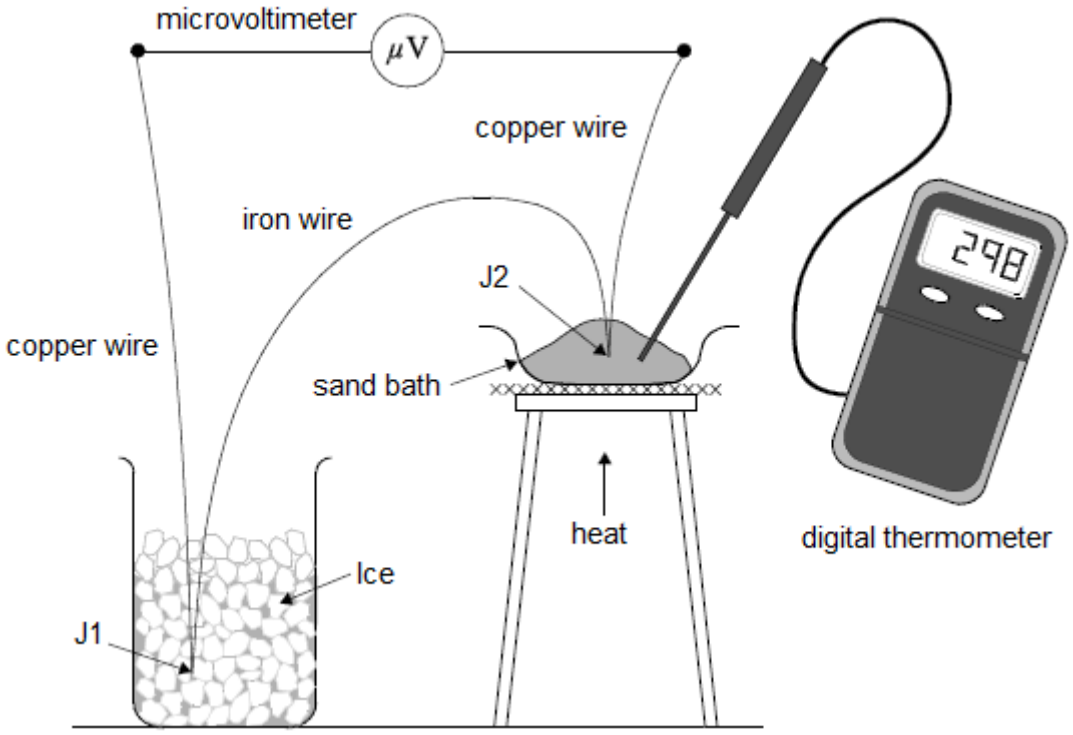
Q1. Lengths of copper and iron wire are joined together to form junctions J1 and J2. When J1 and J2 are at different temperatures an emf ε is generated between them. This emf is measured using a microvoltmeter.
Figure 1 shows J1 kept at 0°C while J2 is heated in a sand bath to a temperature θ measured by a digital thermometer.

Figure 1

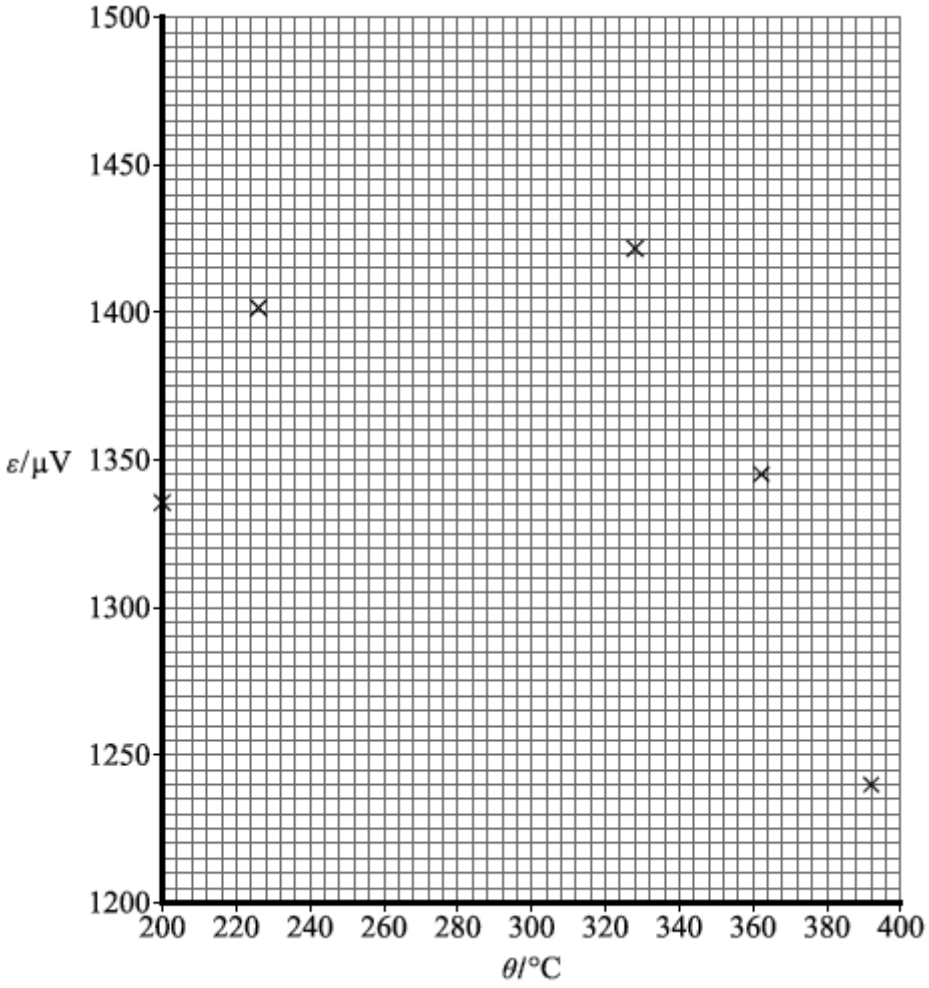


An experiment is carried out to determine how ε depends on θ.

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)

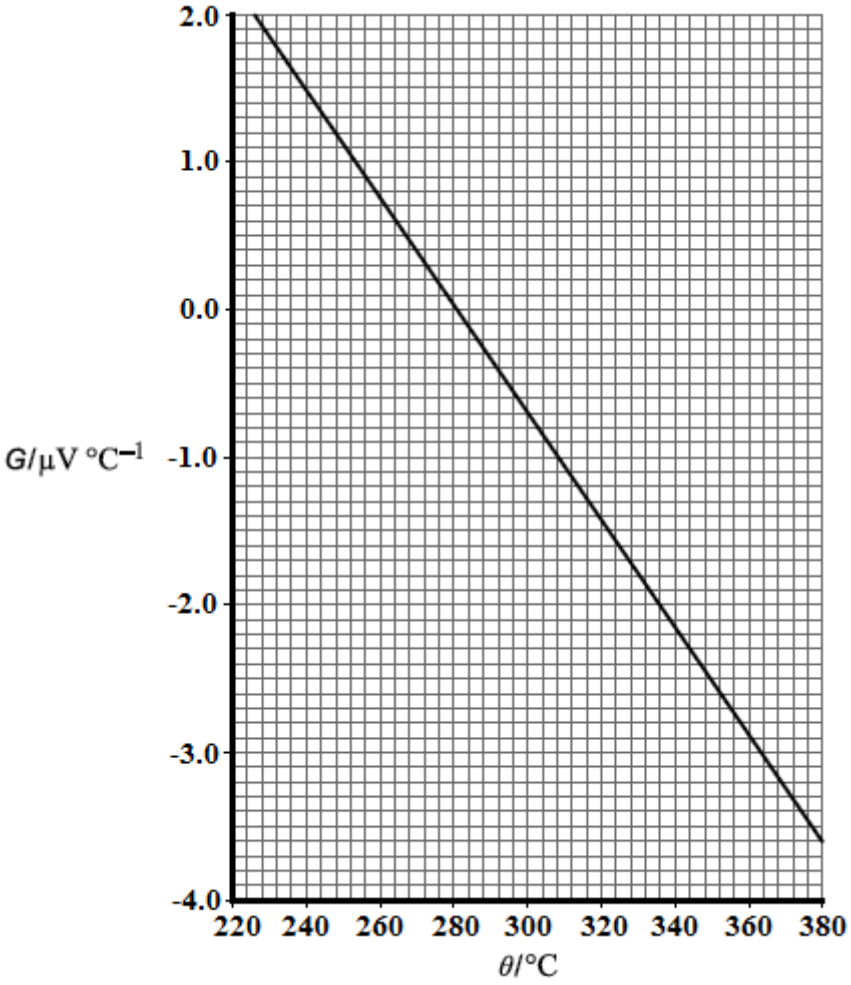
(c) Determine the maximum value of ε.

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.

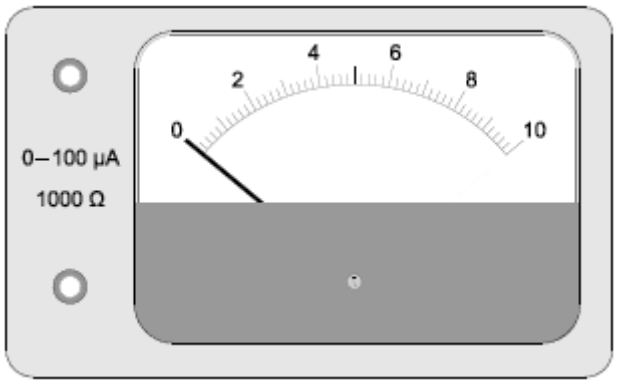
Determine α.

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)

Q2.(a)

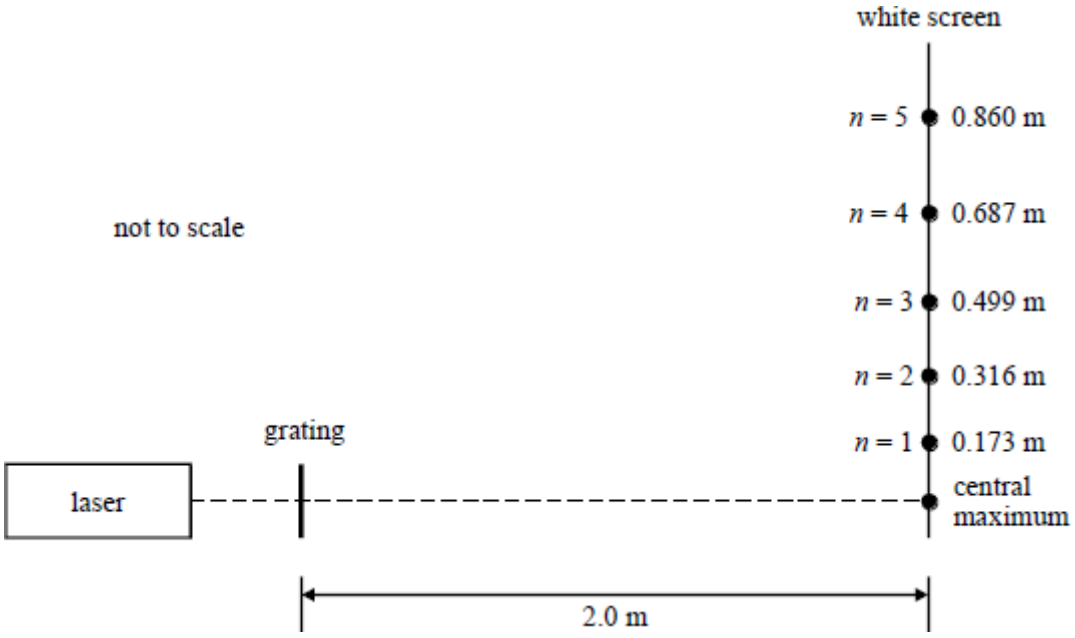

Figure 1

In a laboratory experiment, monochromatic light of wavelength 633 nm from a laser is incident normal to a diffraction grating. The diffracted waves are received on a white screen which is parallel to the plane of the grating and 2.0 m from it. **Figure 1** shows the positions of the diffraction maxima with distances measured from the central maximum.

By means of a graphical method, use all these measurements to determine a mean value for the number of rulings per unit length of the grating.

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(b) Describe and explain the effect, if any, on the appearance of the diffraction pattern of

(i) using a grating which has more rulings per unit length.

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(ii) using a laser source which has a shorter wavelength.

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(iii) increasing the distance between the grating and the screen.

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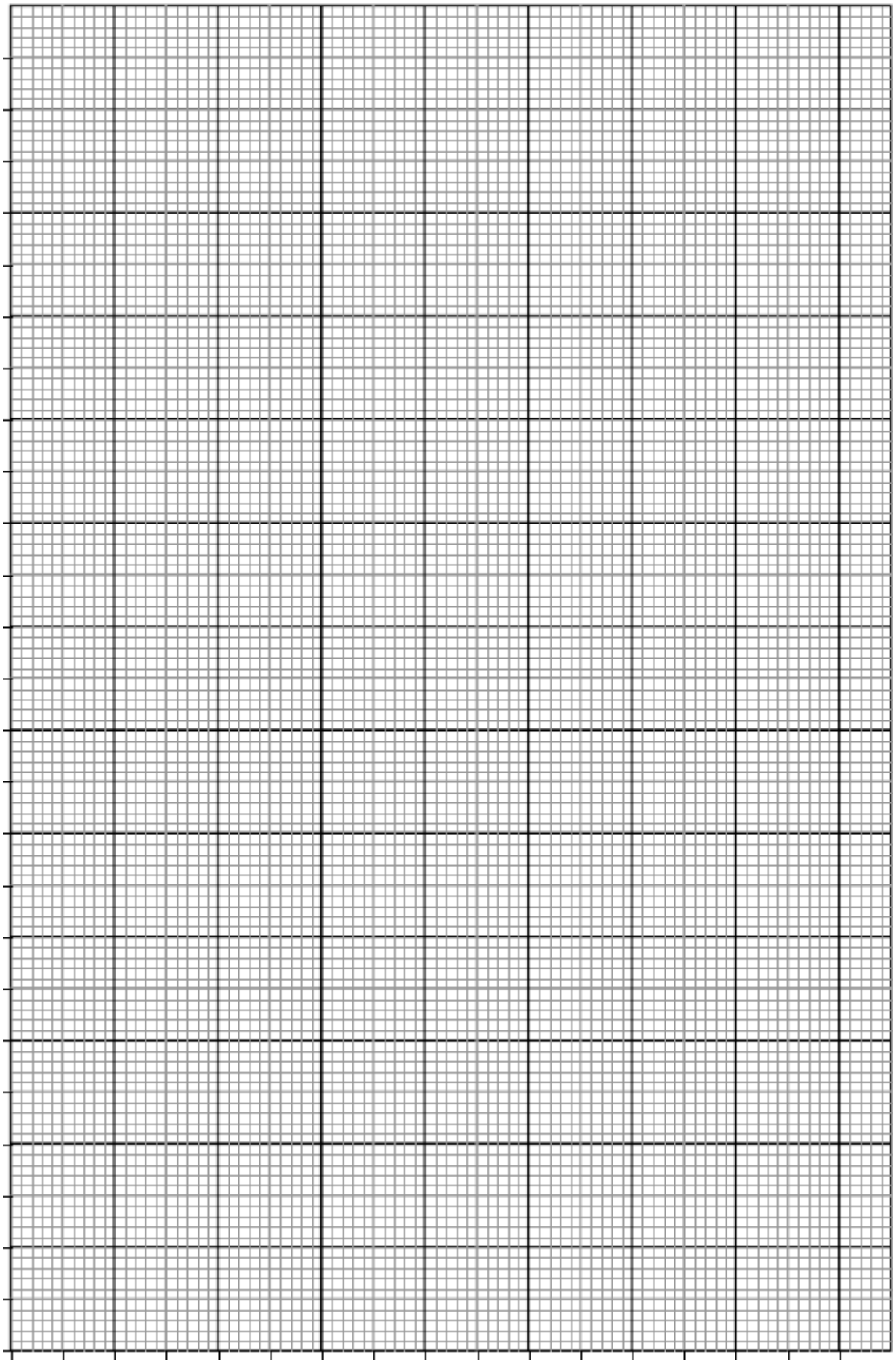
(6)



(6)

(c) **Figure 2**, below, shows the diffracted waves from four narrow slits of a diffraction grating similar to the one described in part (a). The slit separation AB = BC = CD = DE = d and EQ is a line drawn at a tangent to several wavefronts and which makes an angle θ with the grating.

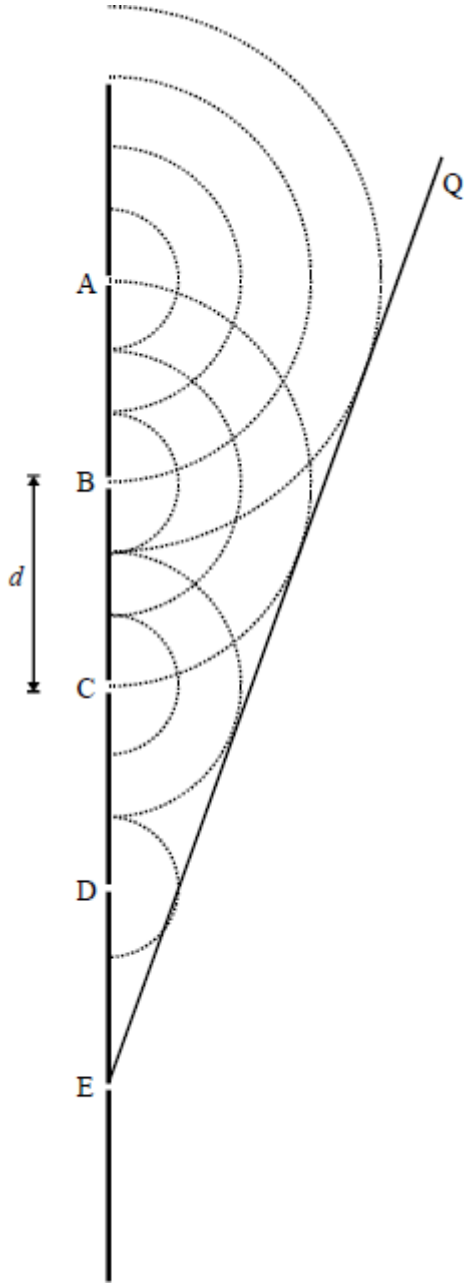


Figure 2

(i) Explain why the waves advancing perpendicular to EQ will reinforce if superposed.

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(ii) Show that this will happen when $\sin\theta = \frac{\lambda}{d}$

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(3)
(Total 15 marks)

Q3. In an attempt to investigate how the resistance of a filament lamp varies with current through the lamp, a student obtains the results shown in the table.

voltage/V	0.50	1.50	3.00	4.50	6.00	12.00
current/A	0.51	1.25	2.00	2.55	2.95	4.00
resistance/Ω						

(a) Complete the table by calculating the corresponding values of resistance.

(2)

(b) (i) On the grid on the next page plot a graph of resistance against current for the filament lamp.

(ii) Use your graph to estimate the resistance of the filament lamp when no current flows through the lamp.

.....

(iii) Use your graph to determine the change in the resistance of the filament when the current increases

from 0 to 1.0 A, ...

.....

from 1.0 A to 2.0 A .....

.....

(iv) Calculate the power dissipated in the lamp filament when the current through the filament is 1.0 A and 2.0 A.

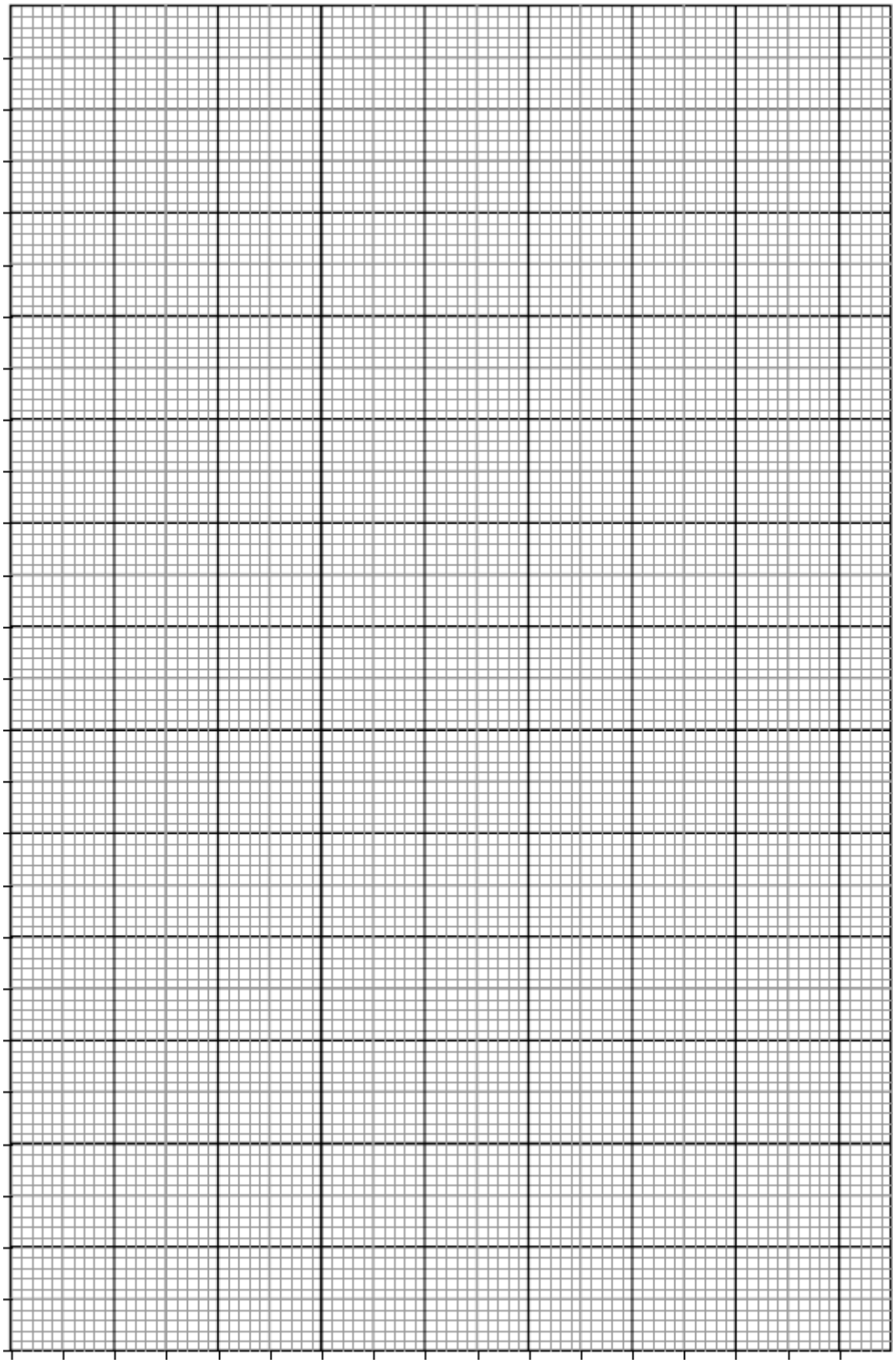
1.0 A .....

.....

2.0 A .....

.....

(8)



(c) Using information from part (b)(iv), explain why the change in resistance of the filament is less for a current change of 0 to 1.0 A than for a current change of 1.0 A to 2.0 A. Do **not** attempt any calculation.

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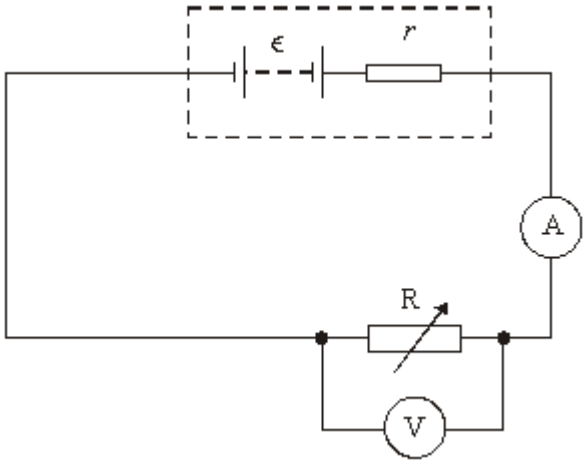
(2)
(Total 12 marks)

Q4. A battery of emf $\in$ and internal resistance *r* is connected in series to a variable resistor R and an ammeter of negligible resistance. A voltmeter is connected across R, as shown in the figure below.



(a) (i) State what is meant by the emf of the battery.

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(ii) The reading on the voltmeter is less than the emf. Explain why this is so.

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(2)

(b) A student wishes to measure ϵ and *r*. Using the circuit shown in the figure above the value of R is decreased in steps and at each step the readings *V* and *I* on the voltmeter and ammeter respectively are recorded. These are shown in the table.

reading on voltmeter/V	**reading on ammeter/A**
8.3	0.07
6.8	0.17
4.6	0.33
2.9	0.44
0.3	0.63

(i) Give an expression relating *V, I*, ϵ and *r.*

.....

(ii) Draw a graph of *V* (on the *y*-axis) against *I (*on the *x*-axis) on the grid.

(iii) Determine the values of ϵ and *r* from the graph, explaining your method.

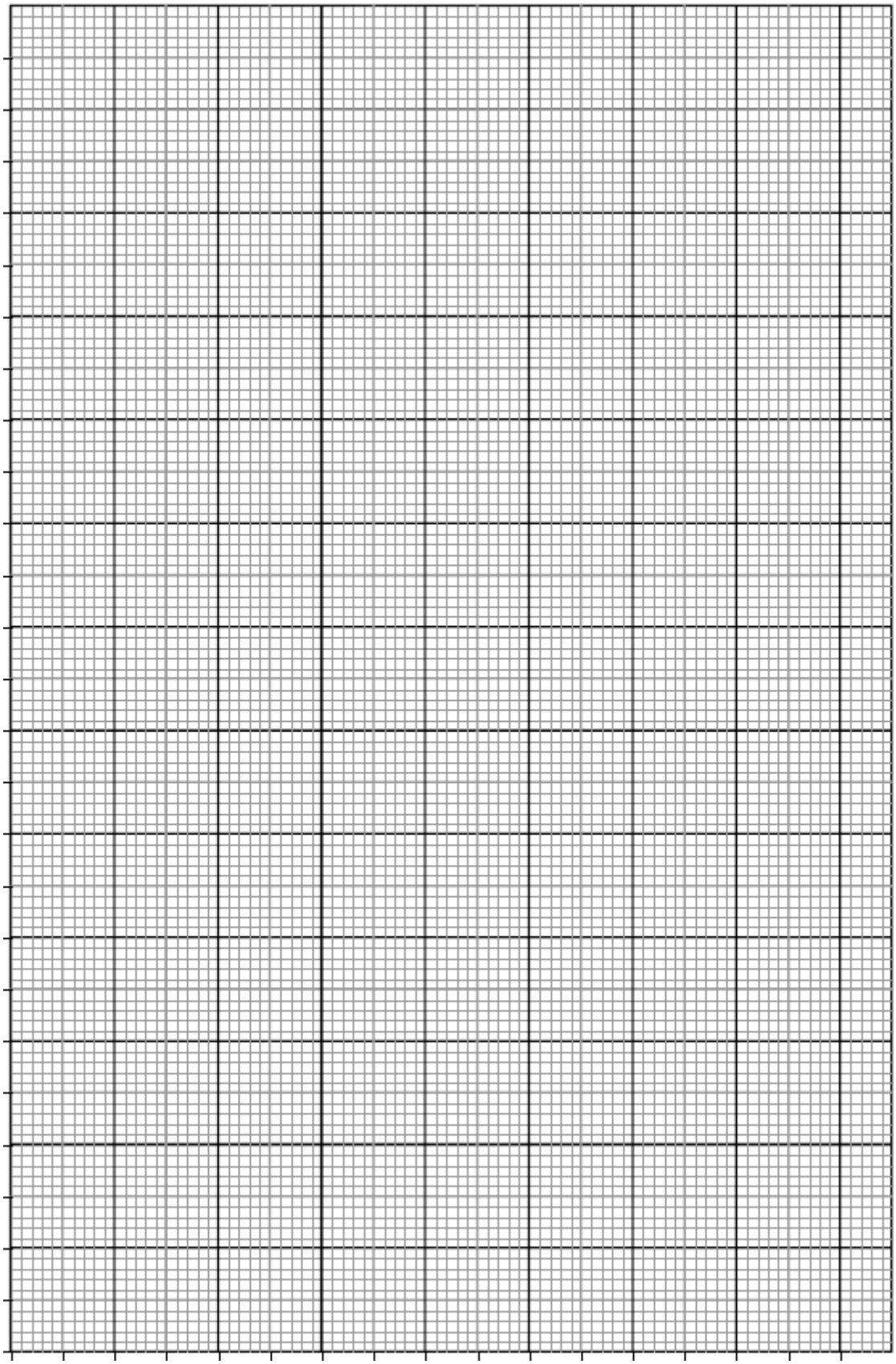
ϵ: …….....

.....

r: .....

.....

(8)
(Total 10 marks)



Q5.(a) (i) Draw and label suitable apparatus required for measuring the Young modulus of a material in the form of a long wire.

(ii) List the measurements you would make when using the apparatus described in part (i).

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(iii) Describe briefly how the measurements listed in part (ii) would be carried out.

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(iv) Explain how you would calculate the Young modulus from your measurements.

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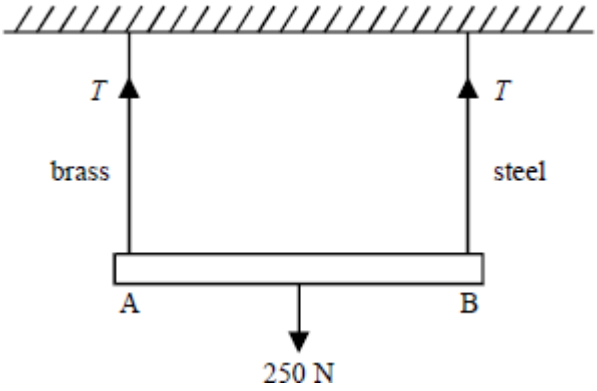
(13)

(b) A uniform heavy metal bar of weight 250 N is suspended by two vertical wires, supported at their upper ends from a horizontal surface, as shown.



One wire is made of brass and the other of steel. The cross-sectional area of each wire is 2.5×10^{-7} m^2 and the unstretched length of each wire is 2.0 m.

the Young modulus for brass = 1.0×10^{11} Pa
the Young modulus for steel = 2.0×10^{11} Pa

(i) If the tension, T, in each wire is 125 N, calculate the extension of the steel wire.

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(ii) Estimate how much lower the end A will be than the end B.

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(3)
(Total 16 marks)

Q6.(a) (i) Define the Young modulus for a material.

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(ii) Explain what is meant by the *elastic limit* for a wire.

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(2)

(b) A wire supported at its upper end, hangs vertically. The table shows readings obtained when stretching the wire by suspending masses from its lower end.

load / N	0	2.0	4.0	6.0	7.0	8.0	9.0	10.0	10.5
extension / mm	0	1.2	2.4	3.6	4.2	4.9	5.7	7.0	8.0

(i) Plot a graph of load against extension on the grid provided.

(ii) Indicate on your graph the region where Hooke's law is obeyed.

(iii) The unstretched length of the wire is 1.6 m and the area of cross-section 8.0×10^{-8} m^2. Calculate the value of the Young modulus of the material.

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(8)

(c) (i) By considering the work done in stretching a wire, show that the energy stored is given by $\frac{1}{2}Fe$, where F is the force producing an extension e.

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(ii) Calculate the energy stored in the wire in part (b) when the extension is 4.0 mm.

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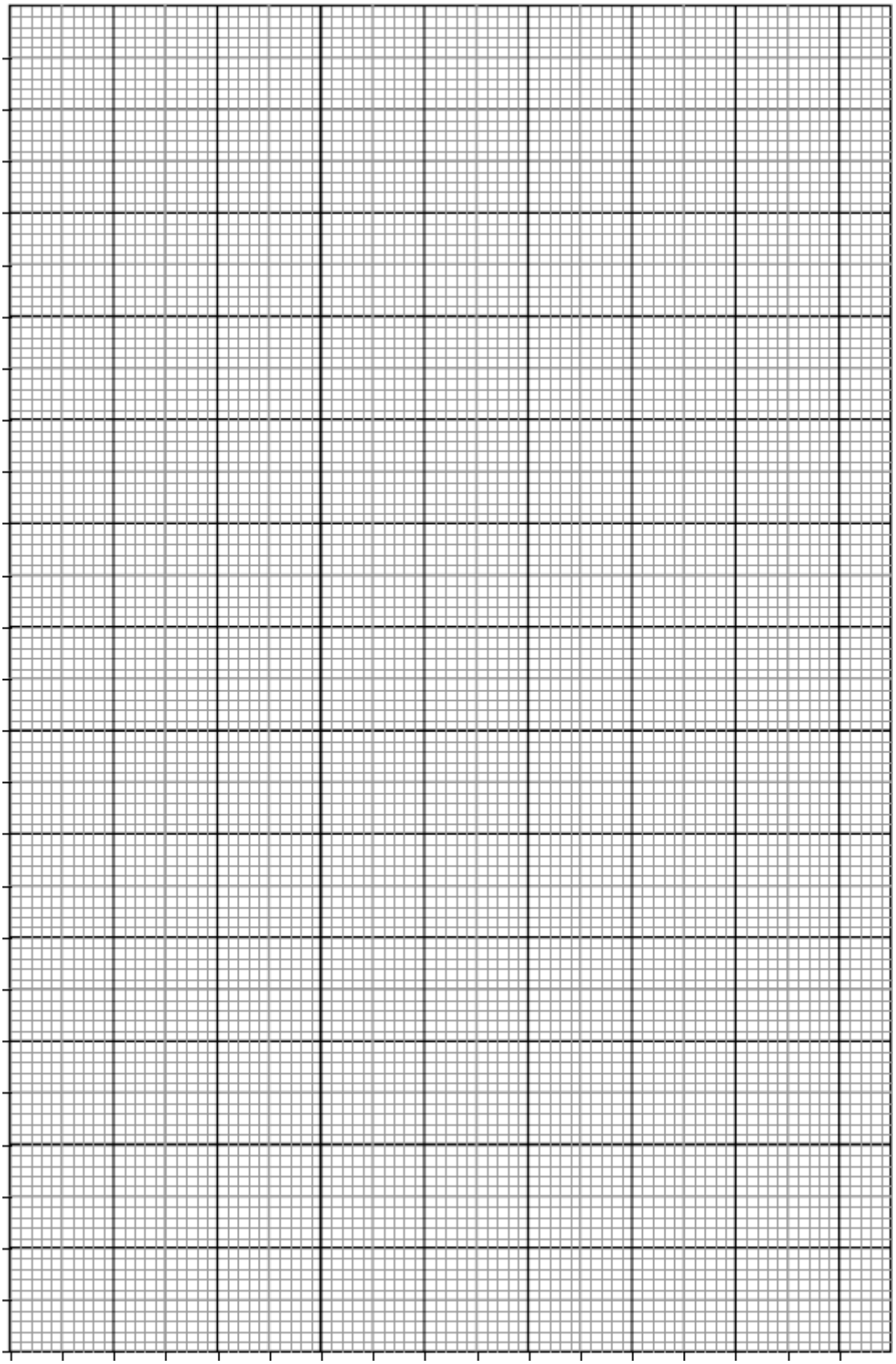
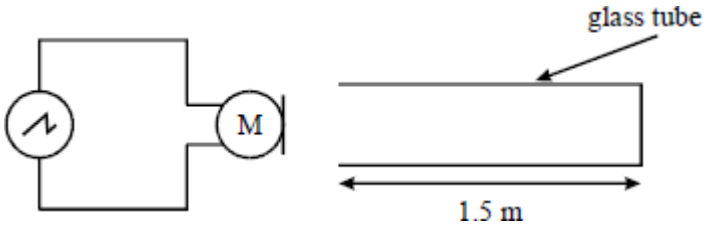
(4)

(Total 14 marks)

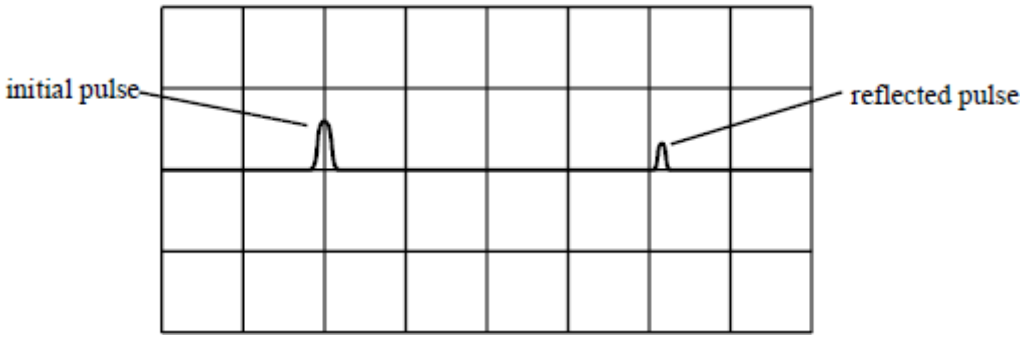


Q7.(a) The diagram shows the apparatus required for a simple experiment to measure the speed of sound.



A pulse of sound is sent down a hollow glass tube and is reflected at the sealed end of the tube. A microphone, M, placed at the open end detects the initial pulse and, at a later time, the reflected pulse. The microphone is connected to an oscilloscope which gives a signal when the microphone detects a pulse of sound.

The signal displayed on the oscilloscope screen is shown below.



If the time base of the oscilloscope is set to 2.0 ms per division, estimate the speed of sound in air.

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(3)

(b) Describe how the frequency of a sinusoidal alternating (ac) voltage source is measured using an oscilloscope.

Your answer should include a sketch of the trace seen on the oscilloscope screen and explain how the frequency is obtained from this trace.

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(5)
(Total 8 marks)

Q8.(a The resistivity of a material in the form of a uniform resistance wire is to be measured. The area of cross-section of the wire is known.

The apparatus available includes a battery, a switch, a variable resistor, an ammeter and a voltmeter.

(i) Draw a circuit diagram using some or all of this apparatus, which would enable you to determine the resistivity of the material.

(ii) Describe how you would make the necessary measurements, ensuring that you have a range of values.

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(iii) Show how a value of the resistivity is determined from your measurements.

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(9)

(b) A sheet of carbon-reinforced plastic measuring 80 mm × 80 mm × 1.5 mm has its two large surfaces coated with highly conducting metal film. When a potential difference of 240 V is applied between the metal films, there is a current of 2.0 mA in the plastic. Calculate the resistivity of the plastic.

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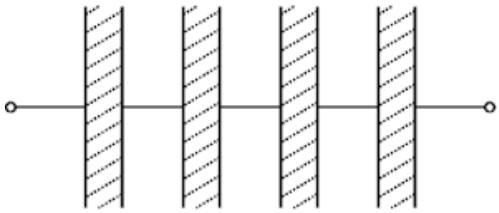
(3)

(c) If four of the units described in part (b) are connected as shown in the diagram, calculate the total resistance of the combination.



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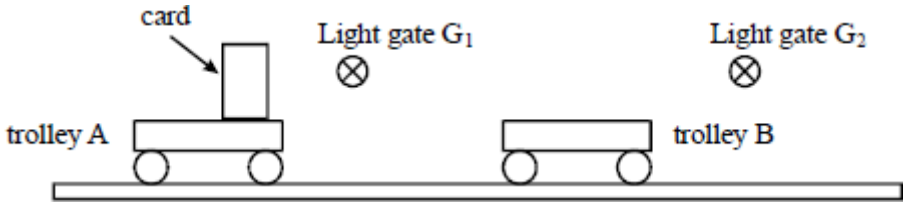
(2)
(Total 14 marks)

Q9. The simplified diagram shows an experimental arrangement to investigate the collision of two trolleys.



In the experiment, trolley A is travelling at speed *v*. It collides with and sticks to, the initially stationary trolley B.

(a) State the measurements you would need to take so that you could determine the speed of

(i) trolley A before the collision,

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(ii) trolleys A and B after the collision.

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(3)

(b) Explain how you would verify that momentum was conserved in this collision, indicating what other measurements would be required.

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(2)

(c) State and explain what you would do to minimise the effects of friction on the motion of the trolleys.

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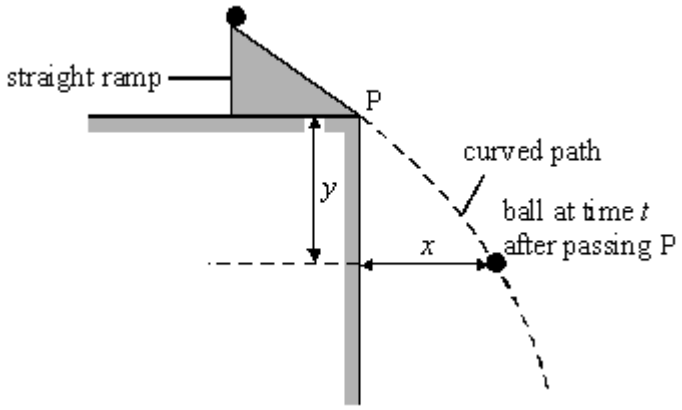
(2)

(Total 7 marks)

Q10. While investigating projectile motion, a student used stroboscopic photography to determine the position of a steel ball at regular intervals as it fell under gravity. With the stroboscope flashing 20 times per second, the ball was released from rest at the top of an inclined track, and left the foot of the track at P, as shown in the diagram below.



For each of the images on the photograph, the student calculated the horizontal distance, x, and the vertical distance, y, covered by the ball at time t after passing P. Both distances were measured from point P. He recorded his results for the distances x and y in the table.

image	x/cm	y/cm	t/s	(y/t)/cm s^{-1}
1	11.6	9.3	0.05	
2	22.0	21.0	0.10	
3	32.4	35.0	0.15	
4	44.2	51.8	0.20	
5	54.8	71.0	0.25	
6	66.0	92.2	0.30	

(a) Using two sets of measurements from the table, calculate the horizontal component of velocity of the ball. Give a reason for your choice of measurements.

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(2)

(b) The student worked out that the variables y and t in the experiment could be represented by

$\frac{y}{t} = u + kt$ where u and k are constants.

(i) Complete the table.

(ii) Use the data in the table to plot a suitable graph to confirm the equation.

(iii) Use your graph to find the values of u and k.

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(9)

(c) State the physical significance of

u .....

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k .....

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(2)

(d) Calculate the magnitude of the velocity of the ball at point P.

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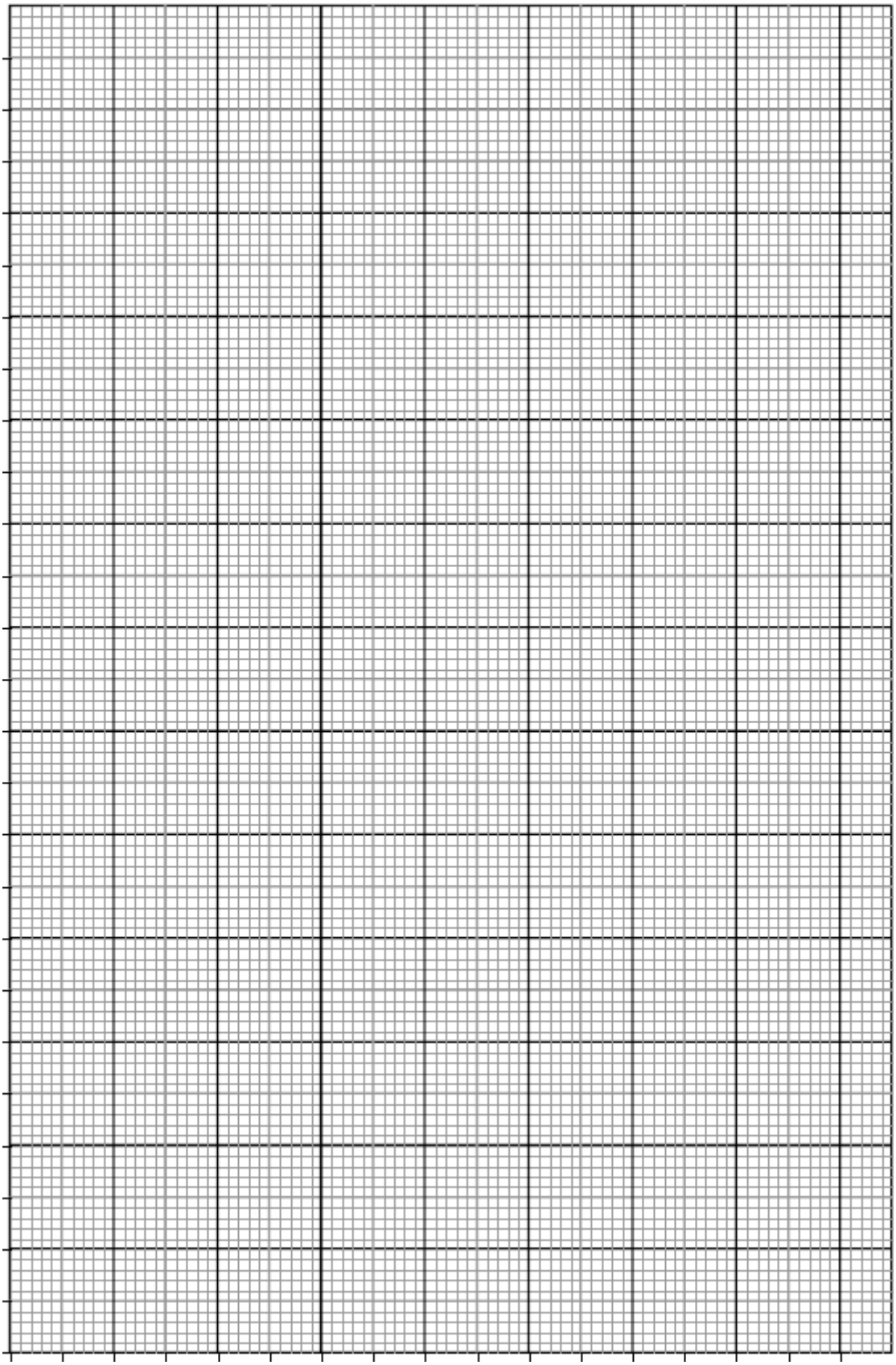
(2)

(Total 15 marks)



Q11. (a) A student wishes to measure the resistivity of the material of a uniform resistance wire. The available apparatus includes a battery, a switch, a variable resistor, an ammeter and a voltmeter.

(i) Draw a circuit diagram which incorporates some or all of this apparatus and which enables the student to determine the resistivity of the material.

(ii) State the measurements which must be made to ensure that a reliable value of the resistivity is obtained.

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(iii) Explain how a value of the resistivity would be obtained from the measurements.

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(10)

(b) A wire made from tin with cross-sectional area 7.8×10^{-9} m^2, has a p.d. of 2.0 V across it. Calculate the minimum length of wire needed so that the current through it does not exceed 4.0 A.

resistivity of tin = 1.1×10^{-7} Ωm

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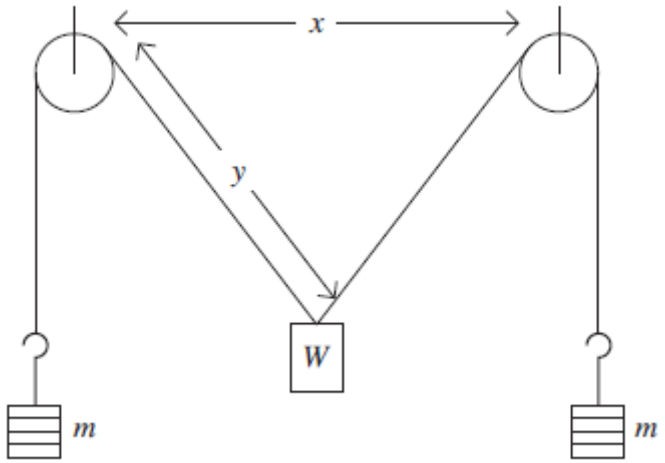
(2)
(Total 12 marks)

Q12. In an experiment an unknown load, of weight, W, was supported by two strings kept in tension by equal masses, m, hung from their free ends, with each string passing over a frictionless pulley. The arrangement was symmetrical and is shown in **Figure 1**.

Figure 1

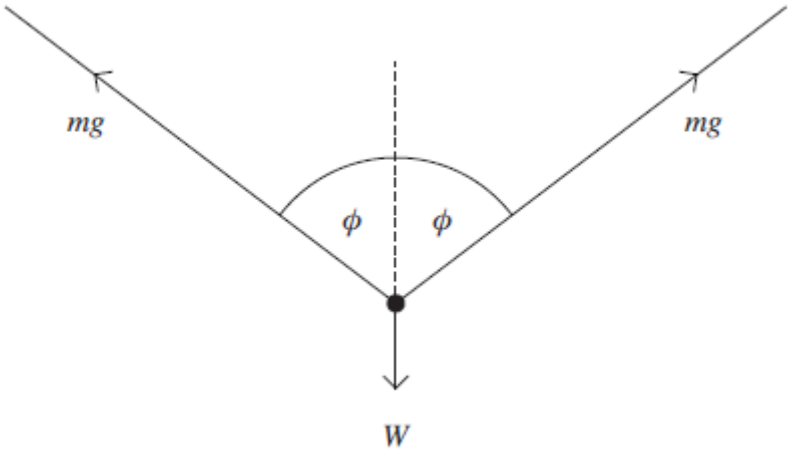


The distance x was kept constant throughout the experiment. The length y was measured for different values of m.

The distance between the strings at the pulleys, x = 0.500m

(a) **Figure 2** shows the three forces acting through the point at which the strings are attached to the load. The weight of the load is W and the tension in each string is mg, where g is gravitational field strength.

Figure 2



(i) By resolving the forces vertically show that $m = \frac{W}{2gcos\phi}$

where Φ is the angle between each string and the vertical.

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(1)

(ii) Draw the line of best fit through the points plotted on the graph.

(b) (i) Determine the gradient of your graph.

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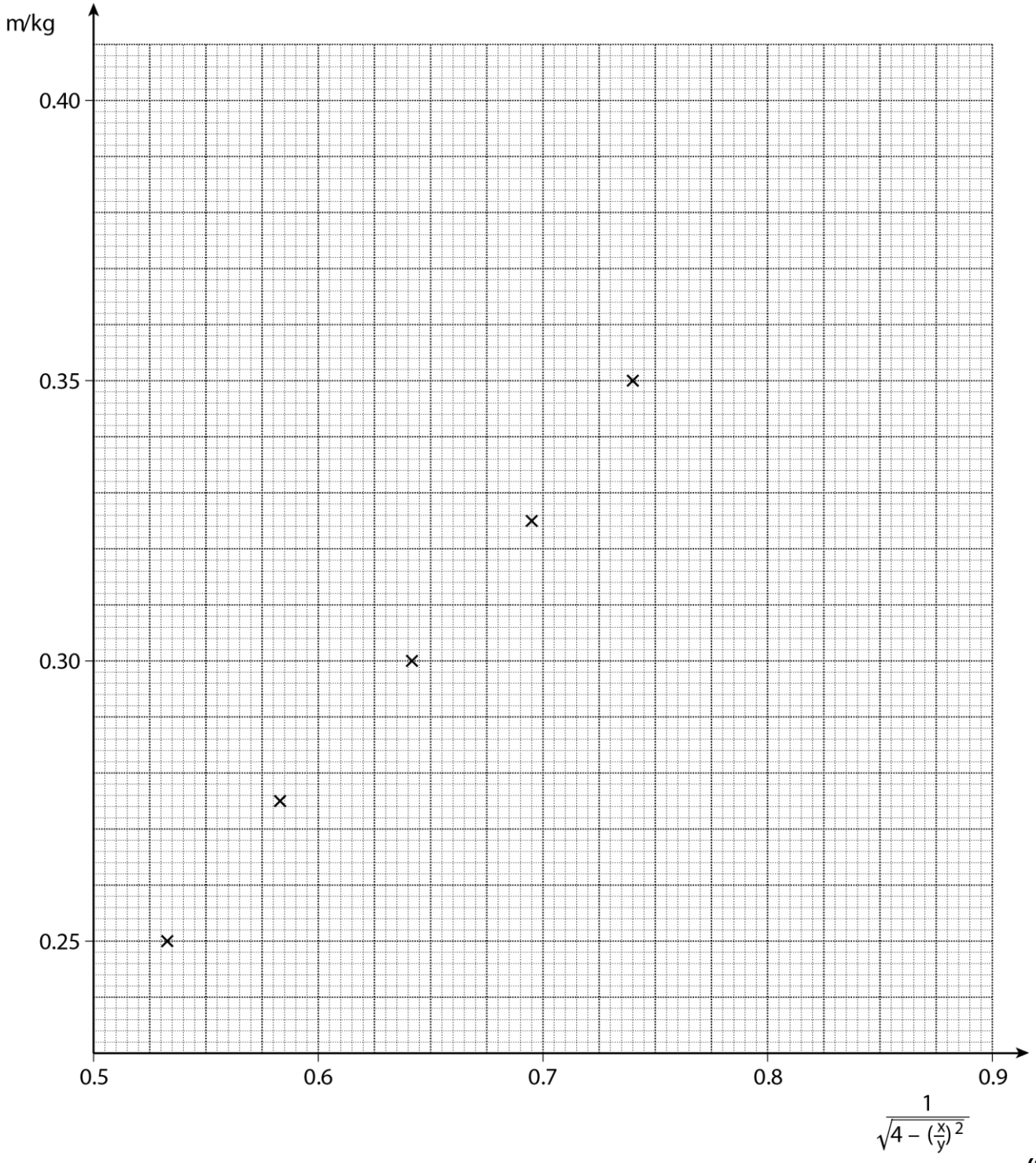
(3)



(1)

(ii) The equation for the straight line is $m = \frac{W}{g} \times \frac{1}{\sqrt{4-\left(\frac{x}{y}\right)^2}}$

Given that g = 9.81Nkg^{-1}, determine a value for W.

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(2)

(c) When m was 0.300 kg, y was 0.400 m.

Calculate the percentage uncertainty in $\left(\frac{x}{y}\right)^2$ for m = 0.300 kg.

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(3)

(d) (i) Explain the term *systematic error*.

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(1)

(ii) In practice, there may be a systematic error in this experiment because of friction in the pulleys.
When the measurements were taken, increasing values of m were used. State and explain how friction in the pulleys would have affected the measured values of y.

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(2)
(Total 13 marks)

Q13. (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

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(ii) Explain what is meant by the elastic limit of the wire.

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(iii) Define the Young modulus of a material and state the unit in which it is measured.

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(5)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire.

A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

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(ii) Explain how the student may obtain a value of the Young modulus.

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(iii) How would a value for the elastic energy stored in the wire be found from the results?

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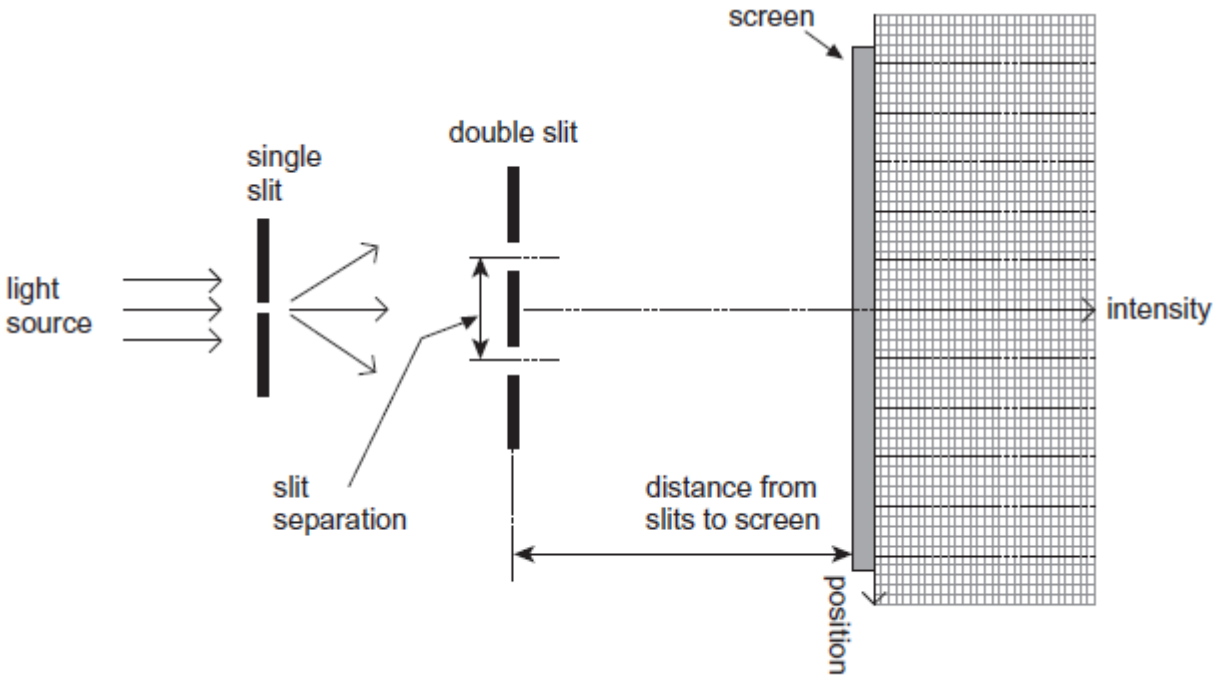
(6)
(Total 11 marks)

Q14. The diagram shows Young's double-slit experiment performed with a tungsten filament lamp as the light source.



not to scale

(a) On the axes in the diagram above, sketch a graph to show how the intensity varies with position for a **monochromatic** light source.

(2)

(b) (i)For an interference pattern to be observed the light has to be emitted by two **coherent sources**.
Explain what is meant by coherent sources.

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(1)

(i) Explain how the use of the single slit in the arrangement above makes the light from the two slits sufficiently coherent for fringes to be observed.

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(1)

(iii) In this experiment light behaves as a wave.
Explain how the bright fringes are formed.

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(3)

(c) (i) A scientist carries out the Young double-slit experiment using a laser that emits violet light of wavelength 405 nm. The separation of the slits is 5.00×10^{-5} m.

Using a metre ruler the scientist measures the separation of two adjacent bright fringes in the central region of the pattern to be 4 mm.

Calculate the distance between the double slits and the screen.

distance = ... m **(2)**

(ii) Describe the change to the pattern seen on the screen when the violet laser is replaced by a green laser. Assume the brightness of the central maximum is the same for both lasers.

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(1)

(iii) The scientist uses the same apparatus to measure the wavelength of visible electromagnetic radiation emitted by another laser.
Describe how he should change the way the apparatus is arranged and used in order to obtain an **accurate** value for the wavelength.

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(3)
(Total 13 marks)

Q15.(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.

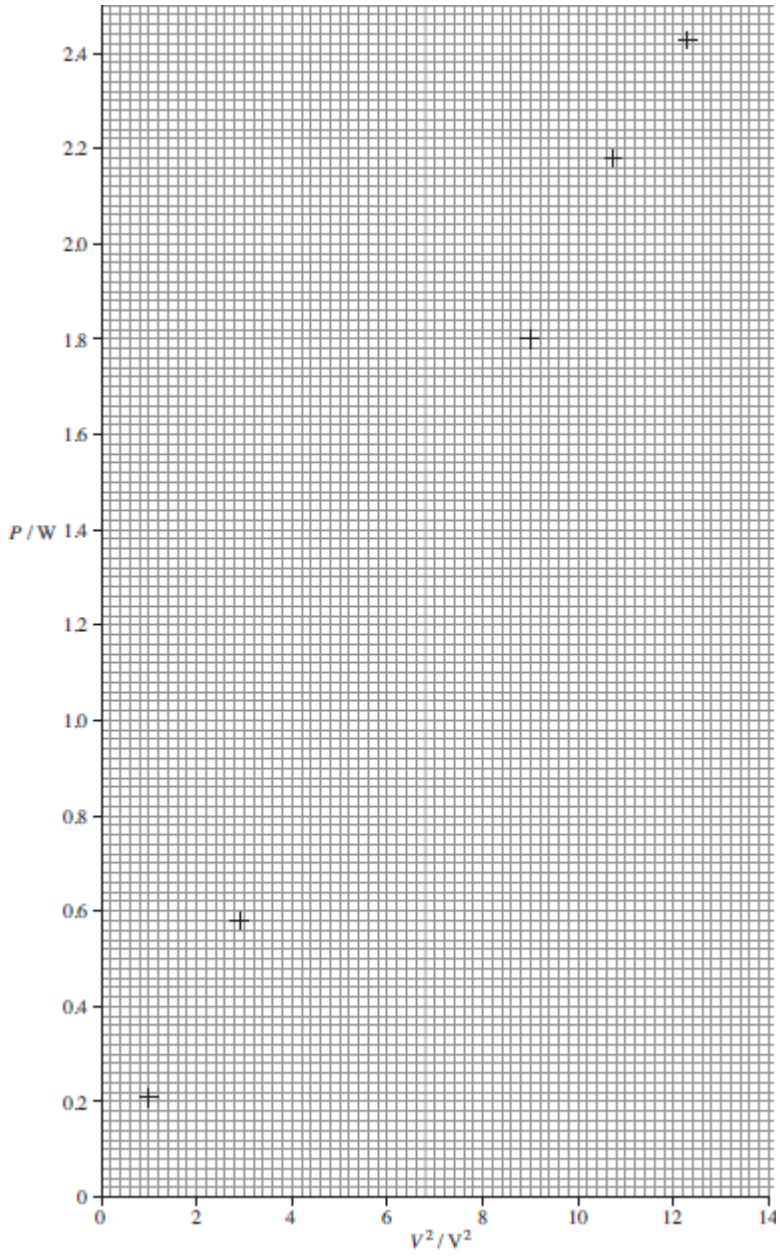
V / V	V^2 / V^2	P / W
1.00	1.0	0.21
1.71	2.9	0.58
2.25		1.01
2.67		1.43
3.00	9.0	1.80
3.27	10.7	2.18
3.50	12.3	2.43

(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 in part (a).

(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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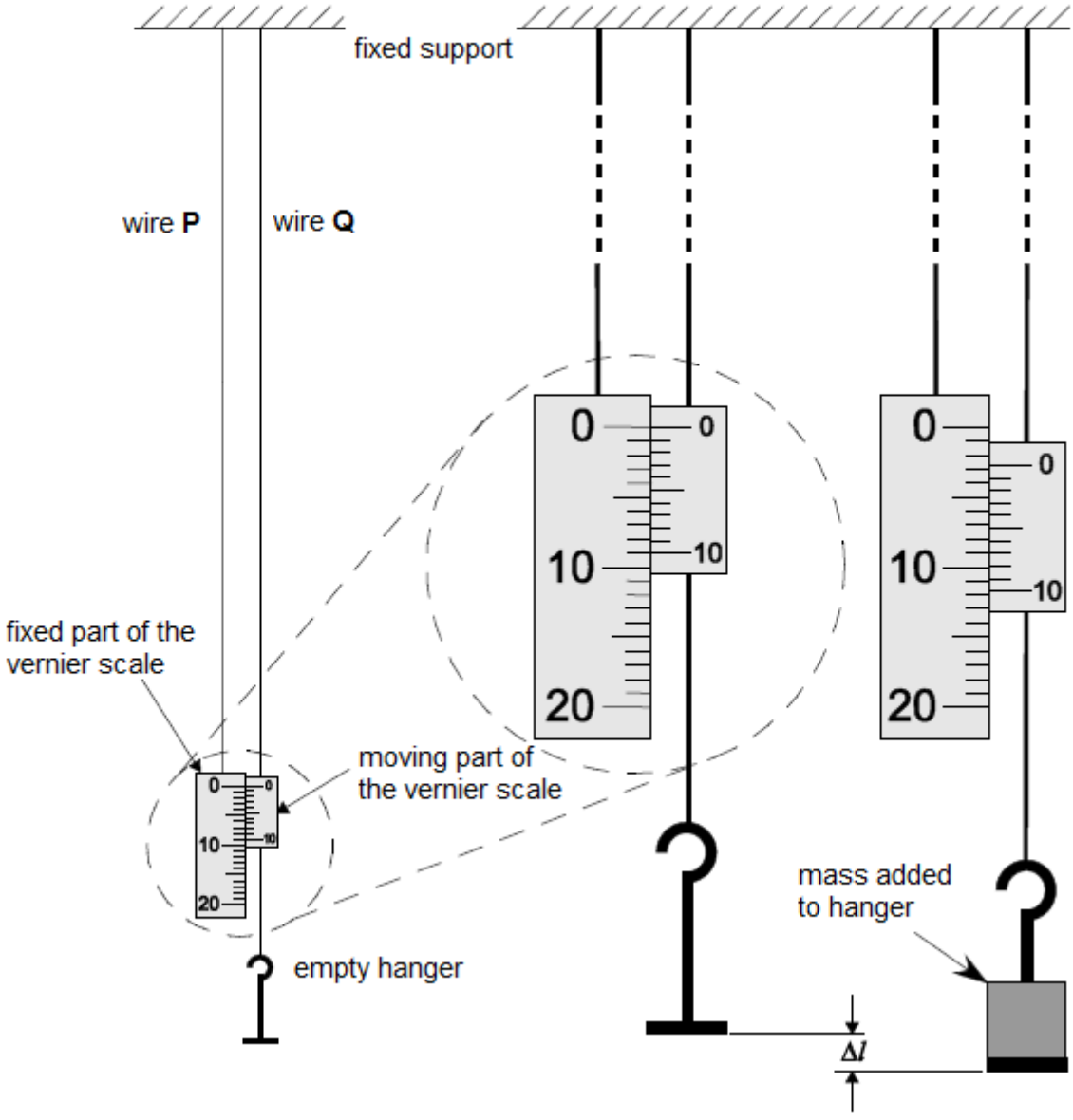
(Total 14 marks)

Q16. 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**.

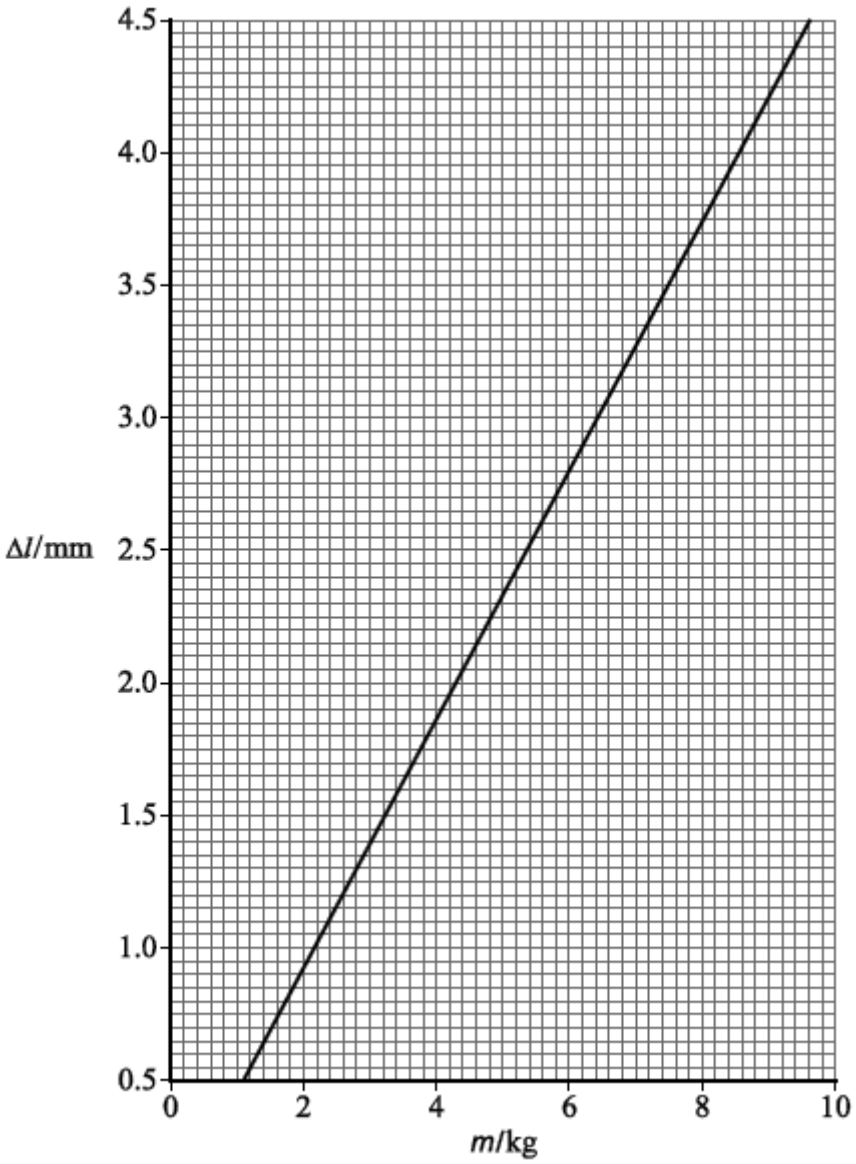
Determine Δl using **Figure 1**.

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



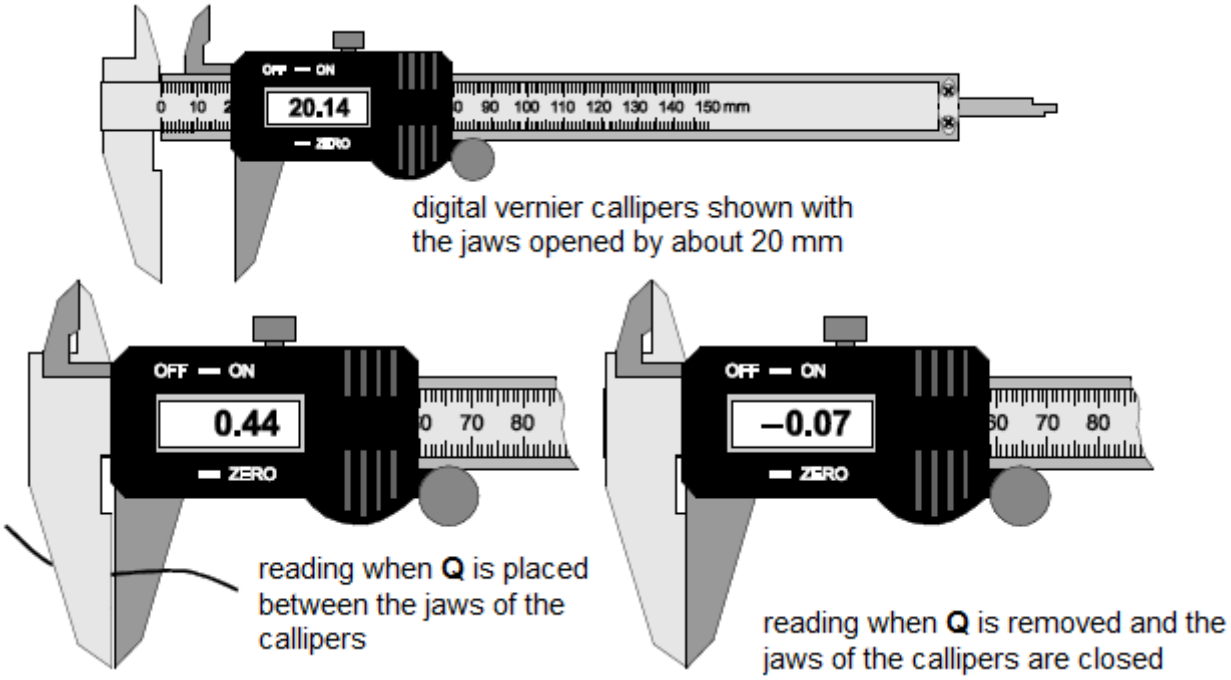
mass = ... kg

(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 .....

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.....

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2 .....

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(4)

(Total 11 marks)

Q17. A student has a diffraction grating that is marked 3.5×10^3 lines per m.

(a) Calculate the percentage uncertainty in the number of lines per metre suggested by this marking.

percentage uncertainty = ... %

(1)

(b) Determine the grating spacing.

grating spacing = ... mm

(2)

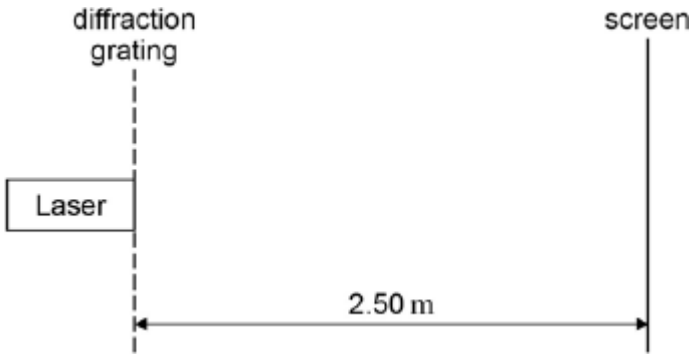
(c) State the absolute uncertainty in the value of the spacing.

absolute uncertainty = ... mm

(1)

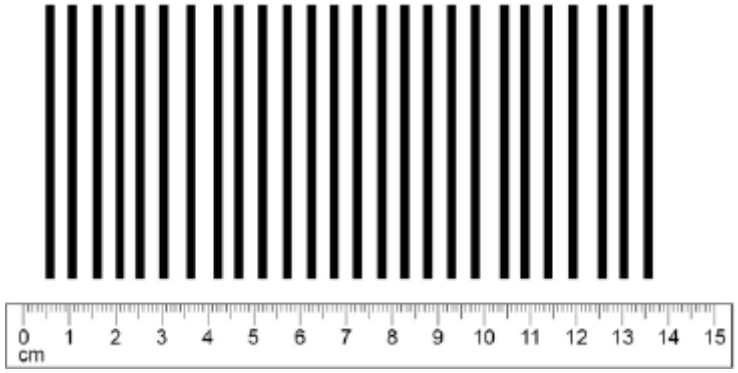
(d) The student sets up the apparatus shown in **Figure 1** in an experiment to confirm the value marked on the diffraction grating.

Figure 1



The laser has a wavelength of 628 nm. **Figure 2** shows part of the interference pattern that appears on the screen. A ruler gives the scale.

Figure 2



Use **Figure 2** to determine the spacing between two adjacent maxima in the interference pattern. Show all your working clearly.

spacing = ... mm

(1)

(e) Calculate the number of lines per metre on the grating.

number of lines = ...

(2)

(f) State and explain whether the value for the number of lines per m obtained in part (e) is in agreement with the value stated on the grating.

.....

.....

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(2)

(g) State **one** safety precaution that you would take if you were to carry out the experiment that was performed by the student.

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(1)
(Total 10 marks)

Q18. Complete the following table.

Quantity	**Vector or Scalar**	**S.I. Unit**
Displacement	Vector	m
Velocity		
Weight		
Energy		

(Total 3 marks)

Q19. Which of the following is **not** a unit of power?

A N m s^{-1} ⬭

B J s ⬭

C W ⬭

D kg m^2 s^{-3} ⬭

(Total 1 mark)

Q20.Data analysis question

Capillary action can cause a liquid to rise up a hollow tube. **Figure 1** shows water that has risen to a height h in a narrow glass tube because of capillary action.

Figure 1

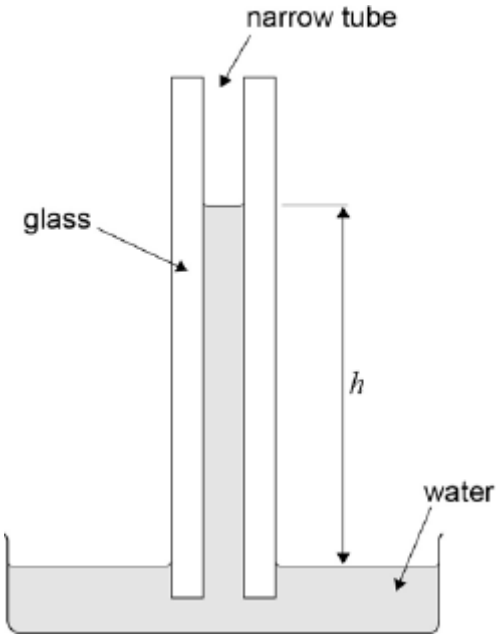
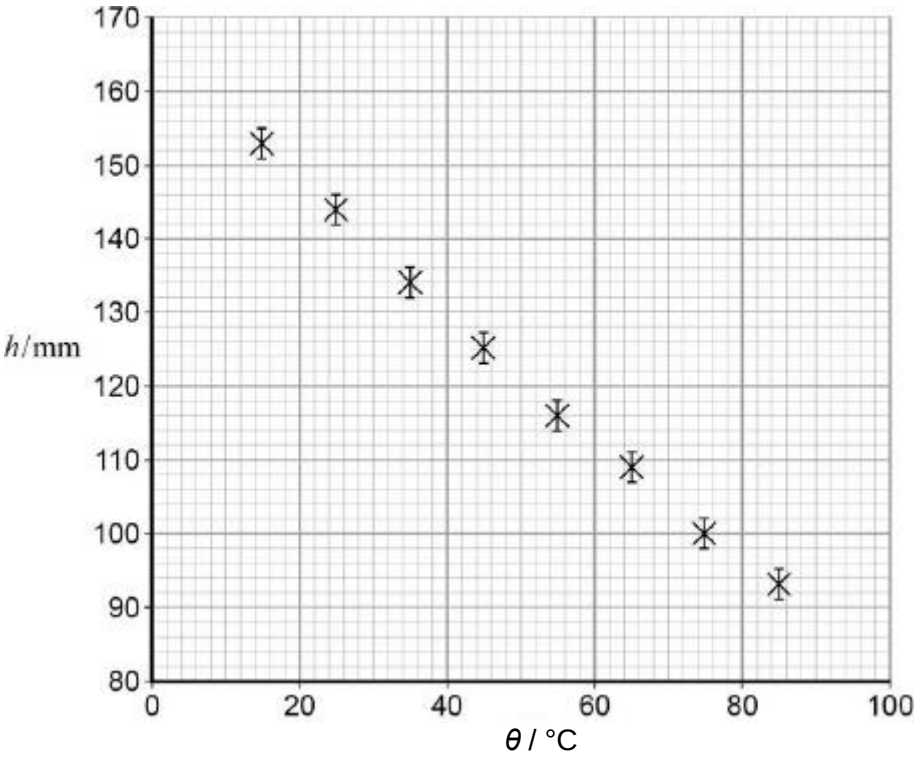


Figure 2 shows the variation of h with temperature θ for this particular tube.

Figure 2



The uncertainty in the measurement of h is shown by the error bars. Uncertainties in the

measurements of temperature are negligible.

(a) Draw a best-fit straight line for these data **(Figure 2)**.

(1)

(b) It is suggested that the relationship between h and θ is

$$h = h_0 - (h_0 k)\theta$$

where h_0 and k are constants.
Determine h_0.

h_0 = = ... mm

(1)

(c) Show that the value of $h_0 k$ is about 0.9 mm K^{-1}.

(3)

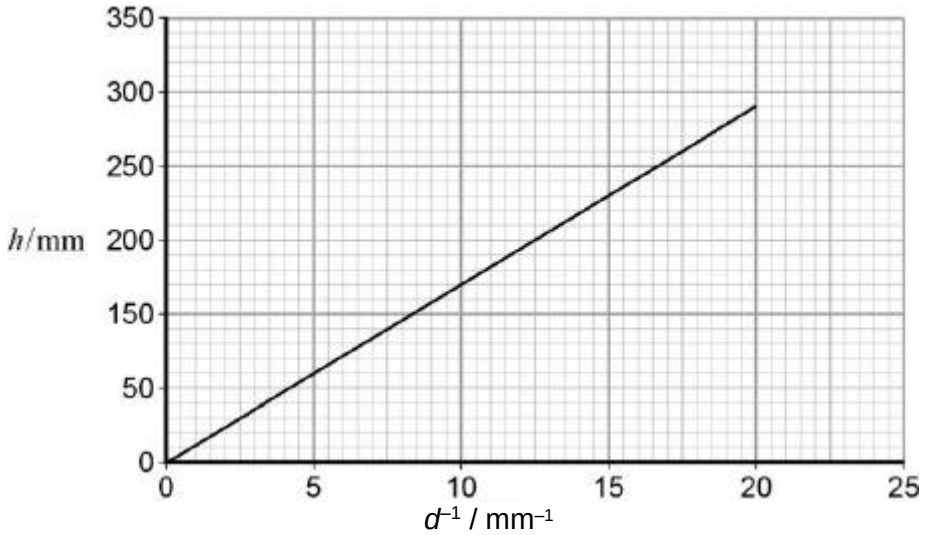
(d) Determine k. State a unit for your answer.

k = ... unit = ...

(2)

(e) A similar experiment is carried out at constant temperature with tubes of varying internal diameter d. **Figure 3** shows the variation of h with $\frac{1}{d}$ at a constant temperature.

Figure 3



It is suggested that capillary action moves water from the roots of a tree to its leaves.

The gradient of **Figure 3** is 14.5 mm^2.

The distance from the roots to the top leaves of the tree is 8.0 m.

Calculate the internal diameter of the tubes required to move water from the roots to the top leaves by capillary action.

(2)

(f) Comment on the accuracy of your answer for the internal tube diameter in part (v).

.....

.....

.....

(1)
(Total 10 marks)

Q21. In which of the following do both quantities have the same unit?

A Electrical resistivity and electrical resistance. ⬭

B Work function Planck constant ⬭

C Pressure and the Young modulus. ⬭

D Acceleration and rate of change of momentum. ⬭

(Total 1 mark)

Q22. Complete the following table by stating whether the quantity is a vector or a scalar and by giving the full name of its unit.

Quantity	Vector or Scalar	S.I. Unit
force	vector	newton
displacement		
kinetic energy		
power		

(Total 3 marks)

Q23. Which one of the following is a possible unit of impulse?

A Ns^{-1}

B $kg\ ms^{-1}$

C $kg\ ms^{-2}$

D sN^{-1}

(Total 1 mark)