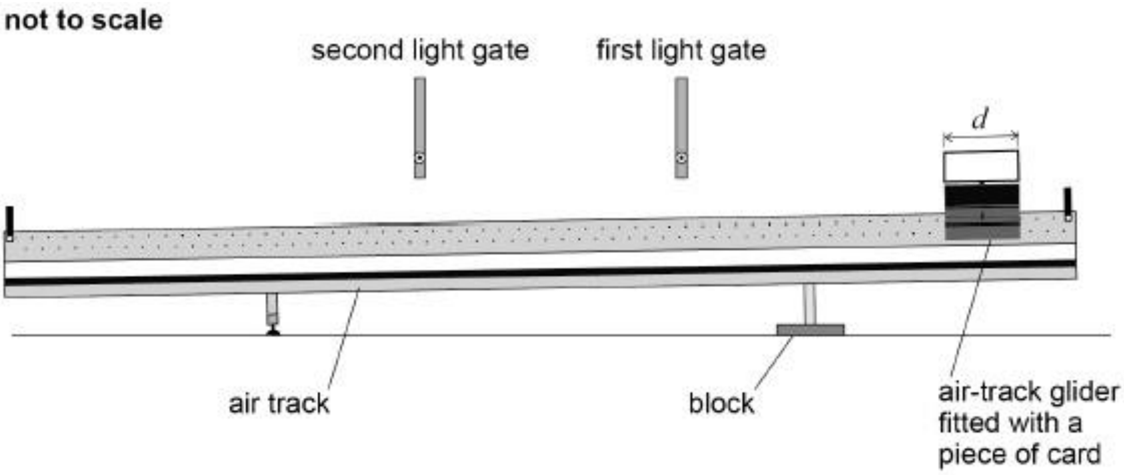
Practical skills

Q1.

Figure 1 shows the apparatus used by a student in an experiment to measure the acceleration due to gravity, g.

Figure 1



In the experiment:

- a block is used to raise one end of the air track as shown in **Figure 1**
- an air-track glider is released from rest near the raised end of the air track and passes through the first light gate and then through the second light gate
- a piece of card of length d fitted to the air-track glider interrupts a light beam as the air-track glider passes through each light gate
- a data logger records the time taken by the piece of card to pass through each light gate and also the time for the piece of card to travel from one light gate to the other.

(a) **Table 1** gives measurements made with the light gates as shown in **Figure 1**.

Table 1

Time to pass through first light gate / s	**Time to pass through second light gate / s**	**Time to travel from first to second light gate / s**
0.50	0.40	1.19

The length d of the piece of card is 10.0 cm

Assume there is negligible change in velocity while the air-track glider passes through a light gate.

Determine the acceleration a of the air-track glider.

a = ____________________ m s^{-2}

(3)

(b) Two further sets of readings, **A** and **B**, are taken each with the light gates in different positions along the air track.
Assume the acceleration is the same in each set.

Table 2 shows these additional sets of results.

Table 2

Set	Time to pass through first light gate / s	Time to pass through second light gate / s	Time to travel from first to second light gate / s
A	0.61	0.42	1.77
B	0.55	0.37	2.11

Explain how the data in **Table 2** show that the distance between the light gates in set **B** is greater than in set **A**.

Assume there is negligible change in velocity while the air-track glider passes through a light gate.

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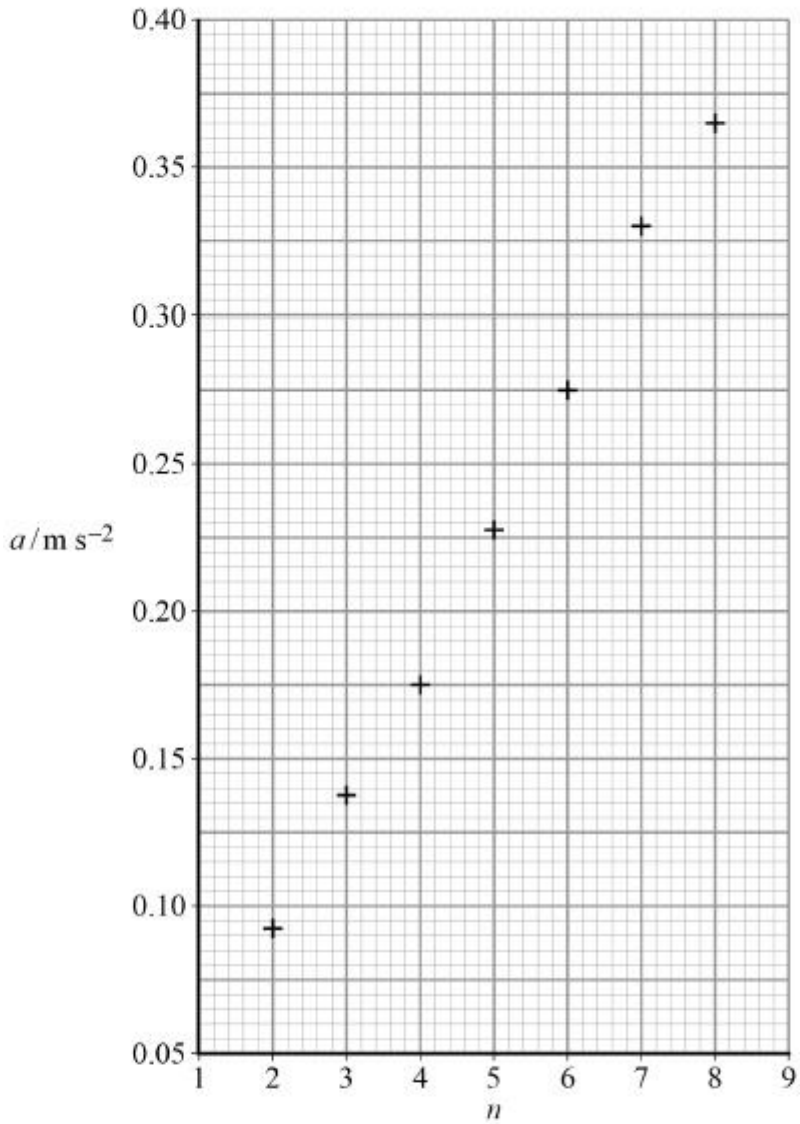
(2)

(c) Additional values for the acceleration of the air-track glider are obtained by further raising the end of the air track by using a stack consisting of identical blocks.
Adding each block to the stack raises the end of the air track by the same distance.

Figure 2 is a graph of these results showing how a varies with n, the number of blocks in the stack.

Figure 2



Draw a suitable best-fit straight line on **Figure 2** and determine G, the gradient of your line.

G = ____________________

(2)

(d) It can be shown that, for the apparatus used by the student, g is equal to $\frac{2G}{h}$ where h is the thickness of each block used in the experiment.

The student obtains a value for g of 9.8 m s^{-2}

Calculate h.

h = ____________________ m

(1)

(e) Explain how you could find out, without drawing another graph, whether the data presented in the graph in **Figure 2** support the suggestion that a is directly proportional to n.

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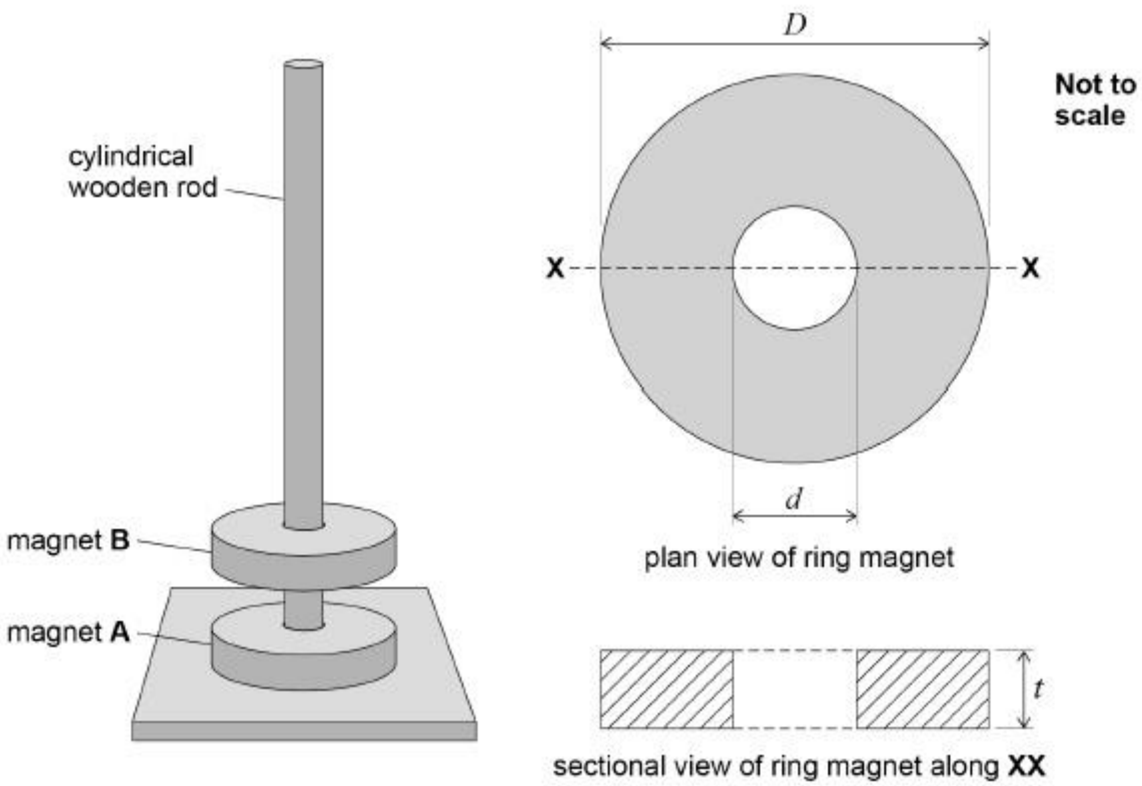
(1)
(Total 9 marks)

Q2.

Identical ring magnets **A** and **B** are arranged on a cylindrical wooden rod. The magnets' magnetic poles are on their largest faces. When placed with like poles in opposition, the magnets repel one another as shown in **Figure 1**.

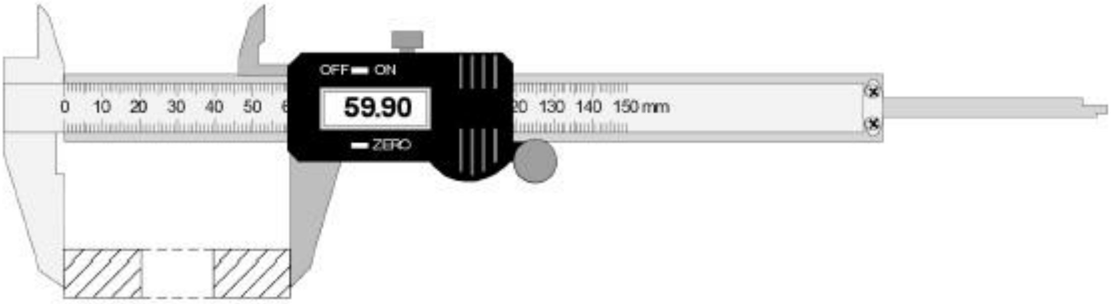
The plan and sectional views in **Figure 1** identify the dimensions of these magnets. Each magnet has a circular cross-section and the central hole is circular.

Figure 1



(a) A student uses digital vernier calipers to find the external diameter D of magnet **B**, as shown in **Figure 2**.

Figure 2



State precautions the student should take to reduce the effect of systematic and random errors when making this measurement.

Precaution to reduce effect of systematic error:

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Precaution to reduce effect of random error:

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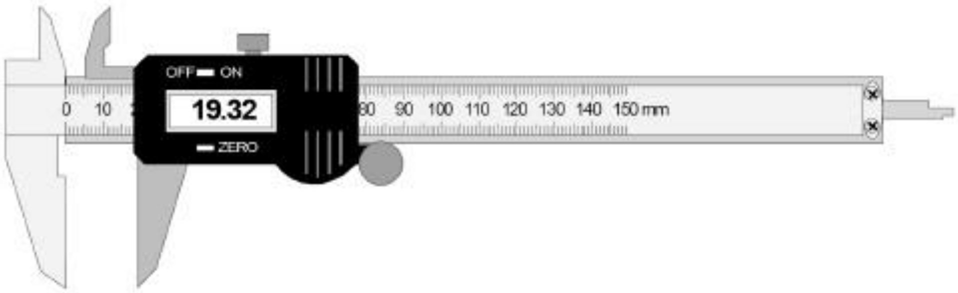
(2)

(b) **Figure 3** shows the reading on the calipers as the internal diameter d is measured.

Draw the sectional view of magnet **B** on **Figure 3** to indicate how d is measured.

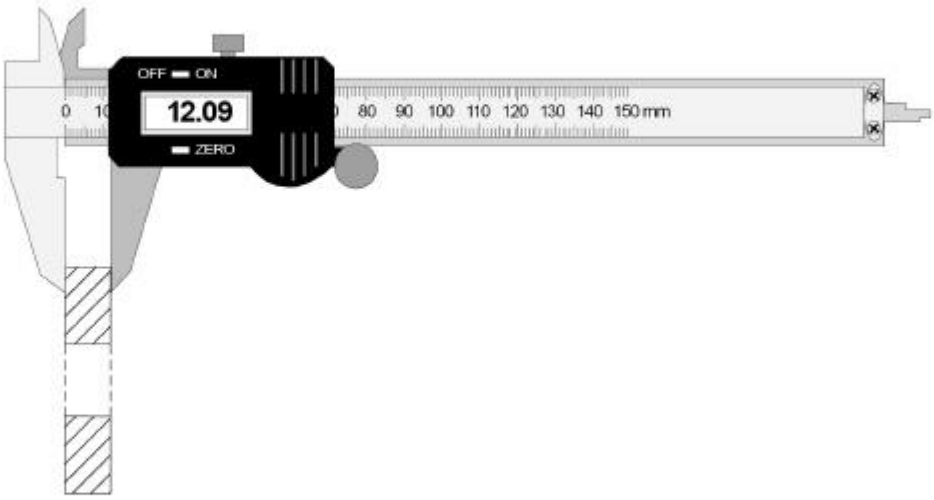
Figure 3



(1)

(c) **Figure 4** shows the reading on the calipers when the thickness *t* of magnet **B** is measured.

Figure 4



The readings that correspond to the dimensions of magnet **B** are shown in **Figures 2**, **3** and **4**.

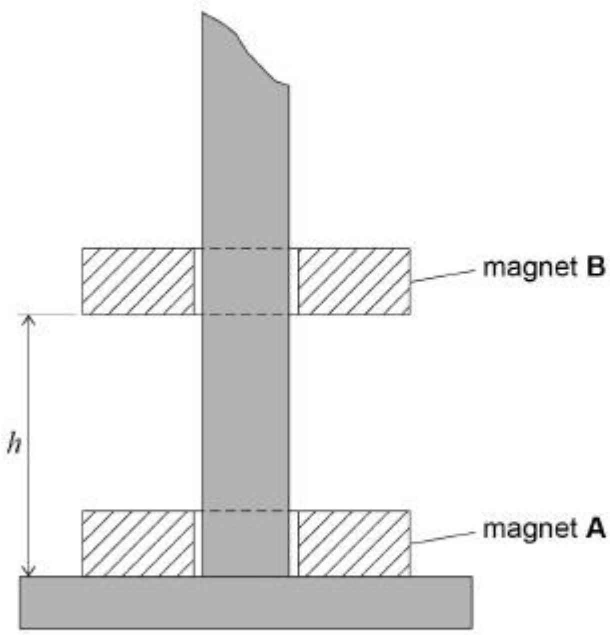
Calculate the volume of magnet **B**.

volume = ____________________ m^3

(3)

(d) The student measures the mass m_B of magnet **B** and then positions the magnet so it is in equilibrium above magnet **A** as shown in **Figure 5**.
The student measures the distance h.

Figure 5



The student adds modelling clay to magnet **B** to reduce h by 50%
She measures the mass m_C of this clay.

She concludes that the force F exerted on magnet **B** by magnet **A** is given by

$F = \frac{k}{h^3}$ where k is a constant.

Describe an experiment to test the student's conclusion that $F = \frac{k}{h^3}$

Your answer should include:

- the procedure that could be used
- how the data produced could be analysed by a graphical method
- how the value of the constant k could be determined.

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(5)

(Total 11 marks)

Q3.

Measurements are made to determine the tension, length and mass per unit length of a string stretched between two supports. The percentage uncertainties in these measurements are shown below.

Quantity	**Percentage uncertainty**
Length	0.80%
Tension	4.0%
Mass per unit length	2.0%

A stationary wave is formed on the string.

What is the percentage uncertainty in the calculated value of the frequency of the first harmonic?

A 1.8% ○

B 3.8% ○

C 6.8% ○

D 13% ⬭

(Total 1 mark)

Q4.

A student carries out an experiment to determine the resistivity of a metal wire.
She determines the resistance from measurements of potential difference between the ends of the wire and the corresponding current. She measures the length of the wire with a ruler and the diameter of the wire using a micrometer. Each measurement is made with an uncertainty of 1%

Which measurement gives the largest uncertainty in the calculated value of the resistivity?

A current ⬭

B diameter ⬭

C length ⬭

D potential difference ⬭

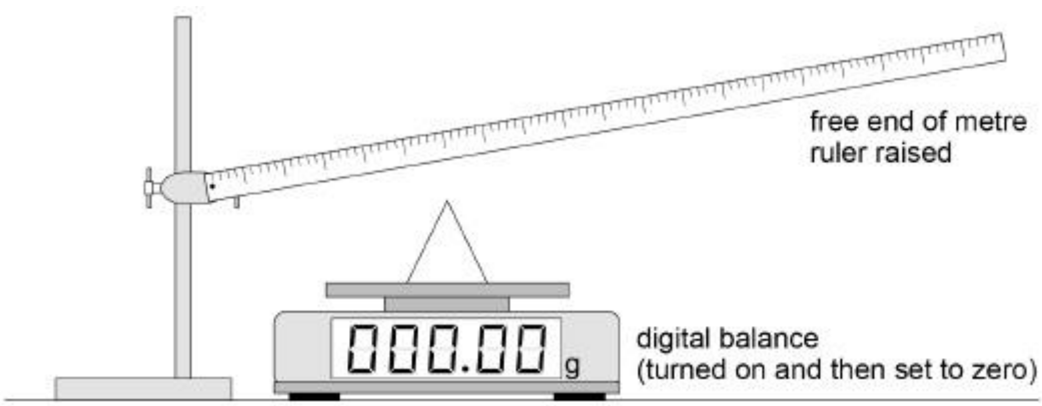
(Total 1 mark)

Q5.

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.

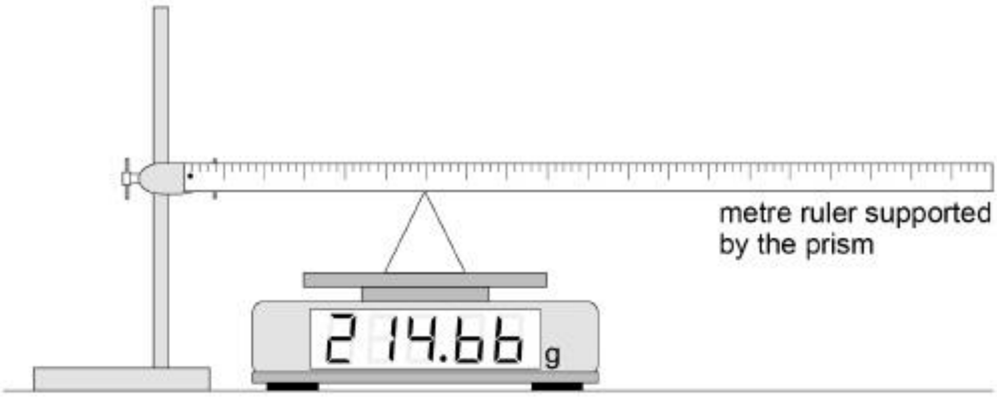
A student carries out the procedure shown in **Figure 1** and **Figure 2**.
A metre ruler is pivoted at the 1.0 cm mark and a prism is placed on a digital balance. The free end of the ruler is raised and the balance is turned on and then set to zero, as shown in **Figure 1**.

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 ____

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(3)

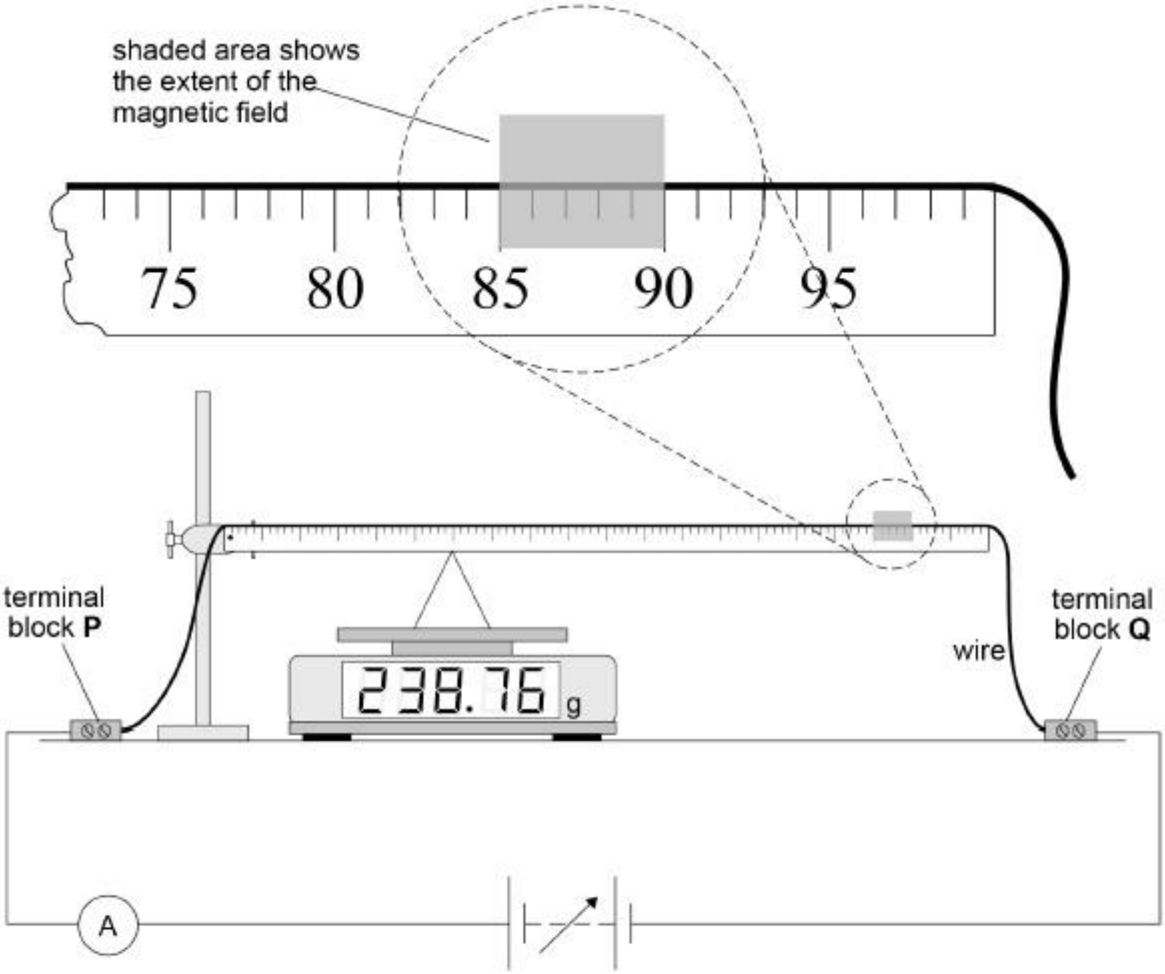
(b) The student attaches a uniform wire to the upper edge of the ruler, as shown in **Figure 3**.

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.

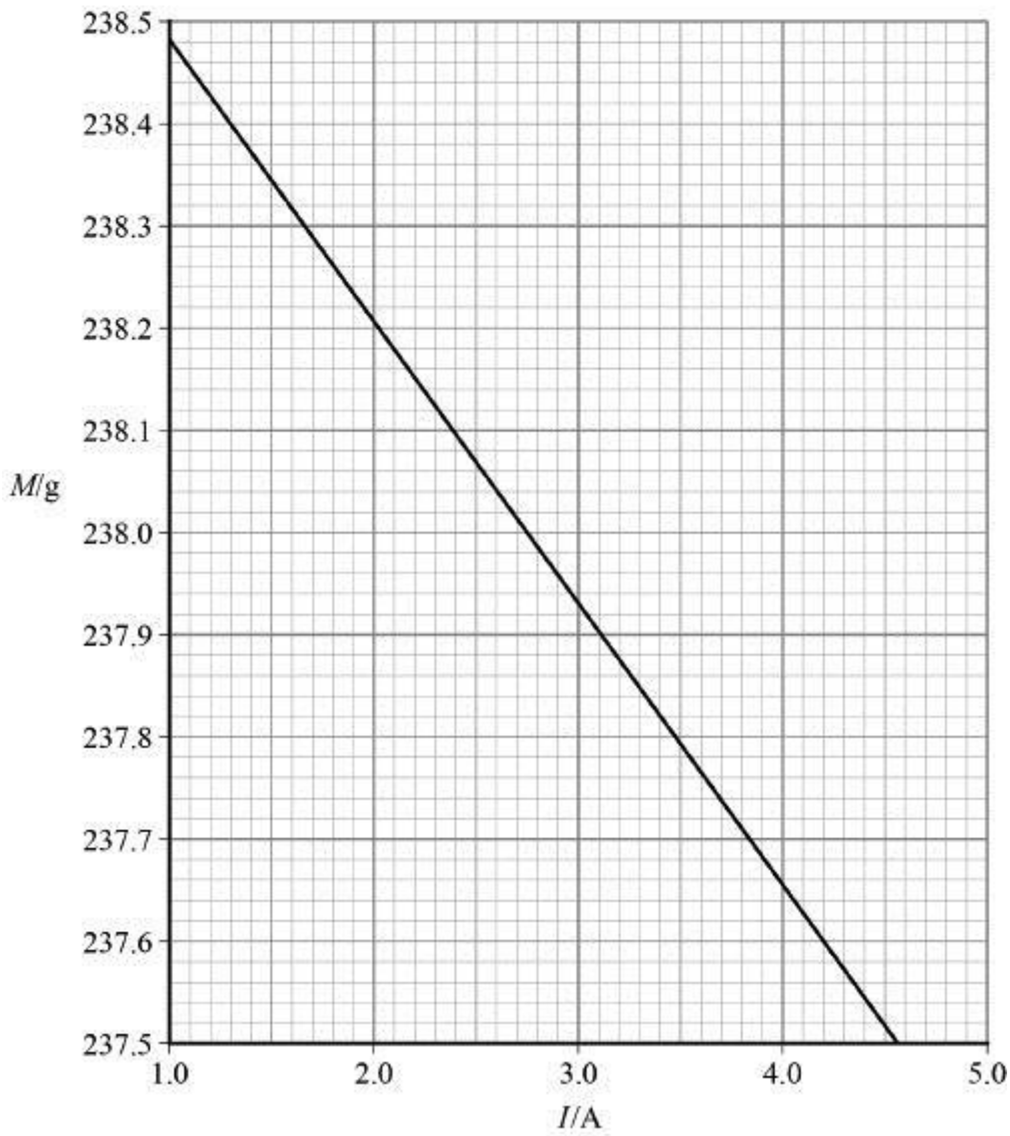
A horizontal uniform magnetic field is applied, perpendicular to the wire, between the 85 cm and 90 cm marks, as shown in the close-up diagram in **Figure 3**.

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.

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(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.

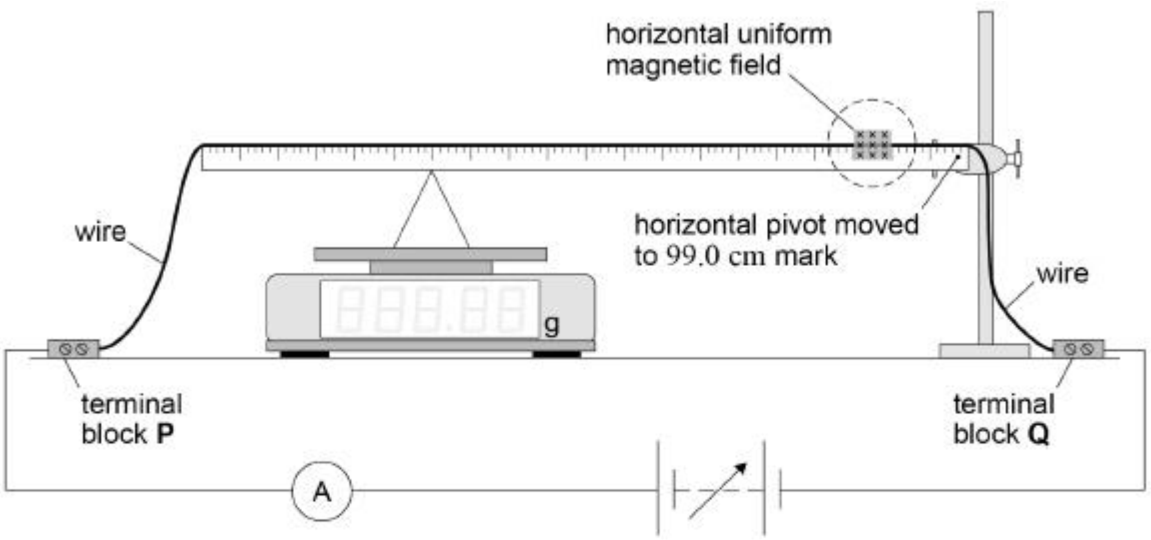
B = ____________________ T

(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			

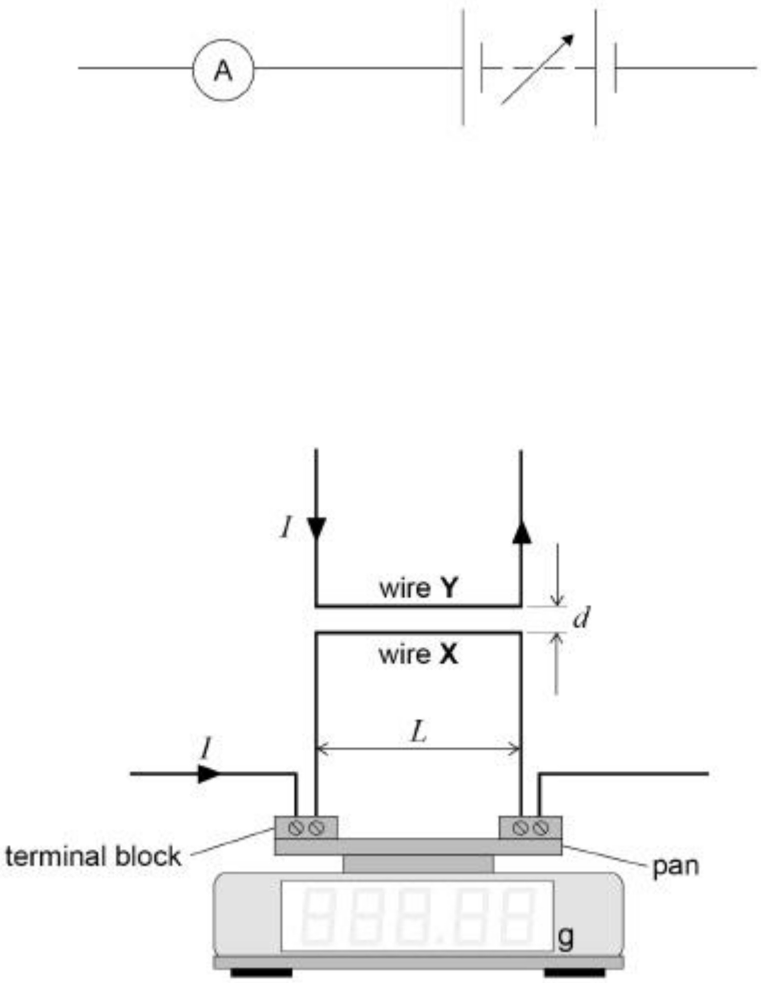
(3)

(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.

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(5)
(Total 19 marks)

Q6.

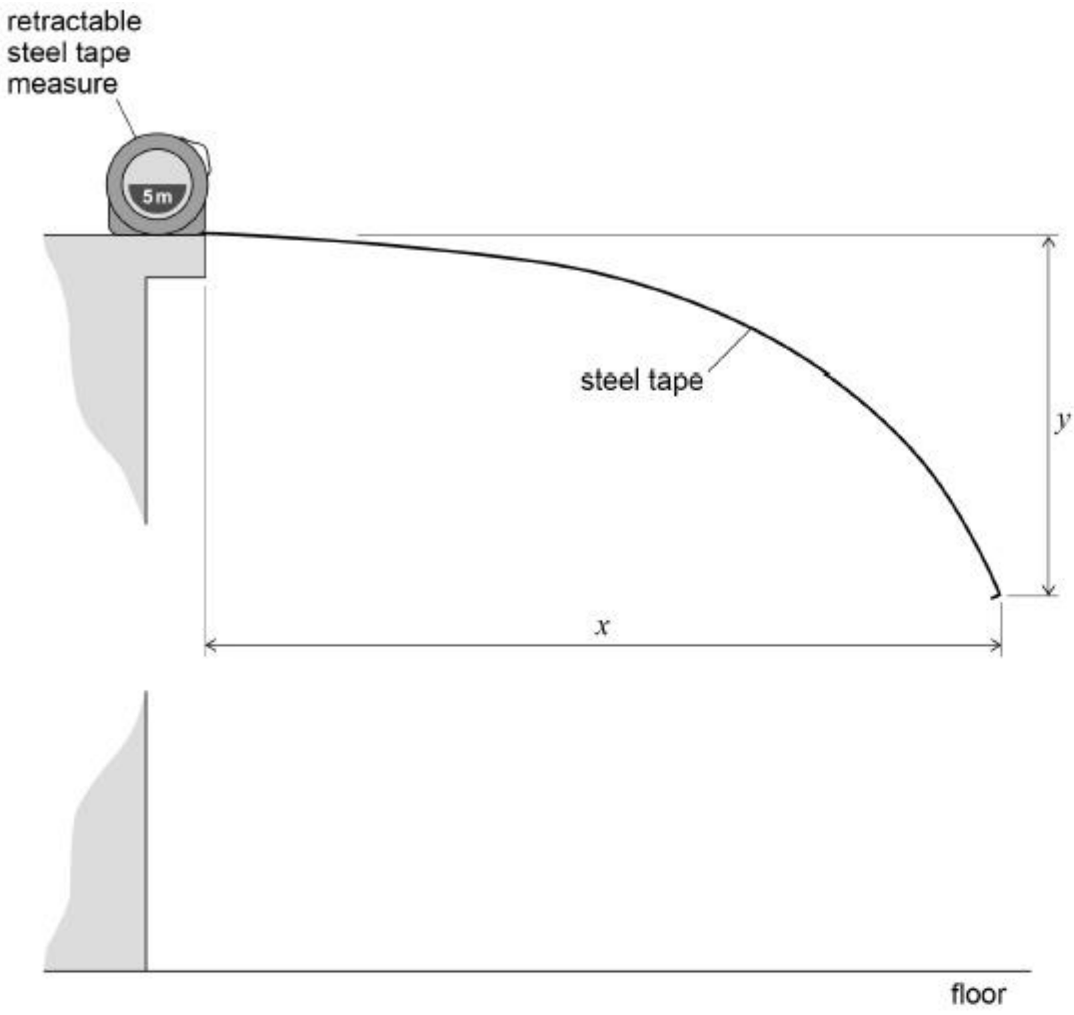
This question is about an experiment with a retractable steel tape measure.

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)

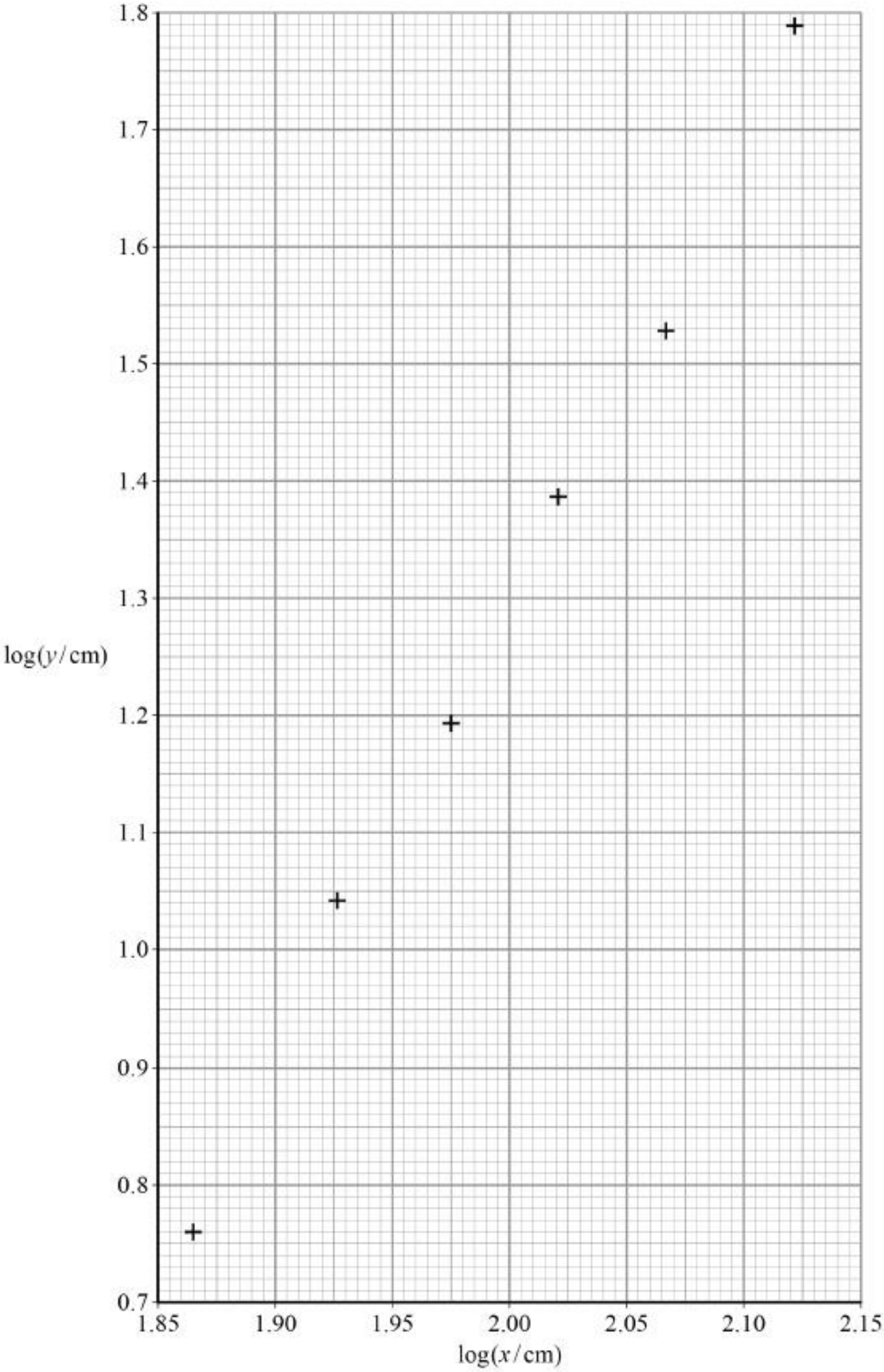
(c) The data from the experiment suggest that $y = Ax^n$ where n is an integer and A is a constant.

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

Determine n using **Figure 2**.

n = ____________________

Figure 2



(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)

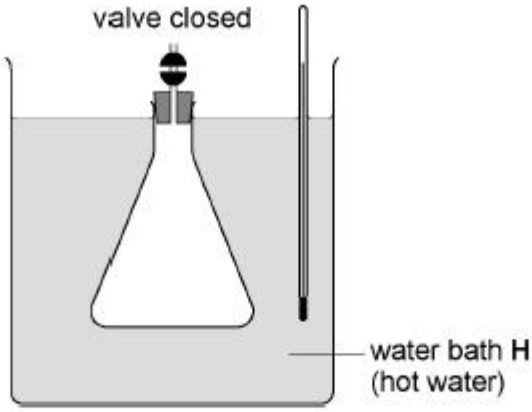
Q7.

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.

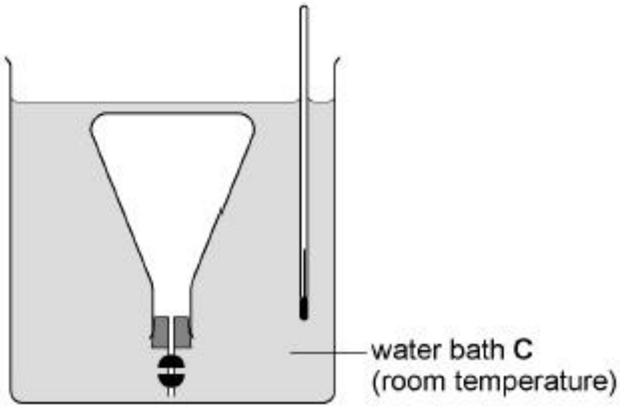
An empty flask fitted with a tube and an open valve is placed in water bath **H** containing hot water. The air inside the flask is allowed to come into thermal equilibrium with the water.
The valve is then closed, trapping a certain volume of air, as shown in **Figure 1a**.

Figure 1a



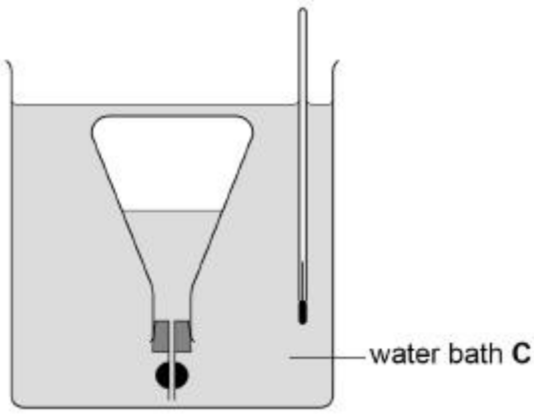
The flask is inverted and placed in water bath **C** in which the water is at room temperature.
The air inside the flask is again allowed to come into thermal equilibrium with the water, as shown in **Figure 1b**.

Figure 1b



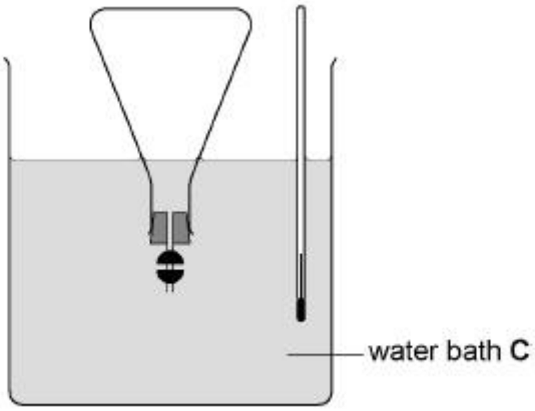
The valve is opened and some water enters the flask, as shown in **Figure 1c**.

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**.

(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.

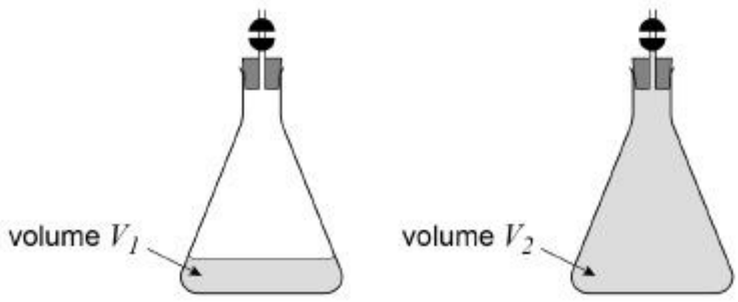
The volume of the water in the flask is V_1

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.

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(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**.

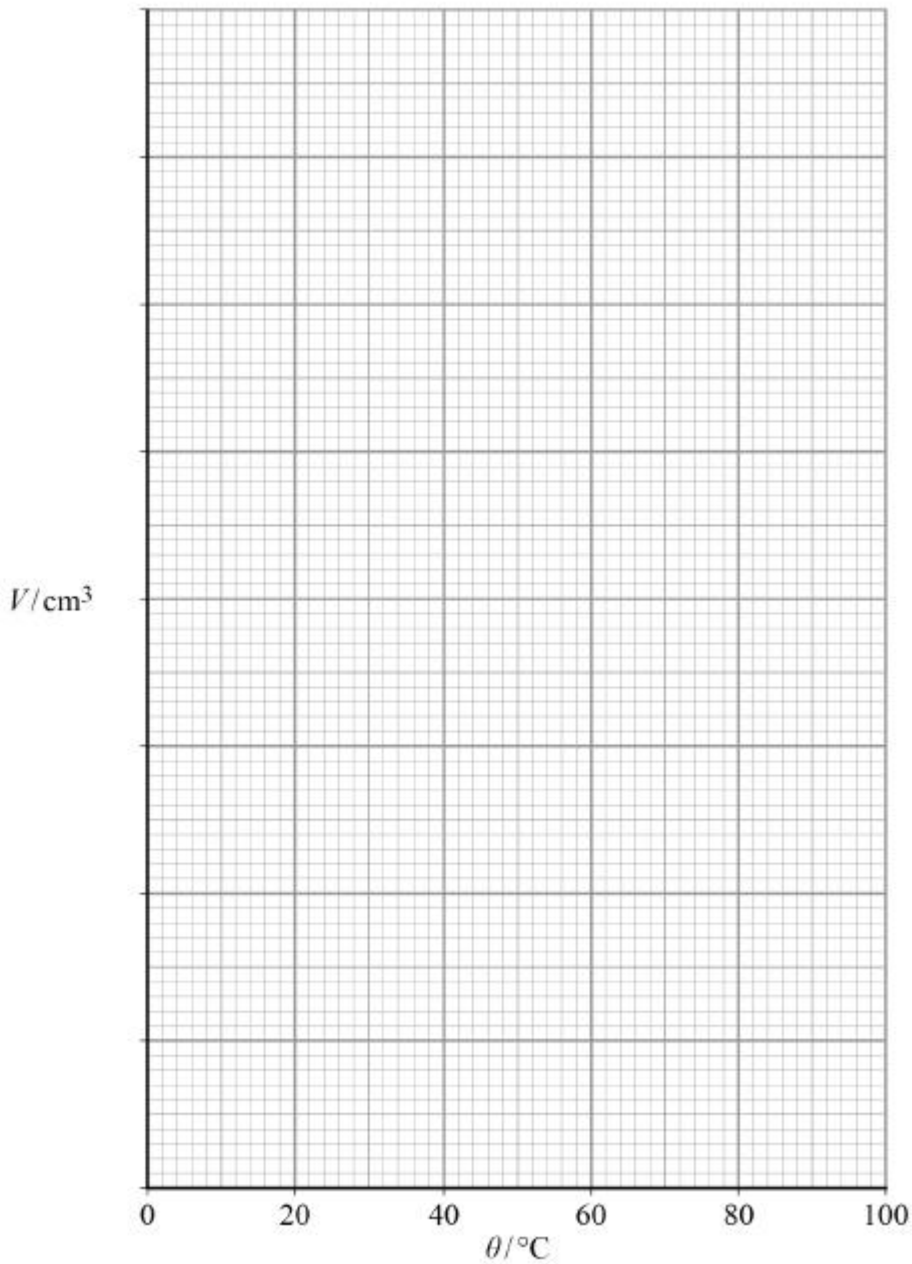
The temperature of the hot water bath is 86 °C

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)

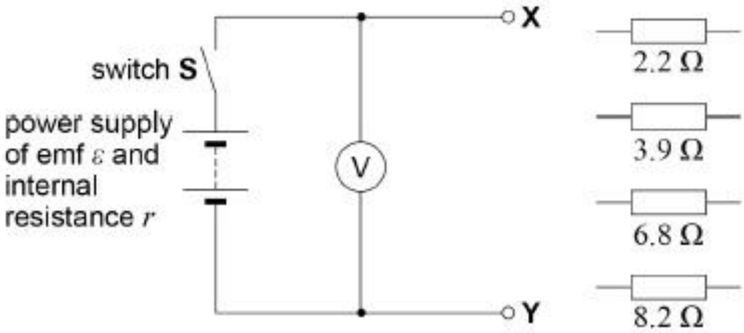
(Total 14 marks)

Q8.

This question is about an experiment to determine the internal resistance of a power supply.

A student is given the circuit and the four resistors of known resistance shown in **Figure 1**.

Figure 1



The student can change the external resistance R of the circuit between terminals **X** and **Y**. This is done by connecting different combinations of **two** resistors in series or in parallel between **X** and **Y**.
This method can produce **12 different values** for R.

(a) Calculate the largest value of R that the student can obtain using **two** resistors.

largest value of R = ______________________________ Ω

(1)

(b) Calculate the smallest value of R that the student can obtain using **two** resistors.

smallest value of R = ______________________________ Ω

(2)

(c) With switch **S** closed (in the on position) and no resistors connected between **X** and **Y** the voltmeter reading V is 1.62 V.

The student concludes that this voltmeter reading equals the emf ε of the power supply.

State why the student's conclusion that ε = 1.62 V was correct.

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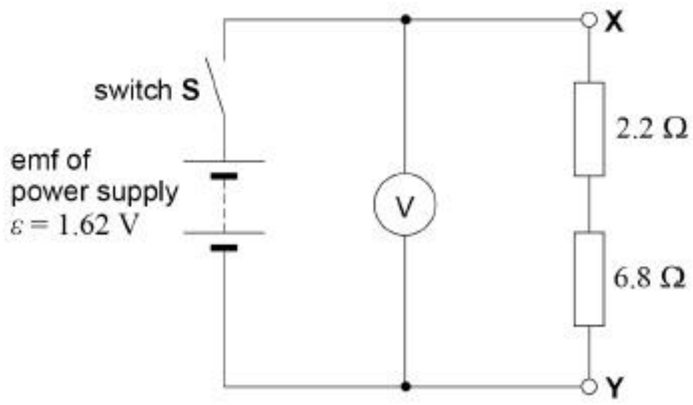
(1)

(d) **Figure 2** shows one particular combination and arrangement of two resistors that the student could use.

Figure 2



When **S** is closed the voltmeter reading V is 1.14 V.

Explain why V is less than 1.62 V when **S** is closed.

(1)

(e) It can be shown that

$$\varepsilon - V = r \times \frac{V}{R}$$

where r is the internal resistance of the power supply.

Determine $(\varepsilon - V)$ and $\frac{V}{R}$ for this circuit using the data given in part (d).

$(\varepsilon - V)$ = ______________________ V

$\frac{V}{R}$ = ______________________ V Ω^{-1}

(1)

(f) The student obtains values of V for five further different values of R.

These data were used to produce the graph of $(\varepsilon - V)$ against $\frac{V}{R}$ in **Figure 3**.

Plot the point you determined in part (e) on **Figure 3** and add a suitable best-fit line.

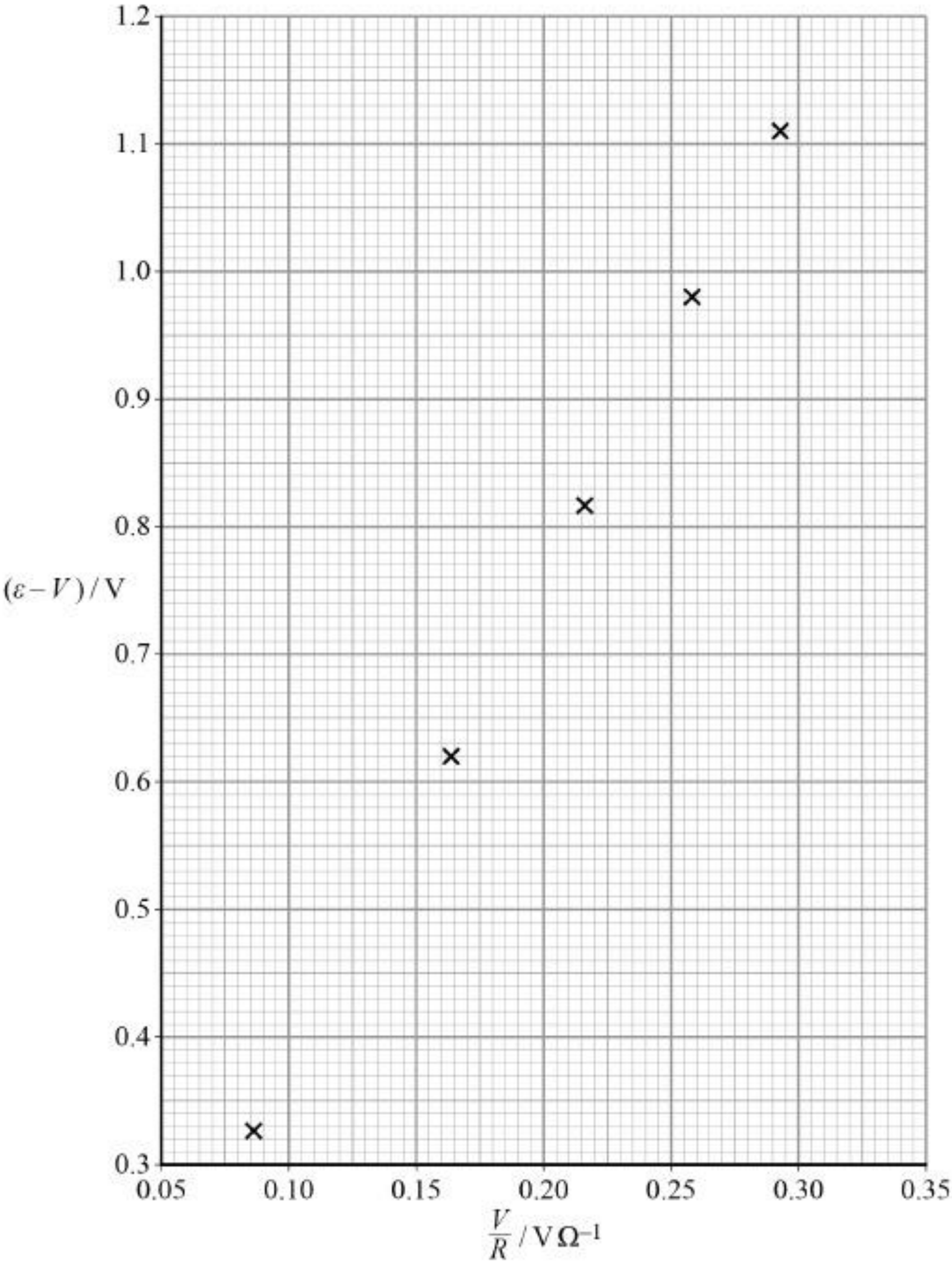
(1)

(g) Use **Figure 3** to determine r.

r = ______________________________ Ω

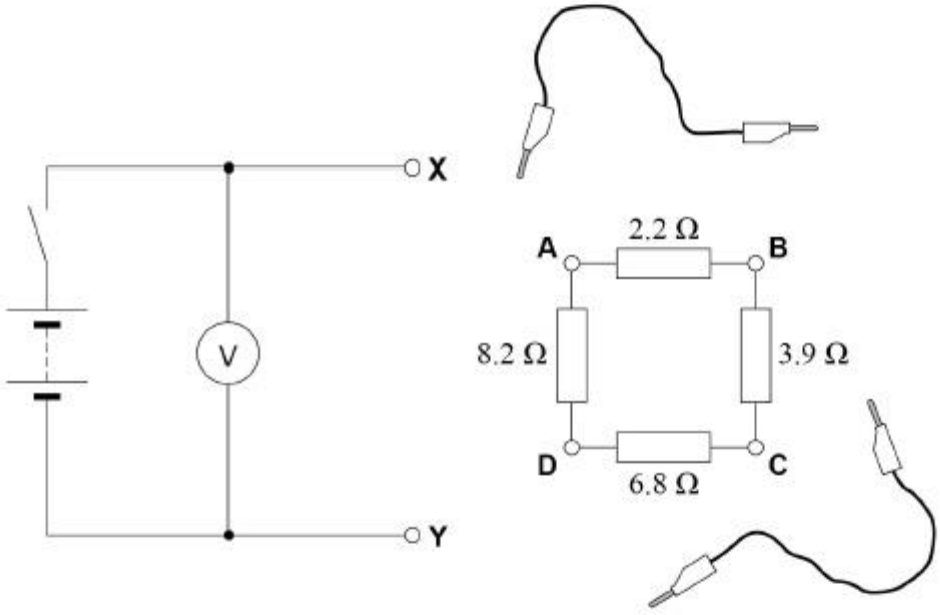
(2)

Figure 3



(h) **Figure 4** shows a different method for varying the resistance R described in part (a).

Figure 4



The four resistors are connected in a loop with sockets **A**, **B**, **C** and **D** at each junction. Two leads are used to connect the resistor loop to **X** and **Y**.

Discuss whether this method is an improvement over the method described in part (a). In your answer, you should refer to the number of different values that can be obtained for R.

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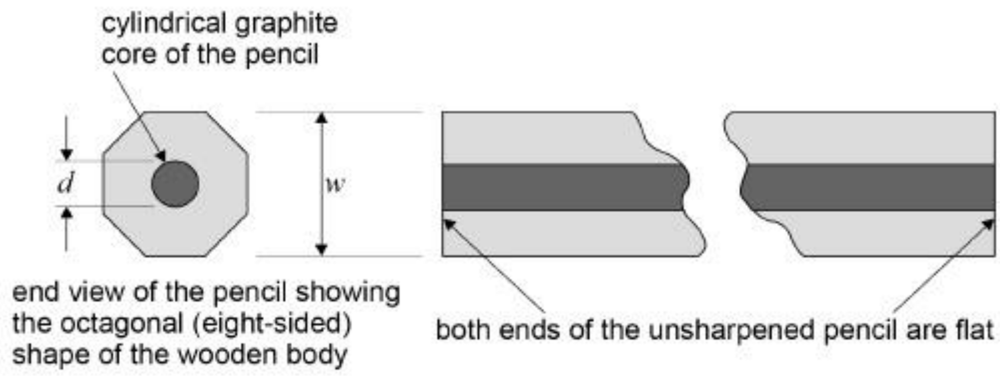
(2)
(Total 11 marks)

Q9.

A pencil, unsharpened at both ends, has a cylindrical graphite core of uniform diameter d surrounded by an octagonal (eight-sided) wooden body.

Figure 1 shows an end view and a cross-sectional slice along the length of the pencil.

Figure 1



(a) A student used a micrometer to measure the width w at several points along the length of the pencil.

Explain why the student used this procedure to determine a value for w.

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(1)

(b) The student's results are shown in the table.

w_1 / mm	w_2 / mm	w_3 / mm	w_4 / mm	w_5 / mm
7.23	7.10	7.06	7.20	7.16

Determine the percentage uncertainty in the result the student obtains for w.

percentage uncertainty = ______________________________ %

(2)

(c) The cross-sectional area A of the end of the pencil is given by

$$A = 0.83\, w^2$$

The volume of the cylindrical core is known to be 9.0% of the volume of the unsharpened pencil.
The cylindrical core of the graphite has a diameter d.

Determine d.

d = ______________________________ mm

(2)

(d) A student investigates the rate at which a similar pencil wears away through use.

The student measures the length of the pencil using a sliding vernier scale placed alongside a fixed scale. The fixed scale has a precision of 1 mm.

Figure 2 shows the vernier scale in the zero position.

Figure 3 shows the pencil (which is now sharpened) placed next to the fixed scale.

The position of the vernier scale is adjusted so that the length of the pencil can be read.

Read and record the length of the pencil shown in **Figure 3**.

length of pencil = ______________________________ mm

(1)

(e) The pencil is then removed from the scale and is used to draw 20 lines on a sheet of paper. Each line has a length 25 cm.

The pencil is then replaced next to the fixed scale and the vernier scale adjusted so the new length of the pencil can be read, as shown in **Figure 4**.

Read and record the new length of the pencil shown in **Figure 4**.

new length of pencil = ______________________________ mm

(1)

(f) $L_{1/2}$ is the length of the line that could be drawn which would cause the original length of the pencil to be halved.

Calculate $L_{1/2}$.

Ignore any decrease in length as a result of sharpening the pencil.

$L_{1/2}$ = ______________________________ m

(2)

Figure 2

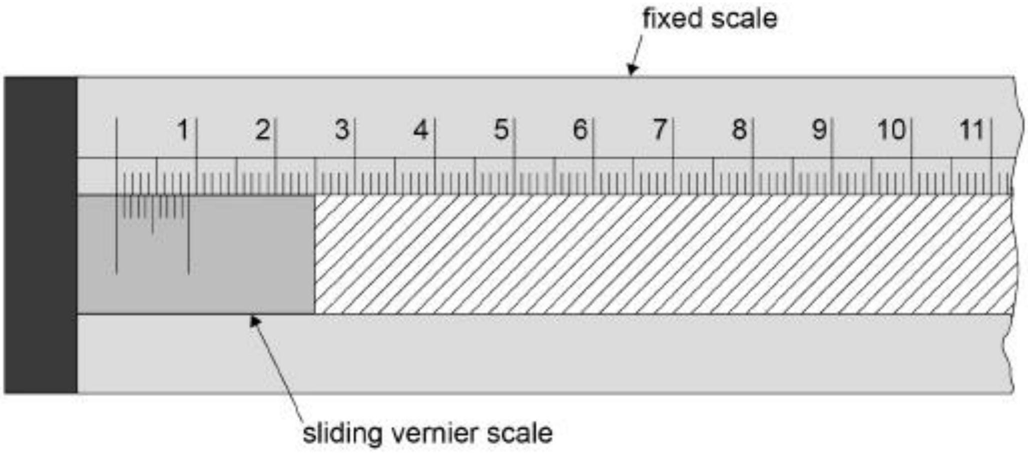


Figure 3

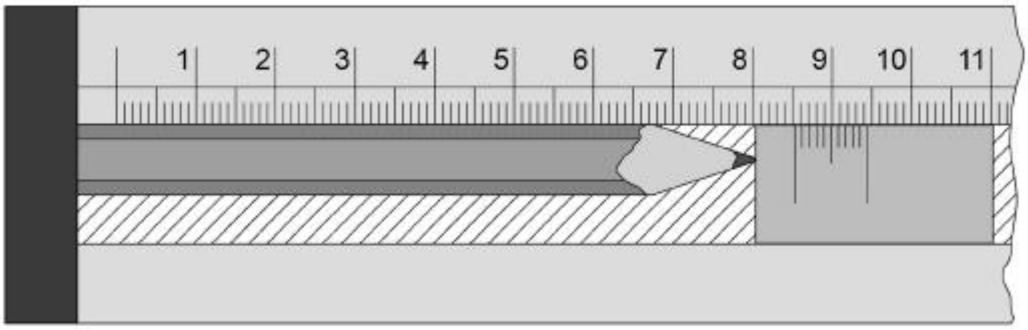
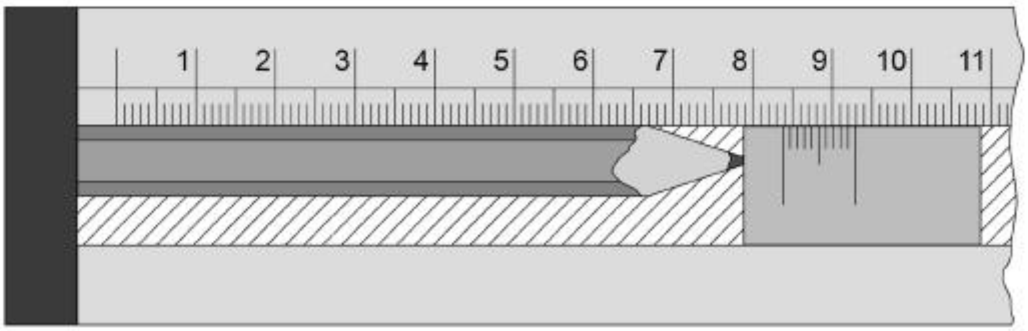


Figure 4



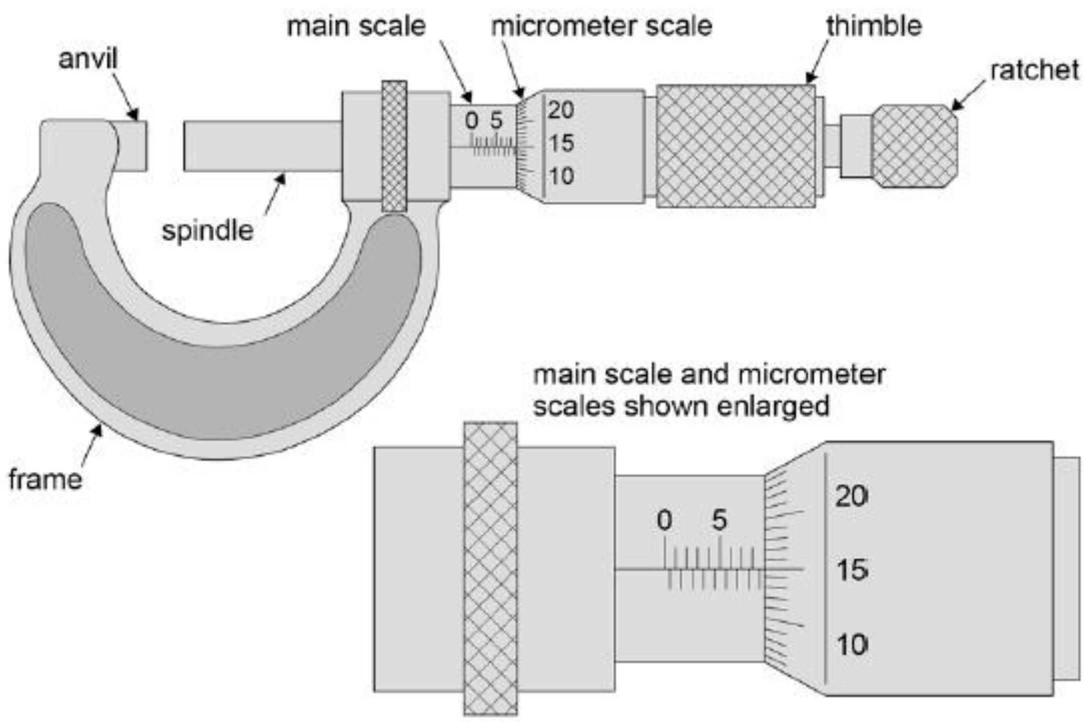
(Total 9 marks)

Q10.

This question is about the determination of the resistivity of a wire.

Figure 1 shows a micrometer screw gauge that is used to measure the diameter of the wire.

Figure 1



(a) State the resolution of the **main scale** on the micrometer in **Figure 1**.

resolution = ____________________ mm

(1)

(b) Determine the distance between the anvil and the spindle of the micrometer in **Figure 1**. State any assumption you make.

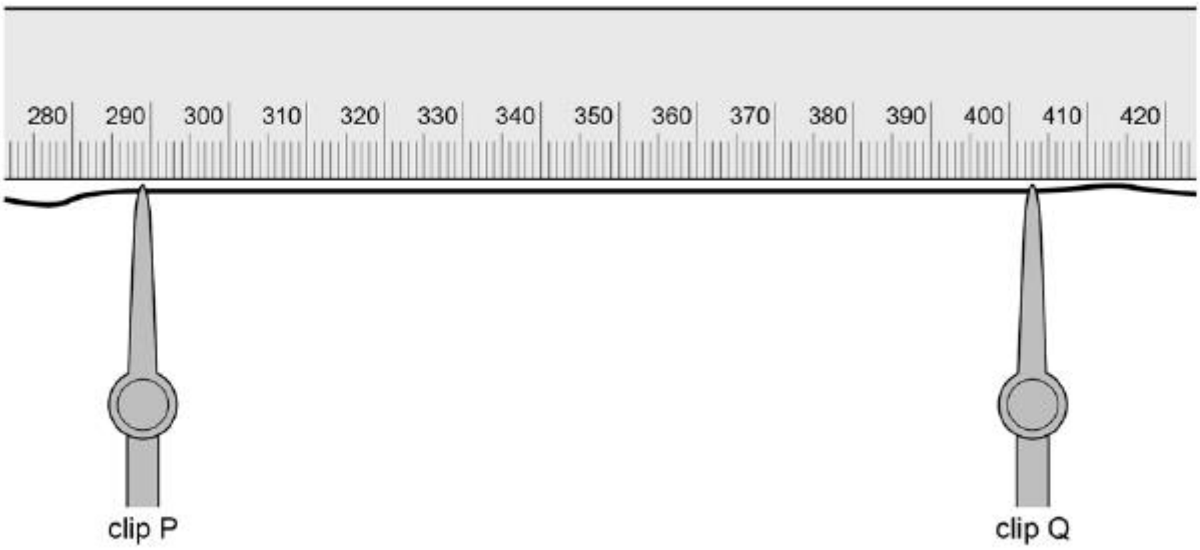
distance = ____________________ mm

(2)

(c) A student must also determine the length L of the wire between clips P and Q that will be connected into a circuit.

Figure 2 shows the metre ruler being used to measure L.

Figure 2



Determine L

L = ________________________ mm

(1)

(d) Calculate the percentage uncertainty in your result for L.

percentage uncertainty = ____________________ %

(2)

(e) State and explain what the student could have done to reduce uncertainty in the reading for L.

____

____

____

(1)

(f) The student intends to make measurements that will allow her to determine the resistance of one metre of the wire. She uses an ohm-meter to measure the resistance R for different lengths L of the wire. The student's measurements are shown in the table below.

L/cm	R/Ω	
81.6	8.10	
72.2	7.19	
63.7	6.31	
58.7	5.85	
44.1	4.70	

Determine the value that the student should record for the resistance per metre of the wire.

Use the additional column in the table above to show how you arrived at your answer.

resistance of one metre of wire = ________________ Ω

(2)

(g) Determine the resistivity of the wire. Give a suitable unit for your answer.

mean diameter of the wire = 0.376 mm

resistivity = ________________ unit = ____________

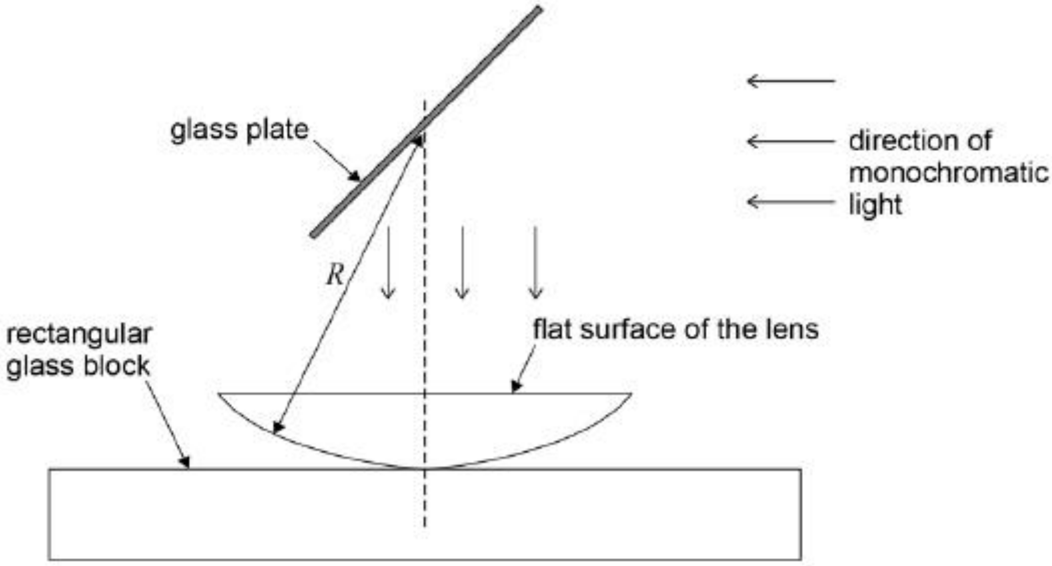
(4)

(Total 13 marks)

Q11.

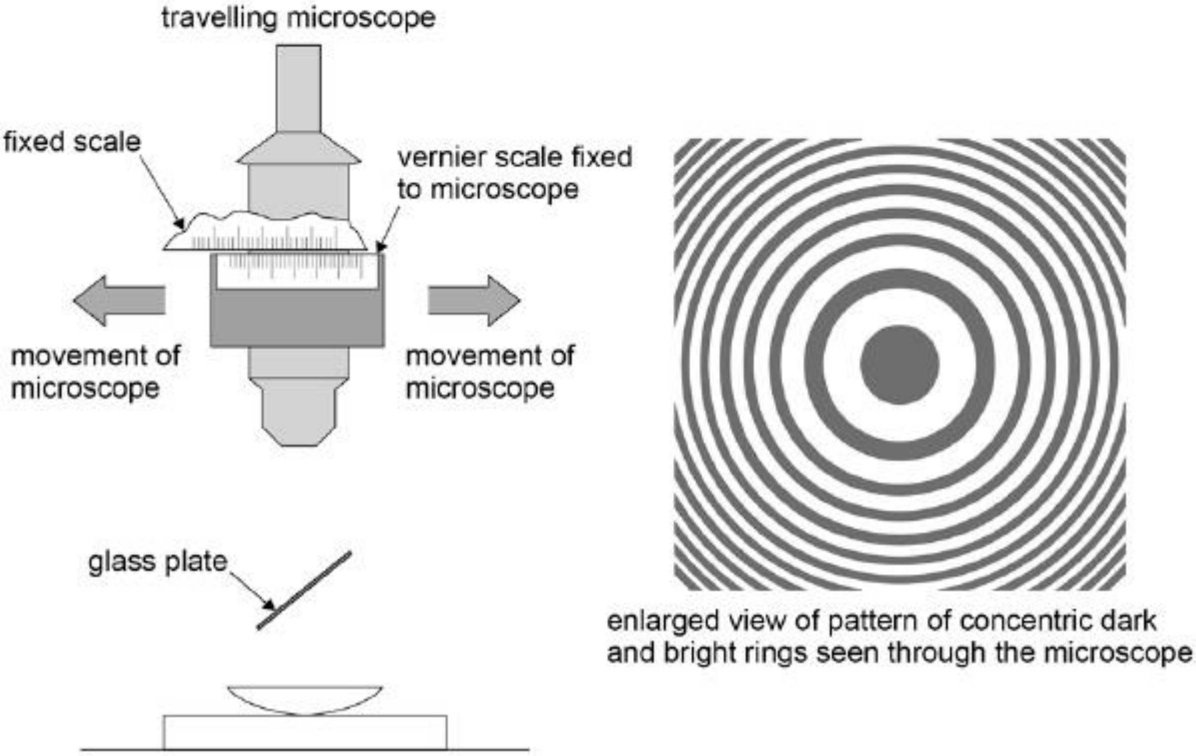
A lens has a flat surface and a curved surface. An experiment is carried out to determine the radius R of the curved surface of the lens. The lens is placed on a rectangular glass block with its flat surface upwards. The lens is illuminated with monochromatic light reflected from a glass plate as shown in **Figure 1**.

Figure 1



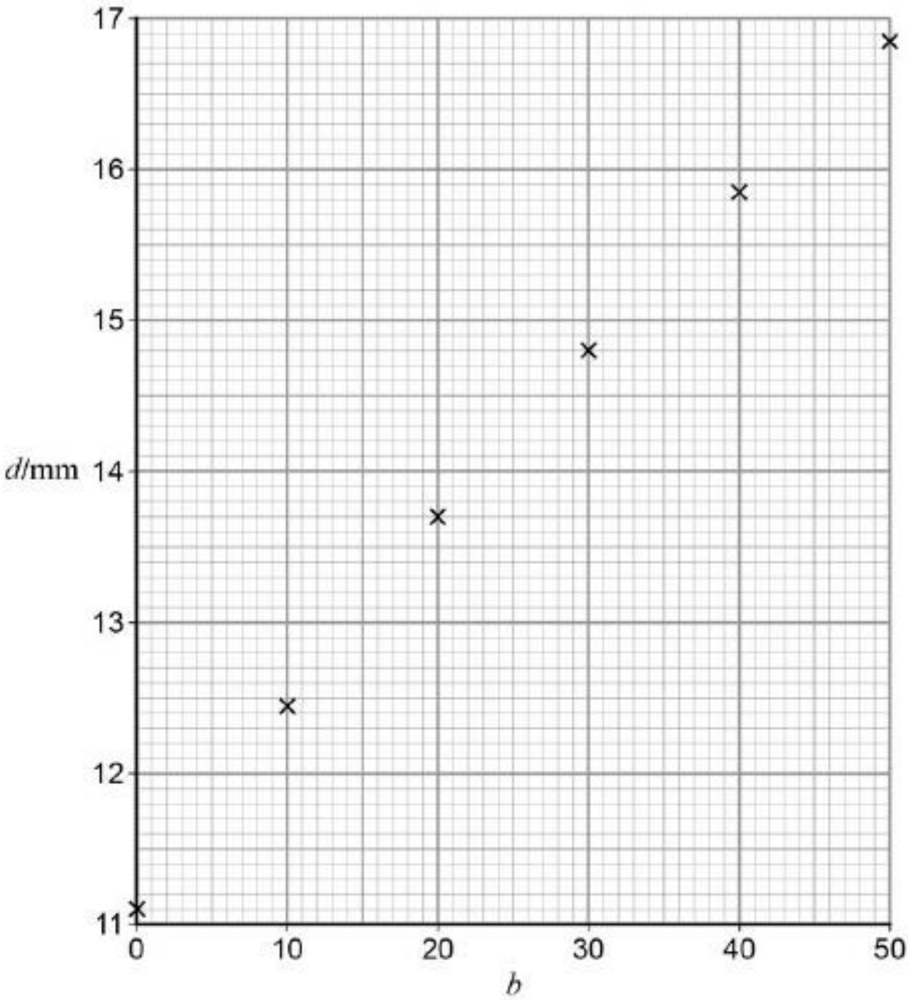
When the apparatus is viewed from above an interference pattern consisting of concentric dark and bright rings is seen. A travelling microscope positioned as shown in **Figure 2** is used to measure the diameter of the **bright** rings.

Figure 2



(a) A student chose a particular bright ring (not at the centre of the pattern) and measured its diameter. He called this ring number 0. Counting outwards from the centre, he measured the diameter of every tenth ring.

Below is a graph of ring number b against ring diameter d.



Draw a line of best fit on the graph above.

(1)

(b) Determine the gradient G corresponding to b = 25.

G = ______________________

(3)

(c) The radius of curvature R of the lens can be calculated using any point on the graph together with the formula

$$R = \frac{Gd}{2\lambda}$$

where λ = 589.3 nm.

Determine R.

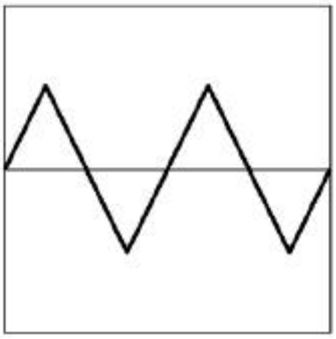
R = ____________________ m

(3)

(Total 7 marks)

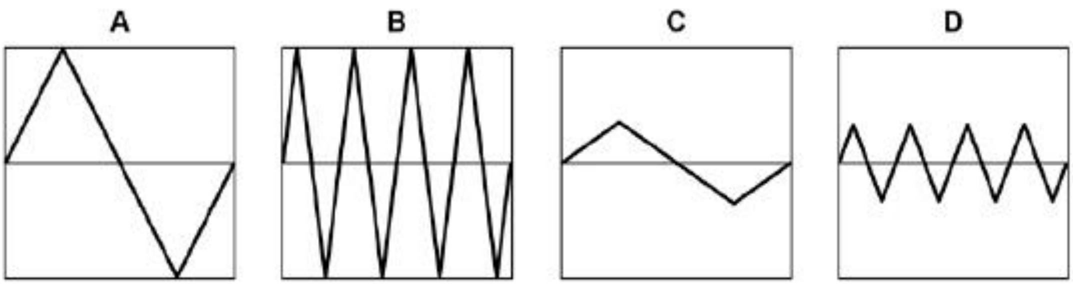
Q12.

A student is using an oscilloscope to investigate an ac voltage waveform. When the input sensitivity is set on 1 V per division and the time base setting is 10 ms per division, the trace appears as follows.



The student then changes the input sensitivity to 2 V per division and the time base setting to 20 ms per division.

What would be observed whilst applying the same signal to the input terminals?



A ☐

B ☐

C ○

D ○

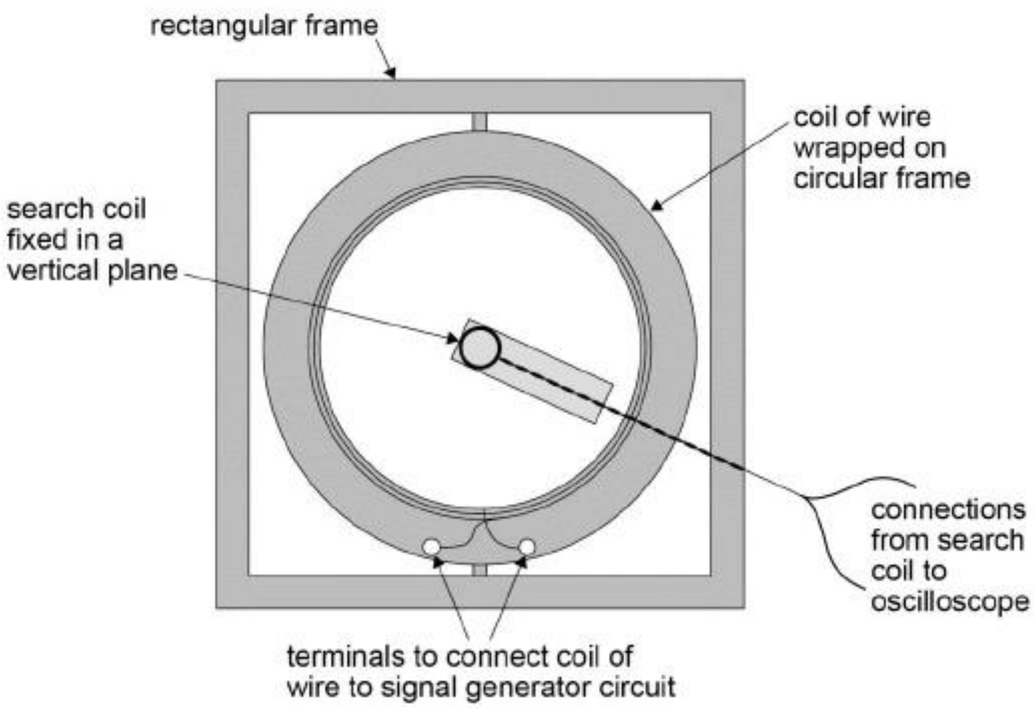
(Total 1 mark)

Q13.

This question is about experiments to investigate the magnetic flux density around a current−carrying conductor.

A student is provided with apparatus shown in **Figure 1**.

Figure 1



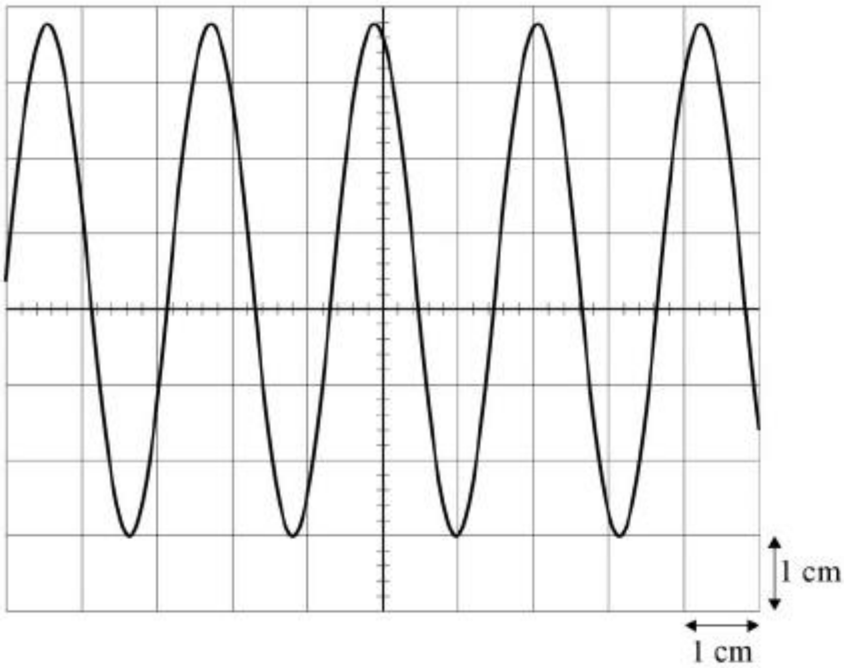
The apparatus consists of a circular frame on which is wound a coil of wire. This arrangement is mounted inside a rectangular frame.

The student clamps a search coil so it is co−axial with the circular coil then arranges the apparatus so that both frames and the search coil lie in the same vertical plane.

The coil of wire is connected to a signal generator and the search coil is connected to an oscilloscope. When a sinusoidal alternating current is passed through the coil an alternating emf is induced in the search coil.

The induced emf displayed on the oscilloscope is shown in **Figure 2**.

Figure 2



(a) Determine, using **Figure 2**, the frequency of the current in the coil.

Time−base setting of the oscilloscope is 0.2 ms cm^{-1}.

frequency = ____________________ Hz

(2)

(b) Determine, using **Figure 2**, the root mean square (rms) voltage of the emf induced in the search coil.

y−voltage gain of the oscilloscope = 10 mV cm^{-1}

rms voltage = ___________________ V

(2)

(c) **Figure 3** and **Figure 4** show the search coil and B_{peak}, the peak magnetic flux density produced by the current in the circular coil, when the apparatus is viewed from above.

Figure 3 shows the direction of B_{peak} when the search coil is arranged as in **Figure**

1.

Figure 4 shows the direction of B_{peak} when the circular frame is rotated through an angle θ.

The shaded area in these diagrams shows how the flux linked with the search coil changes as the circular coil is rotated.

Figure 3

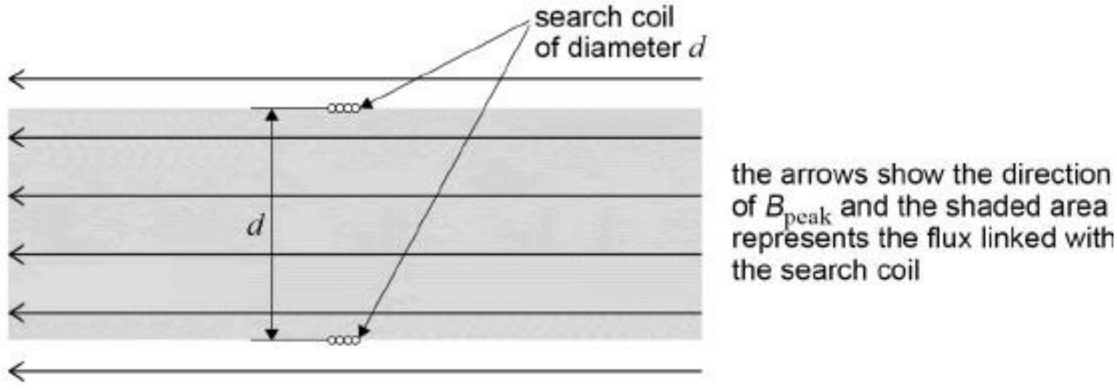
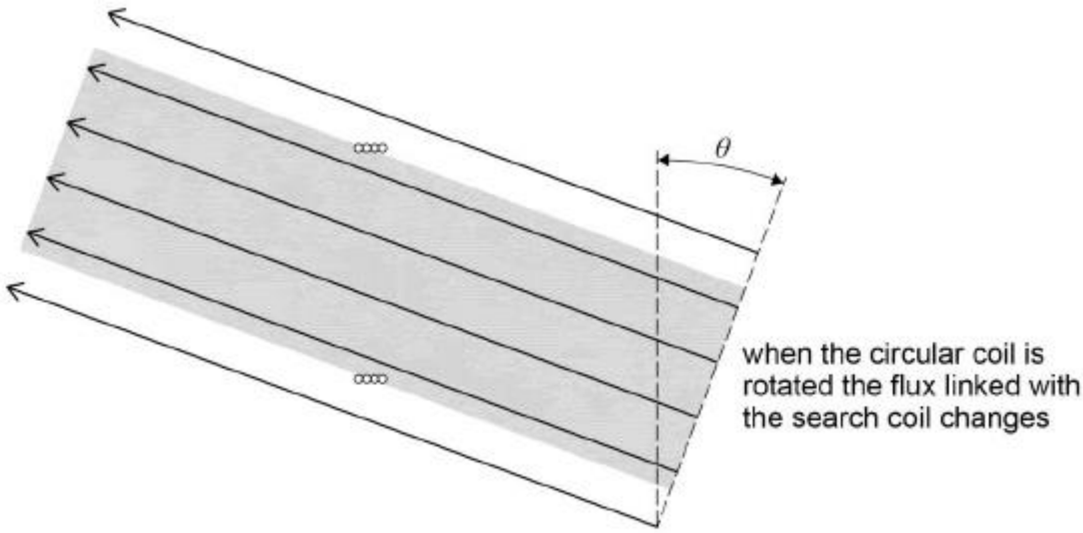


Figure 4



Explain why the flux linked with the coil is directly proportional to cosθ.

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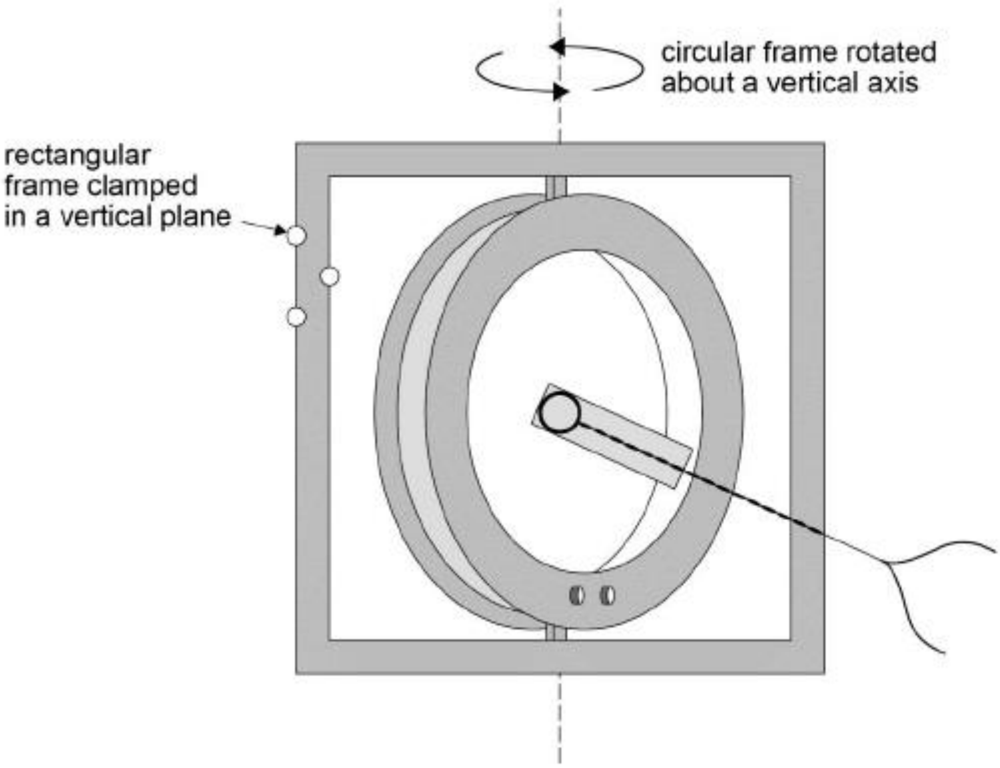
(2)

(d) The student clamps the rectangular frame so that it remains in a vertical plane. Without changing the position of the search coil she rotates the circular frame about a vertical axis so that it is turned through an angle, as shown in **Figure 5**.

Figure 5

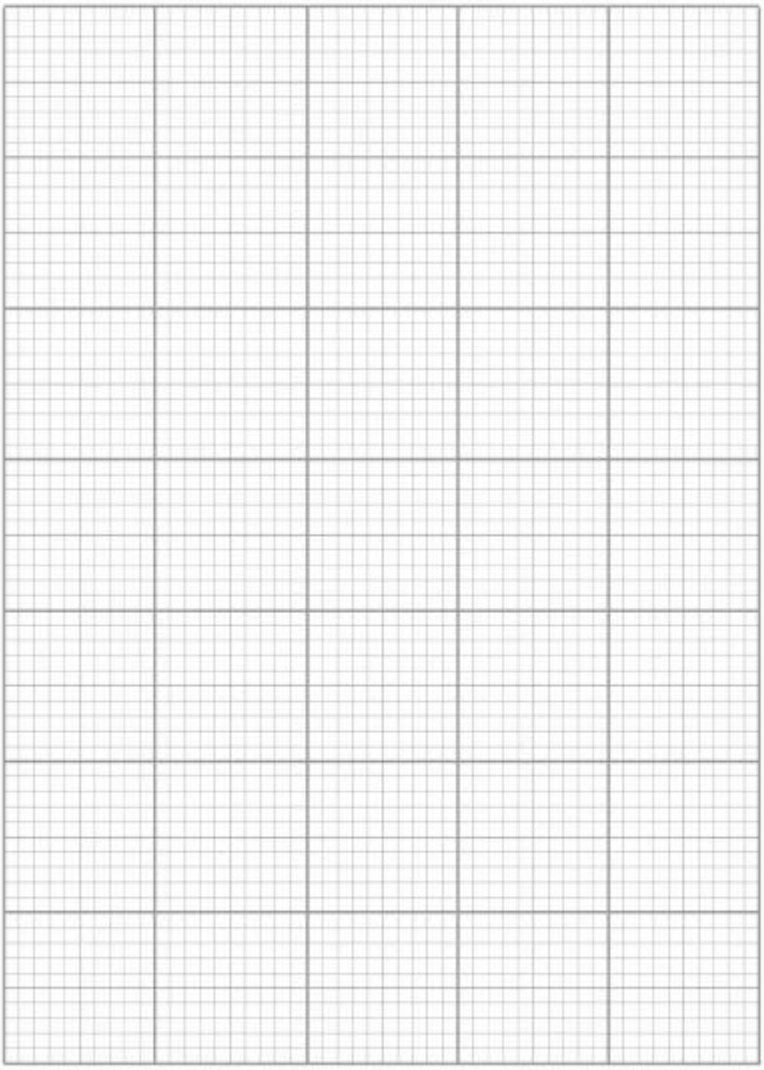


She turns off the time−base on the oscilloscope so that a vertical line is displayed on the screen. Keeping the y−voltage gain at 10 mV cm^{-1} she records the length l of the vertical line and the angle θ through which the circular frame has been rotated. She measures further results for l as θ is increased as shown in the table below.

θ/degree	**l/cm**	**cosθ**
10	6.7	
34	5.6	
50	4.4	
60	3.4	
72	2.1	
81	1.1	

Plot on **Figure 6** a graph to test if these data confirm that l is directly proportional to cosθ. Use the additional column in **Table 1** to record any derived data you use.

Figure 6



(4)

(e) State and explain whether the graph you have drawn confirms the suggestion that l is directly proportional to $\cos\theta$.

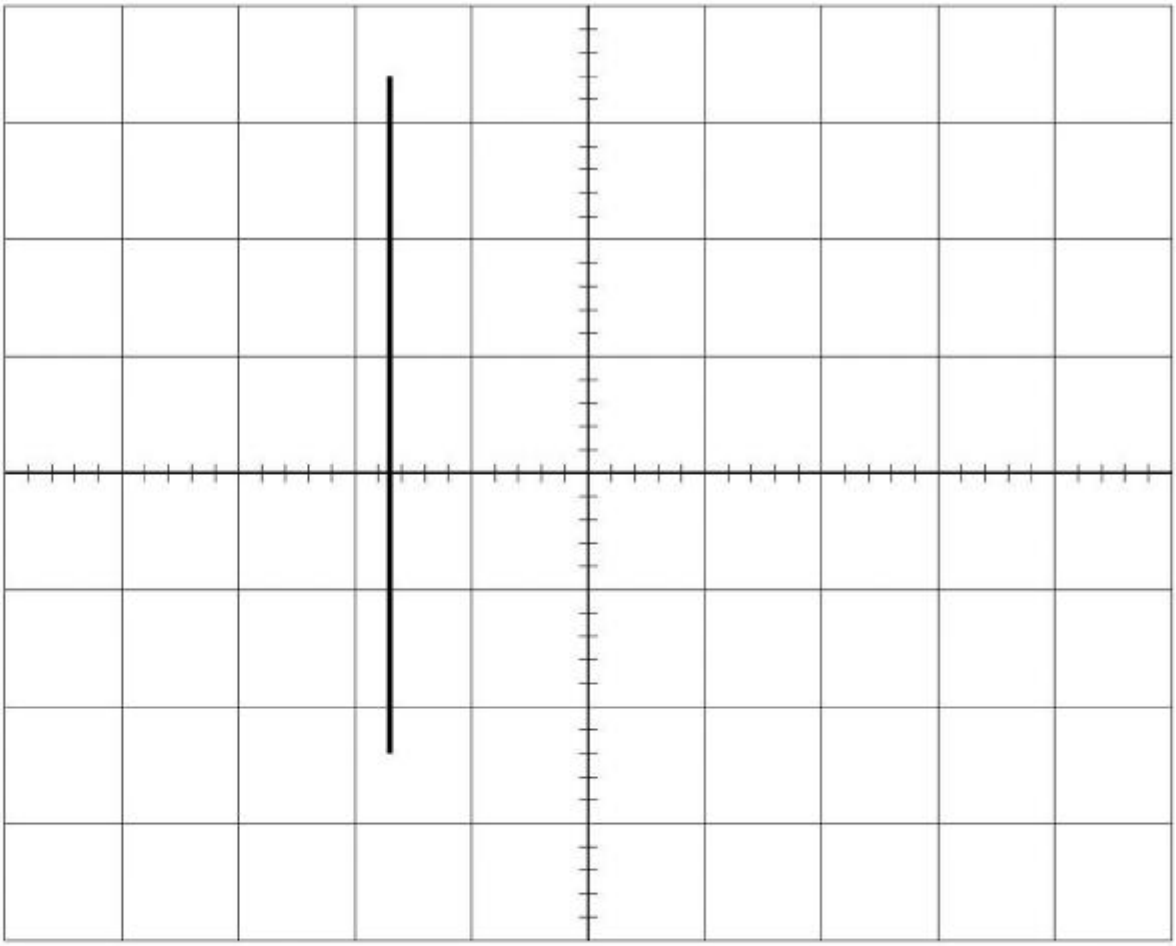
____

____

(1)

(f) When the time−base is switched off, the trace on the oscilloscope appears as shown in **Figure 7**.

Figure 7



Describe **two** adjustments the student should make to the trace to reduce the uncertainty in l.

You should refer to specific controls on the oscilloscope. You may use **Figure 7** to illustrate your answer.

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(4)

(g) The student adjusts the signal generator so that the frequency of the current in the circular coil is doubled.

State and explain any changes she should make to the settings of the oscilloscope in part **(f)** so that she can repeat the experiment.

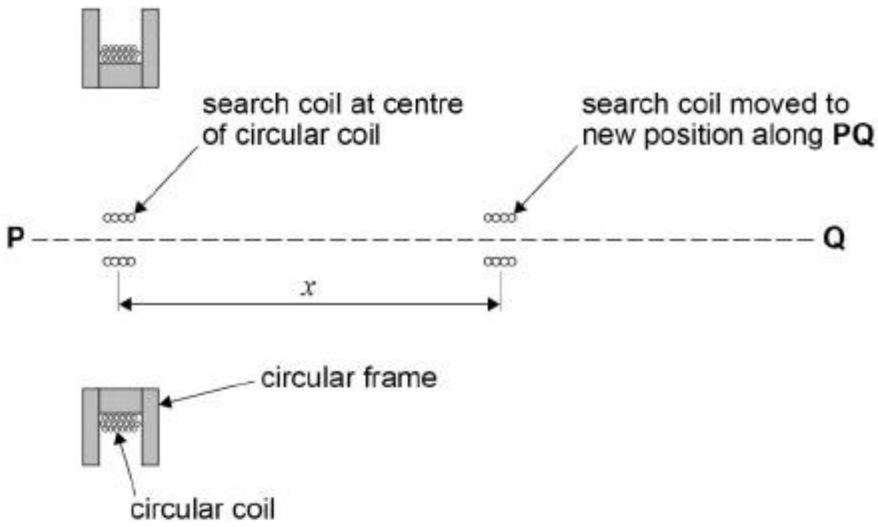
___

(3)

(h) The apparatus is re−arranged as in **Figure 1** so that both coils lie in the same vertical plane and are co-axial along a line **PQ**.

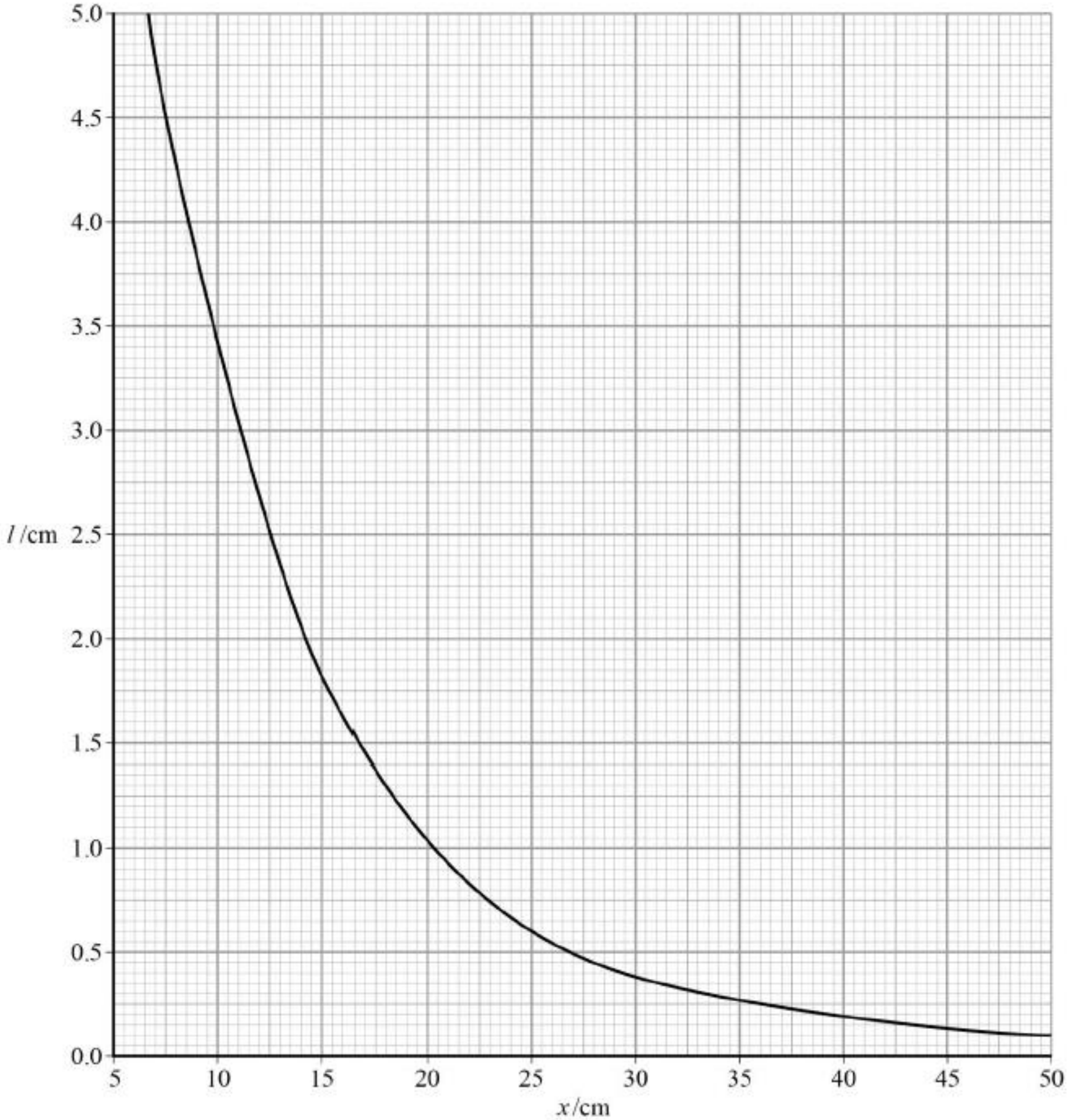
The search coil is then moved a distance x along **PQ**, as shown in **Figure 8**.

Figure 8



The values of I corresponding to different values of x are recorded. A graph of these data is shown in **Figure 9**.

Figure 9



It is suggested that l decreases exponentially as x increases.

Explain whether **Figure 9** supports this suggestion.

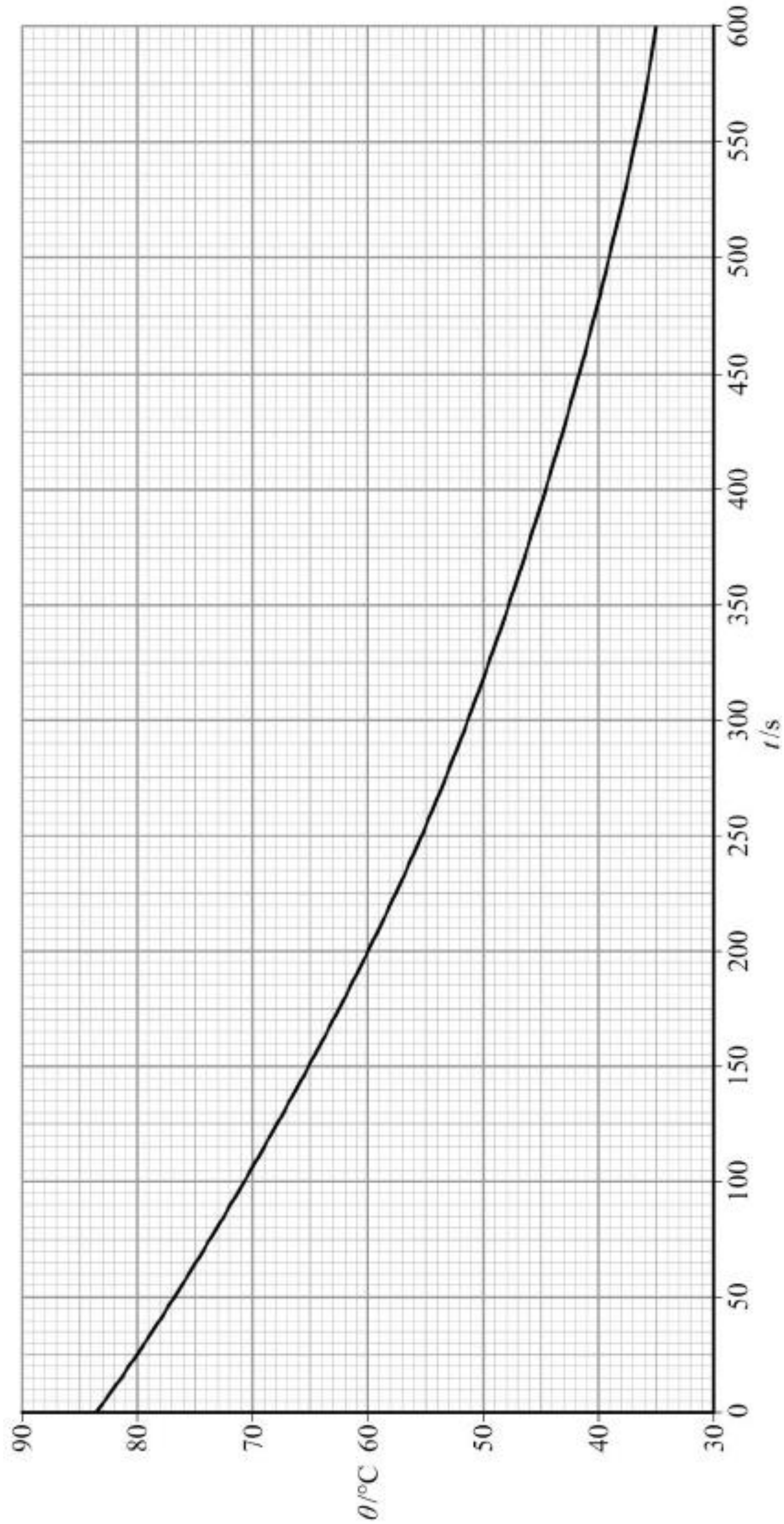
(2)

(Total 20 marks)

Q14.

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)

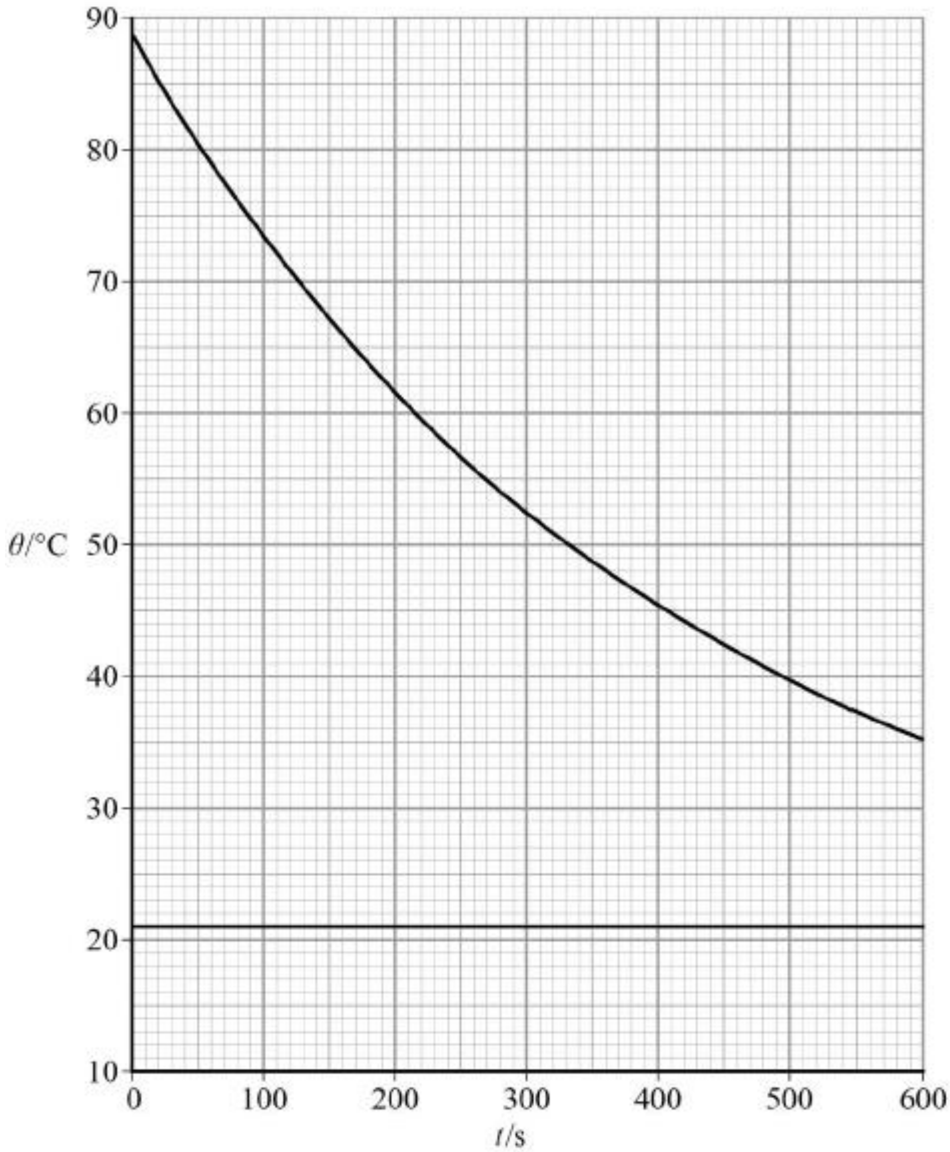
(d) It can be shown that when a hot object at a temperature θ is allowed to cool in a draught, the rate at which the temperature decreases is directly proportional to the temperature difference $(\theta - \theta_R)$ between the object and the surroundings.

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.

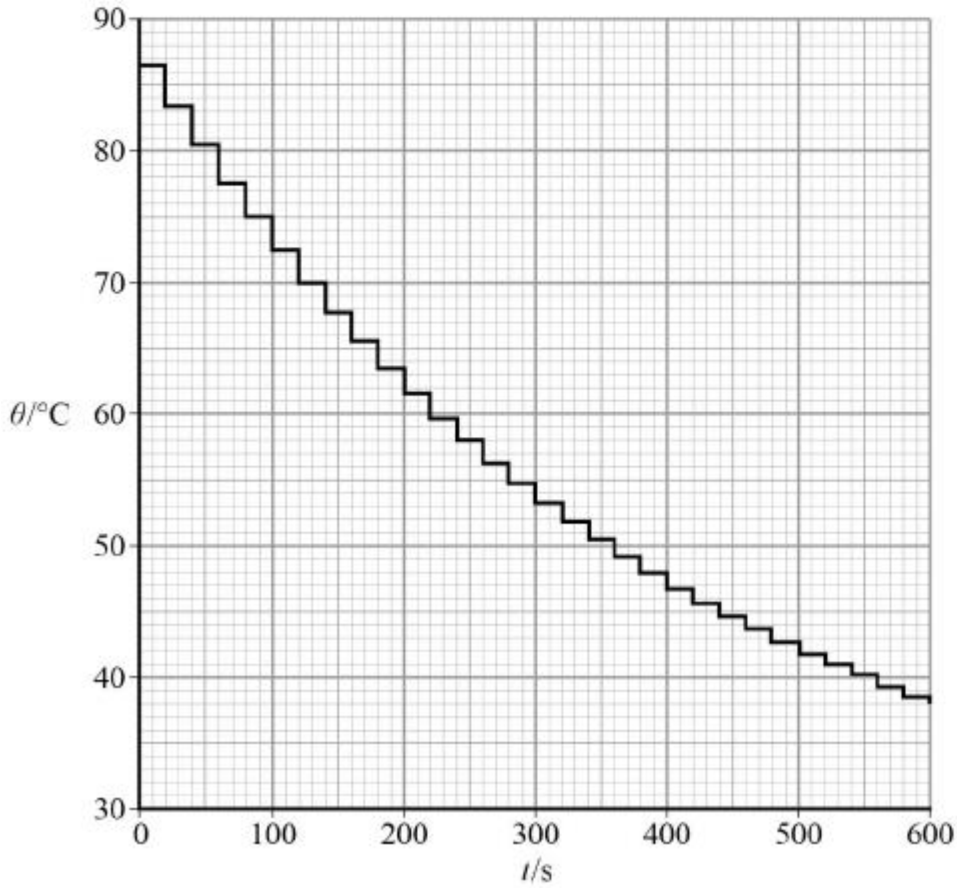
time taken = ____________________ s

(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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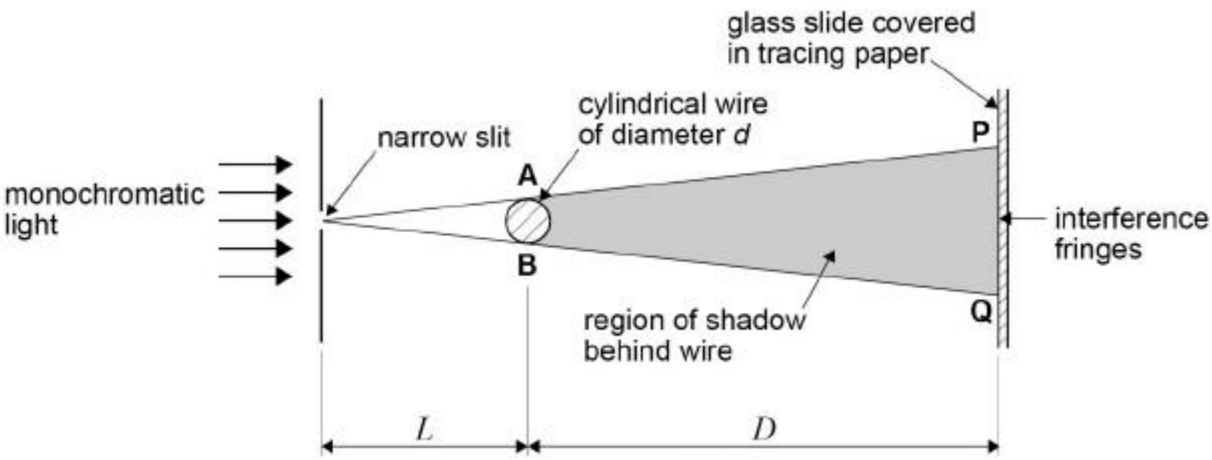
(5)

(Total 14 marks)

Q15.

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**.

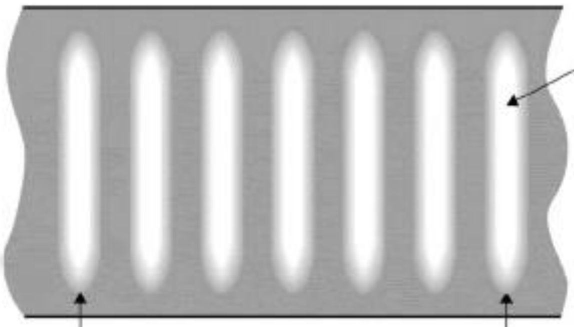
Figure 1



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.

A student performs an experiment to find the acceleration due to gravity. The student measures the time t for a spherical object to fall freely through measured vertical distances s. The time is measured electronically. The results are shown in the table below.

s/**m**	t_1/s	t_2/s	t_3/s	**mean time** t_m/s	t_m^2/s^2
0.300	0.245	0.246	0.244	0.245	0.0600
0.400	0.285	0.286	0.286	0.286	0.0818
0.500	0.319	0.321	0.318	0.319	0.102
0.600	0.349	0.351	0.348	0.349	0.122
0.700	0.378	0.380	0.378	0.379	0.144
0.800	0.403	0.406	0.404		
0.900	0.428	0.428	0.430		

(a) Complete the table by entering the missing values for t_m and t_m^2

(1)

(b) Complete the graph below by plotting the remaining two points and draw a line of best fit.

(2)

(c) Determine the gradient of the graph.

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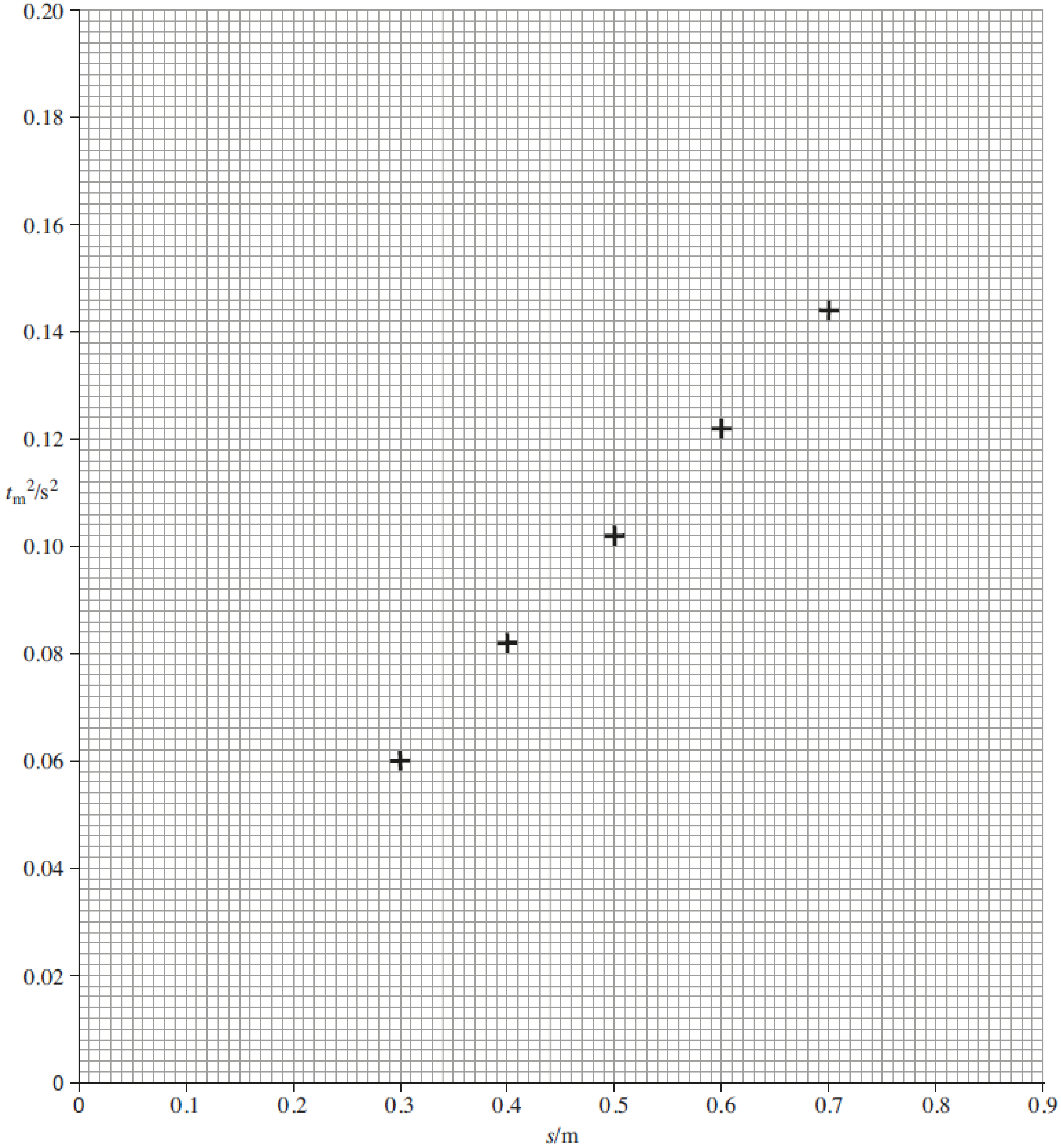
(3)



(d) Theory suggests that the equation for the line is $t^2 = \frac{2s}{g}$ where g is the acceleration due to gravity.

Calculate a value for g using the above equation and the gradient of your graph above.

___

___

___

(1)

(e) Calculate the percentage difference between your value for g and the accepted value of 9.81 m s $^{-2}$.

(1)

(f) Calculate the uncertainty in the smallest value of t_m.

(1)

(g) Calculate the value of g which would be given from the smallest value of t_m and the corresponding value of s.

(3)

(h) The uncertainty in each value of s is ± 0.001 m.

Calculate the uncertainty in the value of g you calculated in part **(g)**.

You will need to use the uncertainty for t_m you calculated in part **(f)**.

(3)

(i) A student wishes to investigate the effect of changing the mass of the spherical object on the acceleration of free fall.

Explain how you would modify the experiment seen at the start of this question.

(3)

(Total 18 marks)

Q22.

The first section of a full-size stroboscopic photograph of a marble released from rest and in free fall is shown below. Every time the strobe light flashes an image of the marble is recorded. The time interval between successive flashes of the strobe light was 0.0435 s.

(a) This photograph can be used to find a value for the acceleration due to gravity g.

(i) Take measurements from the diagram below that can be used to find an accurate value for g.

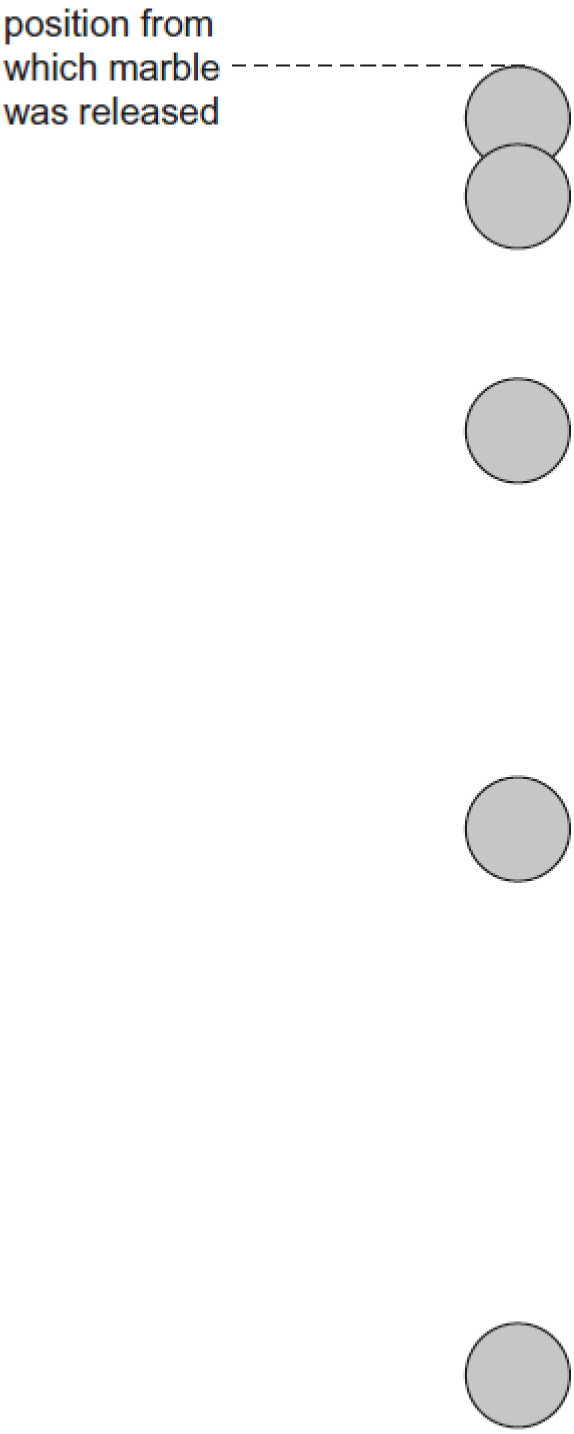
(2)

(ii) Calculate a value for g using your measurements from **(a)(i)**.

(2)

(b) Suggest why the duration of the flash of the strobe should be as short as possible.

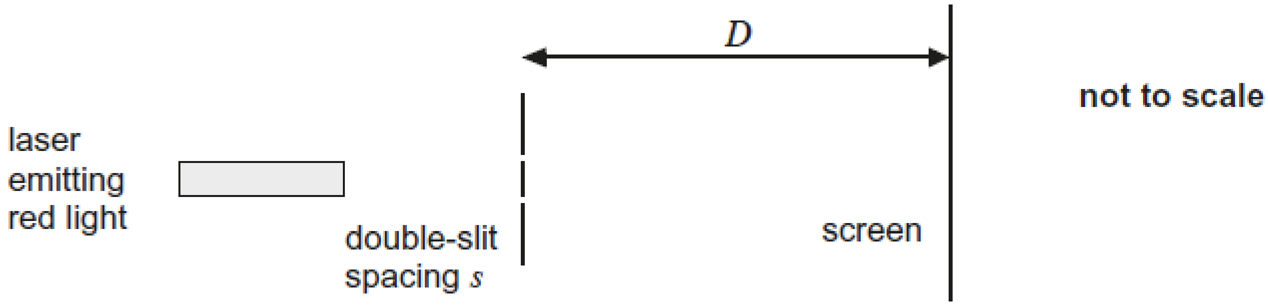
(1)



(Total 5 marks)

Q23.

The diagram shows the arrangement of apparatus in an experiment to measure the wavelength of red light emitted by a laser. The light is incident on a double-slit so that an interference pattern is produced on the screen.



A student sets up the apparatus and measures the fringe width *w* of the interference pattern and the distance *D* between the double-slit and screen.

The student makes further measurements of *w* using the same laser but with different values of *D* and different slit spacing *s*.

The student's results are shown in the table below

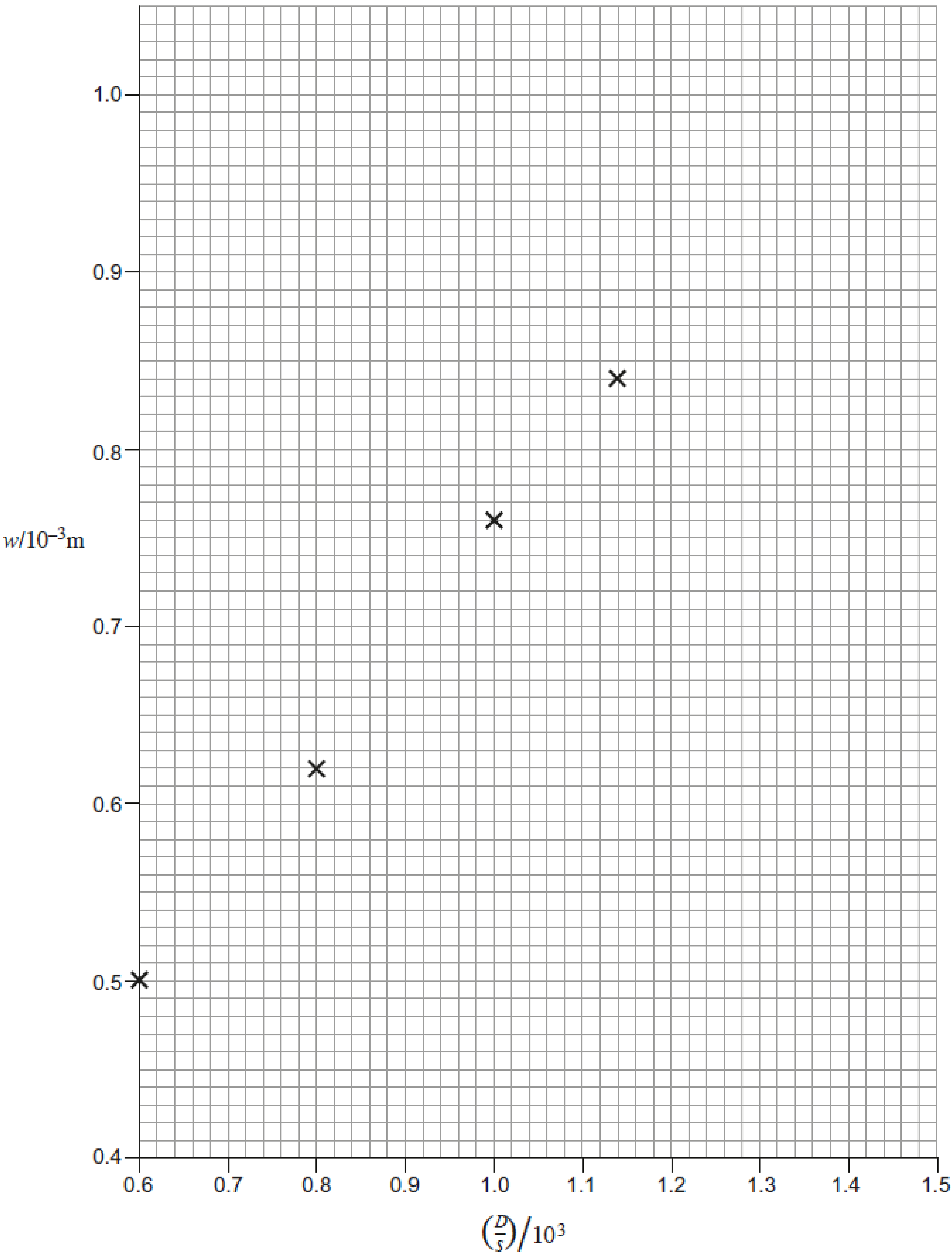
D/m	$S/10^{-3}$ m	$\left(\frac{D}{S}\right)/10^{3}$	$w/10^{-3}$m
1.000	0.70		1.03
0.900	0.70		0.93
0.800	0.70	1.14	0.84
1.000	1.00	1.00	0.76
0.800	1.00	0.80	0.62
0.600	1.00	0.60	0.50

(a) Complete the table above.

(1)

(b) Complete the graph below by plotting the two remaining points and drawing a best fit straight line.

(2)



(c) (i) Determine the gradient of the graph above.

___

(3)

(ii) Determine the wavelength of the red laser light used in this experiment.

(1)

(d) (i) Theory suggests that the graph above should go through the origin.

State and explain what this suggests about the relationship between *w* and $\frac{D}{S}$.

(2)

(ii) The student discovers that the best fit line drawn in the graph does not go through the origin.

Determine, using information from the graph above, the value of *w* corresponding to $\left(\frac{D}{S}\right) = 0$.

(2)

(iii) The graph suggests a systematic error in a measurement.

Identify the measurement.

(1)

(e) The interference pattern produced on the screen is much brighter in the centre of the screen than at the edges.

State what causes this effect.

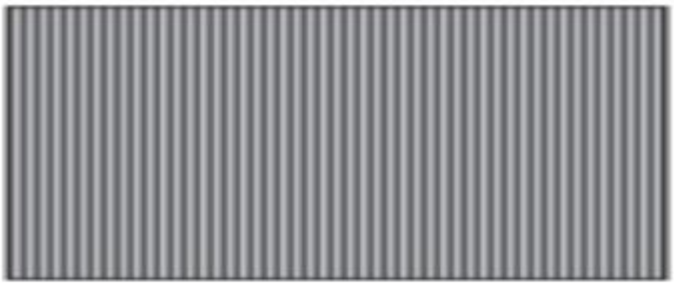
____

____

(1)
(Total 13 marks)

Q24.

(a) The image below shows a full-size photograph of a double-slit interference pattern, using a laser.



Determine the fringe width w using a ruler to take measurements from the image above.
You may use a hand-lens to help you make this measurement.

____

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(3)

(b) Calculate the uncertainty in the value of w measured in part **(a)**.

____

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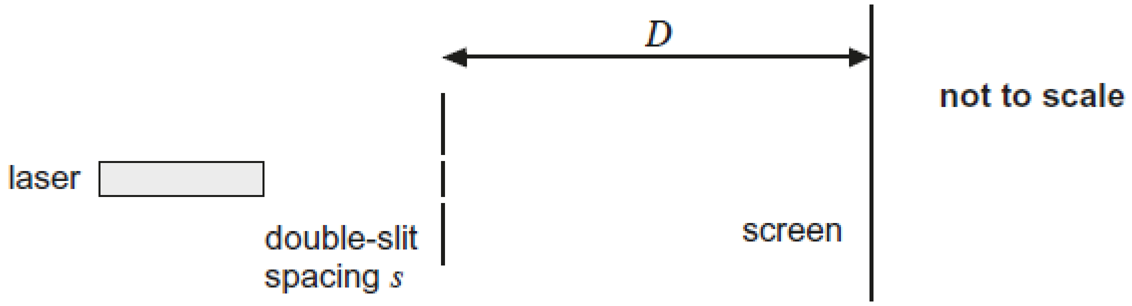
(2)

(c) In the experiment shown in the diagram below, the fringe pattern in the image in part **(a)** is produced.



$s = 0.60 \pm 0.02$ mm
$D = 1.500 \pm 0.002$ m

Using these data and your answers to part **(a)** and part **(b)**, determine

(i) the wavelength of the laser light used

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___

(1)

(ii) the percentage uncertainty in this value of wavelength

___

___

___

(1)

(iii) the absolute uncertainty in this value of wavelength.

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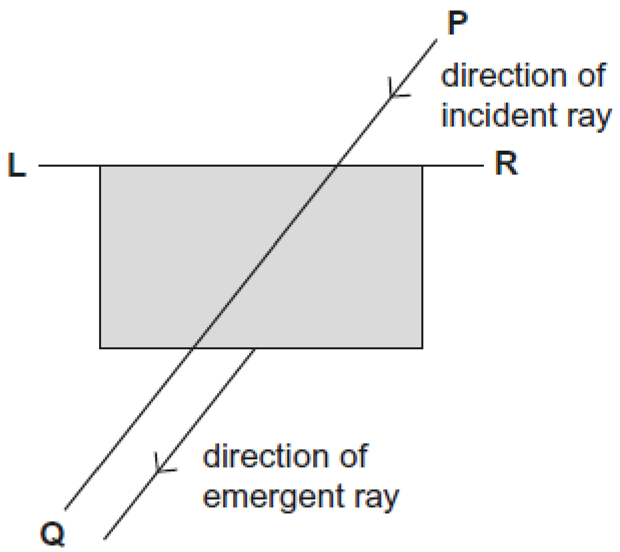
(1)

(Total 8 marks)

Q25.

A student aligns the longer edge of a rectangular glass block along a line **LR**, as shown in **Figure 1**.

Figure 1

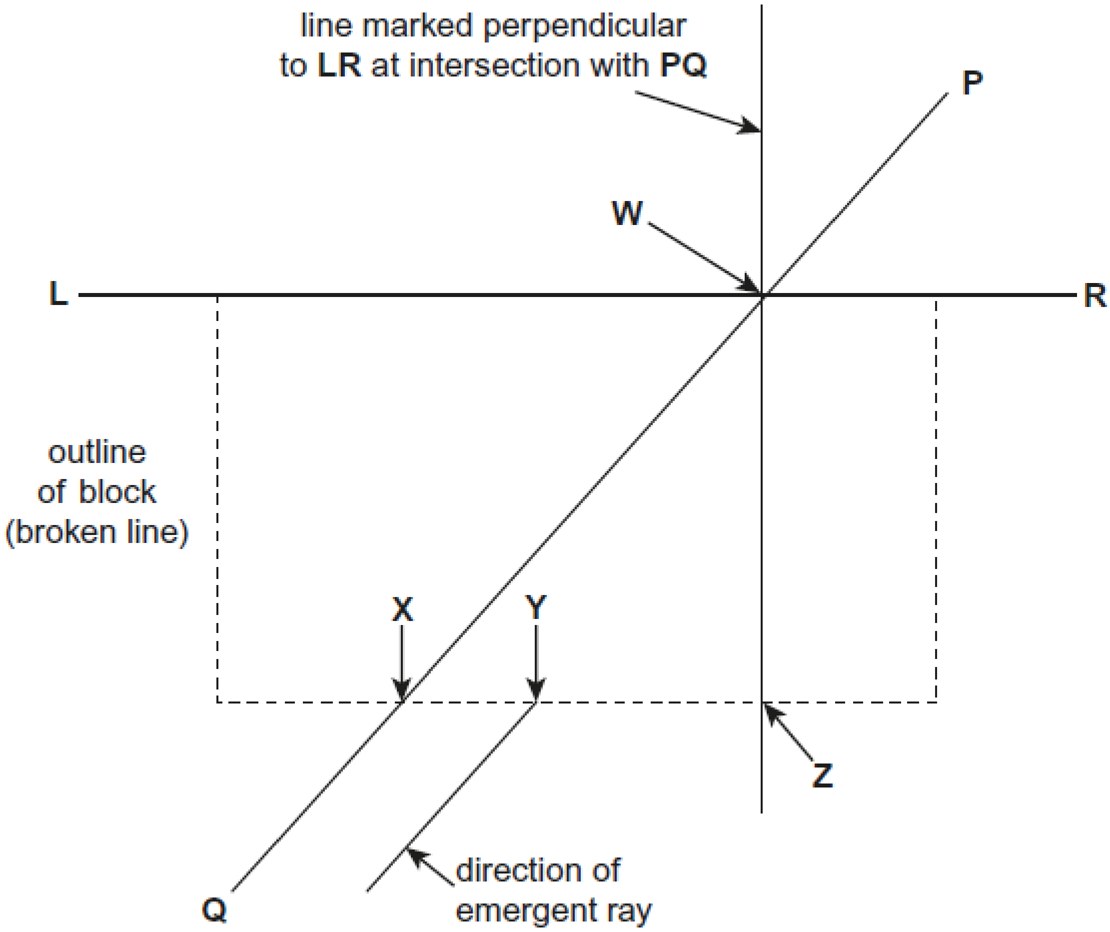


The student marks the outline of the block and directs a ray along **PQ**.

The student marks the direction of the emergent ray then removes the block and marks a line perpendicular to **LR** where **PQ** and **LR** intersect.

The student then marks the points **W**, **X**, **Y** and **Z** that are defined in **Figure 2**.

Figure 2



(a) Show that the refractive index *n* of the block is given by the equation

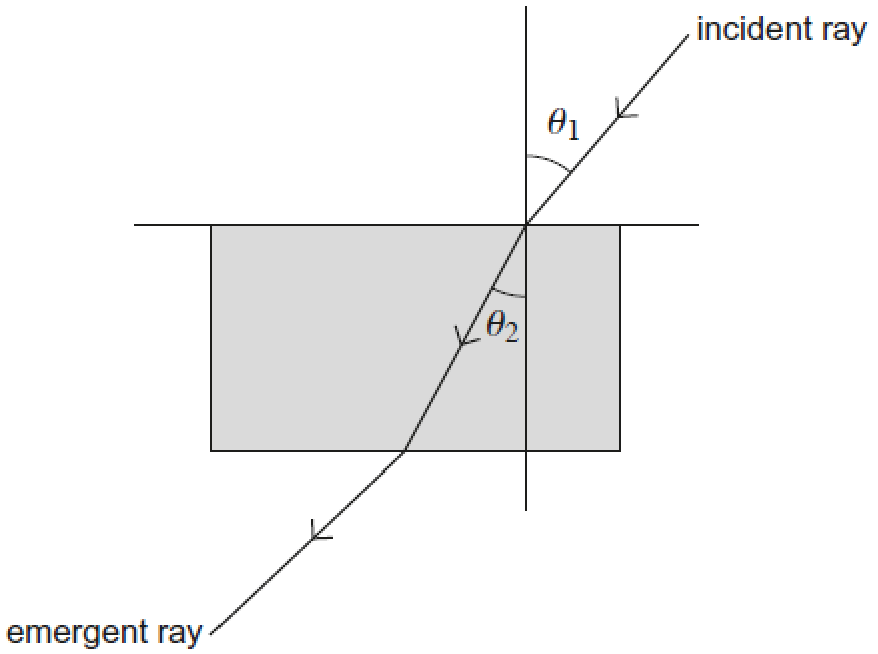
$$n = \frac{XZ \times WY}{YZ \times WX}$$

You may wish to use the equation $n = \frac{\sin\theta_1}{\sin\theta_2}$

where θ_1 and θ_2 are the angles shown in **Figure 3**.

You may also wish to illustrate your answer with a diagram.

Figure 3



(2)

(b) The student repeats the procedure for different directions of the incident ray **PQ**. The student measures **XZ**, **WX**, **YZ** and **WY** for each direction of **PQ**.
State and explain how the student can use these results to obtain a value of *n* by a graphical method.

(2)

(c) The student used a block with dimensions 114 mm × 65 mm × 19 mm to perform the experiment.

The student's data are shown in the table below.

WX/mm	WY/mm	XZ/mm	YZ/mm
130	78	113	44
103	75	80	38
90	73	63	33
81	71	49	27
75	69	38	22
67	66	15	10

Explain whether the range of measurements made by the student is suitable.

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(3)

(Total 7 marks)

Q26.

A student uses a travelling microscope to investigate the perforation holes in a block of postage stamps.

The student positions the microscope to observe the line of perforation holes along the line XY shown in **Figure 1**.

Figure 1

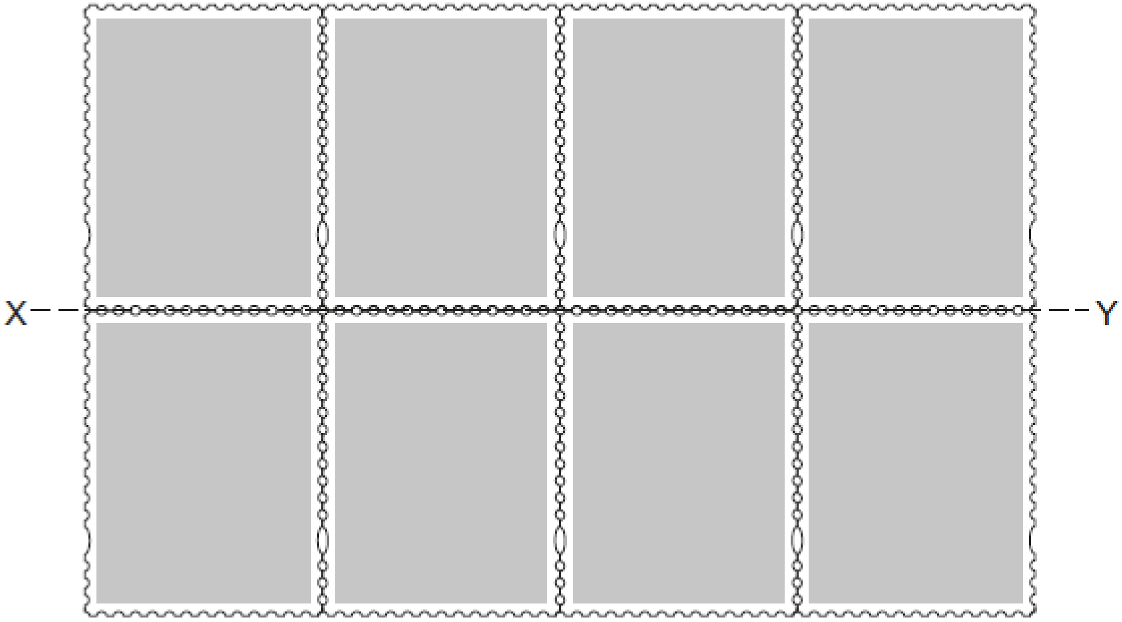
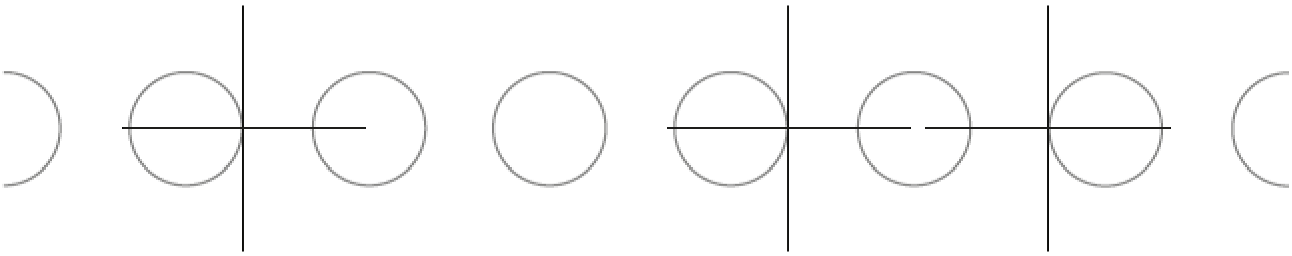


Figure 2 shows the positions of the cross-wires of the microscope when the student makes readings R_1, R_2 and R_3.

Figure 2



The student's readings are shown in the table below.

reading	position / mm
R_1	25.51
R_2	29.80
R_3	31.82

(a) Determine the average separation s between the centres of adjacent perforation holes along line XY.

average separation s = ______________________________ mm

(1)

(b) State the precision of the microscope readings.

precision = ______________________________ mm

(1)

(c) Determine the percentage uncertainty in your result for s.

percentage uncertainty = ______________________________ %

(2)

(d) Determine the diameter d of a perforation hole.

diameter d = ______________________________ mm

(2)

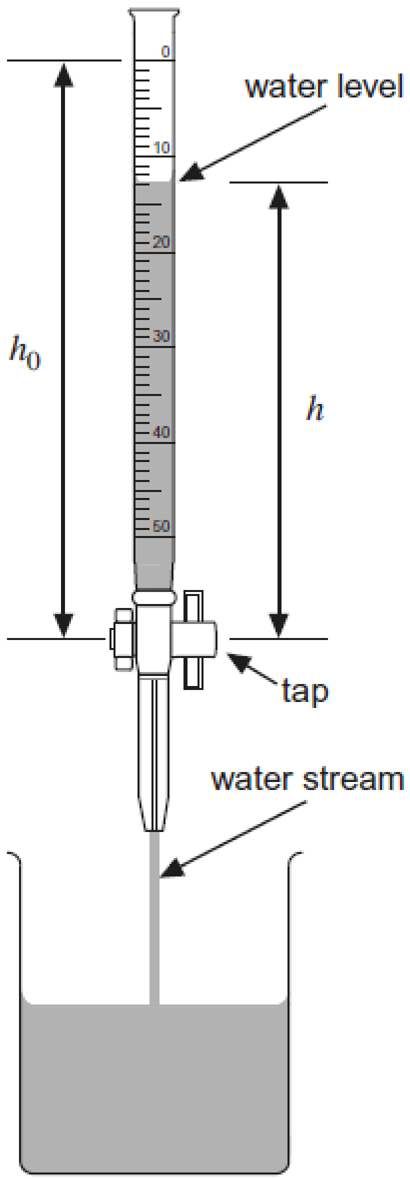
(Total 6 marks)

Q27.

A student investigates how the height *h* of water flowing out of a burette varies with time *t*.
A burette is used by chemists to measure a volume of liquid.

The apparatus the student used is shown in **Figure 1**.

Figure 1



h_0 is the height of the water level above the tap in the burette at time t = 0.

As the tap was opened the student started a stopclock and recorded the height h every 10.0 s as the water drained into the beaker.

Values of h and h_0 were measured using a metre ruler.

The student repeated this procedure twice more. The results are shown in the table below.

t/s	Height above the tap/mm				ln (*h*/mm)
	h_1	h_2	h_3	mean height h	
0	665	665	665	665	6.500
10.0	571	569	576	572	6.349

20.0	517	512	509	513	6.240
30.0	434	429	421	428	6.059
40.0	380	384	379		
50.0	340	338	331		
60.0	291	287	295	291	5.673

(a) Complete the table above.

(1)

(b) Plot the two missing points on the graph in **Figure 2** and draw a best fit straight line.

(2)

(c) Determine the gradient of your line.

gradient = ____

(3)

(d) Theory predicts that the relationship between *h* and *t* is given by the equation

$$h = He^{-\lambda t}$$

where *H* and *λ* are constants.

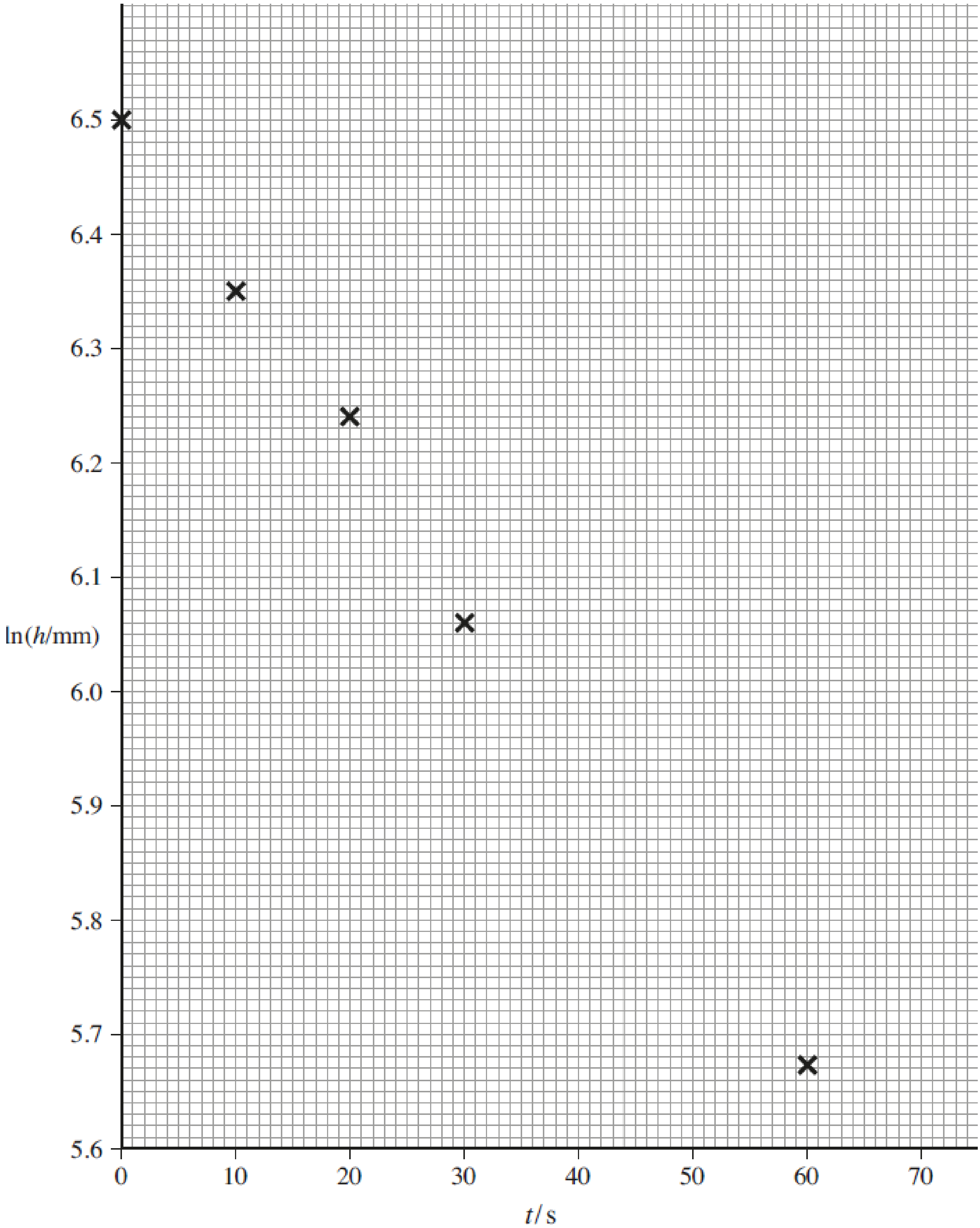
State values for *H* and *λ* with their units.

H = ________________________ unit = _______

λ = ________________________ unit = _______

(3)

Figure 2



(e) Suggest a possible source of systematic error in the burette experiment.

Explain whether this would have affected the value you found for λ.

Source ____

____

Explanation ____

____

(3)

(f) Suggest a possible source of random error in the burette experiment.

Explain whether this would have affected the value you found for λ.

Source ____

____

Explanation ____

____

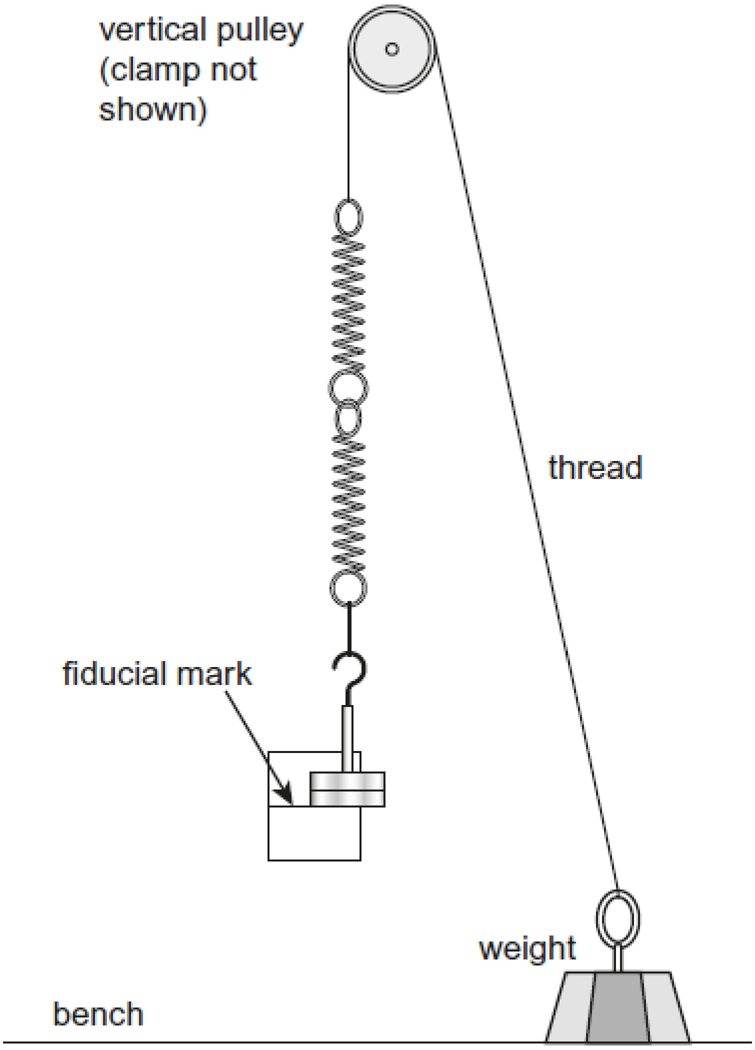
(2)

(Total 14 marks)

Q28.

A student investigates the vertical oscillations of the mass–spring system shown in **Figure 1**.

Figure 1



The system is suspended from one end of a thread passing over a pulley.

The other end of the thread is tied to a weight.

The system is shown in **Figure 1** with the mass at the equilibrium position.

The spring constant (stiffness) is the same for each spring.

(a) Explain why the position of the fiducial mark shown in **Figure 1** is suitable for this experiment.

____

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____

____

(1)

The table below shows the measurements recorded by the student.

Time for 20 oscillations of the mass-spring system/s				
22.9	22.3	22.8	22.9	22.6

(b) (i) Determine the percentage uncertainty in these data.

percentage uncertainty = ____________________

(3)

(ii) Determine the natural frequency of the mass-spring system.

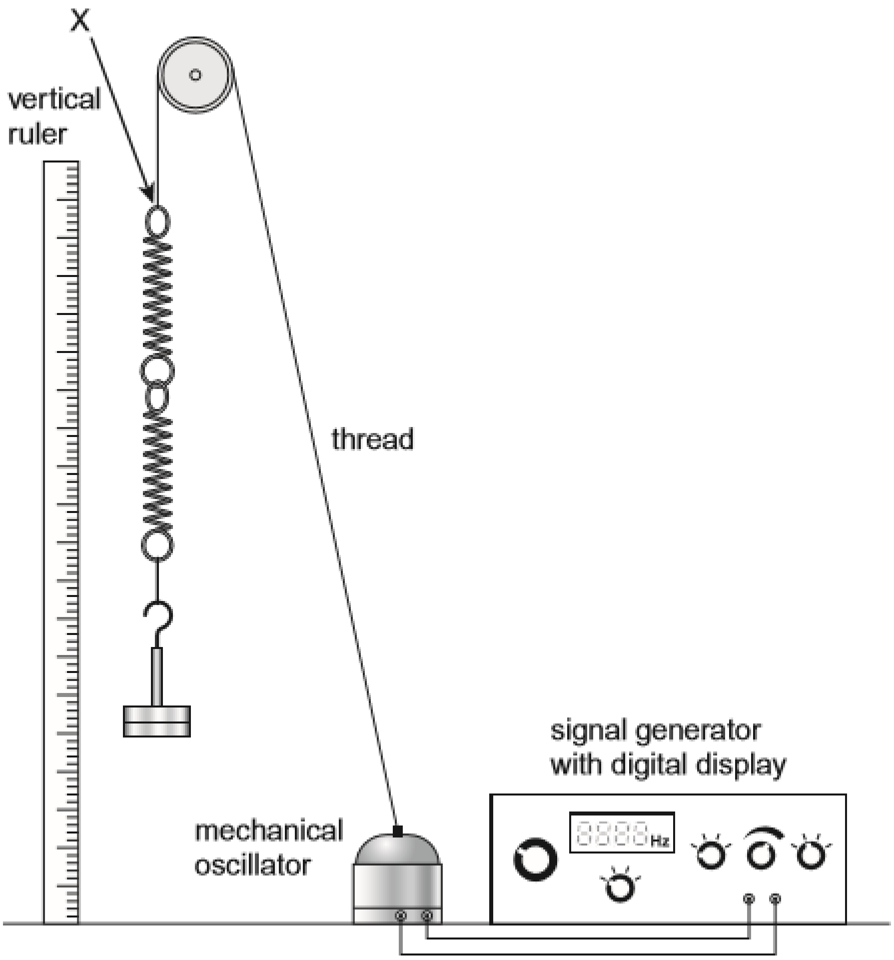
natural frequency = ____________________

(1)

(c) The student connects the thread to a mechanical oscillator. The oscillator is set in motion using a signal generator and this causes the mass–spring system to undergo forced oscillations.

A vertical ruler is set up alongside the mass–spring system as shown in **Figure 2**. The student measures values of *A*, the amplitude of the oscillations of the mass as *f*, the frequency of the forcing oscillations, is varied.

Figure 2



A graph for the student's experiment is shown in **Figure 3**.

(i) Add a suitable scale to the frequency axis.
You should refer to your answer in part **(b)(ii)** and note that the scale starts at 0 Hz.

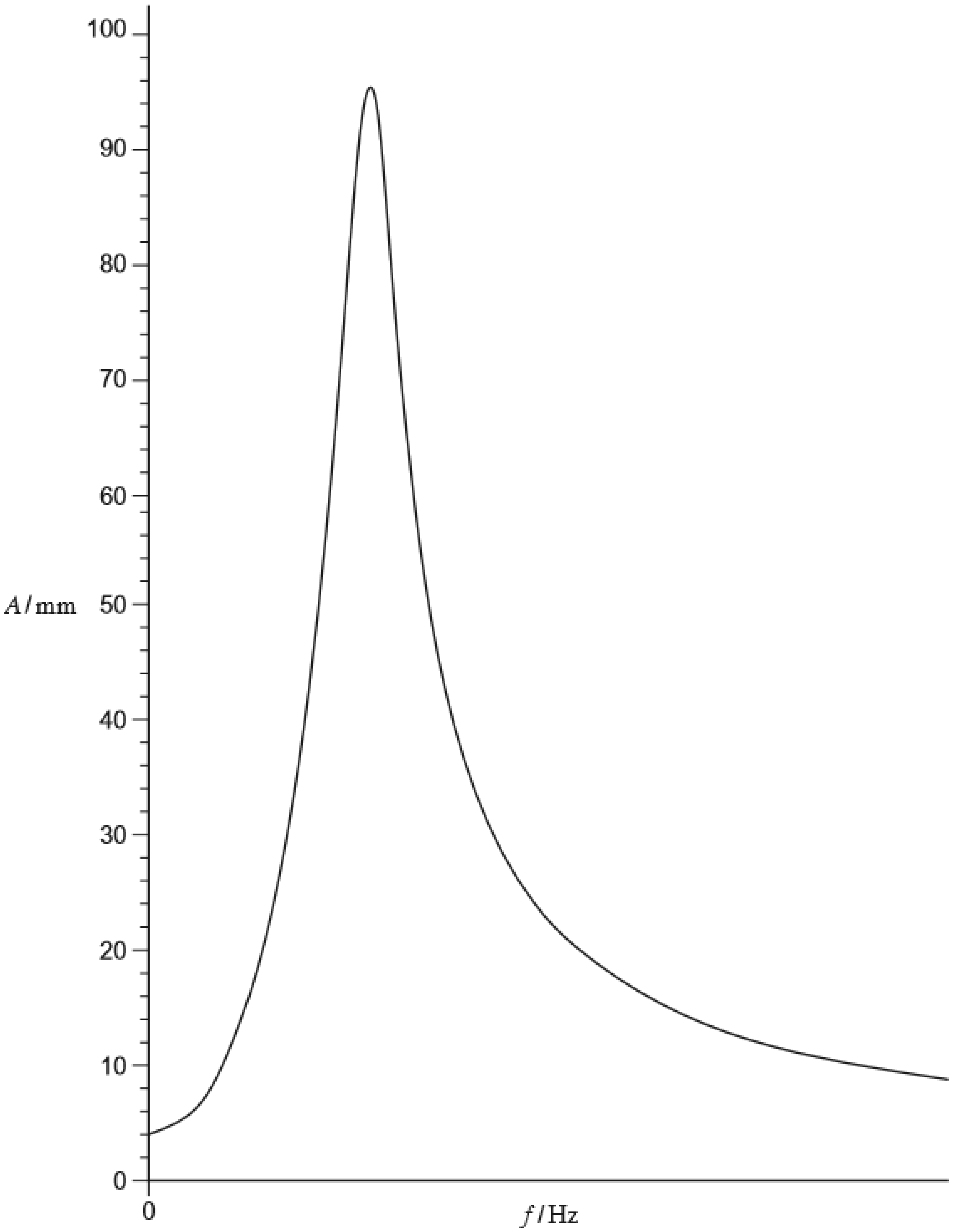
(1)

(ii) Deduce from **Figure 3** the amplitude of the oscillations of X, the point where the mass–spring system is joined to the thread.
You should assume that the length of the thread is constant.

amplitude of X = ____

(1)

Figure 3



(d) (i) State and explain how the student was able to determine the accurate shape of the graph in the region where A is a maximum.

___

___

___

___

(2)

(ii) The student removes one of the springs and then repeats the experiment.

Add a new line to **Figure 3** to show the graph the student obtains.

You may wish to use the equation $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

(2)
(Total 11 marks)

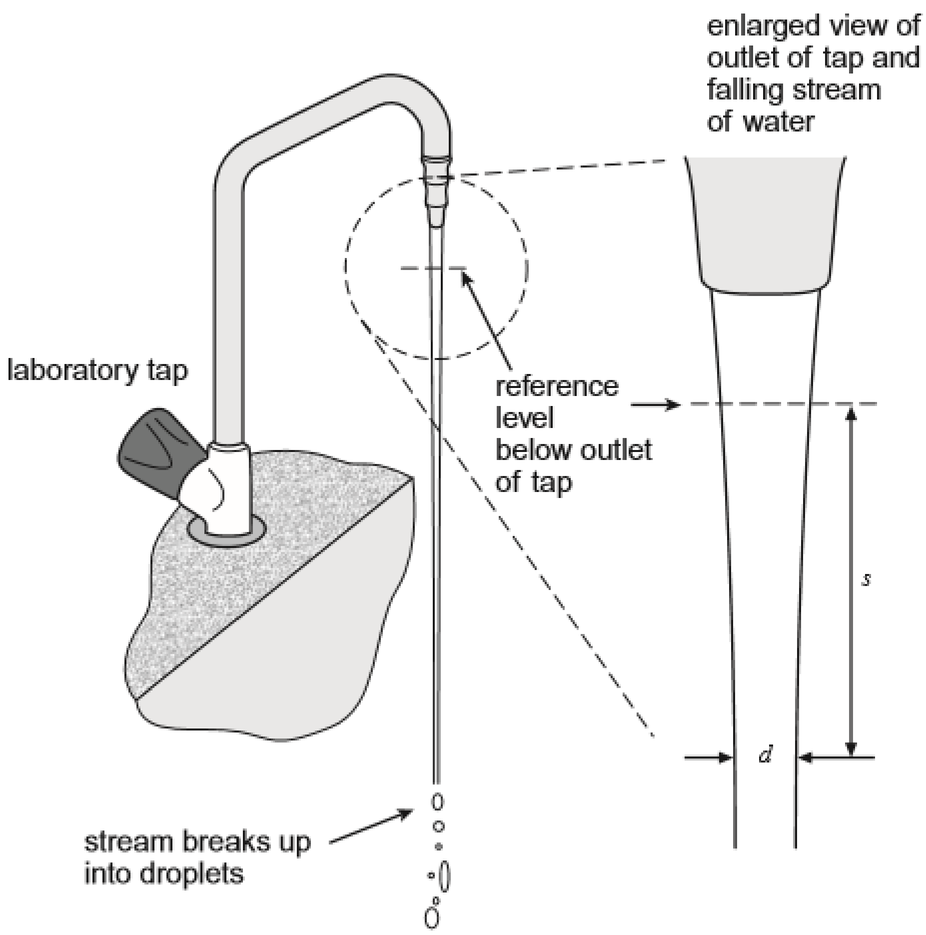
Q29.

A stream of water flowing from a tap at a constant rate accelerates due to gravity. The stream becomes narrower the further it falls, before eventually breaking up into droplets.

An experiment is carried out to find out how *d*, the diameter of the stream of water, depends on *s*, the vertical distance the water has fallen. To avoid problems due to the effects of the tap outlet, *s* is measured from a reference level below the outlet.

The arrangement used for the experiment is shown in **Figure 1**

Figure 1



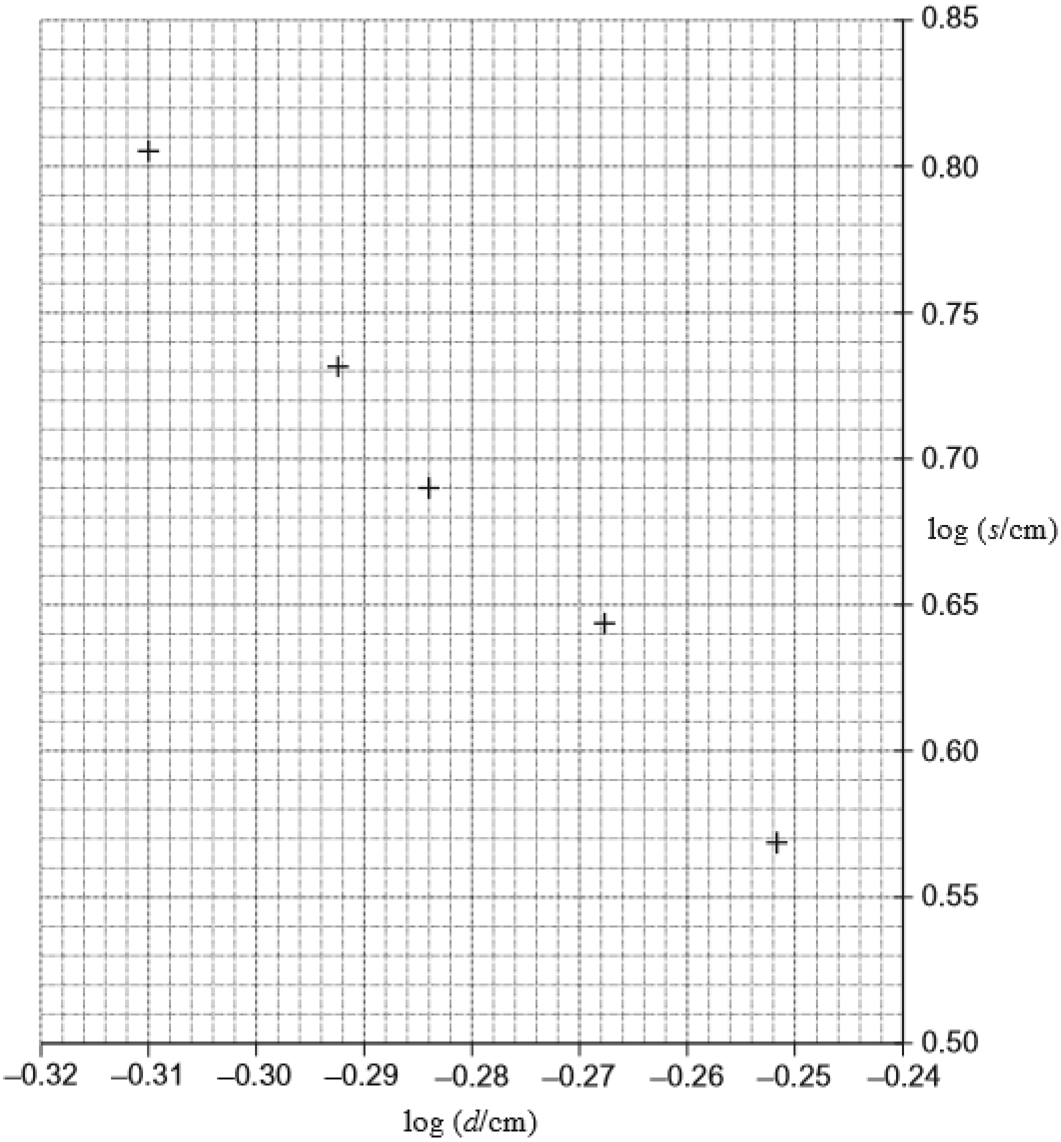
(a) The distance *s* is measured to the nearest mm using a vertical ruler. The diameter *d* is measured to the nearest 0.1 mm using a travelling microscope. Suggest why a travelling microscope was chosen to measure *d* rather than vernier callipers.

(1)

(b) The data from the experiment suggest that $s = kd^n$ where k is a constant and n is an integer.

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

Figure 2



(i) Determine n using **Figure 2**.

n ______________________________

(2)

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

____

____

____

(1)

(iii) Deduce the unit of *k*.

unit of *k* = ______________________________

(1)

(Total 5 marks)

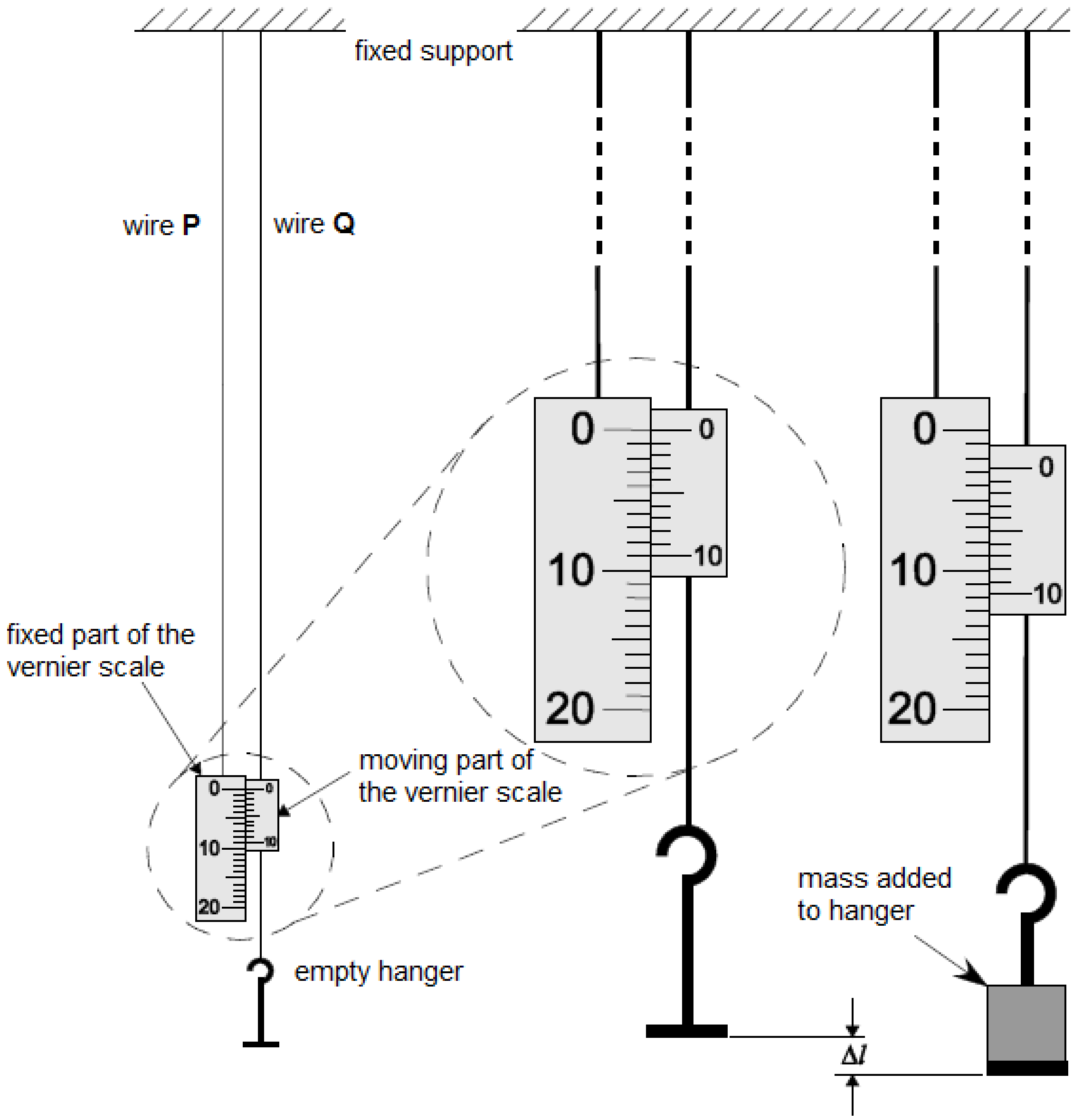
Q30.

This question is about the determination of the Young modulus of the metal of a wire.

In an experiment, two vertical wires **P** and **Q** are suspended from a fixed support. The fixed part of a vernier scale is attached to **P** and the moving part of the scale is attached to **Q**. The divisions on the fixed part of the scale are in mm.

An empty mass hanger is attached to **Q** and the scale is set to zero. A load is added to the mass hanger so that the extension of **Q** can be measured as shown in **Figure 1**.

Figure 1



(a) The reading on the vernier scale can be used to determine Δl, the extension of **Q**.

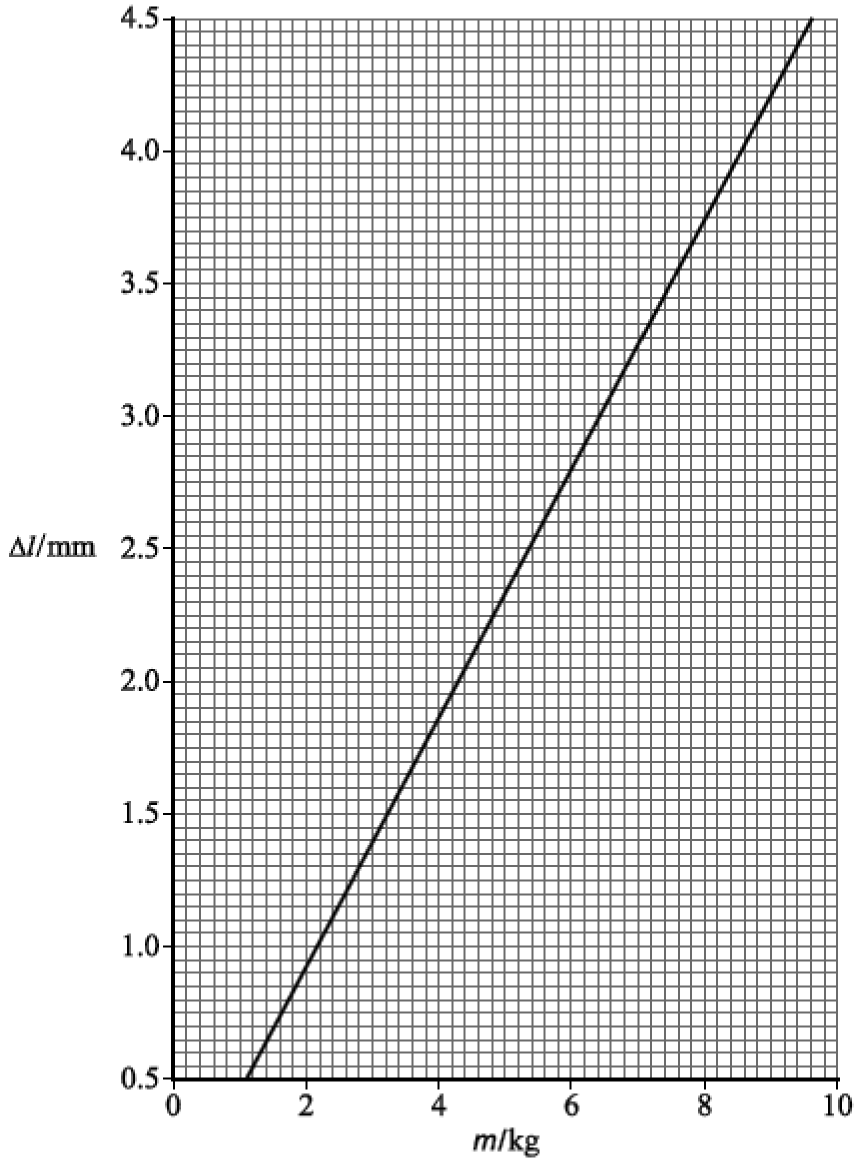
Determine Δl using **Figure 1**.

Δl = ____________________ mm

(1)

(b) **Figure 2** shows how Δl varies with m, the mass added to the hanger.
Determine the mass added to the hanger shown in **Figure 1**.

Figure 2



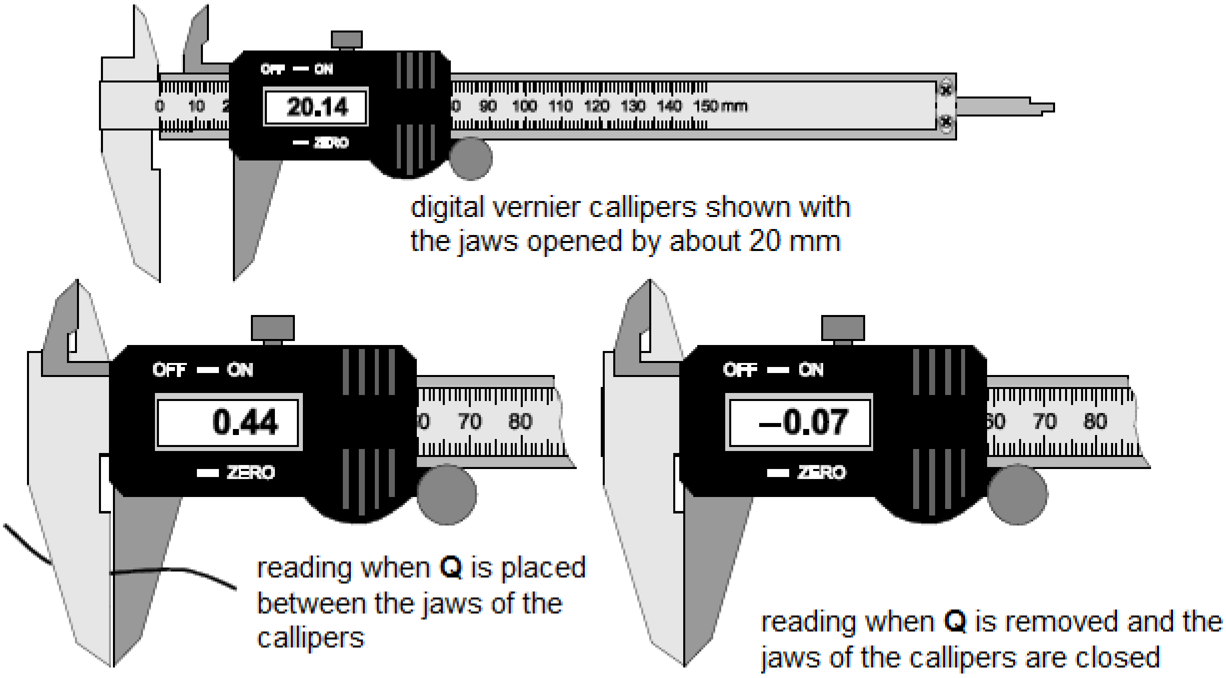
mass = ____________________ kg

(1)

(c) A student uses digital vernier callipers to measure the diameter of **Q**. She places **Q** between the jaws of the callipers and records the reading indicated. Without pressing the zero button she removes **Q** and closes the jaws.

Views of the callipers before and after she closes the jaws are shown in **Figure 3**.

Figure 3



Calculate the true diameter of **Q**.

diameter = ____________________ mm

(1)

(d) The original length of **Q** was 1.82 m.

Determine the Young modulus of the metal in **Q**.

Young modulus = ____________________ Pa

(4)

(e) The student repeats her experiment using a wire of the same original length and metal but with a smaller diameter.

Discuss **two** ways this change might affect the percentage uncertainty in her result for the Young modulus.

1. ____

____

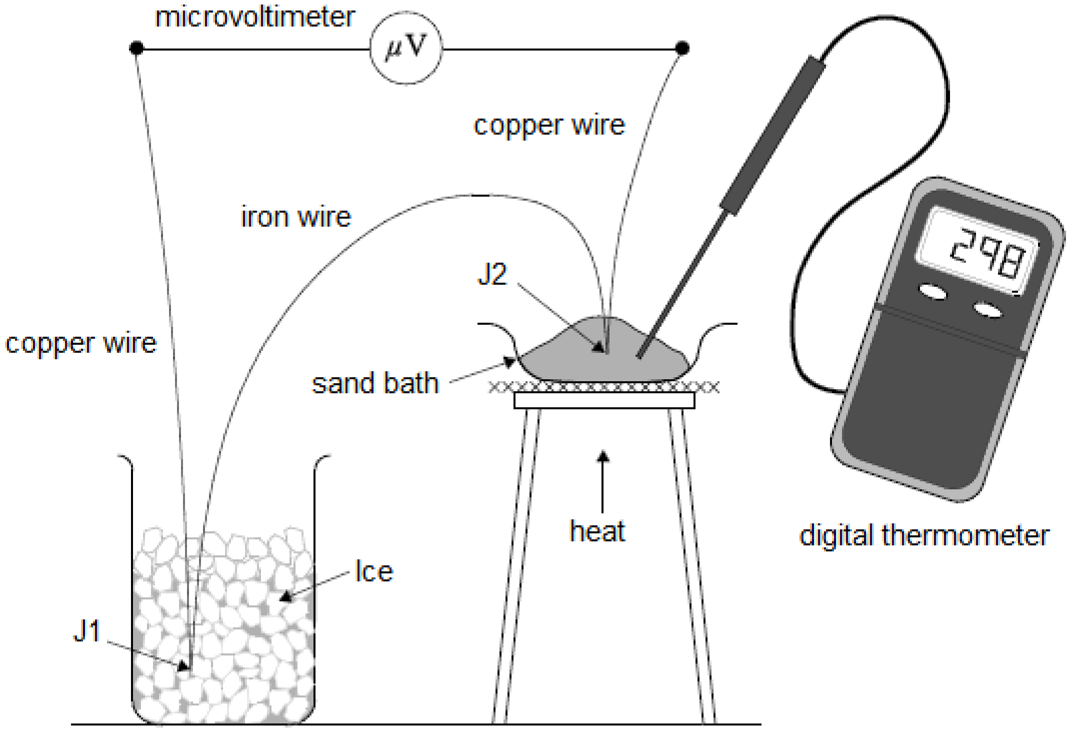
2.

(4)
(Total 11 marks)

Q31.

Lengths of copper and iron wire are joined together to form junctions J1 and J2. When J1 and J2 are at different temperatures an emf ε is generated between them. This emf is measured using a microvoltmeter.
Figure 1 shows J1 kept at 0 °C while J2 is heated in a sand bath to a temperature θ measured by a digital thermometer.

Figure 1



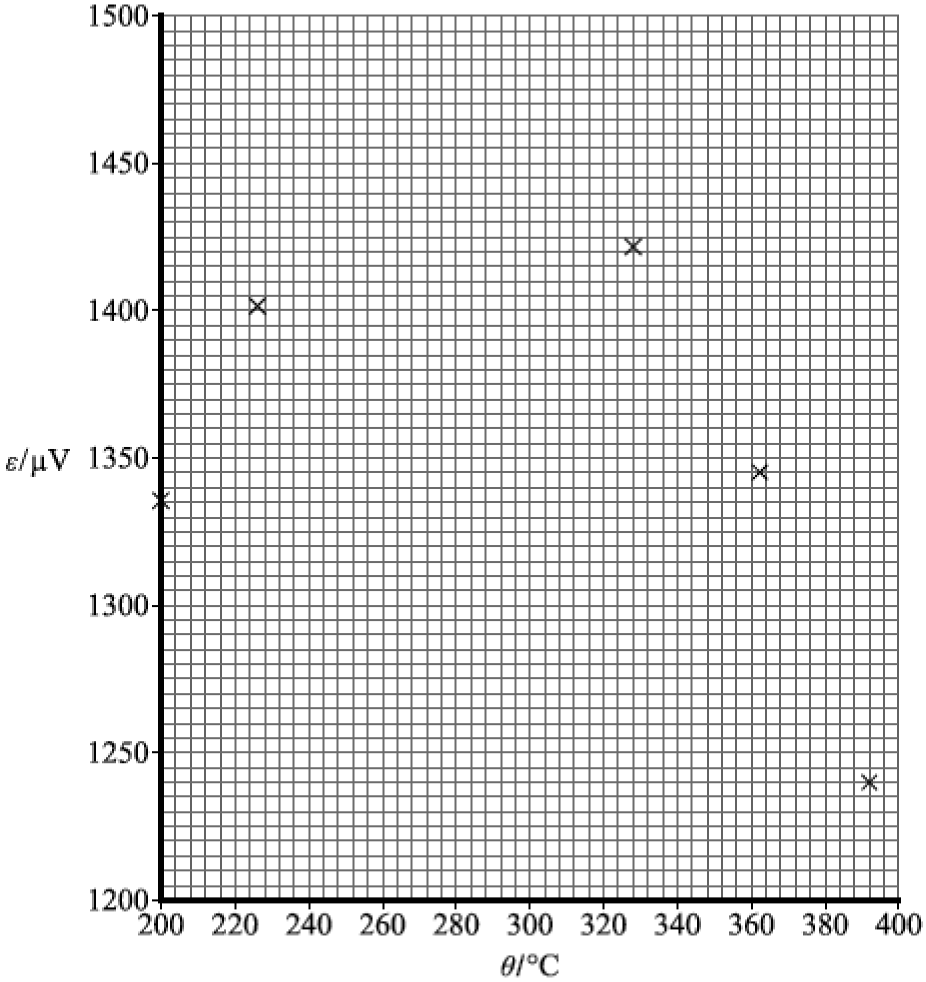
An experiment is carried out to determine how ε depends on θ.

The results of the experiment are shown in the table below and a graph of the data is shown in **Figure 2**.

θ / °C	ε / μV
200	1336
226	1402
258	1450

298	1456
328	1423
362	1345
392	1241

Figure 2



(a) Plot the points corresponding to θ = 258 °C and θ = 298 °C on **Figure 2**.

(1)

(b) Draw a suitable best fit line on **Figure 2**.

(1)

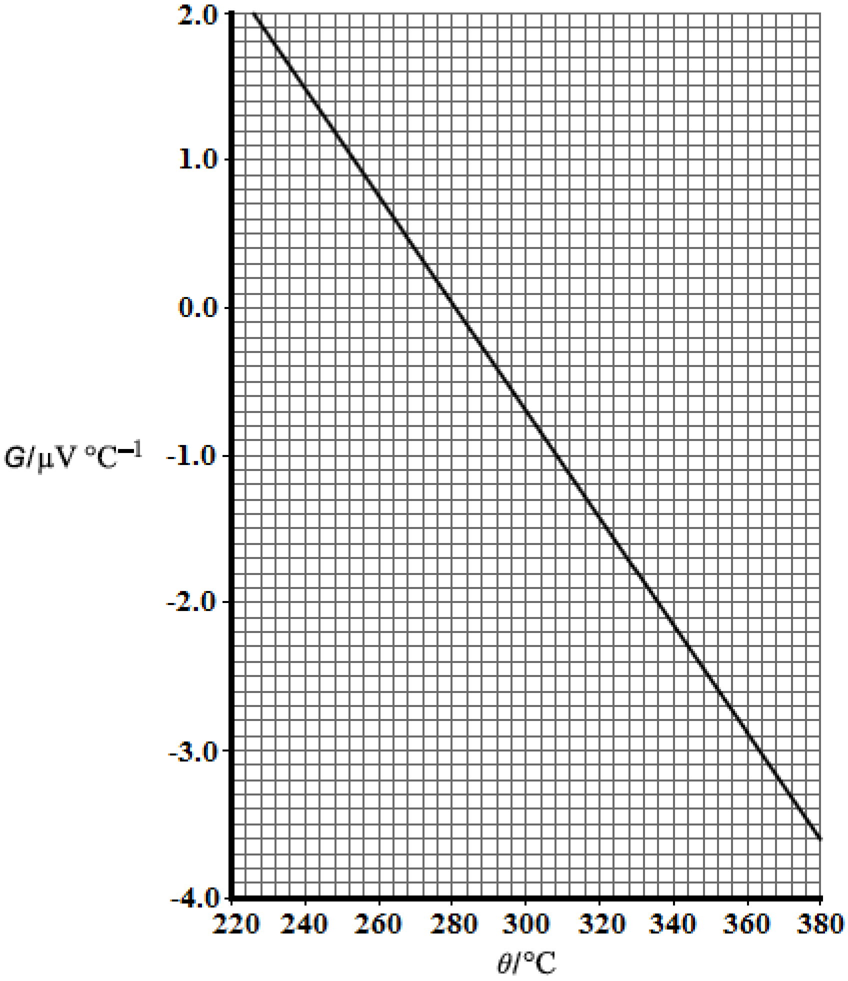
(c) Determine the maximum value of ε.

maximum value of ε = ____________________ μV

(1)

(d) The gradient G of the graph in **Figure 2** is measured for values of θ between 220 °C and 380 °C. A graph of G against θ is plotted in **Figure 3**.

Figure 3



The neutral temperature θ_n is the temperature corresponding to the maximum value of ε. θ_n can be determined using either **Figure 2** or **Figure 3**.

Explain why a more accurate result for θ_n may be obtained using **Figure 3**.

____

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____

(1)

(e) It can be shown that G is given by

$$G = \beta\theta + \alpha$$

where α and β are constants.

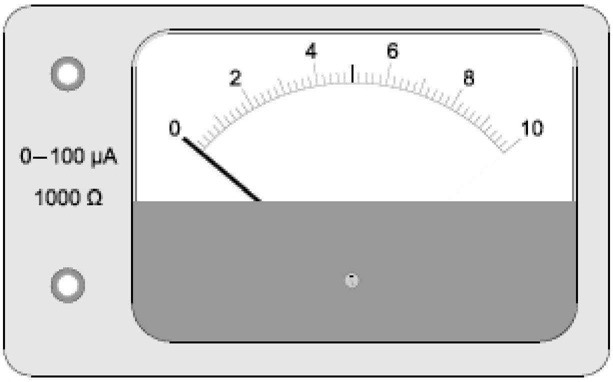
Determine α.

α = ____________________ μV °C⁻¹

(2)

(f) A student decides to carry out a similar experiment. The student thinks the meter in **Figure 4** could be used as the microvoltmeter to measure ε.

Figure 4



When this meter indicates a maximum reading and the needle points to the right-hand end of the scale (full-scale deflection), the current in the meter is 100 μA. The meter has a resistance of 1000 Ω.

Calculate the full-scale deflection of this meter when used as a microvoltmeter.

full-scale deflection = ____________________ μV

(1)

(g) The scale on the meter has 50 divisions between zero and full-scale deflection.

Discuss why this meter is not suitable for carrying out the experiment.

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(2)

(Total 9 marks)

Q32.

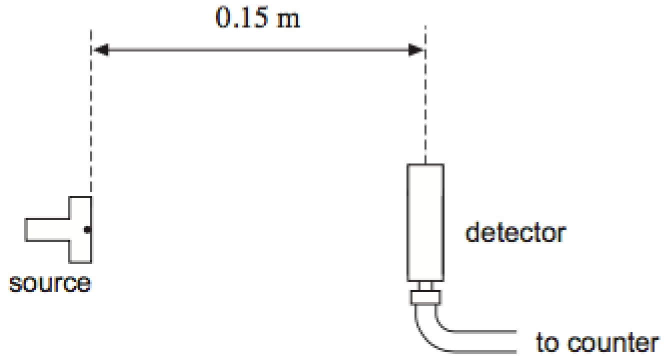
(a) The exposure of the general public to background radiation has changed substantially over the past 100 years.
State **one** source of radiation that has contributed to this change.

____

____

(1)

(b) A student measures background radiation using a detector and determines that background radiation has a mean count-rate of 40 counts per minute. She then places a γ ray source 0.15 m from the detector as shown below.



With this separation the average count per minute was 2050.

The student then moves the detector further from the γ ray source and records the count-rate again.

(i) Calculate the average count-rate she would expect to record when the source is placed 0.90 m from the detector.

count-rate = ______________________ min^{-1}

(3)

(ii) The average count per minute of 2050 was determined from a measurement over a period of 5 minutes. Explain why the student might choose to record for longer than 5 minutes when the separation is 0.90 m.

____

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____

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(1)

(iii) When the detector was moved to 0.90 m the count-rate was lower than that calculated in part **(b)(i)**. It is suggested that the source may also emit β particles.

Explain how this can be checked.

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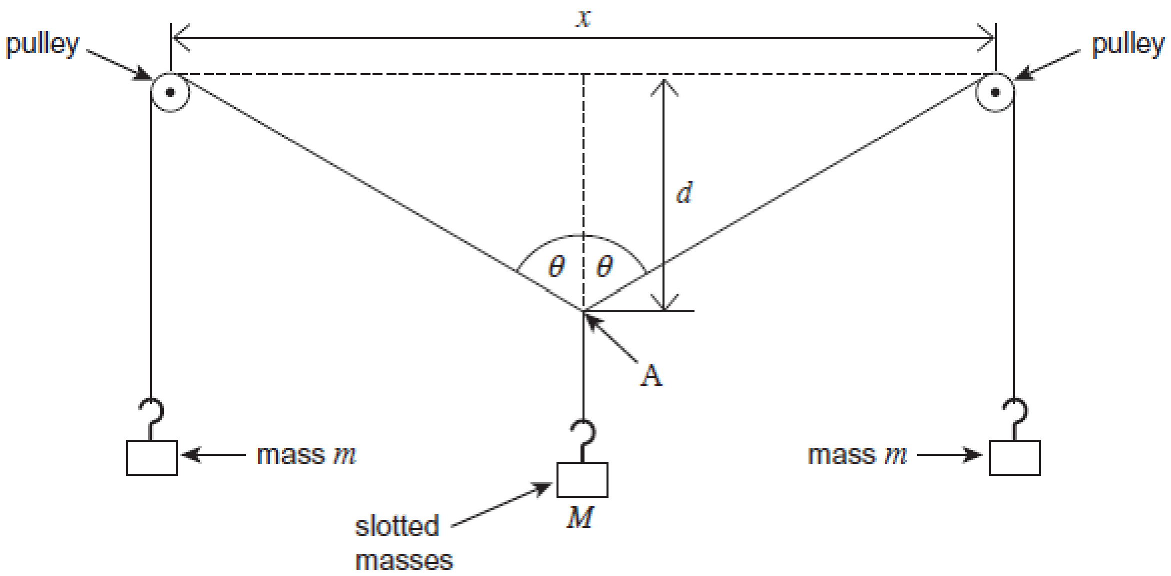
(2)
(Total 7 marks)

Q33.

(a) **Figure 1** shows the arrangement of apparatus in an experiment to investigate the equilibrium of three forces.

Figure 1



The two pulleys are secured in a fixed position at the same height. The centres of the pulleys are separated by a horizontal distance x. Identical masses m are suspended by a continuous string which passes over both pulleys. A third mass M is suspended from the string at point A, equidistant from the pulleys. The strings that pass over the pulleys each make an angle θ to the vertical at point A, as shown in **Figure 1**.

When the forces are in equilibrium the vertical distance d is measured. Mass M is varied and the system is allowed to come into equilibrium. For each M, the corresponding distance d is measured.

The results are shown in the table below.

M / kg	d / m	$\frac{d}{\sqrt{d^2 + \frac{x^2}{4}}}$
0.100	0.035	0.087
0.200	0.066	0.163
0.300	0.105	0.254
0.400	0.139	0.328
0.500	0.183	
0.600	0.228	

(i) Given that x = 0.800 m, complete the table above.

(1)

(ii) Complete the graph in **Figure 2** by plotting the two remaining points and drawing a best fit straight line.

(2)

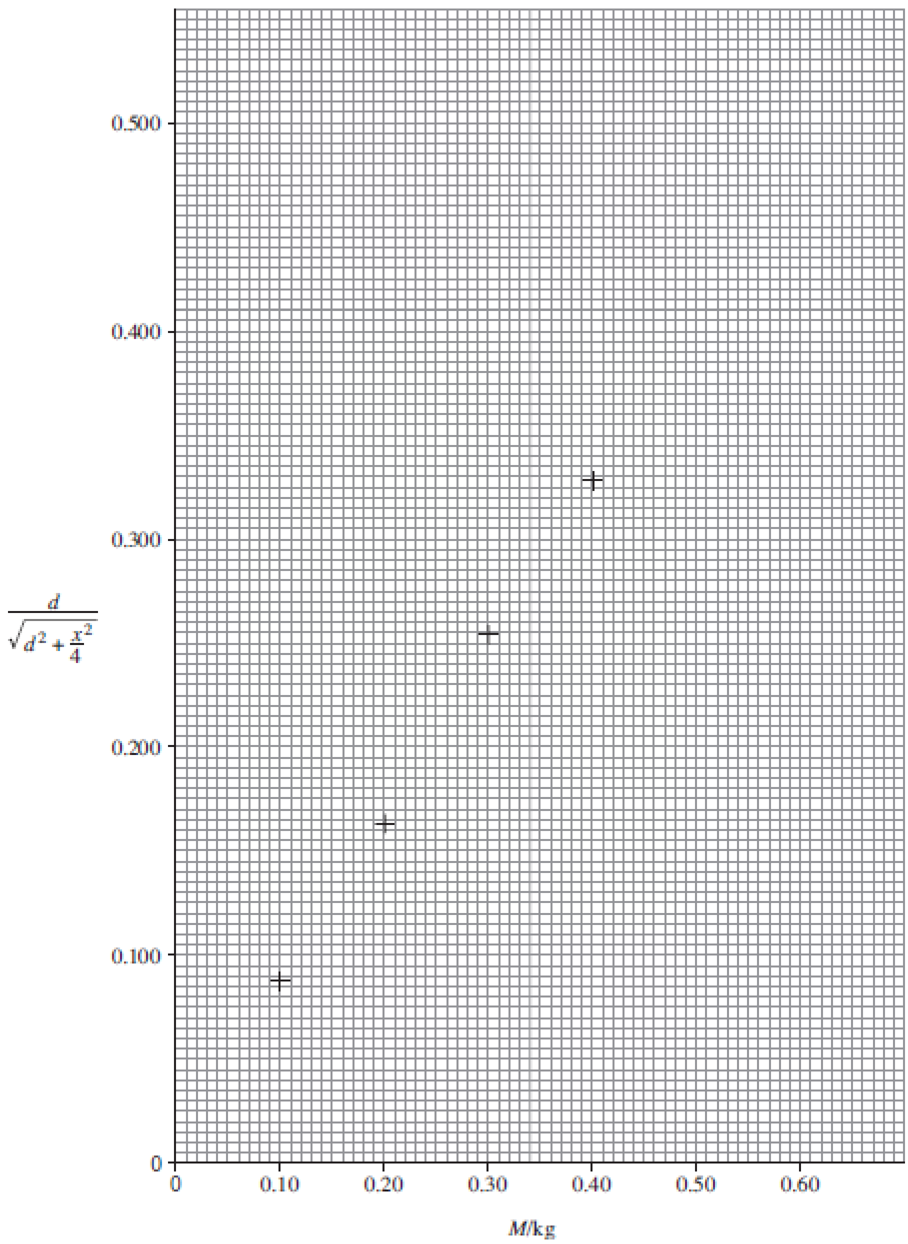
(iii) Determine the gradient of the graph in **Figure 2.**

gradient = ____________________

(3)

(iv) (1) Consider the forces that act at point A in **Figure 1**. By resolving these forces vertically, show that $M = 2m\cos\theta$.

Figure 2



(1)

(2) Express $\cos\theta$ in terms of d and x and hence show that the gradient of the graph is equal to $\frac{1}{2m}$.

(2)

(3) Determine the value of m using your value for the gradient from (iii).

m = ____________________

(2)

(v) A student obtains different results for d when M is increased compared with those obtained when M is decreased.

(1) Suggest why these two sets of results do not agree.

____

____

(1)

(2) State what the student should do with the results to take account of this problem.

____

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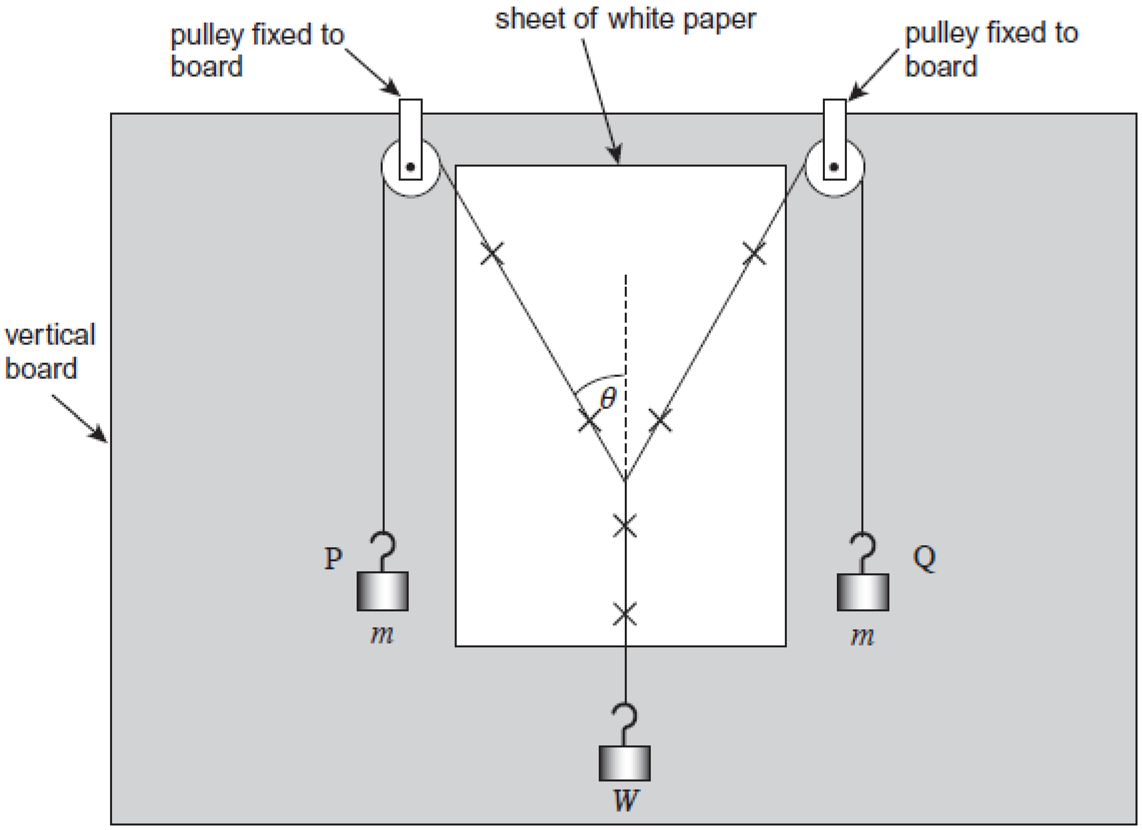
(1)

(b) An arrangement for investigating the equilibrium of forces is shown in **Figure 1**.

Figure 1



In the arrangement shown in **Figure 1**, P and Q are identical masses of mass m. A

student uses this arrangement to investigate the relationship between m and θ when the system of forces is in equilibrium. Weight W is constant.
The student performs the investigation by marking the position of the strings when the forces are in equilibrium for different values of m. He does this by marking crosses on the sheet of white paper.

(i) The string is about 10 mm from the paper. Describe and explain a technique to mark accurately the string positions on the paper.

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____

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(2)

(ii) The crosses on the paper are used to determine the directions of the strings. The results are shown full scale in **Figure 2**.

(1) Use **Figure 2** and your protractor to measure θ as accurately as possible and calculate the percentage uncertainty in your answer. State the precision of the protractor you used.

precision of protractor = ____________________

θ = ____________________

percentage uncertainty = ____________________ %

(3)

(2) Use **Figure 2** and a ruler to determine θ using trigonometry. Show on **Figure 2** the measurements you make.

θ = ____________________

(2)

(iii) Theory suggests that $W = 2mg\cos\theta$.

The student produces a set of results for different values of m and the corresponding values of θ.

Suggest and explain a graphical way of testing this relationship between m and θ.

____

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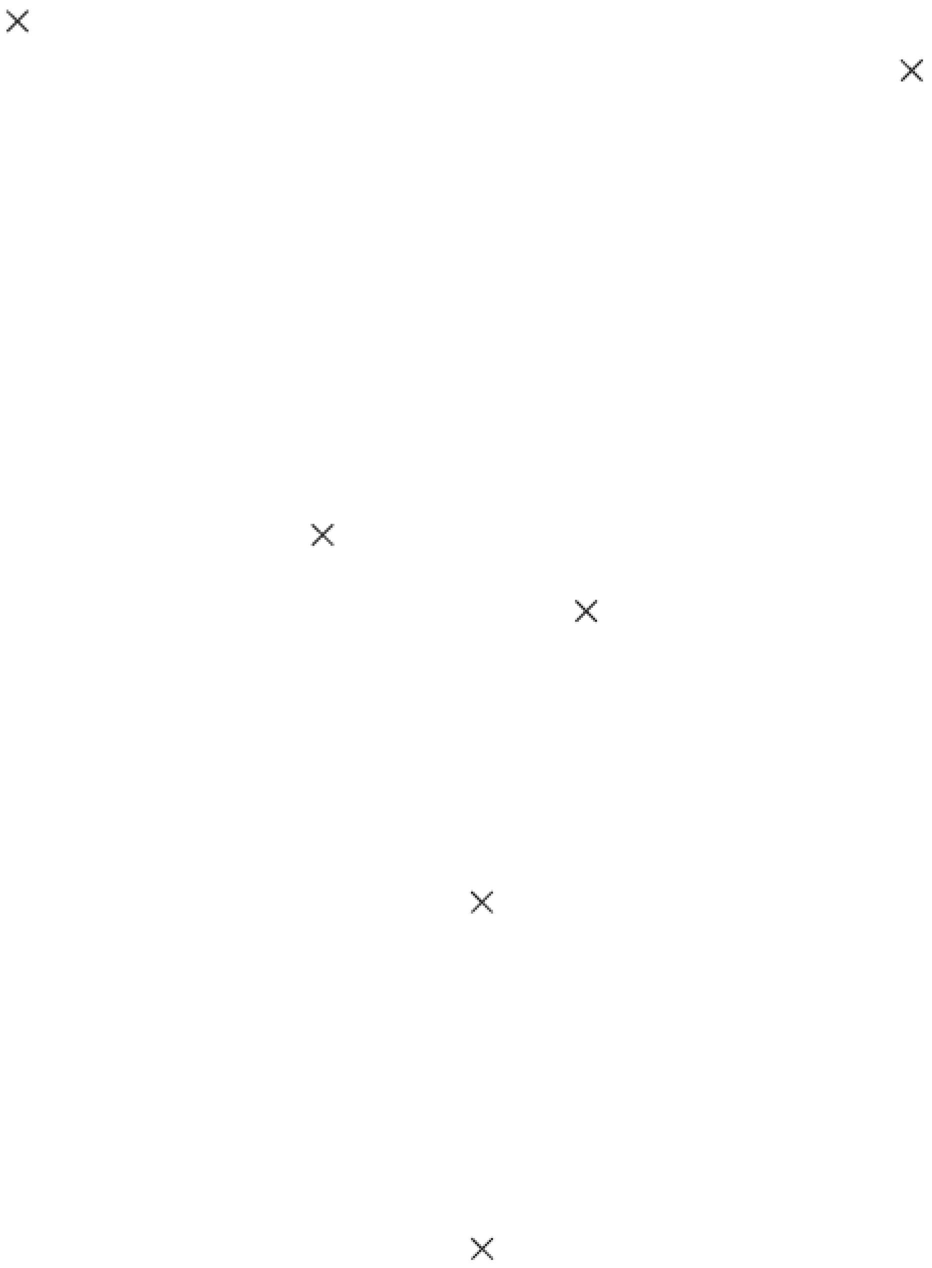
Figure 2



(1)

(Total 21 marks)

Q34.

(a) The power P dissipated in a resistor of resistance R is measured for a range of values of the potential difference V across it. The results are shown in the table below.

V / V	V^2 / V^2	P / W
1.00	1.0	0.21
1.71	2.9	0.58
2.25		1.01

2.67		1.43
3.00	9.0	1.80
3.27	10.7	2.18
3.50	12.3	2.43

(i) Complete the table above.

(1)

(ii) Complete the graph below by plotting the two remaining points and draw a best fit straight line.

(2)

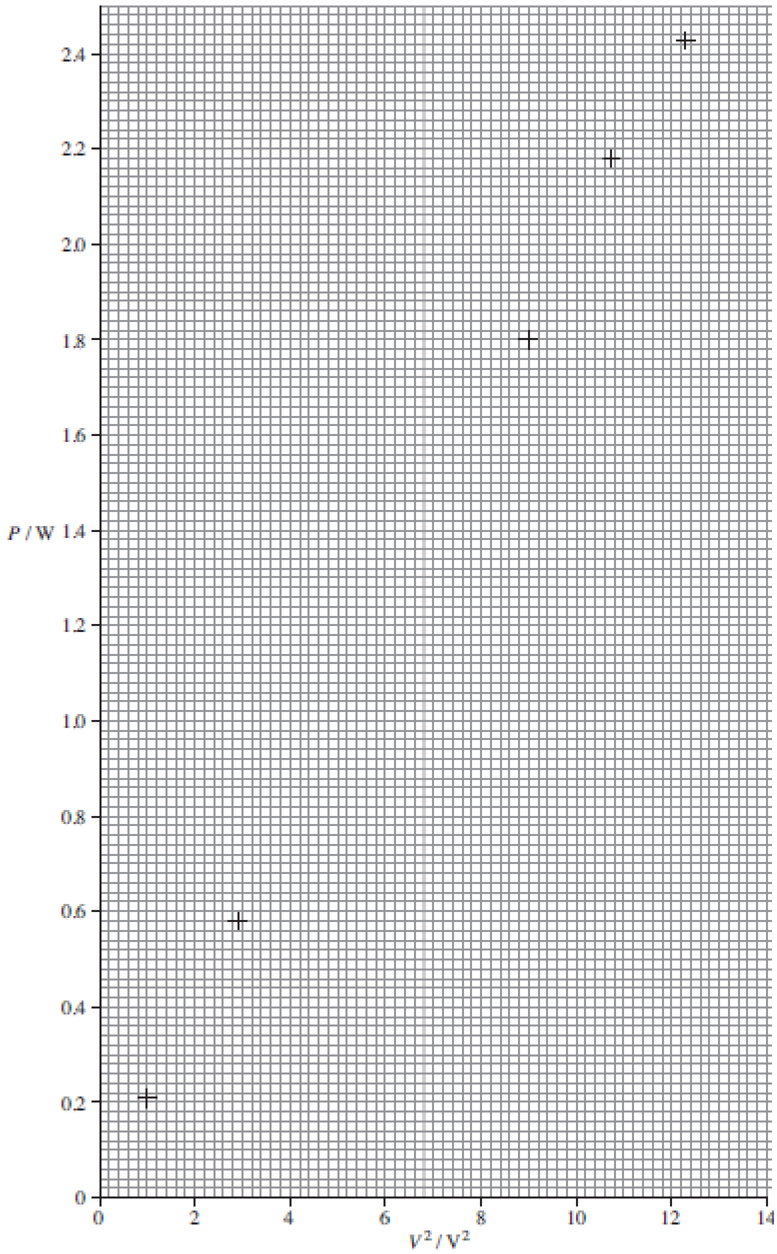
(iii) Determine the gradient of the graph.

gradient = ______________________

(3)

(iv) Use the gradient of the graph to obtain a value for R.

R = ______________________



(1)

(b) The following questions are based on the data in the table above.

(i) Determine the value of R when V = 3.50 V.

R = ____________________ Ω

(1)

(ii) The uncertainty in V is ± 0.01 V. The uncertainty in P is ± 0.05 W.

Calculate the percentage uncertainty in the value of R calculated in part (1).

percentage uncertainty = ____________________ %

(3)

(iii) Hence calculate the uncertainty in the value of R.

uncertainty = ____________________

(1)

(iv) State and explain whether the value of R you calculated in part (1) is consistent with the value of R you determined from the gradient in part (a)(iv).

(2)

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(Total 14 marks)

Q35.

(a) (i) Describe how you would make a direct measurement of the emf ε of a cell, stating the type of meter you would use.

____

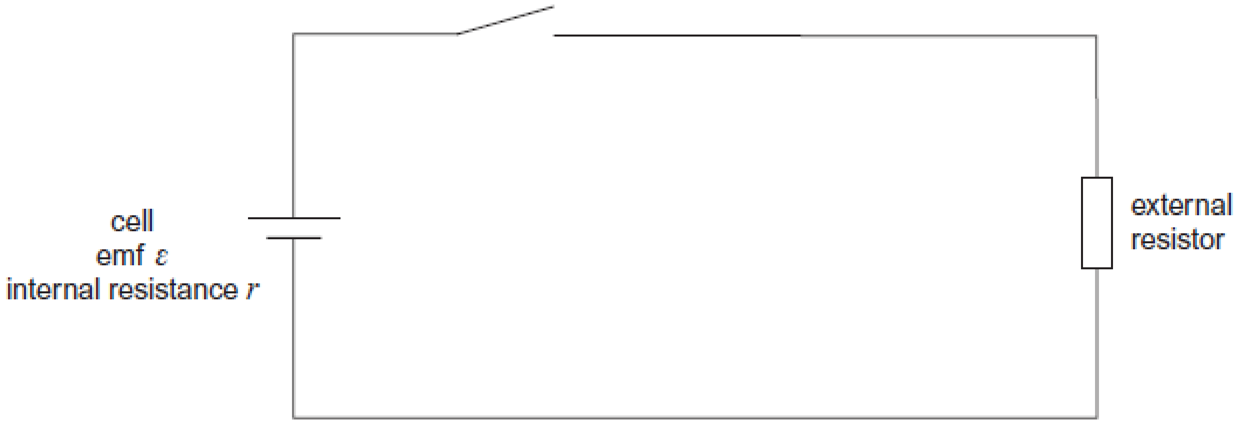
____

(1)

(ii) Explain why this meter must have a very high resistance.

(1)

(b) A student is provided with the circuit shown in the diagram below.



The student wishes to determine the efficiency of this circuit.

In this circuit, useful power is dissipated in the external resistor. The total power input is the power produced by the battery.

$$\text{Efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

The efficiency can be determined using two readings from a voltmeter.

(i) Show that the efficiency = $\frac{V}{\varepsilon}$ where ε is the emf of the cell

and V is the potential difference across the external resistor.

(1)

(ii) Add a voltmeter to the diagram and explain how you would use this new circuit to take readings of ε and V.

(2)

(c) Describe how you would obtain a set of readings to investigate the relationship between efficiency and the resistance of the external resistor. State any precautions you would take to ensure your readings were reliable.

(2)

(d) State and explain how you would expect the efficiency to vary as the value of R is increased.

(2)

(Total 9 marks)

Q1.

(a) (u =)0.2(0) or 20 or 200 **and** (v =)0.25 or 25 or 250 1✓;

__Both__ velocities seen / allow seen in $(a =)\frac{v-u}{t_3}$ */ condone (possible) powers of ten (POT) error for 1st mark and 2nd mark in their v and u and any substitution v and u into* $(a =)\frac{v-u}{t_3}$

Where t_3 has been substituted must be t_3 = 1.19 (s)

substitution of their u and v in $(a =)\frac{v-u}{t_3}$ ✓

Where t_3 has been substituted must be t_3 = 1.19 (s)

Values for:

u (0.20 (m s^{-1}) or 20 (cm s^{-1})200 (mm s^{-1})) and

v (0.25 (m s^{-1}) or 25 (cm s^{-1}) or 250 (mm s^{-1}))

Correctly combined with t_3 (1.19) will earn 1st and 2nd marks

Where u and v are not correct, they must be identifiable as their u and v (2nd mark is only mark available except where error is POT)

Allow their $\frac{\Delta v}{1.19}$ *(= a) where clear it is their* Δv

$a = 4.2 \times 10^{-2}$ (m s^{-2}) 3✓

Correct result for a will earn three marks;

Accept 420 mm s^{-2} or 42 cm s^{-2} if m s^{-2} has been replaced on the answer line

2 sf answer only

3

(b) (set **B** because) it has a greater time / takes longer (to travel between gates) (hence distance between gates is larger) 1✓

(and) set **B**'s average velocity is greater / set **B**'s velocity at gate 1 is greater / Set **B**'s velocity is greater at both gates

Two calculations for gate separation s using either

OR

(and) set **A**'s average velocity is smaller / set **A**'s velocity at gate 1 is smaller/ Set **A**'s velocity is smaller at both gates 2✓

Alternative Method

values of u and v are calculated (condone POT error) and corresponding values for each s determined; 1✓

a comparison of ***their*** distances leading to conclusion that set **B** produced when *s* is largest

OR

ratio $(t_3 \times \frac{t_1+t_2}{t_1 \times t_2})$ is proportional to distance s and **B**'s ratio is greater 2✓

$(s =)\left(\frac{u+v}{2}\right) \times t_3$ ***OR*** $(s) = \frac{v^2 - u^2}{2a}$; ***OR*** $(s=)\, t_3 \times \frac{t_1+t_2}{t_1 \times t_2}$

	u/ms^{-1}	v/ms^{-1}	s/m	$v^2 - u^2$/ m^2s^{-2}
Set A	0.164	0.238	0.356	0.0297
Set B	0.181	0.270	0.476	0.0401

	$t_3 \times \frac{t_1+t_2}{t_1 \times t_2}$
Set A	7.12
Set B	9.54

Allow ecf for acceleration where used to find s

Using a = 0.042: s_A = 0.354 and s_B = 0.478

Treat a larger change in velocity as neutral

2

(c) Continuous, ruled straight best fit line through 1st and last points 1✓

n=4 point below and n=7 above, other points cut by line of best fit

Line must not be thicker than half a square grid

Line must have no variation in thickness

Do not accept more than one line drawn, do not accept discontinuities

Gradient from $\frac{y \text{ step}}{x \text{ step}}$ **seen**

and

G = 0.045 range (0.042 to 0.053) 2✓

Steps at least half the height and half the width of the grid; (at least 3 squares horizontally and at least 5 squares vertically)

Allow $\frac{\text{change in y}}{\text{change in x}}$ *where points are on line and are at least half drawn line apart ($\Delta x \geq 3$ and $\Delta y \geq 0.175$)*

Ignore any units given for G

Allow 1 sf answers of 0.04 or 0.05 where correct working is shown

2

(d) $\frac{\text{their } G}{4.9}$ ✓

($h = 9.2 \times 10^{-3}$ m)

Ecf from part ***(c)***

Expect 2 sf normally*. Penalise 3 or more sf*

Condone 1 sf answers where correct working is shown in part ***(d) and*** *where their G is quoted to 1sf*

In this case, allow use of their rounded G or full carry value

1

(e) idea that the intercept can be found by calculating $a - Gn$ where a and n are values read-off (from a point on the line) and G is the gradient ; intercept compared to 0, 0 (OWTTE in a general y=mx +c description)

Simply explaining how to find the intercept does not fully answer the question and gets no credit must describe the comparison aspect; do not accept idea of extrapolation off the grid or re-plotting on axes that include (0, 0)

OR

Read-off points (of line of best fit for) x_1 and x_2 compare with corresponding y_1 and y_2 , compares the ratio of the x terms to the ratio of the y terms; if equal then directly proportional

OR

Determine the constant of proportionality for at least two points (on line of best fit) and compare, where constant exists then directly proportional ✓

Idea that a and n will share a common factorial increase

1

[9]

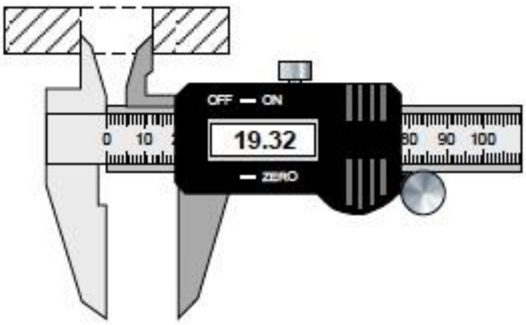
Q2.

(a) to reduce the impact of systematic error: tare [zero] the callipers before use
OR
take reading with callipers fully closed (at some stage) and subtract from readings $_1$✓

to reduce the impact of random error: take measurement several times for different diameters/directions and calculate mean
OR
take measurement several times for different diameters to check for anomalies $_2$✓

2

(b) use of inside jaws on callipers required: must have a clear drawing with inside jaws in contact internal diameter$_1$✓



*A **sectional** view of the magnet must be given*
Jaws must be inside cavity (as here)

1

(c) Determines a cross-sectional area: (larger A=) 2.82 $\times 10^{-3}$ or (smaller area =) 2.932×10^{-4}

OR

states that the cross sectional area from Δ

$$A = \left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right)$$

OR

Calculates one volume correctly ₁✓

Allow POT error ₁✓ and ₂✓
Where r is used must have an additional statement on how r relates to D (in the case where there is no correct substitution and no correct answer)

substitution of $D = 59.90$, $d = 19.32$ and $t = 12.09$ into

$$V = \left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right) \times t$$

OR

V = their $\Delta A \times 12.09$

OR

Correctly finds difference in ***their*** volumes ₂✓

Or equivalent
Correct substitution into

$$V = \left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right) \times t$$

receives the first two marks (allow POT)
Expect values:
$V_D = 3.41 \times 10^{-5}$ (m^3)
$V_d = 3.54 \times 10^{-6}$ (m^3)

3.1×10^{-5} / 3.05×10^{-5} / 3.053×10^{-5} (m^3) ₃✓

no limit on maximum sf
Correct answer scores 3
Allow 3rd sf round error where answer rounds to 3.1×10^{-5} when correct method seen

3

(d) ***Procedure:***

MAX 2

Take more measurement(s) of *h* for additional / different masses (of clay) ✓

More than one added mass, allow varies amount of clay

Convert (total) mass into weight (and equal to the repulsive force of magnet **A** on magnet **B**) ✓

Describe method to measure *h* using ruler or set square ✓

(in this case determination of k must be consistent with graph)

Analysis:

Plot a graph of *F* against $1/h^3$✓

Condone $1/h^3$ against F or equivalent

Should be a straight line of best fit ✓

This mark can be awarded if seen by drawing of straight line with positive gradient on sketch of graph

***Determination of k*:**

MAX 1

Measure gradient and set equal to *k* ✓

*Allow one mark for plot of F against h^3 and statement that area under graph is k. Mark **Procedure** as scheme*

Substitute (total) weight into formula and rearrange to find *k* ✓

Must be consistent with graph

5

[11]

Q3.

B

[1]

Q4.

B

[1]

Q5.

(a) attempt to apply principle of moments either about pivot or (LH) end of ruler 1✓

mass = 127(.04) (g) 2✓

assumption is that ruler is uniform / mass evenly distributed **OR** weight acts at the centre/mid-point/middle **OR**

centre of mass / gravity is at the centre/mid-point/middle $_3$✓

for $_1$✓ for evidence of moments taken expect clockwise and anticlockwise moment;

for moment about pivot expect to see either 29 or 49; for use of LH end of ruler expect 30 or 50

don't insist on seeing masses in kg, distances in m or the inclusion of 9.81 or g in the working; condone g seen on one side only

rounding to 127 g earns $_1$✓ and $_2$✓

3

(b) force on wire is upwards **OR** ↑ $_1$✓

current is from **P** to **Q** **OR** rightwards **OR** (left) to (the) right **OR** → $_2$✓

states direction of force and direction of current (or $_3$✓= 0) and makes a suitably justified deduction, eg

using left-hand rule **OR** LH rule

AND

B is into the page **OR** into plane of **Figure 3** **OR** ⊗ $_3$✓

for $_1$✓ condone 'motion is upwards'

for $_2$✓ 'towards Q' ***OR*** *'positive to negative' are not enough*

allow logically correct (using LH rule) $_3$✓ for either downwards force with correct current ***AND/OR*** *upwards force with wrong current*

increased flux density below wire is acceptable alternative to LH rule

3

(c) gradient calculated from Δ*M* divided by Δ*I*, condone read off errors of ± 1 division; minimum I step ≥ 2.0 A $_1$✓

evidence of g = 9.81 or 9.8 correctly used in working for σ or *B* $_2$✓

|*B*| in range 1.76 × 10^{-2} to 1.87 × 10^{-2} or 1.8 × 10^{-2} (T) $_3$✓

for $_1$✓ expect (–)0.28 (g A^{-1}); do not penalise for missing – sign

for $_2$✓ look for σ = their gradient × 9.81 (× 10^{-3} N)

OR $B = \dfrac{\text{their gradient} \times 9.81(\times 10^{-3})}{15(\times 10^{-2})}$ *; condone POT errors*

for $_3$✓CAO by correct method only; ignore – sign if provided; no limit on maximum sf

3

(d)

	Reduced	No effect	Increased
Force acting on wire		1✓	
Force acting on prism	2✓		
Gradient of graph	3✓		
Vertical intercept	4✓		

1✓ = 1 mark

2✓ = 1 mark

3✓ and 4✓= 1 mark

allow any distinguishing mark as long as only one per row

for ✓and ✗ in same row ignore ✗

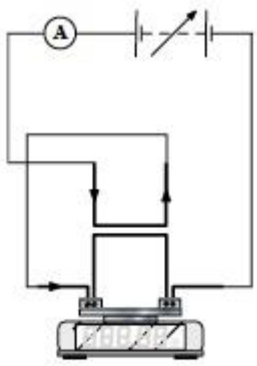
for ✓and ✓in same row give no mark

ignore any crossed-out response unless only distinguishing mark on row

3

(e) any complete circuit connecting the power supply in **Figure 6** to **X** and to **Y** that produces currents in **X** and in **Y** that travel left to right 1✓

wiring correct so that **X** and **Y** are in series (see below) 2✓



allow parallel circuit for 1✓ but reject use of additional power supply

*if **X** and/or **Y** is/are short-circuited award no marks;*

for impractical circuits eg voltmeter added in series, award no marks

ignore any current arrows added to diagram

2

(f) strategy:

states that readings of M (as the dependent variable) will be measured for different values of independent variable, I or d only 1✓

clearly identifies the correct control variable, d or I only;

condone $\frac{d}{L}$ = constant if I varied **OR** I^2L OR IL = constant if d varied;

it must be clear how the value of the control variable is known $_2$✓

states that L will be measured or gives value eg L = 5.0 cm $_3$✓

use of g to convert M reading to F; evidence may be found in expression for k $_4$✓

for $_1$✓ condone F identified as the dependent variable or as the balance reading;

reject 'measure change in mass / change in F'

failure to make M or F the dependent variable cannot score $_1$✓ or $_2$✓

for $_2$✓ if d is being varied and I = 5.0 A is stated, this can be taken to mean I is the control variable and the value is known

*for $_1$✓ and for $_3$✓ insist that M and L are being <u>read</u> **OR** <u>measured</u> **OR** <u>recorded</u>*

for $_4$✓ 'work out force' is not enough; reject 'acceleration' for g

MAX 3

analysis:

suggests a plot with M or F [by itself or combined with another factor] on the vertical axis and some <u>valid manipulation</u> of their independent variable on the horizontal axis $_5$✓

identifies correctly how k can be found using the gradient of their graph; k must be the subject of the expression given $_6$✓ **OR**

if suggesting a plot with log M or log F on the vertical axis etc identifying correctly how k can be found from the graph intercept $_6$✓

OR

suggesting a plot with M or F on the vertical axis etc and identifying correctly how k is found using the area under the line $_{56}$ ✓ = 1 MAX

the intention to plot M against I^2 is taken to mean that M is the <u>dependent</u> variable and is plotted on the vertical axis

examples: plot M against I^2 will earn $_5$✓

and then $k = \frac{g \times d \times \text{gradient}}{L}$ *will earn $_6$✓*

or plot F against $\frac{1}{d}$ will earn $_5$✓ and then

$k = \frac{\text{gradient}}{I^2 \times L}$ *will earn $_6$✓ (note that when F is the dependent variable g will not appear in the expression for k)*

2

[19]

Q6.

class="var"

(a) technique:

at least one instance seen where a metre ruler is made vertical using a set-square in contact with the floor $_1$✓

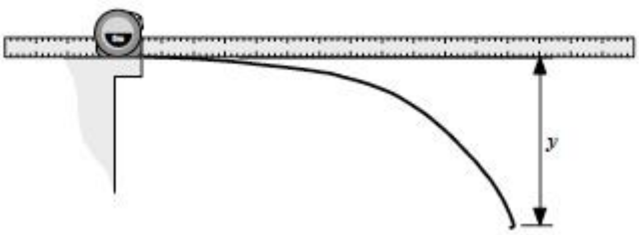
strategy:

(use a metre ruler to) measure the height of the free end of the tape (above the floor) and the height of the tape at the bench [height of the bench];

y = <u>difference</u> between these heights $_2$✓

OR

use a metre ruler or straight edge placed alongside the tape measure and overhanging the (horizontal) bench, eg



y is measured directly using this method using **additional** ruler $_1$✓

using **additional** ruler made vertical (as before) or using set-square placed against horizontal ruler $_2$✓

for $_1$✓ allow use of plumb line or spirit level;

don't insist on the set-square being used against two mutually perpendicular faces of the metre ruler

the floor is assumed to be horizontal if the deflection is found from the difference between two vertical measurements

for $_2$✓ allow metre ruler B made horizontal by use of set-square against vertical ruler A; ruler B establishes vertical position of free end of tape; ruler A is used to measure y directly

either or both marks can be earned for suitable annotation to ***Figure 1***

reject suggestions that y can be found without making at least one vertical measurement

2

(b) (for $x \leq 70$ cm y is small so) <u>percentage/fractional</u> uncertainty in y is (too) large **OR**

(for $x > 70$ cm) <u>percentage/fractional</u> uncertainty in y not (too) large ✓

<u>percentage</u> or <u>fractional</u> and in y are essential;

accept 'error' for 'uncertainty';

reject 'small distances are hard to measure'

1

(c) **continuous ruled** best-fit line drawn (at least) between 1st and 6th points;

line **must** pass below 2nd point and above 5th point;

line **must** pass above 1st point and below 6th point $_1$✓

gradient calculated from their best-fit line;

result, minimum 2 sf, in range 3.5 to 4.7 $_2$✓

result for *n* correctly rounded from their gradient to the nearest integer (expect n = 4) $_3$✓

for $_1$✓ 'pass below' is taken to mean below the intersection of the cross-hairs defining the position of a point; a line that intersects (any of) the cross-hairs of the 1st, 2nd, 5th or 6th points loses this mark

for $_1$✓ the line must not be thicker than half a grid square, must not vary in thickness and must not be too faint; do not allow two lines unless these are drawn to calculate maximum and minimum gradients from which an average is then calculated

for $_2$✓ accept answers to greater than 2 sf which round to 2 sf in range 3.5 to 4.7

do not penalise for small steps or read off errors

for $_3$✓ it must be clear that final result is for n if this is not on the answer line

allow ecf for unexpected gradient result that is then correctly rounded to the nearest integer

if no line is drawn (losing $_1$✓ and $_2$✓) allow $_3$✓ if n given as nearest integer to a gradient result obtained using two points on ***Figure 2***

3

(d) log A = (y) intercept seen

OR

log A = log y when log x = 0

OR

log $y = n$ log x + log A (or correctly rearranged) seen $_1$✓

indirect method to find (vertical) intercept described, eg

using (values for) a <u>point on line</u>;

substitute into <u>equation</u> (for the line); allow 'into $y = mx + c$';

find log A (don't penalise incorrect algebra) $_2$✓

$A = 10^{(\text{y intercept})}$

OR

$A = 10^{(\log y - n \log x)}$ ${}_3$✓

treat ln A = (y) intercept in ${}_1$✓ as a slip and don't penalise but then insist that following work is consistent, eg insist on use of ln $y = n$ ln x + ln A (if seen) to earn ${}_2$✓

and

$A = e^{(\text{y intercept})}$ to earn ${}_3$✓

for ${}_1$✓ allow sensible use of y = mx + c idea;

reject 'log A is where line crosses y axis'

for ${}_2$✓ allow 'use a point on line to find x and y then sub into equation etc';

accept valid similar triangles idea;

reject anything such as extrapolating the line to suggest that the intercept can be found directly;

for ${}_3$✓ accept '(take/find) anti-log of (log y) intercept';

condone 'inverse log of (log y) for anti-log'; reject 'convert'

accept $A = 10^{(\log A)}$ providing ${}_1$✓ awarded

accept substitution of n, eg $A = 10^{(\log y - 4 \log x)}$

reject $A = 10^{(-y \text{ intercept})}$

alternative method:

using a point on line find log x, log y;

<u>anti-log</u> to find x, y ${}_1$✓

use $A = \dfrac{y}{x^n}$ *(equation seen with A the subject or equivalent description of process) ${}_2$✓*

repeat (to find A) using a different point on line;

calculate average (A) ${}_3$✓

reject averaging of x and y or of log x and log y

3

(e) A evaluated using $A = \dfrac{y}{x^n}$ **OR** using $A = 10^{(\log y - n \log x)}$;

correct substitution of n (from part (c)) and of y and x in cm from any row in the table (likely values shown opposite),

A evaluated correctly to minimum 2 sf and correct POT ${}_1$✓

order of magnitude of A = –7 **OR** 10^{-7} (accept index or of power of ten) ${}_2$✓

cm^{-3} ${}_3$✓

OR

$\text{cm}^{(1-n)}$ where n is result given for part (c)

for ${}_1$✓ ECF for non-integer n
values that may be seen in working:

x/cm	y/cm	A when $n = 4$	A when $n = 3.879$ *
132.4	61.2	1.99E-07	3.60E-07
116.8	33.7	1.81E-07	3.22E-07
105.1	24.3	1.99E-07	3.50E-07
94.5	15.6	1.96E-07	3.39E-07
84.3	11.0	2.18E-07	3.72E-07
73.2	5.7	1.99E-07	3.34E-07

**equation of best-fit line gives vertical intercept = 3.879*

for $_2$✓ accept 1 × 10^{-7} (cm^{-3}) but reject 1.0 × 10^{-7} or 2 × 10^{-7} etc;

ECF order of magnitude correct for their value of A;

POT must be consistent with unit given eg if cm^{-3} is converted into m^{-3};

for $_3$✓ CAO;

use of non-integer, eg n = 3.6 requires A in $cm^{-2.6}$

withhold $_2$✓ and $_3$✓ if A is not evaluated

alternative approaches:

A evaluated from $A = \frac{y}{x^n}$ **OR** from A = $10^{(\log y - n \log x)}$;

correct substitution of *n* (from part (c)) and of *y* and *x* in (in m) etc;

A evaluated correctly to minimum 2 sf and correct POT $_1$✓

order of magnitude of A = –1 **OR** 10^{-1} $_2$✓

m^{-3} $_3$✓

x/m	y/m	A when $n = 4$	A when $n = 3.879$ *
1.324	0.612	1.99E-01	2.06E-01
1.168	0.337	1.81E-01	1.85E-01
1.051	0.243	1.99E-01	2.00E-01
0.945	0.156	1.96E-01	1.94E-01
0.843	0.110	2.18E-01	2.13E-01
0.732	0.057	1.99E-01	1.91E-01

alternative approaches:

A evaluated from $A = \frac{y}{x^n}$ **OR** from A = $10^{(\log y - n \log x)}$;

correct substitution of *n* (from part (c)) and of *y* and *x* in (in mm) etc;

A evaluated correctly to minimum 2 sf and correct POT $_1$✓

order of magnitude of A = –10 **OR** 10^{-10} $_2$✓

mm^{-3} ₃✓

x/mm	y/mm	A when $n = 4$	A when $n = 3.879$ *
1324	612	1.99E-10	4.75E-10
1168	337	1.81E-10	4.26E-10
1051	243	1.99E-10	4.62E-10
945	156	1.96E-10	4.48E-10
843	110	2.18E-10	4.92E-10
732	57	1.99E-10	4.41E-10

ecf for wrong or non-integer value of n, ie for $cm^{(1-n)}$

3

[12]

Q7.

(a) pressure (of air) in **Figure 1c** is greater than (pressure of air) in **Figure 1d**

OR

pressure in **Figure 1d** is lower than pressure in **Figure 1c** $_1$✓

(since) temperature is the same

OR

Boyle's Law applies

OR

PV = constant; $_2$✓

any suggestion that pressure is constant **OR** the volume is constant **OR** the temperature changes **OR** the amount of air in the flask increases as flask is raised loses both marks

for $_1$✓ *must refer to either of the relevant figures or give other detail, eg 'when flask is lifted' so their meaning is unambiguous;*

allow 'when volume decreases pressure increases' but must be comparing ***1c*** *with* ***1d***

allow 'water pressure decreased in ***1d****'*

treat 'air was compressed' (in ***1c****) as neutral*

reject 'pressure released (in ***1d****)'*

for $_2$✓ *allow mean KE of molecules is the same*

accept $P \propto \frac{1}{V}$ *;*

allow nRT = constant;

reject PV = k (unless k = constant is also seen)

2

(b) same (air) pressure $_1$✓

same mass of air ₂✓

any suggestion that temperature is constant **OR** that volume is constant **OR** that pressure has changed **OR** the amount of air in the flask decreases as flask is moved from H to C loses both marks

for $_1$✓ and $_2$✓ accept constant/unchanged = same and condone 'assume same pressure/mass of gas'

for $_2$✓accept same (number of) moles or same amount of gas

no credit for stating 'volume increases as temperature increases'

'temperature is in equilibrium' is neutral

2

(c) relevant quantity and instrument seen:

volume(s) (of liquid) measured using a <u>measuring cylinder</u> **OR** graduated beaker $_1$✓

reject 'measuring beaker' and 'burette'

eye level <u>with the bottom</u> of the meniscus (allow suitable sketch showing eye) $_2$✓

'measure at eye level' **OR** 'eye level with graduation' **OR** 'eye perpendicular to graduation' are not enough to avoid <u>parallax</u> error $_3$✓

see alternative opposite; if both approaches are given record the mark to whichever scores most

alternative

for $_1$✓mass (of liquid/flask) measured using a <u>balance</u>

reject 'scales' and reject 'weigh/find weight/weigh the mass'

*for $_2$✓valid method to account for the mass of flask eg tare/zero balance (ECF 'scales') with (same) empty flask on balance and then measure mass of flask with liquid **OR***

*<u>subtract</u> mass of empty flask from mass of flask containing liquid; don't penalise 'weigh' twice **OR***

ensure the balance is on a horizontal surface for $_3$✓find volume(s) using $V = \frac{m}{\rho}$; V must be subject

3

(d) suitable vertical scale for their data points covering at least half the grid;

false origin on the vertical scale correctly marked;

vertical scale marked at sensible intervals, based around intervals of 1, 2, 4 or 5 etc; graduations no further than 2 major divisions apart $_1$✓

19, 207 plotted to nearest ½ grid square $_2$✓

86, 255 plotted to nearest ½ grid square $_3$✓

for $_1$✓the two correct data points a suitable scale is 10 cm^3 for each major division

an unmarked origin is be assumed to be (0, 0); if a broken *scale symbol is not used and the V scale becomes non-linear, withhold the mark*

award $_{23}$✓ = 1 MAX for thick or poorly-marked points eg thicker than half a grid square;

reject blobs, dots and circles

3

(e) **continuous ruled** best-fit line of <u>positive</u> gradient through intersection of cross-hairs of their points ✓

apply same criteria for judging line quality as in part (c); don't penalise thick line if thick points are penalised in part (d)

1

(f) legitimate method to <u>calculate</u> horizontal intercept

eg gradient calculated from ΔV divided by $\Delta\theta$ ie numerical evidence of 2 steps required; don't penalise read off errors or small steps

reads (to within 1 grid square) **OR** uses a point on the line to calculate (with correct use of $y = mx + c$) the vertical intercept; sensible values are shown on the right $_1$✓

correct use of their vertical intercept and their gradient to calculate the horizontal intercept using –1 × vertical intercept divided by gradient $_2$✓

OR

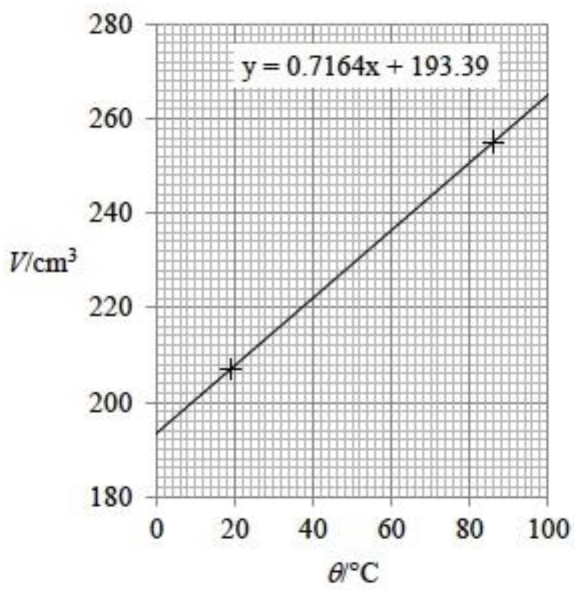
similar triangles, eg

$\frac{255-207}{86-19} = \frac{207-0}{19-\theta}$ or similar seen $_1$✓

minimum $\Delta\theta$ = 86 – 19 (= 67as in example above) $_2$✓

result in range –260°C to –285°C $_3$✓

withhold mark for missing sign; no credit for unsupported answer



in $_1$✓ condone V changed to m³ when calculating gradient and finding intercept values *for a graph with a negative gradient allow credit for ₁✓only = 1 MAX*

no credit for non-linear graph = 0 MAX

data which may be seen in working include

V = 193 cm³, θ = 0 °C; V = 265 cm³, θ = 100 °C;

V = 207 cm³, θ = 19 °C; V = 255 cm³, θ = 86° C

3

[14]

Q8.

(a) 15(.0) (Ω) ✓

Only acceptable answer

Must be on answer line or clearly identified as (largest)R

by R = 15 (.0) (Ω) seen.

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

If not on the answer line, units must be stated.

1

(b) 1.4(1) (Ω) ✓✓

Only selects 2.2 Ω and 3.9 Ω in parallel ✓

Accept evidence from working or a clear labelled sketch of 2.2 Ω and 3.9 Ω in parallel

Possible allowed combinations include:

$(\frac{1}{R}=)\frac{1}{2.2}+\frac{1}{3.9}$

Condone $R=\frac{1}{2.2}+\frac{1}{39}$

$(R=)\frac{1}{\frac{1}{2.2}+\frac{1}{3.9}}$

$(R=)(\frac{1}{2.2}+\frac{1}{3.9})^{-1}$

$(\frac{1}{R}=)\frac{5}{11}+\frac{10}{39}$

$(R=)\frac{2.2\times 3.9}{2.2+3.9}$

Accept 1.407 Ω but not >4 sf

Must be on answer line or clearly identified as (smallest)R

by R = 1.4 (1) (Ω) seen.

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

Common wrong answer = 0.71 (Ω) is worth one mark with correct supporting working

2

(c) Any of the following statements:

Power supply is on open circuit (so current is zero)

OR

Voltmeter has a (very) large resistance (so current is zero)

OR

No current (load) (so no lost volts)

OR

(Current is zero) so no lost volts

Accept 'negligible' current for zero current

Accept 'very large' resistance; don't penalise 'voltmeter has very large internal resistance'

Do not allow:

Resistance is zero

Only resistance is the internal resistance

No other component (this implies that the internal resistance is zero)

1

(d) (Current through power supply leads to)

lost volts (across the internal resistance)

OR

(Current through power supply leads to)

voltage drop across the internal resistance

OR

(Current through power supply leads to)

Some of the emf is used in the internal resistance

OR

Voltage is shared between the internal and external resistances

Allow correct 'energy transfer in the internal resistance' arguments

Must refer to a voltage across the internal resistance or r except when the term "lost volts" is used.

Do not allow:

The current decreases

1

(e) $\varepsilon - V$ = (1.62 – 1.14 =) 0.48(0) (V)

and

$\frac{V}{R} = \left(\frac{1.14}{9.0} = \right) = 0.13(\text{V}\Omega^{-1})$ ✓

Both results required for ✓; accept 0.127 or 0.1267 for $\frac{V}{R}$

Do not allow answers expressed in terms of unknown variables

Answers must be on answer line or clearly identified as answer by using correct subject and equals sign

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

1

(f) Point correctly plotted to nearest 1 mm (half a grid square)

and

continuous ruled best fit line for the 5 (originally printed) points ✓

Withhold mark if point is hidden or if best fit line is of variable thickness or has discontinuities.

Data point should be marked with a cross. Both × and + marks are acceptable.

***Do not allow** points plotted as dots / dots in circles*

If point is wrongly calculated in Part 1.5 allow CE for an accurate plot of this but this should then be treated as anomalous when judging the best fit line.

The best fit line must intersect each of the 5 originally printed X symbols.

Allow no plot where ECF (even as algebraic equation) point won't fit on the grid and student has stated that it can't be plotted.

If no answer / no plottable answer in 1.5 but student chooses to plot a point then it must be the correct point only (0.13, 0.48)

1

(g) Gradient triangle for **Figure 3**; correct read-offs for points (± 1 mm) from triangle with the $\varepsilon - V$ step at least 0.5 V

Allow $\frac{y2 - y1}{x2 - x1}$ seen or gradient triangle drawn with $\frac{\Delta y}{\Delta x}$ seen, read-offs must be substituted into $\frac{y2 - y1}{x2 - x1}$ or $\frac{\Delta y}{\Delta x}$

Condone one read-off error in four read-offs for gradient method

(common error: candidates miss non-origin on ordinate axis)

(common error: makes a power of 10 error on abscissa)

r in range 3.49 to 3.95 (Ω)

Any correct method other than gradient method (no read-off errors here) allow 1 mark

i.e. allow 1 mark for the accurate use of 1 point from their line

r must be quoted to a minimum of 2 significant figures

***ecf** for r (their gradient from their best fit line)* *r must be supported by correct working*

2

(h) The **Figure 1** method is better **because** more R values are available ✓

6 values of R (possible) for method (seen) in Fig 4 ✓

Do not allow:

The 2nd method has a wider range

The 2nd method has a larger maximum resistance

The 2nd method has a smaller minimum resistance

The 2nd method only goes up to 8.2 Ω

(resistances available in Fig 4: 2.0 Ω, 3.2 Ω, 4.3 Ω, 4.6 Ω, 5.0 Ω, 5.3 Ω)

2

[11]

Q9.

(a) To detect anomalies so these can be rejected

Reason for calculating a mean must be qualified.

Ignore:

To decrease the percentage uncertainty

OR

Determine a mean thus producing a more accurate / repeatable / reproducible value

Ignore:

To make it more accurate (without reason why)

OR

To reduce the effect of random error / variations in width of pencil

Ignore:

To make the reading more reliable

OR

Readings from micrometer are more accurate / have a smaller (percentage) uncertainty (than using a ruler) because the micrometer has a greater resolution

Ignore:

To make it more precise

Condone 'sensitivity' for resolution

1

(b) $\% \text{ uncertainty} = \dfrac{\frac{1}{2}\text{range}}{\text{mean}} \times 100) = 1.19\%$ ✓ ✓

1.19 % awarded 2 marks without supporting working

1 % or 1.2 % are permissible answers but must be supported by convincing working

Maximum of 3 sf permissible for answer

1 mark can be awarded for:

(Evidence for a calculated mean =) 7.15 (mm)

Reject 7.2 for calculated mean

OR

$(\frac{1}{2}\text{range} =) 0.085 (\text{mm})$

Reject $\frac{1}{2}\text{range} = 0.09 (\text{mm})$

OR

Use of % uncertainty = $\frac{uncertainty}{mean} \times 100$

OR

Use of % uncertainty = $\frac{\frac{1}{2}\text{range}}{\text{mean}} \times 100$

Allow their "½ range", their "uncertainty" and their "calculated mean" in use of...

But will need to see formula quoted on page and numbers or correct subject and equals sign and numbers for awarding use of...

2

(c) d = 2.2(1) mm ✓ ✓

Correct answer worth 2 marks

Condone 3rd sf rounding error if process correct

ECF from (b)

1 mark can be awarded for:

(Area of core = 0.09 × 42.43 or =) 3.8(2) seen

Penalise Talk Out on same line by use of a subject that is not an area

Allow $\frac{\pi d^2}{4}$ *as area of core or* πr^2

Allow any value of w from this list (7.06, 7.10, 7.15, 7.16, 7.20, 7.23, 7.1, 7.2, 7) or ECF from (b)

Allow any value of 0.83 w^2 *from this list (41.37, 41.84, 42.43, 42.55, 43.02, 43.39, 40.67) or ECF from (b)*

Allow any value of core from this list (3.72, 3.77, 3.82, 3.83, 3.87, 3.90, 3.66) or ECF from (b)

Condone power 10 error for 1 mark

OR

$$d = \sqrt{\frac{4 \times 0.09 \times 0.83 w^2}{\pi}}$$

Accept their area (as a numerical value) for ($0.09 \times 0.83\ w^2$)

Do not allow *area of core =* $0.83\ d^2$

OR

$$r = \sqrt{\frac{0.09 \times 0.83 w^2}{\pi}}$$

Accept their area (as a numerical value) for ($0.09 \times 0.83\ w^2$)

Answers must be on answer line or clearly identified as answer by using correct subject and equals sign

2

(d) 85.3 **or** 85.4 (mm) ✓

General Marker

Must be 3 sf

1

(e) 83.8 **or** 83.9 (mm) ✓

General Marker

Mark together with (d)

Where both (d) and (e) are incorrectly quoted as the ***cm*** *value then award a compensatory 1 mark. Otherwise mark independently*

e.g: (8.53 and 8.39) or (8.53 and 8.38) or (8.54 and 8.39) or (8.54 and 8.38): award 1 mark

Must be 3 sf

1

(f) Answers 133.43, 142.33, 152.32, 142.16 ✓ ✓

(Allow 2 sf or more)

Allow **ECF**

One of these correct answers without working obtains two marks.

ECF must be supported by appropriate working

1 mark can be awarded for:

(Decrease in length per cm drawn found =)

$$\frac{\text{change in length (ans to (e)} - \text{ans to (d))}}{20 \times 25} = 2.8 \times 10^{-3}$$

OR

$$\frac{\text{half pencil length (ans to (d)} \div 2)}{\Delta\text{length (ans to (e) - ans to (d))}}$$

Allow ecf from answers to (d) and (e), *condone any power of 10 errors on intermediate working seen*

2

[9]

Q10.

(a) 0.5 mm [0.05 cm, 0.0005 m] ✓

only acceptable answers

1

(b) 8.65 mm [0.865 cm, 0.00865 m] 1✓

the micrometer reads zero when the jaws are closed 2✓

only 3sf answers are acceptable for 1✓

accept no <u>zero</u> error for 2✓

2

(c) L = (403 − 289 =) 114 mm ✓

1

(d) absolute uncertainty = 1 mm 1✓

percentage uncertainty = $\frac{1}{114} \times 100 = 0.88\%$ 2✓

accept 2 mm for ab. uncertainty 1✓

allow ecf for wrong L and / or wrong ΔL

accept 1.75%

2

(e) should move wire directly over / closer to scale on the ruler to avoid <u>parallax</u> error ✓

both statement and explanation required for this mark

1

(f) five values of *R*/*L* correct, recorded to 3 sf [last row to 3sf or 4sf]; accept values in Ω cm^{-1} ✓

mean based on <u>first four</u> rows only; result 9.94 Ω m^{-1} [9.94×10^{-2} Ω cm^{-1}] ✓

L/cm	*R/Ω*	*(R/L)Ωm⁻¹*
81.6	*8.10*	*9.93*
72.2	*7.19*	*9.96*
63.7	*6.31*	*9.91*
58.7	*5.85*	*9.97*
44.1	*4.70*	*10.66 (10.7)*

2

(g) cross-sectional area = $\frac{\pi d^2}{4}$ $_1$✓

resistivity from $\frac{R}{L}$ $\times A$, correct substitution of result from 01.6 $_2$✓

1.10×10^{-6} $_3$ ✓

Ω m $_4$✓

resistivity from $\frac{R}{L} \times \frac{\pi d^2}{4}$ *earns* $_{12}$✓✓

allow $_2$✓ *if* $\frac{R}{L}$ *value is not based on mean or on a mean from all five rows of table in 01.6*

condone 1.12×10^{-6} *for* $_3$✓ *if fifth row in 01.6 was not rejected*

withhold $_3$✓ *for POT error*

4

[13]

Q11.

(a) smooth curve of decreasing positive gradient through all 5 points ✓

shaky or fuzzy line does not gain mark

1

(b) sensible tangent drawn at b = 25; correct read−offs for points (± 1 mm) from triangle with step sizes at least 8 × 8 $_1$✓

substitution correct $_2$✓

G = 0.11(2) $_3$✓

change in d divided by change in b for $_3$*; don't penalise if change in d is given in m* ✓

acceptable range if d is in mm 0.109 to 0.116 for d in m adjust accordingly; accept only 0.11 for 2 sf; accept ≥ 3 sf for 3✓

3

(c) d in range 14.25 to 14.30 mm $_1$✓

substitution correct $_2$✓

R in range 1.34 to 1.38 m $_3$✓

accept result for R in mm; no ecf for incorrect or out of range G

3

[7]

Q12.

D

[1]

Q13.

(a) period determined from at least 4 cycles, in range 3.8(0) to 5.0(0) × 10^{-4} s ✓

frequency = $\frac{1}{\text{period}}$ in range 2300 ± 300 Hz ✓

accept 2 sf period, 2.3 × 10^3 Hz

2

(b) peak to peak voltage = 6.8 divisions seen ✓

rms voltage = 24 mV ✓

accept 24.0 or 24.1 mV

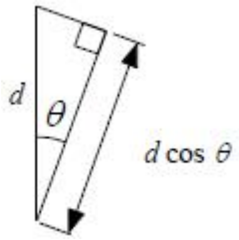
2

(c) flux linked with the search coil depends on the <u>area</u> of coil presented $_1$✓
area is proportional to *d* cosθ_2✓

[flux linked with the search coil depends on component of B perpendicular to the plane of the coil$_1$ ✓
component is prop *B* cosθ , or suitable sketch]$_2$ ✓

for $_1$✓accept Nφ = BA

for $_2$✓accept evidence in sketch, e.g.



2

(d) six correctly calculated values of cosθ ; accept all to 3 sf or all to 4 sf $_1$✓

axes labelled, correct separator and unit with l, suitable scales $_2$✓

plots correct to half a square (check at least one) $_3$✓

ruled straight line extrapolated to meet either or both axes $_4$✓

[for false plot allow $_2$✓ and $_4$✓ = 2 MAX]

θ/°	l/cm	cosθ
10	6.7	0.985
34	5.6	0.829
50	4.4	0.643

60	3.4	0.500
72	2.1	0.309
81	1.1	0.156

4

(e) direct proportionality is confirmed since graph is a straight line with zero [negligible] intercept✓

[allow ecf for false plot]

must refer to intercept

1

(f) idea of repositioning trace $_1$✓

(to reposition the trace) so that an end of the line is aligned with [close to] a (horizontal) graduation $_2$✓

(to reposition the trace) so that the line is aligned with the central (vertical) graduation on the screen $_3$✓

associates *y*-shift and *x*-shift correctly with trace change $_4$✓

accept clear marks on Fig 7 for all except 4th point

allow alignment with graduation (can be major or minor) of either end of the line for $_2$✓

4

(g) adjust *y*-voltage gain to a less sensitive [precise] setting [20 mV cm^{-1}] ✓

since *I* is increased beyond the range of the screen [vertical length of trace is too great] ✓

because induced emf is proportional to rate of change of flux linkage [or quotes Faraday's Law] ✓

and rate of change of flux linkage is doubled [same flux change in half the time] ✓

accept 'reduce Y gain' but reject 'use lower Y gain setting'

no credit for suggestions that time-base setting should be changed

answer without quantitative detail 2 MAX

3 MAX

(h) evidence of suitable test employed to test whether curve shows exponential decrease, e.g. valid measurement of half life over more than one region $_1$✓

states that trend is not exponential $_2$✓

cannot earn $_2$✓ *without valid* $_1$✓

2

[20]

Q14.

(a) θ_1 = 61.0 ± 0.5 °C ✓

reject 2 sf θ_1

1

(b) sensible tangent drawn at *t* = 190 s; correct read-offs for points (± 1 mm) from triangle with step sizes at least 8 × 8 $_1$ ✓

$G_1 = -9.57 \times 10^{-2}$ $_3$✓

for $_3$✓ *insist on correct sign and POT; accept result in range 1.05 ×* 10^{-1} *to* -9.0×10^{-2}

3

(c) substitution correct leading to $\theta_R = 17.3 \pm 2.0$ °C ✓

allow ECF

1

(d) $\theta_0 - \theta_R$ correctly evaluated to ± 1 °C for θ_0 at suitable reference time $_1$ ✓

evaluates $\frac{\theta_0 - \theta_R}{e}$ $_2$✓

evaluates θ from $\frac{\theta_0 - \theta_R}{e} + \theta_0$; time constant deduced from graph with evidence of working (read offs to both axes are required) $_3$✓

time for object to reach room temperature in range 1900 to 2000 s $_4$✓

example for $_1$✓: $\theta_0 = 89$ °C *at t = 0 gives* $\theta_0 - \theta_R = 89 - 21 = 68$ °C

allow ecf for failure to take account of θ_R *in* $_1$ ✓

example for $_2$✓: $\frac{\theta_0 - \theta_R}{e} = \frac{68}{2.718} = 25$ *; allow ecf for failure to take account of* θ_R *in* $_1$✓

example for $_3$✓: $\theta = 25 + 21 = 46$*; time constant = 390 s*

example for $_4$✓*: time to reach room temperature = 5 × 390 = 1950 s; no ecf for errors in* $_1$✓ *or in* $_3$✓

4

(e) the starting temperature was lower $_1$✓

the starting temperature was 86.5 °C compared to 89.0 °C $_2$✓

the room temperature was higher $_3$✓

the draught was less $_4$✓

the water had only cooled to 38.0 °C after 600 s $_5$✓

the sample rate of the data logger was lower $_6$✓

samples were recorded every 20 s (rate for original experiment was much higher) $_7$✓

other approaches are possible

allow ± 0.3 °C for any temperature quoted for $_2$✓ *or for* $_5$✓

MAX 5

Q15.

(a) w from $\frac{R2 - R1}{6} = 0.408\text{mm} = 4.08 \times 10^{-4}\text{m}$ ✓

3 sf answer ✓

2

(b) double slit formula rearranged to give $d = \frac{\lambda \times D}{w}$ $_1$✓

$d = \frac{589.3 \times 10^{-9} \times 0.395}{0.408 \times 10^{-3}} = 5.7(1) \times 10^{-4}\text{m}$ $_2$✓

allow ecf in $_2$✓ for wrong w but not for POT error

2

(c) use of $PQ = \frac{d \times (D + L)}{L} = 5.46 \times 10^{-3}\text{m}$ $_1$ ✓

allow ecf for wrong d in $_1$ ✓

number of fringes seen $= \frac{PQ}{w} = \frac{5.46}{0.41}$ $_2$ ✓

number of fringes seen = 13 (integer only)$_3$ ✓

allow 12 or 14 fringes

3

(d) close jaws using ratchet ✓

confirm that instrument reads zero ✓

2

(e) mean = 0.57(0) mm; uncertainty = 0.5 × range ✓

percentage uncertainty $= 100 \times \frac{0.5 \times (0.574 - 0.566)}{0.570} = 0.70(2)\%$ ✓

2

[11]

Q21.

(a) Both t_m values correct: 0.404, 0.429
AND
Both t_m^2 values correct: 0.163, 0.184 ✓

Exact values required for the mark.

1

(b) Both plotted points to nearest mm ✓
Best line of fit to points ✓

The line should be a straight line with approximately an equal number of points on either side of the line.

2

(c) Large triangle drawn (at least 8 cm × 8 cm) ✓
Correct values read from graph ✓
Gradient value in range 0.190 to 0.222 ✓

Allow 2 or 3 sf for gradient

3

(d) g = 9.71 (ms^{-2}) or correct value from gradient value in **(c)** ✓.

(The answer must be in the range 9.0 to 10.5 (ms^{-2})).

Allow 2 or 3 sf.

Unit not required

1

(e) $$\%\ difference = \frac{(9.81 - 9.71)}{9.81} \times 100 = 1.02$$

OR correct computation using value from **(d)** ✓

If the candidate's value is exactly 9.81, then a statement that there is no (or zero) percentage difference is acceptable.

No sf penalty.

NB. Allow an answer from a calculation with either the candidate's value or the accepted value as the denominator in the equation.

1

(f) 0.001 s✓ (half the spread)
(Must have unit).

1

(g) $g = 2s/t_m^2$ ✓
$= 2 \times 0.300/0.245^2$ ✓
= 10.0 (or 10.00) ms^{-2} ✓

Unit required and 3 or 4sf for the last mark.

3

(h) % uncertainty in s = 0.33 **and**
% uncertainty in t_m = 0.41 ✓

*Allow ecf from part **(f)**.*

% uncertainty in g
= 0.33 + (2 × 0.41) = 1.15 ✓

Allow ecf at each stage of calculation.

Uncertainty in g
= 10.0 × 1.15/100 = 0.12 m s^{-2} or 0.1 m s^{-2} ✓

*Allow ecf from part **(g)**.*

(allow 1 or 2 sf only)
(Must have unit for 3rd mark).

3

(i) (a) Use spherical objects of different mass **and** determine mass with balance ✓

Annotate the script with the appropriate letter at the point *where the mark has been achieved.*

(b) Would need **same diameter** spherical objects for fair comparison (same air resistance etc) ✓

(c) Time spherical object falling through same height **and** compare times

*Alternative for **(c)**:*
i.e. repeat whole of experiment, plot extracted values of g against mass. Horizontal line expected, concluding acceleration same for different masses.

3

[18]

Q22.

(a) (i) maximum distance from 1st to 5th image = 139 mm (allow 138 to 140mm) ✓

Any other correctly measured distance(s), to provide additional data, but do not allow the distance from 1st to 2nd image (as this is too small).

Alternatively allow a repeat measurement of the maximum distance for this mark. ✓

E.g. 1st to 4th image distance = 79 mm, 1st to 3rd image distance = 34 mm (allow ± 1mm on these values)

*If a candidate measures distances which do not go back to the first image the initial velocity, u, will not be zero. Use of the 'suvat' equations is then considerably more complicated. A mark can still be awarded, **provided** the candidate illustrates how g can be calculated **or** correctly calculates g from this value in **(a)(ii)**.*

If the printing process in your centre alters the scale of this diagram, measure the values on your printed papers and mark the scripts accordingly. (Send details to the moderator).

If the candidate is visually impaired and is using a modified paper that alters the scale of this diagram, measure the values on the printed paper and mark the script accordingly.

2

(ii) Evidence of correct number of time intervals to match the distance used.(e.g Using distance from 1st to 5th marble with 4 time intervals, time = 0.174 s) ✓

Value of g = 9.18 or 9.2 m s^{-2} (based on 139 mm and 0.174 s)

*Allow ecf from value of time in **(a)**,and ecf from incorrect measurements in **(b)**, but to allow ecf candidate **must** show workings of the calculation and not just state a value for g*

(Allow also 918 or 920 cm s^{-2} and 9180 or 9200 mm s^{-2}) Answer must have correct unit ✓

*Allow this mark based on a correct calculation from just one measurement of distance in **(a)(i)***

No sf penalty

2

(b) So image is sharp / less blurred / image is well defined
OR
Any answer referring to 'motion blurring'
Allow reference to 'image' or 'marble'
1
[5]

Q23.

(a) 1.43, 1.29
1

(b) Both plotted points to nearest mm ✓

Best line of fit to points ✓
The line should be a straight line with approximately an equal number of points on either side of the line.
2

(c) (i) Large triangle drawn (at least 8 cm × 8 cm) ✓

Correct values read from graph ✓

Gradient value in range (0.618 to 0.652) × 10^{-6} to 2 or 3 sf ✓
Allow the 2nd mark for incorrect numerical values read ignoring incorrect power of 10.
Incorrect power of 10 is penalised in gradient value.
3

(ii) Same figure quoted for gradient but with correct unit
1

(d) (i) Straight line (through origin) ✓

(directly) proportional ✓
2

(ii) Evidence of substituting data from the table / graph into $w = mD/s + c$ (from $y = mx + c$) ✓

Computation of correct value for c (i.e. value of w when $D/s = 0$) with correct unit.
Should be approximately 0.1 × 10^{-3} m, depending on the exact lobf drawn.
2

(iii) w
1

(e) Any reference to **either** width of slits **OR** single slit diffraction ✓
1
[13]

Q24.

(a) Measurement of at least 30 fringe widths (check that candidate has not miscounted) e.g. 30 fringe widths = 40 mm or 41 mm.

Correct answer of 1.3 or 1.4 mm quoted to 2sf with unit ✓(one mark)
OR
Correct answer 1.33 – 1.37 mm to 3sf with correct unit ✓✓ (two marks).

If candidate quotes value in range 1.33 – 1.37 mm to 3sf they achieve both the 2nd and 3rd marks (A quote to 3sf is justified in terms of uncertainty if a large number of fringe widths have been measured).

For 2nd & 3rd marks allow ecf from incorrect measurement in 1st mark.

If the printing process in your centre alters the scale of this diagram, measure the values on your printed question papers and mark the scripts accordingly. Send details to the moderator.

If a candidate is visually impaired and using a modified paper that alters the scale of this diagram, measure the values on the printed question paper and mark the script accordingly.

3

(b) 1 mark for intermediate step where candidate doesn't get correct final answer. i.e. calculating % uncertainty of total measurement (i.e. % uncertainty in *w*) ✓

OR for both marks:

Uncertainty in *w* = ± 0.03 mm ✓✓

(Full 2 marks for correct answer with unit – No unit no mark unless a correct intermediate step has been completed which will have been credited for 1 mark as explained above)

Uncertainty in measurement of multiple fringes is ± 1 mm (precision of ruler used).

E.g. for length 41 mm ± 1 mm % uncertainty = 1/41 x 100 = 2.4 %

Uncertainty in w (single fringe)
= 2.4 x 1.4/100 = ±0.03 mm

Simply quoting 0.03 - ***NO marks***

No penalty for omission of ±

2

(c) (i) (Using w = 1.40 mm)

Wavelength = 5.60 × 10^{-7} m ✓

Allow ecf for value of w from ***(b)***

Consistent unit required for the mark. No sf penalty.

1

(ii) (Intermediate step) % uncertainty = 5.8% ✓

(From %uncty s = 3.3%, w = 2.4%, D = 0.1% % uncertainty

in wavelength = 3.3 +2.4+0.1 = 5.8%).
*Allow ecf from **(b)***

1

(iii) (Using wavelength = 5.60×10^{-7} m)

Uncertainty in wavelength = $\pm 3.2 \times 10^{-8}$ (m) ✓ or ± 32 (nm) or $\pm 3.2 \times 10^{-5}$ (mm)
*Allow ecf from **(c)(i)** & **(ii)***
No sf penalty
*If the value is consistent with the wavelength quoted in **(c)(i)**, **allow the numerical answer without the unit**, otherwise a unit is required.*

1

[8]

Q25.

(a) $\sin\theta_1 = \frac{XZ}{WX}$ and $\sin\theta_2 = \frac{YZ}{WY}$ or $\frac{\sin\theta_1}{\sin\theta_2} = \frac{(XZ)\div(WX)}{(YZ)\div(WY)}$ 1 ✓

(must see this step either separately or in substitution for $\frac{\sin\theta_1}{\sin\theta_2}$ or 0/2

condone *i* and *r* for *θ* etc.)

$$n = \frac{(XZ)\div(WX)}{(YZ)\div(WY)} = \frac{XZ}{WX} \times \frac{WY}{YZ}$$ 2 ✓

$$\left(= \frac{(XZ)\times(WY)}{(WX)\times(YZ)}\right)$$

2

(b) idea implied that (XZ) × (WY) = *n* × (WX) × (YZ) is of form *y* = *mx* (+ *c*);

plot (XZ) × (WY) against (WX) × (YZ) [$\frac{XZ}{WX}$ against $\frac{YZ}{WY}$ etc] or 0/2 1 ✓

calculate gradient to find *n* (false plot loses both marks) 2 ✓

[must mention XZ, WX, YZ and WY for full credit: bland 'plot sin θ_1 against sin θ_2 and calculate gradient to find *n*'= 1 MAX]

[alternative method is to plot XZ against WX to find G_1 and plot YZ against

WY to find G_2 1 ✓; evaluate $\frac{G_1}{G_2}$ to find *n* 2 ✓]

2

(c) upper limit of (XZ) range [largest value] is suitable 1 ✓

largest XZ value ≈ length of block (114) [largest WX value ≈ diagonal distance (131) across block / used

(approximately) largest value of XZ [WX] available]2✓

lower limit of (XZ or YZ) range [smallest value] is not suitable3✓

smallest YZ [XZ] values have large percentage uncertainty / are unreliable] 4✓
(reject idea these values are too close to zero)

smallest WX value ≈ width of block (65)5✓

[statement that range is suitable plus quantitative comment comparing length of block (114) with 98 (the range of XZ data) or covers more than 85% of available range] 12✓✓

equivalent statement regarding WX: compares available range (131 to 65 = 66) with 63 (the range of WX data) 12✓✓ = 2 MAX

statement that range is suitable plus simple qualitative comment relating range to the block, e.g. 'a large fraction / part of the available XZ [WX] range is covered' 12✓
= 1 MAX (bland 'range is large / wide' is not enough)]

MAX 3

[7]

Q26.

(a) s from $\frac{R_2 - R_1}{3} = 1.43\,\text{mm}$ ✓ (accept bald answer for 1 mark)

1

(b) 0.01 mm (condone 0.005 mm) ✓

1

(c) uncertainty in 3*s* [in *s*] = 0.02 ✓ [2 × answer for **(b)**] or 0/2

percentage uncertainty in $3s = \frac{0.02}{4.29} \times 100 = 0.47\%$ ✓ (use of R_2 (use of R_1 is required; accept 1 sf 0.5%)

[for precision = 0.005 mm, % uncertainty in $3s = \frac{0.01}{4.29} \times 100 = 0.23\%$ ✓

(use of R_2 and R_1 is required; accept 1 sf 0.2% but reject 0.3%)

2

(d) evidence of suitable working, e.g. *d* from $2s - (R_3 - R_2)$ or from

$5s - (R_3 - R_1)$ or from $\frac{2(R_3 - R_1) - 5(R_2 - R_1)}{3}$ ✓

$d = 0.84$ mm ✓

[allow ecf for incorrect *s*: the candidate in **(a)** who evaluates the distance between the edges of adjacent holes will get $s = 0.59$ mm; they get the correct result for *d* using $\frac{R_2 - R_1}{3} - 0.59]$

2

[6]

Q27.

(a)

h/mm	ln(*h*/mm)
381	5.943
336	5.817 or 5.818

✓

Exact answers only.

1

(b) Both points plotted within 1 mm ✓
An accurate best fit straight line drawn with an even scatter of points on either side of the line ✓

2

(c) Triangle drawn with smallest side at least 8 cm in length (or 8 grid squares) **and** correct values read from the line of best fit ✓
Correct answer for gradient in the range -0.0140 to -0.0138 ✓✓

Note: correct answer marks:

One mark for the minus sign plus one mark for a value in the range 0.0136 to 0.0140 expressed to 2 or 3 sf

3

(d) *H* = 665 or a correctly calculated value from the intercept on the graph **and** the unit quoted for *H* quoted as mm ✓
λ = candidate's answer to part **(c) without the minus sign** ✓
Unit for λ = s^{-1} ✓

No sf penalty

3

(e) There could be a systematic error in the measurement of *h* ✓
Consideration of the effect of this on the natural log values that are being plotted ✓
An explanation involving recognition that a (small) change in gradient is likely and this would result in a change in λ ✓

Alternative (simplistic) answer for ***2 marks max***

There could be a systematic error in the measurement of h ✓

This would be unlikely to affect the gradient of the line since h is numerically large and so the value found for λ would not be affected. ✓

3

(f) There could be random errors associated with the use of a stopclock for measuring time ✓

By taking repeat readings these should have been minimised so the value found for λ would not be affected. ✓

2

[14]

Q28.

(a) (mark should be at the equilibrium position) since this is where the mass moves with <u>greatest speed</u> [transit time is least] ✓

1

(b) (i) mean time for 20*T* (from sum of times ÷5) = 22.7 (s)₁ ✓ (minimum 3sf)

uncertainty (from half of the range) = 0.3 (s) ₂ ✓ (accept trailing zeros here)

percentage uncertainty

$$\text{(from } \frac{0.3}{22.7} \times 100)[\frac{100}{5} \times \sum \frac{0.3}{20T}] = 1.3\ (22)\%_3$$ ✓

(allow full credit for conversion from 20*T* to *T*, e.g. 1.135 = ₁✓ 0.015 =₂ ✓ ecf for incorrect ₁ ✓ and / or ₂ ✓ earns ₃ ✓

3

(ii) natural frequency $\text{(from } \frac{20}{22.7} \text{ and minimum 2 sf)} = 0.88\ (1)\text{Hz [accept s}^{-1}]$ ✓

(ecf for wrong mean 20*T*; accept ≥ 4 sf)

1

(c) (i) linear scale with at least 3 evenly-spaced convenient values (i.e. not difficult multiples) marked; the intervals between 1 Hz marks must be 40 ± 2 mm (100 ± 5 mm corresponds to 2.5 Hz) ✓

(ecf for wrong natural frequency: 100 ± 5 mm corresponds to $\frac{2.5f}{0.88}$ Hz)

1

(ii) 4 mm [allow ± 0.2 mm] ✓

1

(d) (i) student decreased intervals [smaller gaps] between [increase frequency / density of] readings (around peak / where A is maximum) ✓ ✓

[student took more / many / multiple readings (around peak) ✓]
(reject bland ‘repeated readings’ idea; ignore ideas about using data loggers with high sample rates)

2

(ii) new curve starting within ± 1 mm of A = 4 mm, f = 0 Hz

with peak to right of that in Figure 3
(expect maximum amplitude shown to be less than for 2 spring system but don't penalise if this is not the case; likewise, the degree of damping need not be the same (can be sharper or less pronounced)

Peak at $\sqrt{2}$ value given in **(b)(ii)**; expect 1.25 Hz so peak should be directly over 50 ± 5 mm but take account of wrongly-marked scale ✓

2

[11]

Q29.

(a) the travelling microscope won't interfere with / change the path / interrupt / affect the stream [flow] of water / affect the reading (being taken)
[vernier callipers will interfere with etc] ✓

(reject 'cannot grip / clamp the flow')

1

(b) (i) straight best-fit line drawn passing within ± 2 mm of 1st and 5th points, 3rd and 4th points to be either side of line;

attempt to measure the gradient (i.e. using $\frac{d(\log s)}{d(\log d)}$ from the line or from two of the plotted points if these lie on the line; do not penalise for small steps, false read-off(s) (including failure to take account of false origin) or for calculation error ✓

n = –4 (integer value only, e.g. reject –4.0) ✓

2

(ii) $k = 10^{\text{intercept}}$ [antilog of (log s) intercept] ✓

[take values of log s and log d and evaluate $10^{(\log s - (-4)\log d)}$ ✓]

('log k = intercept' is insufficient)

1

(iii) units of k = cm^5 [accept m^5 or mm^5; allow ecf for wrong or non-integer value for n, eg ecf for $cm^{(1-n)}$ ✓

1

[5]

Q30.

(a) extension of wire Q = 2.7 (mm) ✓

ignore any precision given eg ± 0.1 mm

if > 2 sf condone if this rounds to 2.7

1

(b) mass = 5.8 (kg) ✓

allow ce for incorrect 0.1.1 (only look at 01.1 if answer here is incorrect)

allow ± 0.1 kg

1

(c) 0.51 (mm) ✓

ignore any precision given eg ± 0.005 mm

1

(d) method 1:

use of $E = \frac{\text{(tensile) stress}}{\text{(tensile) strain}}$ 1 ✓

for 1✓ expect to see some substitution of numerical data

cross – section area from $\frac{\pi \times d^2}{4}$ 2 ✓

correct use of diameter for 2✓; ignore power of ten error;
expect CSA = 2.0(4) × 10^{-7}; allow ce from 01.3 (eg for d = 0.37 mm
CSA = 1.0(8) × 10^{-7} m^2)

(tensile) stress = $\frac{mg}{\text{CSA}}$ 3 ✓

penalise use of g = 10 N kg^{-1}

(tensile) strain = $\frac{\Delta l}{l}$ 4 ✓

value of Δl must correspond to Figure 2 value of m; answers to 01.1 and 01.2 are acceptable

expect l = 1.82 m but condone 182 etc; accept mixed units for l and Δl

MAX 3

method 2:

evidence of $\frac{\Delta l}{\Delta m}$ from Figure 2 to calculate gradient 1✓

expect gradient between 0.45 to 0.48 mm kg^{-1}

$E = \frac{g \times \text{original lenght}}{\text{CSA} \times \text{gradient}}$ 2✓ 3✓

missing g loses 3✓

substitution of l = 1.82 m 4✓

condone 182 etc 4✓

cross-sectional area from $\frac{\pi \times d^2}{4}$ 5✓

correct use of diameter for 2✓; ignore power of ten error;
expect CSA = 2.0(4) × 10^{-7}; allow ce from 01.3 (eg for d = 0.37 mm
CSA = 1.0(8) × 10^{-7} m^2)

MAX 3

result in range 1.84 × 10^{11} to 1.91 × 10^{11} 5✓

condone 1.9 × 10^{11}

5✓ mark requires correct working and no power of ten errors: allow ce for error(s) in 01.1, 01.2 and for false/incorrect CSA (eg for d = 0.37 mm allow result in range 3.49 × 10^{11} to 3.63

× 10^{11}, 3.5 × 10^{11} or 3.6 × 10^{11})*

1

(e) (smaller diameter) produces larger extensions $_1$✓
reduces (percentage) uncertainty (in extension and in result for Young Modulus) $_2$✓

(smaller diameter) increases (percentage) uncertainty in diameter **or** cross sectional area is smaller **or** increases (percentage) uncertainty in cross sectional area $_3$✓
increases (percentage) uncertainty (in result for Young Modulus) $_4$✓

(smaller diameter) increases likelihood of wire reaching limit of proportionality or of wire snapping or reduces range of readings $_5$✓
increases (percentage) uncertainty (in result for Young Modulus) $_6$✓

outcome and correct consequence for 2 marks, ie $_1$✓ followed by $_2$✓, $_3$✓ followed by $_4$✓ etc

dna 'error' for 'uncertainty'

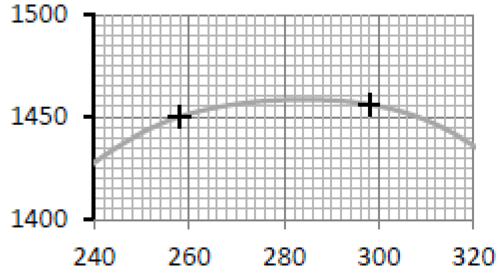
no mark for consequence if outcome not sensible, eg 'it gets longer and reduces uncertainty' earns no mark for 'diameter smaller so uncertainty greater' award $_1$✓ (need to see further mention of uncertainty to earn $_2$✓)

MAX 4

[11]

Q31.

(a) 2 missing points plotted, each to nearest 1 mm (half a grid square); points marked + or × or ⊙; reject thick points, blobs or uncircled dots ✓



1

(b) continuous smooth best fit line through all 7 points to 1 mm ✓

allow mis-plotted points to be treated as anomalies; multiple lines or points of inflexion lose the mark

1

(c) candidate's value from Figure 2 ± ½ grid square ✓

if multiple lines are drawn condone value if ± ½ grid square of all lines

1

(d) finding θ_N from Figure 3 is easy since the result is read off where G = 0 $_1$✓
or

finding θ_N from Figure 2 is difficult since θ has a range of values for which ε is a maximum $_2$✓

accept evidence that G = 0 used shown on Figure 3; physics error about how Figure 3 used means no credit for any further valid comment about Figure 2

accept 'curve is shallow at peak' for $_2$✓

MAX 1

(e) method:
correctly determines gradient of Figure 3 or uses gradient result with any point on line to determine (vertical) intercept $_1$✓

result in range 9.8 to 10.9 $_2$✓

gradient values in the range −0.040 to −0.034 for $_1$✓(minus sign essential)

for $_1$✓allow the substitution of at least one pair of correct values of G and θ into $G = \beta\theta + \alpha$ to obtain α using simultaneous equations

condone 2sf '10' for $_2$✓

2

(f) full scale pd = 100 × 1000 = 100000 or 10^5 μV ✓

allow 100 mV or 0.1 V if μV deleted from answer line ✓

1

(g) idea that resolution of the meter is not satisfactory $_1$✓
because the largest pd that will be measured is less than 1500 μV
OR
only uses 1.5% of the range
OR
pd across meter at full-scale deflection ÷ divisions = $\frac{10^5}{50}$ =
2000 μV per division $_2$✓

condone use of 'sensitivity' or 'precision' for 'resolution'; ignore 'meter is not accurate'

allow 'hard to tell different readings apart'

for $_2$✓allow ce for incorrect 02.6

allow 'unable to measure to nearest <u>micro</u>volt'

allow 'resolution of scale should be 1 μV'

2

[9]

Q32.

(a) nuclear fallout / testing / weapons / nuclear accidents / Chernobyl / nuclear waste / nuclear medicine / X-rays / specific uses of radioactive sources eg medical tracers CT scan etc. / cosmic rays as a result of air travel ✓
(Any source of radiation that an individual may encounter which would not have existed 100 years ago)

No mark for general answers such as 'medical' or Nuclear

Power / nuclear plant.

If a list is given all must be correct but ignore generalisations such as medical or nuclear power.

1

(b) (i) I_{15CCR} = 2050 – 40 = 2010 ✓

Use of inverse square law eg $I_{CCR90} = I_{CCR15} \left(\frac{d_{15}}{d_{90}}\right)^2$ √ = 2010 × (0.15 / 0.90)^2 = 55.8

I_{90CR} = 55.8 + 40

I_{90CR} = 96 counts min^{-1} ✓

regardless of order:

1st mark subtraction of background in original data

2nd mark is for using inverse square function

3rd mark is for the answer

3

(ii) (reduce impact of) random error / decrease the (percentage) uncertainty / improve the statistics (because the percentage error is proportional to the inverse square-root of the count) ✓ (owtte)

The answer must be an uncertainty related statement and not increases reliability / accuracy or increased chance of a reading (although these ideas can accompany a correct answer) Ignore comparisons with the background count.

1

(iii) use (sensible) absorber between source and detector ✓ (sensible absorber means it must have a noticeable effect e.g. 1mm of metal / aluminium sheet / 5mm perspex but do not allow metal foil / paper sheets. Also its effect must not be so great that it reduces the gamma rays noticeably)

(These two marks are independent)
β shown by count rate falling when sheet of aluminium absorber is used ✓ Or (using the existing apparatus)
Compare the results (at various distances) in air with the expected inverse square law ✓
Below the range of beta law does not work but above range it does. ✓

2nd mark no mark given if count rate falls to zero as γ is still present

(magnetic deflection is not common but if seen.

Use of magnetic deflection ✓correct deflection of beta from the beam ✓)

(If a cloud chamber is suggested. Observe the tracks in a cloud chamber ✓beta tracks have varying lengths or they are curly / not straight ✓

(The value of the range of beta is not a marking point so accept 15 – 80 cm if a number is given)

2

[7]

Q33.

(a) (i) 0.416 or 0.417 and 0.495 or 0.496

1

(ii) Both plotted points to nearest mm✓

Straight line of best fit ✓

The line should be a straight line with approximately an equal number of points on either side of the line.

2

(iii) Large triangle drawn (at least 8cmx8cm) ✓

Correct values read from graph✓

Gradient value in range 0.805 to 0.837 to 2 or 3 sf✓

3

(iv) (1) For showing correct vertical component of at least one of the forces / tensions as $mg\cos\theta$ or both vertical components as 2 $mg\cos\theta$

Question specifically referred to resolving forces so component <u>must</u> include *g*.✓

1

(2) $\cos\theta = \frac{d}{\text{hypotenuse}} = \frac{d}{\sqrt{(d^2 + (x^2/4))}}$ ✓

$\frac{d}{\sqrt{(d^2 + (x^2/4))}} = \frac{M}{2m}$ compared to $y = mx$ ✓

(Hence gradient is $\frac{1}{2m}$)

2

(3) Magnitude of *m* correct from

E.g middle gradient value gives m = 0.609 kg

$\frac{1}{2 \times \text{their gradient from (c)}}$ ✓ kg and 2 or 3 sf ✓

Allow ecf from gradient value.

Sf and unit mark depends on correct calculation of m from the gradient value.

2

(v) (1) Friction <u>at the pulleys</u> ✓

1

(2) Take a mean value of readings from loading and unloading ✓

1

(b) (i) Description of technique:

Use small plane mirror beneath string / use of set square / bright light source to project shadow of the strings onto the paper, and marking points on shadow to aid drawing lines ✓

Explanation:

Line of sight not perpendicular from string to paper / mark on paper depends on the angle the eye is positioned at / reference to parallax error. ✓

2

Markers should measure the angle to check that no scaling error has been introduced in the photocopying of the paper. If the angle is different, mark accordingly.

Answers should be consistent with protractor precision stated by the candidate.

(ii) (1) Value of θ quoted as 30° or 31° (for a protractor with precision ±1°)
OR
θ = 30.0, 30.5, 31.0
(for a protractor with precision ± 0.5°) ✓

Correct computation of % uncertainty, answer quoted to 2 or 1sf ✓

Allow ecf for incorrect angle (penalised in 1st marking point).(e.g. if using a protractor with 1° precision % uncertainty will be 1/31 × 100% = 3.2% or 3% OR for candidates who measured the angle 2 θ % uncertainty = 1/62 × 100 = 1.6% or 2%. With a protractor with precision ± 0.5° the % uncertainties will be half these values)

This is because the question specifically stated "as accurately as possible". It should be clear from the candidate's percentage uncertainty calculation whether 2θ or θ has been measured.

Extra mark for a candidate who measures the angle 2θ (rather than just the single angle θ) ✓
(This 3rd mark can also be awarded for a candidate who has measured θ on both sides of the 'vertical line',and taken the mean value)

3

(2) Evidence of right angled triangle drawn on to the diagram with dimensions of two sides also shown on the diagram. The minimum dimension shown must be 70mm. ✓

Correct use of cosine rule without right angled triangle is acceptable.

Angle correctly computed using sine cosine or tangent, with value quoted in the range 30.0° to 31.4° ✓

Angle quoted to 3 sf/to 0.1°
2nd mark is still available to a candidate who didn't achieve the 1st mark.

2

(iii) Plot a graph of cos θ against 1/*m*
AND
Statement that it should give a straight line through origin. ✓

Allow graphs of 1/m ***against*** *cos θ, against 1/cos θ against m, which would all be straight lines through the origin.*

1

[21]

Q34.

(a) (i) 5.1 and 7.1 ✓

Exact answers only

1

(ii) Both plotted points to nearest mm ✓

Best line of fit to points ✓

The line should be a straight line with approximately an equal number of points on either side of the line

2

(iii) Large triangle drawn at least 8 cm × 8 cm ✓

Correct values read from graph ✓

Gradient value in range 0.190 to 0.210 to 2 or 3 sf ✓

3

(iv) ($R = \frac{1}{\text{gradient}}$) = 5.0 Ω   Must have unit ✓

Allow ecf from gradient value

No sf penalty

1

(b) (i) 5.04 (Ω) or 5.0 (Ω) ✓

(Allow also 5.06 Ω or 5.1 Ω, obtained by intermediate rounding up of 3.50^2)

From $R = \frac{V^2}{P}$

1

(ii) (Uncertainty in V = 0.29%)

Uncertainty in V^2 = 0.57%, 0.58% or 0.6% ✓

From uncertainty in V = 0.01 / 3.50 × 100%

Uncertainty in P = 2.1% ✓

From uncertainty in P = 0.05 / 2.43 × 100% = 2.1%

Uncertainty in R =2.6%, 2.7% or 3%

Answer to 1 or 2 sf only ✓

2.1 % + uncty in V^2 (0.6%) = 2.7%

Allow ecf from incorrect uncertainty for V^2 or P

3

(iii) (Absolute) uncertainty in R is (±) 0.14 or just 0.1 Ω (using 2.6%) (or 0.15 or 0.2 Ω using 3%) ✓

Must have unit (Ω)

Must be to 1 or 2 sf and must be consistent with sf used from (ii)

No penalty for omitting ± sign

1

(iv) Works out possible range of values of R based on uncertainty in (iii), e.g. R is in range 5.0 to 5.2 Ω using uncertainty of ± 0.1 Ω ✓

No credit for statement to effect that the values are or are not consistent, without any reference to uncertainty

Allow ecf from (iii)

Value from (a)(iv) is within the calculated range (or not depending on figures, allowing ecf) ✓

Allow ecf from (a)(iv)

2

[14]

Q35.

(a) (i) Voltmeter across terminals with nothing else connected to battery / no additional load. ✓

1

(ii) This will give zero / virtually no current ✓

1

(b) (i) $\frac{VI}{\varepsilon I}$

Answer must clearly show power: εI and VI, with I cancelling out to give formula stated in the question ✓

1

(ii) Voltmeter connected across cell terminals ✓

Switch open, voltmeter records ε
Switch closed, voltmeter records V
Both statements required for mark ✓

Candidates who put the voltmeter in the wrong place can still achieve the second mark providing they give a detailed description which makes it clear that:

To measure emf, the voltmeter should be placed across the cell with the external resistor disconnected

<u>And</u>

To measure V, the voltmeter should be connected across the external resistor when a current is being supplied by the cell

2

(c) Vary external resistor and measure new value of V, for at least 7 different values of external resistor ✓

Precautions - switch off between readings / take repeat readings (to check that emf or internal resistance not changed significantly) ✓

2

(d) Efficiency increases as external resistance increases ✓

Explanation
Efficiency = Power in R / total power generated
$I^2R / I^2(R + r) = R / (R + r)$
So as R increases the ratio becomes larger or ratio of power in load to power

in internal resistance increases ✓

Explanation in terms of V and ε is acceptable

2

[9]

Q1.

(a) Many students incorrectly assumed the air-track glider's velocity was zero at the first light gate. Other common mistakes seen included using the total travel time of 2.09 s rather than 1.19 s and assuming that the distance travelled was 10.0 cm. Nevertheless, nearly a quarter of students scored all three marks.

(b) There were lots of undeveloped statements; students implied that a longer time equalled a greater distance. In many cases, the supporting arguments presented were flawed with many students stating that with the same acceleration a greater time would result in a larger distance. There was some good analysis of the data but such an approach was usually only taken by higher grade students. Only 12.8% of students gained both marks.

(c) The lines of best fit seen were generally of good quality. Many students demonstrated best practice for determining the gradient. Large gradient triangles were drawn with the read-off co-ordinates and corresponding differences clearly seen. Mistakes that occurred most frequently included not taking the false origin into account and drawing a gradient triangle that was too small. Very nearly 90% of students scored at least one mark here.

(d) Appropriate use of significant figures is particularly important in Section A. Calculated quantities should be shown to the number of significant figures of the data with the least number of significant figures. 53.4% of students gained this mark.

(e) A significant number of students disregarded the instruction "without drawing another graph" and chose to describe how to test the relationship by drawing a graph. They did not appreciate the significance of the term "directly proportional" and could only apply it to descriptions of the graph one would expect for such a relationship. Students were unable to describe how such a relationship could be tested by non-graphical means. A common error presented was that a linear relationship was the same as a directly proportional one. This was evidenced by statements such as "constant gradient", "straight line", "as a increases, n increases". Disappointingly, only 6.9% of students scored the mark.

Q2.

(a) Many students were able to demonstrate how to reduce the effect of the systematic error but only 12% were able to gain both marks. The main reason for this was the lack of detail in the description of how to reduce the effect of random error. Students need to ensure they give sufficient detail that is relevant to context and not limit answers to superficial "repeat and average" statements.

(b) Many students were unfamiliar with how to use vernier callipers to measure internal diameters and lined up the magnet with the lower jaws instead. 31% of students were successful here.

(c) High ability students dealt confidently and competently with this calculation. Their working was well-laid out containing few errors and no mid-calculation rounding. Other students gained some credit for partial workings where their method demonstrated some stages in the process. Students would be advised to ensure their workings are well-laid out with appropriate subjects to their calculations as this makes their partially correct work more convincing and more likely to receive compensatory marks. Some students attempted to find the difference in the diameters and use this in the formula for area rather than determining the areas separately and then determining the difference in areas.

(d) The students often made little headway in this question. The plans seen lacked details on how to vary the mass and how to record the value of h. Many students did not know how to process the data to obtain a straight-line graph for $F = k\,h^{-3}$. Just over 40% of students managed to score at least two marks here.

Q3.

Most students were not able to deal with this uncertainty calculation (30.1% correct). The most common incorrect answer was distractor C; these students did not know how to deal with the square root and instead added the percentage uncertainties together.

Q4.

46.6% correct

Q5.

This question addressed some of the ideas behind required practical activity 10.

(a) Much of the working seen convinced examiners that the students had taken moments about the pivot, although some used 30.0 rather than 29.0 in the calculation. A few forfeited a mark by rounding their result to two significant figures. Weaker students attempted a solution based on proportions of the balance reading shown in Figure 2, while others simply copied the balance reading on to the answer line. While some stated the assumption they made was that the ruler was in equilibrium, examiners were looking for a statement implying that the ruler was uniform or that the centre of mass was at the 50 cm mark. Significant numbers of students gave a creditworthy assumption although those that stated “the ruler has uniform density” or “the mass is in the middle” were unsuccessful. Just over two-thirds of students scored at least one mark.

(b) The key failing of some students here was (surprisingly) that they seemed to think that the current direction was self-evident and not worthy of comment, even if they had correctly deduced the direction of the force (despite some tying themselves in knots with Newton’s third law). Some students relied on the examiners spotting relevant annotation made to Figure 3. Statements that the current was ‘from positive to negative’ or ‘clockwise’ were not accepted. Unless the directions of the force and the current were both stated, no credit was given for stating the direction of the field. Logically correct deductions, based on incorrect force and/or current directions, could score as long as the left-hand rule was mentioned in support. For these reasons, approximately a third of the students scored one of the three marks and nearly another third scored zero. Thankfully, 17.1% gave a detailed, fully-justified and correct response earning full credit.

(c) Most students recognised that they should find the gradient of the graph in Figure 4 to score the first mark, although a minority predictably failed to spot at least one of the false origins. Some mistakenly thought they should use the information in Figures 2 and 3, and others thought σ was the value of M when the current was 1 A. Correct use of 9.81 earned the second mark for many. While few students failed to correctly insert 5 cm into their calculation for B, most struggled with the various power of ten issues. This discriminated strongly in favour of the better students who could expect to score at least two marks.

(d) The first row of Table 1 attracted the most correct responses and thereafter things got patchier. Examiners needed to see correct responses in both row 3 and row 4 to earn the third marking point; this proved beyond all but the most able, with only 11.4% obtaining full credit.

(e) The need here to get the currents in X and Y travelling from left to right was met in most, but by no means all, solutions by drawing a parallel circuit. However, to guarantee that the currents had the same magnitude, X and Y needed to be in series. This involved a figure-of-eight arrangement; the subtlety of this was lost on all but 7.9% of the students. The majority of diagrams were drawn freehand and were often untidy so that, in some cases, gaps were left and no credit could be earned. The addition of superfluous detail such as a voltmeter sometimes led to unworkable circuits. A surprising proportion of students (11.5%) did not attempt this question.

(f) This was for many the most successful part of the paper, so much so that most students ran out of space in their enthusiasm to set out their solution. There were four marks available for outlining a suitable strategy and students could earn any three of these for maximum credit. In common with the approach on paper 7407/2, examiners insisted on seeing that the dependent variable, correctly identified as m or F, was 'read', 'measured' or 'recorded'. These are the terms examiners expect students to use if similar questions are posed in future papers. Students were split on whether the perpendicular distance d or the current I would be the independent variable, but were nearly universal in their conviction that the balance reading would be the dependent variable. Despite being told that the pan of the balance moves a negligible amount during use, a few students decided that in varying I they could make d the dependent variable. Some students penalised themselves by overlooking the need to measure the length L of wire X. Others failed to clearly identify the remaining control variable and to state that this too should be measured. A few students thought the balance read the vertical force F directly, but many correctly saw the need to introduce g. The analyses given were impressive and varied; most could explain a relevant graph with m or F involved somewhere on the vertical axis. Examiners took statements such as "plot F against I 2" to mean that F was the dependent variable and would be plotted on the vertical axis, otherwise the use of the gradient to find k could not be verified. Most students gave an expression to show how their gradient could be manipulated to obtain k; examiners expected k to be the subject of this expression. There was strong representation at each mark for this question, from zero to five; 16% of students obtained full credit for their answer.

Q6.

This question addressed the general practicalities of making measurements (which was conspicuously poorly-answered in 2017) and use of log graphs to discover power laws.

(a) Two approaches were seen for obtaining the vertical distance y. The indirect approach involved measuring the height of the tape (from the floor) at the free end and subtracting this from the height of the bench. The two measurements involved required the use of a vertical ruler and how this was to be achieved was widely ignored. Examiners were looking for the use of a set-square in contact with the ruler and the floor to make the ruler vertical, a detail that could easily be provided if the students added detail to Figure 7 as was suggested. That so few chose to follow this advice explains why barely 10% were able to score both marks. Another suggested method employed a horizontal reference, established by laying a straight edge along the bench to overhang the free end of the tape. A ruler (made vertical with a set-square) could then measure y directly. Those students taking this route were more prepared to add detail to the diagram, but often showed the straight edge failing to reach the bench or omitted detail involving the set-square. Other approaches, where safe and relevant, could earn credit, such as the use of a plumb line or spirit level. Those who suggested using bits of string, lasers or trigonometry did not gain credit. Disappointingly, nearly half of the students failed to gain any credit for their answer.

(b) Many students identified that y would become very small if x was less than 70 cm but barely 10% correctly stated that this made the percentage uncertainty in y unacceptably high.

(c) All of the marking points discriminated well but not always in combination, so only 10.2% of students scored all three marks. The line quality was usually good, but examiners expected the line to pass above the first and below the sixth points: a surprising number of students drew their line passing through or below the first point. The result of the gradient calculation usually fell within the expected range, but those who truncated it (usually to 4) were penalised. In addition, those who copied their gradient result onto the answer line for n failed to recognise that an integer was expected, so they too failed to score.

(d) About half of the students correctly stated that log A was the (log) y-intercept and many then correctly explained how, having obtained the intercept, they could calculate A. A few spoiled their answer by using base 10 for the first point and base e for the latter, and others, anticipating 02.5, stated that they would use data from Table 2. With a three-mark tariff, it was surprising how few students provided detail of how the intercept could be calculated indirectly, a comparatively easy process to describe if done carefully. Over a third of students scored two marks, but very few (4.3%) scored all three.

(e) The work seen here was sometimes very good and two-thirds of students could at least produce a suitable value for A. The problem for many was identifying the order of magnitude (most simply copied their result for A onto the answer line). To a lesser extent, many struggled to identify the unit, particularly when a non-integer was given for n. For a typical value of A, using the top row in Table 2, a result of 1.99×10^{-7} was routinely obtained. Examiners accepted -7 or 10^{-7} for the order of magnitude and cm^{-3} for the unit. A non-integer n such as 3.3 would produce $A = 6.09 \times 10^{-6}$ so the order of magnitude is -5 and the unit $cm^{-2.3}$. As with question 02.4, all the marking points were accessible, but it was unusual to see all scored together; just less than 10% gained full credit.

Q7.

This question addressed some of the ideas behind required practical activity 8.

(a) Many students stated that the volume of air in 9c was less because water had entered the flask, but the better students realised that the expected response was that the pressure of the air had increased. Only 16% qualified their answer by adding that the temperature was the same for the situations in 9c and 9d, or that Boyle's Law could be applied. Some disqualified themselves by stating that air entered the flask as it was raised. Knowledge of the gas laws seemed generally patchy, with only approximately 40% of students making progress with this question or with 03.2.

(b) Many answers suggested that Charles's Law was even less well understood than Boyle's Law. Only the better students realised that they were being asked to give two conditions that should be met if Charles's Law is to apply. While some correctly stated that pressure must remain the same, only 7% added that the mass of gas must be constant.

(c) The direct and the indirect approaches to finding the volumes proved equally popular, but a small minority of students tried unsuccessfully to use some variant of the gas laws. Examiners expected a measuring cylinder to be used for the direct method and wanted students to explain that the reading was taken with the eye level with the bottom of the meniscus to avoid parallax error. Very few could give a completely correct response. For the indirect approach, examiners gave no credit for ‘scales’ rather than ‘balance’ (the instrument had been clearly identified in question 1) and rejected the idea that mass could be ‘weighed’. However, many students gave a sensible way to account for the mass of the flask when determining the mass of water and could explain how the volume was obtained, as the density was known. Examiners did not allow “1 g = 1 cm3”, variants of which were seen rather too frequently. As with question 01.6, students frequently wrote more than they needed to, yet the number scoring all three marks (5.1%) was disappointing.

(d) Many students plotted (19, 48) which probably saved the graph scaling mark but ruined their chances of earning full credit in question 03.6. Those plotting the correct (19, 207) and (86, 255) often chose to include the origin, compressing the scale. A minority plotted (19, 255) and (86, 48), producing a graph with a negative gradient. Nearly 60% of the students scored at least two marks.

(e) The lines drawn were of mixed quality. Unfortunately, some students forced the line through the origin. Examiners expected the line to pass through both plotted points, yet over 40% of students were unable to score.

(f) The work here was sometimes very good and usually easy to follow. Even when the line had been drawn to pass through (19, 207), producing a small positive value for absolute zero, the students tried a logical approach to the problem and duly gained some credit.
Clearly at this point, the students who had produced a graph with a negative gradient should have been asking themselves some serious questions, so it was disappointing to see how few revisited question 03.4 rather than optimistically writing down −273. Students need to be reminded they should inspect their work before moving on. Those who did everything right but omitted the minus sign with their result would be annoyed by their oversight. Over half of the students made some progress and more than 20% obtained full credit.

Q8.

(a) The success-rate on this question was more than 90%. Common wrong answers seen included 21.1 Ω and 8.2 Ω, both suggesting that the students did not read the question carefully enough. (21.1 Ω is the sum of all four resistors while 8.2 Ω is the value of the largest single resistor.)

(b) This showed a much greater range of attainment by students; over 60% of students obtained 2 marks. Many students offered 6.1 Ω as the answer, treating the series combination of 2.2 Ω and 3.9 Ω as the lowest possible value. Other students did not invert the sum of in the final step, leaving their answer as 0.71 Ω.

A significant number of candidates were unable to add two fractions:

$\frac{1}{2.2}+\frac{1}{3.9}$ and believed the answer to be $\frac{1}{6.1}$.

Another common incorrect response was

$\frac{1}{8.2}+\frac{1}{6.8}=0.27$

This error clearly demonstrated a poor understanding of the effect on resistance of combining resistors in parallel, and a lack of knowledge of the mathematical process used to determine the resistance of two resistors in parallel.

(c) Students' level of achievement in questions involving internal resistance would be improved if they were encouraged to concentrate on the effect the current has on the terminal pd. Students are expected to treat voltmeters as ideal, that is having infinite resistance. This being the case, students should recognise that the current is zero and therefore the terminal pd equals the emf.

Students had difficulty with this question, suggesting significant gaps in their understanding of emf, terminal pd and resistance. Many students stated that resistance between X and Y is zero when there is no resistor connected between X and Y.

This misunderstanding led students to believe that a current was flowing and/or all the voltage was across the internal resistance. Others stated that the voltmeter was the only component in the circuit without stating why this meant that it read the emf, or students stated that without a resistance between X and Y there was nowhere else the voltage could be lost than across the internal resistance.

Students need to be made aware of the fact that the voltmeter cannot directly read the lost volts and should be encouraged to consider the formula in this form:

Terminal pd = $\varepsilon - Ir$

A significant number of students believe that in a parallel circuit, or a series circuit that includes a voltmeter connected in parallel, resistance increases when a switch is closed. These students will state that current decreases when a switch is closed thus neglecting the fact that the resistance between the contacts of the open switch can be considered infinite compared to resistance elsewhere in the circuit.

High quality answers addressed the very high resistance of the voltmeter and the effect this had on the current and the lost volts.

(d) Many students thought that the resistance in the circuit increased when the resistors were added between X and Y. These students often stated that the current in the circuit decreased when resistors were added.

Other students stated that the voltage decreased because it was now shared between these (external) resistors. This response showed a lack of appreciation of the fact that the voltmeter was connected across both resistors, as well as demonstrating a lack of awareness regarding the impact of the internal resistance. Students were required to relate the sharing of the voltage between the internal and external resistances.

The focus of many answers was incorrect. This question is about terminal pd, internal resistance and current. Students should remember to make sure their answers address these main points; too often the answer centred on limited descriptions of what would happen to the two resistors connected between X and Y.

(e) Students should be aware of the need to quote numerical answers in section A to an appropriate number of significant figures. Students did not obtain the mark when they quoted $\frac{V}{R}$ as 0.126 rather than as 0.13.

(f) Many students plotted (0.115, 0.48) instead of (0.13, 0.48). Reading of scales needs to be done with care to avoid this type of error. The line of best fit needs to be drawn with due care. Students should be encouraged to draw lines of uniform thickness without any discontinuities.

(g) It is considered good practice to draw a gradient triangle on the line of best fit. Students were expected to draw a suitably large gradient triangle where the change in voltage was at least 0.5 V. In general, the triangle should be as large as possible, choosing points that can be read accurately. The points used should be indicated by labelling of the values on the line and subsequent working should be clearly presented.

In cases where a student used a single point from the line and substituted this into the equation of the line they received a maximum of 1 mark.

Common errors seen included:

- Read-off error of the y co-ordinate at the point the line cuts the x-axis;
- Read-off error of the x co-ordinate at the point the line cuts the x-axis;
- Choosing to use a gradient triangle that was too small.

(h) The first mark was straightforward, awarded for stating that the number of values available was less in the new method. Many students were under the impression that in the second method the resistors could not be connected in parallel. Answers that discussed the range were treated as neutral because the question asked the students to consider the number of different values of R available in method 2 compared to method 1. The second mark was harder to achieve; the students had to appreciate that this method yielded 6 values for R. Less than 20% of students obtained both marks.

Q9.

(a) This question asked students to explain why taking repeat readings was desirable in determining a value for *w*. Many students stated that this enabled a mean to be determined but did not explain the advantage of this. The question required students to explain why the mean was an improvement over a single reading. Appropriate, technical language was expected and students would do well to familiarise themselves with the glossary of terms in the online Practical Handbook.

(b) Just over 20% of students performed this calculation correctly. Many students correctly calculated the mean of *w* but then used ± 0.01 mm as the absolute uncertainty rather than $\pm \frac{\text{range in } w}{2}$.

(c) Higher achieving students performed well in this calculation, with 30% of students obtaining 2 marks. The calculations presented by these students were structured in an easy-to-follow way. Lower achieving students were less sure about how to proceed with this calculation but compensatory marks were available for certain partially correct workings shown. Students should be encouraged to set out their working in a way that demonstrates their thinking to the examiner. Marks can only be awarded for working seen on the script.

(d)/(e) The term precision was used to describe the **resolution** of the Vernier scale. This term was not used in the manner defined in the Practical Handbook and will not be used in this way again. It is not believed that the use of the term here disadvantaged any student; this is a piece of equipment that uses the type of scale students are expected to have used as described in section 7.1 ATe on page 80 of the specification.
Surprisingly, less than 20% of students read the Vernier scales correctly. A very

large number of students ignored the zero on the sliding Vernier scale and read off the values as 80.5 mm and 78.3 mm respectively.

(f) Many students carried out this calculation correctly, but too often this was preceded by poor reading of the Vernier scale. Weaker students often got confused with powers of ten, wrongly converting from centimetres to metres, often in the final stage. Some students misunderstood the situation and simply found the mean of the answers from part (d) and part (e).

Q21.

(a) Correctly answered by almost all candidates.

(b) As usual in this question a small proportion of candidates failed to accurately plot both points and an even greater proportion were unable to draw an acceptable line of best fit.

(c) Less marks were lost on this question than in previous years, most likely because these were mostly A2 candidates re-sitting the paper. Most candidates were able to calculate a gradient value within the allowed range.

(d) This was straightforward for nearly all candidates.

(e) A familiar question, well answered by most candidates.

Parts **(f)**, **(g)** and **(h)** discriminated well, with only the most able candidates scoring five marks or more.

(f) The easiest part of the question, requiring use of ‘uncertainty = 0.5 × range’

(g) Although this was considered to be straightforward, many candidates failed to score the full three marks. Common errors were incorrect substitution into the formula and missing the unit in the final answer.

(h) This was the most discriminating part of the question, with candidates often scoring no marks. The process of adding percentage uncertainties to calculate the percentage uncertainty in the calculated value of g, and then converting back to an absolute uncertainty with suitable significant figures and unit was beyond most candidates.

(i) This proved to be difficult, and only the most able candidates scored more than one mark. An easy mark was often lost by lack of reference to measuring the mass of the spheres with a balance. Many candidates failed to realise that for a fair comparison the spherical objects would need to have the same diameter so that air resistance was the same.

Q22.

This question discriminated well, with only the most able candidates scoring four or five marks.

(a) (i) Some candidates attempted to measure the largest distance, between the initial and 4th position. A tolerance of +/-1 mm was allowed on their measurement.

Fewer candidates attempted a second measurement, although the question clearly referred to measurement<u>s</u>

(ii) This proved to be much more difficult, and candidates had to compute the correct time interval for the distance measured, and then use the correct formula. Only the most able candidates were able to compute a correct value for *g*.

(b) Fewer than half of the candidates appreciated how the sharpness of the image would depend on the duration of the flash.

Q23.

(a) Correctly answered by almost all candidates.

(b) As usual in this question a small proportion of candidates failed to accurately plot both points and an even greater proportion were unable to draw an acceptable line of best fit.

(c) (i) A large proportion of candidates ignored the powers of 10 on the graph axes.

(ii) A good discriminator, with only the most able candidates giving the correct unit.

(d) (i) A straightforward question with all but the weakest responses scoring both marks.

(ii) A good discriminator, with only the most able candidates correctly using '$y = mx + c$' and substituting data from the table or graph to find intercept *c*.

(iii) Only the most able candidates correctly identified the systematic error to be in *w*.

(e) Not well understood by many candidates, with only a small proportion referring to single slit diffraction.

Q24.

As anticipated this question provided good discrimination.

(a) Most students attempted to count and measure a large number of fringe widths. A common error was to measure from the first to the fiftieth fringe, but count this as 50 fringe widths rather than 49.

(b) Weaker responses were unsure how to calculate the uncertainty in a single fringe width from the uncertainty in the total measurement.

(c) (i),(ii) & (iii) Many candidates failed to score on any part of this question, despite part **(i)** being a straightforward substitution into the formula quoted. The uncertainty calculations in **(ii)** & **(iii)** were only successfully completed by the most able candidates.

Q25.

In part **(a)** most showed that $\sin\theta_1 = \frac{XZ}{WX}$ and $\sin\theta_2 = \frac{YZ}{WY}$ to earn a mark but some missed a key step in the manipulation that followed in arriving at $\frac{(XZ) \times (WY)}{(WX) \times (YZ)}$

In part **(b)** the majority saw we expected a simple application of the $y = mx + c$ idea and gained both marks.

Part **(c)** proved challenging for the candidates, most of whom made only limited progress by making an observation without any supporting explanation, e.g. by comparing the largest XZ value with the length of the block or by computing the diagonal distance across the face of the block and comparing this with the largest WX value. We wanted the candidates to discuss whether the limiting values of the data in the table showed if a suitable range had been used. Clearly the upper limit was ideal but the lower limit raised the question of whether such values could be measured without attracting a significant percentage uncertainty.

Better answers seen compared the range of the XZ data with the length of the block but we saw very few responses that earned full credit.

Several candidates used each row to calculate six values of refractive index and decided on the suitability of the data looking at the spread of results. Others judged the quality of the data based on the intervals between the values in each column. These approaches earned no credit.

Few could score more than 5 out of 7. A/B candidates scored between 3 and 5 while E/U candidates usually scored 1 or 2.

Q26.

Many were successful in part **(a)** although a few found the distance between the edges of adjacent holes (despite this they were still able to go on and successfully attempt part **(d)**).

Success with part **(b)** was almost universal, candidates clearly taking the cue from the precision implied in the readings for R_1 R_2 and R_3. Instances were seen where candidates gave 0.005 mm as the precision and these answers gained full credit.

Part **(c)** was a different matter: most chose to use the ratio of their previous answers to find the percentage uncertainty, e.g. $\frac{0.01}{1.43} \times 100$ and only very few saw that the method required was $\frac{2 \times 0.01}{R_2 - R_1} \times 100$. We gave a mark if the answer given showed 2 × precision given in **(b)** in the numerator but otherwise very few were able to score.

Many correct answers were seen to part **(d)** although the solutions were often too convoluted to follow.

A/B candidates typically scored 3 or 4 out of 6 but E/U graders often struggled to score more than 1.

Q27.

(a) Correctly answered by almost all candidates.

(b) It was rare to see misplotted points on this graph. The line of best fit was more difficult due to a deliberate scattering of points around the line, and a proportion of candidates were unable to draw an acceptable line.

(c) A relatively straightforward gradient calculation, although weaker responses often missed the negative sign.

(d) The most able candidates were able to score the full three marks but a proportion of weaker responses often quoted an incorrect unit or were unsure of the value of λ.

(e) This was a difficult question, requiring an understanding of how a systematic error in *h* would affect the log values. Only the most able students accessed the full three marks.

(f) Accessible across the ability range, although weaker responses were often unsure as to how this error might affect the value of λ.

Q28.

Encouraging numbers knew to say in **(a)** that the fiducial mark is placed at the equilibrium position because this is where 'the transit time is least' or 'the speed of the mass is greatest' but it was common to find statements such as 'this is where the mass must pass through in every oscillation' which attracted no credit.

Part **(b)(i)** and **(b)(ii)** were routine calculations in which candidates were usually successful although errors for the frequency arose due to rounding down earlier in the calculation. Full credit could be earned if the correct result for percentage uncertainty was reached using *T* rather than 20*T* but we withheld a mark in **(b)(ii)** if no unit was seen.

Part **(c)(i)** was very good and we took account of an incorrect **(b)(ii)** answer that led to an unexpected scale. We expected the scale to be linear and at least three convenient intervals marked. For the expected of 0.88 Hz result in **(b)(ii)** the 1 Hz intervals on the axis should have been 40 mm apart.

Many stated in **(c)(ii)** that the initial amplitude of X was 4 mm but a common error was to read off the amplitude at resonance (95 mm).

Part **(d)** was the most discriminating part of this question. In **(d)(i)** many grasped the idea behind the question but simply saying 'take more readings' was insufficient and only gained one mark. Some candidates avoided any ambiguity by saying 'the intervals between the frequency readings around the peak were reduced' to earn full credit. A common but unsuccessful idea was to assume a data logger was in use and to say that the sample rate was increased around the peak.

In **(d)(ii)** saw that removing one spring doubled the stiffness and increased the resonant frequency by a factor of $\sqrt{2}$. The new curve now had a resonant peak at about 1.25 Hz which for an axis with the expected calibration was 50 mm along the axis. Some spoiled their answer by starting the curve at 0 Hz with amplitude less than 4 mm.

Unlike last year the full mark range was utilised and the question discriminated very well. Those at the A/B boundary usually earned between 7 and 9 out of 11 and E/U candidates often scoring between 4 and 6.

Q29.

Although all saw the intention of the question in part **(a)** it was difficult to see enough merit in the response, seen many times, that 'callipers cannot grip water'. To earn the mark we wanted a clear indication that using the callipers would distort the flow, changing the diameter in the process.

In **(b)(i)** virtually all drew an acceptable line and attempted a valid gradient calculation to

find the integer *n*. Many predictably forgot that *n* was an integer or omitted the negative sign. Some calculated the log *s* and log *d* steps but then anti-logged these before calculating the ratio.
Many correct answers were seen to **(b)(ii)**. Those who wrote $k = 10^{\log k}$ needed to have clearly explained that log *k* was the intercept otherwise the mark was withheld. Those who said $k = 10^{0.52}$ by mistakenly failing to notice the false origin in Figure 2 were not penalised. The many who claimed $k = e^{\text{intercept}}$ gained no credit.
In **(b)(iii)** we expected cm^5 but we did not penalise for m^5 etc or for any logical consequence of a non-integer result for *n* in **(b)(i)**.

This was another discriminating question with those at the A/B boundary typically earning 3 or 4 out of 5 and E/U candidates scoring between 1 and 3.

Q30.

This question was about the determination of the Young modulus of the metal of a wire, one of the six required AS practicals. It gave students the opportunity to demonstrate familiarity with a range of practical equipment and techniques.
The work seen suggested that the majority of students were familiar with the experiment and could process the raw data. Problems arose when students were asked to comment on the effect of changing the dimensions of the wire, for example.

(a) Vernier scales are a common feature of the equipment used to measure extension in a Young Modulus determination. Many students were unable to give the correct answer, however, with 2.8 mm a fairly common error.

(b) Students were allowed to carry an error forward from (a) and many students were able to read the scale correctly. Where the answer to (a) fell outside the graph some students attempted to extrapolate or carry out a y = mx + c calculation; these students may have benefited from checking their answer to (a) first.

(c) Most students were able to correctly compensate for the zero error in the calliper reading, although adding it to obtain 0.37 mm was fairly common. Some students also attempted to use the 20.14 mm value seen at the top of figure 3.

(d) This calculation was reasonably well carried out with the majority of students getting at least 3 marks out of 4. Although students should be encouraged to use the gradient of figure 2 to help calculate a value of E, the use of individual points was acceptable on this occasion. It was common to see the values obtained in the previous three sections used to work out the cross sectional area, and then the strain and stress separately, before combining them to calculate E. The two common errors in this approach were the use of the diameter for the radius, and missing out "g" in the calculation of the force. Several students also made powers of ten errors in the cross-sectional area calculation, or mixed their units in the calculation of strain. This commonly led to the fourth mark being lost.
Students should be encouraged to set out their answers logically so that it is easier to check for errors. Some students inevitably lost marks if they made an error attempting to perform the calculation in one go. Over reliance on the data sheet also led to problems with some students using $F = k\Delta l$, and using the Boltzmann constant for k.
Any errors from (a), (b) or (c) were carried forward so that no student was denied the opportunity to earn subsequent marks.

(e) When guiding students with their responses to questions such as this it is important to emphasise the need for clarity in expression, as examiners cannot credit ambiguous or vague answers. To gain credit, answers required an outcome (e.g. the extension increases) and consequence (the percentage uncertainty in E decreases).

It was common for students to miss out the word 'percentage' but on this occasion this was not penalised. There were several different correct approaches but each was accompanied by its own common errors. For example, students who simply stated that the wire would get longer, rather than the extension would increase, failed to get the mark. Students who based an answer on the increased percentage uncertainty in the measurement of the diameter often failed to go on to state how this would affect the percentage uncertainty in the value of E. It was also relatively common to see incorrect physics, for example answers claiming that the value of E would be affected.

Q31.

(a) Students should expect to be required to interpolate between grid lines when plotting points. Most students were able to do this satisfactorily, but errors reading the ε scale were surprisingly common. Another issue was associated with the style of point used. The standard has been long established in the legacy EMPA and ISA tests: thick points or blobs were not accepted.

(b) Thick, discontinuous, faint or straight lines forfeited this mark. Whilst some excellent lines were seen in answer to this question, some lines were thick enough to obscure the points. The line was expected to pass within half a grid square of all of the points. It was common to see careless drawing near the last point (392,1241), which lost the mark. Where it was clear that the points were incorrectly plotted far from the trend line it is surprising that students did not go back and check their answer to (a).

(c) An error was carried forward from their answer to (b) and most students were able to read the maximum correctly to half a grid square. However, it was common to see 1456 (the maximum in the table) even when the line on the graph did not support this value. 1335 was a common incorrect answer, suggesting that students were treating the ε axis as a number line.

(d) This question discriminated in favour of those who could write without ambiguity. Examiners were looking for an answer that explained that θ_n could be found from figure 3 simply by reading off where the value of G was zero (280 °C). Answers that discussed the difficulty of reading the value from figure 2 as there is a range of values for which ε is at, or close to, a maximum, also gained credit. Unfortunately many students implied that the gradient of figure 3 was easier to measure, or stated that finding where the gradient was zero was easier on figure 3 (seeming to suggest that there is such a point on figure 3). Some erroneously wrote about the relative difficulties of reading a point from a straight line rather than a curve. It was also relatively common to see comments referring to the different scale ranges in the two diagrams.

(e) Many very good answers to this question were seen, clearly demonstrating an understanding of the equation of a straight line and an ability to obtain data, such as the gradient, from a graph. An alternative acceptable approach was to use the values from two points and solve the two simultaneous equations produced. Many students incorrectly thought α was the value of G where the line touched the y-axis, and extrapolated the line back and extended the axis to find this point. Others mistakenly took α to be the gradient.

(f) Although many correct answers were seen, some suggested that several students were unfamiliar with the term “full scale deflection”, despite this being defined in the question. Others did not spot the μ on the answer line, writing down a value of 0.1 without changing the unit to match.

(g) There were many answers expressed so poorly that credit could not be given.

Common examples were “the scale is too large”, “the divisions are not small enough” and “the scale does not have enough divisions”. Discussions related to accuracy gained no credit either. The best answers made it clear that the resolution of the meter was unsatisfactory, supporting this with a relevant calculation, such as the change in pd represented by one division (2000 μV). There was consideration made for answers based on an incorrect answer to (f). For example, those who had calculated the full-scale deflection to be 0., could gain credit for arguing that the range of the meter was inadequate. Several unsuccessfully argued that it was the susceptibility of the analogue meter to parallax error which made it unsuitable.

Q32.

(a) Acceptable answers were seen regularly and showed that many students understood the nature of the question about how modern military, industrial and medical practices and also the increased use of air travel by the public have led to an average increase in exposure to background radiation. A significant number of students failed to gain the mark by being too brief. They gave answers like, 'medicine' or 'flying'. With a few more words these could have been converted into scoring answers. There were also some students that simply quoted a source of background radiation such as 'cosmic rays' and 'radon gas'.

(b) (i) A majority of students could use the inverse relationship correctly. The main problem came in dealing with the background. About half subtracted the background from the 2050 but following the calculation very few of those added the background to obtain the expected reading.

(ii) A large number of students failed to refer to the randomness of the count-rate in any respect. They instead focused on the number of counts being reduced because of the distance from the source. Alternatively some tried to express the idea that the background had more effect at larger distances. The idea that a larger count helps reduce the statistical percentage uncertainty inherent in smaller readings proved too much for the vast majority of students.

(iii) A range of approaches were accounted for within the mark scheme and a range of responses were seen. The most direct, common and successful approach was the use of a sensible absorber placed between the source and detector. There were a number of students who did not know the approximate thickness of a material that would absorb most of the beta particles. The most common alternative approach was to consider the count- rate fall with distance. Using this approach a majority did not compare the count-rate with the expected inverse square function in and out of the range of beta particles. Most simply thought the count-rate would suddenly fall as the detector moved out of range of the beta particles. While some non-standard approaches could gain full marks, such as the use of magnetic/electric fields and cloud chambers, students were expected to say exactly how the nature of the suspected beta radiation would be revealed which proved too much for the majority who took these routes.

Q33.

(a) (i) Correctly answered by almost all students.

(ii) As usual in this question a small proportion of students failed to accurately plot both points and an even greater proportion were unable to draw an acceptable line of best fit.

(iii) The most common error by weaker students was misreading data from the graph. Most students were able to calculate a gradient value within the allowed range.

(iv) (1) This was straightforward for all but the weakest students, who failed to quote the correct force components.

(2) A better discriminator, with weaker students unable to score both marks.

(3) This should have been straightforward, but a significant proportion of students were unable to compute the correct value of *m* and quote it together with appropriate unit and significant figures.

(v) (1) This proved to be a very demanding question.

(2) Only the most able students were able to offer the correct option of taking the mean value of data from loading and unloading.

(b) The most popular answer was reference to use of a light source to project a shadow of the string onto the paper. Explanations in terms of ‘parallax’ were poor, with only the more able students achieving both marks.

(i) A proportion of weaker students were unable to correctly draw the string positions on the crosses despite there being an exact replica of the diagram on the page.

With the correct ‘lines’ drawn on the diagram, a large proportion of students successfully measured the correct angle with their protractor. Only the most able students were able to calculate the percentage uncertainty in their measurement and quote this to an acceptable number of significant figures.

(ii) As intended this question provided discrimination for the more able students. Reference had been made to the percentage uncertainty in their angle measurement in (b)(i), and it was expected that more able students would carefully consider the appropriate number of significant figures to use when calculating the angle from distance measurements. In practice most students did quote the angle to within 0.1° as required by the markscheme. Weaker students lost credit by measuring distances well below the minimum of 70 mm allowed in the mark scheme.

Q34.

(a) (i) Correctly answered by almost all students.

(ii) As usual in this question a small proportion of students failed to accurately plot both points and an even greater proportion were unable to draw an acceptable line of best fit.

(iii) The most common error by weaker students was misreading data from the graph. Most students were able to calculate a gradient value within the allowed range.

(iv) A large proportion of students correctly calculated the value of *R*. A small proportion of students lost credit by failing to quote the unit.

As anticipated this proved to be a demanding question, with only the very best students achieving full marks on all four parts.

(b) (1) Most students successfully calculated the value of *R* from the data in the table.

(2) Only the more able students successfully calculated the percentage uncertainty in *R*. The most common mistakes were failure to double the percentage error in *V*, and correctly add this to the percentage uncertainty in *P*. Credit was also lost by the significant figure penalty on the final answer.

(3) A relatively easy calculation but made more demanding by the requirements for correct units and significant figures.

(4) This was the most demanding part of the question, and required students to use the uncertainty value calculated to work out the possible range of values of *R* to decide whether the two values were compatible.

Q35.

(a) (i) Students had to make it clear that the voltmeter 'alone' should be connected across the cell.

(ii) A correct explanation was given by a large proportion of students.

(b) (i) Answered well by the more able students.

(ii) A proportion of students seemed to understand how to use the voltmeter but failed to show the correct position on the circuit diagram.

(c) This question discriminated well. Many students failed to give sufficient detail as required by the mark scheme for the first marking point. The second marking point proved to be more accessible, with a greater proportion of students able to suggest an appropriate precaution.

(d) As anticipated this proved to be very demanding, with only the more able students successfully stating and explaining why efficiency would increase as external resistance increases.