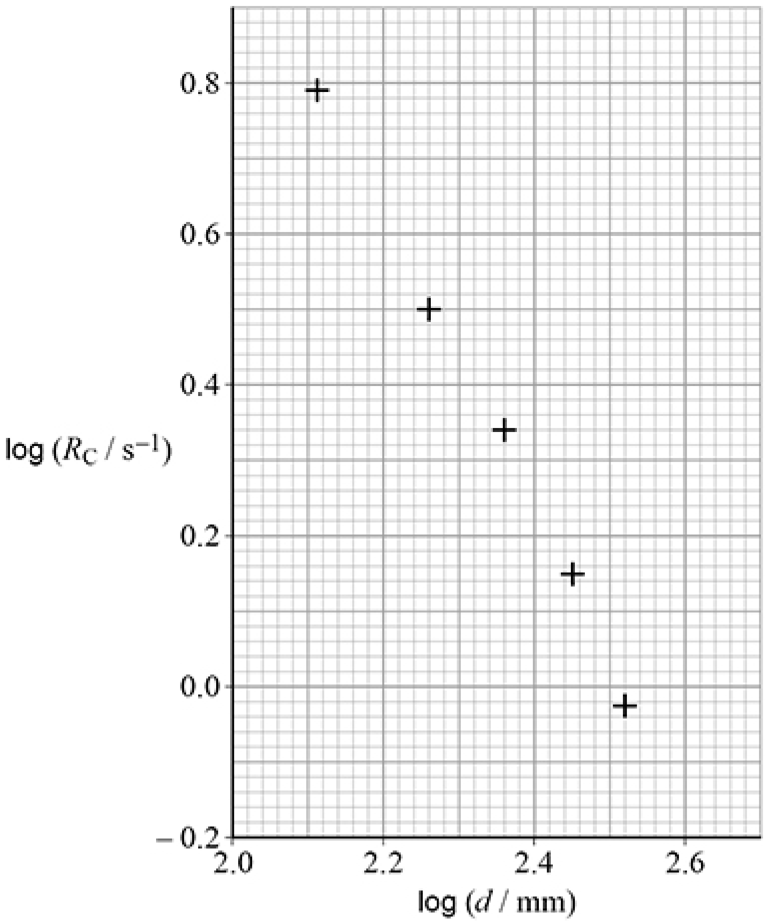
(2)

(d) Describe a safe procedure to reduce d. Give a reason for your procedure.

(2)

The student determines R_C for further values of d.
The values of d change by the same amount Δd between each measurement.
Figure 2 shows these data.

Figure 2



(e) Determine Δd.

Δd = _______________ mm

(2)

(f) Explain how the student could confirm whether the graph above supports the prediction:

$$R_C = \frac{k}{d^2}$$

No calculation is required.

(3)

When a gamma photon is detected by the detector, another photon cannot be detected for a time t_d called the dead time.

It can be shown that:

$$t_d = \frac{R_2 - R_1}{R_1 \times R_2}$$

where R_1 is the measured count rate
R_2 is the count rate when R_1 is corrected for dead time error.

(g) The distance between the source and the detector is adjusted so that d is very small and R_1 is 100 s^{-1}.
On average, two of the gamma photons that enter the detector every second are not detected.

Calculate t_d for this detector.

t_d = ________________ s

(1)

(h) A student says that if 100 gamma photons enter a detector in one second and t_d is 0.01 s, all the photons should be detected.

Explain, with reference to the nature of radioactive decay, why this idea is **not** correct.

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(2)
(Total 16 marks)

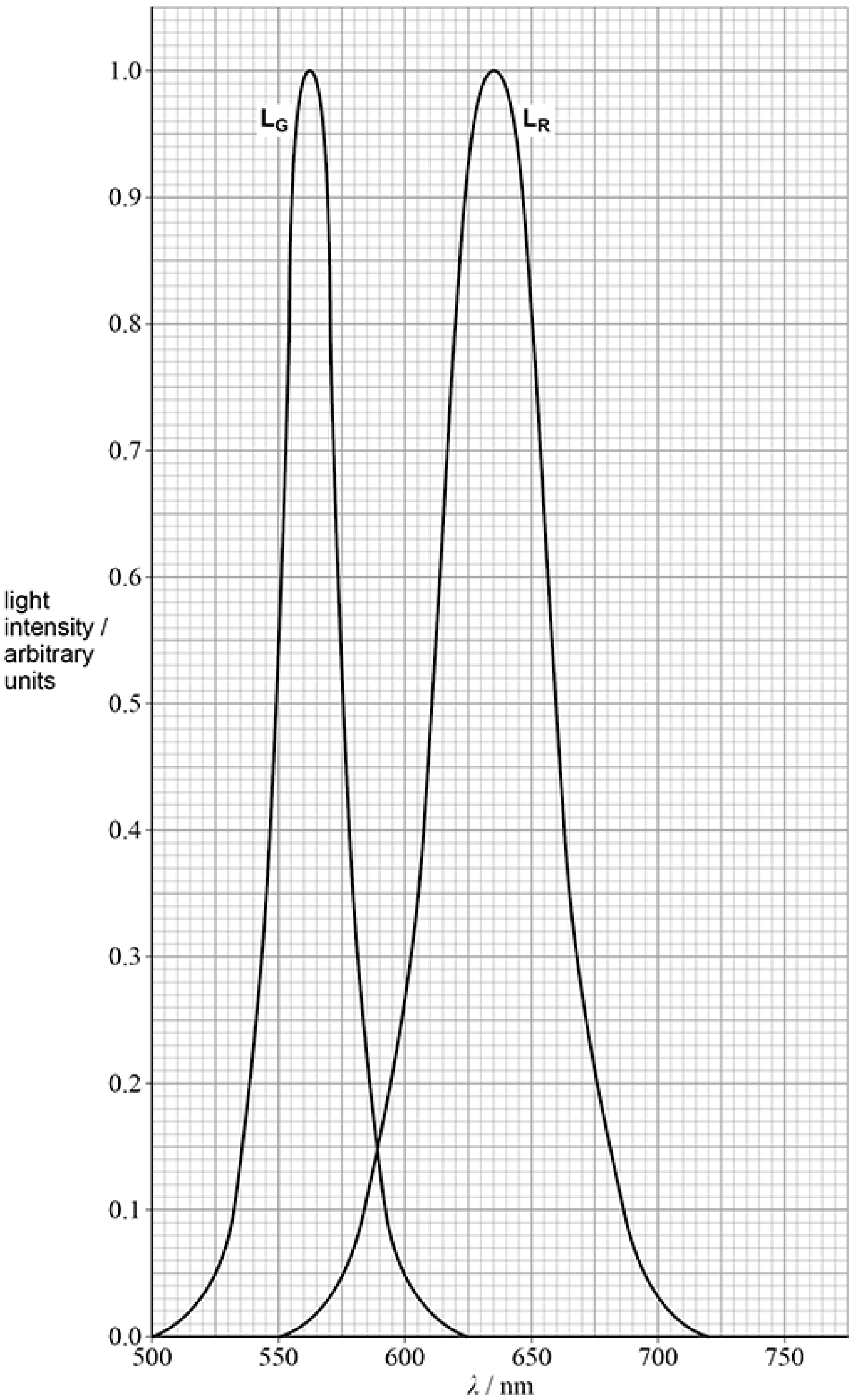
Q10.

A light-emitting diode (LED) emits light over a narrow range of wavelengths. These wavelengths are distributed about a peak wavelength λ_p.

Two LEDs $\mathbf{L_G}$ and $\mathbf{L_R}$ are adjusted to give the same maximum light intensity. $\mathbf{L_G}$ emits green light and $\mathbf{L_R}$ emits red light.

Figure 1 shows how the light output of the LEDs varies with the wavelength λ.

Figure 1



(a) Light from $\mathbf{L_R}$ is incident normally on a plane diffraction grating.
The fifth-order maximum for light of wavelength λ_p occurs at a diffraction angle of 76.3°.

Determine N, the number of lines per metre on the grating.

N = _______________ m^{-1}

(3)

(b) Suggest **one** possible disadvantage of using the fifth-order maximum to determine N.

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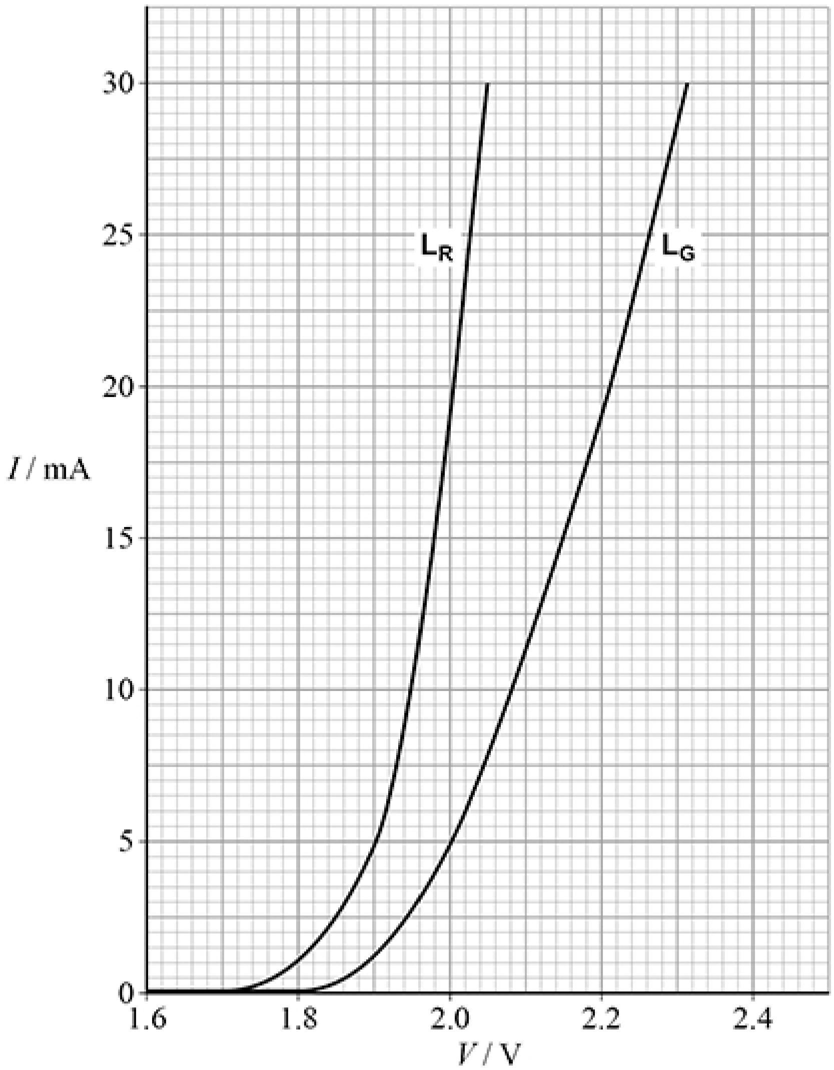
(1)

(c) **Figure 2** shows part of the current−voltage characteristics for $\mathbf{L_R}$ and $\mathbf{L_G}$.

Figure 2



When the linear part of the characteristic is extrapolated, the point at which it meets the horizontal axis gives the activation voltage V_A for the LED.
V_A for $\mathbf{L_G}$ is 2.00 V.

Determine, using **Figure 2**, V_A for $\mathbf{L_R}$.

V_A for $\mathbf{L_R}$ = ________________ V

(2)

(d) It can be shown that:

$$V_A = \frac{hc}{e\lambda_p}$$

where h = the Planck constant.

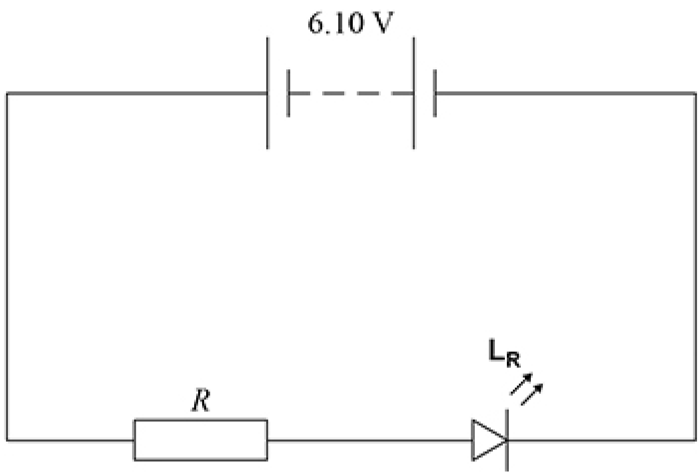
Deduce a value for the Planck constant based on the data given about the LEDs.

h = _______________ J s

(2)

(e) **Figure 3** shows a circuit with $\mathbf{L_R}$ connected to a resistor of resistance R.

Figure 3



The power supply has emf 6.10 V and negligible internal resistance.
The current in L_R must not exceed 21.0 mA.

Deduce the minimum value of R.

minimum value of R = ________________ Ω

(2)

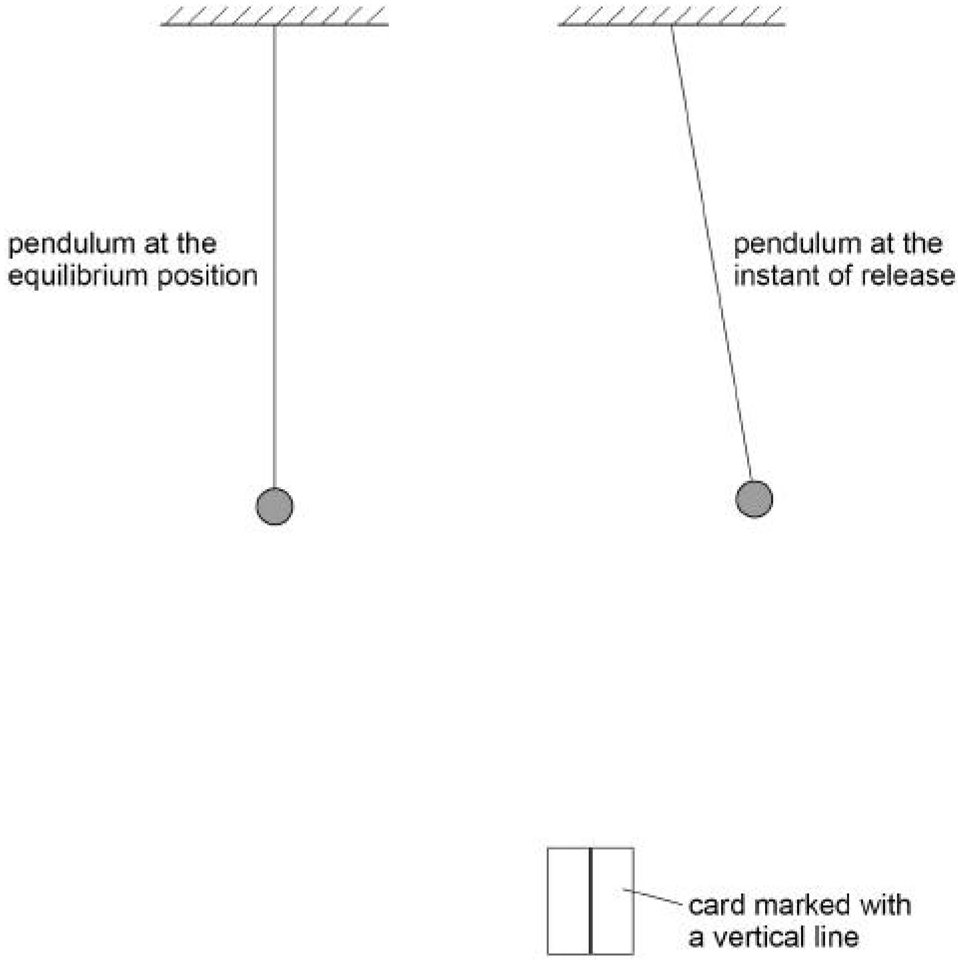
(Total 10 marks)

Q11.

A simple pendulum performs oscillations of period T in a vertical plane.

Figure 1 shows views of the pendulum at the equilibrium position and at the instant of release. **Figure 1** also shows a rectangular card marked with a vertical line.

Figure 1



(a) The card can be used as a fiducial mark to reduce uncertainty in the measurement of T.

Annotate **Figure 1** to show a suitable position for the fiducial mark. Explain why you chose this position.

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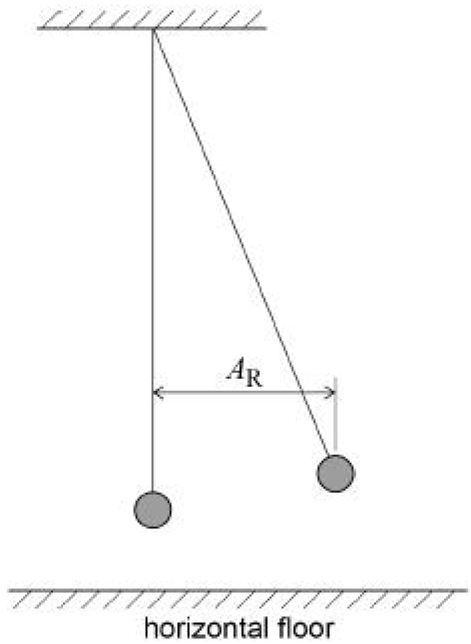
(2)

(b) The period of the pendulum is constant for small-amplitude oscillations. **Figure 2** shows an arrangement used to determine the maximum amplitude that can be considered to be small, by investigating how T varies with amplitude.

Figure 2



Describe a suitable procedure to determine A_R, the amplitude of the pendulum as it is released.
You may add detail to **Figure 2** to illustrate your answer.

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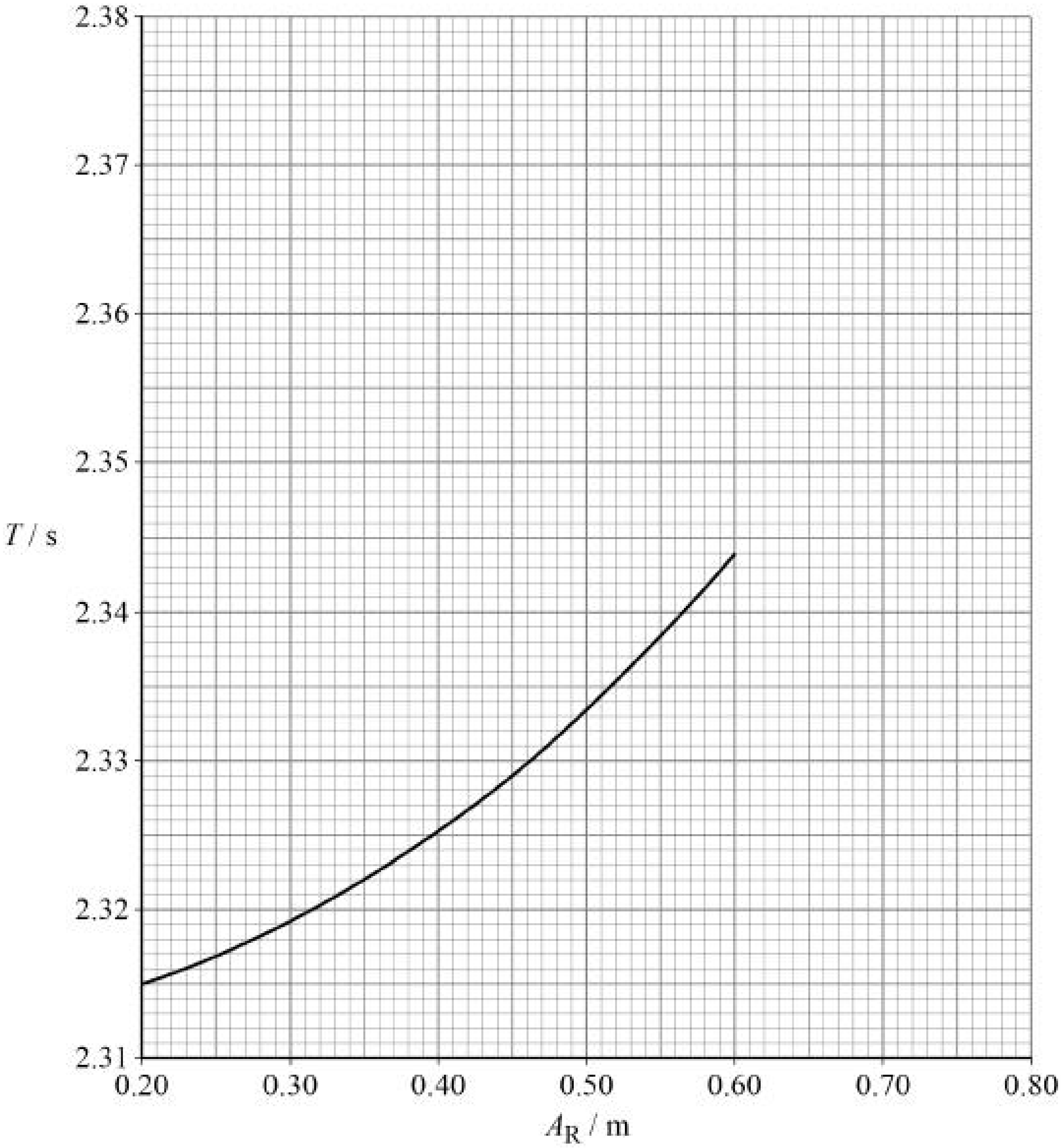
(2)

(c) **Figure 3** shows some of the results of the experiment.

Figure 3



Estimate, using **Figure 3**, the expected percentage increase in T when A_R increases from 0.35 m to 0.70 m.
Show your working.

percentage increase = ______________ %

(3)

In another experiment the pendulum is released from a fixed amplitude.
The amplitudes A_n of successive oscillations are recorded, where n = 1, 2, 3, 4, 5... .

Table 1 shows six sets of readings for the amplitude A_5.

Table 1

A_5 / m	0.217	0.247	0.225	0.223	0.218	0.224

(d) Determine the result that should be recorded for A_5.
Go on to calculate the percentage uncertainty in this result.

A_5 = ________________ m

percentage uncertainty = ________________ %

(3)

(e) **Table 2** shows results for A_n and the corresponding value of ln(A_n / m) for certain values of n.

Table 2

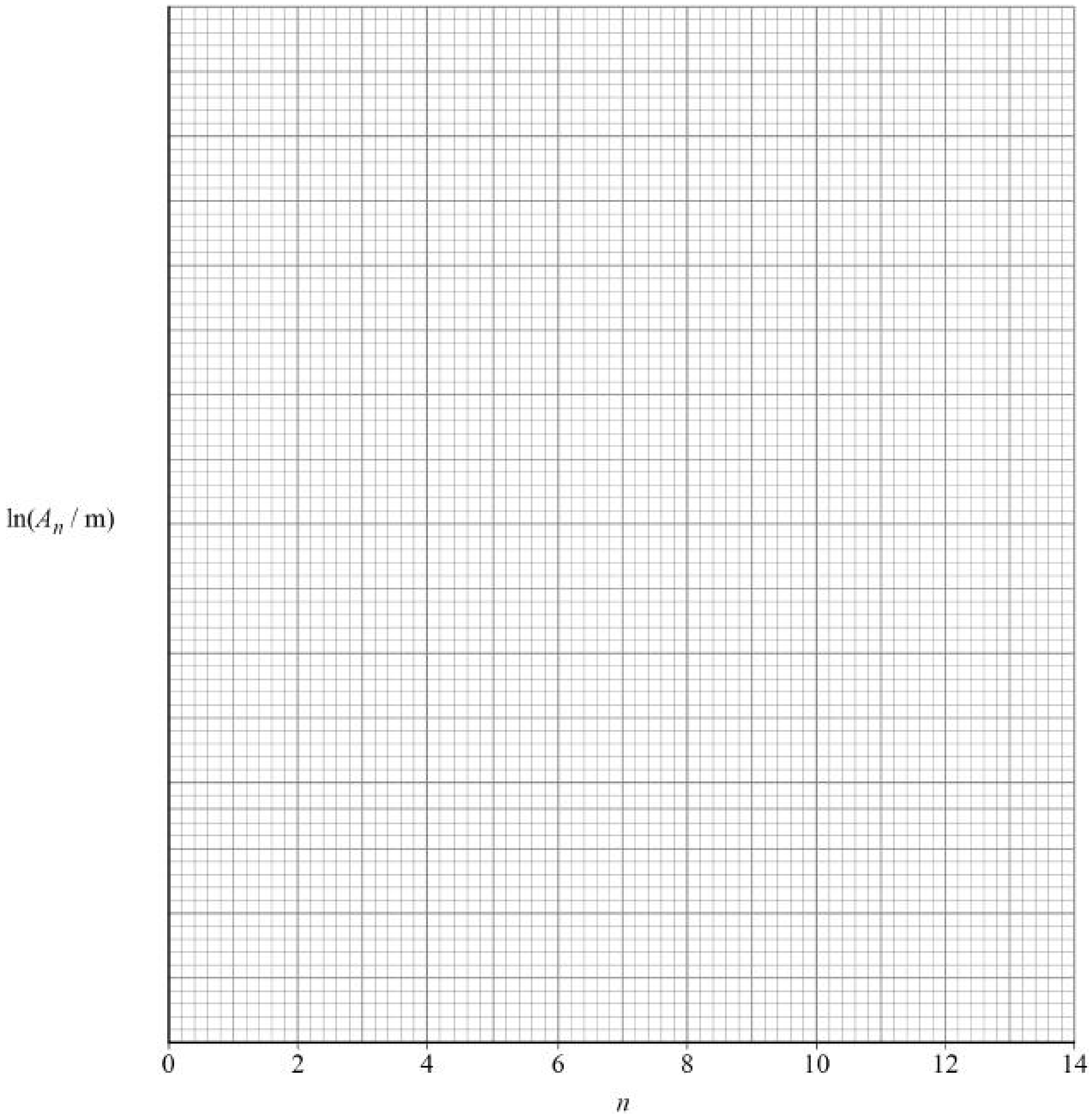
n	A_n / m	ln(A_n / m)
2	0.238	−1.435
4	0.225	
7	0.212	−1.551
10	0.194	−1.640
13	0.183	−1.698

Complete **Table 2**.

(1)

(f) Plot on **Figure 4** a graph of ln(A_n / m) against n.

Figure 4



(g) It can be shown that

$$A_n = A_0 \delta^{-n}$$

where A_0 is the amplitude of release of the pendulum
δ is a constant called the damping factor.

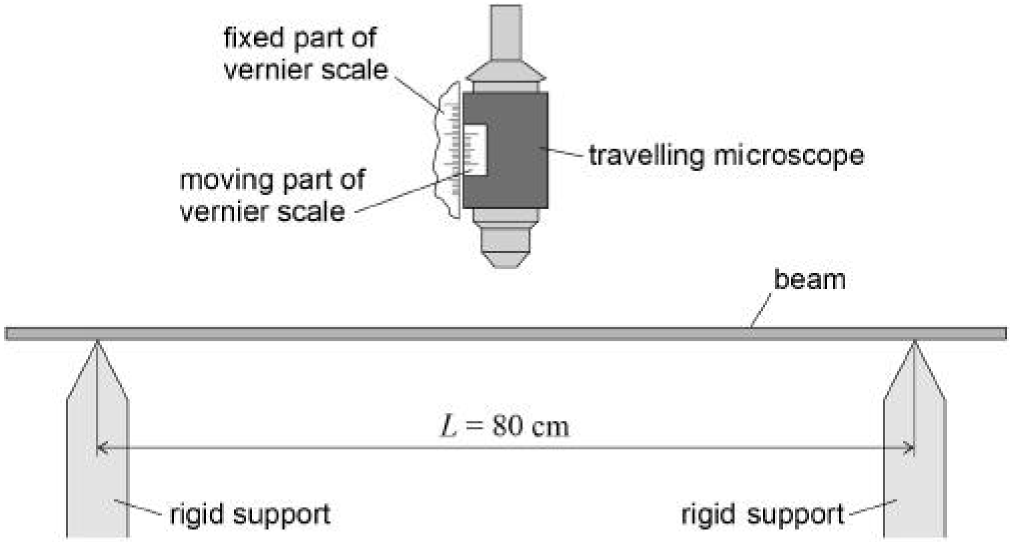
Explain how to find δ from your graph.
You are **not** required to determine δ.

(2)
(Total 15 marks)

Q12.

Figure 1 shows apparatus used to investigate the bending of a beam.

Figure 1

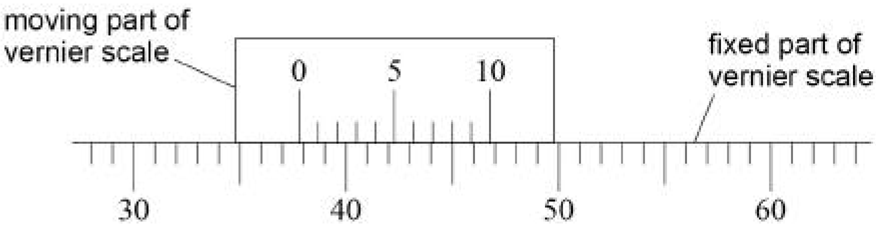


The beam is placed horizontally on rigid supports.
The distance L between the supports is 80 cm.

A travelling microscope is positioned above the midpoint of the beam and focused on the upper surface.

(a) **Figure 2** shows an enlarged view of both parts of the vernier scale.

Figure 2



The smallest division on the fixed part of the scale is 1 mm.

What is the value of the vernier reading R_0 in mm?
Tick (✓) **one** box.

34.8 ☐

37.8 ☐

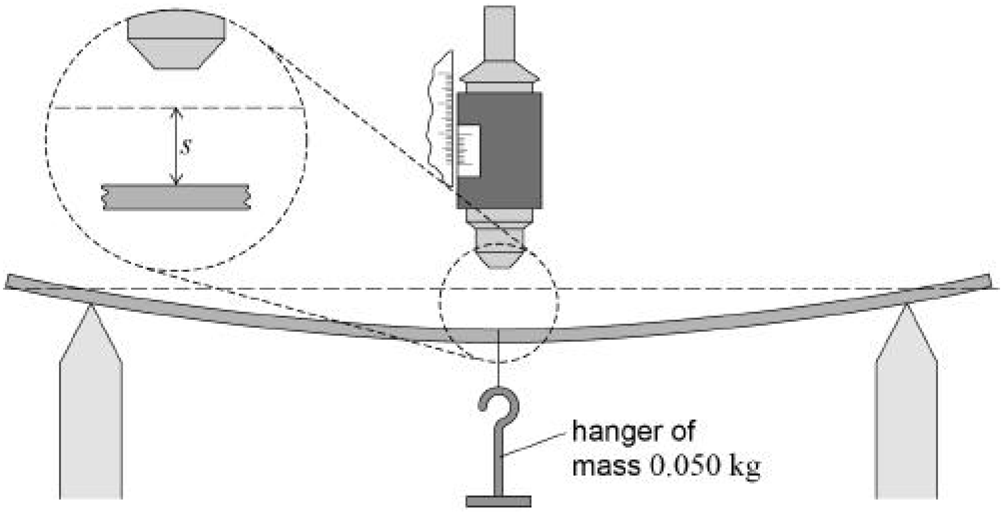
45.8 ☐

49.8 ☐

(1)

(b) **Figure 3** shows the beam bending when a hanger of mass 0.050 kg is suspended from the midpoint.

Figure 3



The microscope is refocused on the upper surface and the new vernier reading R is recorded.
The vertical deflection s of the beam is equal to $(R - R_0)$.

The total mass m suspended from the beam is increased in steps of 0.050 kg.
A value of s is recorded for each m up to a value of m = 0.450 kg.
Further values of s are then recorded as m is decreased in 0.050 kg steps until m is zero.

Student **A** performs the experiment and observes that values of s during unloading are **sometimes** different from the corresponding values for loading.

State the type of error that causes the differences student **A** observes.

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(1)

(c) Student **B** performs the experiment using a thinner beam but with the same width and made from the same material as before.

Discuss **one** possible advantage and **one** possible disadvantage of using the thinner beam.

Advantage ____

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Disadvantage ____

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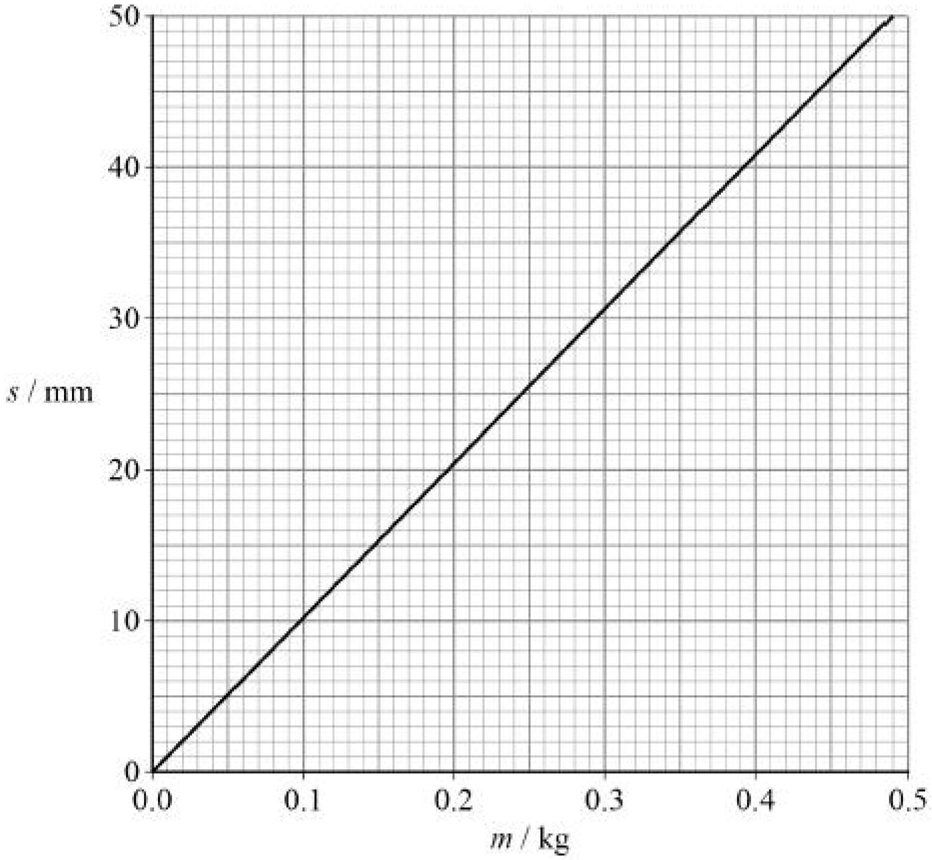
(3)

(d) **Figure 4** shows the best-fit line produced using the data collected by student **A**.

Figure 4



It can be shown that $s = \frac{\eta m}{E}$

where E is the Young modulus of the material of the beam and η is a constant.

Deduce in s^{-2} the order of magnitude of η.

E = 1.14 GPa

order of magnitude of η = _______________ s^{-2}

(4)

(e) Student **C** performs a different experiment using the same apparatus shown in **Figure 1**.
A mass M is suspended from the midpoint of the beam.
The vertical deflection s of the beam is measured for different values of L.

Figure 5 shows a graph of the results for this experiment.

Figure 5

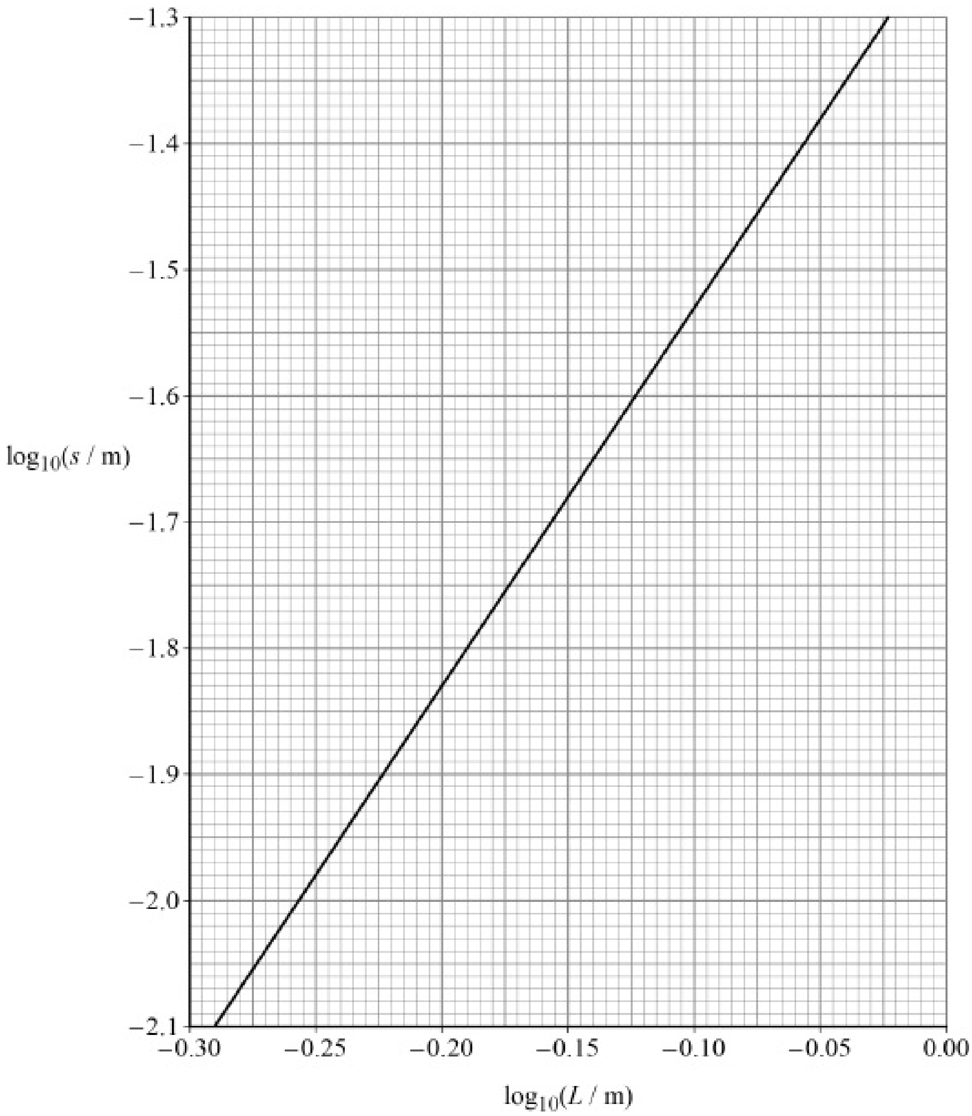


Figure 5 shows that log10(s / m) varies linearly with log10(L / m).

State what this shows about the mathematical relationship between s and L. You do **not** need to do a calculation.

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(1)

(f) Deduce, using **Figure 5**, the value of s when L = 80 cm.

s = ________________ m

(2)

(g) Determine M using **Figure 4**.

M = ________________ kg

(1)

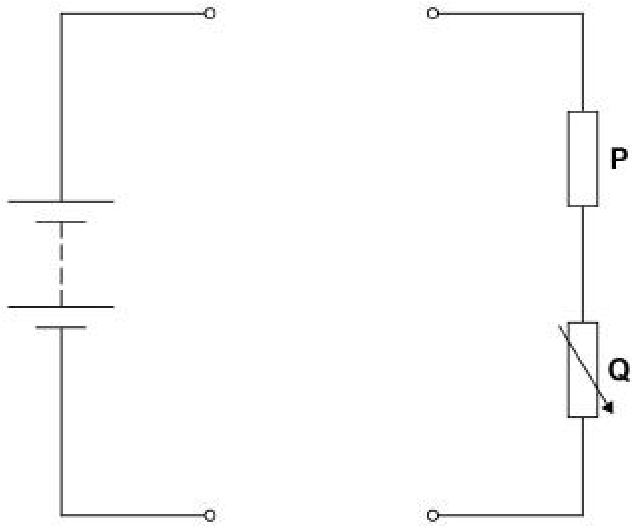
(Total 13 marks)

Q13.

Figure 1 shows a partly-completed circuit used to investigate the emf ε and the internal resistance r of a power supply.

The resistance of **P** and the maximum resistance of **Q** are unknown.

Figure 1



(a) Complete **Figure 1** to show a circuit including a voltmeter and an ammeter that is suitable for the investigation.

(1)

(b) Describe

- a procedure to obtain valid experimental data using your circuit
- how these data are processed to obtain ε and r by a graphical method.

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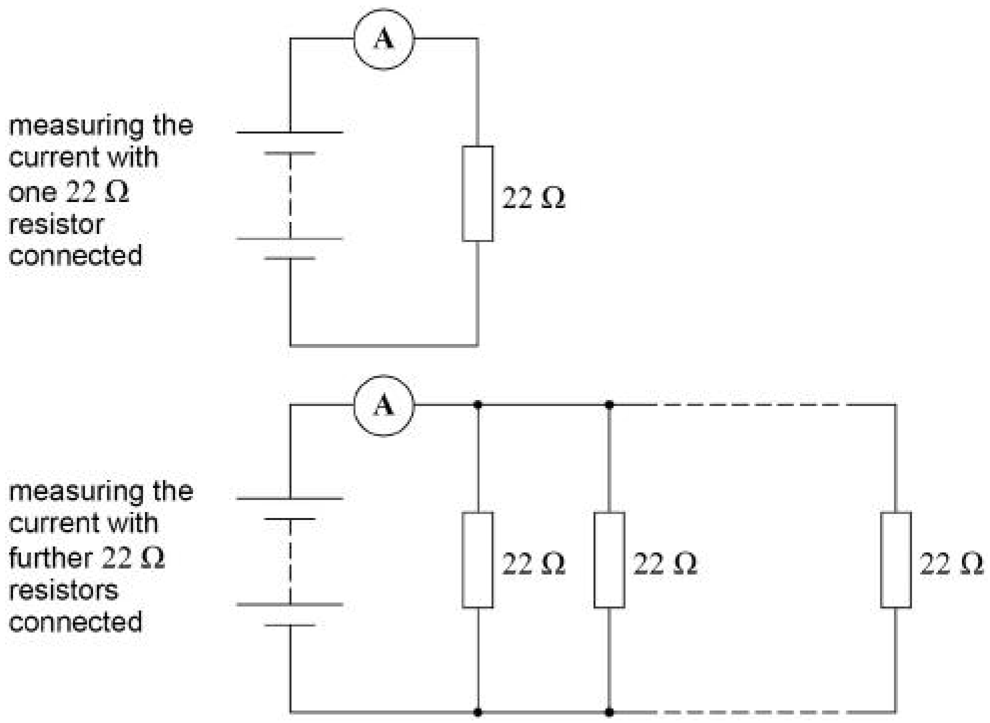
(4)

Figure 2 shows a different experiment carried out to confirm the results for ε and r.

Figure 2



Initially the power supply is connected in series with an ammeter and a 22 Ω resistor. The current I in the circuit is measured.

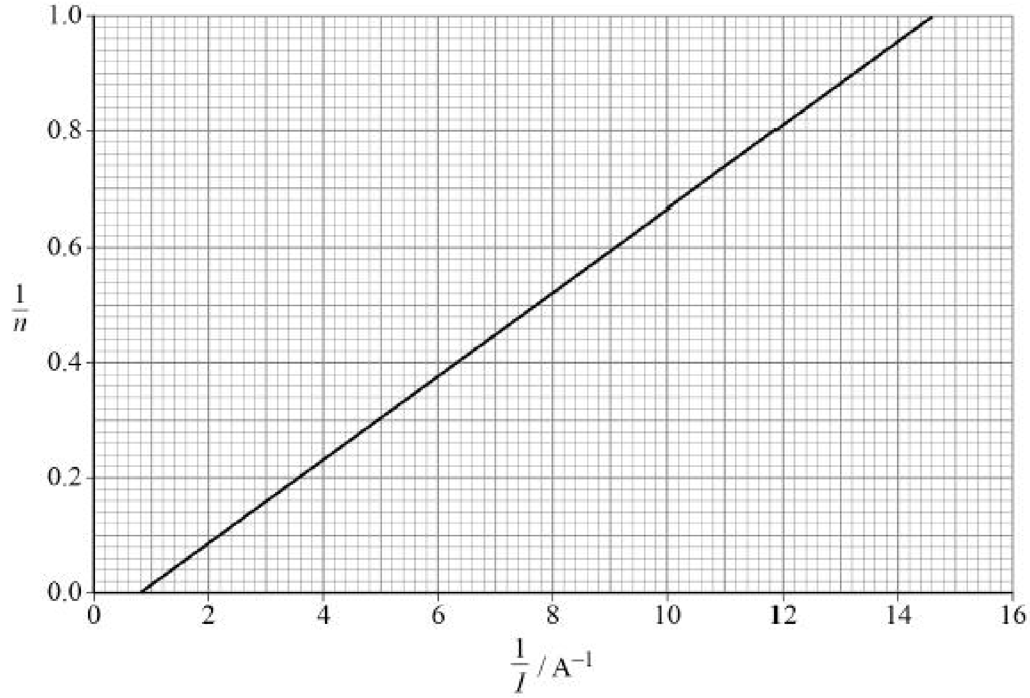
The number n of 22 Ω resistors in the circuit is increased as shown in **Figure 2**. The current I is measured after each resistor is added.

It can be shown that

$$\frac{22}{n} = \frac{\varepsilon}{I} - r$$

Figure 3 shows a graph of the experimental data.

Figure 3

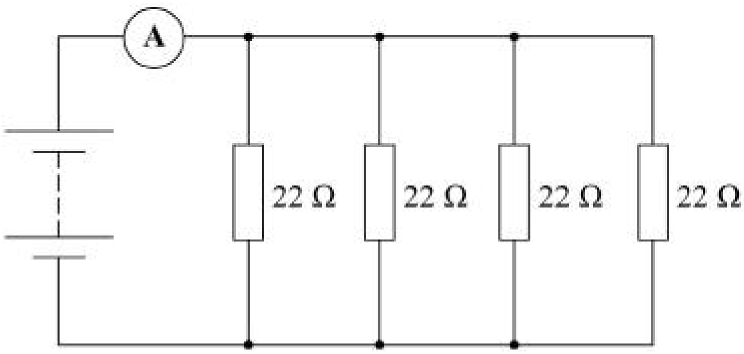


(c) Show that ε is about 1.6 V.

(2)

(d) **Figure 4** shows the circuit when four resistors are connected.

Figure 4



Show, using **Figure 3**, that the current in the power supply is about 0.25 A.

(1)

(e) Deduce, for the circuit shown in **Figure 4**,

- the potential difference (pd) across the power supply
- r.

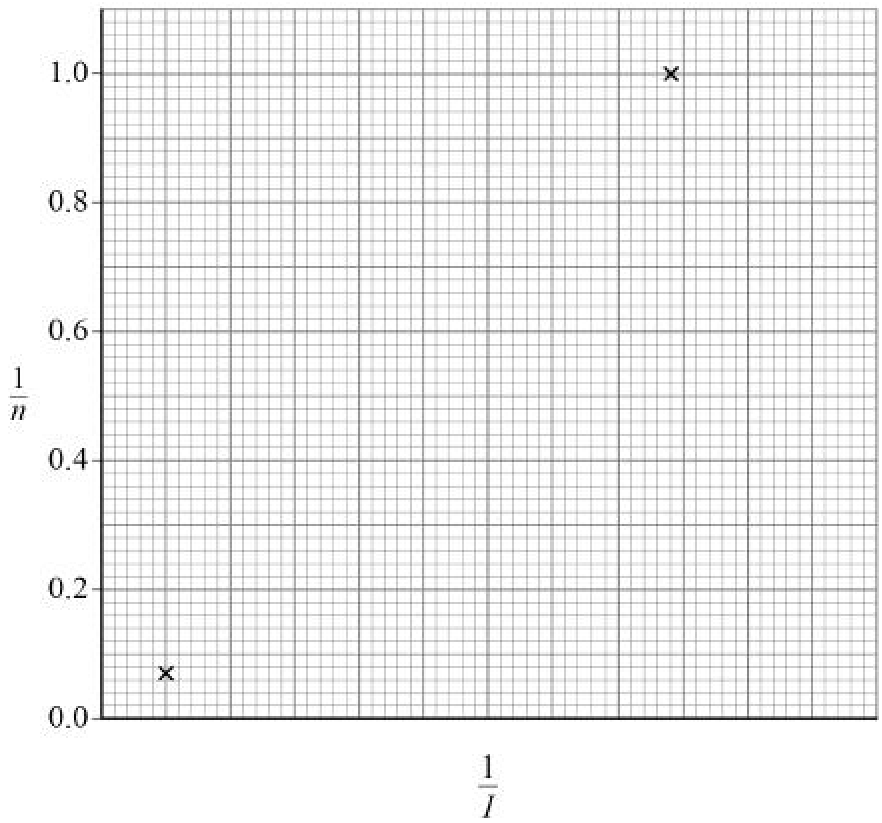
pd = _______________ V

r = _______________ Ω

(4)

(f) **Figure 5** shows the plots for n = 1 and n = 14

Figure 5



Three additional data sets for values of n between n = 1 and n = 14 are needed to complete the graph in **Figure 5**.

Suggest which additional values of n should be used.
Justify your answer.

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(3)

(g) The experiment is repeated using a set of resistors of resistance 27 Ω.

The relationship between n and I is now

$$\frac{27}{n} = \frac{\varepsilon}{I} - r$$

Show on **Figure 5** the effect on the plots for n = 1 and n = 14
You do **not** need to do a calculation.

(2)
(Total 17 marks)

Q14.

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

Figure 1

(a) State **two** safety procedures to reduce risk when using this type of source.

Safety procedure 1 ____

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Safety procedure 2 ____

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(2)

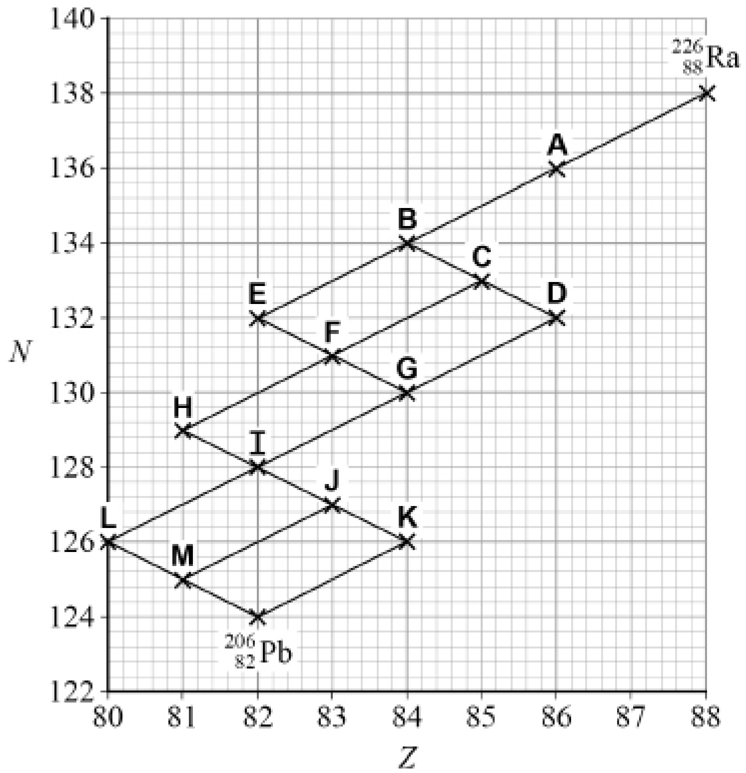
(b) A sealed source contains radium-226 ($^{226}_{88}\text{Ra}$).

$^{226}_{88}\text{Ra}$ decays by emitting α and β⁻ particles to produce $^{206}_{82}\text{Pb}$ which is stable.

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

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

Figure 2



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

____ **(1)**

(c) Identify which of the nuclei **A** to **M** are common to all the possible ways that $^{226}_{88}\text{Ra}$ decays into $^{206}_{82}\text{Pb}$.

____ **(3)**

(d) The sealed source emits γ radiation in addition to α and β^- particles.
A student uses the sealed source to investigate the inverse-square law for γ 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.

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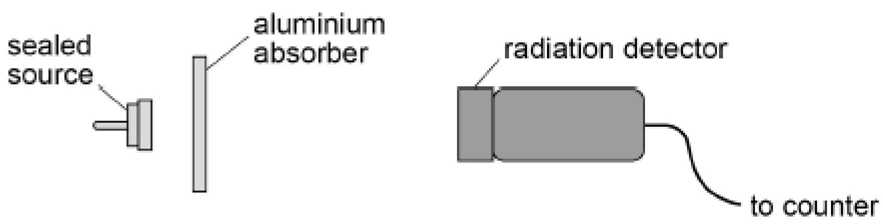
(3)

(e) **Figure 3** shows an aluminium absorber placed between the sealed source and a radiation detector. This is to make sure that only γ radiation from the source reaches the detector.

Figure 3

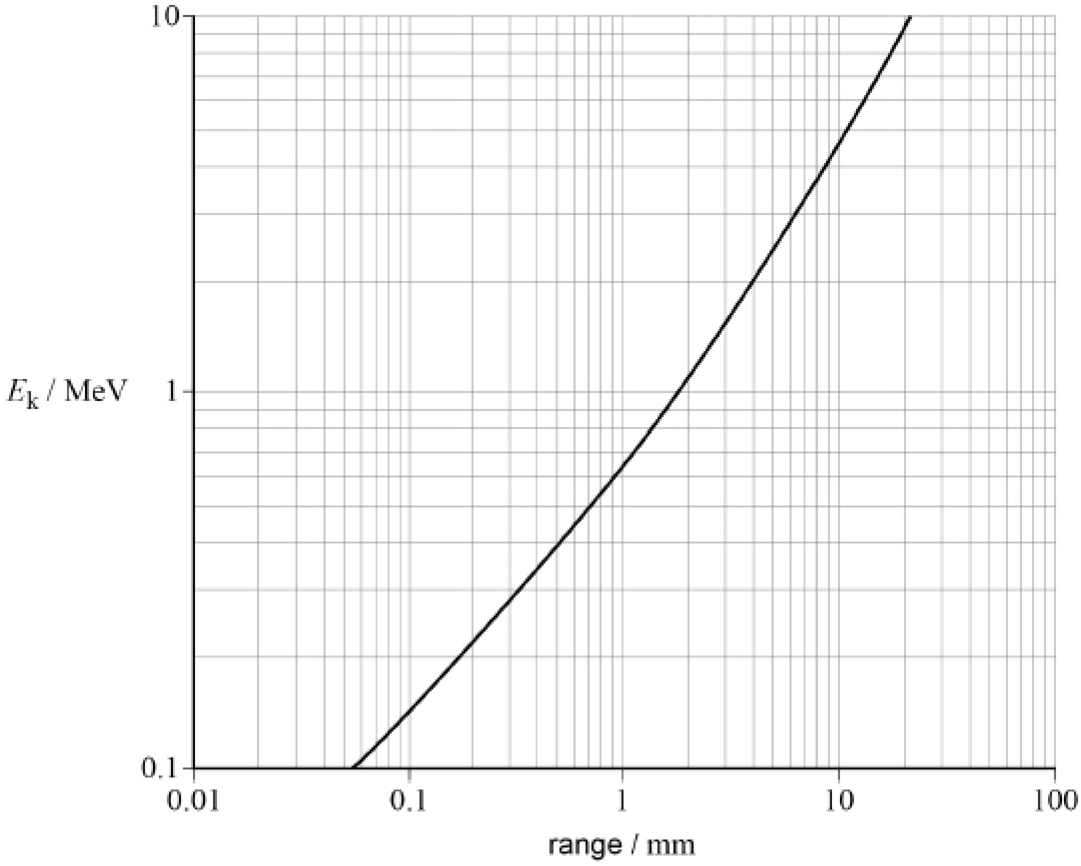


The sealed source emits:

- α particles with energy E_k between 3.8 MeV and 7.8 MeV
- β^- particles with energy E_k between zero and 5.5 MeV.

Figure 4 shows how the range of β^- particles in aluminium depends on E_k.

Figure 4



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

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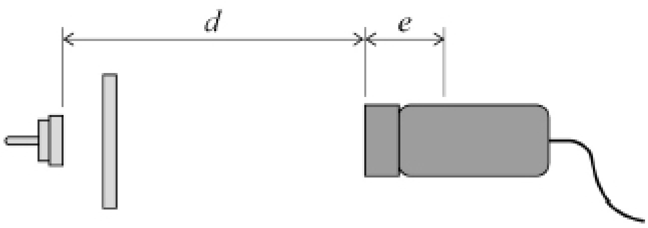
minimum thickness = ____________________ mm

(3)

(f) 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.

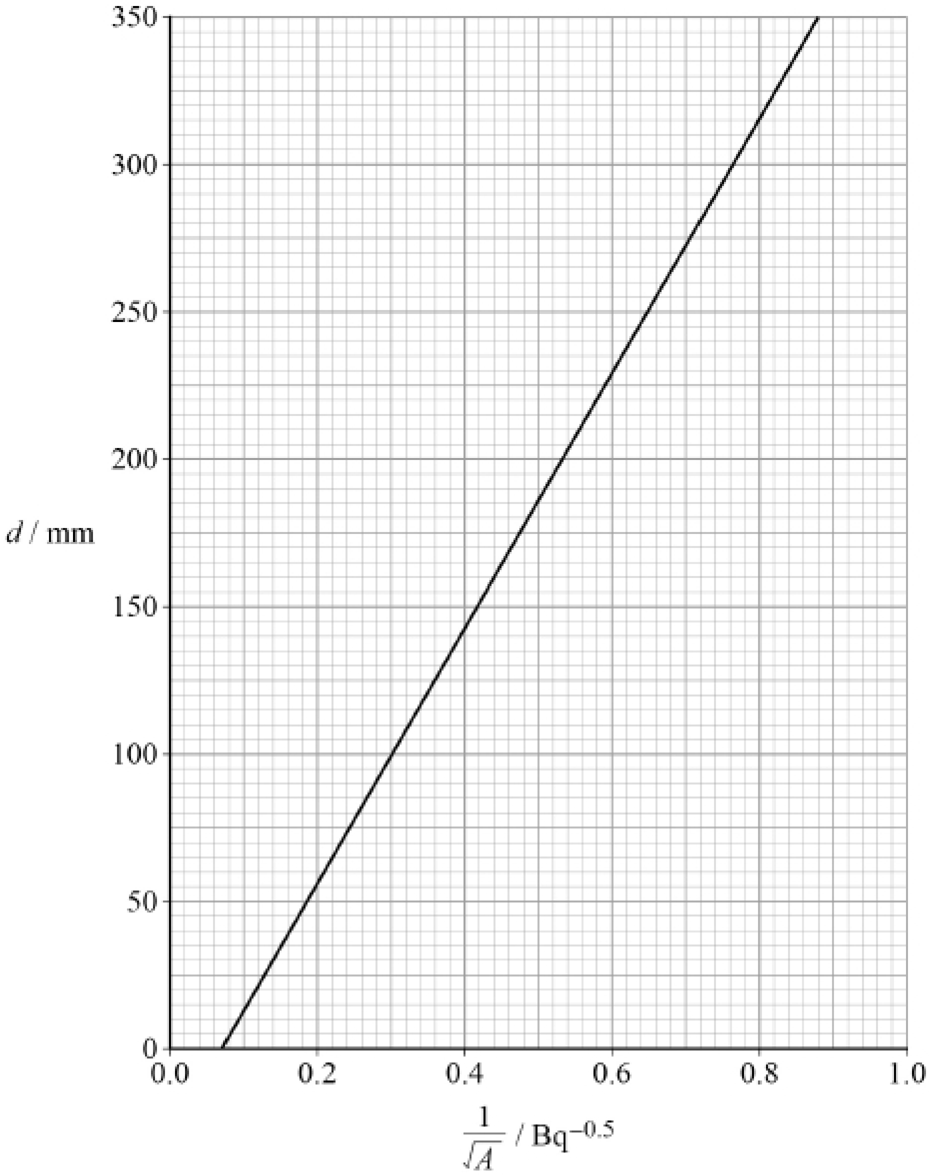
The student plots the graph of d against $\frac{1}{\sqrt{A}}$ shown in **Figure 6**.

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

k = ____________________ unit _______

(5)

Figure 6



(g) Determine e using **Figure 6**.

e = ____________________ mm

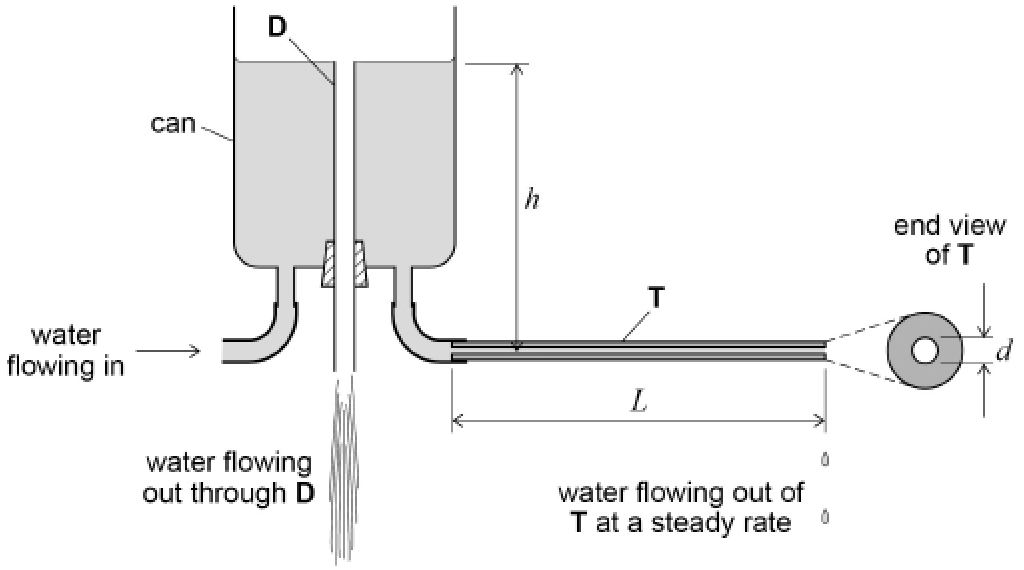
(2)

(Total 19 marks)

Q15.

Figure 1 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 1



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.

(a) The volume flow rate through **T** is Q, where Q is in $m^3\ s^{-1}$.
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.

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(4)

(b) It can be shown that

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

where ρ is the density of water
g is the gravitational field strength
η is a property of the water called the coefficient of viscosity.

What is the SI unit for η?

Tick (✓) **one** box.

$N\ m^{-1}\ s$ ☐

$N\ m^{-2}\ s$ ☐

$N\ m^{-1}\ s^{-1}$ ☐

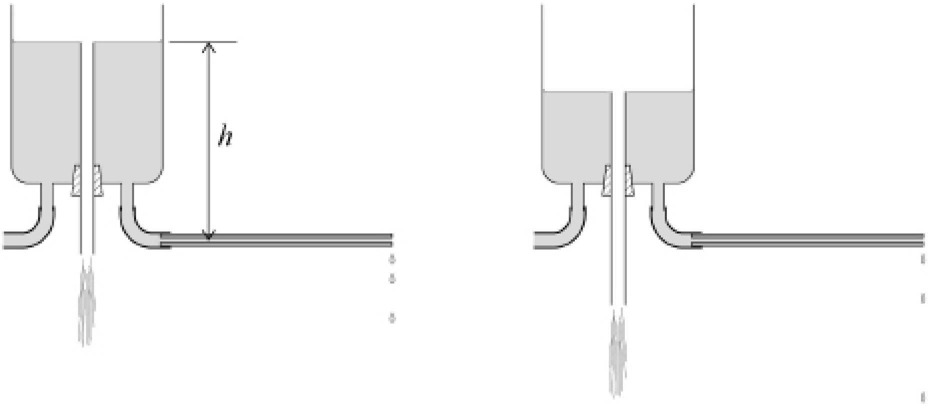
$N\ m^{-2}\ s^{-1}$ ☐

(1)

(c) An experiment is carried out to determine η 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 2**.

Figure 2



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 ρ and g are negligible.

Deduce the percentage uncertainty in the result for η.

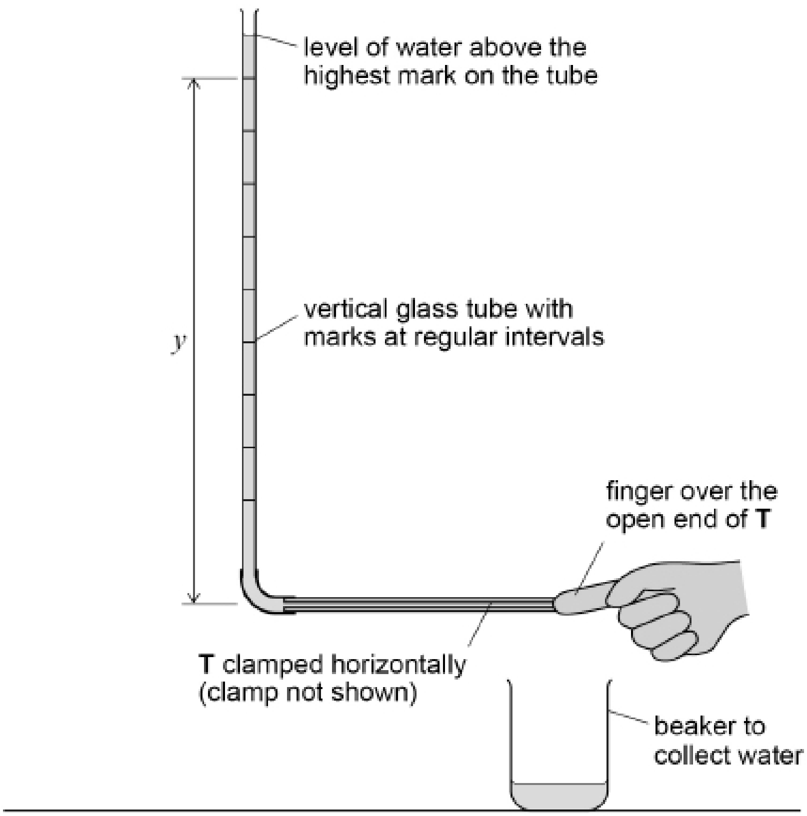
percentage uncertainty in η = ____________________

(2)

(d) 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 3**.

Figure 3



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 3** to illustrate your answer.

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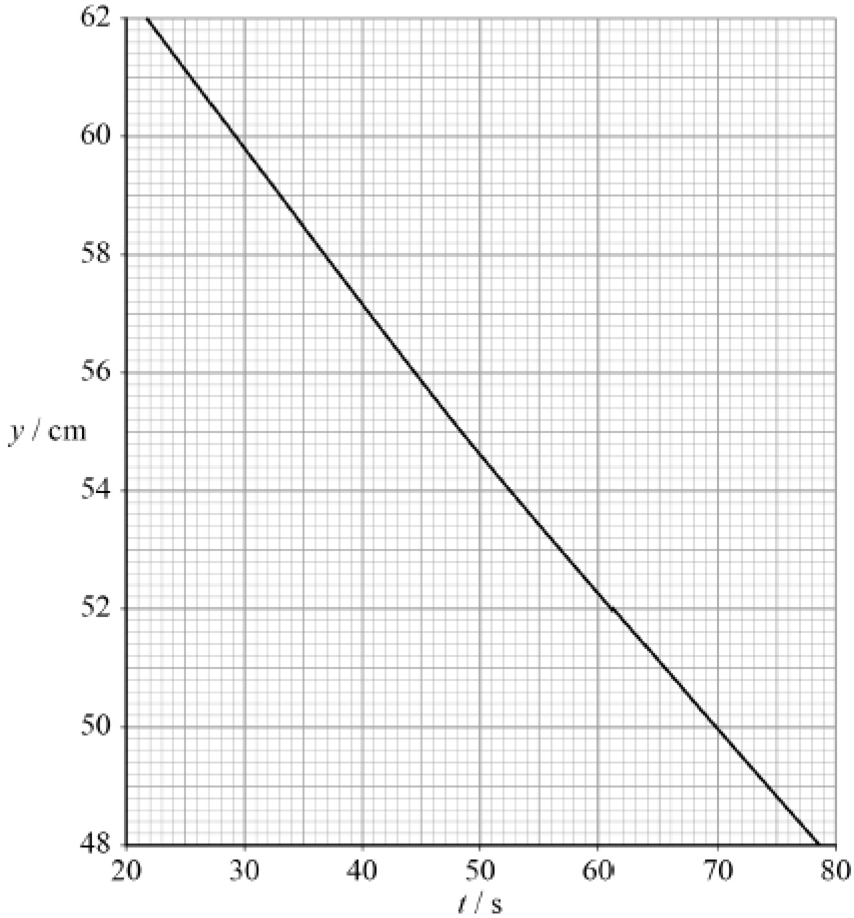
(1)

(e) **Figure 4** shows part of the graph drawn from the student's data.

Figure 4



It can be shown that y decreases exponentially with t.

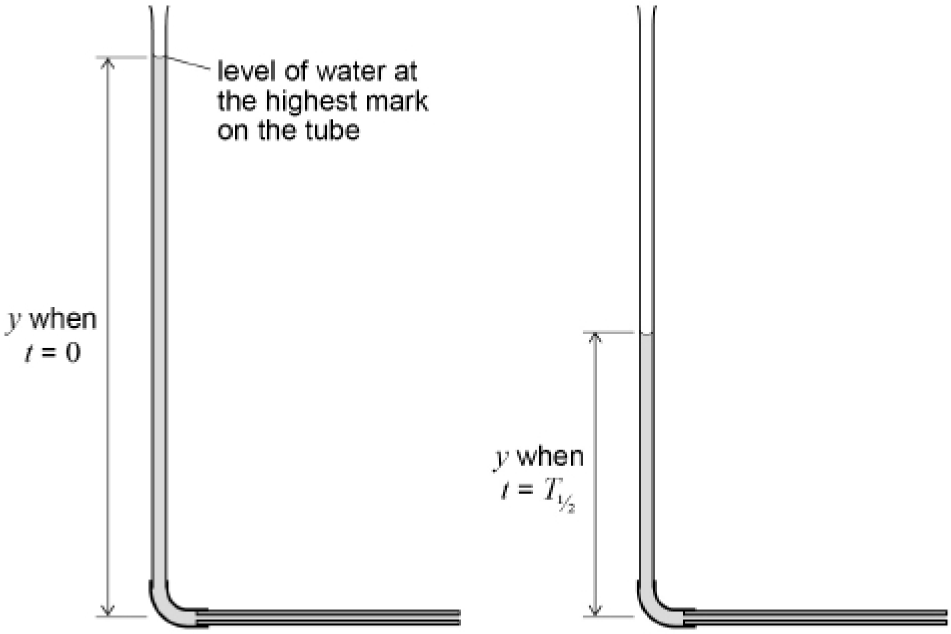
Show that λ, the decay constant for this process, is about 4.5×10^{-3} s^{-1}.

λ = ______________________ s^{-1}

(2)

(f) $T_{½}$ is the time for y to decrease by 50%, as shown in **Figure 5**.

Figure 5

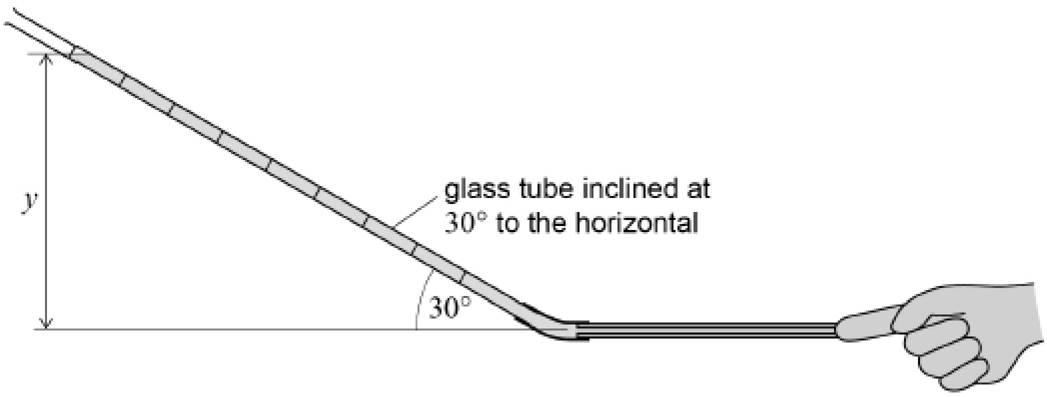


$T_{½}$ = ____________________ s

(1)

(g) The apparatus is adjusted so that the glass tube is inclined at 30° to the horizontal tube **T**, as shown in **Figure 6**.

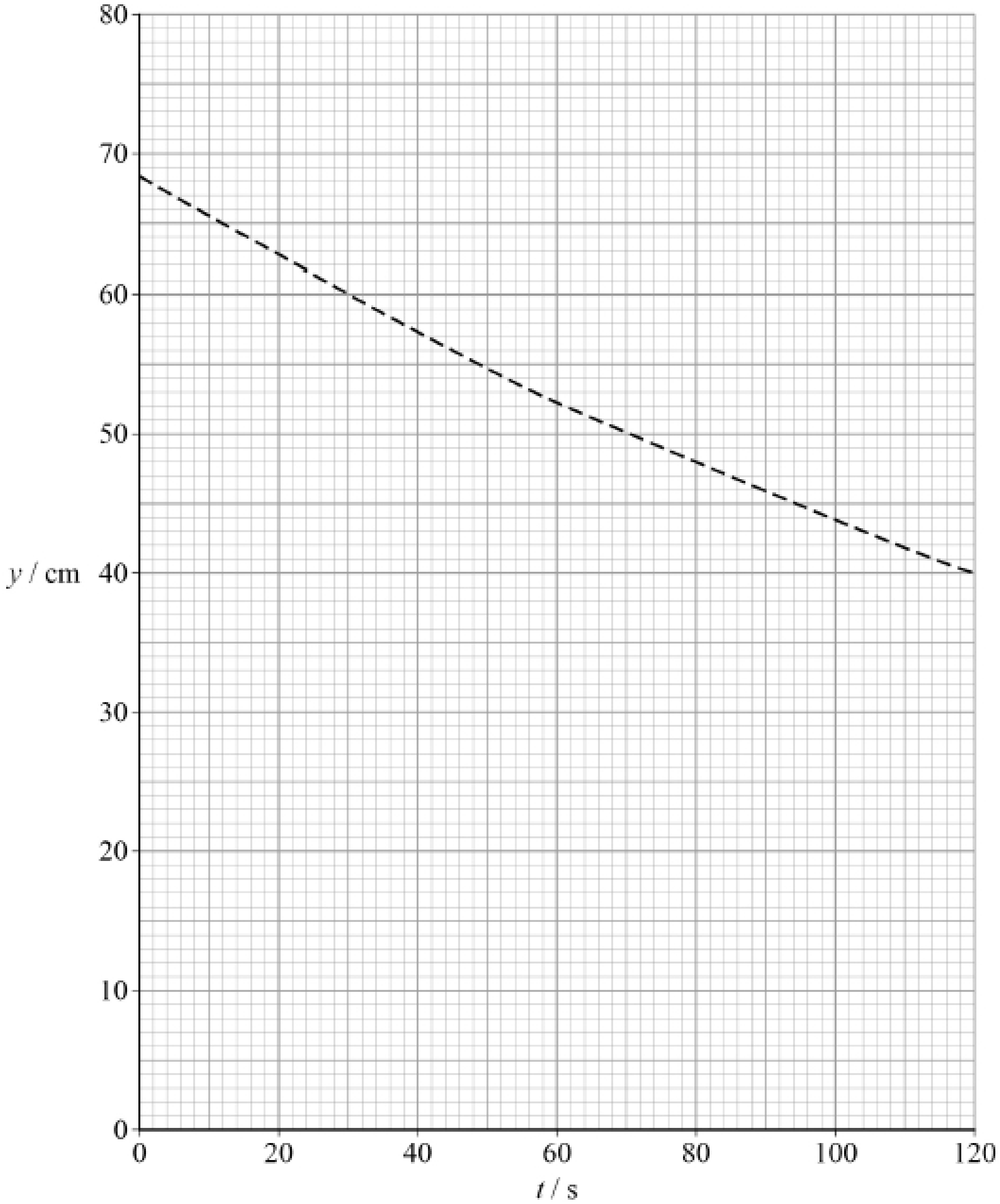
Figure 6



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 7** 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 3**.

Figure 7



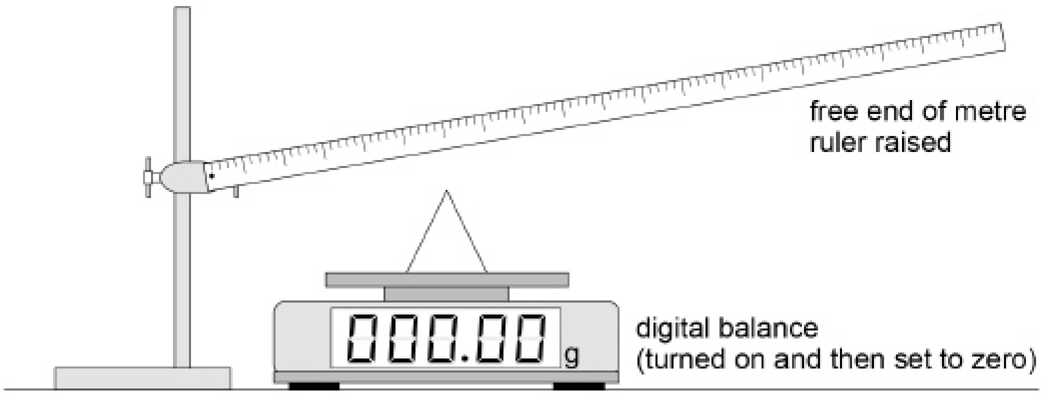
(2)
(Total 13 marks)

Q16.

This question is about using a digital balance to investigate the force on a wire placed in a magnetic field when there is an electric current in the wire.

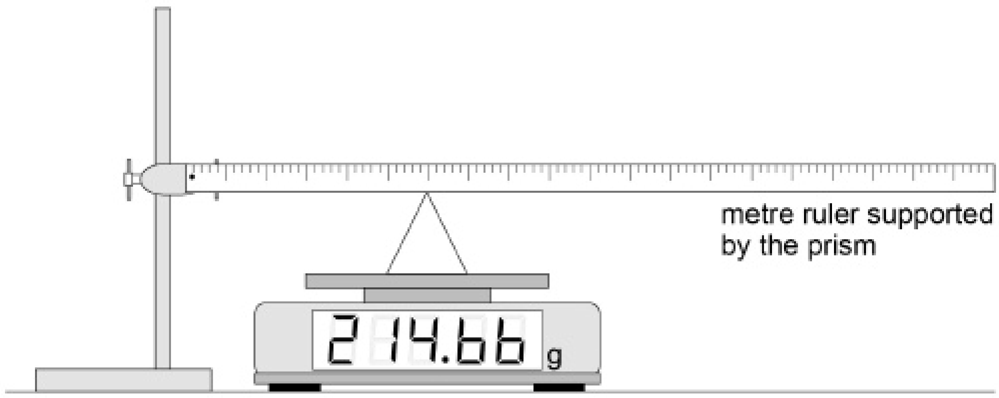
A student carries out the procedure shown in **Figure 1** and **Figure 2**.
A metre ruler is pivoted at the 1.0 cm mark and a prism is placed on a digital balance. The free end of the ruler is raised and the balance is turned on and then set to zero, as shown in **Figure 1**.

Figure 1



The ruler is then supported by the prism with the apex of the prism at the 30.0 cm mark as shown in **Figure 2**. The height of the pivot is adjusted so that the ruler is horizontal.

Figure 2



(a) Deduce the mass of the ruler.
State **one** assumption you make.

mass of ruler = ____________________ g

assumption ____

____

(3)

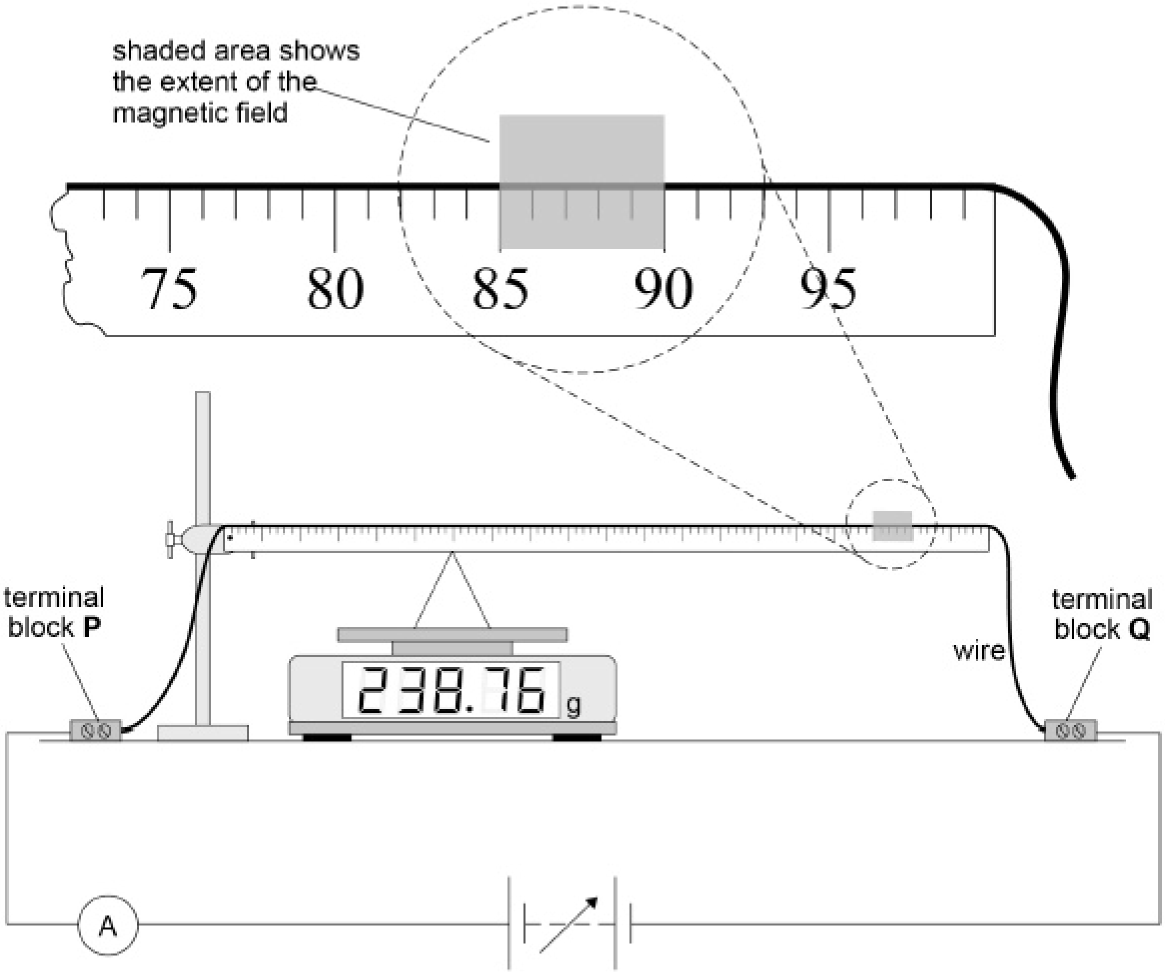
(b) The student attaches a uniform wire to the upper edge of the ruler, as shown in **Figure 3**.

The ends of the wire are connected to terminal blocks **P** and **Q** which are fixed firmly to the bench. A power supply and an ammeter are connected between **P** and **Q**.

These modifications cause the balance reading to increase slightly.

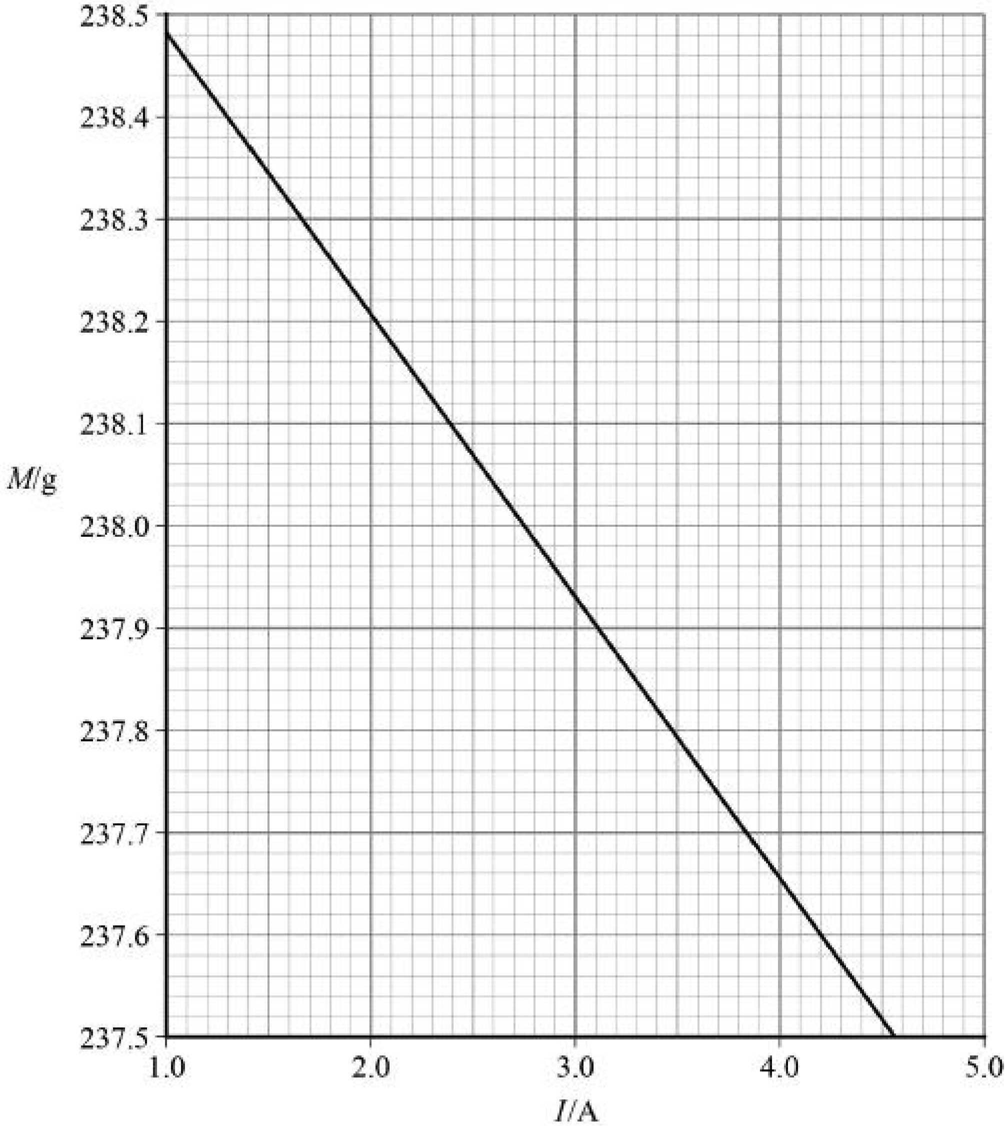
A horizontal uniform magnetic field is applied, perpendicular to the wire, between the 85 cm and 90 cm marks, as shown in the close-up diagram in **Figure 3**.

Figure 3



The balance reading M is recorded for increasing values of current I.
A graph of these data is shown in **Figure 4**.

Figure 4



State and explain the direction of the horizontal uniform magnetic field.

(3)

(c) It can be shown that B, the magnitude of the magnetic flux density of the horizontal uniform magnetic field, is given by

$$B = \frac{\sigma}{3L}$$

where

σ = change in force acting on the prism per unit current in the wire
L = length of the region where the magnetic field cuts through the wire.

Determine B.

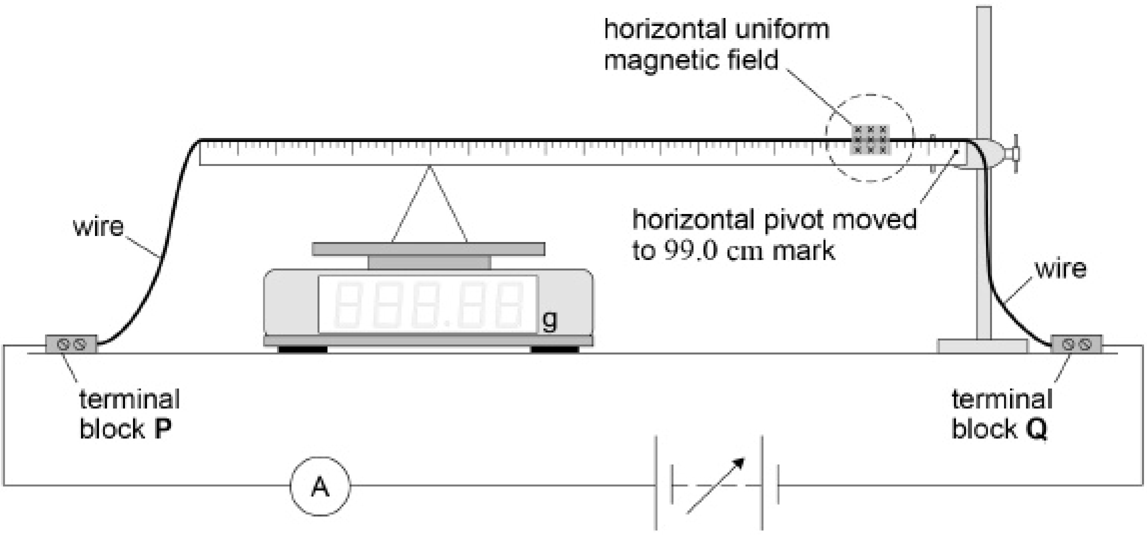
B = ____________________ T

(3)

(d) The experiment is repeated with the ruler pivoted at the 99.0 cm mark. Nothing else is changed from **Figure 3**.

This arrangement is shown in **Figure 5**.

Figure 5



Tick (✓) **one** box in row 1 and **one** box in row 2 of the table to identify the effect, if any, on the magnitude of the forces acting on the apparatus as a certain current is passed through the wire.

Tick (✓) **one** box in row 3 and **one** box in row 4 of the table to identify the effect, if any, on the graph produced for this modified experiment compared with the graph in **Figure 4**.

		Reduced	No effect	Increased
1	Force acting on the current-carrying wire due to the horizontal uniform magnetic field			
2	Force acting on the prism due to the pivoted ruler			
3	Gradient of the graph			
4	Vertical intercept of the graph			

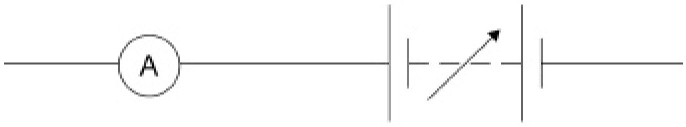
(3)

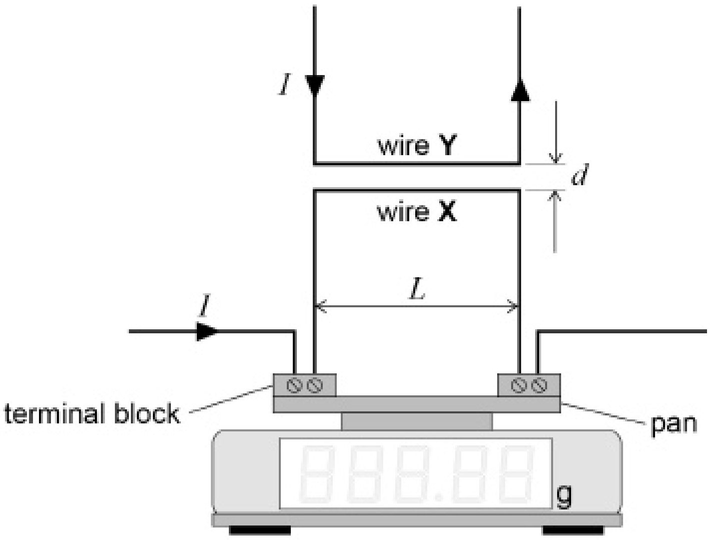
(e) **Figure 6** shows the balance being used to measure the forces between two wires.
The connections joining these wires to the power supply are not shown.

The pan of the balance moves a negligible amount during use and it supports a straight conducting wire **X** of horizontal length L.
Terminal blocks are used to connect **X** into the circuit. The weight of these does not affect the balance reading.
A second conducting wire **Y** is firmly supported a distance d above **X**.

Show, by adding detail to **Figure 6**, the wire connections that complete the circuit.
The currents in **X** and **Y** must have the same magnitude and be in the directions indicated.

Figure 6





(2)

(f) The vertical force F on wire **X** due to the magnetic field produced by wire **Y** is given by

$$F = \frac{kI^2L}{d}$$

where

k is a constant
d is the perpendicular distance between **X** and **Y**
I is the current in the wires

and

L is the horizontal length of wire **X**.

A student wants to measure k using the arrangement in **Figure 6**.

The student is told that the following restrictions must apply:

- L is fixed
- I must not exceed 5.0 A
- the result for k must be obtained using a **graphical method**
- the experimental procedure must involve **only one** independent variable.

Explain what the student could do to find k.

(5)

(Total 19 marks)

Q17.

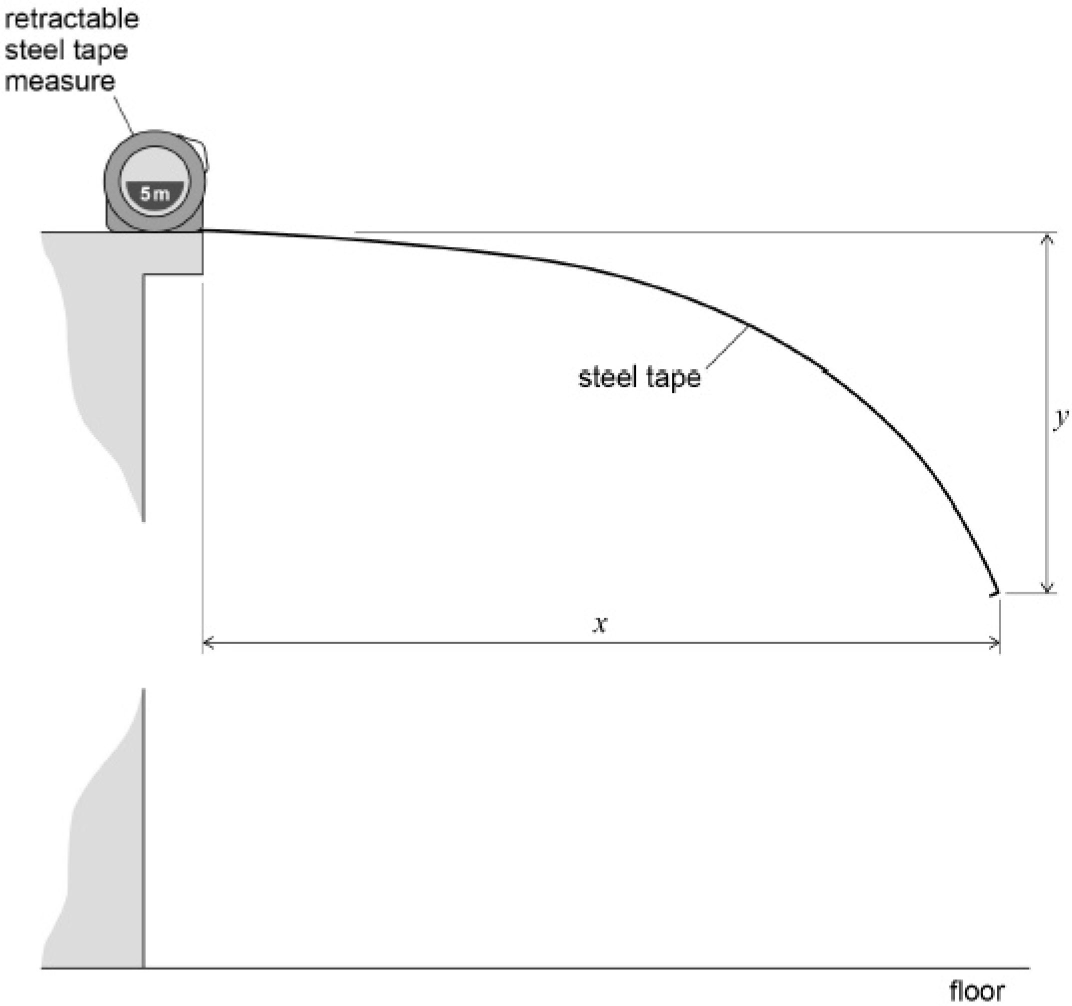
This question is about an experiment with a retractable steel tape measure.

The tape measure is placed at the edge of the bench and about 1 m of the steel tape is extended so that it overhangs the bench.

The tape is then locked in this position to stop it from retracting.

A student measures the dimensions x and y, the horizontal and vertical displacements of the free end of the tape, as shown in **Figure 1**.

Figure 1



(a) Describe a suitable procedure the student could use to measure y.
You may add detail to **Figure 1** to illustrate your answer.

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(2)

(b) By changing the extension of the tape, the student obtains further values of x and y.

These data are shown in the table.

x / cm	y / cm
132.4	61.2
116.8	33.7
105.1	24.3
94.5	15.6
84.3	11.0
73.2	5.7

Suggest why the student chose to make **all** measurements of x greater than 70 cm

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(1)

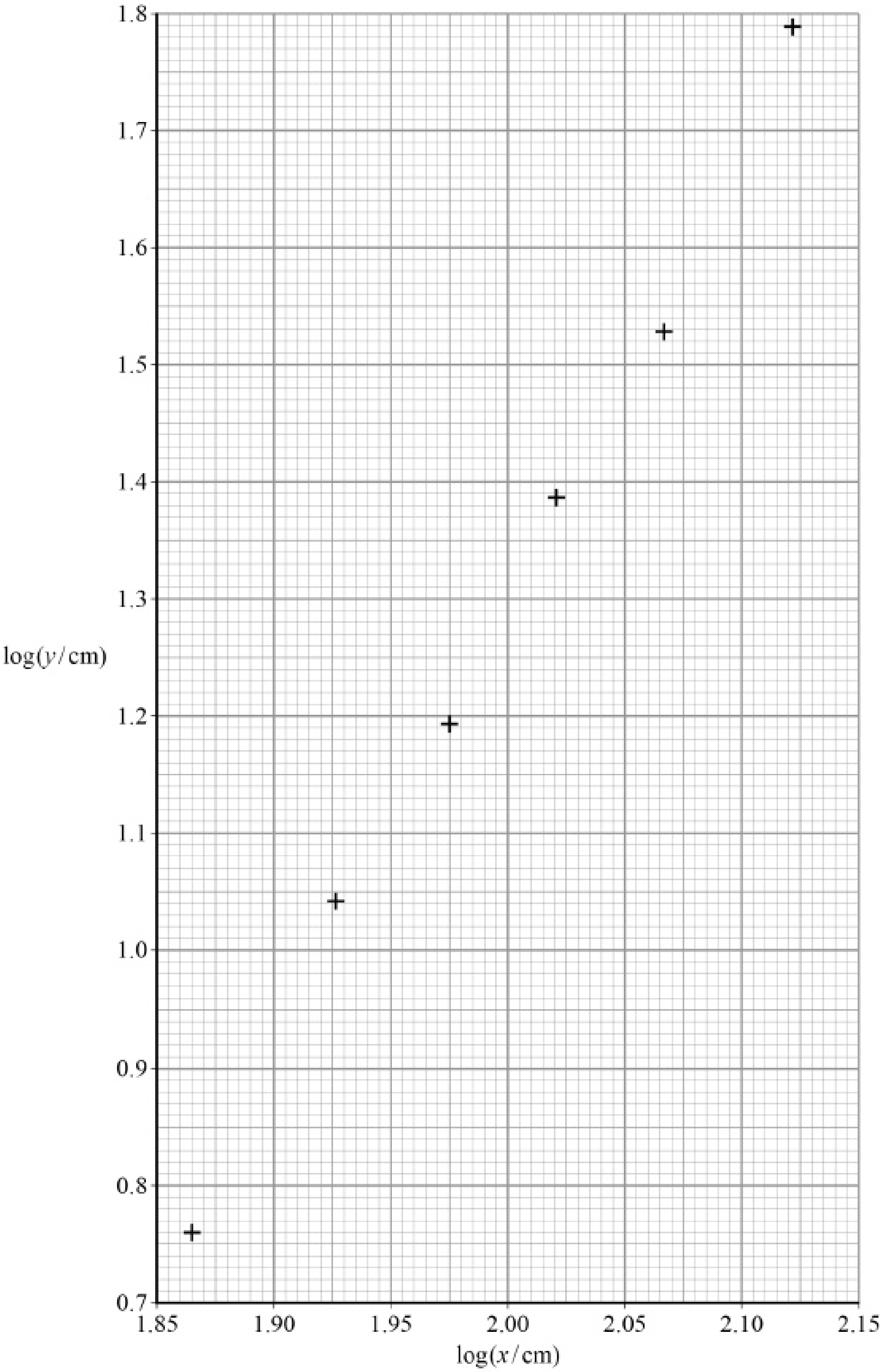
(c) The data from the experiment suggest that $y = Ax^n$ where n is an integer and A is a constant.

These data are used to plot the graph in **Figure 2**.

Determine n using **Figure 2**.

n = ____________________

Figure 2


1.8
1.7
1.6
1.5
1.4
1.3
log(y/cm)
1.2
1.1
1.0
0.9
0.8
0.7
1.85
1.90
1.95
2.00
2.05
2.10
2.15
log(x/cm)

(3)

(d) Explain how the numerical value of A can be obtained from **Figure 2**.

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(3)

(e) Estimate the order of magnitude of A.
You should use data for x and y from any **one** row in the table above.
Give your answer with an appropriate unit.

order of magnitude of A = ____________________ unit ___________

(3)

(Total 12 marks)

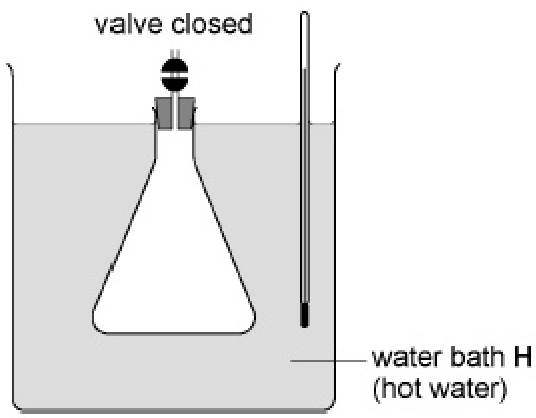
Q18.

This question is about an experiment to estimate absolute zero.

Figures 1a to 1d show the stages in the procedure carried out by a student.

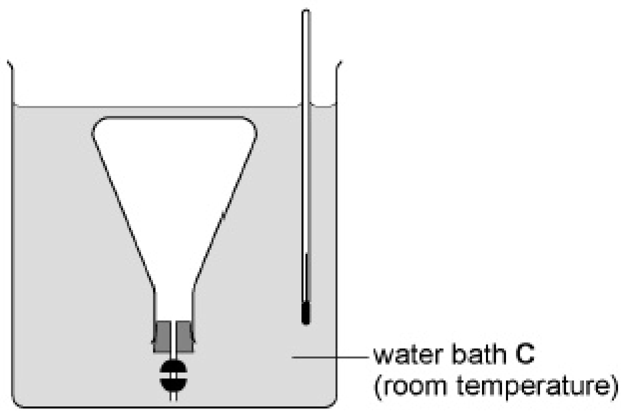
An empty flask fitted with a tube and an open valve is placed in water bath **H** containing hot water. The air inside the flask is allowed to come into thermal equilibrium with the water.
The valve is then closed, trapping a certain volume of air, as shown in **Figure 1a**.

Figure 1a



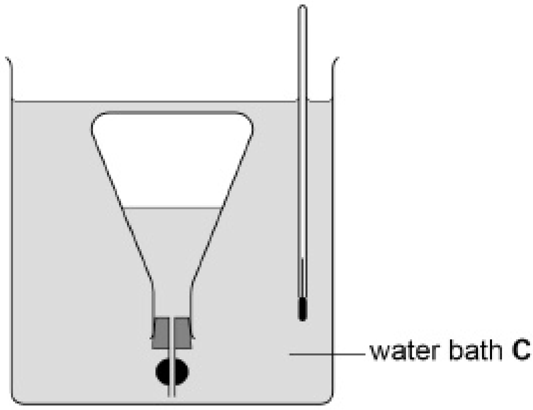
The flask is inverted and placed in water bath **C** in which the water is at room temperature.
The air inside the flask is again allowed to come into thermal equilibrium with the water, as shown in **Figure 1b**.

Figure 1b



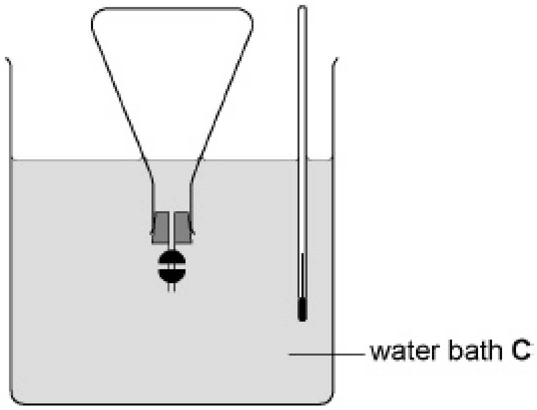
The valve is opened and some water enters the flask, as shown in **Figure 1c**.

Figure 1c



The depth of the inverted flask is adjusted until the level of water inside the flask is the same as the level in the water bath.
The valve is then closed, trapping the air and the water inside the flask, as shown in **Figure 1d**.

Figure 1d



(a) Explain why the volume of the air in the flask in **Figure 1c** is less than the volume of the air in the flask in **Figure 1d**.

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(2)

(b) Explain why Charles's Law can be applied to compare the air in the flask in **Figure 1a** with the air in the flask in **Figure 1d**.

(2)

(c) The flask is removed from water bath **C** and the valve and stopper are removed.

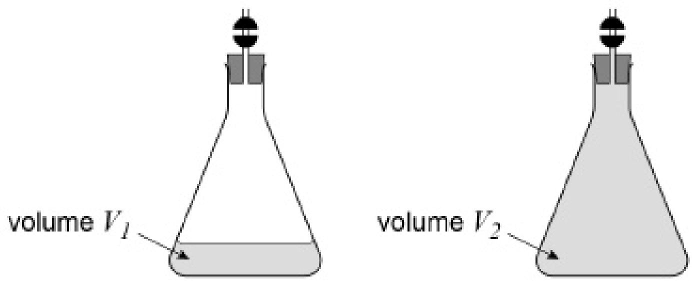
The volume of the water in the flask is V_1

The flask is then completely refilled with water and the valve and stopper replaced.

The volume of the water now in the flask is V_2

The volumes V_1 and V_2 are shown by the shaded parts in **Figure 2**.

Figure 2



Explain how V_1 and V_2 can be determined.

In your answer you should

- identify a suitable measuring instrument
- explain a suitable procedure to eliminate possible systematic error.

(3)

(d) Plot on **Figure 3** points to show the volume V and the temperature θ of the air in the flask when

- the flask is as shown in **Figure 1a**
- the flask is as shown in **Figure 1d**.

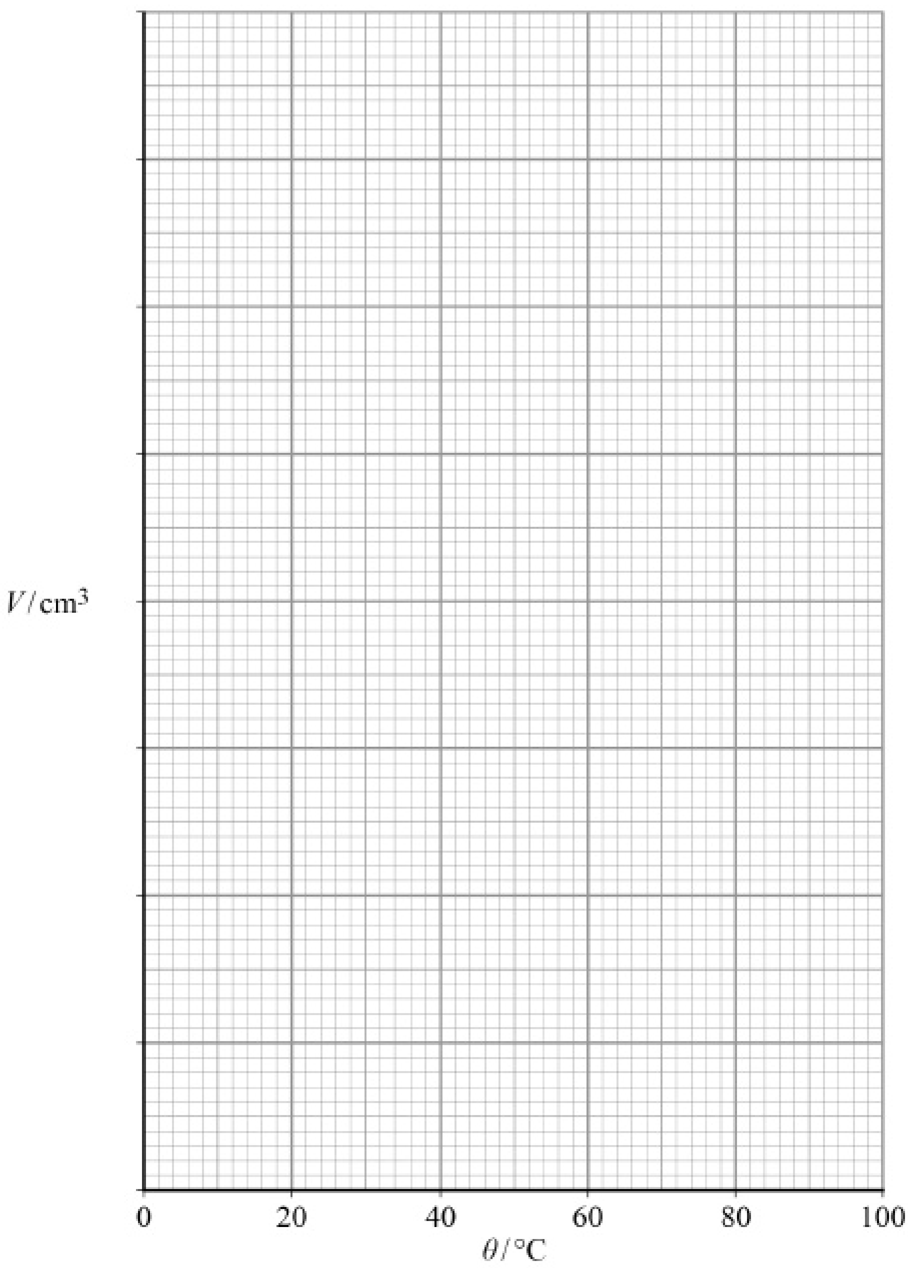
The temperature of the hot water bath is 86 °C

Room temperature is 19 °C

V_1 = 48 cm^3

V_2 = 255 cm^3

Figure 3



(3)

(e) Add a best fit line to your graph in **Figure 3** to show how V should vary with θ according to Charles's Law.

(1)

(f) Determine the value of absolute zero in °C using your graph in **Figure 3**.

value of absolute zero = ____________________ °C

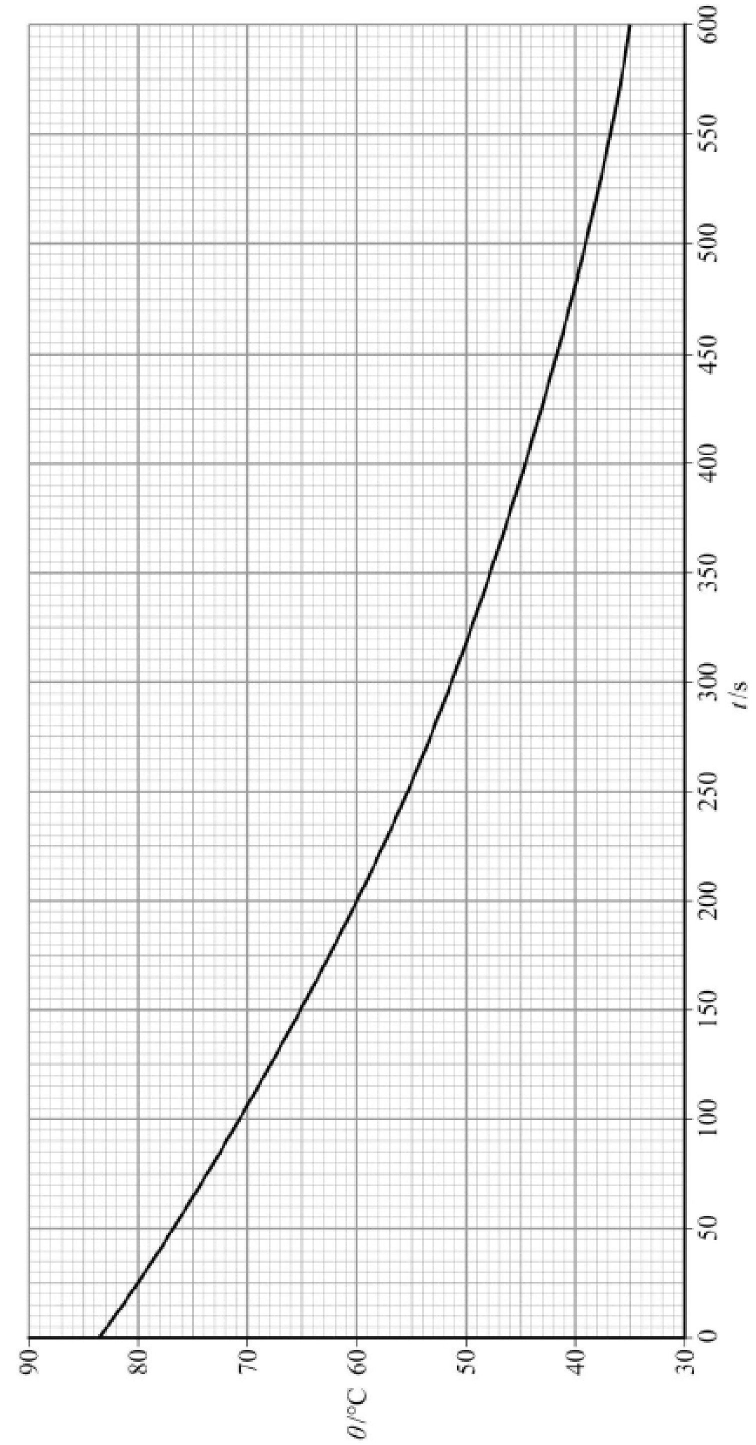
(3)

(Total 14 marks)

Q19.

A temperature sensor is connected to a data logger to monitor how the temperature θ of a fixed mass of recently−boiled water varies with time t, over an interval of 600 s. These data are processed to produce the graph shown in **Figure 1**.

Figure 1



(a) Determine the temperature θ_1 of the water when t is 190 s.

θ_1 = ____________________ °C

(1)

(b) Determine the gradient G_1 of the graph at t is 190 s.

G_1 ______________________

(3)

(c) When t = 370 s the temperature θ_2 = 46.6 °C and the gradient G_2 = −0.0645.

The room temperature θ_R is given by $\dfrac{G_1\theta_2 - G_2\theta_1}{G_1 - G_2}$

Evaluate θ_R.

θ_R = ____________________ °C

(1)

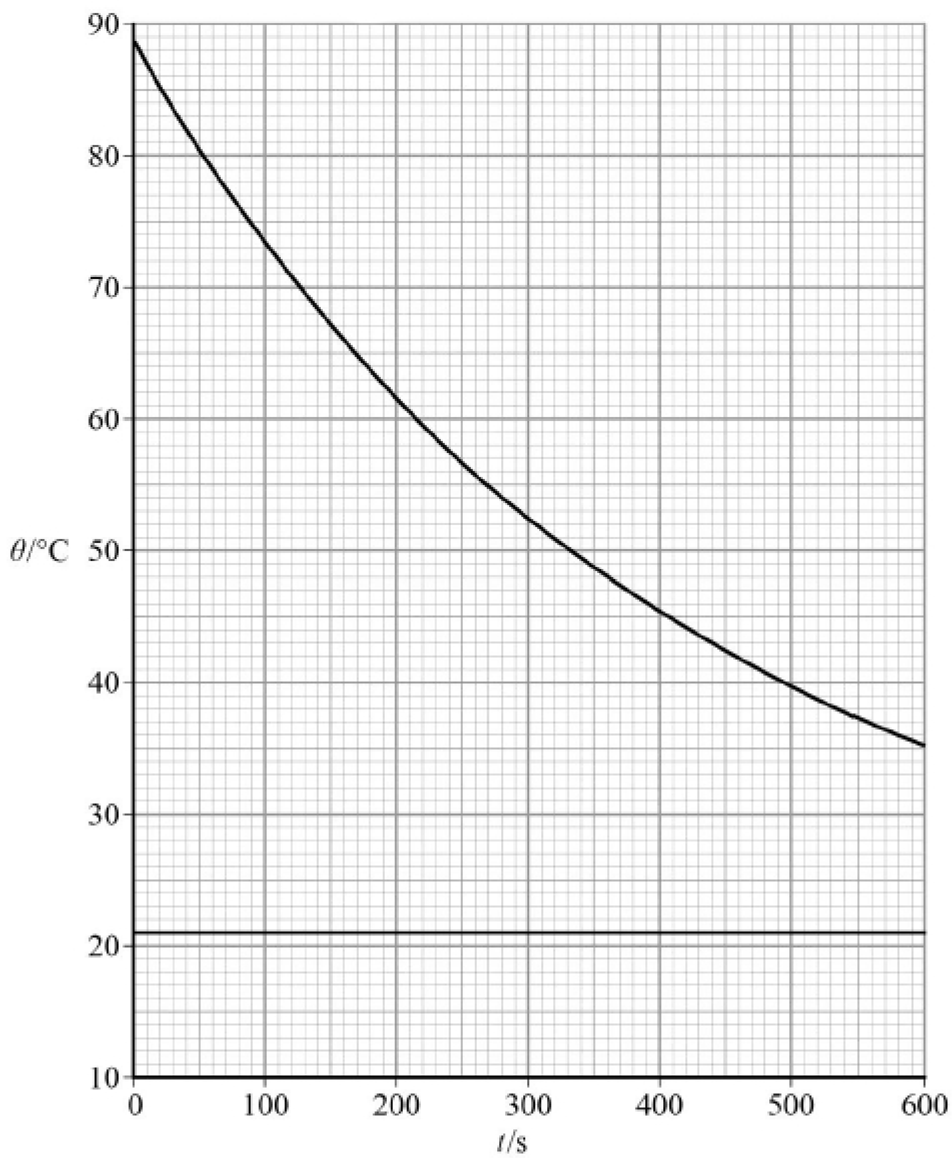
(d) It can be shown that when a hot object at a temperature θ is allowed to cool in a draught, the rate at which the temperature decreases is directly proportional to the temperature difference $(\theta - \theta_R)$ between the object and the surroundings.

A student realises that $(\theta - \theta_R)$ will decrease exponentially with time and designs an experiment in which two temperature sensors are connected to a data logger.

- Sensor 1 is placed in a beaker of recently−boiled water.
- Sensor 2 measures the air temperature in the room.
- The data logger is programmed to record the output from the sensors as the water cools for 600 s.

The output data from the sensors are processed to produce the graph shown in **Figure 2**.

Figure 2



$(\theta - \theta_R)$ will decrease exponentially in the same way that the potential difference (pd) across a discharging capacitor decreases with time.

When a capacitor discharges, the pd across the capacitor falls to $\frac{1}{e}$ of an initial value in a time called the **time constant**. Electronic engineers assume that a capacitor becomes fully discharged in a time equal to **5 time constants**.

Estimate the time taken for the water to cool down to room temperature.

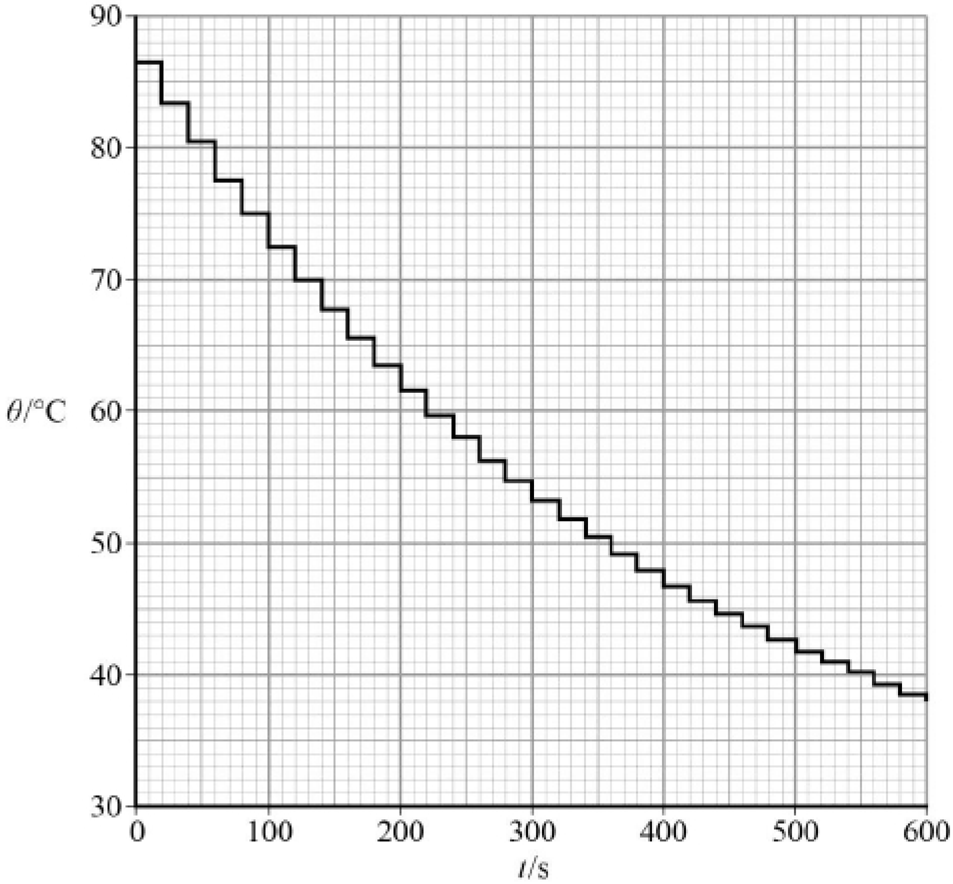
time taken = ____________________ s

(4)

(e) Another student carries out the experiment using the same mass of recently−boiled water and beaker as before.

The output data for sensor 1 from this student's experiment are shown in **Figure 3**.

Figure 3



Account for the differences between these results and the way they are displayed, with those shown in **Figure 2**.

You should include appropriate quantitative detail in your answer.

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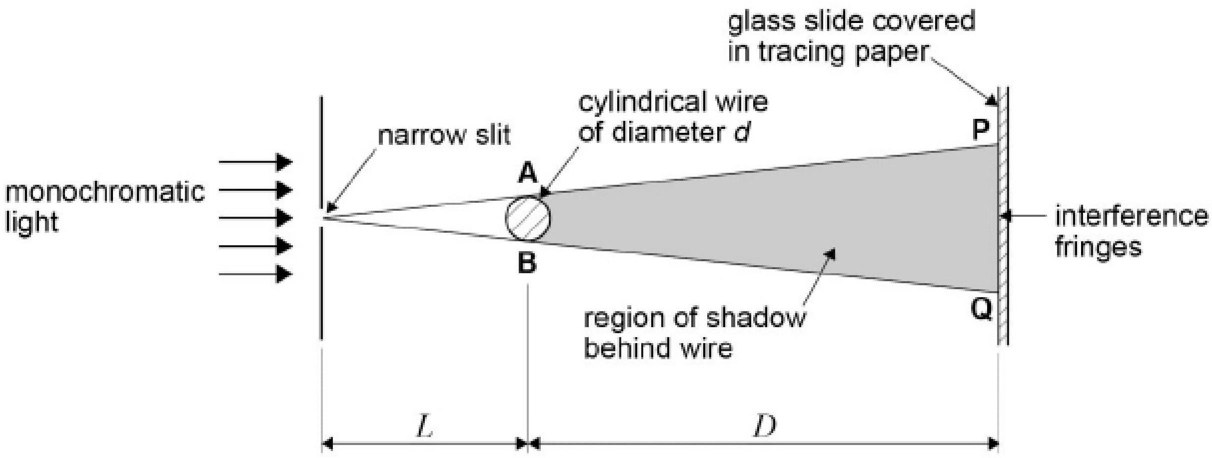
(5)
(Total 14 marks)

Q20.

A student carries out an experiment to determine the diameter of a cylindrical wire based on the theory of Young's double−slit experiment, using the arrangement shown in **Figure 1**.

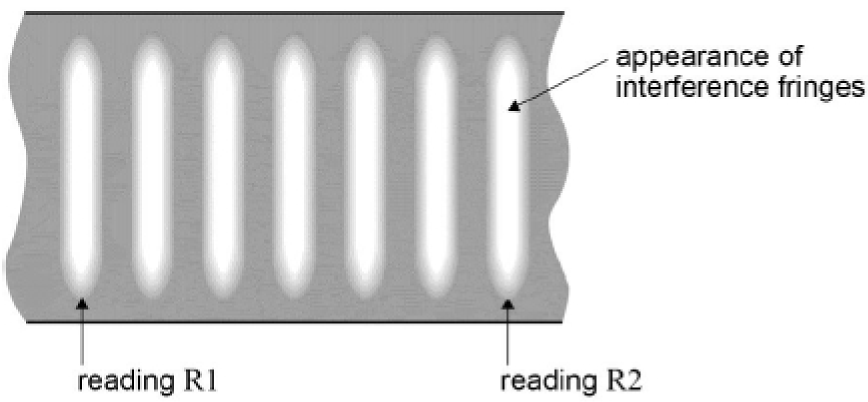
Figure 1



The wire is mounted vertically in front of a single narrow slit which is illuminated by monochromatic light. The wire produces a shadow between points **P** and **Q** on a glass slide covered with tracing paper. The light diffracts as it passes the wire. Points **A** and **B** act as coherent sources causing interference fringes to be seen between **P** and **Q**.

The student uses a metre ruler to measure the distances L and D shown in **Figure 1**. **Figure 2** shows the pattern of interference fringes between **P** and **Q**. The student takes readings from a vernier scale to indicate the positions of the centres of two of the fringes.

Figure 2



The student's measurements are shown in **Table 1**.

Table 1

L/mm	D/mm	R1/mm	R2/mm
46	395	8.71	11.16

(a) Determine the spacing of the interference fringes w using **Figure 1** and the data in **Table 1**.

Give your answer to an appropriate number of significant figures.

w ____________________ m

(2)

(b) Determine the diameter d of the wire.

wavelength of the monochromatic light = 589.3 nm

d = ____________________ m

(2)

(c) Estimate the number of interference fringes seen between **P** and **Q**.

number of interference fringes = ____________________

(3)

(d) The student uses a micrometer screw gauge to confirm his result for d.

Describe a suitable procedure that the student should carry out before using the micrometer to ensure that the measurements are not affected by systematic error.

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(2)

(e) To reduce the impact of random error, the student takes several measurements of the diameter at different points along the wire so that he can calculate a mean value for d.

These measurements are shown in **Table 2**.

***d*/mm**
0.572
0.574
0.569
0.571
0.566
0.569

Use the data from **Table 2** to determine the percentage uncertainty in the student's result for d.

percentage uncertainty = ____________________ %

(2)

(Total 11 marks)

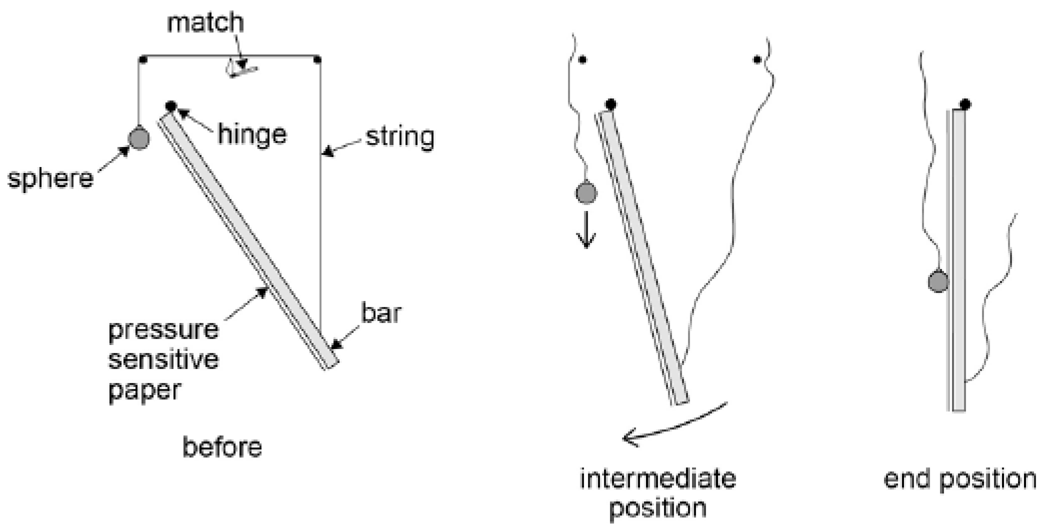
Q21.

This question is about measuring the acceleration of free fall g.

A student undertakes an experiment to measure the acceleration of free fall.

Figure 1 shows a steel sphere attached by a string to a steel bar. The bar is hinged at the top and acts as a pendulum. When the string is burnt through with a match, the sphere falls vertically from rest and the bar swings clockwise. As the bar reaches the vertical position, the sphere hits it and makes a mark on a sheet of pressure-sensitive paper that is attached to the bar.

Figure 1



The student needs to measure the distance d fallen by the sphere in the time t taken for the bar to reach the vertical position.

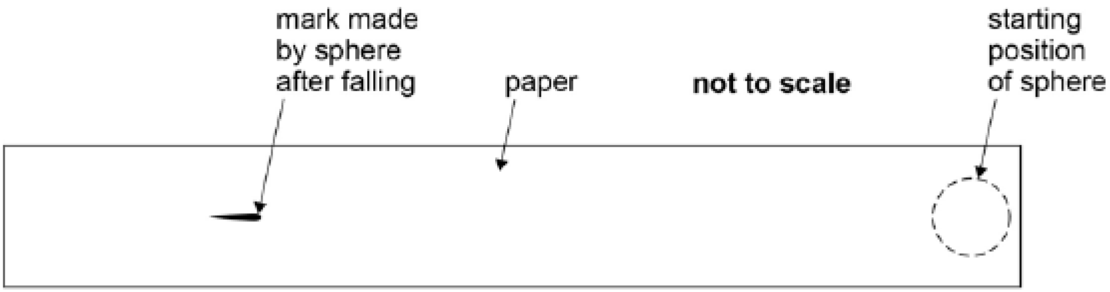
To measure d the student marks the initial position of the sphere on the paper. The student then measures the distance between the initial mark and the mark made by the sphere after falling.

To measure t the student sets the bar swinging without the string attached and determines the time for the bar to swing through 10 small-angle oscillations.

(a) **Figure 2** shows the strip of paper after it has been removed from the bar. The initial position of the sphere and the final mark are shown.

Mark on **Figure 2** the distance that the student should measure in order to determine d.

Figure 2



(1)

(b) The student repeats the procedure several times.

Data for the experiment is shown in the table below.

d / m
0.752
0.758
0.746
0.701
0.772
0.769

Time for bar to swing through 10 oscillations as measured by a stop clock = 15.7 s

Calculate the time for one oscillation and hence the time t for the bar to reach the vertical position.

time____________________s

(1)

(c) Determine the percentage uncertainty in the time t suggested by the precision of the recorded data.

uncertainty = ____________________ %

(2)

(d) Use the data from the table to calculate a value for d.

d = ____________________ m

(2)

(e) Calculate the absolute uncertainty in your value of d.

uncertainty = ____________________ m

(1)

(f) Determine a value for g and the absolute uncertainty in g.

g = ____________________ ms^{-2}

uncertainty = ____________________ ms^{-2}

(3)

(g) Discuss **one** change that could be made to reduce the uncertainty in the experiment.

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(2)

(h) The student modifies the experiment by progressively shortening the bar so that the time for an oscillation becomes shorter. The student collects data of distance fallen s and corresponding times t over a range of times.

Suggest, giving a clear explanation, how these data should be analysed to obtain a value for g.

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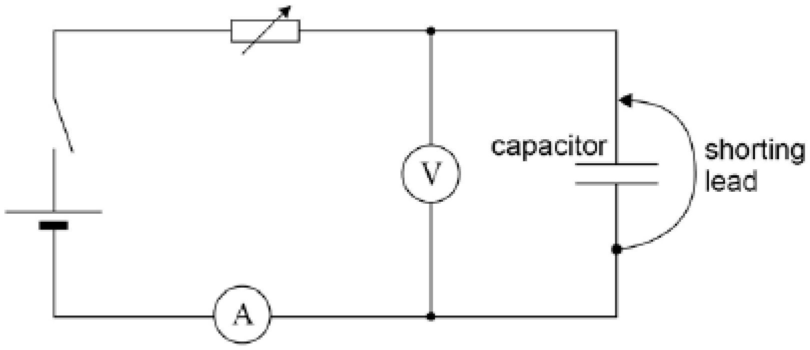
(3)

(Total 15 marks)

Q22.

This question is about capacitor charging and discharging.

A student designs an experiment to charge a capacitor using a constant current. The figure below shows the circuit the student designed to allow charge to flow onto a capacitor that has been initially discharged.



The student begins the experiment with the shorting lead connected across the capacitor as in the figure above. The variable resistor is then adjusted to give a suitable ammeter reading. The shorting lead is removed so that the capacitor begins to charge. At the same instant, the stop clock is started.

The student intends to measure the potential difference (pd) across the capacitor at 10 s intervals while adjusting the variable resistor to keep the charging current constant.

The power supply has an emf of 6.0 V and negligible internal resistance. The capacitor has a capacitance of 680 μF. The variable resistor has a maximum resistance of 100 kΩ.

(a) The student chooses a digital voltmeter for the experiment. A digital voltmeter has a very high resistance.

Explain why it is important to use a voltmeter with very high resistance.

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(1)

(b) Suggest **one** advantage of using an analogue ammeter rather than a digital ammeter for this experiment.

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____

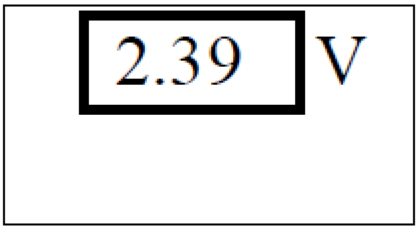
(1)

(c) Suggest a suitable full scale deflection for an analogue ammeter to be used in the experiment.

full scale deflection = ____________________

(2)

(d) The diagram shows the reading on the voltmeter at one instant during the experiment. The manufacturer gives the uncertainty in the meter reading as 2%.



Calculate the absolute uncertainty in this reading.

uncertainty = ____________________ V

(1)

(e) Determine the number of different readings the student will be able to take before the capacitor becomes fully charged.

number = ____________________

(3)

(f) The experiment is performed with a capacitor of nominal value 680 μF and a manufacturing tolerance of ± 5 %. In this experiment the charging current is maintained at 65 μA. The data from the experiment produces a straight-line graph for the variation of pd with time. This shows that the pd across the capacitor increases at a rate of 98 mV s^{-1}.

Calculate the capacitance of the capacitor.

capacitance = ____________________ μF

(2)

(g) Deduce whether the capacitor is within the manufacturer's tolerance.

____

____

____

(1)

(h) The student decides to confirm the value of the capacitance by first determining the time constant of the circuit when the capacitor **discharges** through a **fixed** resistor.

Describe an experiment to do this. Include in your answer:

- a circuit diagram
- an outline of a procedure
- an explanation of how you would use the data to determine the time constant.

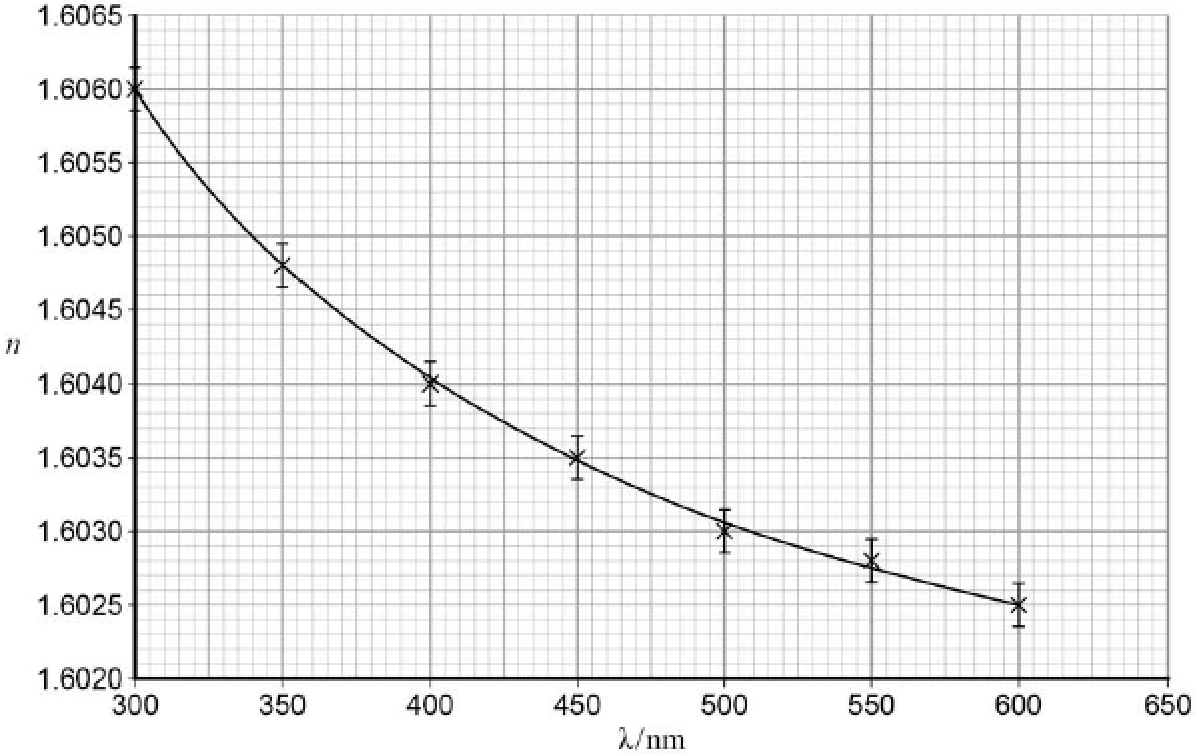
(4)

(Total 15 marks)

Q23.

Figure 1 shows how the refractive index n of a type of glass varies with the wavelength of light λ passing through the glass. The data for plotting the graph were determined by experiment.

Figure 1



(a) A student says that **Figure 1** resembles that of the decay of radioactive atomic nuclei with time and that it shows half-life behaviour.

Comment on whether the student is correct.

___

___

___

(1)

(b) The dispersion D of glass is defined as the rate of change of its refractive index with wavelength. At a particular wavelength $D = \frac{\Delta n}{\Delta \lambda}$.

Determine D at a wavelength of 400 nm. State an appropriate unit for your answer.

D ____________________ unit __________

(3)

(c) It is suggested that the relationship between n and λ is of the form

$$n = a + \frac{b}{\lambda^2}$$

where a and b are constants. The data plotted in **Figure 1** are given in the table below.

λ / nm	n			
300	1.6060			
350	1.6048			
400	1.6040			
450	1.6035			
500	1.6030			
550	1.6028			
600	1.6025			

You are to determine a using a graph of n against $\frac{1}{\lambda^2}$.

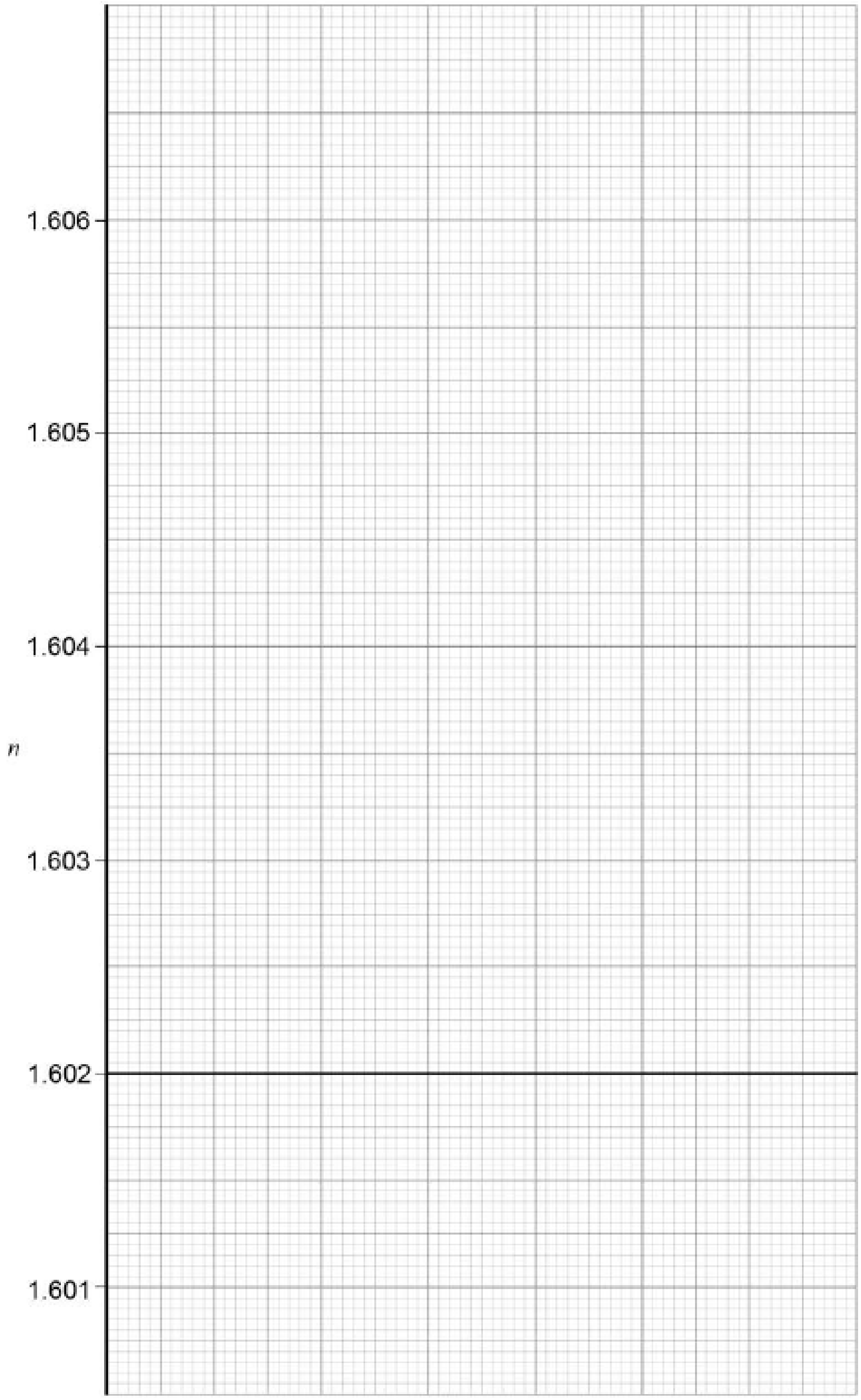
.

Make any calculations that you need to in order to plot your graph. The columns in the table are for you to use to calculate and tabulate the derived data that you need.
You may not need all the columns.

(3)

(d) Plot your graph on **Figure 2**. The values of n are provided on the y-axis.

Figure 2



(3)

(e) Use your graph to determine a.

(1)

(f) State the significance of a.

(1)

(g) Another suggestion for the relationship between n and λ is that

$$n = c\lambda^d$$

where c and d are constants.

Explain how d can be determined graphically. Do not attempt to carry out this analysis.

(3)

(Total 15 marks)