AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.1 MEASUREMENTS AND PRACTICAL SKILLS

SCORE	PERCENTAGE
/311	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

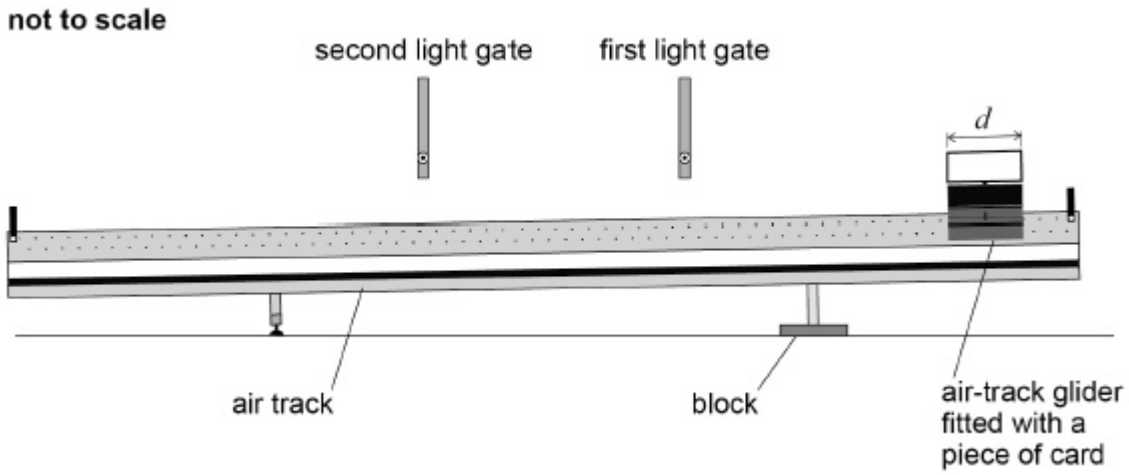
AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

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.

STEMUP.CO.UK

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.

_____

_____

_____

_____

_____

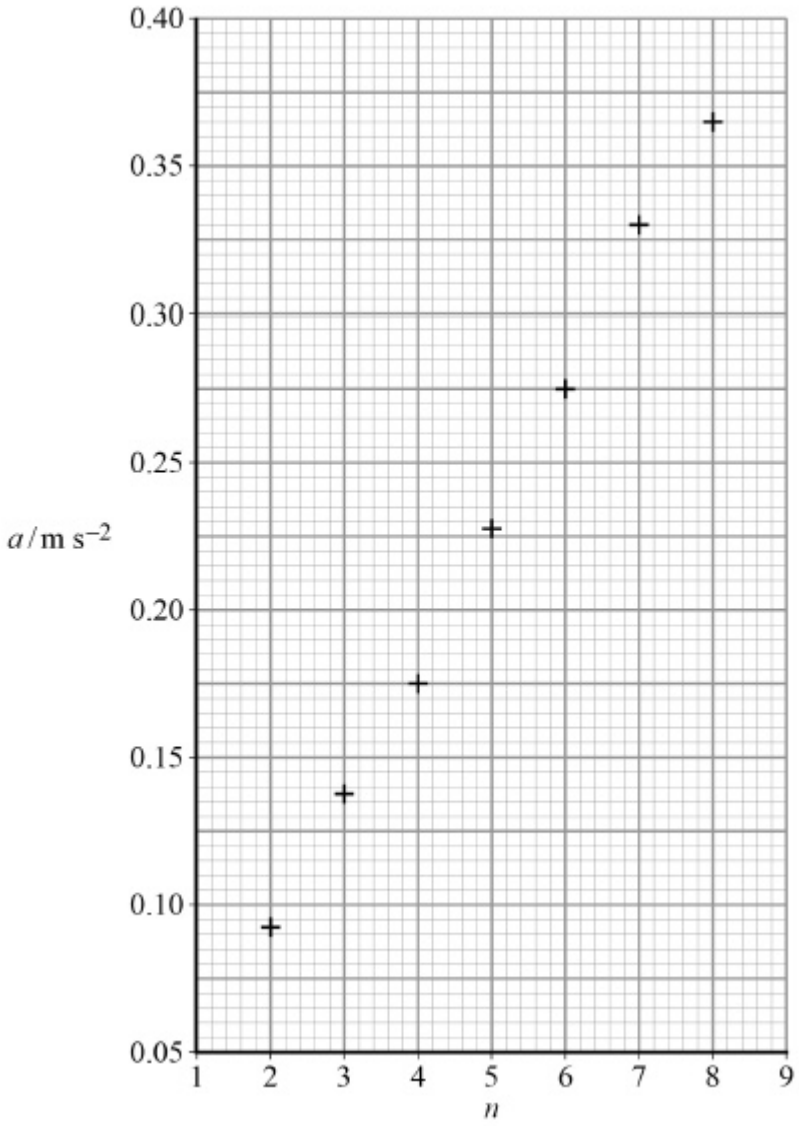
(2)

(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

STEMUP.CO.UK



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)

STEMUP.CO.UK

(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.

_____

_____

_____

_____

_____

(1)

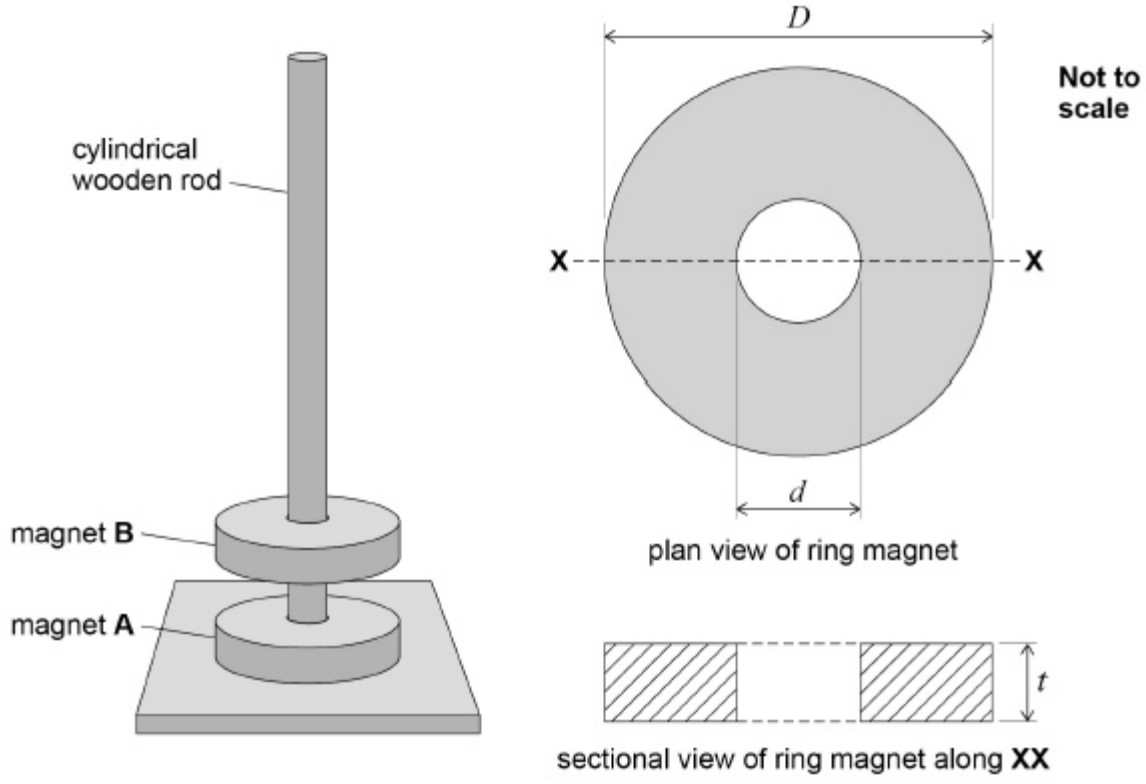
(Total 9 marks)

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.

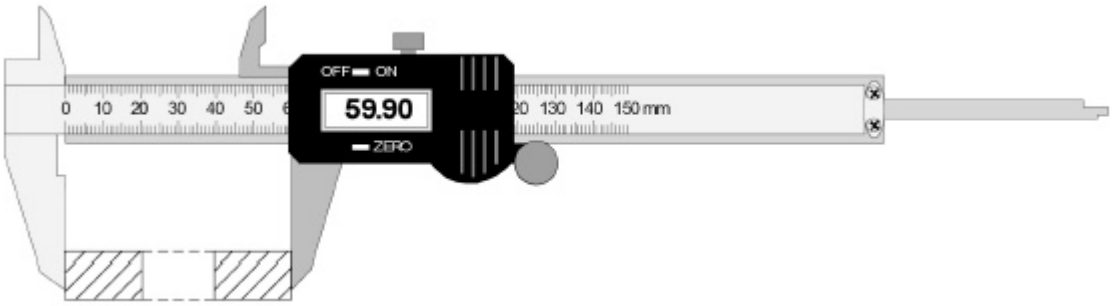
Figure 1



STEMUP.CO.UK

(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:

_____

_____

_____

Precaution to reduce effect of random error:

_____

_____

_____

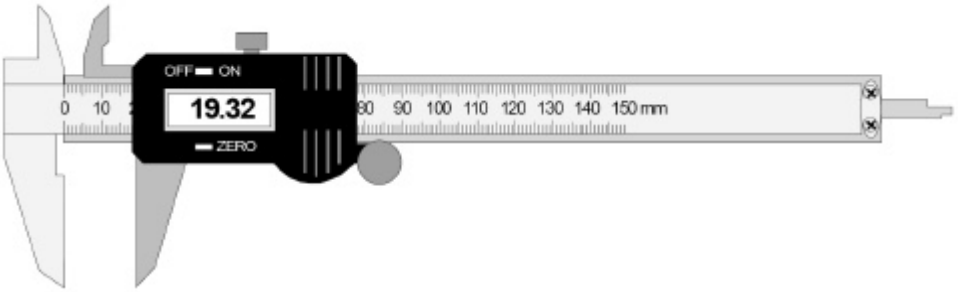
(2)

(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

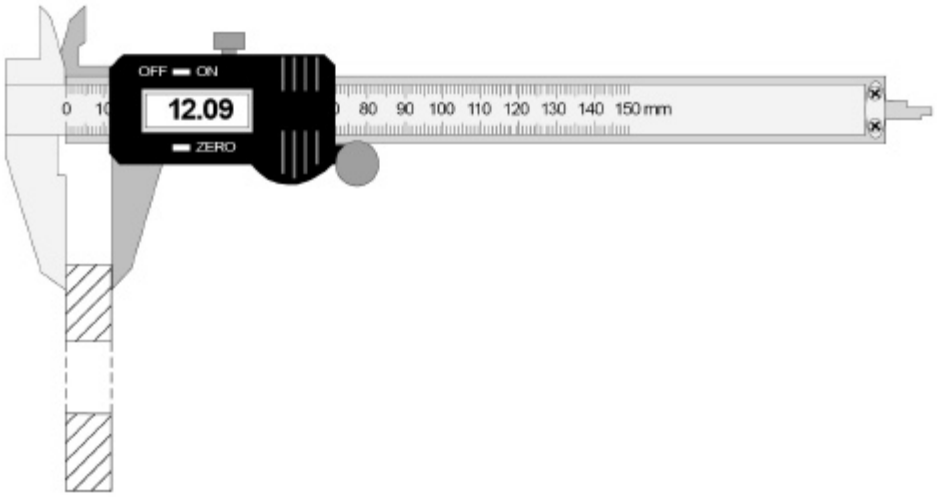
STEMUP.CO.UK



(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**.

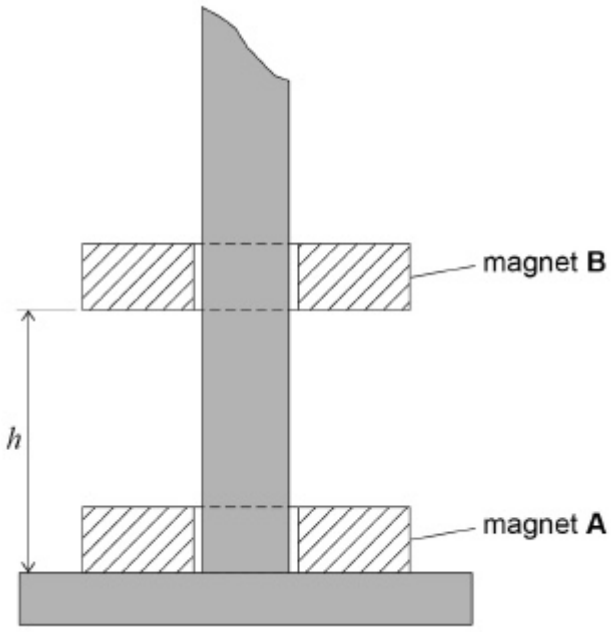
STEMUP.CO.UK

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.

STEMUP.CO.UK

(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% ⬭

STEMUP.CO.UK

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 ⬭

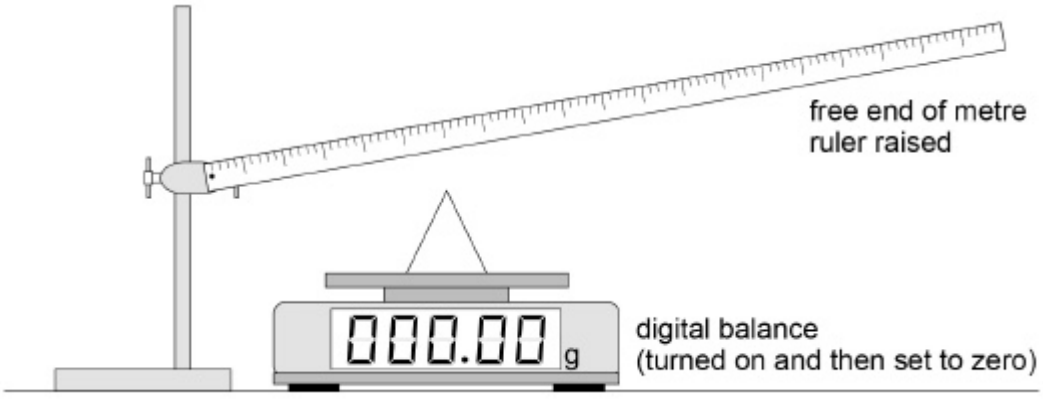
(Total 1 mark)

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**.

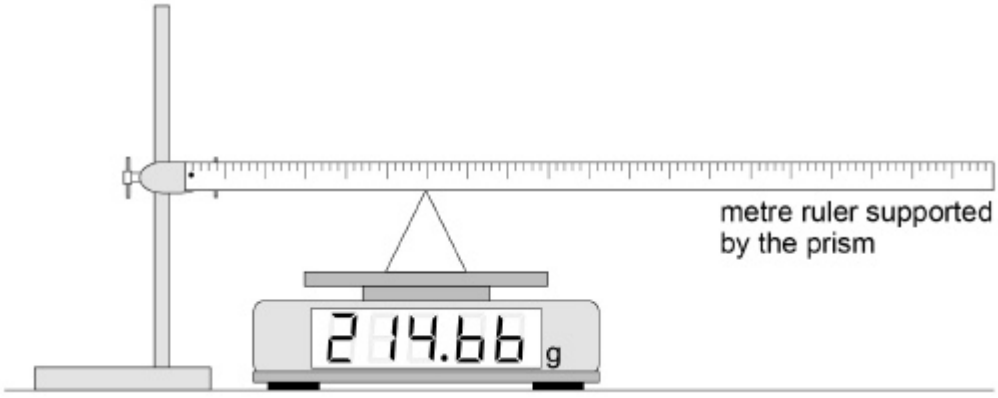
Figure 1



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

STEMUP.CO.UK



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

mass of ruler = _____ g

assumption _____

_____

(3)

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

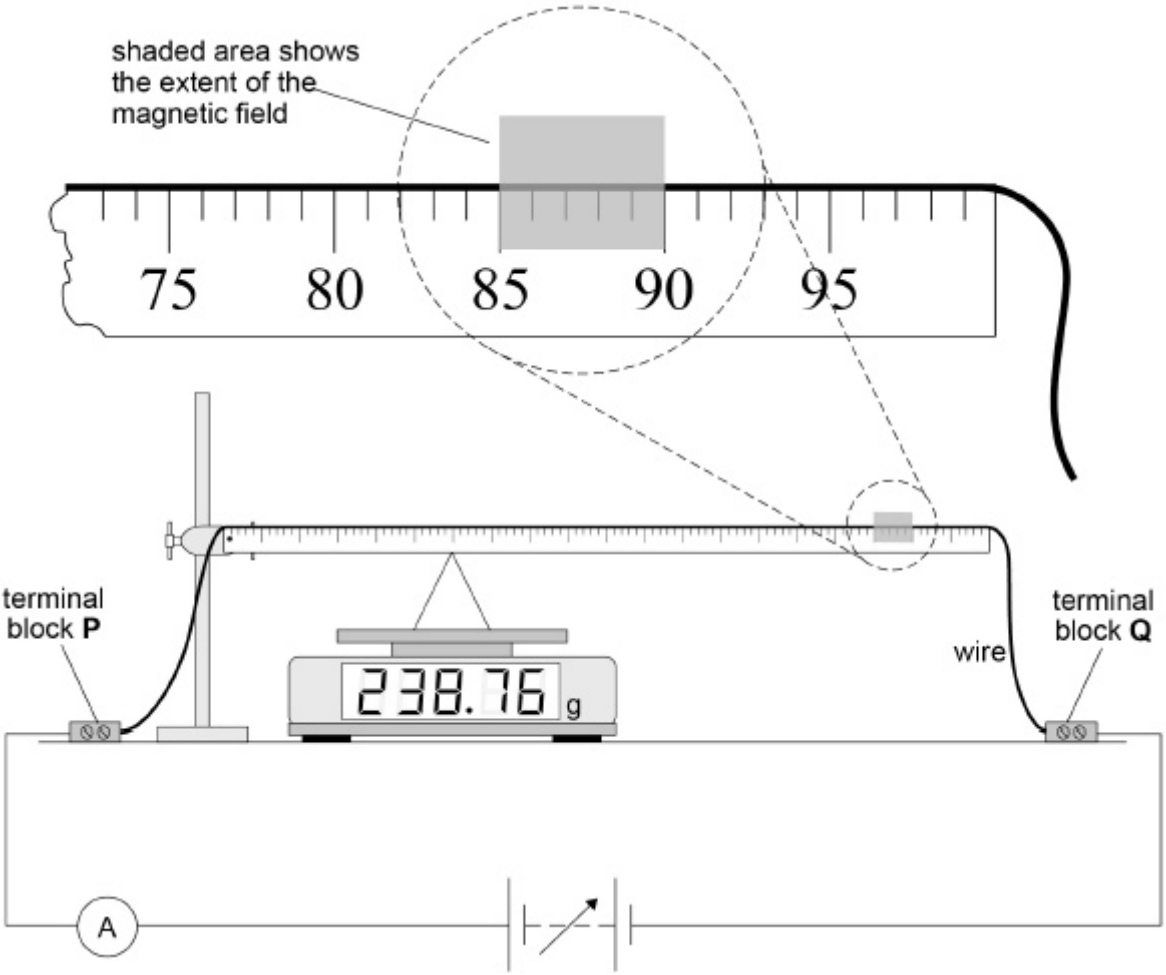
The ends of the wire are connected to terminal blocks **P** and **Q** which are fixed firmly to the bench. A power supply and an ammeter are connected between **P** and **Q**.

These modifications cause the balance reading to increase slightly.

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

Figure 3

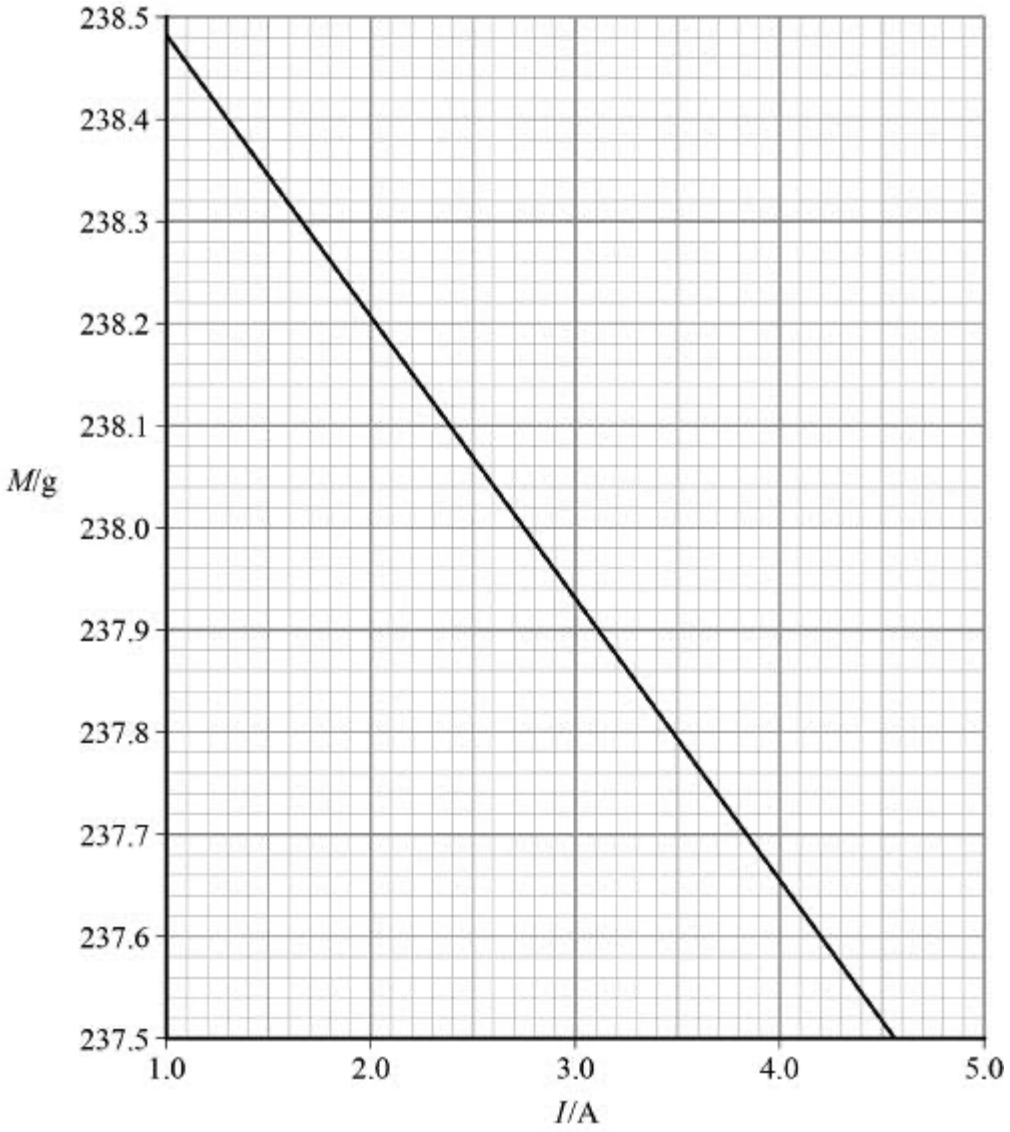
STEMUP.CO.UK



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

Figure 4

STEMUP.CO.UK



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

(3)

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

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

STEMUP.CO.UK

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.

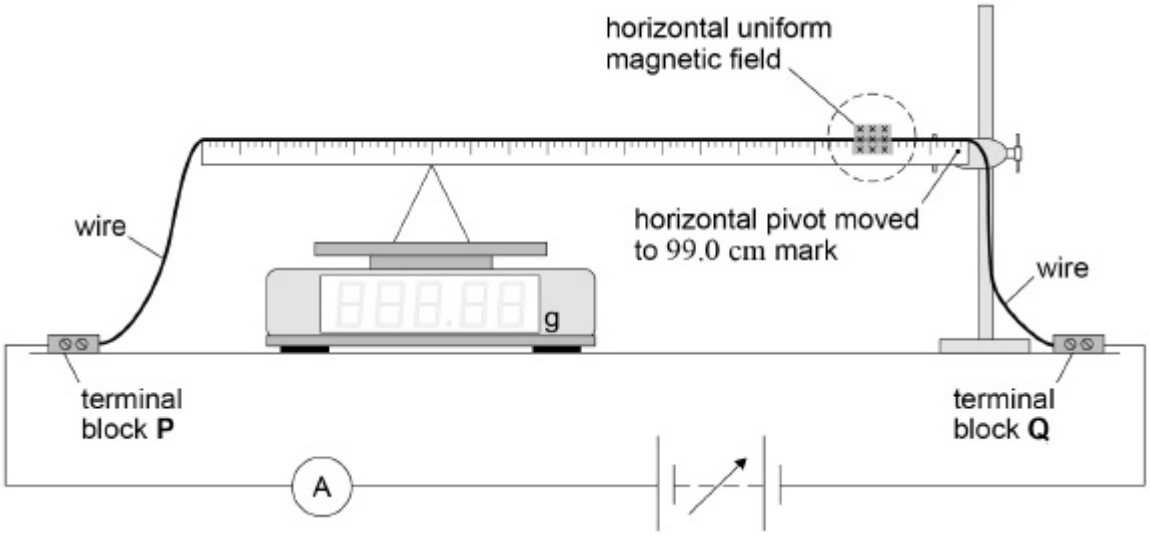
B = _____ T

(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			

STEMUP.CO.UK

3	Gradient of the graph			
4	Vertical intercept of the graph			

(3)

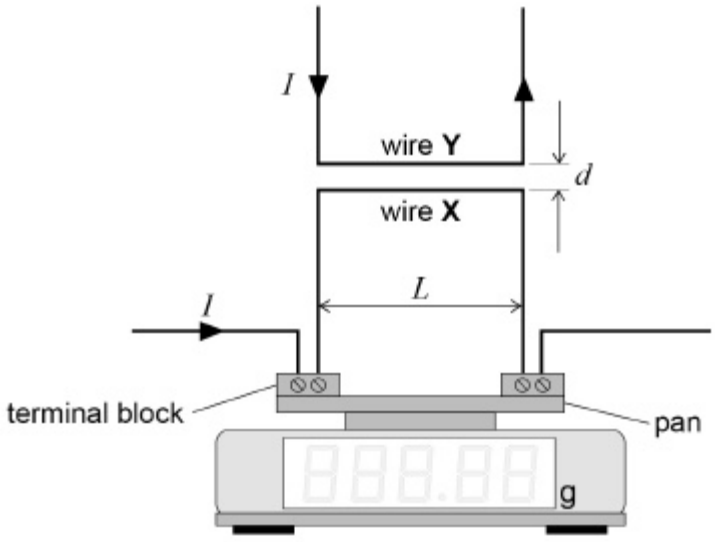
(e) **Figure 6** shows the balance being used to measure the forces between two wires. The connections joining these wires to the power supply are not shown.

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

STEMUP.CO.UK

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

where

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

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

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

The student is told that the following restrictions must apply:

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

Explain what the student could do to find k.

(5)
(Total 19 marks)

Q6.

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

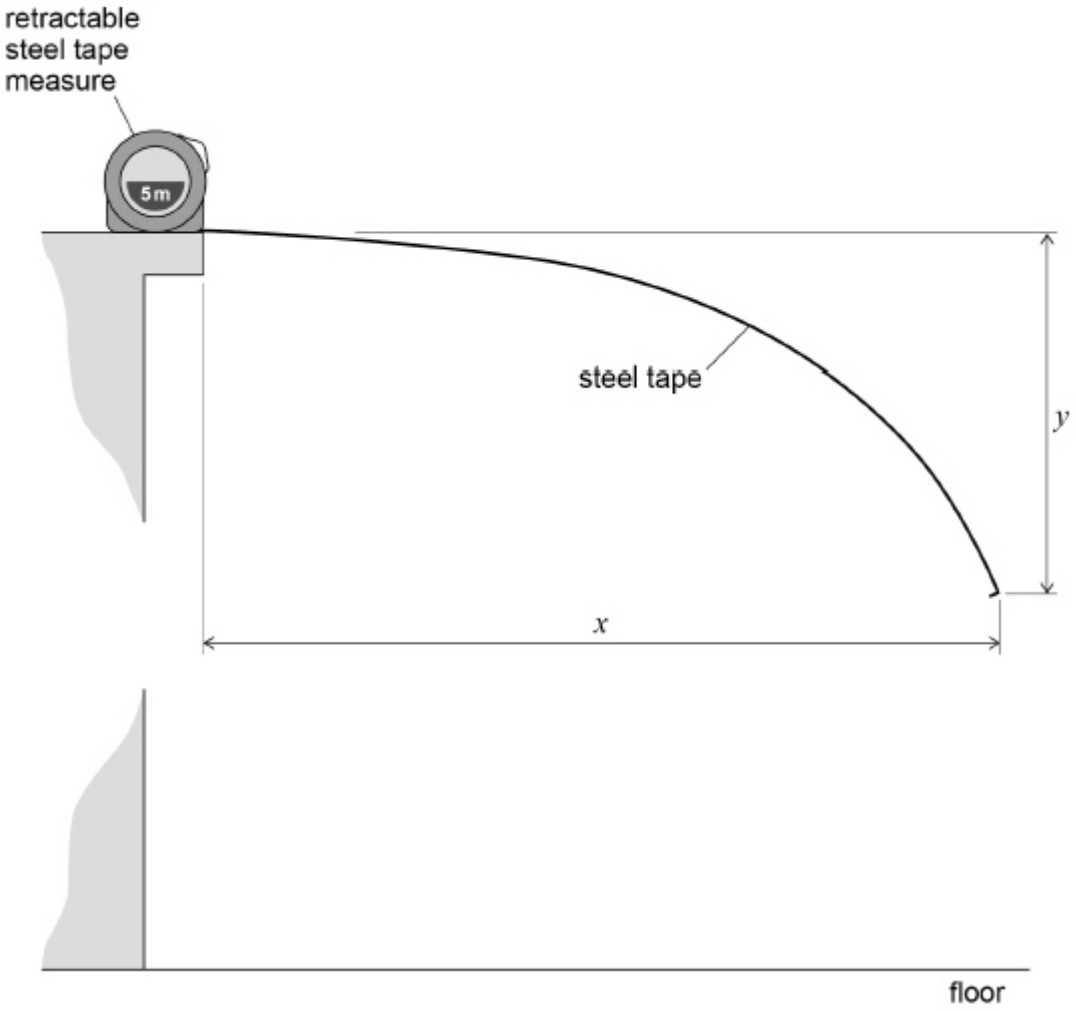
The tape measure is placed at the edge of the bench and about 1 m of the steel tape is extended so that it overhangs the bench.

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

STEMUP.CO.UK

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.

(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.

STEMUP.CO.UK

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

_____

_____

_____

_____

(1)

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

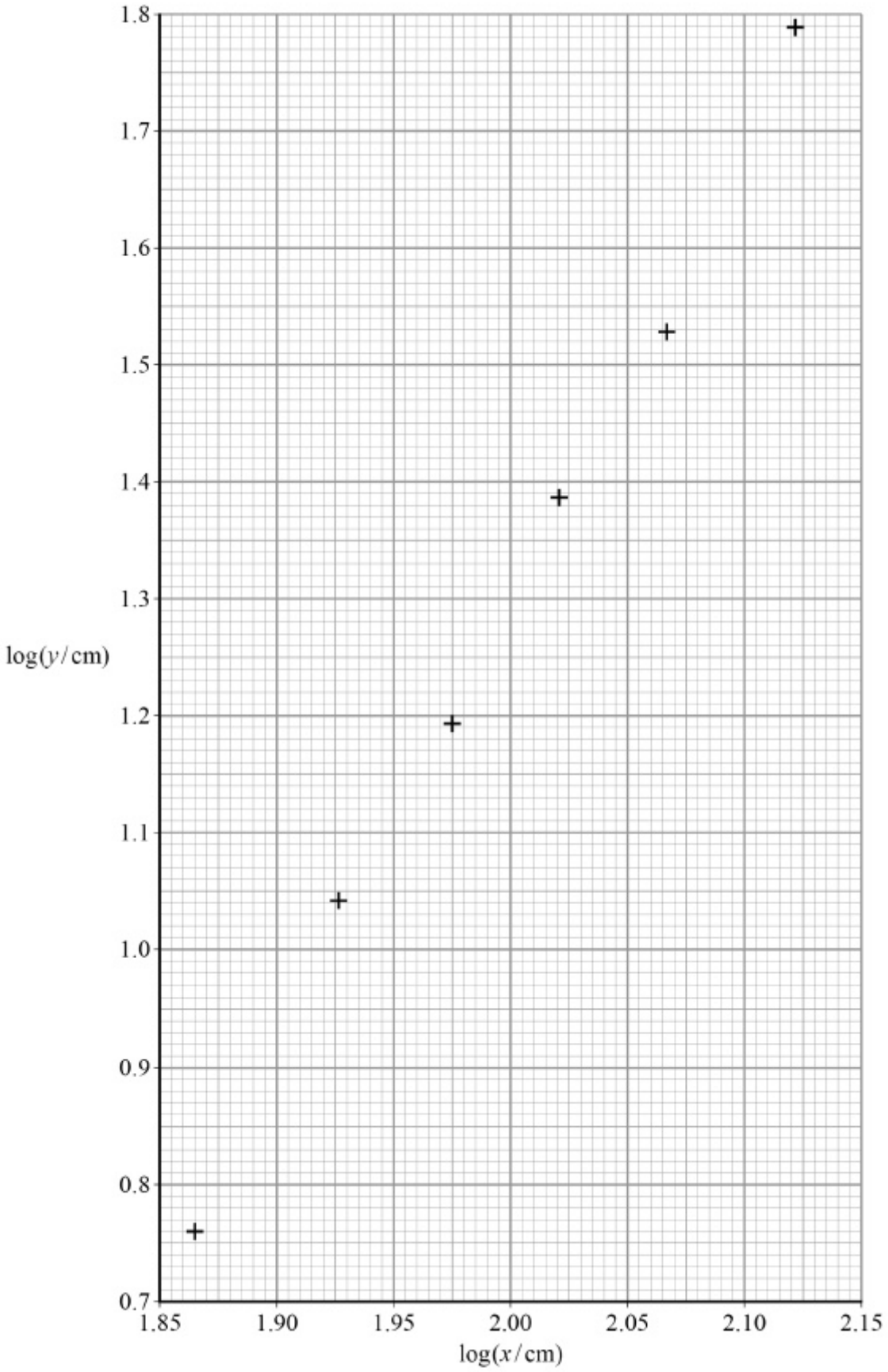
These data are used to plot the graph in **Figure 2**.

Determine n using **Figure 2**.

n = _____

Figure 2

STEMUP.CO.UK



(3)

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

_____

STEMUP.CO.UK

_____

_____

_____

_____

_____

_____

_____

(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.

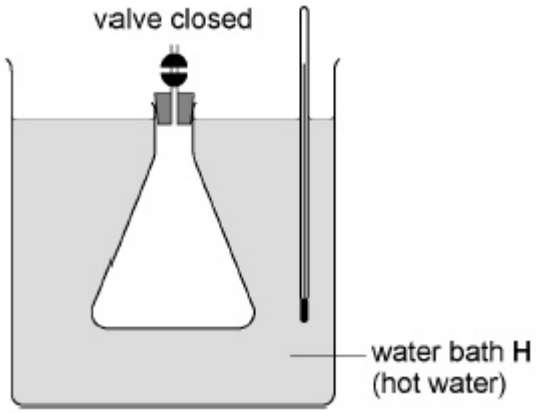
This question is about an experiment to estimate absolute zero.

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**.

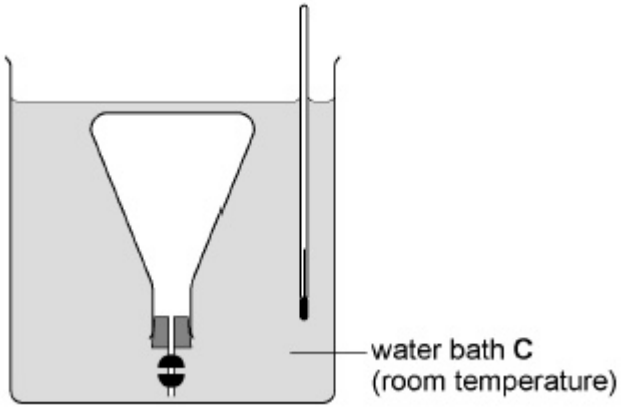
Figure 1a

STEMUP.CO.UK



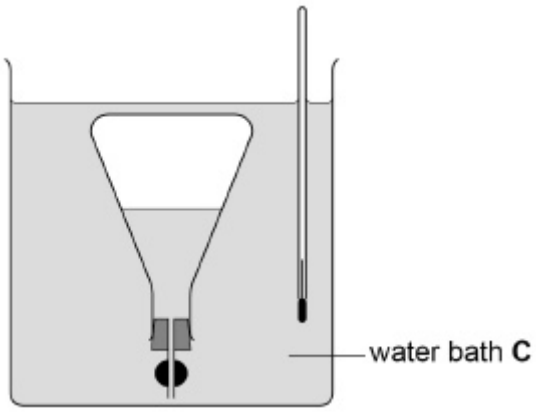
The flask is inverted and placed in water bath **C** in which the water is at room temperature.
The air inside the flask is again allowed to come into thermal equilibrium with the water, as shown in **Figure 1b**.

Figure 1b



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

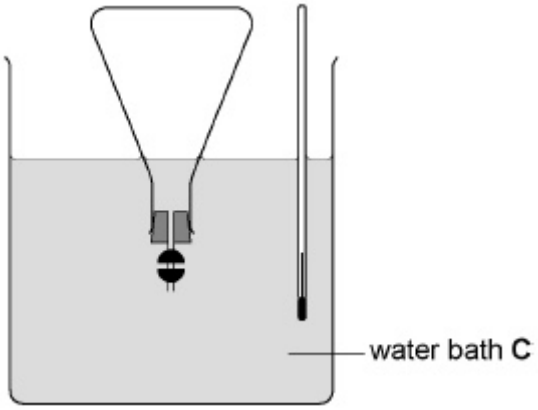
Figure 1c



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

STEMUP.CO.UK



(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

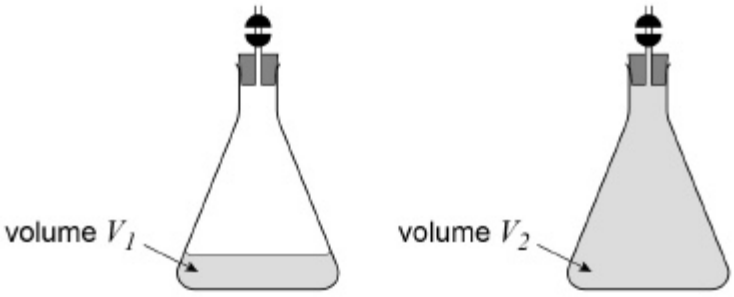
The flask is then completely refilled with water and the valve and stopper replaced.

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

STEMUP.CO.UK



Explain how V_1 and V_2 can be determined.

In your answer you should

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

(3)

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

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

The temperature of the hot water bath is 86 °C

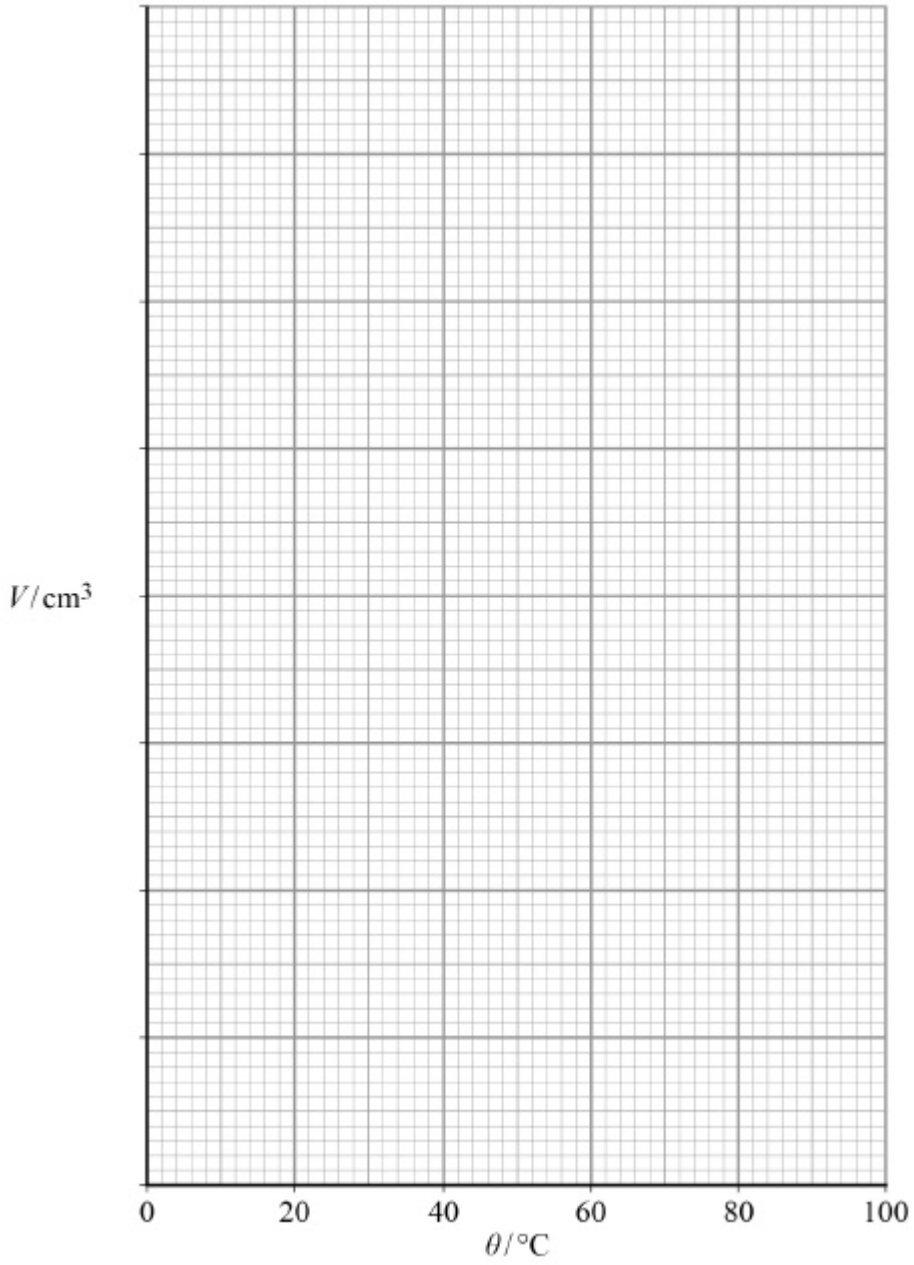
Room temperature is 19 °C

V_1 = 48 cm^3

V_2 = 255 cm^3

Figure 3

STEMUP.CO.UK



(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**.

STEMUP.CO.UK

value of absolute zero = _____ °C

(3)

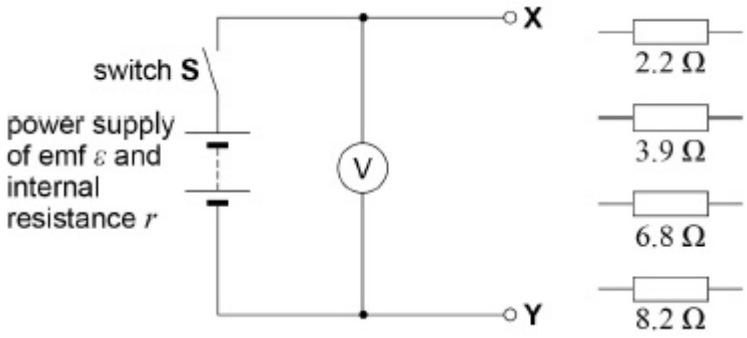
(Total 14 marks)

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.

_____

_____

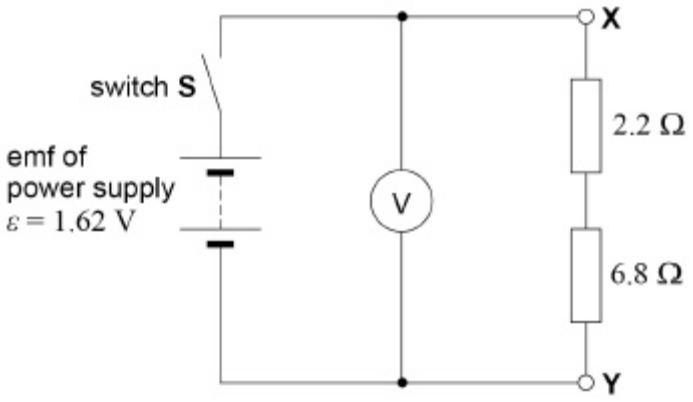
STEMUP.CO.UK

_____

(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 (ε – 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.

STEMUP.CO.UK

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)

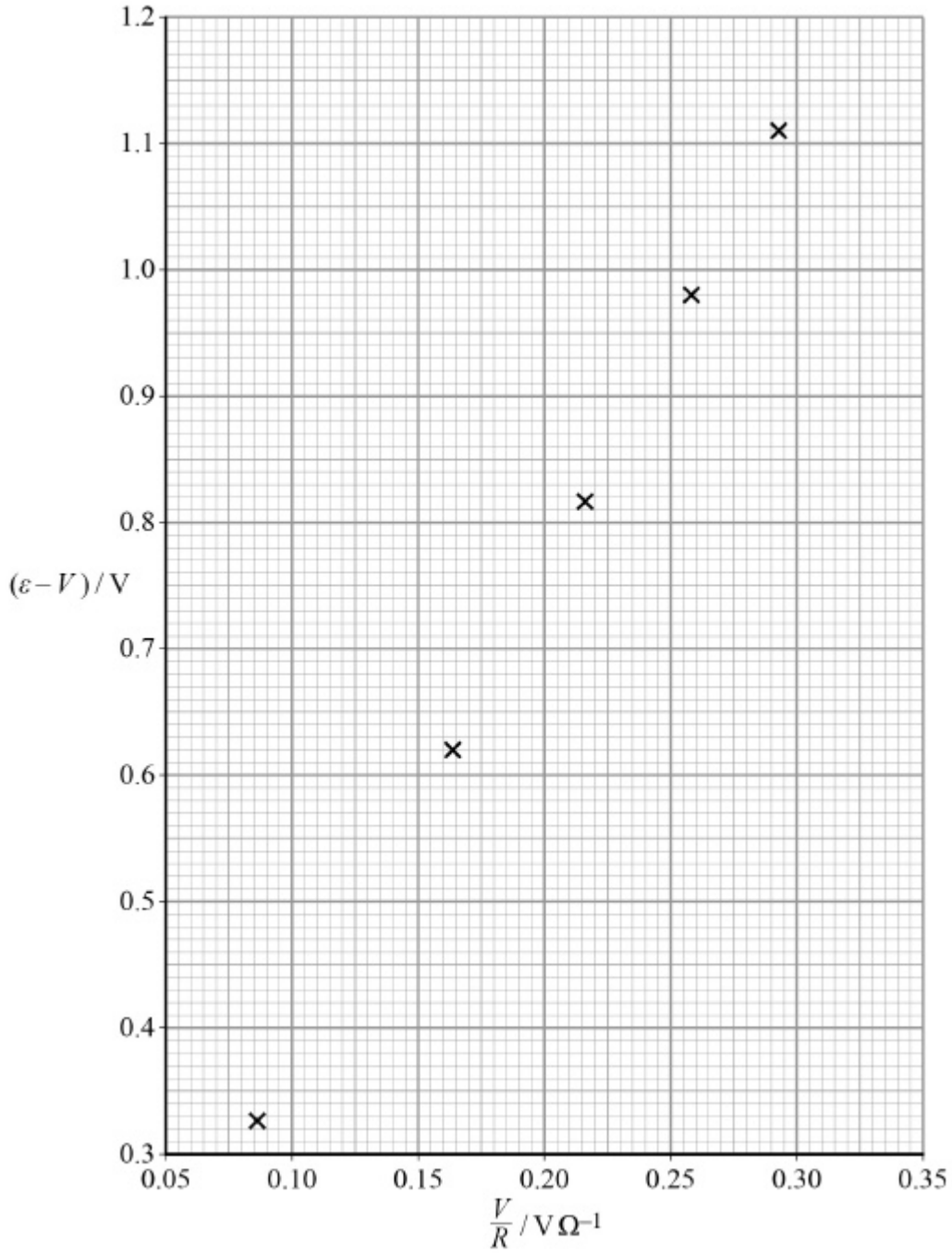
(g) Use **Figure 3** to determine r.

r = _____ Ω

(2)

Figure 3

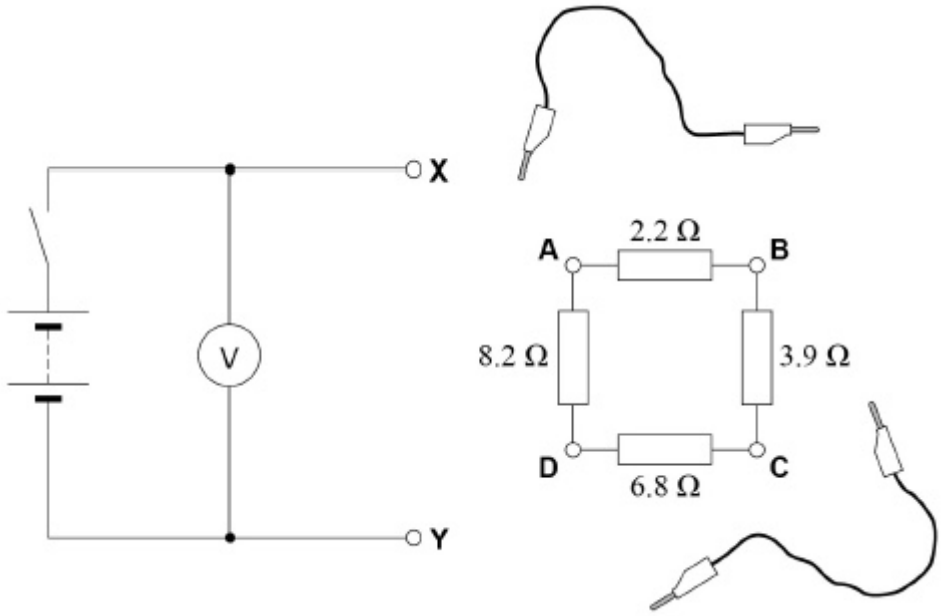
STEMUP.CO.UK



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

Figure 4

STEMUP.CO.UK



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.

(2)

(Total 11 marks)

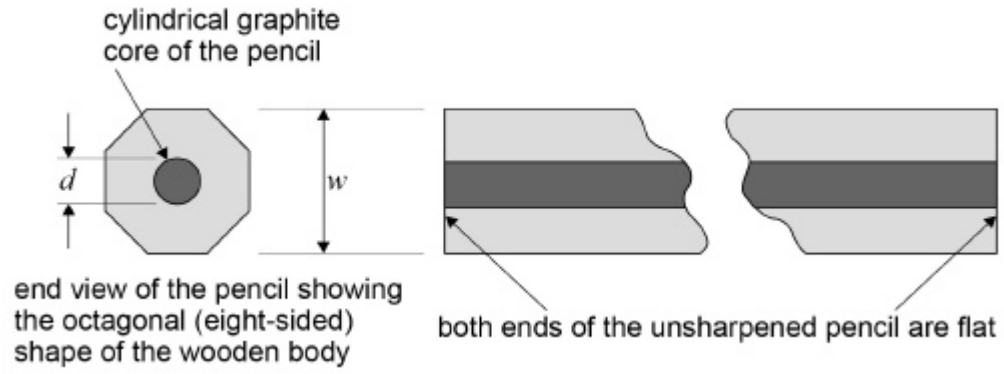
Q9.

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

STEMUP.CO.UK



(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.

_____

_____

_____

_____

_____

(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.

STEMUP.CO.UK

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

STEMUP.CO.UK

(2)

Figure 2

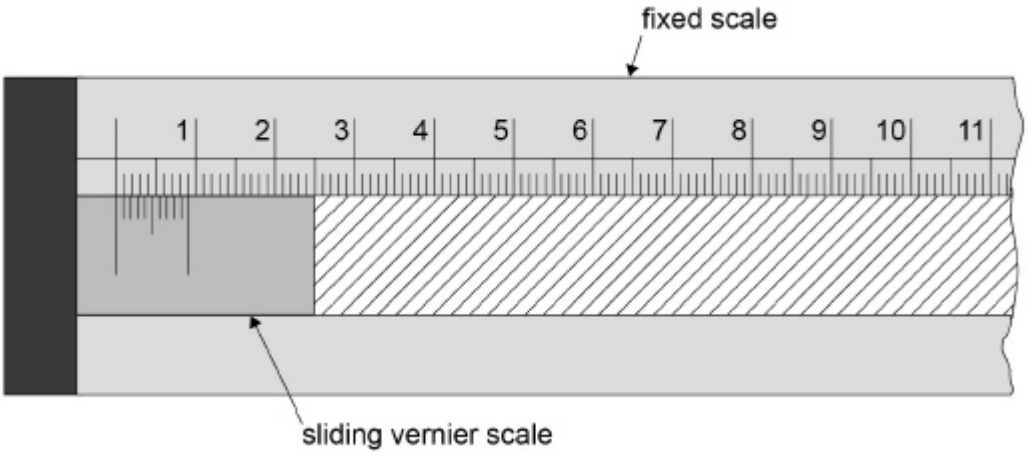


Figure 3

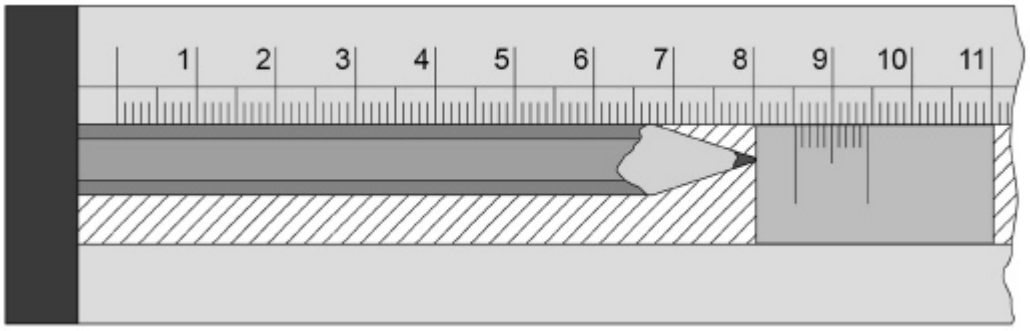
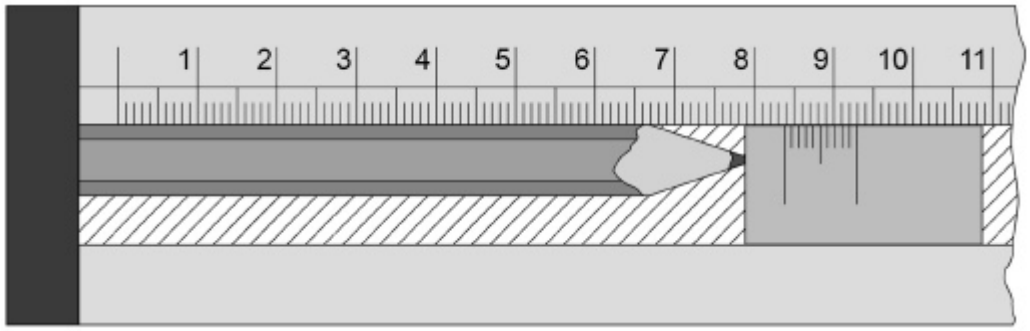


Figure 4



(Total 9 marks)

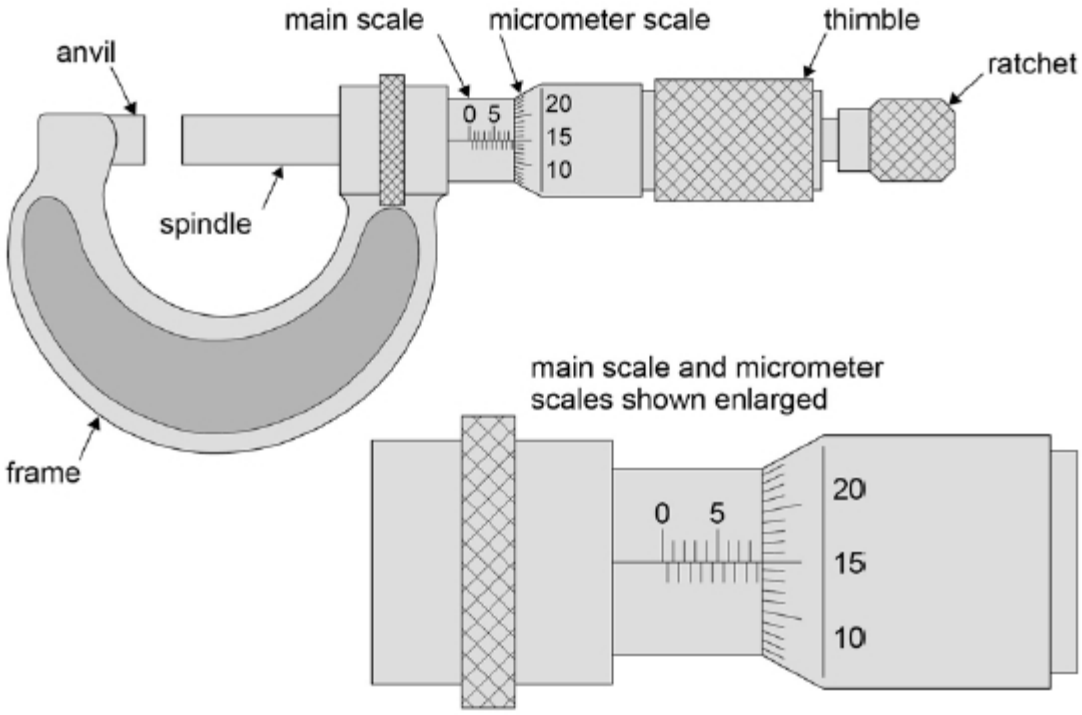
Q10.

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

STEMUP.CO.UK



(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

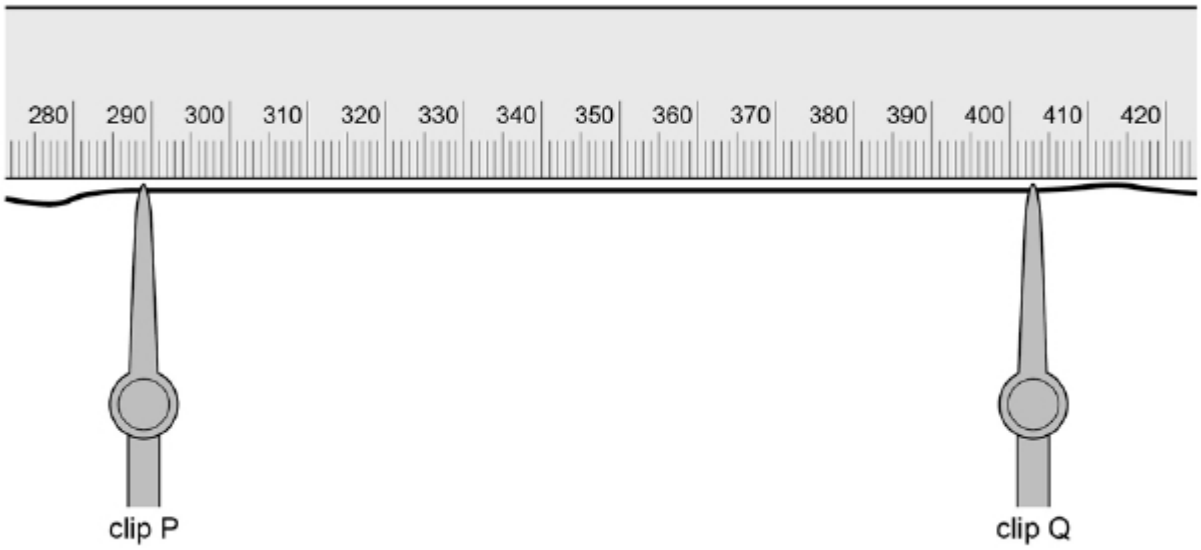
(2)

(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

STEMUP.CO.UK



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

STEMUP.CO.UK

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)

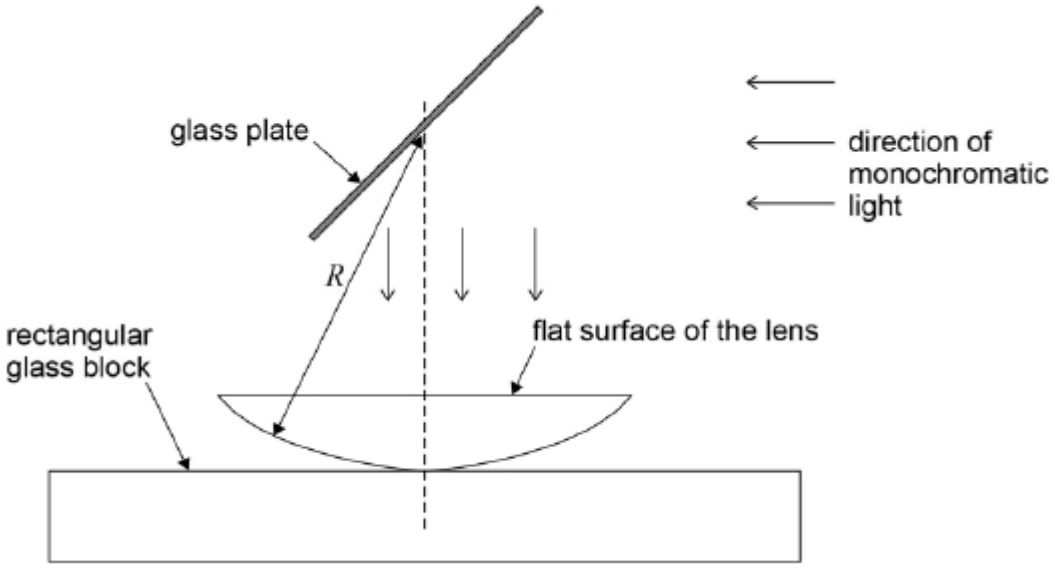
(Total 13 marks)

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**.

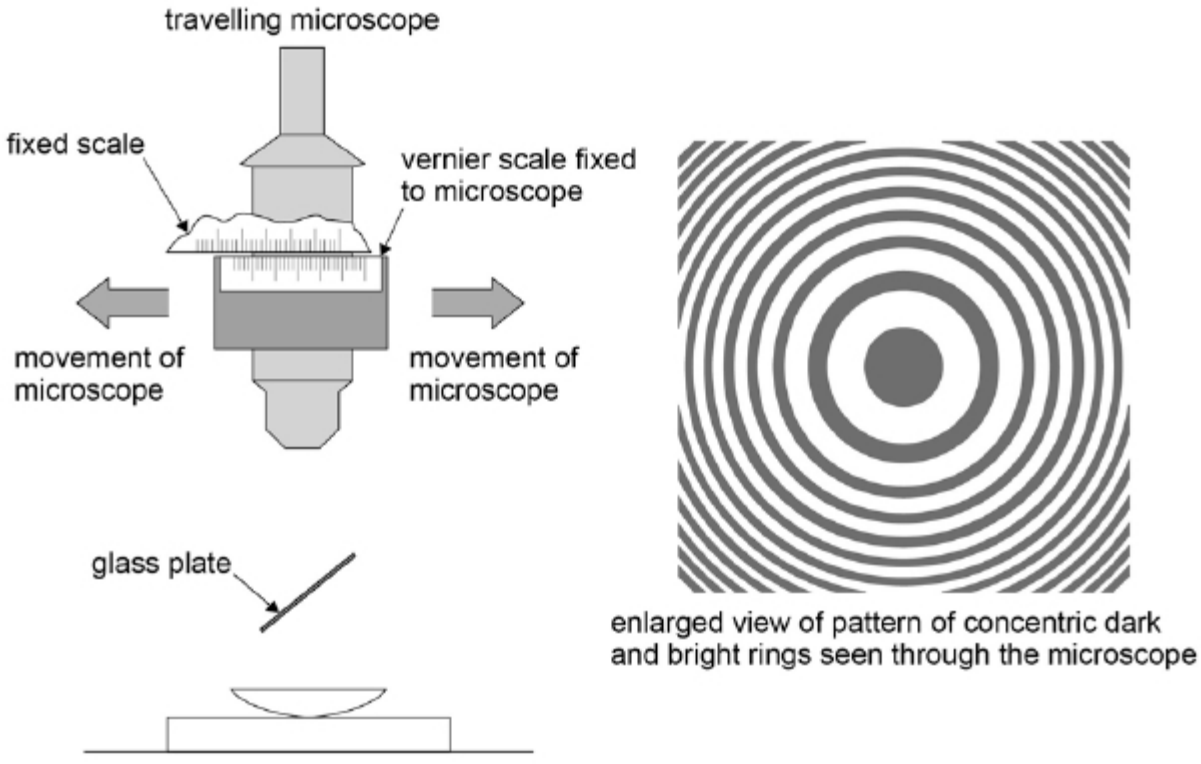
STEMUP.CO.UK

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.

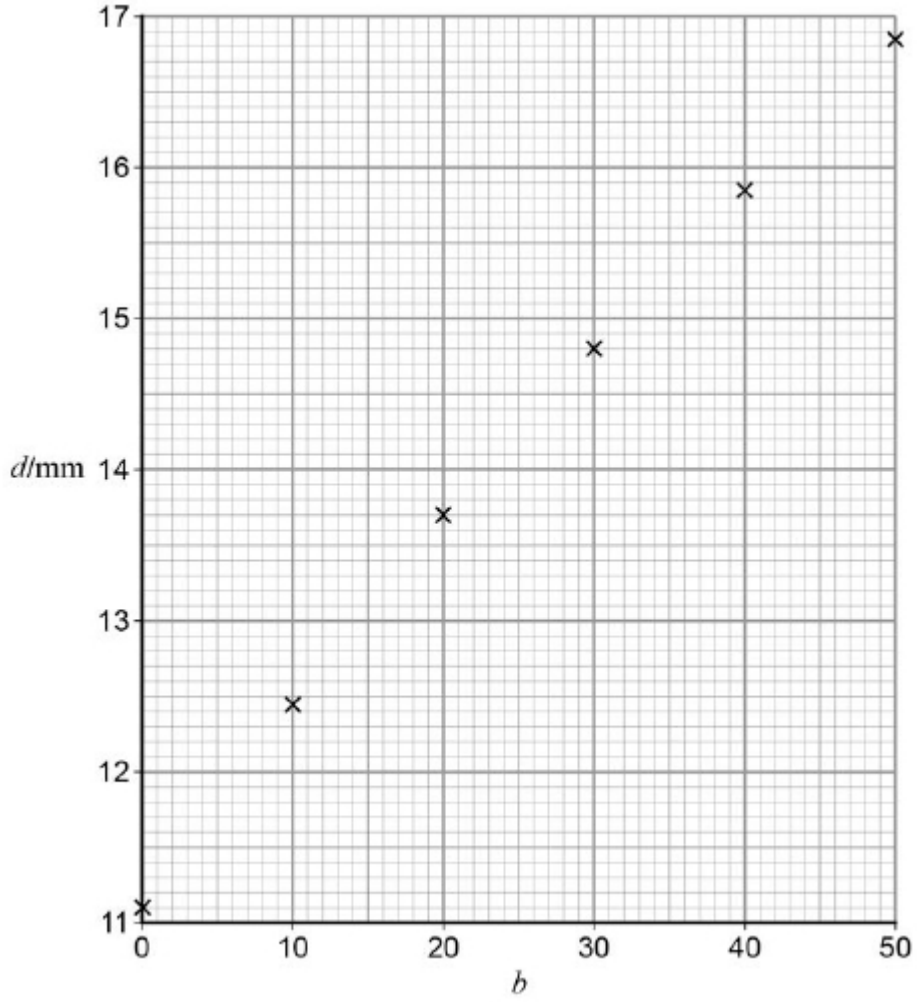
Figure 2



(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.

STEMUP.CO.UK



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

STEMUP.CO.UK

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

where λ = 589.3 nm.

Determine R.

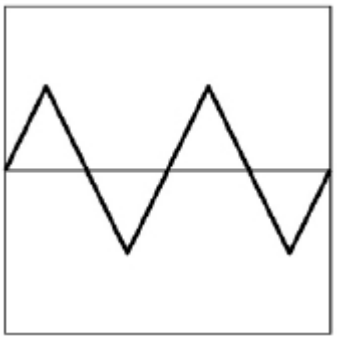
R = _____ m

(3)

(Total 7 marks)

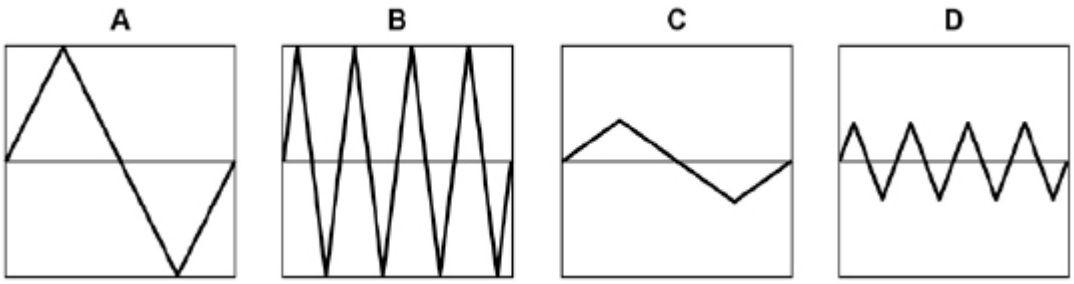
Q12.

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 ⬭

STEMUP.CO.UK

C ⬭

D ⬭

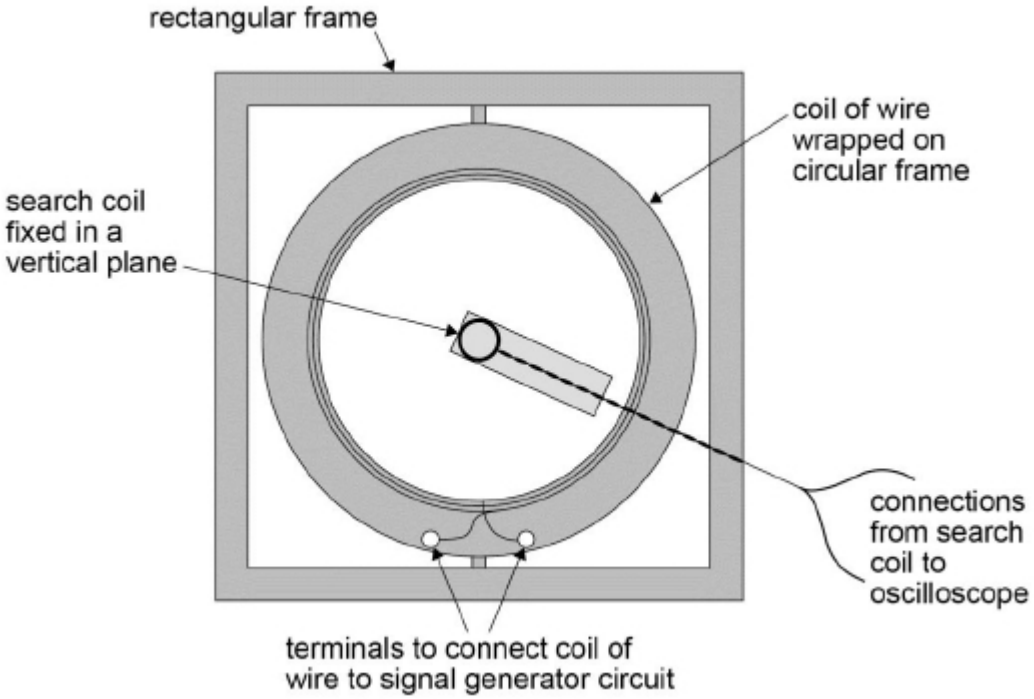
(Total 1 mark)

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.

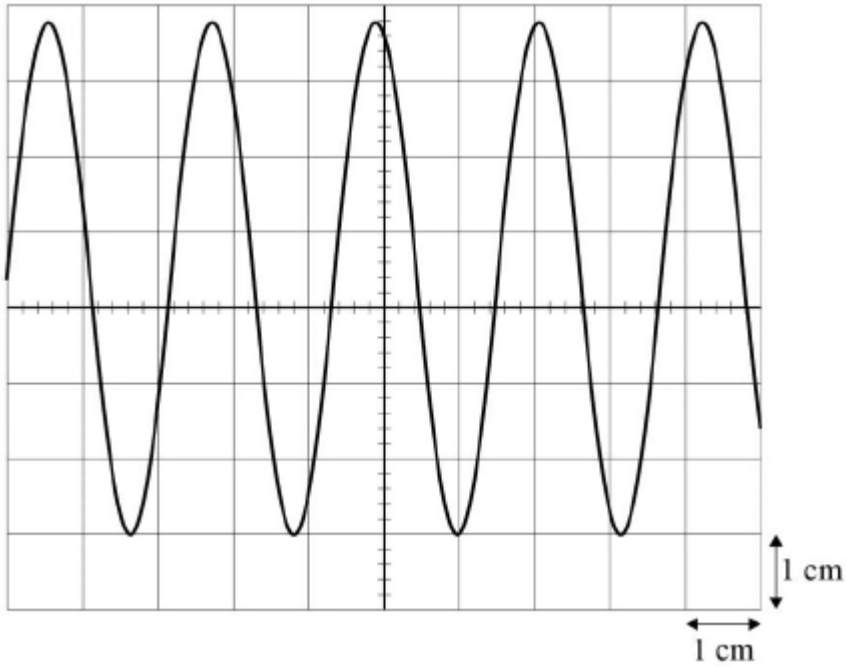
The student clamps a search coil so it is co−axial with the circular coil then arranges the apparatus so that both frames and the search coil lie in the same vertical plane.

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

STEMUP.CO.UK



(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**

STEMUP.CO.UK

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

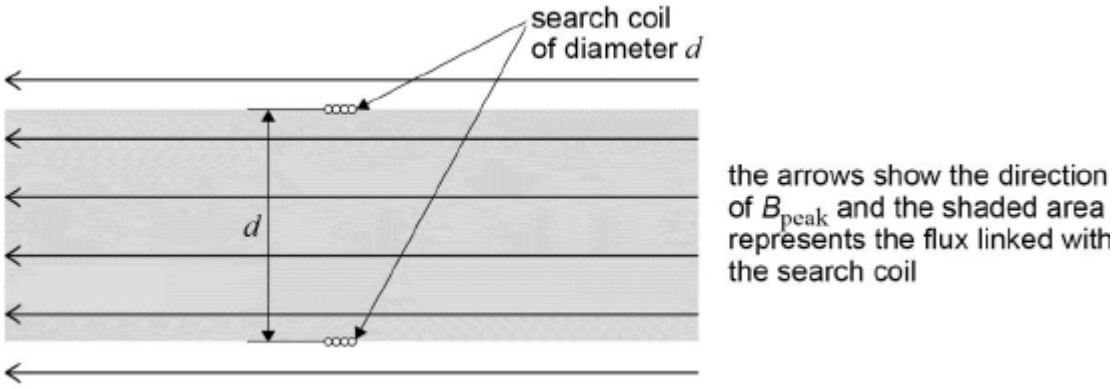
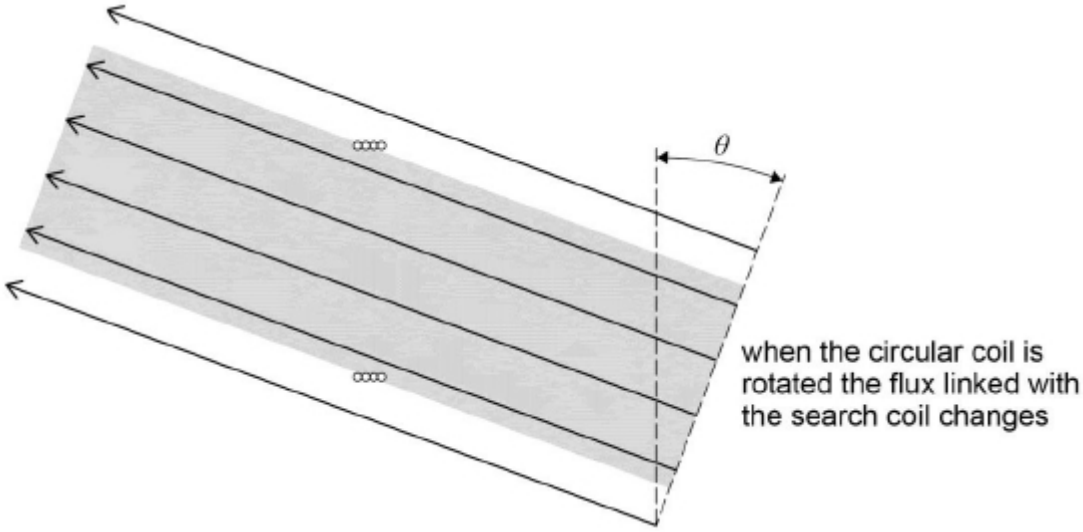


Figure 4



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

_____

_____

_____

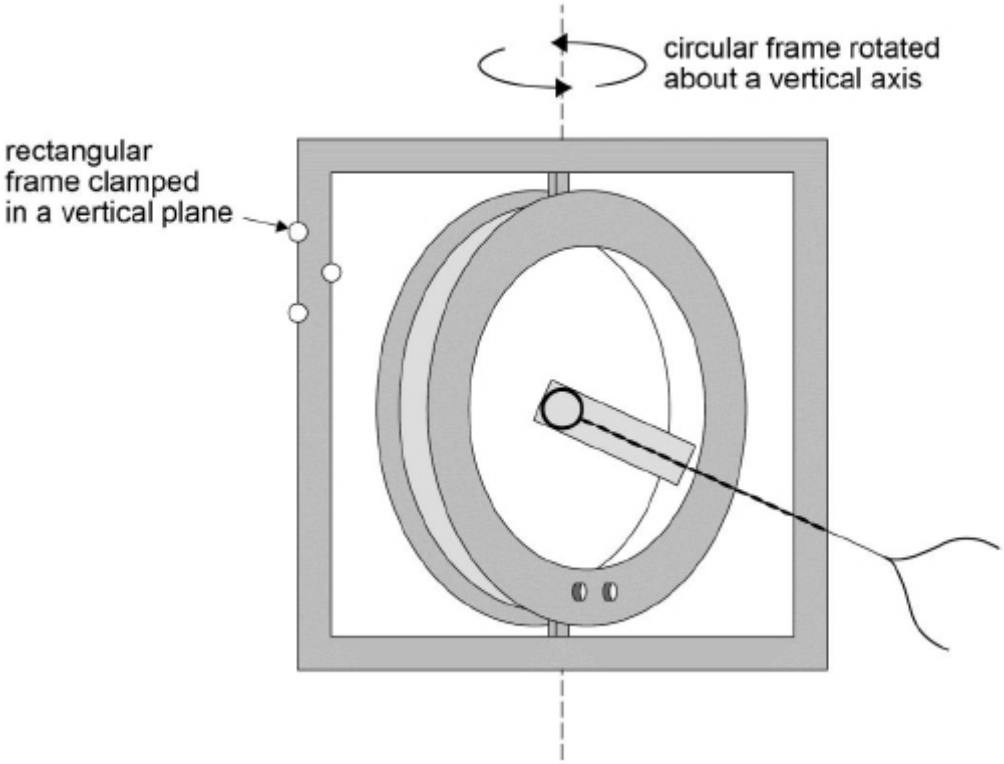
_____

(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**.

STEMUP.CO.UK

Figure 5



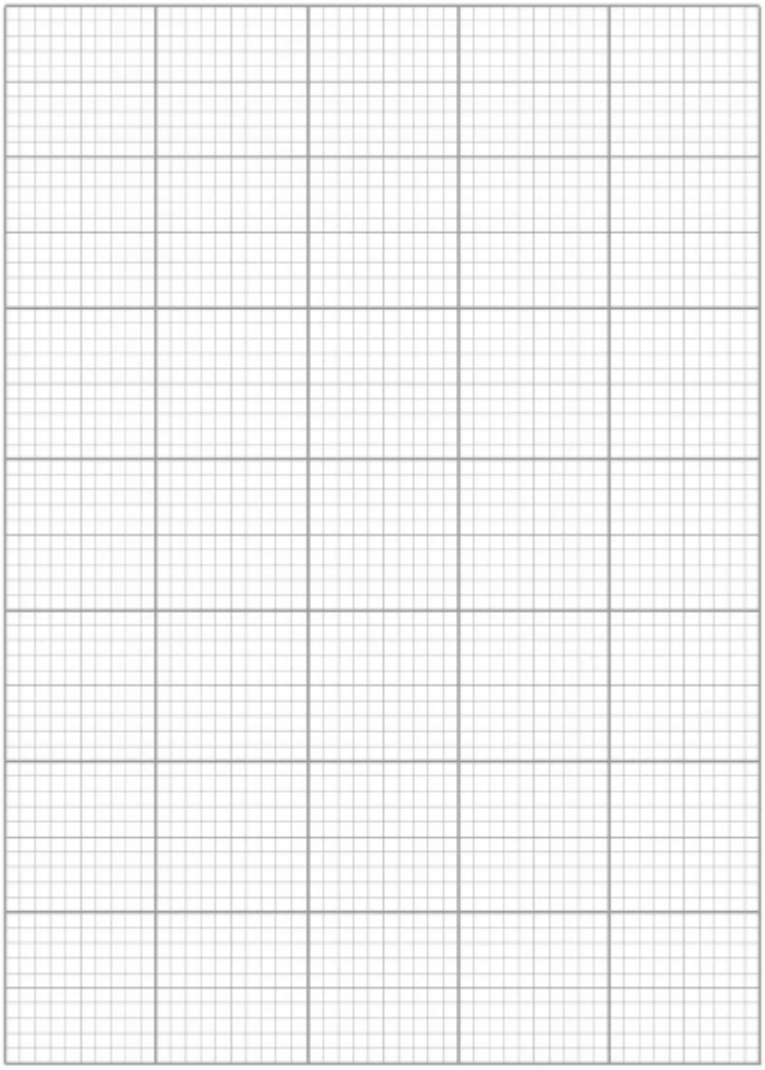
She turns off the time−base on the oscilloscope so that a vertical line is displayed on the screen. Keeping the y−voltage gain at 10 mV cm^{-1} she records the length l of the vertical line and the angle θ through which the circular frame has been rotated. She measures further results for l as θ is increased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

STEMUP.CO.UK



(4)

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

_____

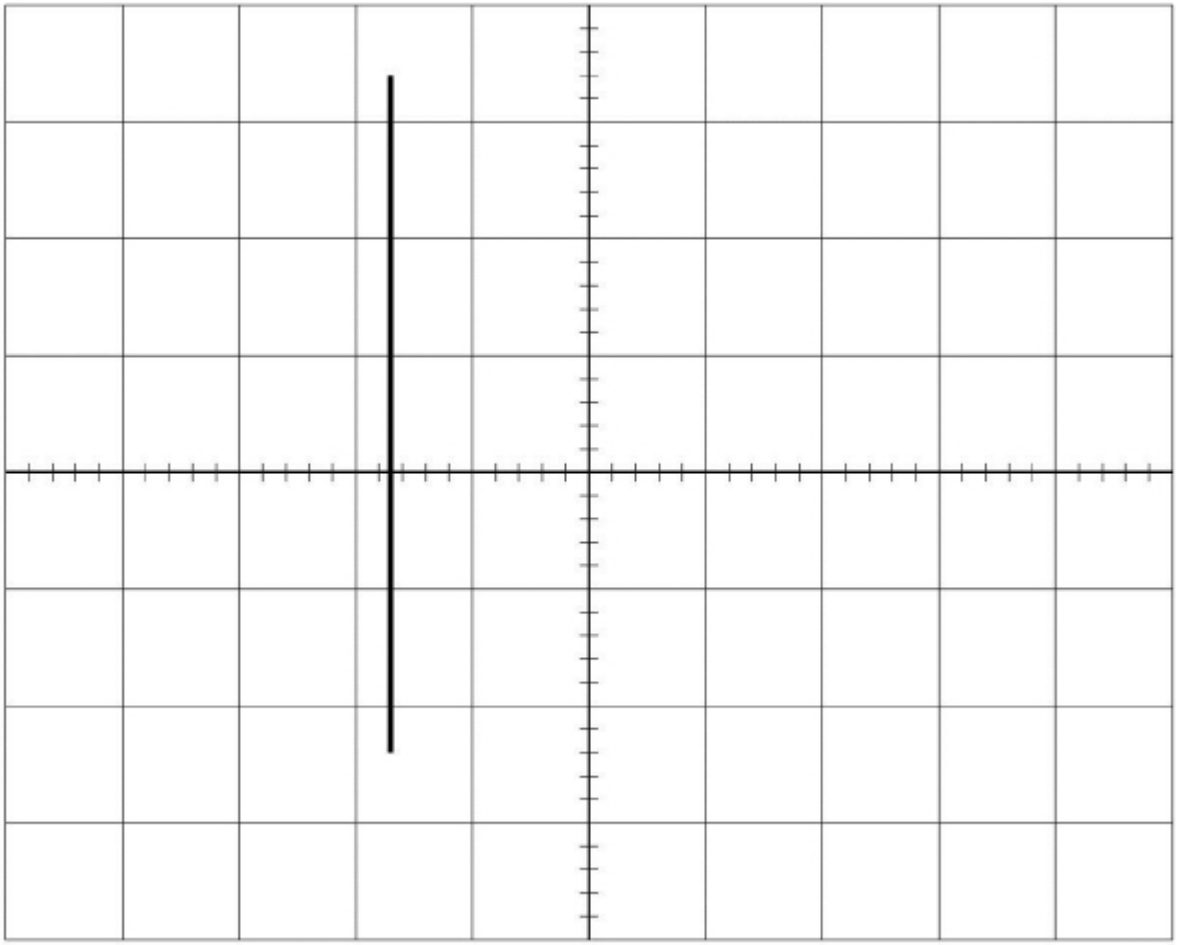
_____

(1)

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

Figure 7

STEMUP.CO.UK



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.

(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.

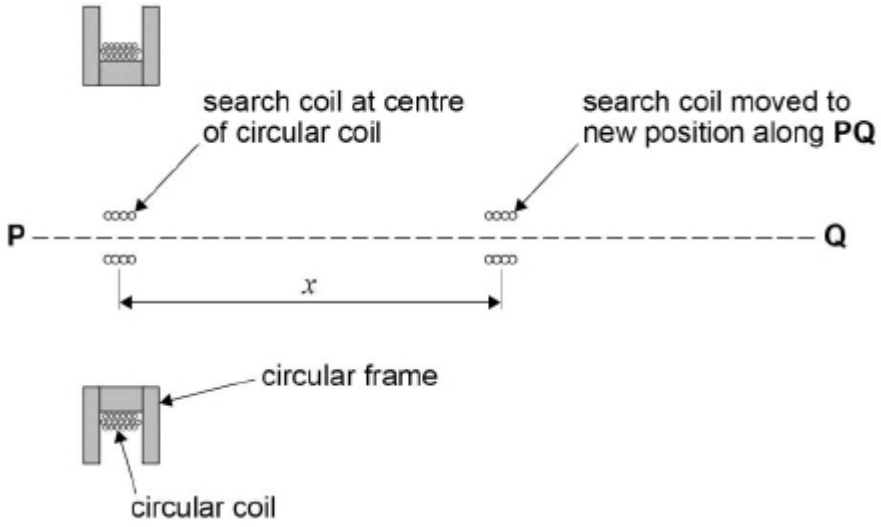
STEMUP.CO.UK

(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**.

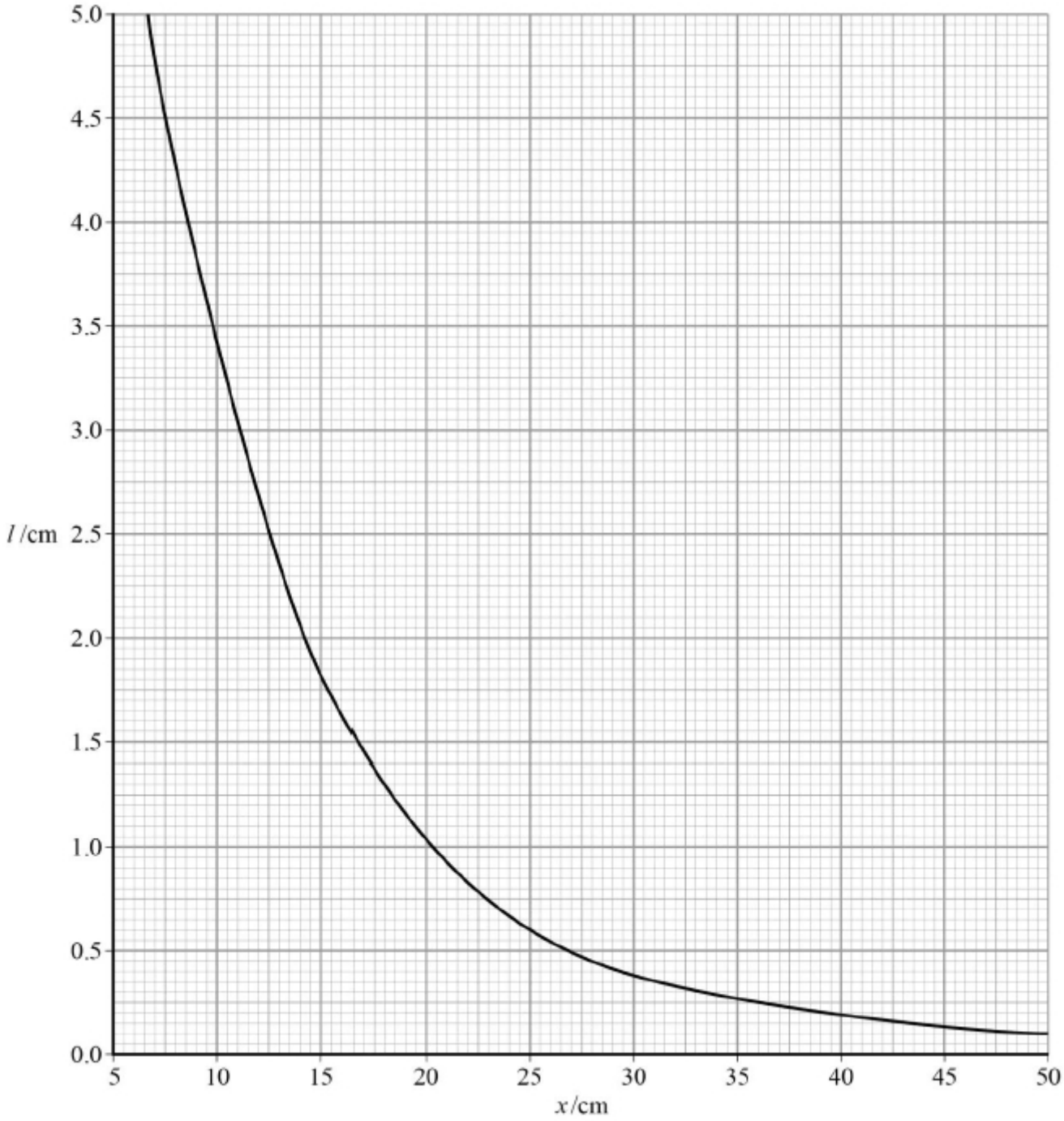
Figure 8



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

Figure 9

STEMUP.CO.UK



It is suggested that l decreases exponentially as x increases.

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

_____

_____

_____

_____

(2)

(Total 20 marks)

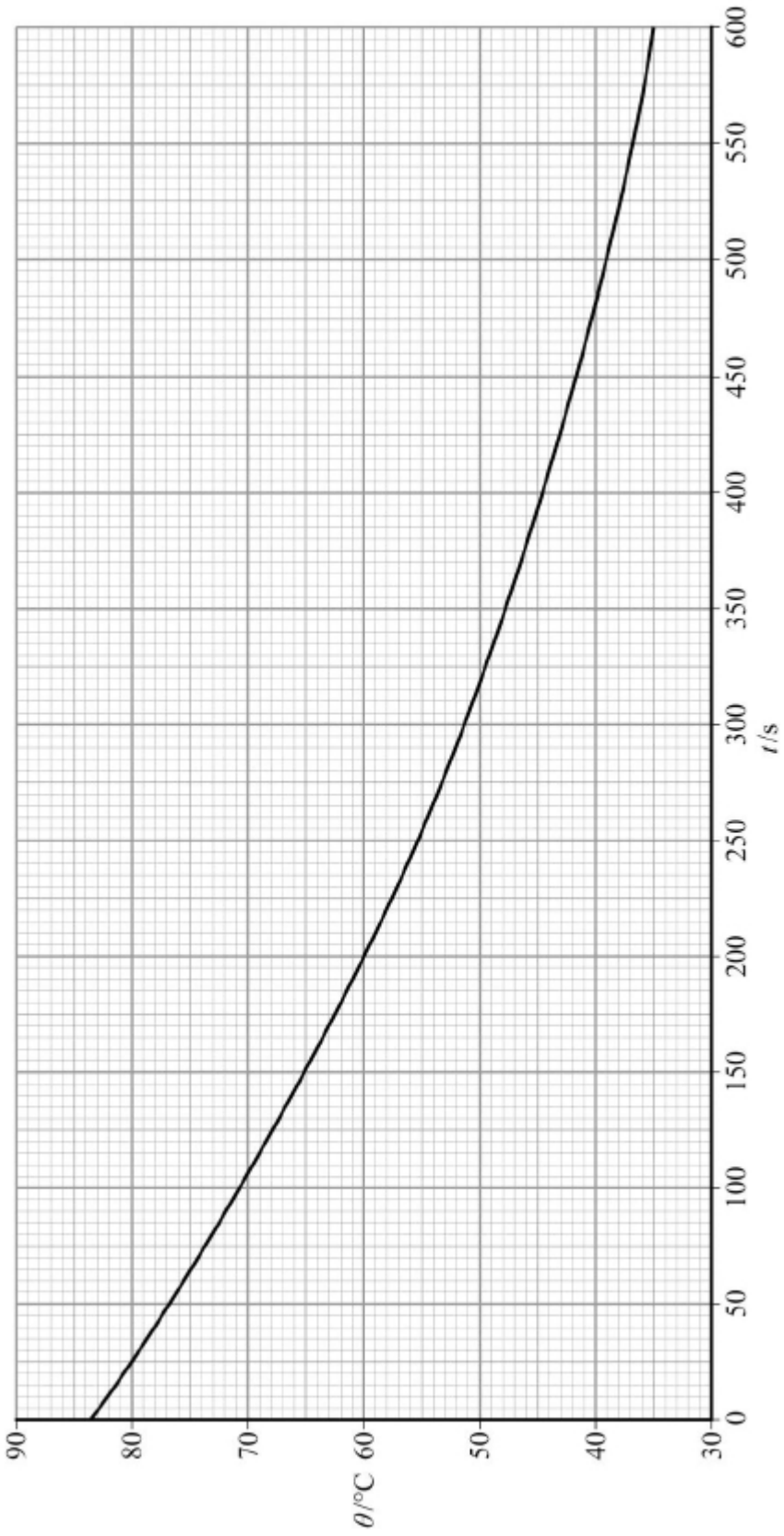
STEMUP.CO.UK

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

STEMUP.CO.UK



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

STEMUP.CO.UK

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 $\frac{G_1\theta_2 - G_2\theta_1}{G_1 - G_2}$

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.

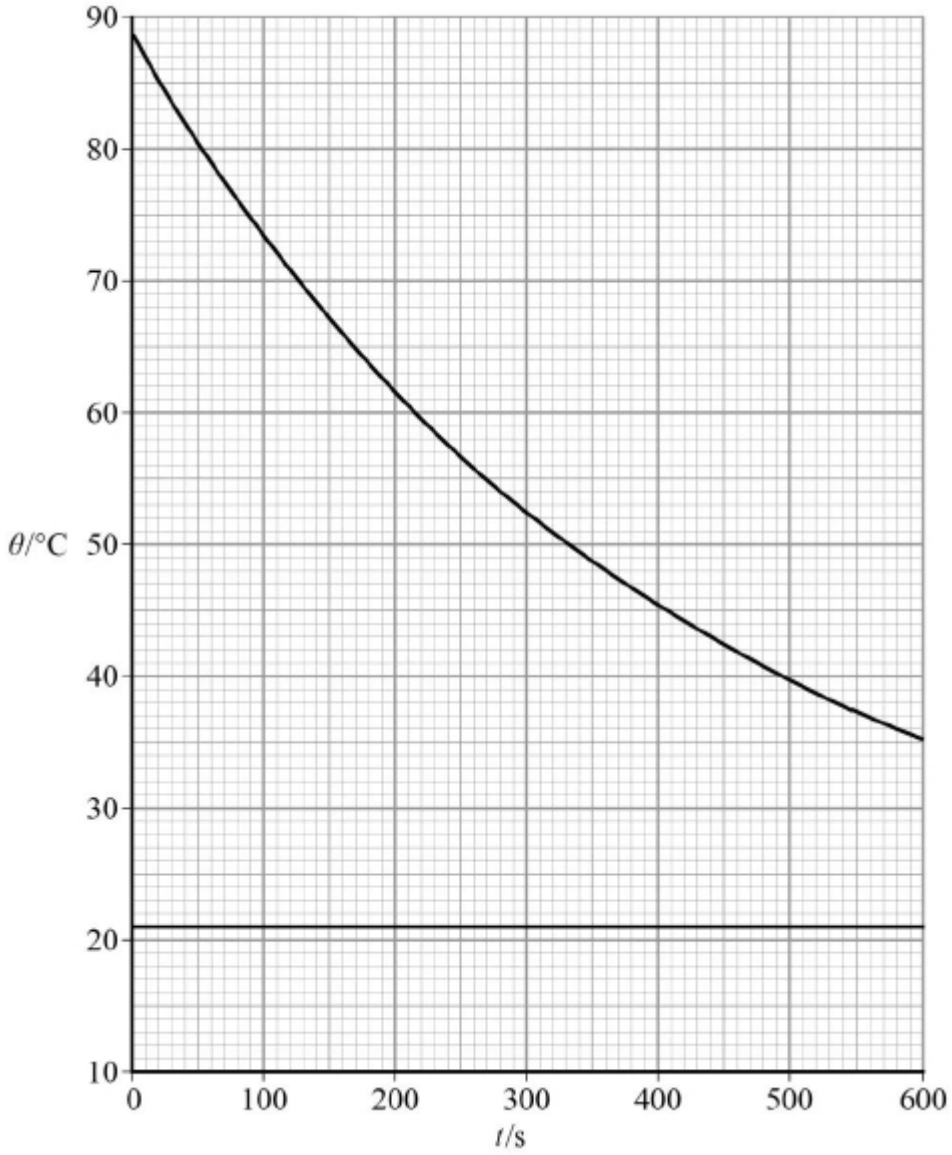
A student realises that ($\theta - \theta_R$) will decrease exponentially with time and designs an experiment in which two temperature sensors are connected to a data logger.

- 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

STEMUP.CO.UK



($\theta - \theta_R$) 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.

STEMUP.CO.UK

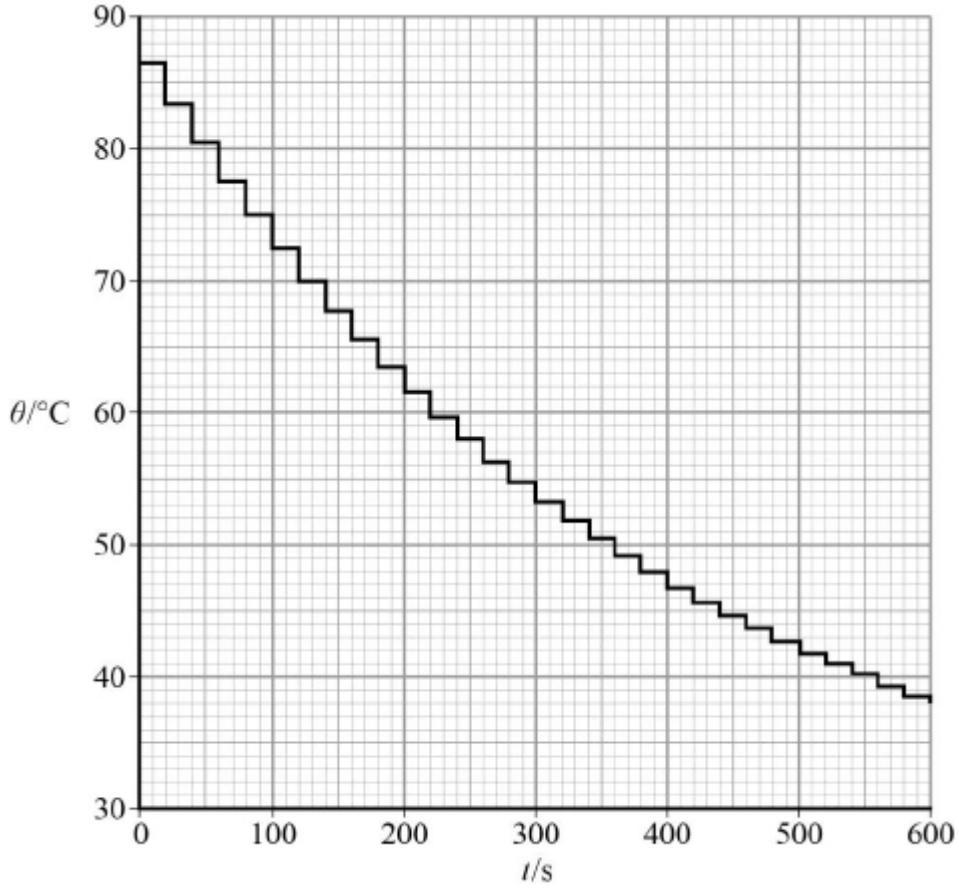
time taken = _____ s

(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.

STEMUP.CO.UK

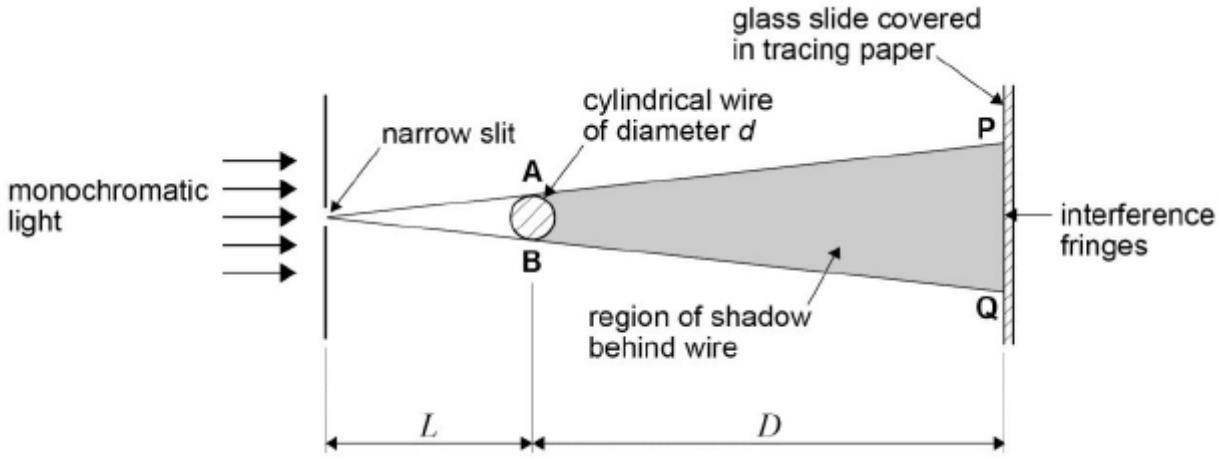
(5)

(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

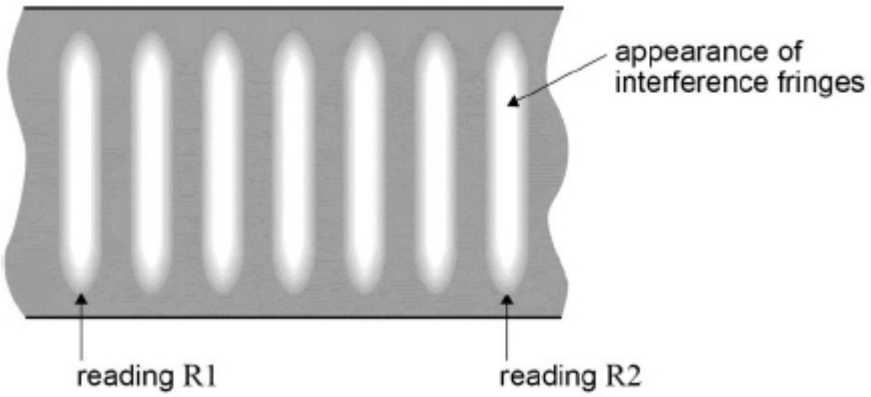


The wire is mounted vertically in front of a single narrow slit which is illuminated by monochromatic light. The wire produces a shadow between points **P** and **Q** on a glass slide covered with tracing paper. The light diffracts as it passes the wire. Points **A** and **B** act as coherent sources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

STEMUP.CO.UK



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**.

STEMUP.CO.UK

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.

_____

_____

_____

_____

(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.

STEMUP.CO.UK

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.

_____

_____

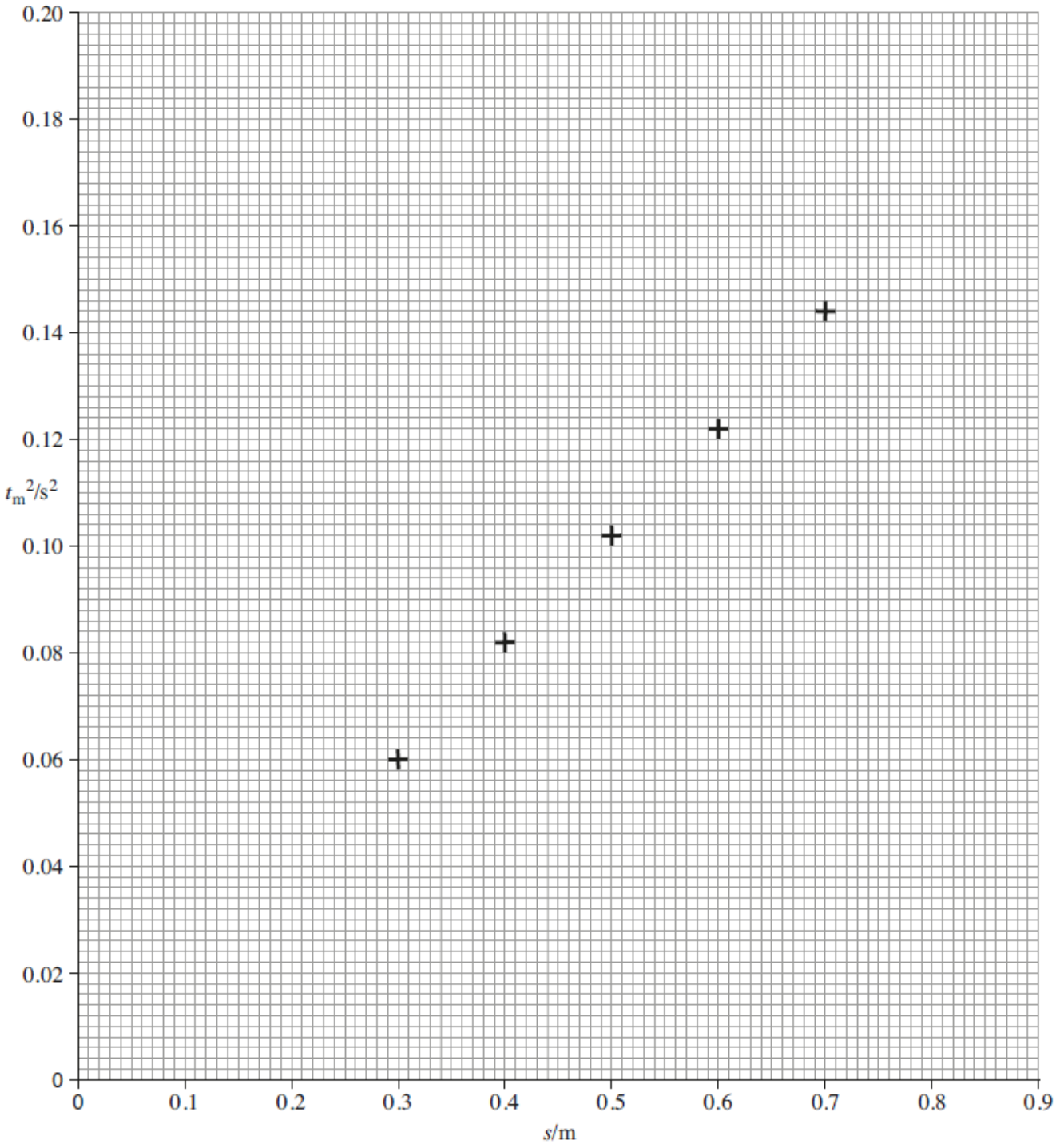
_____

_____

_____

(3)

STEMUP.CO.UK



(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.

STEMUP.CO.UK

(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)**.

STEMUP.CO.UK

(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.

STEMUP.CO.UK

(2)

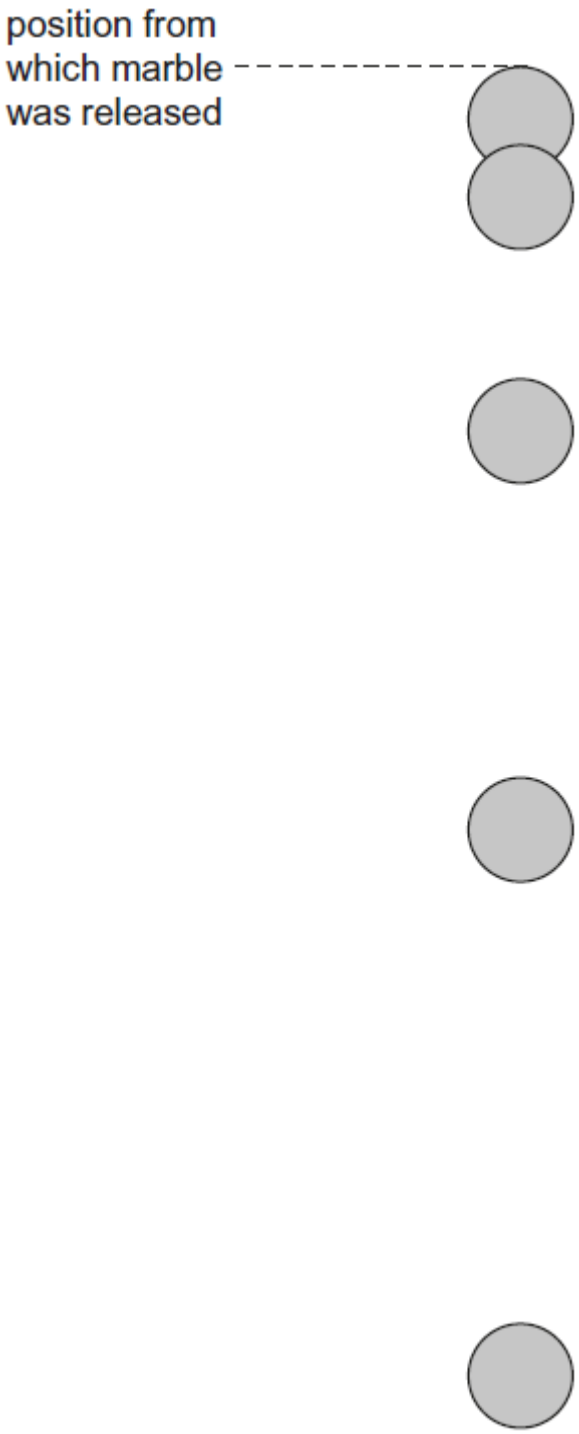
(ii) Calculate a value for g using your measurements from **(a)(i)**.

(2)

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

(1)

STEMUP.CO.UK

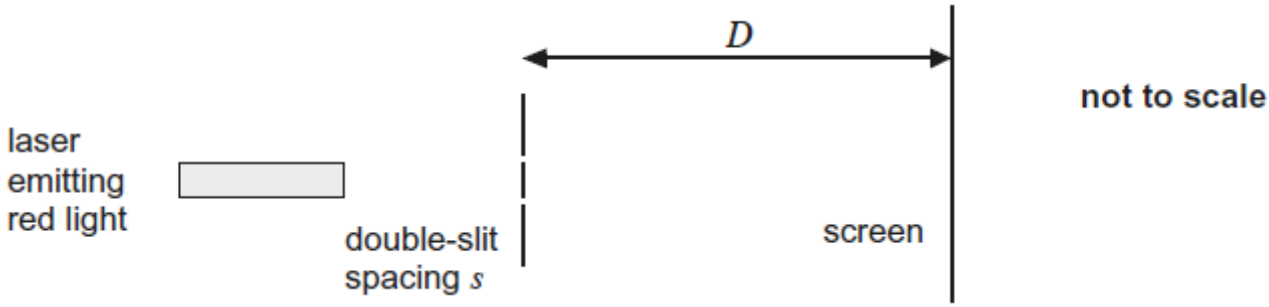


(Total 5 marks)

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.

STEMUP.CO.UK



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

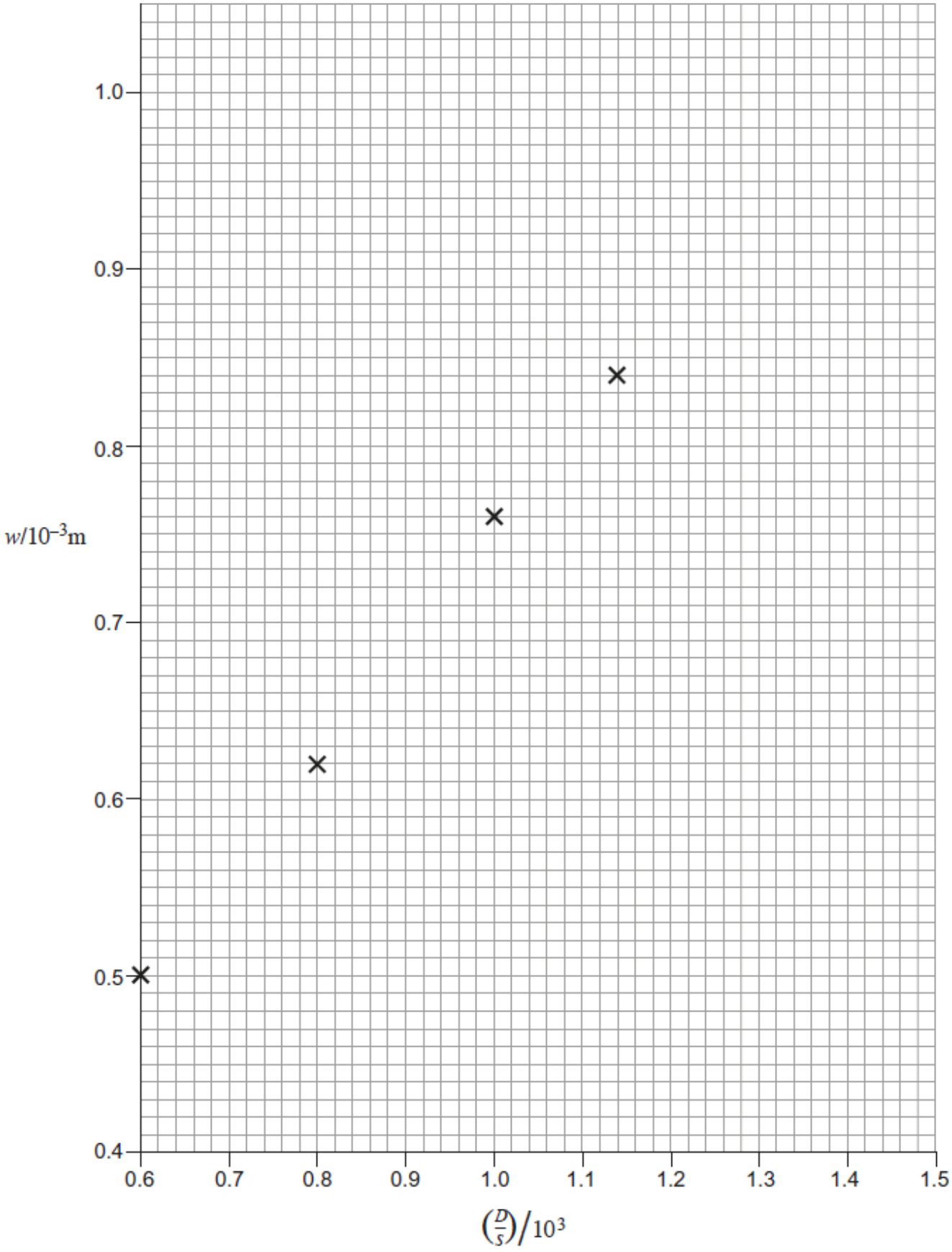
(a) Complete the table above.

(1)

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

(2)

STEMUP.CO.UK



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

STEMUP.CO.UK

(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.

STEMUP.CO.UK

(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.

_____

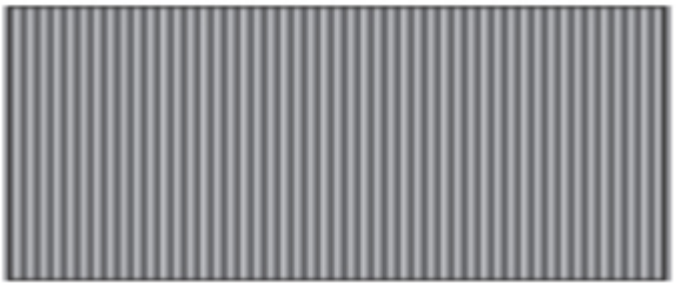
_____

(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.

_____

_____

_____

_____

(3)

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

_____

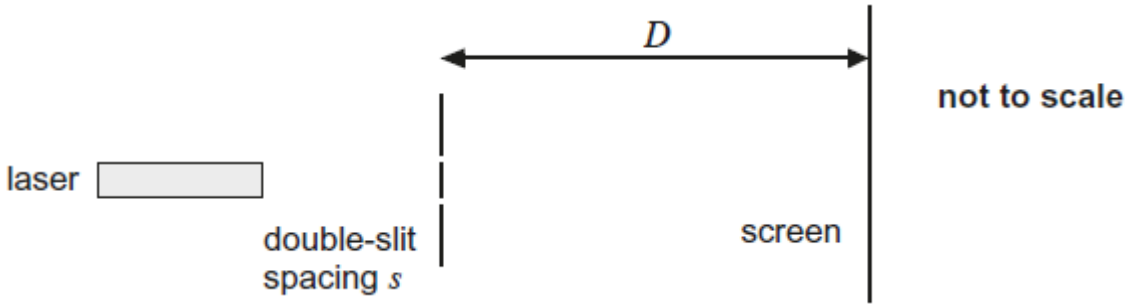
_____

_____

(2)

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

STEMUP.CO.UK



s = 0.60 ± 0.02 mm
D = 1.500 ± 0.002 m

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

(i) the wavelength of the laser light used

_____

_____

_____

(1)

(ii) the percentage uncertainty in this value of wavelength

_____

_____

_____

(1)

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

_____

_____

_____

(1)

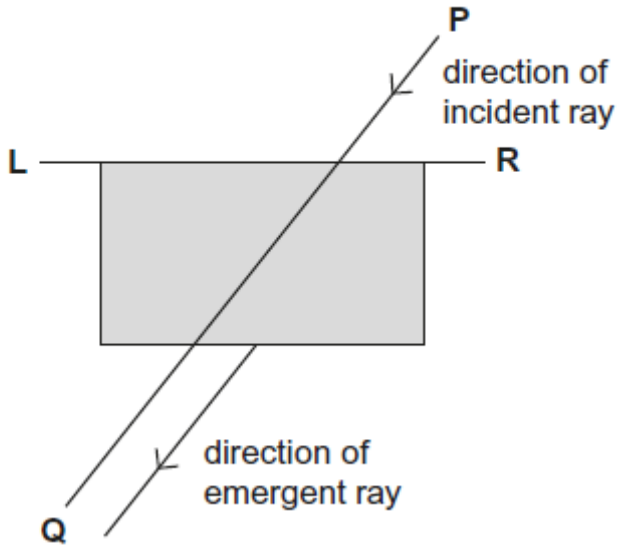
(Total 8 marks)

Q25.

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

STEMUP.CO.UK

Figure 1



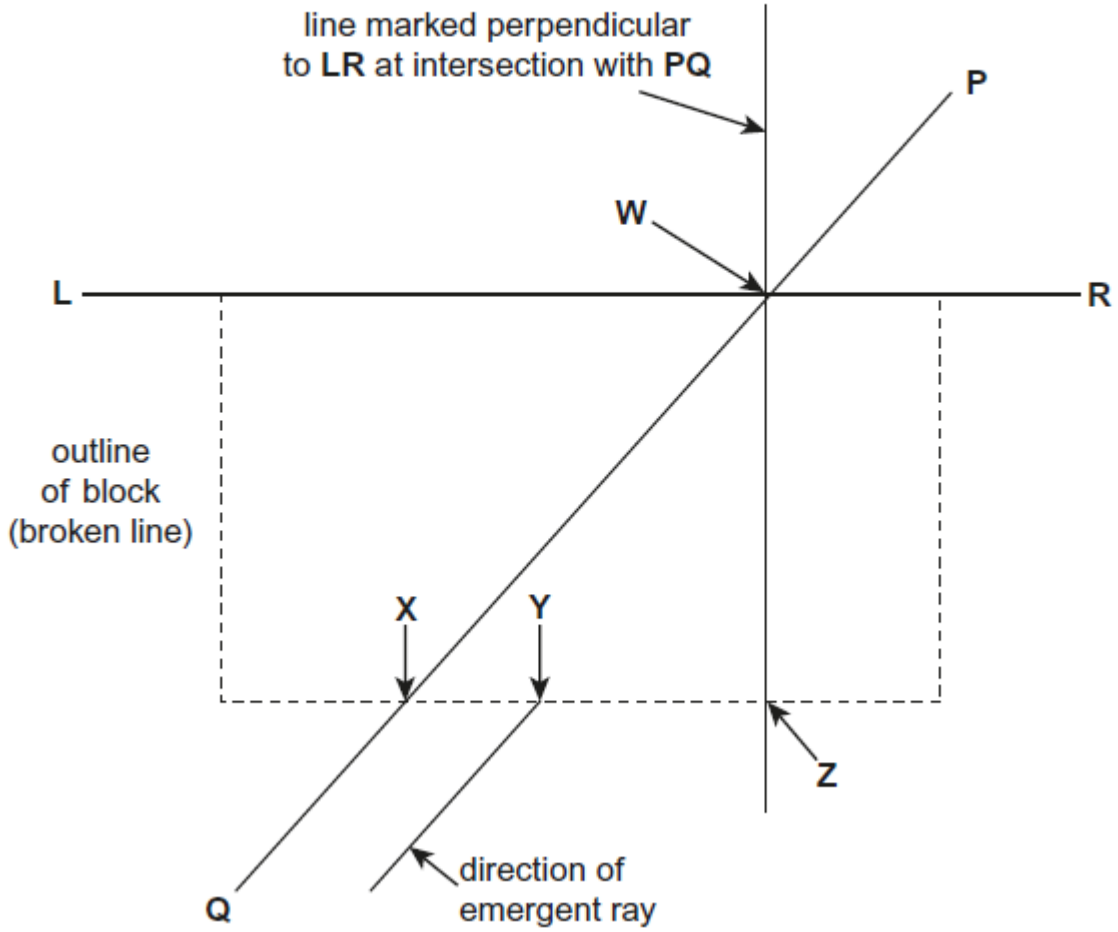
The student marks the outline of the block and directs a ray along **PQ**.

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**.

STEMUP.CO.UK

Figure 2



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

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

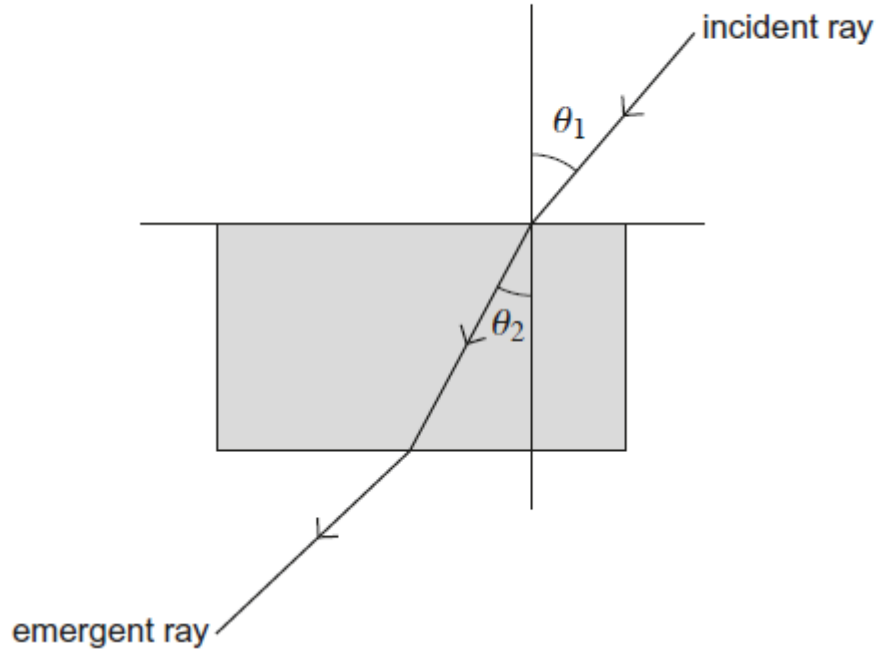
You may wish to use the equation $n = \frac{\sin\theta_1}{\sin\theta_2}$

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

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

STEMUP.CO.UK

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.

STEMUP.CO.UK

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.

_____

_____

_____

_____

_____

_____

(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**.

STEMUP.CO.UK

Figure 1

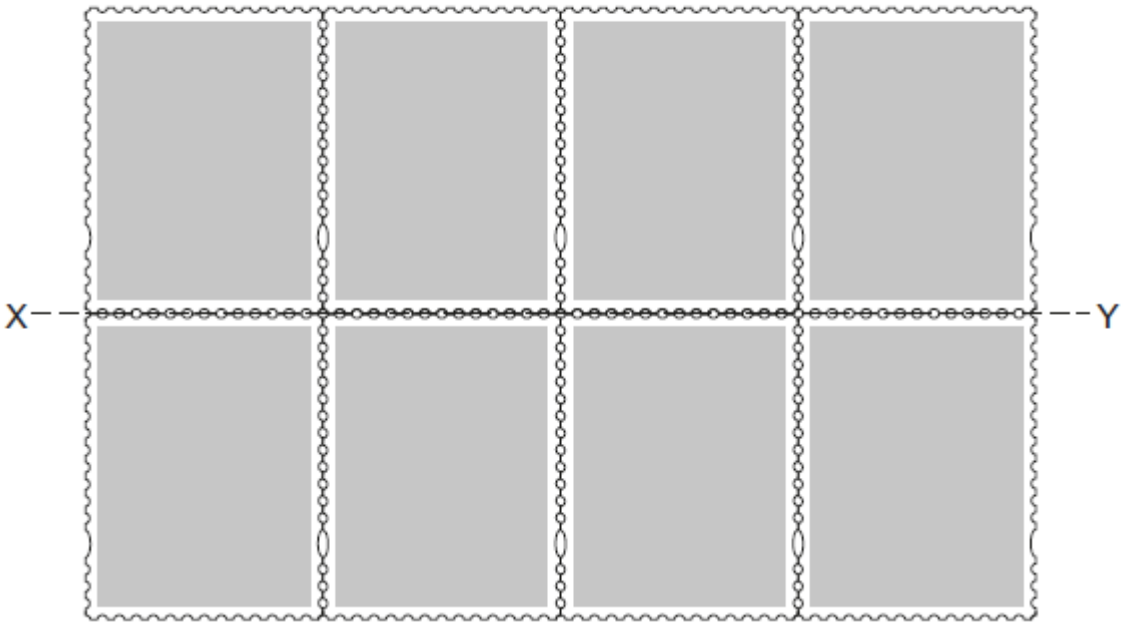
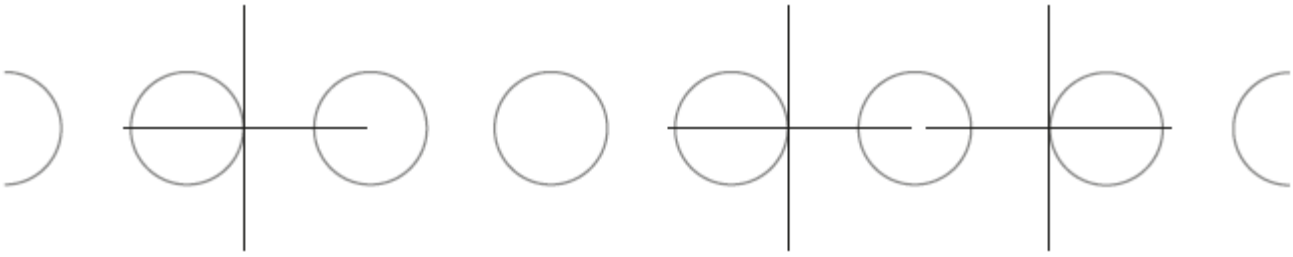


Figure 2 shows the positions of the cross-wires of the microscope when the student makes readings R_1, R_2 and R_3.

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.

STEMUP.CO.UK

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)

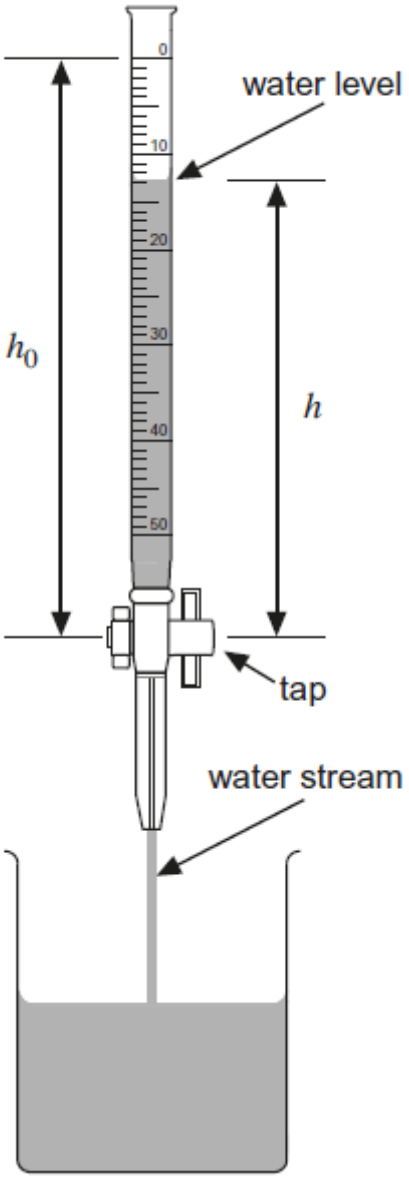
Q27.

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**.

STEMUP.CO.UK

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

STEMUP.CO.UK

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.

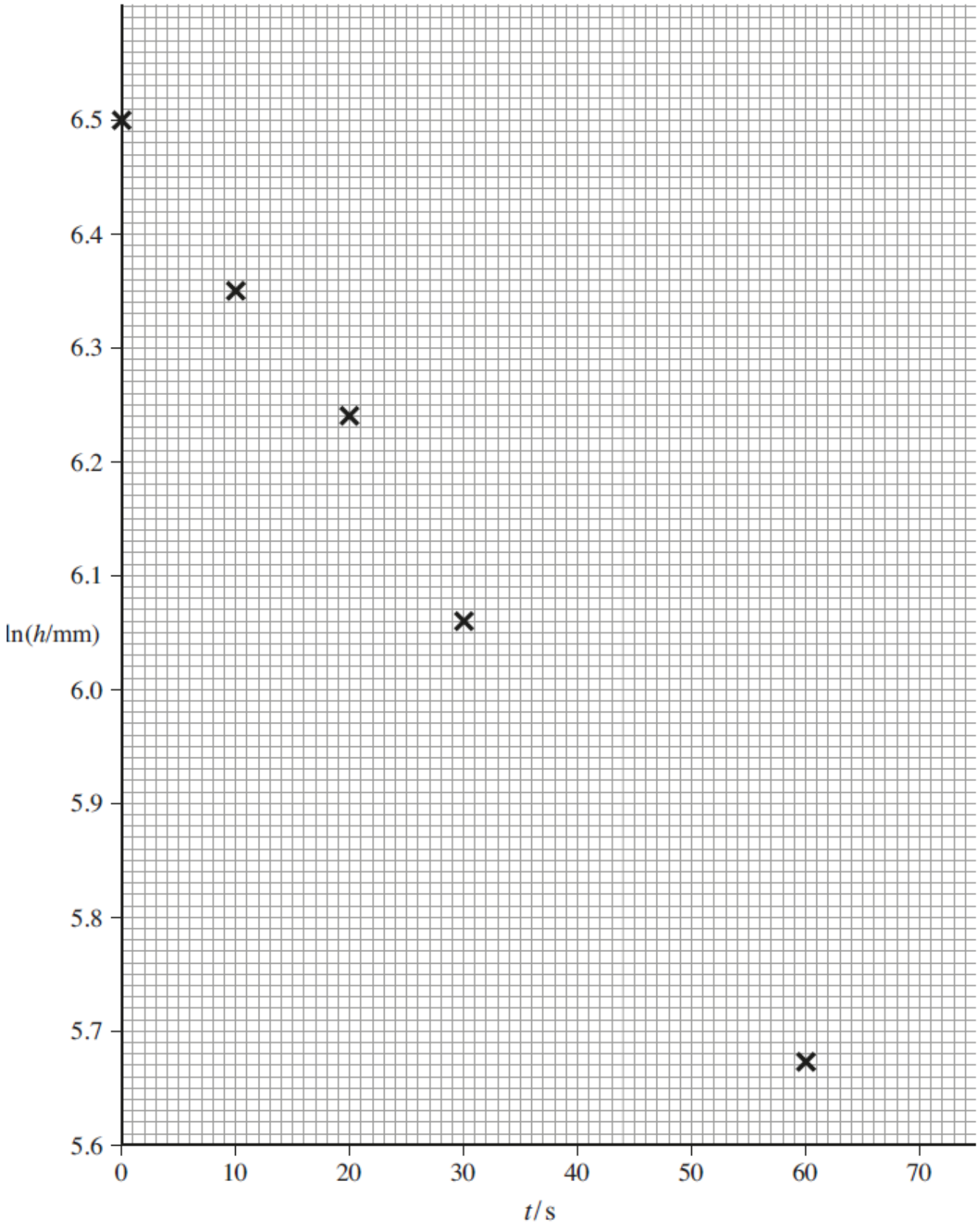
H = _____ unit = _____

λ = _____ unit = _____

(3)

STEMUP.CO.UK

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.

STEMUP.CO.UK

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)

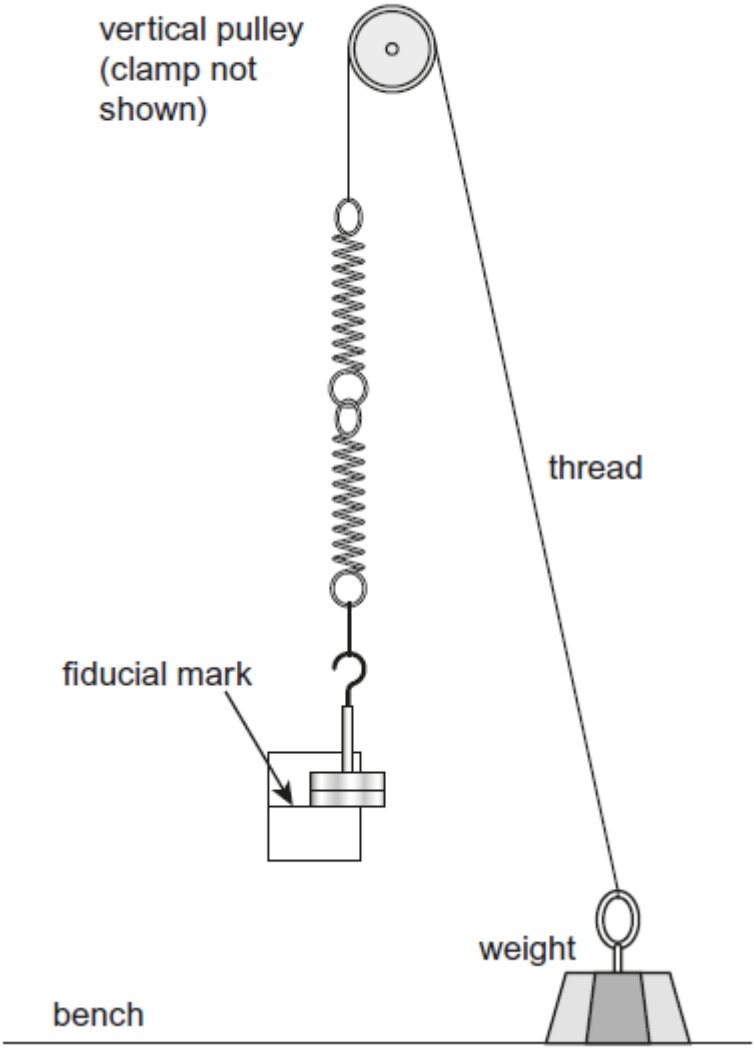
(Total 14 marks)

Q28.

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

STEMUP.CO.UK

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.

_____

_____

_____

_____

(1)

The table below shows the measurements recorded by the student.

STEMUP.CO.UK

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 = _____

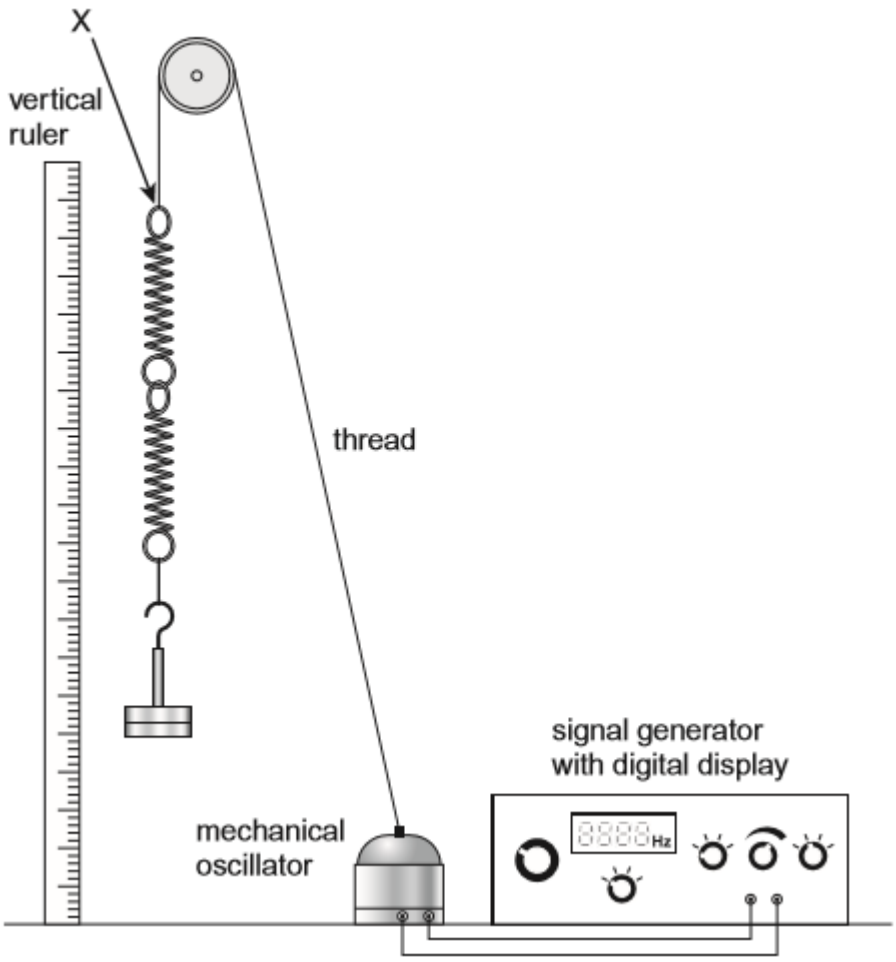
(1)

(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.

STEMUP.CO.UK

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)

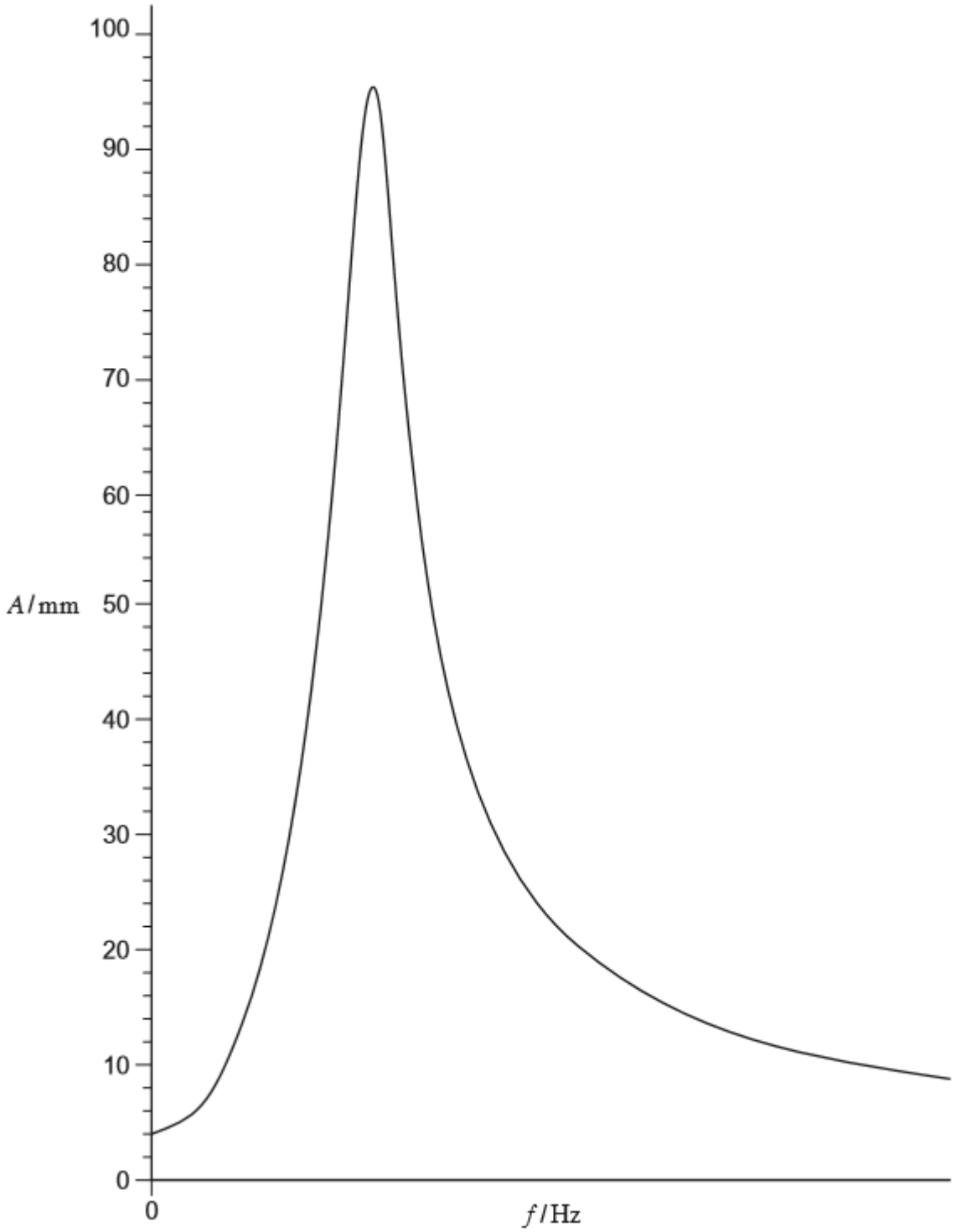
(ii) Deduce from **Figure 3** the amplitude of the oscillations of X, the point where the mass–spring system is joined to the thread.
You should assume that the length of the thread is constant.

amplitude of X = _____

(1)

STEMUP.CO.UK

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.

STEMUP.CO.UK

(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)

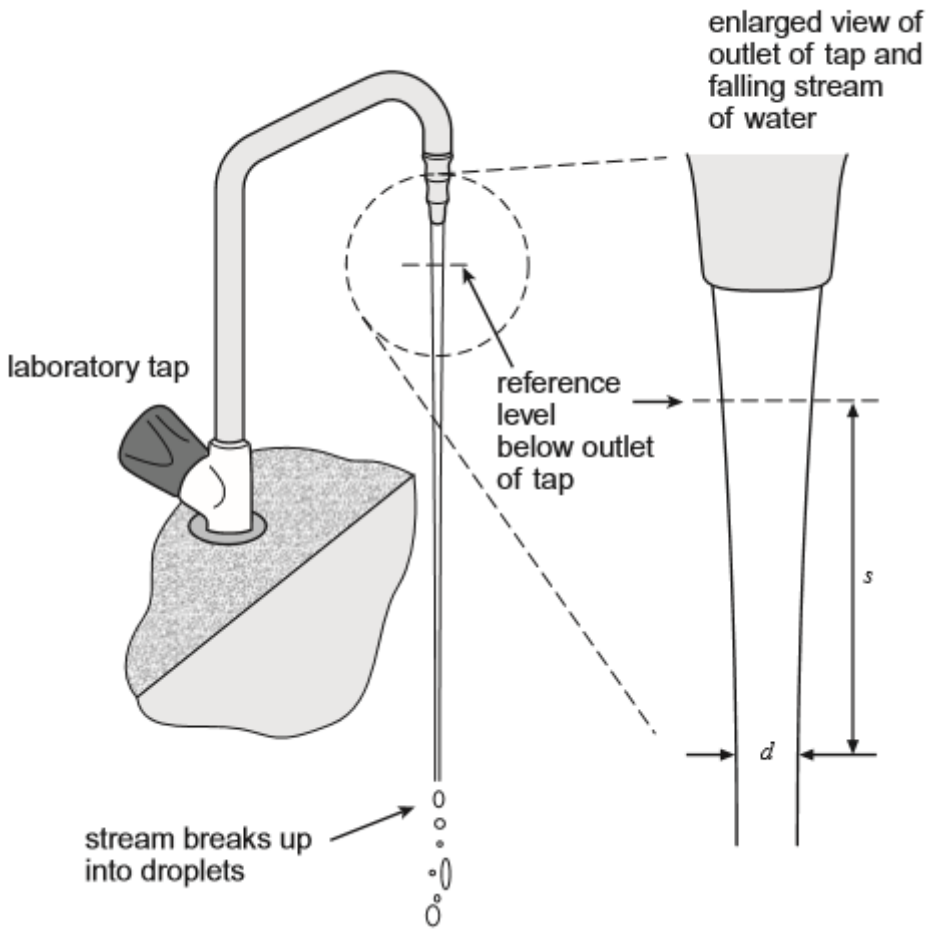
Q29.

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.

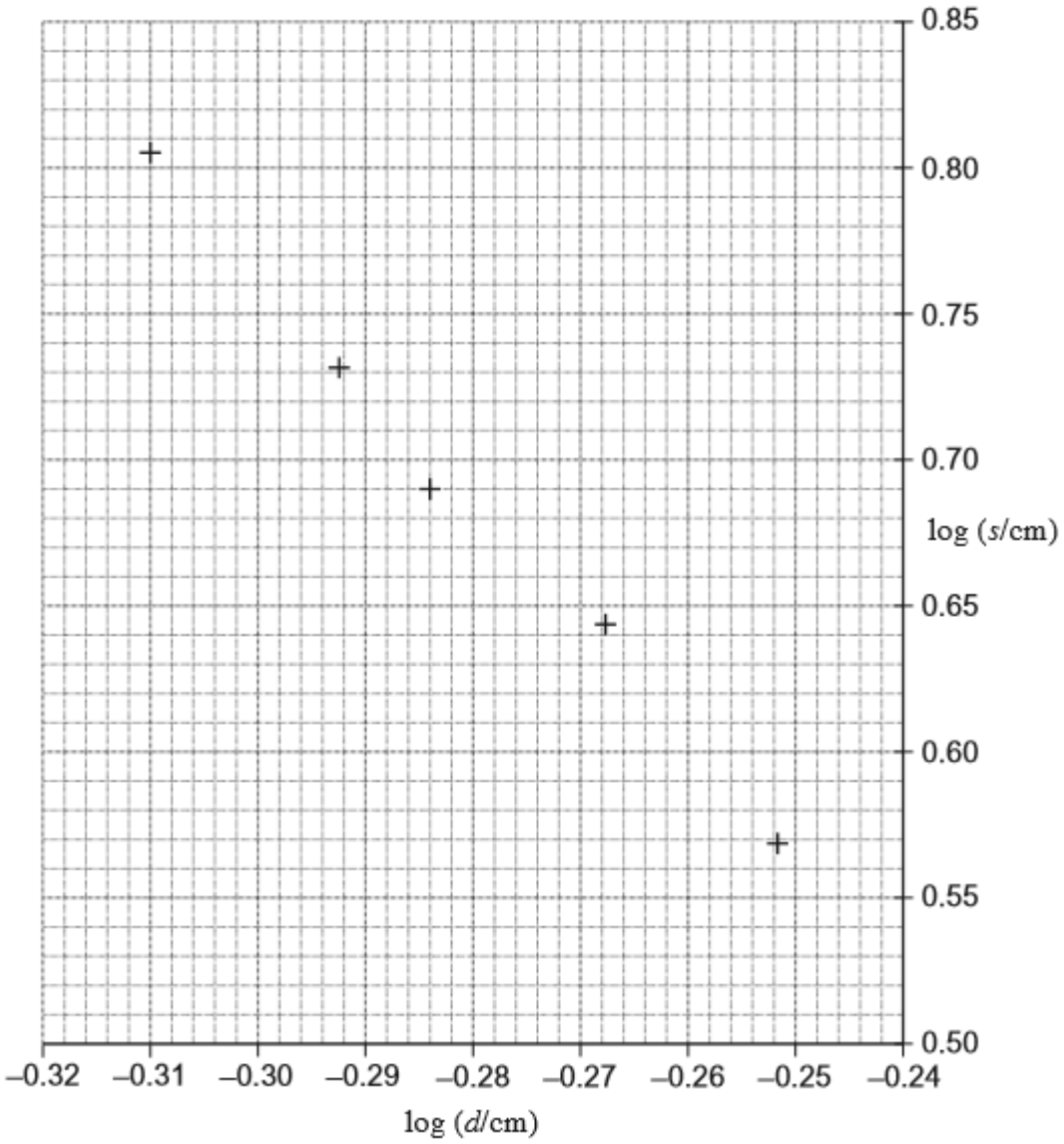
STEMUP.CO.UK

(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**.

STEMUP.CO.UK

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.

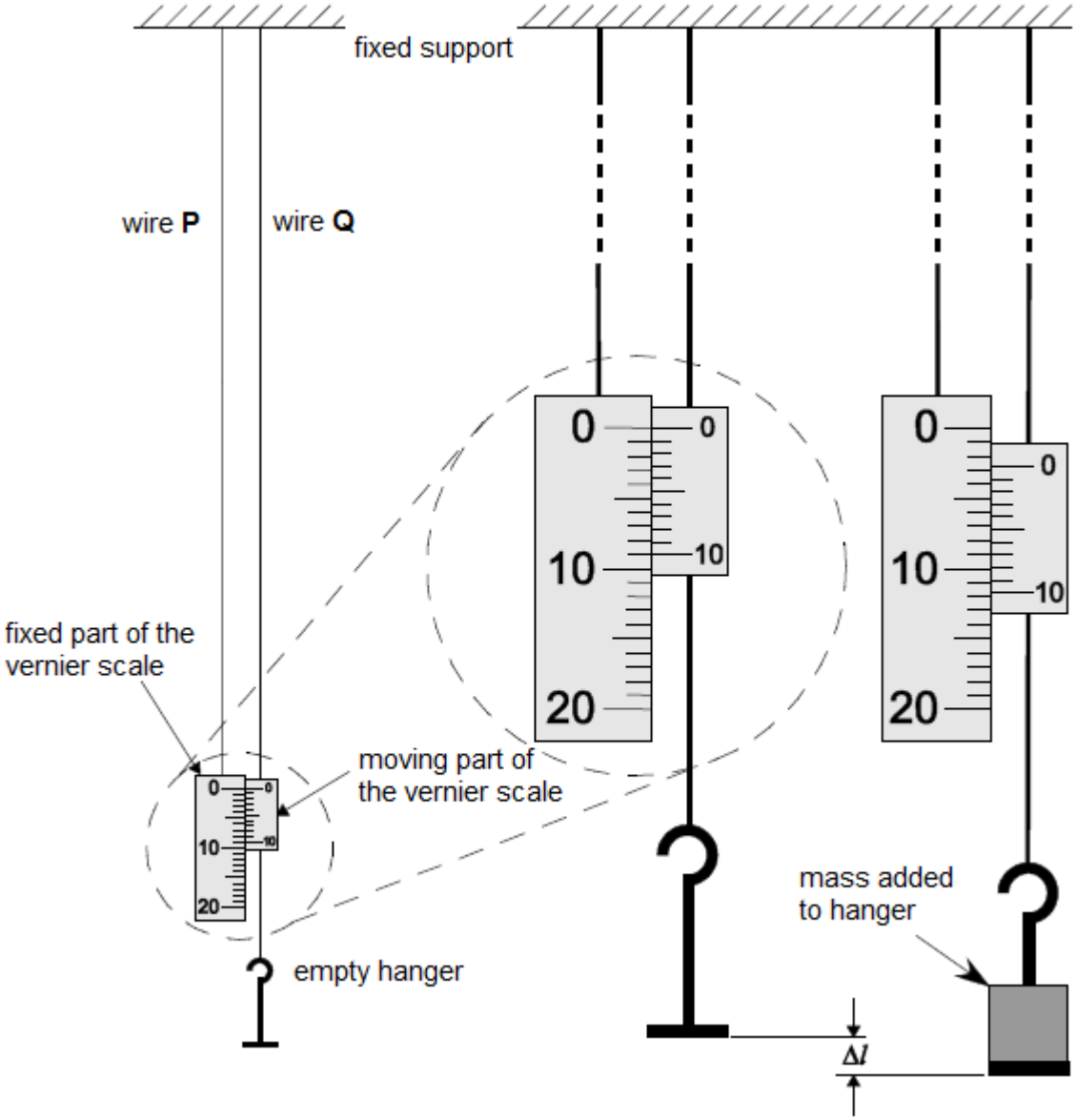
This question is about the determination of the Young modulus of the metal of a wire.

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

STEMUP.CO.UK



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

Determine Δl using **Figure 1**.

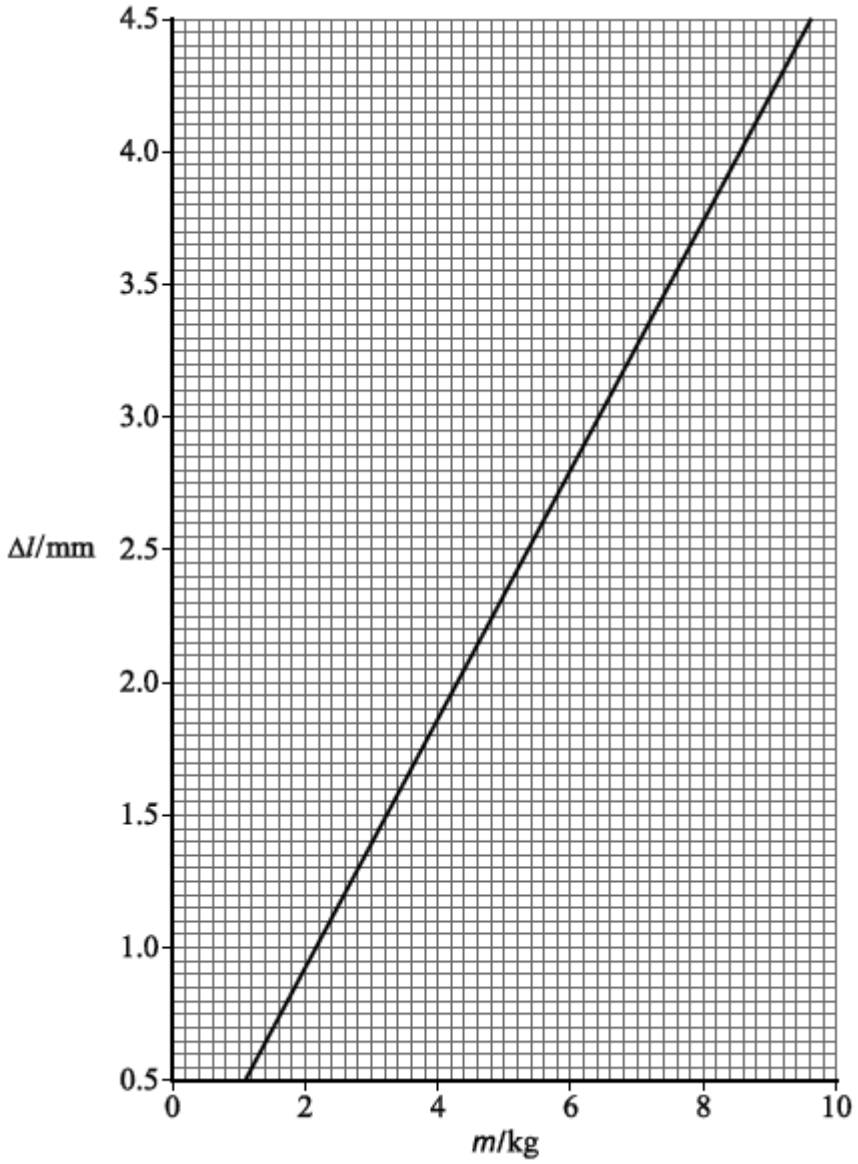
Δl = _____ mm

(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

STEMUP.CO.UK



mass = _____ kg

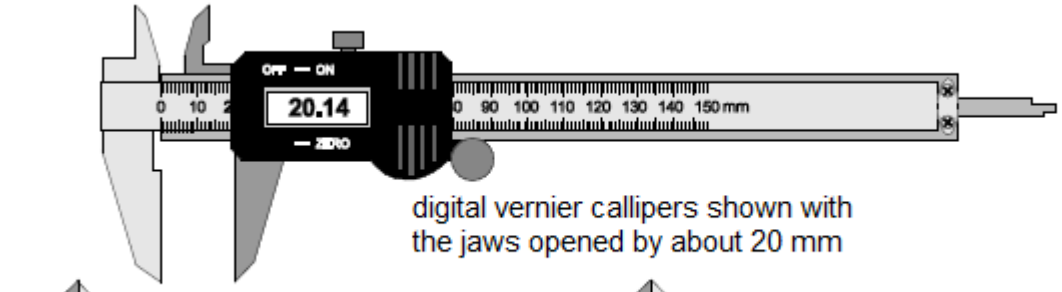
(1)

(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.

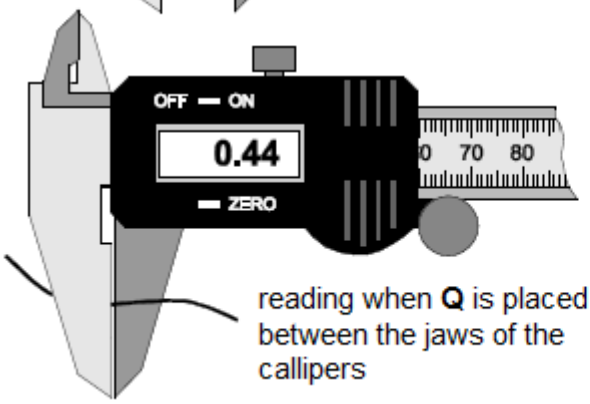
Views of the callipers before and after she closes the jaws are shown in **Figure 3**.

Figure 3

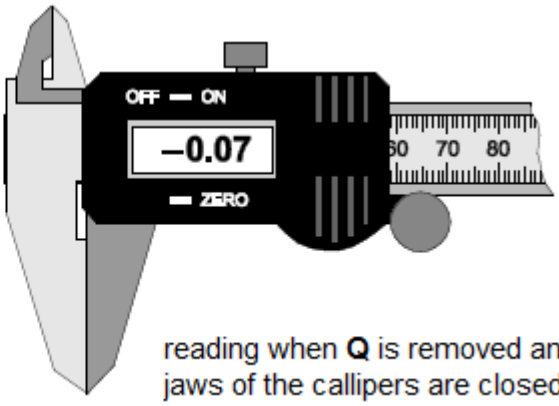
STEMUP.CO.UK



digital vernier callipers shown with the jaws opened by about 20 mm



reading when **Q** is placed between the jaws of the callipers



reading when **Q** is removed and the jaws of the callipers are closed

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. _____

_____

STEMUP.CO.UK

2. _____

(4)

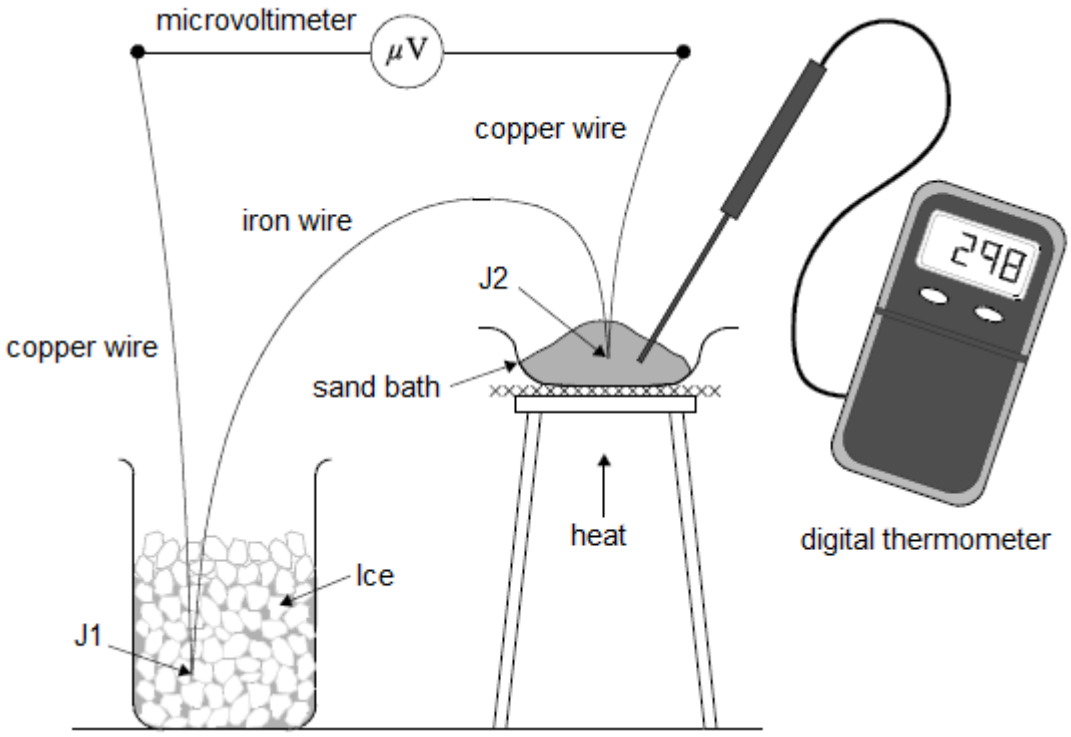
(Total 11 marks)

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.

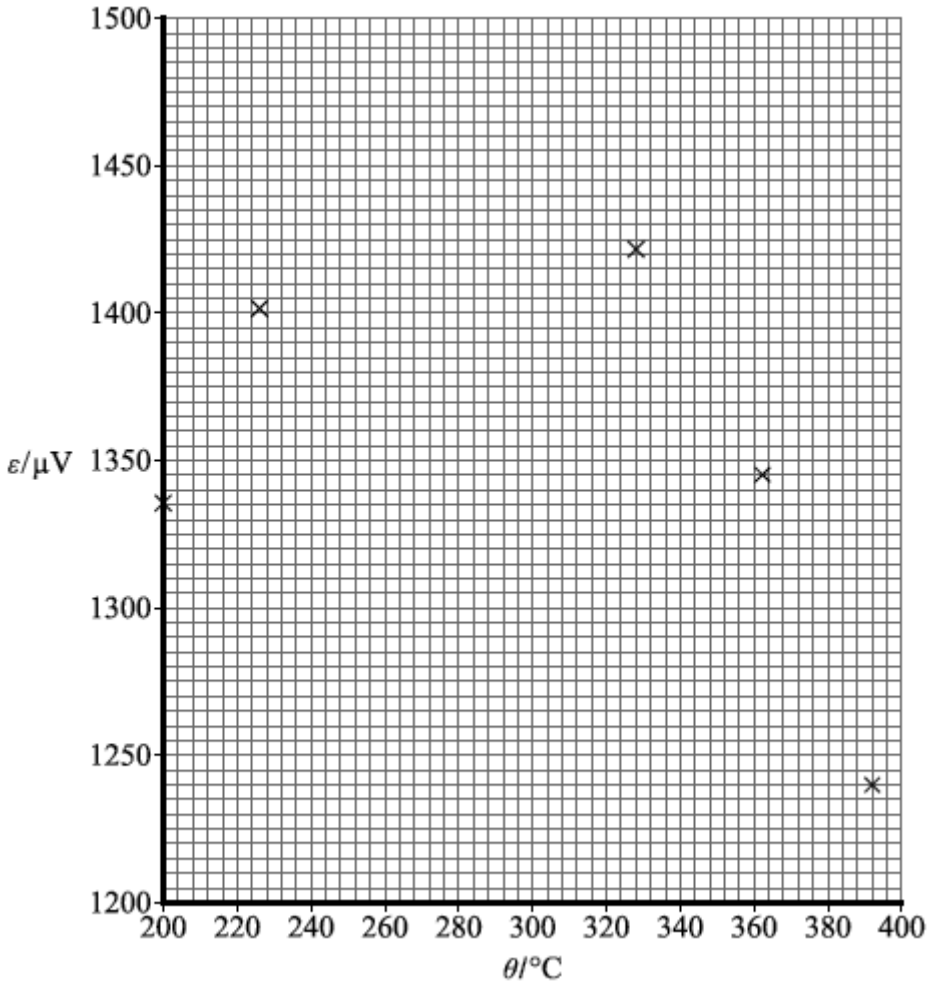
The results of the experiment are shown in the table below and a graph of the data is shown in **Figure 2**.

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

STEMUP.CO.UK

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.

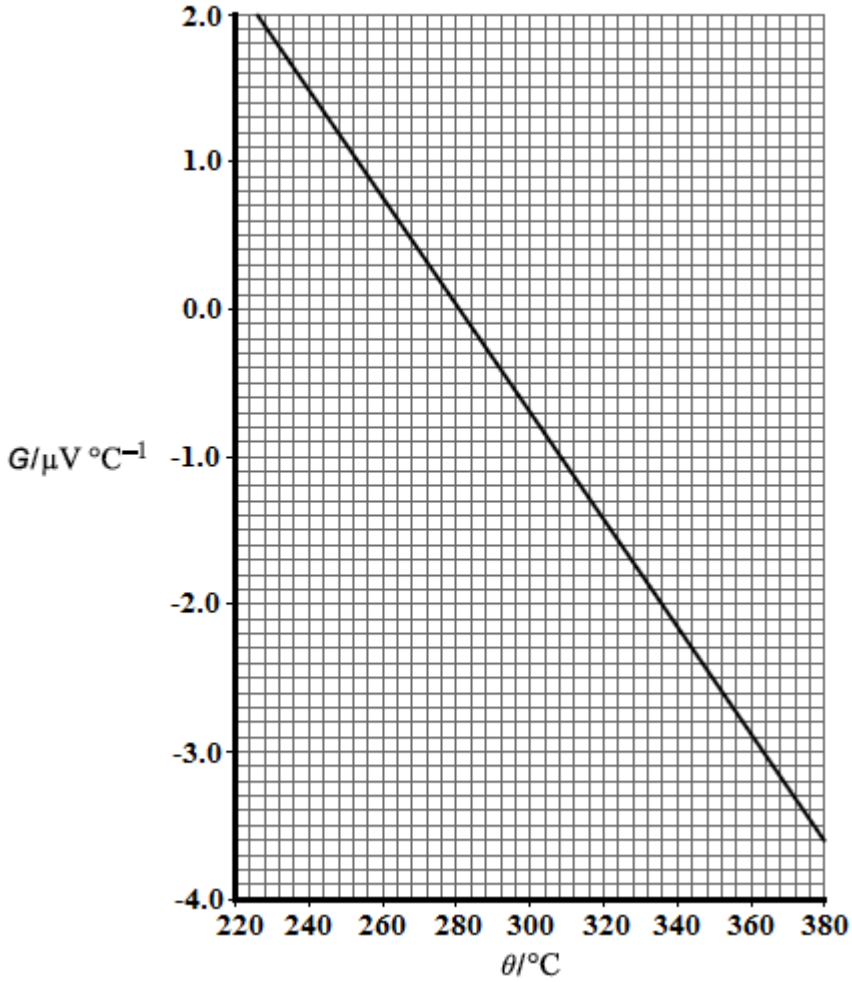
maximum value of ε = _____ μV

(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

STEMUP.CO.UK



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**.

(1)

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

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

where α and β are constants.

Determine α.

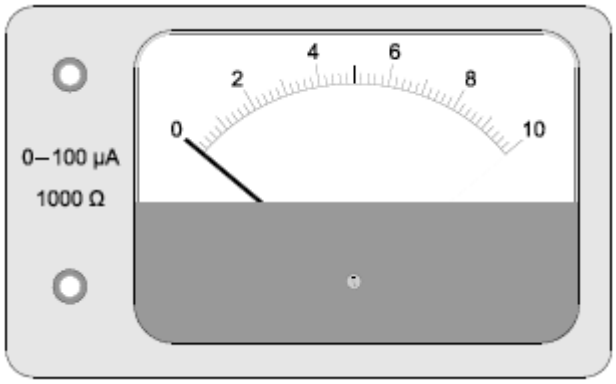
STEMUP.CO.UK

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.

_____

_____

_____

_____

_____

_____

(2)

STEMUP.CO.UK

(Total 9 marks)

Q32.

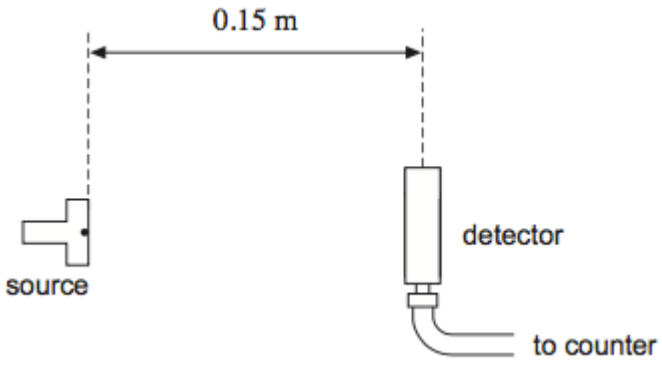
(a) The exposure of the general public to background radiation has changed substantially over the past 100 years.
State **one** source of radiation that has contributed to this change.

_____

_____

(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.

_____

_____

_____

_____

(1)

STEMUP.CO.UK

(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.

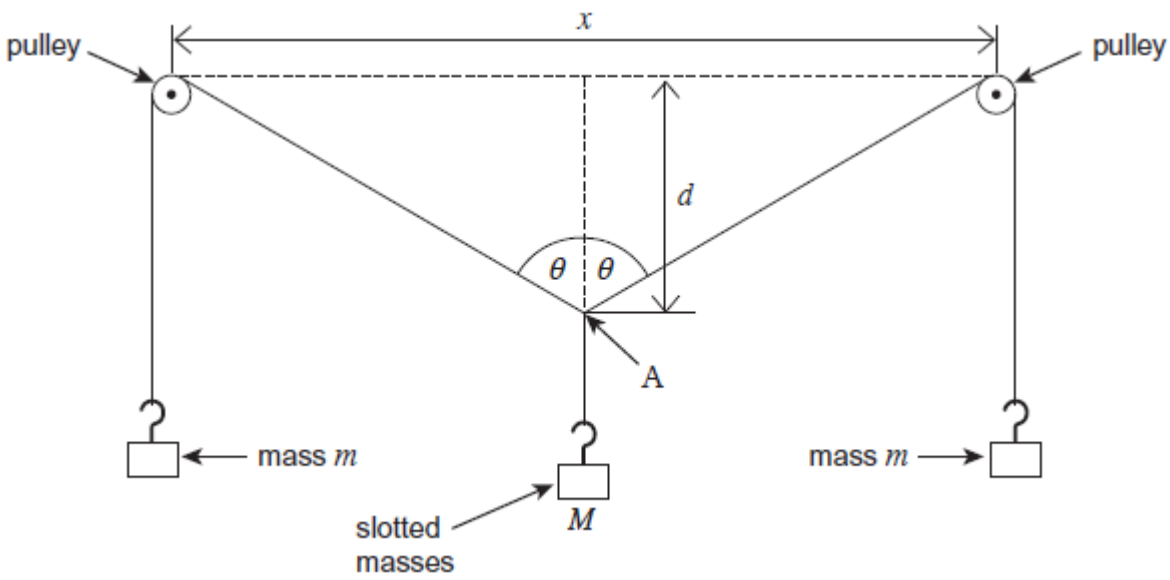
(2)

(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**.

STEMUP.CO.UK

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.**

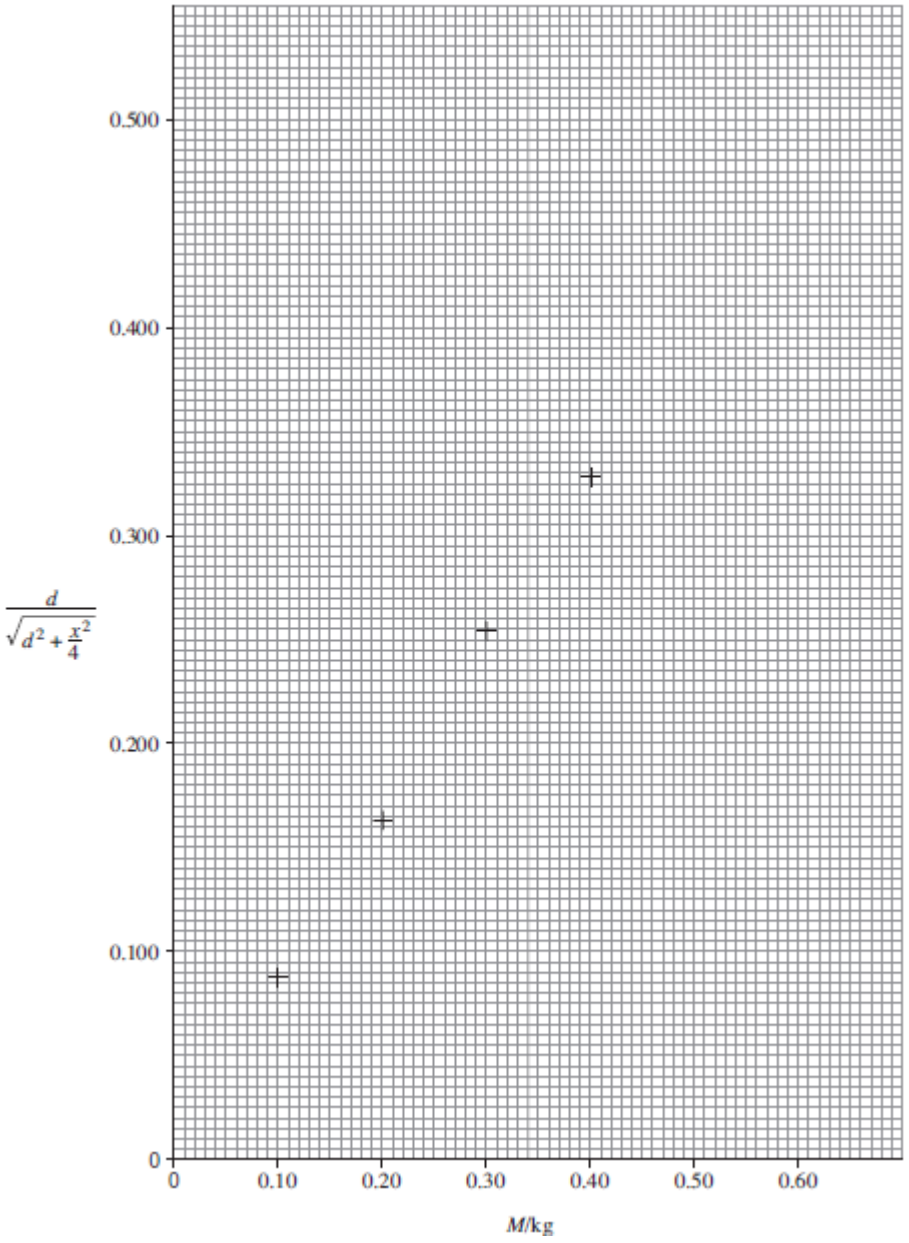
gradient = _____

(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

STEMUP.CO.UK



(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).

STEMUP.CO.UK

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.

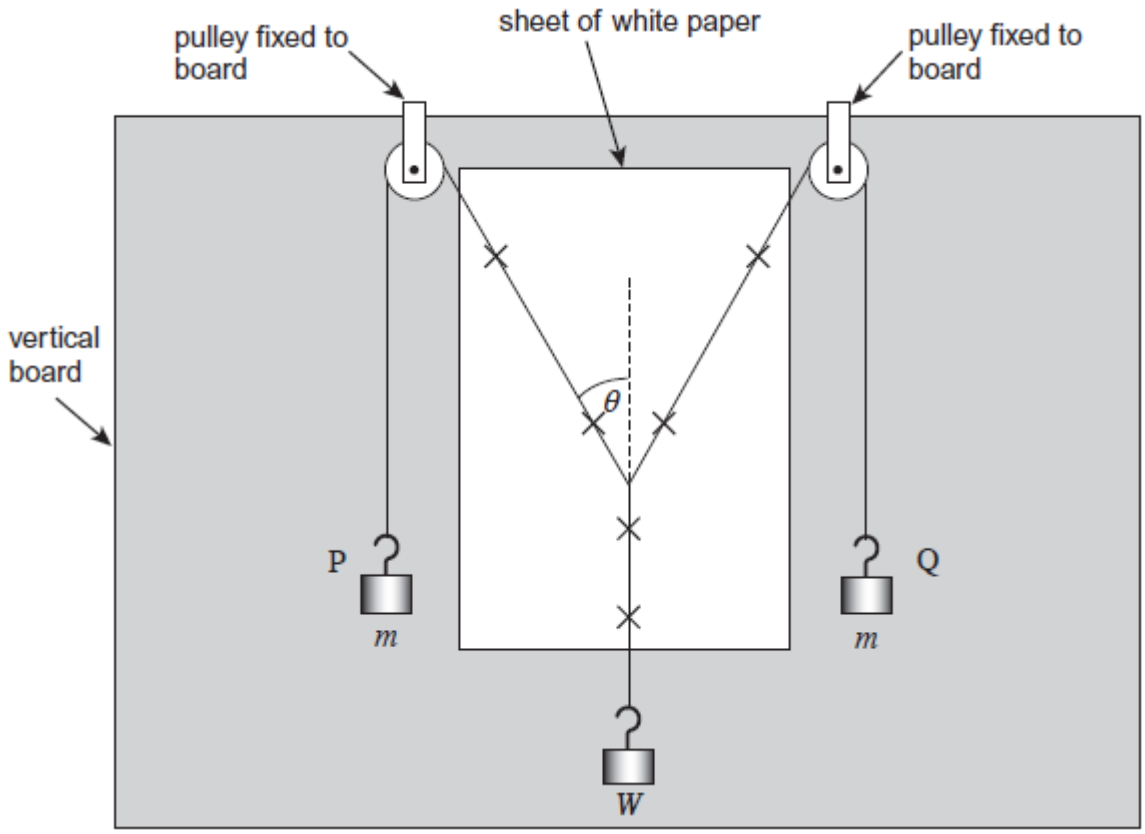
_____

_____

(1)

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

Figure 1



STEMUP.CO.UK

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.

_____

_____

_____

_____

_____

_____

(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.

STEMUP.CO.UK

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.

_____

_____

_____

_____

Figure 2

STEMUP.CO.UK

(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

STEMUP.CO.UK

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.

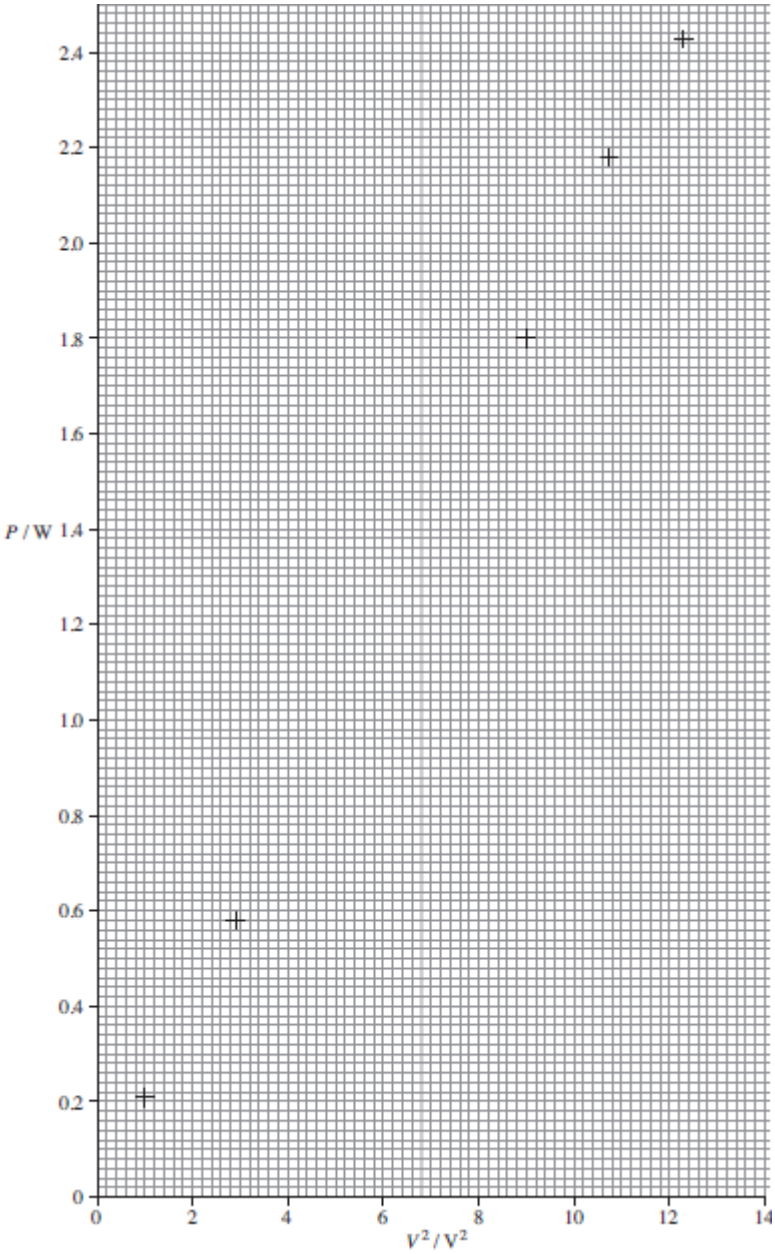
gradient = _____

(3)

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

R = _____

STEMUP.CO.UK



(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.

STEMUP.CO.UK

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)

_____

_____

_____

_____

_____

_____

(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.

_____

_____

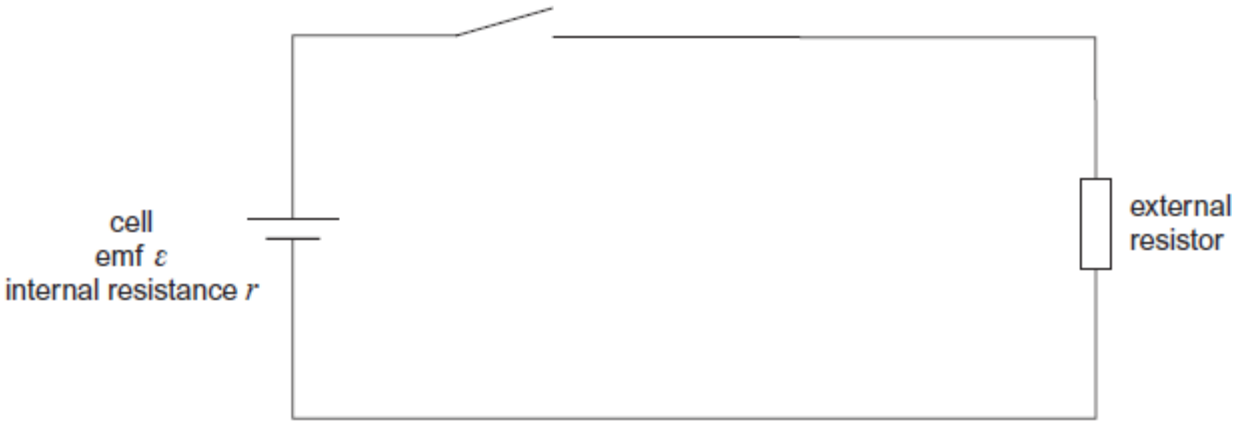
(1)

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

STEMUP.CO.UK

(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

STEMUP.CO.UK

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)

STEMUP.CO.UK