AS Practical Skills

Name:

Class:

Date:

Time: **514 minutes**

Marks: **279 marks**

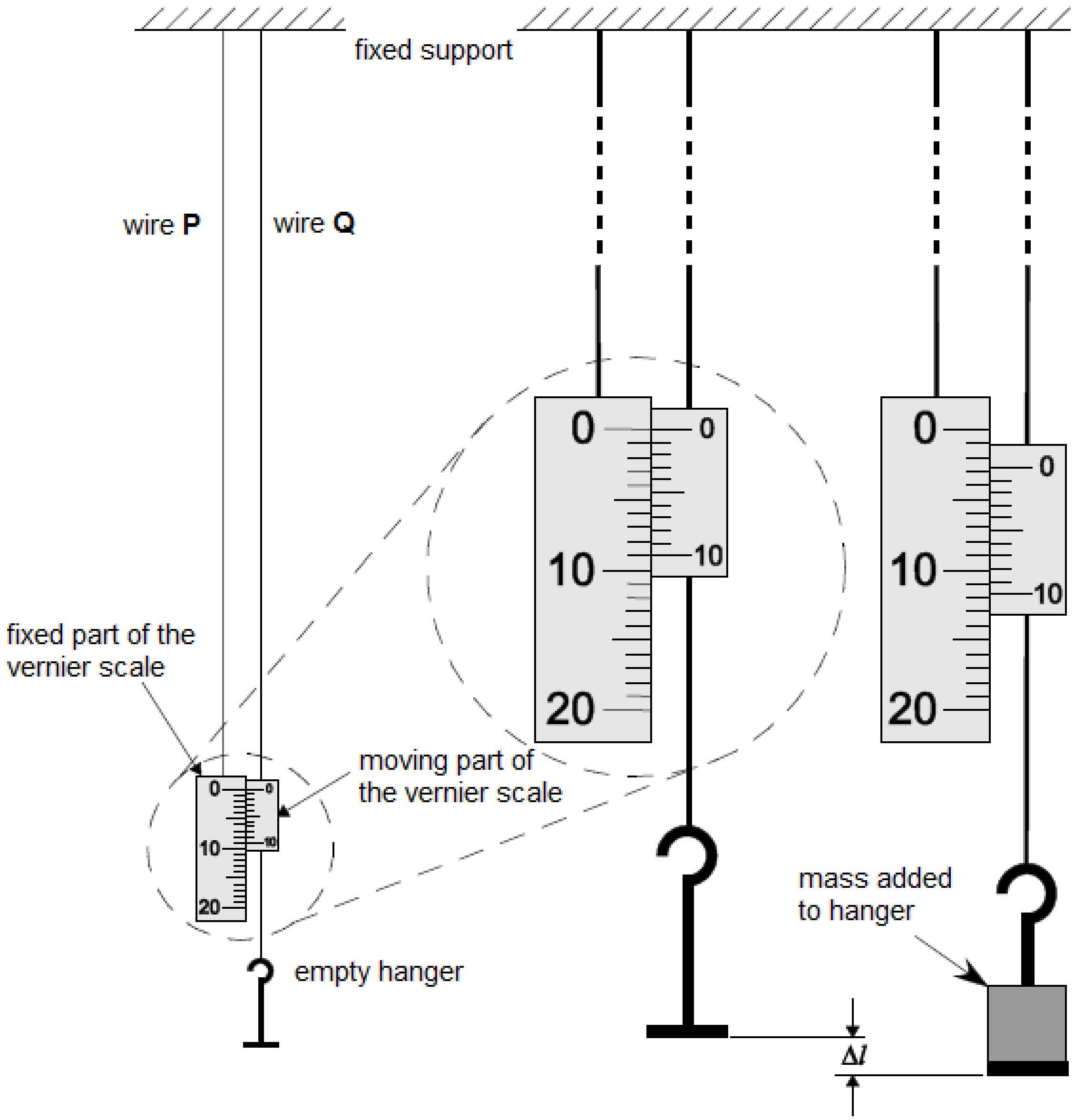
Comments:

1 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**.

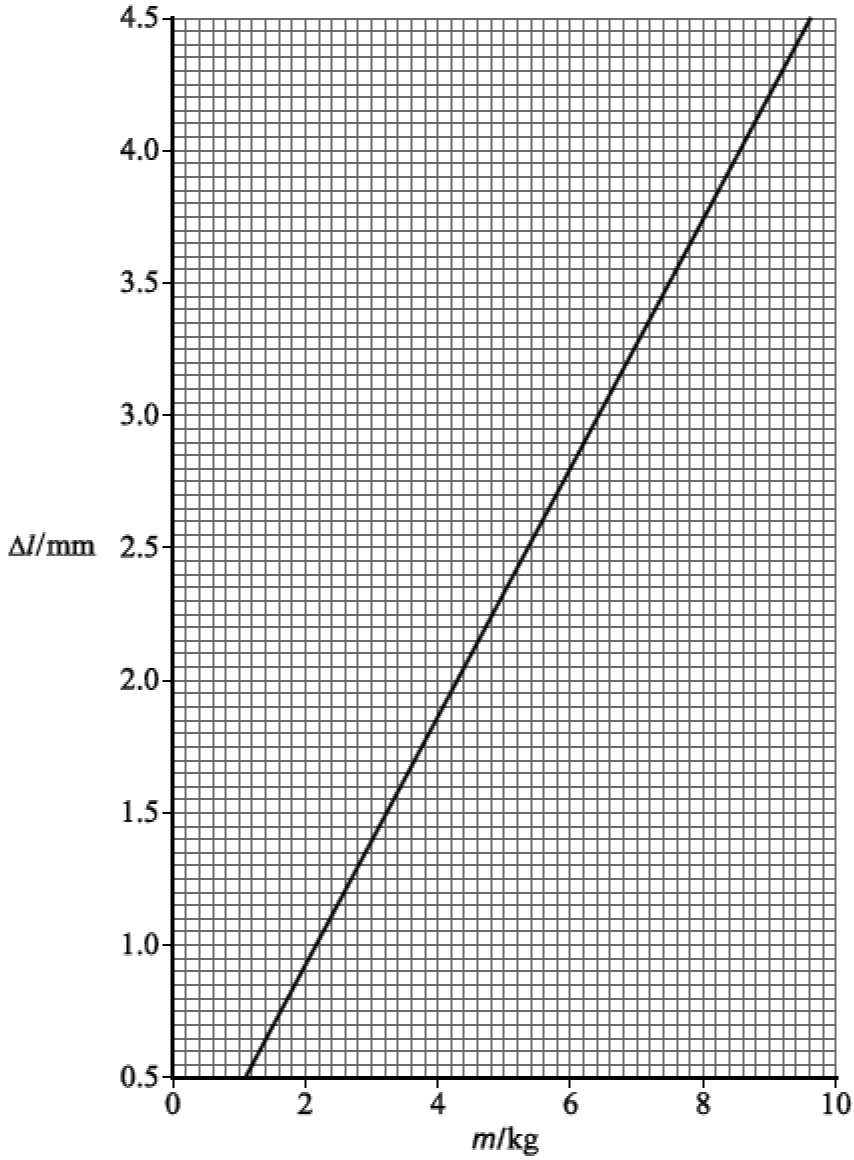
Determine Δl using **Figure 1**.

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



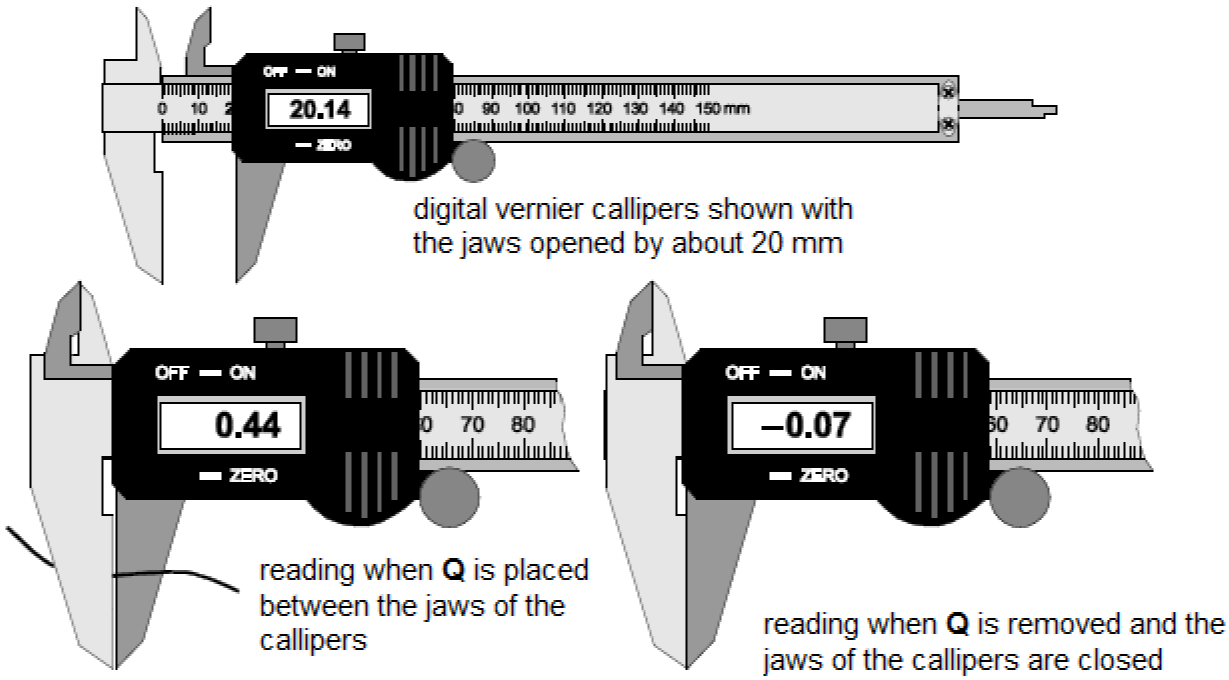
mass = ____________________ kg

(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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2. ____

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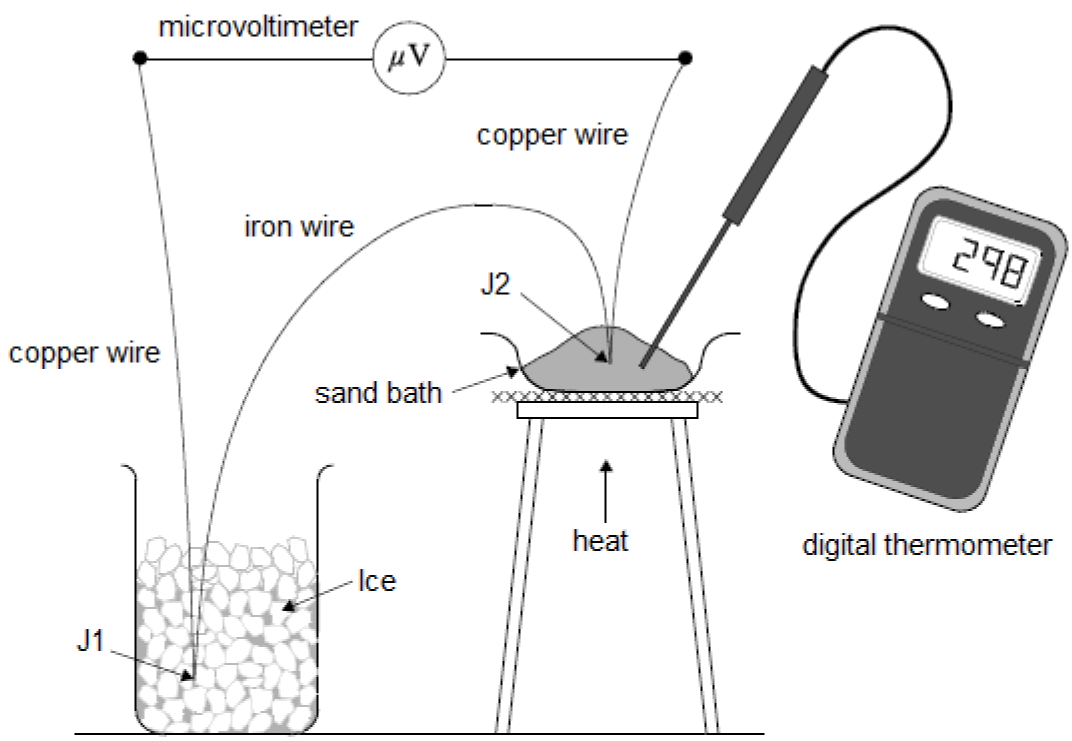
(4)

(Total 11 marks)

2 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

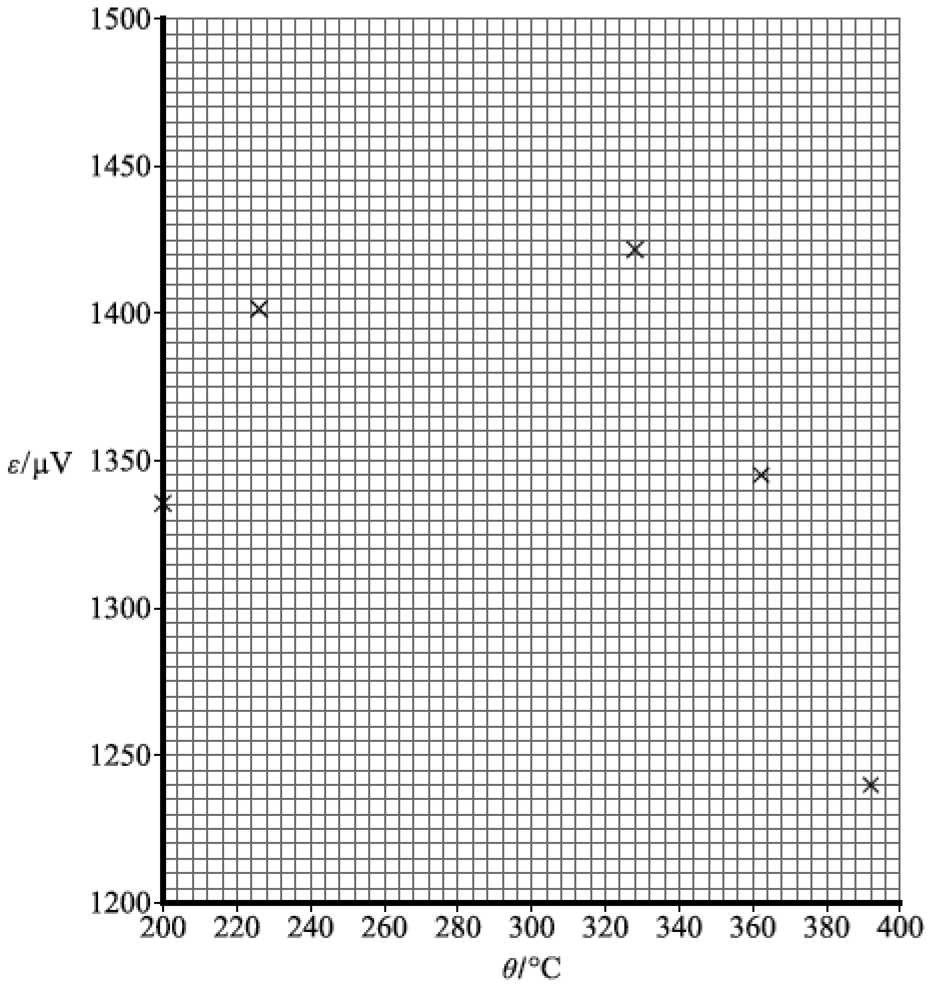


An experiment is carried out to determine how ε depends on θ.

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)

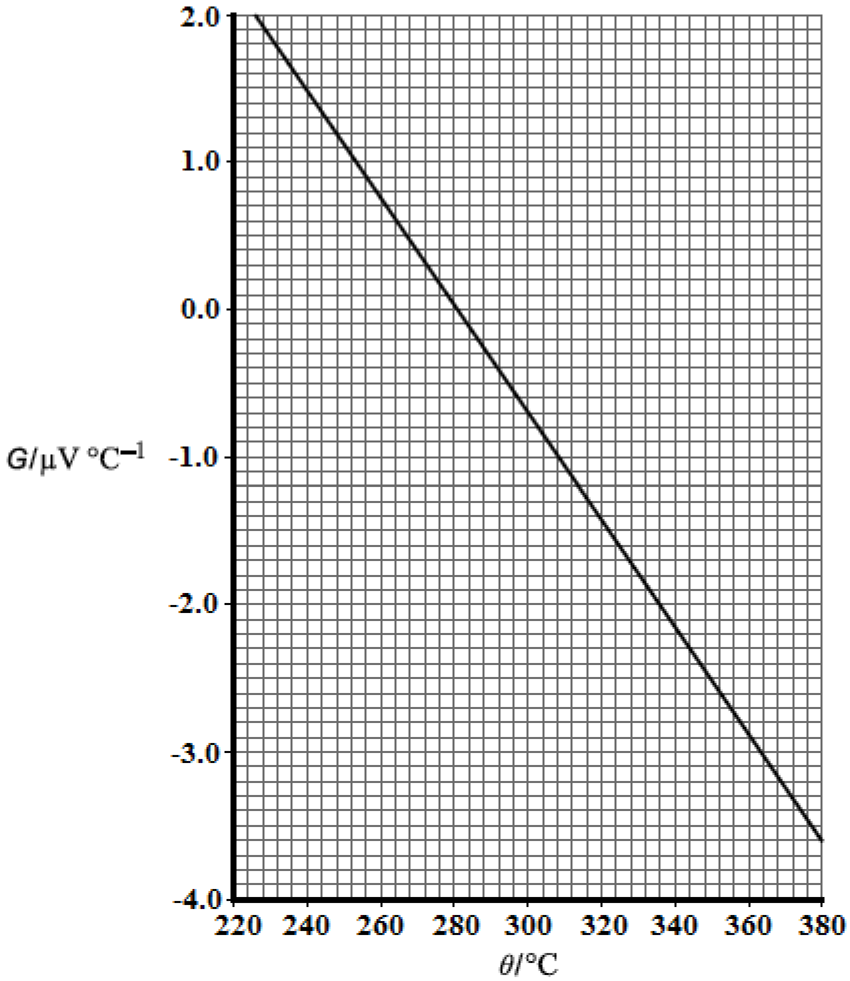
(c) Determine the maximum value of ε.

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.

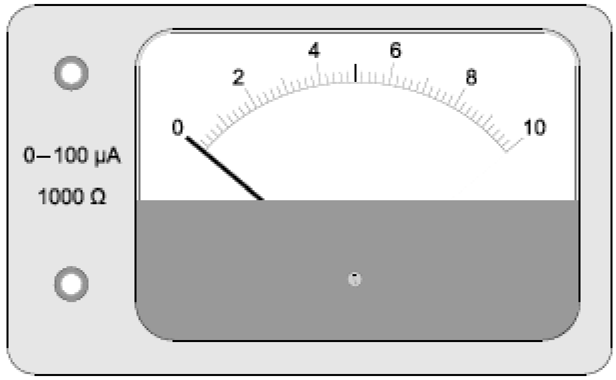
Determine α.

α = ____________________ $\mu V\ °C^{-1}$

(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)

3 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)

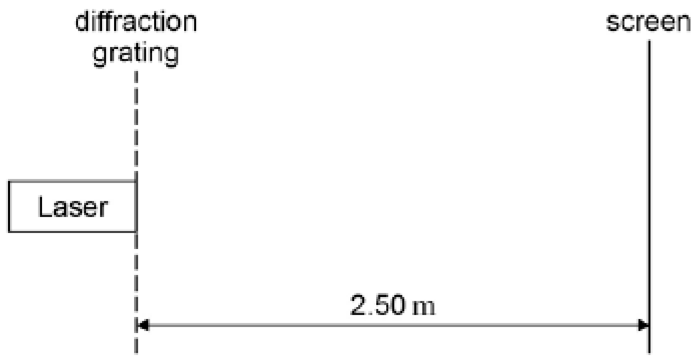
(c) State the absolute uncertainty in the value of the spacing.

absolute uncertainty = ____________________ mm

(1)

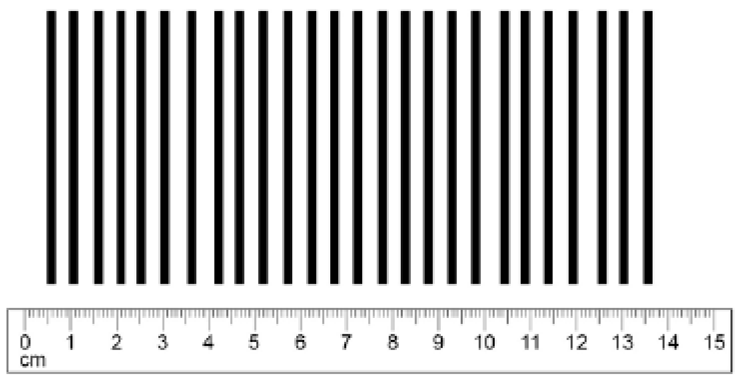
(d) The student sets up the apparatus shown in **Figure 1** in an experiment to confirm the value marked on the diffraction grating.

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.

(2)

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

(1)
(Total 10 marks)

4 **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

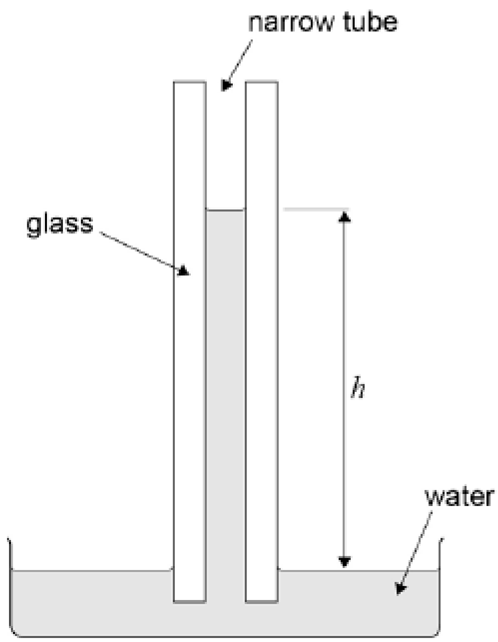
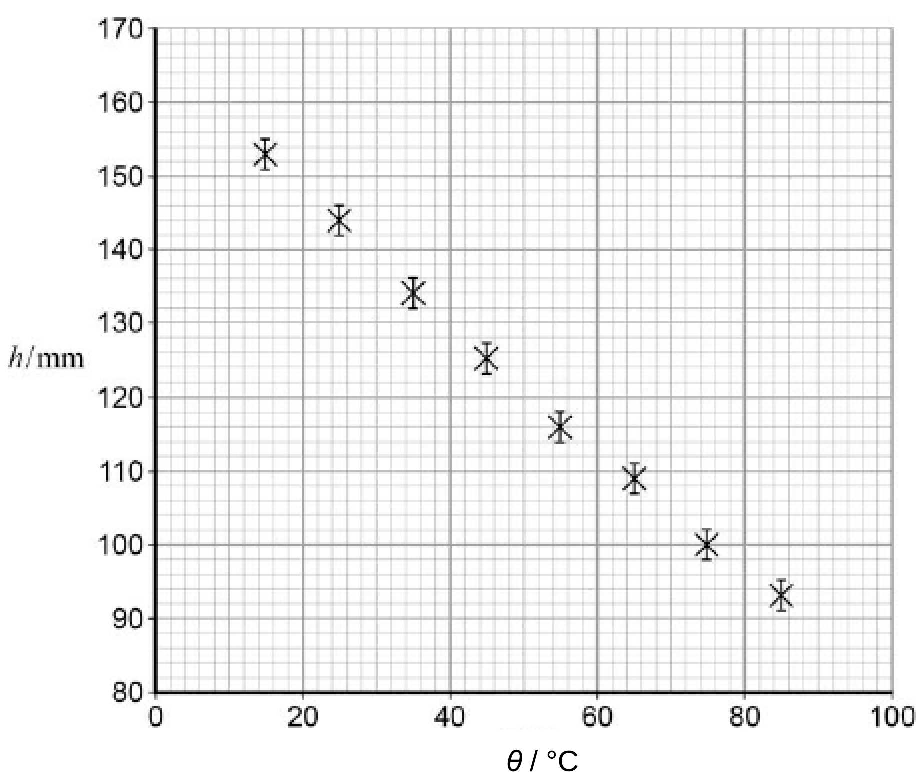


Figure 2 shows the variation of h with temperature θ for this particular tube.

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)

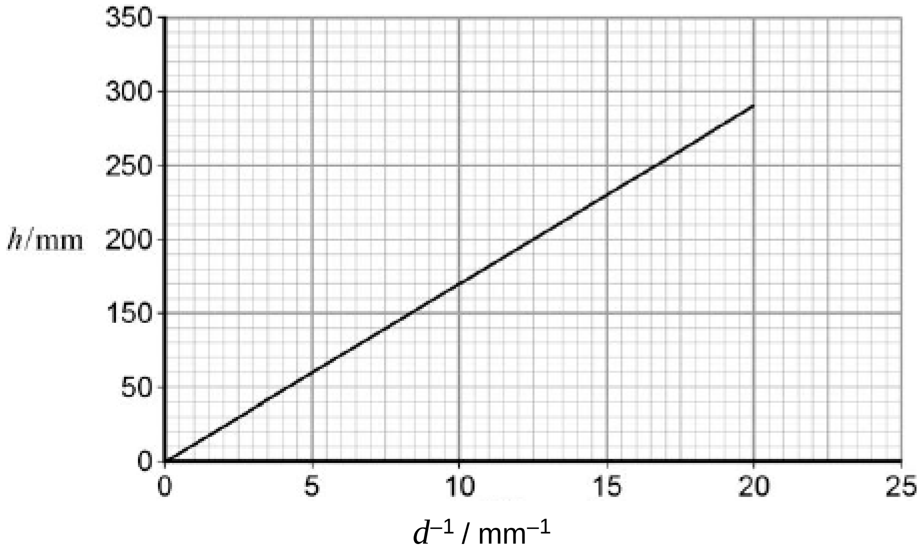
(d) Determine k. State a unit for your answer.

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).

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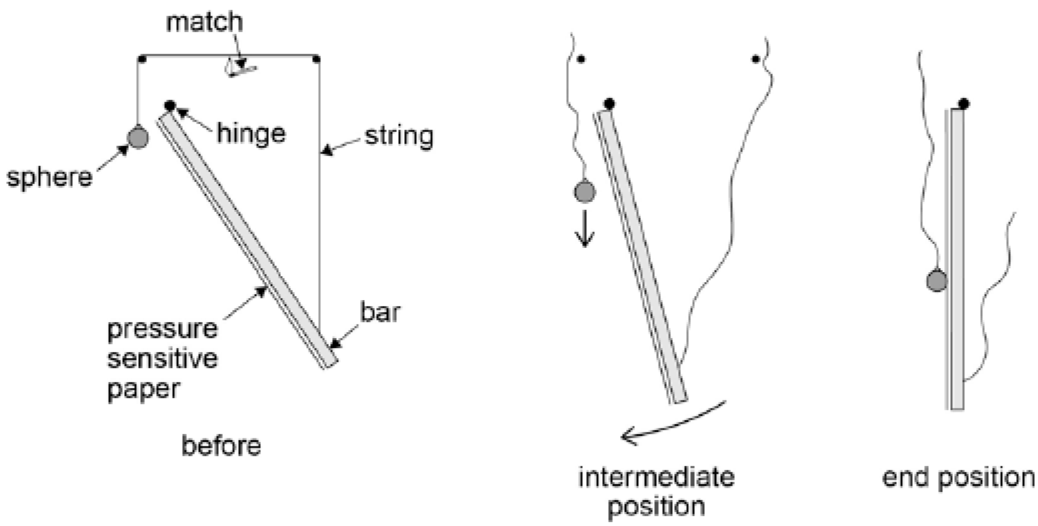
(1)
(Total 10 marks)

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

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

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

Figure 1



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

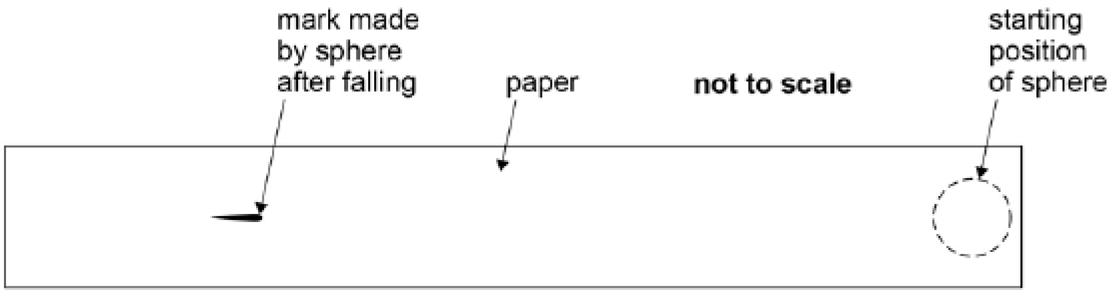
To measure d the student marks the initial position of the sphere on the paper. The student then measures the distance between the initial mark and the mark made by the sphere after falling.

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

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

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

Figure 2



(1)

(b) The student repeats the procedure several times.

Data for the experiment is shown in the table below.

d / m
0.752
0.758
0.746
0.701
0.772
0.769

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

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

time____________________s

(1)

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

uncertainty = ____________________ %

(2)

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

d = ____________________ m

(2)

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

uncertainty = ____________________ m

(1)

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

g = ____________________ ms^{-2}

uncertainty = ____________________ ms^{-2}

(3)

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

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(2)

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

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

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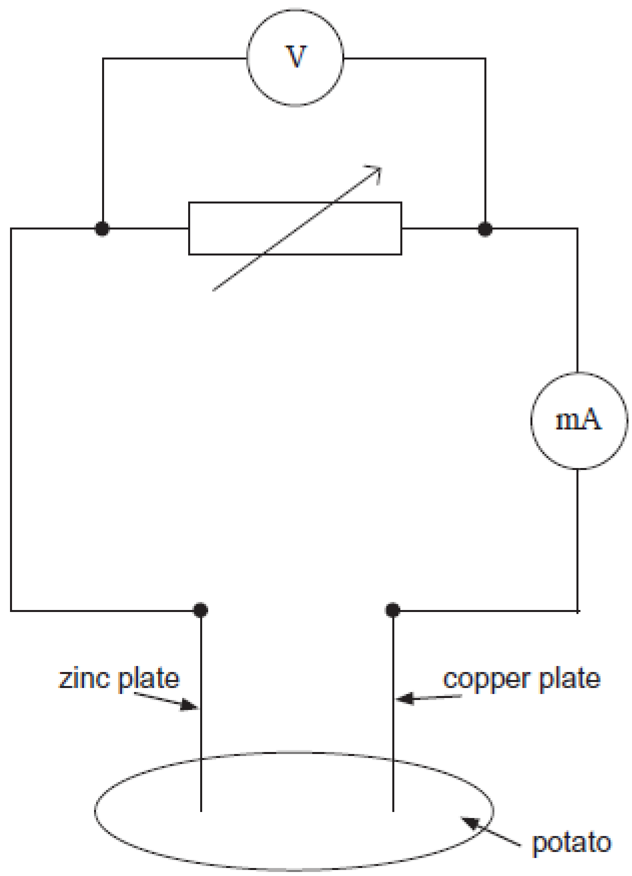
(3)

(Total 15 marks)

6 A 'potato cell' is formed by inserting a copper plate and a zinc plate into a potato. The circuit shown in **Figure 1** is used in an investigation to determine the electromotive force and internal resistance of the potato cell.

Figure 1



(a) State what is meant by electromotive force.

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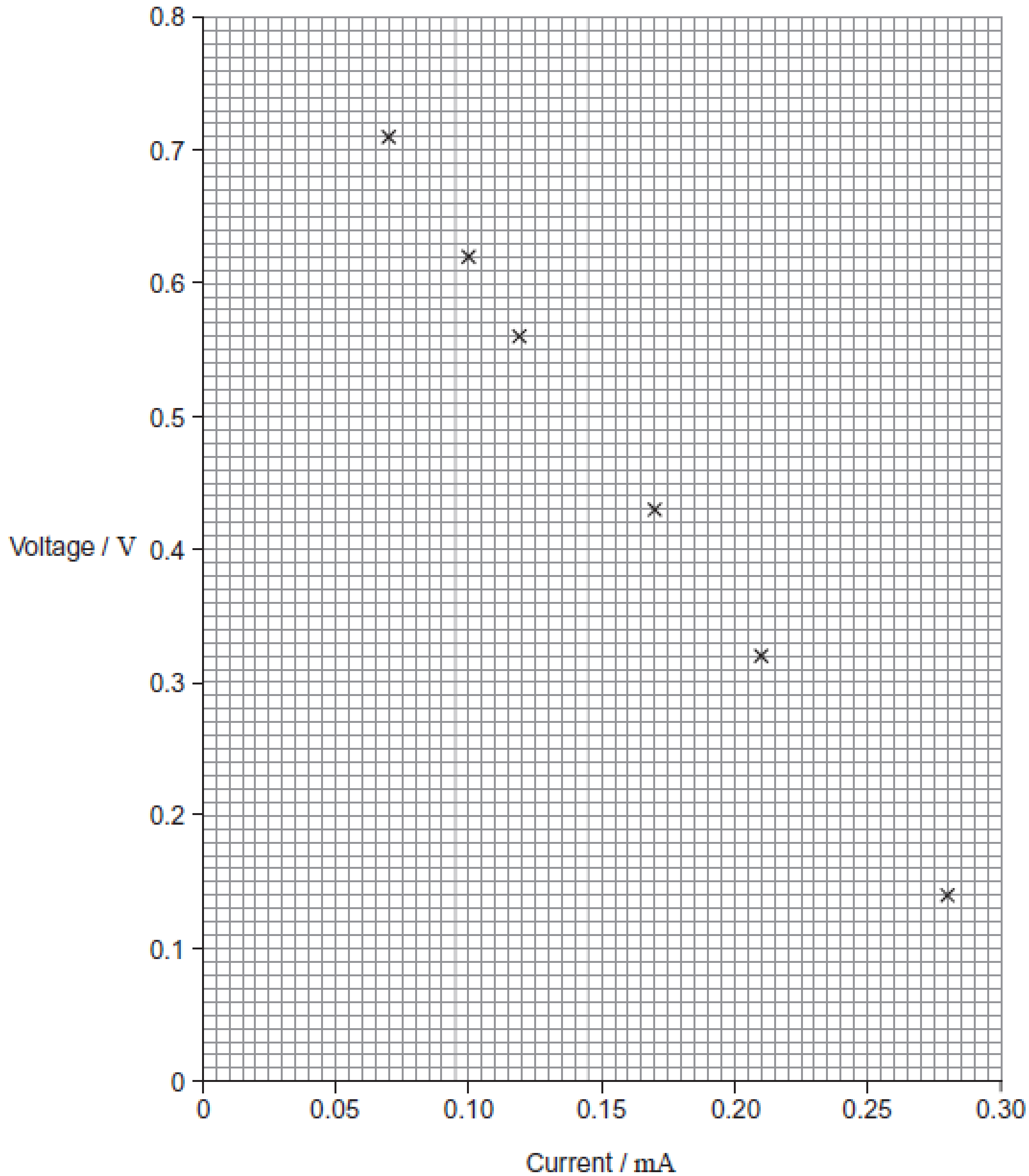
(2)

(b) The plotted points on **Figure 2** show the data for current and voltage that were obtained in the investigation.

Figure 2



(i) Suggest what was done to obtain the data for the plotted points.

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(1)

(ii) The electromotive force (emf) of the potato cell is 0.89 V. Explain why the voltages plotted on **Figure 2** are always less than this and why the difference between the emf and the plotted voltage becomes larger with increasing current.

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(3)

(iii) Use **Figure 2** to determine the internal resistance of the potato cell.

internal resistance = ____________________ Ω

(3)

(c) A student decides to use two potato cells in series as a power supply for a light emitting diode (LED). In order for the LED to work as required, it needs a voltage of at least 1.6 V and a current of 20 mA.

Explain whether the LED will work as required.

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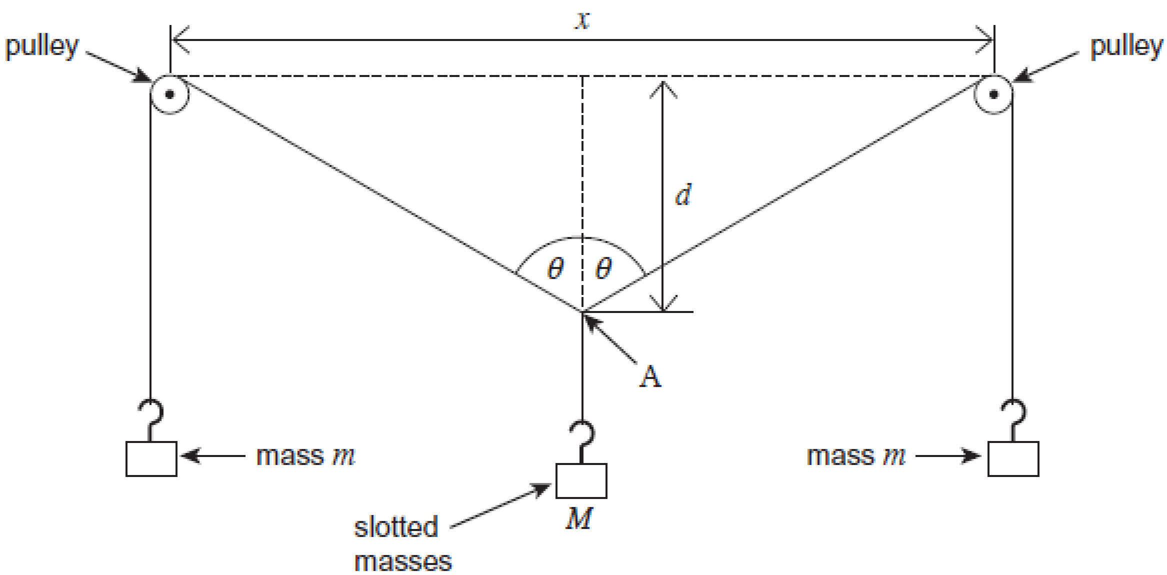
(2)
(Total 11 marks)

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

Figure 1



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

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

The results are shown in the table below.

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

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

(1)

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

(2)

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

gradient = ____________________

(3)

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

Figure 2

(1)

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

(2)

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

m = ____________________

(2)

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

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

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(1)

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

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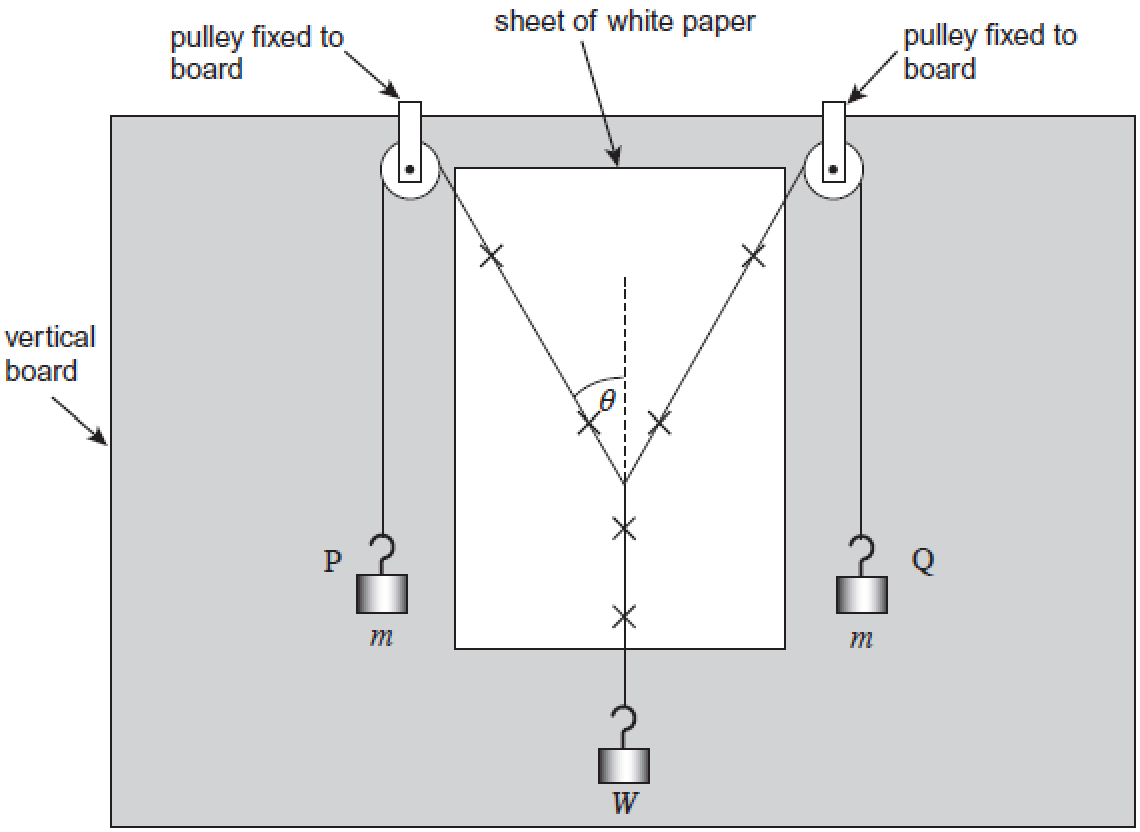
(1)

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

Figure 1



In the arrangement shown in **Figure 1**, P and Q are identical masses of mass m. A student uses this arrangement to investigate the relationship between m and θ when the system of forces is in equilibrium. Weight W is constant.
The student performs the investigation by marking the position of the strings when the forces are in equilibrium for different values of m. He does this by marking crosses on the sheet of white paper.

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

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(2)

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

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

precision of protractor = ____________________

θ = ____________________

percentage uncertainty = ____________________ %

(3)

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

θ = ____________________

(2)

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

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

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

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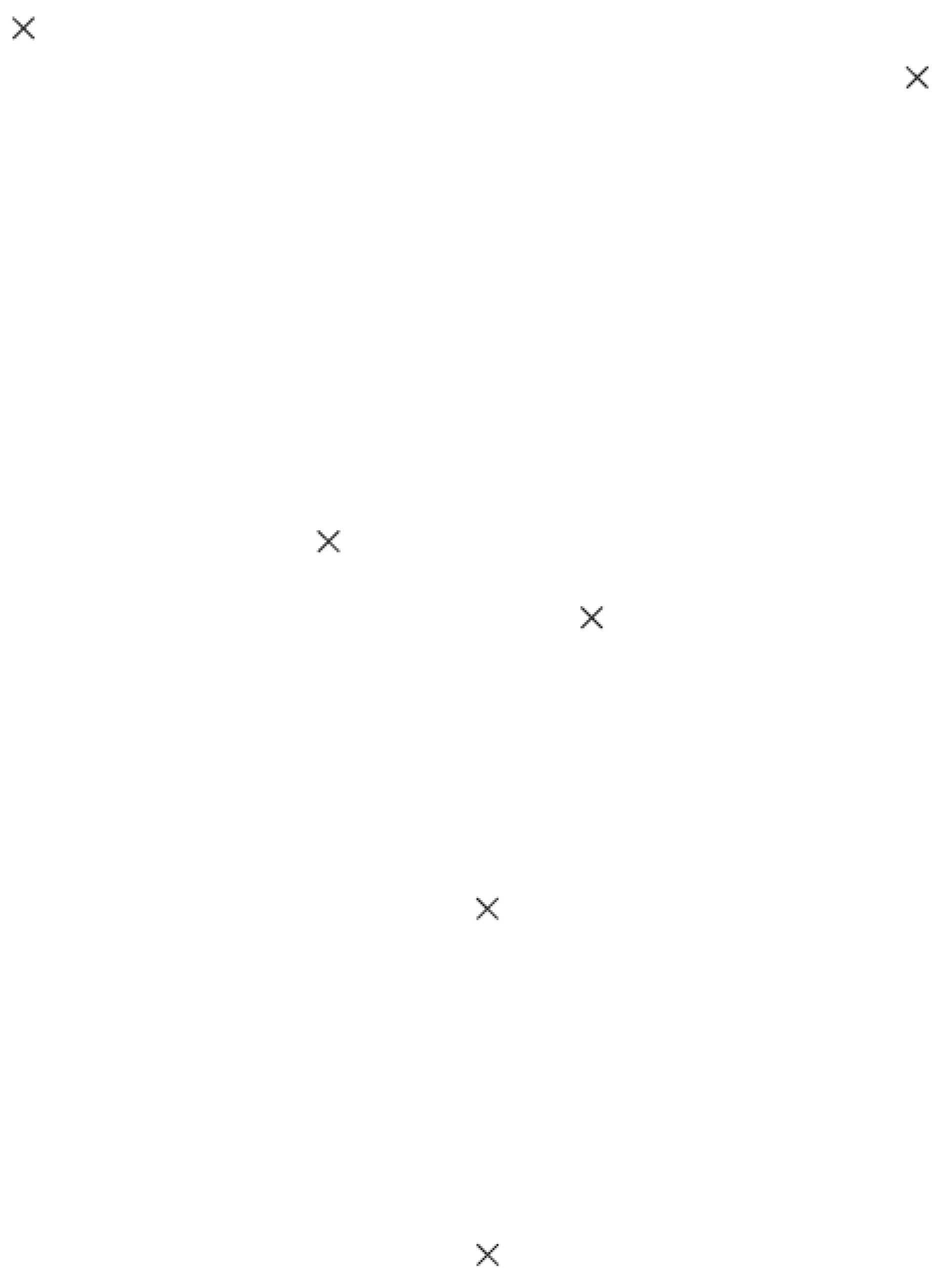
Figure 2



(1)

(Total 21 marks)

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

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

(i) Complete the table above.

(1)

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

(2)

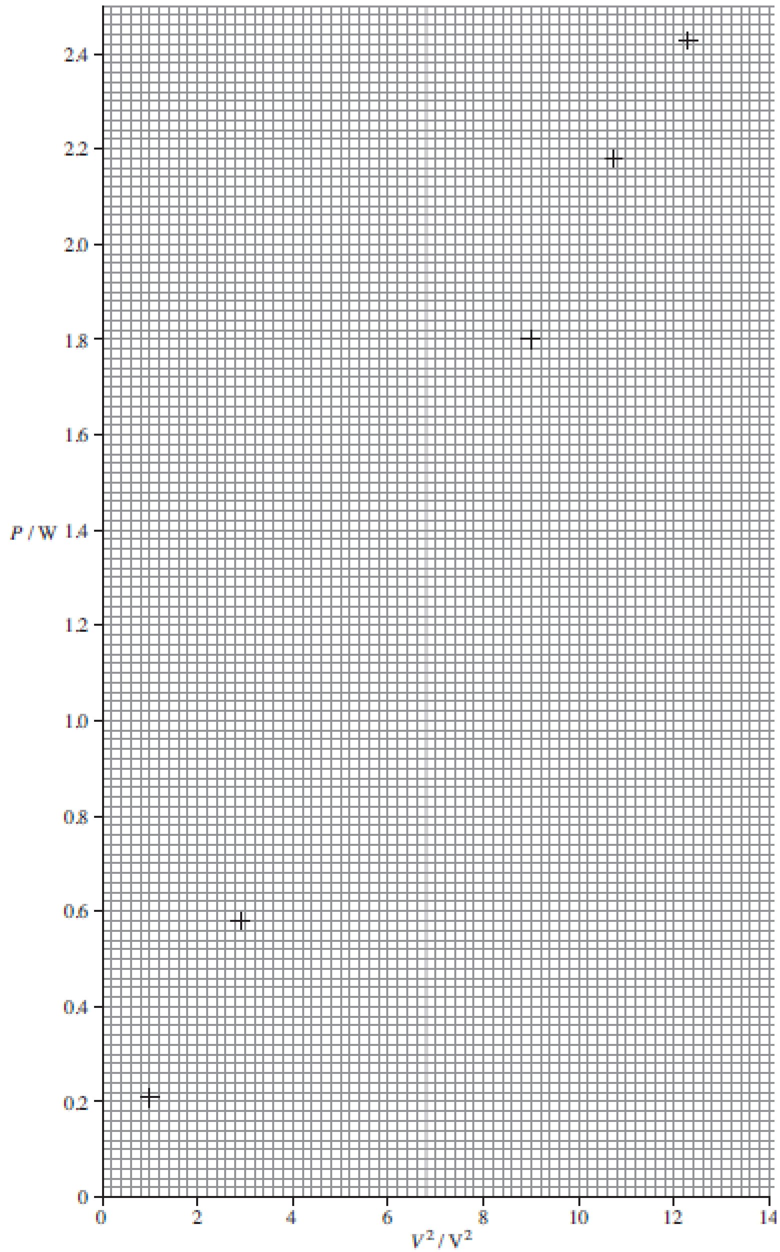
(iii) Determine the gradient of the graph.

gradient = ______________________

(3)

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

R = ______________________



(1)

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

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

R = ____________________ Ω

(1)

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

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

percentage uncertainty = ____________________ %

(3)

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

uncertainty = ____________________

(1)

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

(2)

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(Total 14 marks)

9 (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.

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(1)

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

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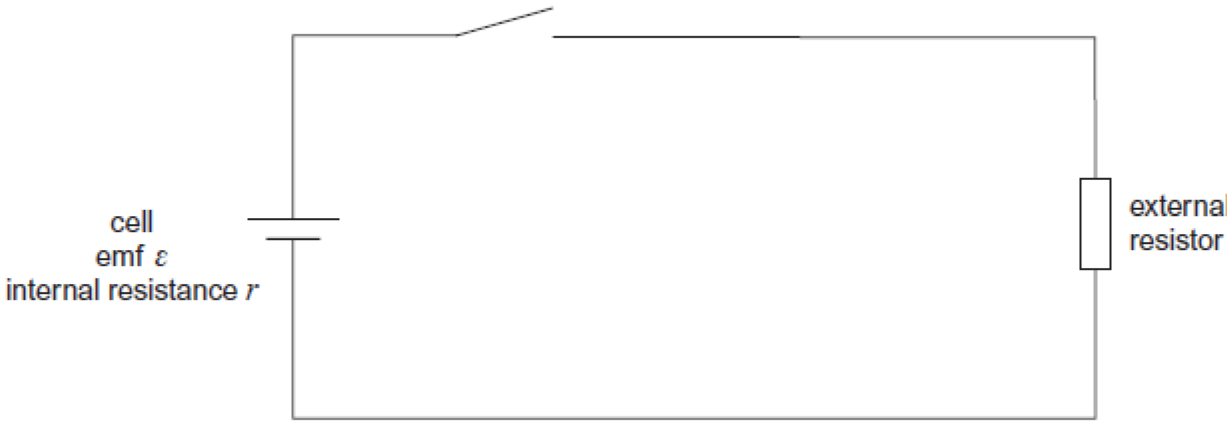
(1)

(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.

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(2)

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

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(2)

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

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(2)
(Total 9 marks)

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

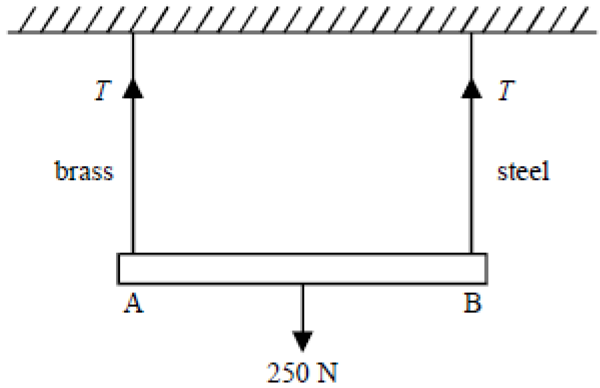
(ii) List the measurements you would make when using the apparatus described in part (i).

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

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

(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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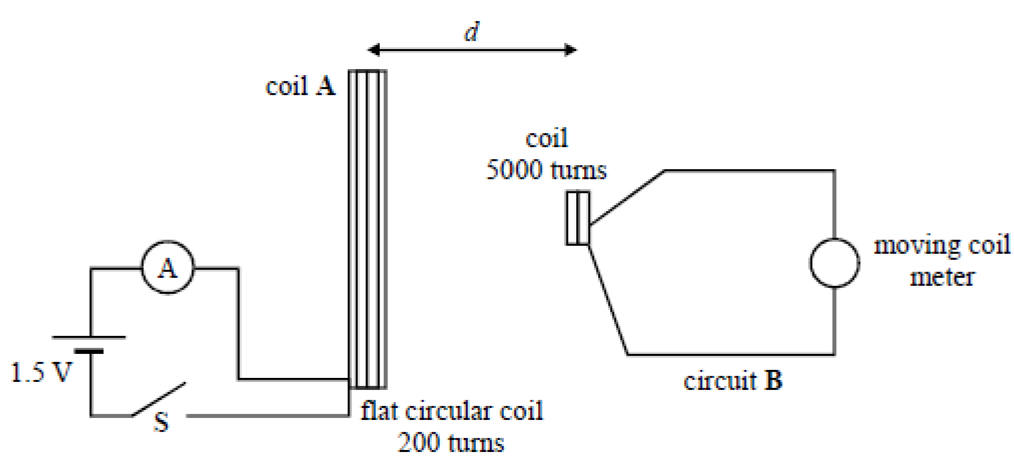
(3)
(Total 16 marks)

11 A student conducted an investigation using the apparatus shown below.



Switch **S** was closed and the current in coil **A** was allowed to reach its maximum value. When the switch **S** was opened, the maximum voltage V in circuit **B** was measured for different positions of the 5000 turn coil along the axis of coil **A**.

The maximum voltage V was measured using a moving coil meter marked in mm divisions, a deflection of 25 mm representing a potential difference of 0.01 V.

The distance d between the centres of the coils was measured using a metre rule.

The student thought that the maximum voltage might be inversely proportional to d^3.

All the data collected by the student is shown below.

Meter deflection / mm	V**/V**	d**/m**
121	0.0484	0.080
72	0.0288	0.098
32	0.0128	0.152
14	0.0056	0.201
7	0.0028	0.249

(a) (i) Determine the percentage uncertainties in V and d for the third set of data.

(2)

(ii) Use the data to test the student's theory. Show your method and state your conclusions clearly.

(3)

(b) Coil **A** had an average diameter of 0.070 m. It was made of wire that had an area of cross-section of 6.6×10^{-7} m^2. The maximum current recorded by the ammeter was 0.45 A. Determine the resistivity of the wire that was used to wind the coil.

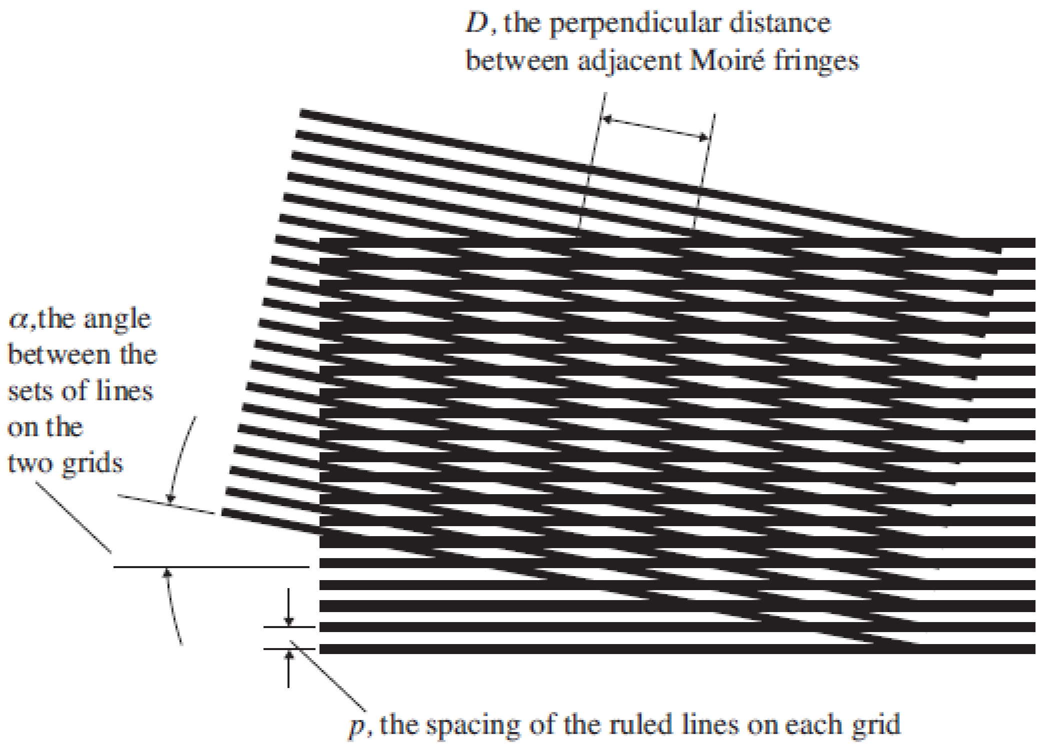
(3)

(c) Suggest changes you could make to the apparatus and procedure to improve the experiment. Justify the changes you would make. You can gain up to 2 marks in this question for good written communication.

(6)

(Total 14 marks)

12 Two grids of parallel ruled lines can be used to produce Moiré fringe patterns, as shown below.



A student obtains two diffraction gratings thought to be identical with a line spacing of about 3×10^{-6} m. The student finds that when these are placed together and viewed against a white background a Moiré fringe pattern is observed when one grating is rotated slightly. For small angles, the distance between the Moiré interference fringes, D, is given by the approximate equation, $D \simeq \frac{57p}{\alpha}$, where α is in degrees.

By assuming that $p = 3.0 \times 10^{-6}$ m, the student uses this equation in a spreadsheet to find D for values of α up to 16°.

The student's results are shown below.

α / °	D / mm
2	0.0855
4	0.0428
6	0.0285
8	0.0214
10	0.0171
12	0.0143
14	0.0122
16	0.0107

The student intends to view the Moiré fringes through a microscope to check the spreadsheet results for D by measuring D using the microscope directly.
The vernier scale on the microscope can measure to the nearest 0.01 mm.

(a) Explain using suitable calculations why this microscope is not suitable to check the results of the spreadsheet calculation.

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(4)

(b) The equation for D can be rearranged to give $p \simeq \frac{\alpha D}{57}$.

The student suggests that if a better microscope can be provided and α can be set to produce values of D greater than 0.10 mm, the value of p can be found experimentally. Discuss whether the student's suggestion is sensible.

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(2)

(c) The theoretical separation of the Moiré fringes when α = 2°, shows D = 0.0859 mm. Calculate the percentage difference between this value and the student's spreadsheet result for D when α = 2°.

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(2)

(Total 8 marks)

13 A student investigates the variation of electric potential with distance along a strip of conducting paper of length *l* and of uniform thickness. The strip tapers uniformly from a width 4*w* at the broad end to 2*w* at the narrow end, as shown in **Figure 1**. A constant pd is applied across the two ends of the strip, with the narrow end at positive potential, V_l, and the broad end at zero potential. The student aims to produce a graph of pd against distance x, measured from the broad end of the strip.

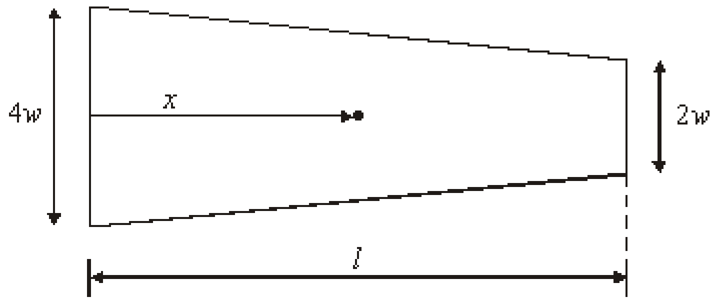

Figure 1

(a) Draw a labelled circuit diagram which would be suitable for the investigation.

(2)

(b) The student obtained some preliminary measurements which are shown below.

pd, V/V	0	2.1	4.5	7.2
Distance, x/m	0	0.100	0.200	0.300

By reference to the physical principles involved, explain why the increase of V with x is greater than a linear increase.

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(4)

(c) The potential, V, at a distance x from the broad end is given by

$$V = k - 1.44V_l \ln (2l - x),$$

where V_l is the potential at the narrow end, and k is a constant.

(i) The student's results are given below. Complete the table.
l = 0.400 m

distance x/m	potential V/V	$(2l - x)$/m	$\ln (2l - x)$
0.100	2.1	0.700	– 0.357
0.200	4.5		
0.270	6.4		
0.330	8.3		
0.360	9.3		
0.380	10.1		

(ii) Plot a graph of V against $\ln(2l - x)$ and explain whether or not it confirms the equation.

(iii) Use the graph to calculate V_l.

(10)
(Total 16 marks)

14 A strain gauge is made from a constantan wire of original length 25 mm. If the wire stretches its resistance changes. The gauge is attached to an object that is then placed under tension, which causes the length of the constantan wire to increase. The resistance, R, was measured for various lengths, l, and the following results were obtained:

R / Ω	99.96	100.64	101.76	102.80	103.85	104.71
l / 10^{-2} m	2.500	2.508	2.523	2.536	2.548	2.557

When the wire is stretched, it may be assumed that for small extensions:

$$R \propto l^2$$

(a) Complete the table showing the value of l^2 for each value of R.

(2)

(b) Plot a graph of R on the y-axis against l^2 on the x-axis.

(4)

(c) Use your graph and the value for the resistivity of constantan given below to find the diameter of the wire when its resistance is 103.40 Ω.

resistivity of constantan = 4.7×10^{-7} Ωm

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(5)

(d) Define tensile strain. Use your graph to determine the strain when the resistance of the wire is 103.40 Ω.

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(2)

(Total 13 marks)

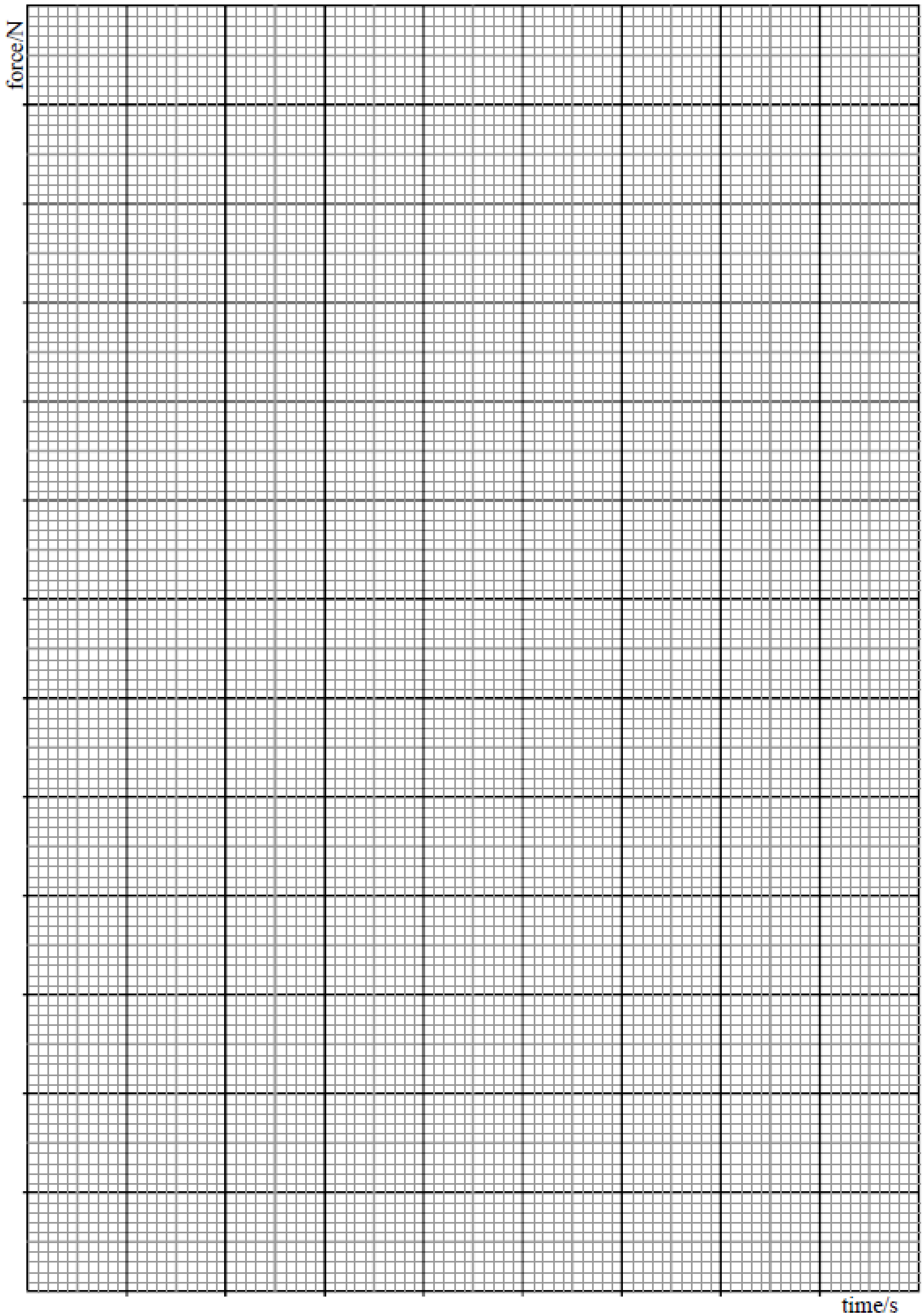
15 In an attempt to investigate how the resistance of a filament lamp varies with current through the lamp, a student obtains the results shown in the table.

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 below 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.

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(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 ____

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

1. ____

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2. ____

____

(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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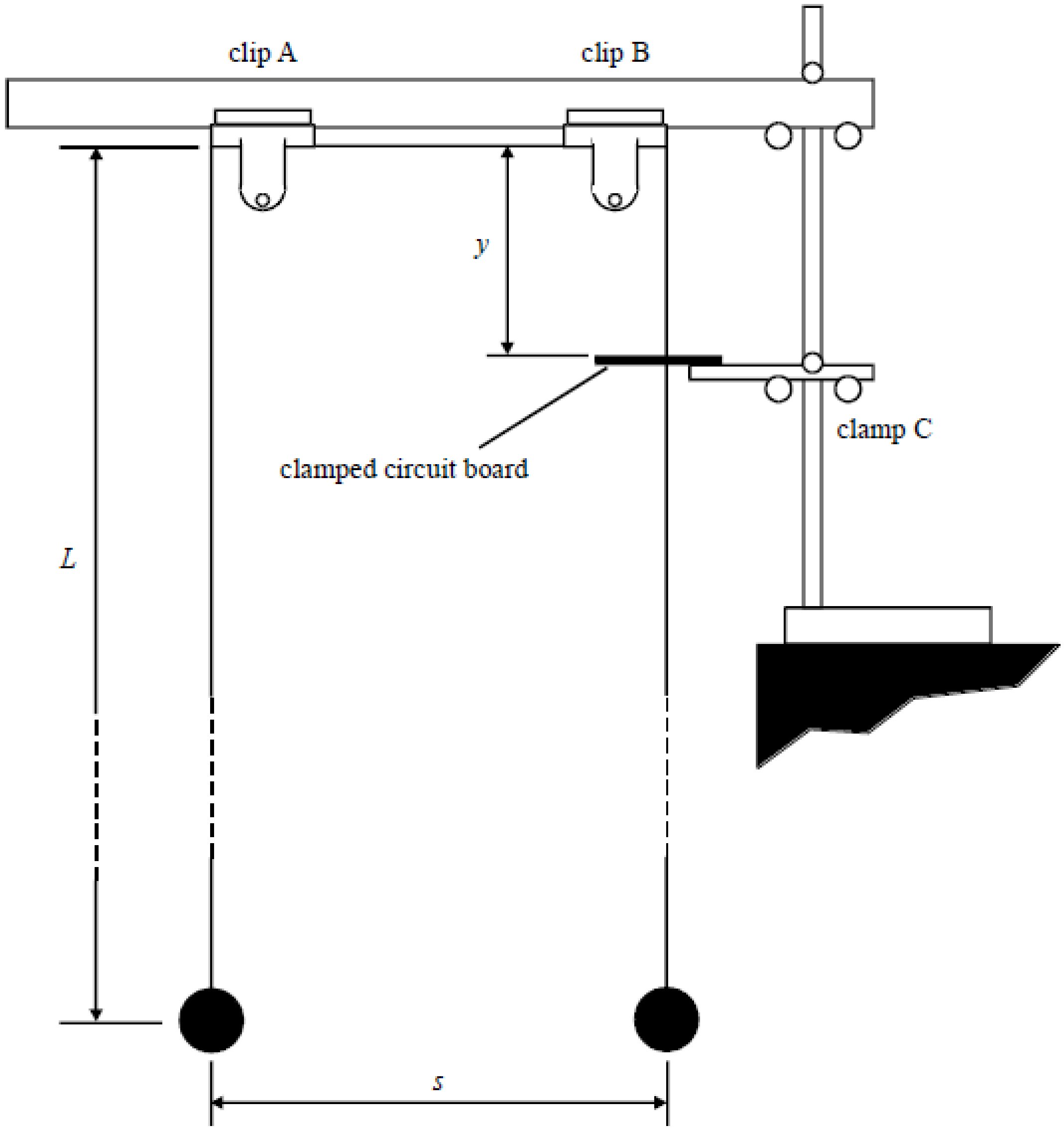
(2)

(Total 12 marks)

16 In this experiment you will investigate how the time between two pendulums moving in phase depends on their relative lengths.

No description of the experiment is required. You should devote your time to making and recording observations, and giving only the specific information requested.

You are provided with the apparatus shown in the diagram.



(a) (i) Adjust the horizontal separation of the strings, s, by moving clip A so that, **with each pendulum bob at the same height above the floor**, the longer pendulum has a length, L, of about 1.00 m.

(ii) Adjust the height of clamp C until the distance, y, defined in the diagram, is about 0.20 m. Ensure that the part of the string between clip B and the clamped circuit board is vertical.

(iii) Measure and record the distances, s, y and L.

(b) (i) Displace and release one of the pendulums so that it performs small-amplitude oscillations in a plane which is parallel to the edge of the bench. Set the other pendulum in motion so that it performs oscillations in a plane that is parallel to the edge of the bench.

(ii) Start the stopwatch at the instant when the two pendulum motions are seen to be exactly in phase.

(iii) Measure and record, T, which is the time until the pendulums are next seen to move exactly in phase.

(iv) By adjusting clamp C and ensuring that the values of s and L remain unchanged, measure and record further values of T, which correspond to four **larger** values of y.

(c) (i) Plot a graph of $\sqrt{\frac{L}{L-y}}$ on the vertical axis against $\frac{1}{T}$ on the horizontal axis.

(ii) Measure and record the gradient, G, of your graph.

(iii) Evaluate $\frac{G}{\sqrt{L}}$.

(16)

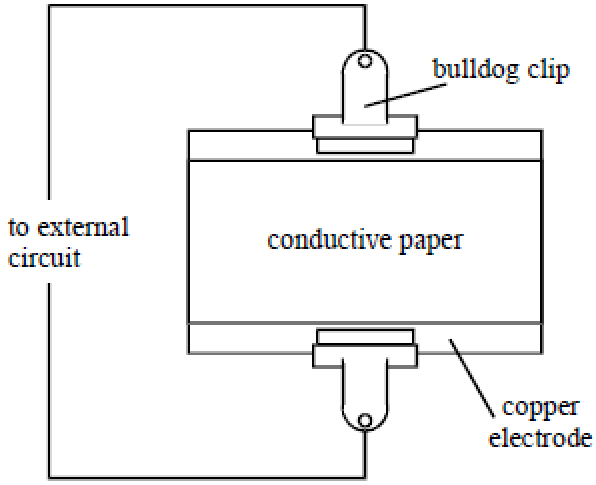
(d) (i) Describe the measures that you took to ensure that the part of the string between clip B and the clamped circuit board was vertical.

(ii) Describe and explain the factors you considered when choosing your additional values for y.

(iii) A student suggests that in order to extend the enquiry, additional measurements of T should be made using values of y that were **much smaller** than 20.0 cm. Discuss briefly whether you think that such additional readings would improve the quality of the evidence obtained from the experiment.

(6)
(Total 22 marks)

17 Conductive paper, sometimes called *Teledeltos* paper, is produced by coating one surface of the paper with a thin layer of graphite paint. To investigate its electrical properties, pieces of the paper can be joined to a conventional wired circuit using copper electrodes and bulldog clips, as shown below.



It is known that the paper obeys Ohm's Law providing the current through it does not exceed 200 mA. The company that manufactures it estimates that under typical laboratory conditions, the resistivity of the paint is between 1.0×10^{-5} Ωm and 5.0×10^{-5} Ωm.

Design an experiment that investigates some characteristic of the conductive paper.

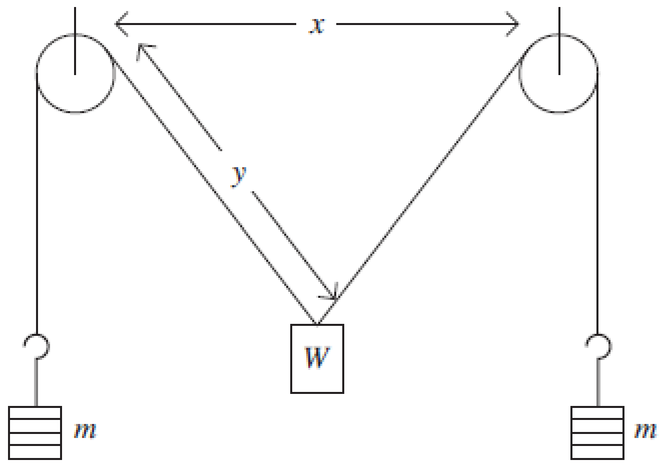
You should consider the following in your answer.

- The variables you intend to measure and how to ensure that they are measured accurately.
- The factors you will need to control and how you will do this.
- The expected outcome of the experiment that you design.
- How any difficulties in performing the experiment could be overcome.

(Total 8 marks)

18 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

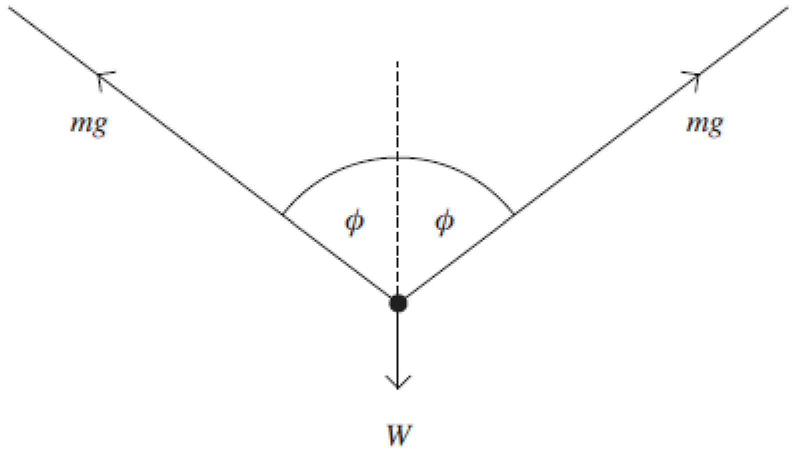


The distance x was kept constant throughout the experiment. The length y was measured for different values of m.

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 $m = \dfrac{W}{2g\cos\phi}$

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

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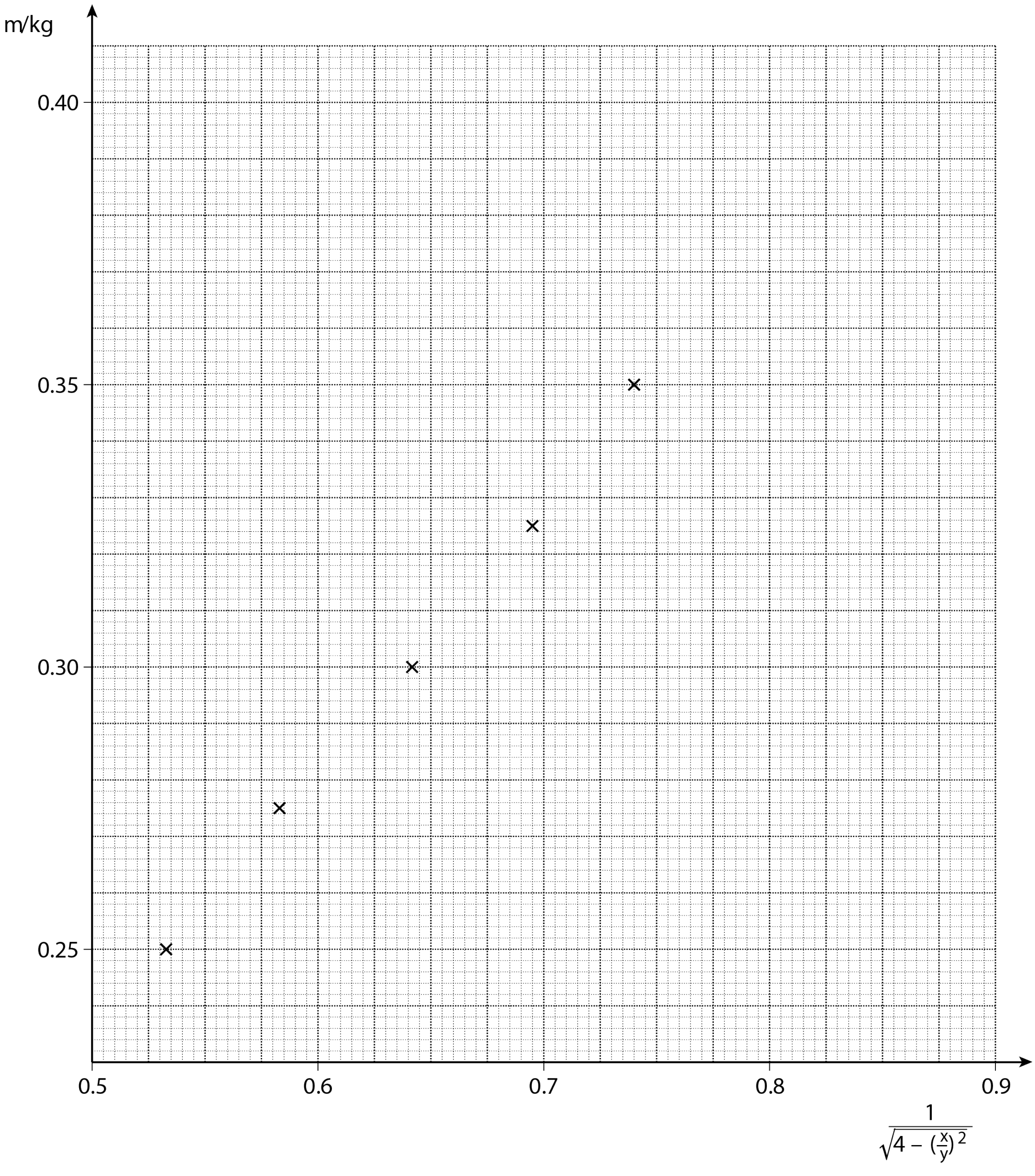
(1)

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



(1)

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

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(3)

(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*.

(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.

(2)

(Total 13 marks)

19 (a)

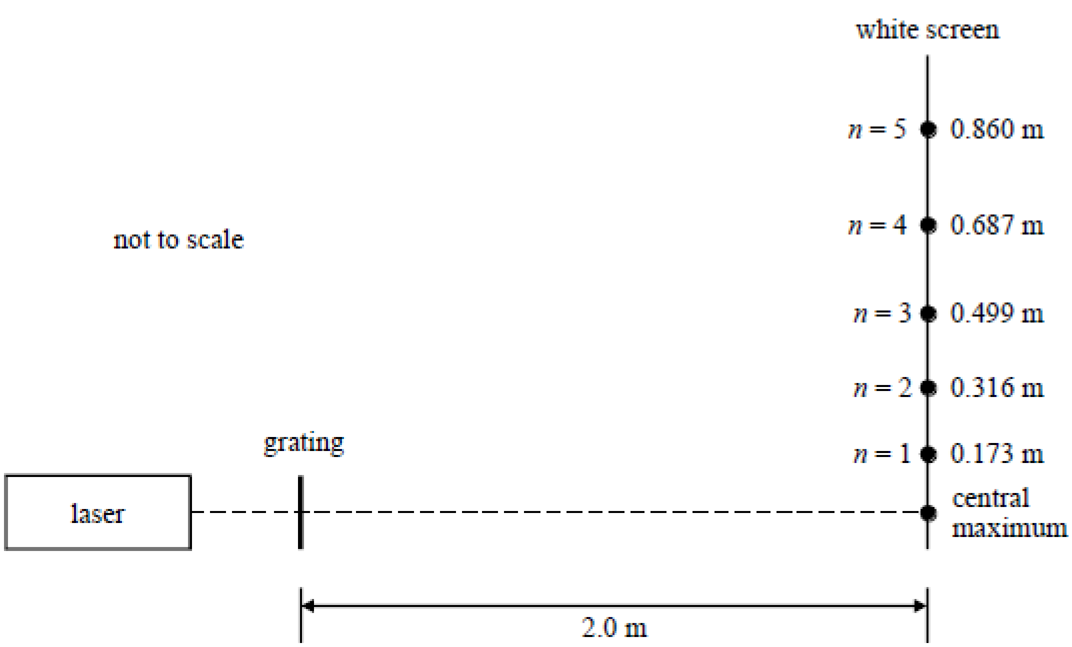

Figure 1

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.

(6)

(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.

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

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

(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.

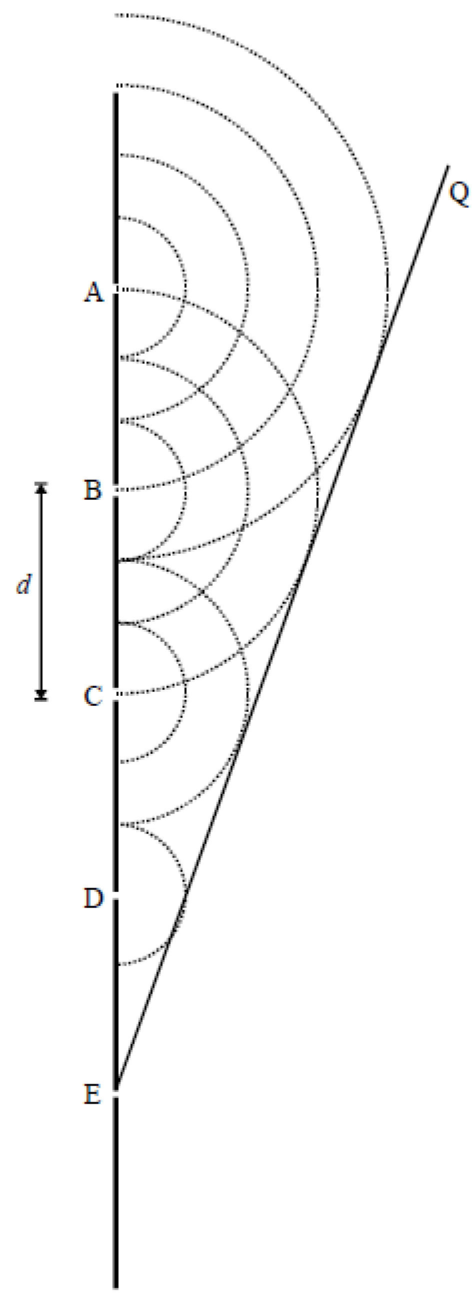

Figure 2

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

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

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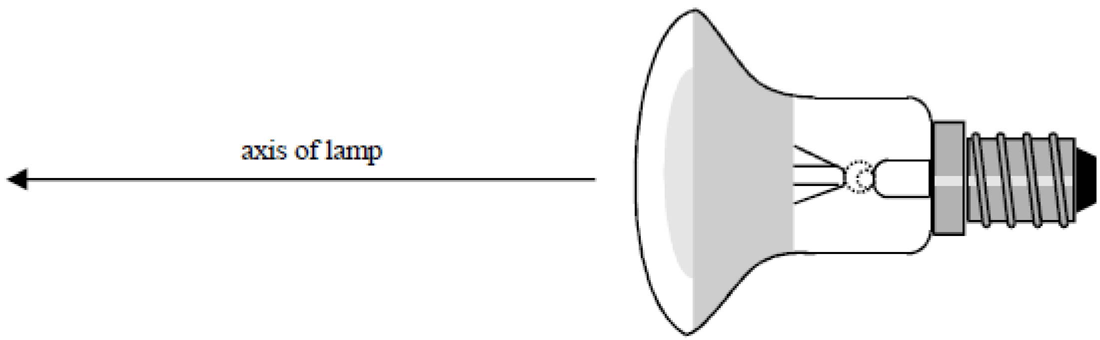
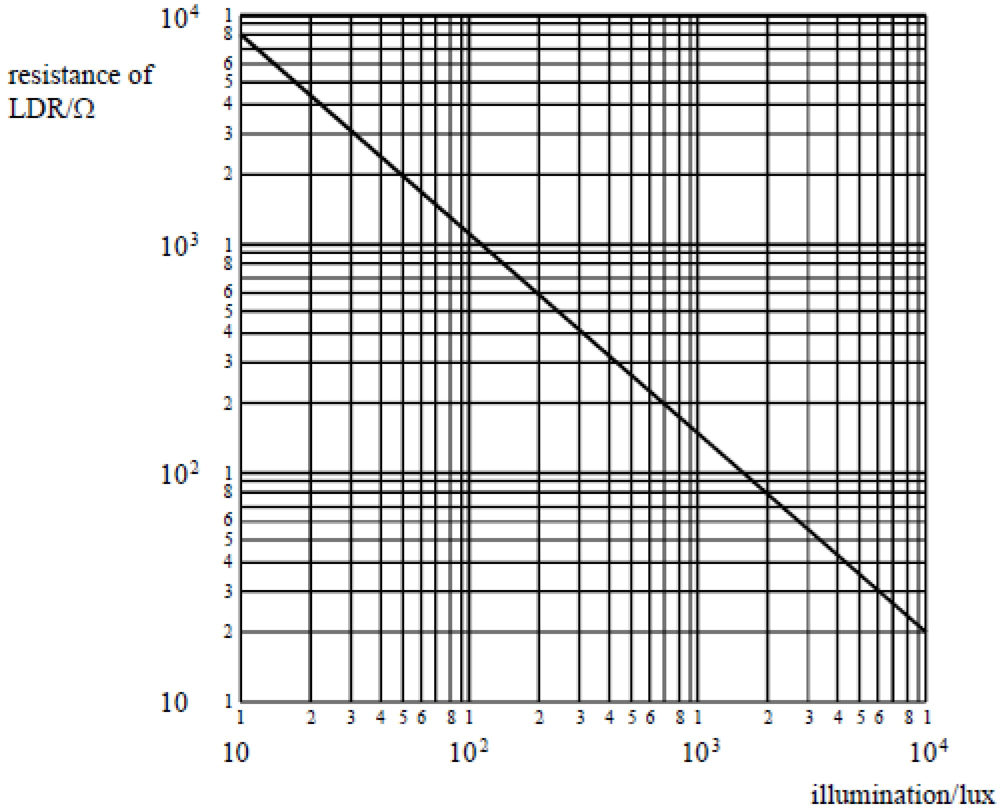
(3)
(Total 15 marks)

20 Two students discuss how the intensity of the illumination provided by a spotlight varies with the distance along the axis of the lamp.



Student A argues that the lamp should be regarded as a point source so the intensity of illumination should vary as the inverse-square of the distance along the axis from the lamp. Student B disagrees, pointing out that the lamp incorporates a reflector that produces a narrow concentrated beam. Therefore, he reasons, the intensity must decrease exponentially with the distance along the axis from the lamp. Researching the problem, the students discover the calibration graph, shown below, that shows how the resistance of a light dependent resistor (LDR) varies with the intensity of the illumination falling on it.



Design an experiment that the students could perform to test their theories.

You should assume that a well-equipped physics laboratory is available to you.
You are advised to draw a suitable diagram of the arrangement you intend to use as part of your answer.

You should also include the following in your answer:

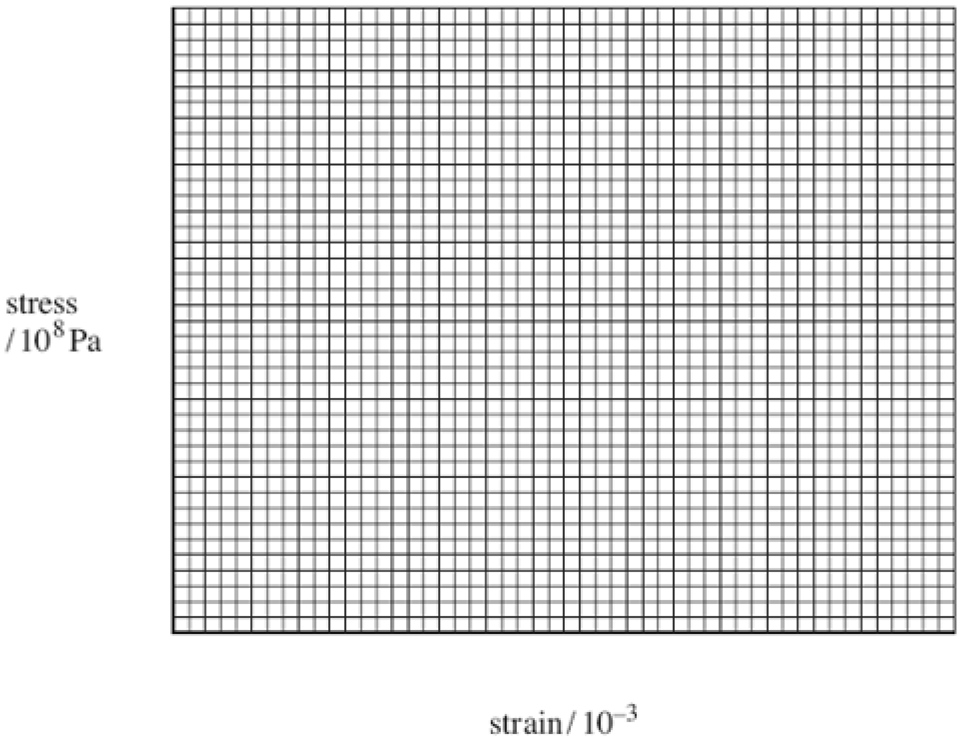
- The quantities you intend to measure and how you will measure them.
- How you propose to use your measurements to settle the argument between the students.
- The factors you will need to control and how you will do this.
- How you could overcome any difficulties in obtaining reliable results.

(Total 8 marks)

21 The table below shows the results of an experiment where a force was applied to a sample of metal.

(a) On the axes below, plot a graph of stress against strain using the data in the table.

Strain / 10^{-3}	0	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Stress / 10^{8} Pa	0	0.90	2.15	3.15	3.35	3.20	3.30	3.50	3.60	3.60	3.50



(3)

(b) Use your graph to find the Young modulus of the metal.

answer = ______________________ Pa

(2)

(c) A 3.0 m length of steel rod is going to be used in the construction of a bridge. The tension in the rod will be 10 kN and the rod must extend by no more than 1.0mm. Calculate the minimum cross-sectional area required for the rod.

Young modulus of steel = 1.90×10^{11} Pa

answer = ______________________ m^2

(3)

(Total 8 marks)

22 In an experiment, a set of light emitting diodes LEDs that emitted light of different colours was used. The minimum pd V_{min} for light to be emitted by each diode was measured. The results are given in the table, together with the average wavelength λ of the light emitted by each diode and the corresponding frequencies f for some of the LEDs. Some points are plotted on the graph of V_{min} against f.

colour	**wavelength** λ**/nm**	**frequency** f **/ 10^{14} Hz**	**minimum pd** V_{min} **/V**
infrared	940	3.19	0.92
red	665	4.51	1.54
orange	625	4.80	1.54
yellow	595	5.04	1.78
green	565		1.87
blue	470		2.37

(a) Complete the table.

(1)

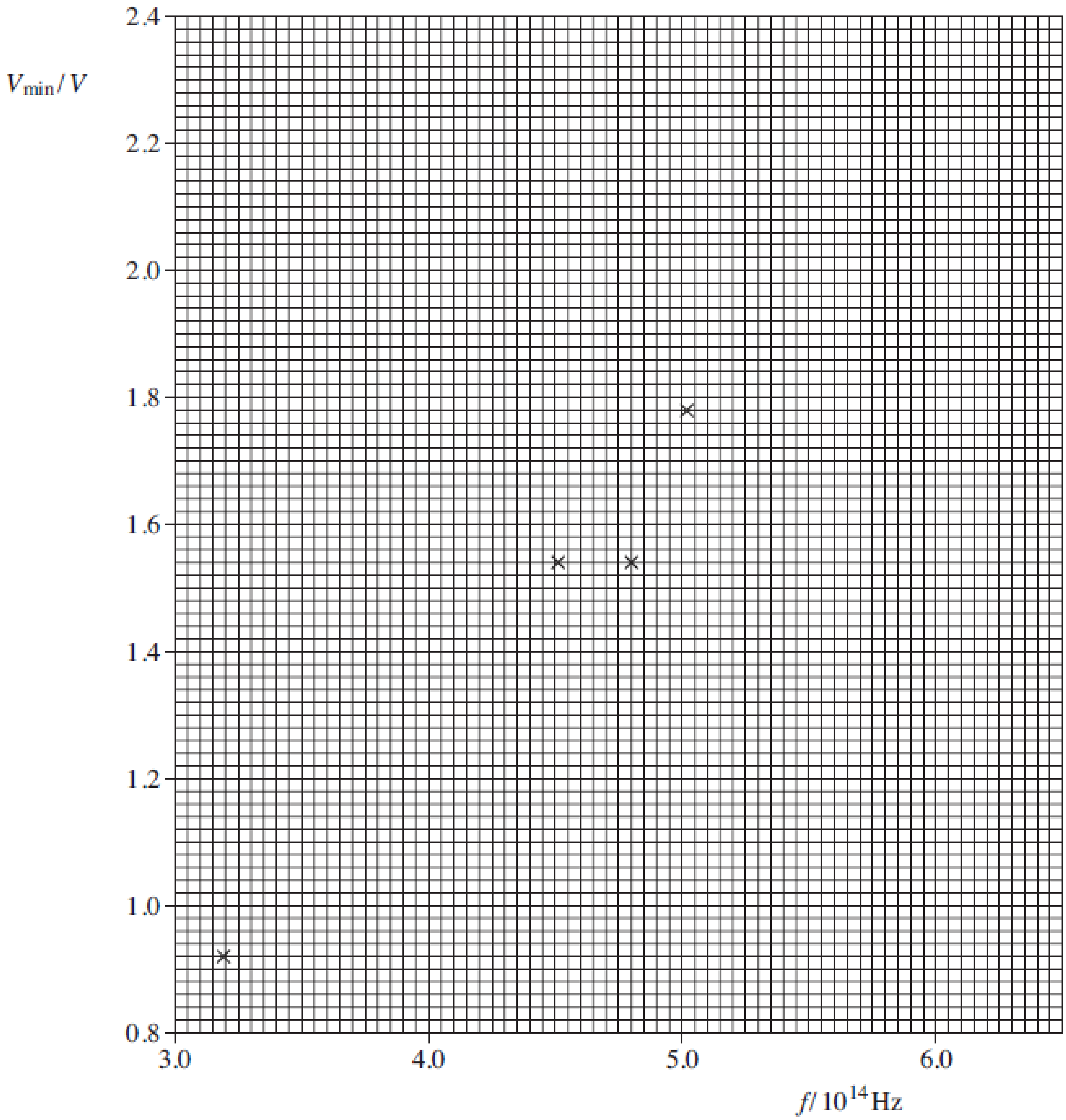
(b) Complete the graph by plotting the missing two points and drawing a straight line of best fit.

(2)

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

(3)

Graph of minimum pd against frequency



(ii) Discuss the reliability of your value for the gradient.

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(2)

(d) Theory predicts that the energy lost by the electron in passing through the LED is theenergy of the emitted photon. Hence

$$eV_{min} = hf,$$

where h is the Planck constant and $e = 1.60 \times 10^{-19}$ C.

(i) Find a value for h by using the general equation of a straight line, $y = mx + c$, and your answer to part (c)(i).

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(3)

(ii) The accepted value for $h = 6.63 \times 10^{-34}$ J s. Calculate the percentage difference between the value calculated in part (d)(i) and the accepted value.

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(1)

(iii) The precision of the voltmeter was ± 0.01V. Calculate the percentage uncertainty this produces in the value of V_{min} for the infrared radiation.

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(1)

(iv) A student assumes that the percentage difference calculated in part (d)(ii) is due only to the uncertainty in V_{min}, as determined in part (d)(iii), and the uncertainty in the frequency. Using this assumption calculate the uncertainty in the value of the infrared frequency quoted in the table.

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(3)

(Total 16 marks)

Mark schemes

1 (a) extension of wire Q = 2.7 (mm) ✓

ignore any precision given eg ± 0.1 mm

if > 2 sf condone if this rounds to 2.7

1

(b) mass = 5.8 (kg) ✓

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

allow ± 0.1 kg

1

(c) 0.51 (mm) ✓

ignore any precision given eg ± 0.005 mm

1

(d) method 1:

use of $E = \frac{\text{(tensile) stress}}{\text{(tensile) strain}}$ $_1$✓

for $_1$✓ expect to see some substitution of numerical data

cross – section area from $\frac{\pi \times d^2}{4}$ $_2$✓

correct use of diameter for $_2$✓; ignore power of ten error; expect CSA = 2.0(4) × 10^{-7}; allow ce from 01.3 (eg for d = 0.37 mm CSA = 1.0(8) × 10^{-7} m^2)

(tensile) stress = $\frac{mg}{\text{CSA}}$ $_3$✓

penalise use of g = 10 N kg^{-1}

(tensile) strain = $\frac{\Delta l}{l}$ $_4$✓

value of Δl must correspond to Figure 2 value of m; answers to 01.1 and 01.2 are acceptable

expect l = 1.82 m but condone 182 etc; accept mixed units for l and Δl

MAX 3

method 2:

evidence of $\frac{\Delta l}{\Delta m}$ from Figure 2 to calculate gradient $_1$✓

expect gradient between 0.45 to 0.48 mm kg^{-1}

$E = \frac{g \times \text{original lenght}}{\text{CSA} \times \text{gradient}}$ $_2$✓ $_3$✓

missing g loses $_3$✓

substitution of l = 1.82 m $_4$✓

condone 182 etc $_4$✓

cross-sectional area from $\frac{\pi \times d^2}{4}$ $_5$✓

correct use of diameter for $_2$✓; ignore power of ten error; expect CSA = 2.0(4) × 10^{-7}; allow ce from 01.3 (eg for d = 0.37 mm CSA = 1.0(8) × 10^{-7} m^2)

MAX 3

result in range 1.84 × 10^{11} to 1.91 × 10^{11} $_5$✓

condone 1.9 × 10^{11}

$_5$✓ mark requires correct working and no power of ten errors: allow ce for error(s) in 01.1, 01.2 and for false/incorrect CSA (eg for d = 0.37 mm allow result in range 3.49 × 10^{11} to 3.63 × 10^{11}, 3.5 × 10^{11} or 3.6 × 10^{11})

1

(e) (smaller diameter) produces larger extensions $_1$✓
reduces (percentage) uncertainty (in extension and in result for Young Modulus) $_2$✓

(smaller diameter) increases (percentage) uncertainty in diameter **or** cross sectional area is smaller **or** increases (percentage) uncertainty in cross sectional area $_3$✓
increases (percentage) uncertainty (in result for Young Modulus) $_4$✓

(smaller diameter) increases likelihood of wire reaching limit of proportionality or of wire snapping or reduces range of readings $_5$✓
increases (percentage) uncertainty (in result for Young Modulus) $_6$✓

outcome and correct consequence for 2 marks, ie $_1$✓ followed by $_2$✓, $_3$✓ followed by $_4$✓ etc

dna ‘error’ for ‘uncertainty’

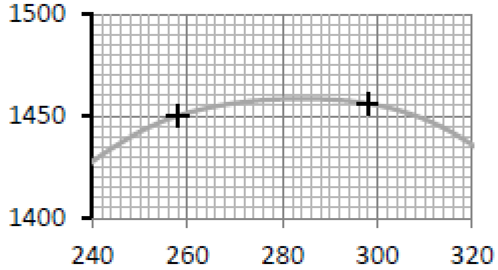
no mark for consequence if outcome not sensible, eg ‘it gets longer and reduces uncertainty’ earns no mark for ‘diameter smaller so uncertainty greater’ award $_1$✓ (need to see further mention of uncertainty to earn $_2$✓)

MAX 4

[11]

2

(a) 2 missing points plotted, each to nearest 1 mm (half a grid square); points marked + or × or ⊙; reject thick points, blobs or uncircled dots ✓



1

(b) continuous smooth best fit line through all 7 points to 1 mm ✓

allow mis-plotted points to be treated as anomalies; multiple lines or points of inflexion lose the mark

1

(c) candidate's value from Figure 2 ± ½ grid square ✓

if multiple lines are drawn condone value if ± ½ grid square of all lines

1

(d) finding θ_N from Figure 3 is easy since the result is read off where $G = 0$ $_1$✓

or

finding θ_N from Figure 2 is difficult since θ has a range of values for which ε is a maximum $_2$✓

accept evidence that $G = 0$ used shown on Figure 3; physics error about how Figure 3 used means no credit for any further valid comment about Figure 2

accept 'curve is shallow at peak' for $_2$✓

MAX 1

(e) method:

correctly determines gradient of Figure 3 or uses gradient result with any point on line to determine (vertical) intercept $_1$✓

result in range 9.8 to 10.9 $_2$✓

gradient values in the range −0.040 to −0.034 for $_1$✓ *(minus sign essential)*

for $_1$✓ *allow the substitution of at least one pair of correct values of G and θ into $G = \beta\theta + \alpha$ to obtain α using simultaneous equations*

condone 2sf '10' for $_2$✓

2

(f) full scale pd = 100 × 1000 = 100000 or 10^5 μV ✓

allow 100 mV or 0.1 V if μV deleted from answer line ✓

1

(g) idea that resolution of the meter is not satisfactory $_1$✓
because the largest pd that will be measured is less than 1500 μV
OR
only uses 1.5% of the range
OR
pd across meter at full-scale deflection ÷ divisions = $\frac{10^5}{50}$ = 2000 μV
per division $_2$✓

condone use of 'sensitivity' or 'precision' for 'resolution'; ignore 'meter is not accurate'

allow 'hard to tell different readings apart'

for $_2$✓ allow ce for incorrect 02.6

allow 'unable to measure to nearest microvolt'

allow 'resolution of scale should be 1 μV'

2

[9]

3

(a) 2.9% ✓

Allow 3%

1

(b) $\frac{1}{3.5\times10^3}$ seen ✓

1

0.29 mm or 2.9 x 10^{-4} m✓ must see 2 sf **only**

1

(c) ± 0.01 mm ✓

1

(d) Clear indication that at least 10 spaces have been measured to give a spacing = 5.24 mm✓

spacing from at least 10 spaces
Allow answer within range ±0.05

1

(e) Substitution in $d\ sin\theta = n\lambda$✓

The 25 spaces could appear here as n with sin θ as 0.135 / 2.5

1

d = 0.300 x 10^{-3} m so
number of lines = 3.34 x10^3✓

Condone error in powers of 10 in substitution

Allow ecf from 1-4 value of spacing

1

(f) Calculates % difference (4.6%) ✓

1

and makes judgement concerning agreement ✓

Allow ecf from 1-5 value

1

(g) care not to look directly into the laser beam✓

OR

care to avoid possibility of reflected laser beam ✓

OR

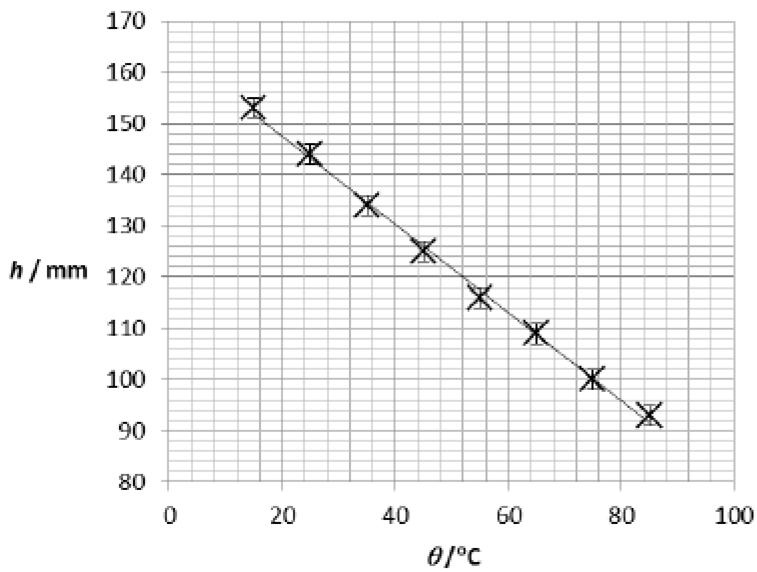
warning signs that laser is in use outside the laboratory✓

ANY ONE

1

[10]

4 (a) Straight line of best fit passing through all error bars ✓



Look for reasonable distribution of points on either side

1

(b) h_0 = 165 ± 2 mm✓

1

(c) Clear attempt to determine gradient ✓

1

Correct readoffs (within ½ square) for points **on line** more than 6 cm apart and correct substitution into gradient equation ✓

1

h_0k gradient =(-) 0.862 mm K^{-1} and negative sign quoted ✓

Condone negative sign
Accept range -0.95 to -0.85

1

(d) $k = \frac{\text{candidate value for } h_0 k}{\text{candidate value for } h_0}$

= 5.2×10^{-3} ✓

Allow ecf from candidate values

1

K^{-1} ✓

Accept range 0.0055 to 0.0049

1

(e) for h = 8000 mm, $d^{-1} = \frac{8000}{14.5}$ ✓

1

$d = 1.8 \times 10^{-3}$ mm ✓

1

(f) Little confidence in this answer because

One of

It is too far to take extrapolation ✓

OR

This is a very small diameter ✓

1

[10]

5 (a) Clear identification of distance from centre of sphere to right hand end of mark, or to near r.h.end of mark ✓

1

(b) 0.393 (s) ✓

Accept 0.39 (s)

1

(c) For 10 oscillations percentage uncertainty = $\frac{0.1}{15.7}$ = 0.00637 ≡ 0.64% ✓

same for the ¼ period ✓

2

(d) Identifies anomaly [0.701] ✓ and calculates mean distance = 0.759 (m)✓

Allow 1 max if anomaly included in calculation giving 0.750 (m)

2

(e) Largest to smallest variation = 0.026 (m)

Absolute uncertainty = 0.013 (m)✓

1

(f) Use of $g = \frac{2d}{t^2}$ leading to

9.83 (m s^{-2}) ✓

Allow 9.98 (m s^{-2}) if 0.39 used

Ecf if anomaly included in mean in (d)

percentage uncertainty in distance = 1.7%✓

Total percentage uncertainty =

1.7 + 2 x 0.64 = 3.0%

Absolute uncertainty = 0.30 (m s^{-2}) ✓

[g = 10.0 ± 0.3 m s^{-2}]

Expressed sf must be consistent with uncertainty calculations

3

(g) suggests one change ✓

Sensible comment about change or its impact on uncertainty ✓

eg

Use pointed mass not sphere

Because this will give better defined mark OR because the distance determination has most impact on uncertainty

OR

Time more swings / oscillations

As this reduces the percentage uncertainty in timing

OR

longer / heavier bar would take a greater time to swing to the vertical increasing t and s and reducing the percentage uncertainty in each

If data logger proposed, it must be clear what sensors are involved and how the data are used.

2

(h) $[s = \frac{g}{2}t^2]$

plot graph of s against t^2 or $\sqrt{s}$ against t ✓

calculate the gradient ✓

the gradient is g / 2 or $\sqrt{(g / 2)}$ ✓

Accept: plot s against t^2 / 2 or plot 2s against t^2:

calculate the gradient

in both cases gradient gives g

Allow 1 max for answer that evaluates g for each data point and averages

3

[15]

6 (a) emf is the work done / energy transferred by a voltage source / battery / cell ✓per unit charge✓
OR
electrical energy transferred / converted / delivered / produced✓
per unit charge✓
OR
pd across terminals when no current flowing / open circuit✓✓

not in battery

accept word equation OR symbol equation with symbols defined if done then must explain energy / work in equation for first mark

2

(b) (i) by altering the (variable) resistor✓

1

(ii) reference to correct internal resistance✓

e.g. resistance of potato (cell)

terminal pd = emf – pd across internal resistance / lost volts✓
pd / lost volts increases as current increases OR as (variable) resistance decreases greater proportion / share of emf across internal resistance✓

accept voltage for pd

3

(iii) draws best fit straight line and attempts to use gradient✓
uses triangle with base at least 6 cm✓
value in range 2600 – 2800 (Ω)✓

3

stand-alone last mark

(c) total emf is above 1.6 V✓
but will not work as current not high enough / less than 20 mA✓

2

[11]

7 (a) (i) 0.416 or 0.417 and 0.495 or 0.496

1

(ii) Both plotted points to nearest mm✓

Straight line of best fit ✓

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

2

(iii) Large triangle drawn (at least 8cmx8cm) ✓

Correct values read from graph✓

Gradient value in range 0.805 to 0.837 to 2 or 3 sf✓

3

(iv) (1) For showing correct vertical component of at least one of the forces / tensions as *mg*cosθ or both vertical components as 2 *mg*cosθ

Question specifically referred to resolving forces so component <u>must</u> include *g*.✓

1

(2) $\cos\theta = \dfrac{d}{\text{hypotenuse}} = \dfrac{d}{\sqrt{(d^2 + (x^2/4))}}$ ✓

$$\frac{d}{\sqrt{(d^2 + (x^2/4))}} = \frac{M}{2m}$$ compared to $y = mx$ ✓

(Hence gradient is $\dfrac{1}{2m}$)

2

(3) Magnitude of *m* correct from

E.g middle gradient value gives m = 0.609 kg

$\dfrac{1}{2 \times \text{their gradient from (c)}}$ ✓ kg and 2 or 3 sf ✓

Allow ecf from gradient value.

Sf and unit mark depends on correct calculation of m from the gradient value.

2

(v) (1) Friction <u>at the pulleys</u> ✓

1

(2) Take a mean value of readings from loading and unloading ✓

1

(b) (i) Description of technique:
Use small plane mirror beneath string / use of set square / bright light source to project shadow of the strings onto the paper, and marking points on shadow to aid drawing lines ✓

Explanation:
Line of sight not perpendicular from string to paper / mark on paper depends on the angle the eye is positioned at / reference to parallax error. ✓

2

Markers should measure the angle to check that no scaling error has been introduced in the photocopying of the paper. If the angle is different, mark accordingly.

Answers should be consistent with protractor precision stated by the candidate.

(ii) (1) Value of θ quoted as 30º or 31º (for a protractor with precision ±1º)
OR
θ = 30.0, 30.5, 31.0
(for a protractor with precision ± 0.5º) ✓

Correct computation of % uncertainty, answer quoted to 2 or 1sf ✓

Allow ecf for incorrect angle (penalised in 1st marking point).(e.g. if using a protractor with 1º precision % uncertainty will be 1/31 × 100% = 3.2% or 3% OR for candidates who measured the angle 2 θ % uncertainty = 1/62 × 100 = 1.6% or 2%. With a protractor with precision ± 0.5º the % uncertainties will be half these values)

This is because the question specifically stated "as accurately as possible". It should be clear from the candidate's percentage uncertainty calculation whether 2θ or θ has been measured.

Extra mark for a candidate who measures the angle 2θ (rather than just the single angle θ) ✓
(This 3rd mark can also be awarded for a candidate who has measured θ on both sides of the 'vertical line',and taken the mean value)

3

(2) Evidence of right angled triangle drawn on to the diagram <u>with</u> dimensions of two sides also shown on the diagram. <u>The minimum dimension shown must be 70mm.</u> ✓

Correct use of cosine rule without right angled triangle is acceptable.

Angle correctly computed using sine cosine or tangent, with value quoted in the range 30.0º to 31.4º ✓

Angle quoted to 3 sf/to 0.1º
2nd mark is still available to a candidate who didn't achieve the 1 st mark.

2

(iii) Plot a graph of cos θ against $1/m$

AND

Statement that it should give a straight line through origin. ✓

Allow graphs of 1/m ***against*** *cos θ, against 1/cos θ against m, which would all be straight lines through the origin.*

1

[21]

8 (a) (i) 5.1 and 7.1 ✓

Exact answers only

1

(ii) Both plotted points to nearest mm ✓

Best line of fit to points ✓

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

2

(iii) Large triangle drawn at least 8 cm × 8 cm ✓

Correct values read from graph ✓

Gradient value in range 0.190 to 0.210 to 2 or 3 sf ✓

3

(iv) ($R = \dfrac{1}{\text{gradient}}$) = 5.0 Ω   Must have unit ✓

Allow ecf from gradient value

No sf penalty

1

(b) (i) 5.04 (Ω) or 5.0 (Ω) ✓

(Allow also 5.06 Ω or 5.1 Ω, obtained by intermediate rounding up of 3.50^2)

From $R = \dfrac{V^2}{P}$

1

(ii) (Uncertainty in V = 0.29%)

Uncertainty in V^2 = 0.57%, 0.58% or 0.6% ✓

From uncertainty in V = 0.01 / 3.50 × 100%

Uncertainty in P = 2.1% ✓

From uncertainty in P = 0.05 / 2.43 × 100% = 2.1%

Uncertainty in R =2.6%, 2.7% or 3%

Answer to 1 or 2 sf only ✓

2.1 % + uncty in V^2 (0.6%) = 2.7%

Allow ecf from incorrect uncertainty for V^2 or P

3

(iii) (Absolute) uncertainty in R is (±) 0.14 or just 0.1 Ω (using 2.6%) (or 0.15 or 0.2 Ω using 3%) ✓

Must have unit (Ω)
Must be to 1 or 2 sf and must be consistent with sf used from (ii)
No penalty for omitting ± sign

1

(iv) Works out possible range of values of R based on uncertainty in (iii), e.g. R is in range 5.0 to 5.2 Ω using uncertainty of ± 0.1 Ω ✓

No credit for statement to effect that the values are or are not consistent, without any reference to uncertainty

Allow ecf from (iii)

Value from (a)(iv) is within the calculated range (or not depending on figures, allowing ecf) ✓

Allow ecf from (a)(iv)

2

[14]

9 (a) (i) Voltmeter across terminals with nothing else connected to battery / no additional load. ✓

1

(ii) This will give zero / virtually no current ✓

1

(b) (i) $\frac{VI}{\varepsilon I}$

Answer must clearly show power: εI and VI, with I cancelling out to give formula stated in the question ✓

1

(ii) Voltmeter connected across cell terminals ✓

Switch open, voltmeter records ε
Switch closed, voltmeter records V
Both statements required for mark ✓

Candidates who put the voltmeter in the wrong place can still achieve the second mark providing they give a detailed description which makes it clear that:

To measure emf, the voltmeter should be placed across the cell with the external resistor disconnected

And

To measure V, the voltmeter should be connected across the external resistor when a current is being supplied by the cell

2

(c) Vary external resistor and measure new value of *V*, for at least 7 different values of external resistor ✓

Precautions - switch off between readings / take repeat readings (to check that emf or internal resistance not changed significantly) ✓

2

(d) Efficiency increases as external resistance increases ✓

Explanation
Efficiency = Power in R / total power generated
$I^2R / I^2(R + r) = R / (R + r)$
So as *R* increases the ratio becomes larger or ratio of power in load to power in internal resistance increases ✓

Explanation in terms of V and ε is acceptable

2

[9]

10 (a) (i) diagram to show:
(long) wire fixed at one end **(1)**
mass / weight at other end **(1)**
measuring scale **(1)**
mark on wire, or means to measure extension **(1)**

max 3

[alternative for two vertical wires:
two wires fixed to rigid support **(1)**
mass / weight at end of one wire **(1)**
other wire kept taut **(1)**
spirit level and micrometer or sliding vernier scale **(1)**]

(ii) measurements:
length of the wire between clamp and mark **(1)**
diameter of the wire **(1)**
extension of the wire **(1)**
for a known mass **(1)**

max 3

(iii) length measured by metre rule **(1)**
diameter measured by micrometer **(1)**
at several positions and mean taken **(1)**
(known) mass added and extension measured
by noting movement of fixed mark against vernier scale
(or any suitable alternative) **(1)**
repeat readings for increasing (or decreasing) load **(1)**

max 5

(iv) graph of mass added / force against extension **(1)**

gradient gives $\frac{F}{e}$ or $\frac{m}{e}$ **(1)**

correct use of data in $E = \frac{Fl}{eA}$ where A is cross-sectional area **(1)**

[if no graph drawn, then mean of readings
and correct use of data to give 2_{max}) **(1)**

max 2
(13)

The Quality of Written Communication marks are awarded for the quality of answers to this question.

(b) (i) for steel (use of $E = \frac{Fl}{eA}$ gives) $e = \frac{FL}{EA}$ **(1)**

$e = \frac{125 \times 2}{2.0 \times 10^{11} \times 2.5 \times 10^{-7}}$ **(1)**

$= 5.0 \times 10_{-3}$ m **(1)**

(ii) extension for brass would be $10 \times 10_{-3}$(m) (or twice that of steel) **(1)**
end A is lower by 5 mm √ (allow C.E. from (i))

max 3
[16]

11 (a) (i) percentage uncertainty in meter deflection = 1 / 32 × 100 = 3%

B1

uncertainty in d = 1 / 152 × 100 = 0.7%

B1
(2)

(ii) calculates V / d^3 correctly for 2 sets of data

M1

calculates this correctly for all sets of data

A1

states conclusion

A1
(3)

(b) resistance of coil = 1.5 / 0.45 = 3.3 Ω

C1

length of wire = $n\pi d$ = 44 m

C1

resistivity = 5.0×10^{-8} Ω m (c.a.o.)

A1
(3)

(c) increase turns on 5000 turn coil
or
increase turns on 200 turn coil **and** increase the supply voltage
or
increase the supply voltage / current

M1

this will increase the voltage measured by increasing the rate of change of flux

A1

repeat observations and average

M1

this reduces the uncertainty in the readings

A1

make more measurements at more frequent d intervals

M1

to improve confidence and the limits over which the hypothesis is correct

A1
(Max 4)

any two changes with corresponding justification

the use of Physics terms is accurate, the answer is fluent / well argued with few errors in spelling, punctuation and grammar

(2)

the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor

(1)

the use of Physics terms is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar

(0)
(Max 2)

[14]

12 (a) D could not be measured with enough **precision**; [can only resolve to 1 sf / 2 dp (and 3 sf / 4 dp needed) / needs to measure to 0.0001 mm] ✓
example given to correctly illustrate this point, eg 0.0855 mm would be read as 0.09 mm ✓

same D would be produced for different α ✓
example given to correctly illustrate this point, eg when α = 12° / 14° / 16° ✓

there would be a large **percentage** uncertainty [**percentage** error] in D ✓
example given to correctly illustrate this point, eg when α = 8° percentage uncertainty is 47% ✓ (tolerate answers using ΔD = 0.01 mm or 0.02 mm)

α / °	D / mm spreadsheet	D / mm to 0.01 mm	% uncertainty (ΔD = 0.01 mm)
2	0.0855	0.09	11.7%
4	0.0428	0.04	23.4%
6	0.0285	0.03	35.1%
8	0.0214	0.02	46.8%
10	0.0171	0.02	58.5%
12	0.0143	0.01	70.2%
14	0.0122	0.01	81.9%
16	0.0107	0.01	93.6%

max 4

(b) argument is not sensible because (larger value of D leads to) very small values of α ✓
(hence) α cannot be measured accurately [uncertainty would be very large] ✓

2

(c) $\dfrac{0.0859 - 0.0855}{0.0859} \times 100$ ✓ (working must show 0.0859 in denominator, or 0 / 2)

= 0.466% or 0.47% **only** ✓ (ie 0.5% is worth 1 max)

2

[8]

13 (a) circuit diagram to show:
wide end of conducting strip to – of battery, narrow end to + **(1)**
voltmeter between wide end and probe **(1)**

2

(b) resistance gradient increases as *x* increases **(1)**
because strip becomes narrower (as *x* increases) **(1)**
current constant throughout strip **(1)**
voltage gradient = current × resistance gradient, so
voltage gradient increases as *x* increases **(1)**

4

(c) (i)

$(2l - x)$	$\ln(2l - x)$
(0.700)	(–0.357)
0.60(0)	–0.511
0.53(0)	–0.635
0.47(0)	–0.755
0.44(0)	–0.821
0.42(0)	–0.868

1st column correct to 2 s.f. **(1)**
2nd column correct to 3.s.f. **(1) (1)**
(only 4 values correct, **(1)**)

(ii) suitable scales **(1)**
axes labelled and units included **(1)**
5 points correctly plotted **(1)**
acceptable straight line **(1)**
straight line confirms equation because equation is of form
$y = mx + c$ with negative gradient **(1)**

(iii) gradient = (–) $\frac{10.5}{0.68}$ = (–) 15.4 (V) **(1)**

1.44 V_1 = 15.4 gives V_1 = 11 V **(1)** (10.7 ± 0.2 V)
[alternative: $V = V_1$ when $x = l$ and $\ln(2l - x)$ (= ln 0.4) = 0.92 **(1)**
at $\ln(2l - x)$ = 0.92, graph gives V_1 = 11 V **(1)** (10.7 ± 0.2 V)]

10

[16]

14 (a)

R / Ω	99.96	100.64	101.76	102.80	103.85	104.71
l / 10^{-2} m	2.500	2.508	2.523	2.536	2.548	2.557
l^2 / 10^{-4} m^2	6.250	6.290	6.366	6.432	6.492	6.538

correct values above **(1)(1)** (deduct one mark for each error)
(If two significant figures only – deduct one mark)

(2)

(b) both axes, with units, correctly labelled **(1)**
six points correctly plotted **(1)**
best straight line through plotted points **(1)**
sensible scale **(1)**

(4)

(c) at R = 103.40 Ω, l^2 = 6.46 **(1)** × 10^{-4} m^2 **(1)**
thus l = 2.542 × 10^{-2} **(1)** (m)
constantan resistivity = 47 × 10^{-8} (Ωm) **(1)**
= 1.2(1) × 10^{-5} m **(1)**

(5)

(d) tensile strain = $\frac{\text{extension}}{\text{original length}}$ **(1)**

(at R = 103.40 Ω, l = 2.542 × 10^{-2} m)

thus strain = $\frac{(2.542 - 2.5)}{2.5}$ **(1)** = 0.017 **(1)**

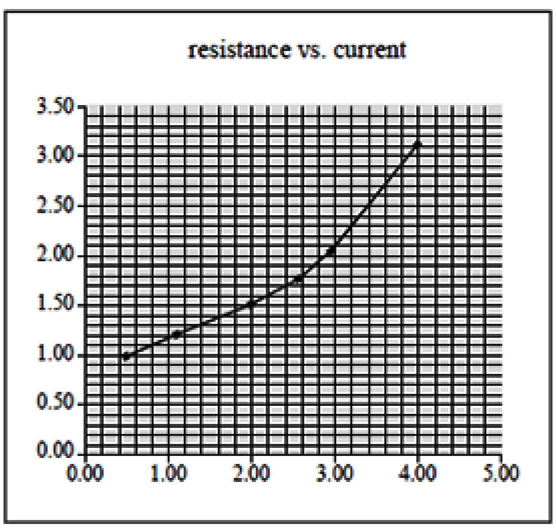
(max 2)

[13]

15 (a) resistance / Ω 0.98 1.20 1.50 1.76 2.03 3.00 **(1)** **(1)**
[deduct one mark for each incorrect value]

2

(b) (i) sensible scales chosen **(1)**
points plotted correctly [deduct one mark for each mistake] **(1)** **(1)**
line of best fit **(1)**



(ii) 0.90 Ω **(1)**

(iii) 0.22 Ω **(1)**
0.38 Ω **(1)**

(iv) 1.12 W **(1)**
6.0 W **(1)**

max 8

(c) resistance increases with increasing temperature **(1)**
increase in heat dissipation for 1.0 A to 2.0 A is greater than for 0 to 1.0 A **(1)**
and so a greater corresponding rise in temperature **(1)**

max 2

[12]

16 ***implementing***

accuracy:	T from nT where n or $\Sigma n \geq 3$ * L in range 95 to 105 cm * * **(1)**
tabulation:	y / m T / s **(1)**
readings:	5 sets, y range ≥ 20 cm **(1) (1) (1)**
significant figures:	all T to 0.01 s * s to 1.0 mm * * **(1)**
	all $\sqrt{\frac{L}{L-y}}$ and $\frac{1}{T}$ values tabulated to 3 s.f. **(1)**
quality:	at least 4 points to ± 2 mm of straight line, suitably scaled graph **(1)**

analysis

axes:	marked $\sqrt{\frac{L}{L-y}}$ / no unit (vertical), $\frac{1}{T}$ / s^{-1} (horizontal) **(1)**
scale:	suitable (e.g. 8 × 8) **(1)**
points:	5 plotted correctly (check at least one) **(1)**
line:	straight, positive gradient, best-fit **(1)**
G:	Δ suitable size **(1)** to 3 s.f, in s **(1)**
result:	in range 1.90 to 2.10 s $m^{-1/2}$ [1.80 to 2.20 s $m^{-1/2}$ **(1)**] **(1)** **(1)**

(16)

evaluating

(i) check that (horizontal) distance between vertical strings is the same at two places **(1)**
check that the string is aligned with the longer pendulum [the string passes through the hole in the stripboard without touching the sides] **(1)**

(ii) wide range, even distribution **(1)**
in order to define the shape of the graph **(1)**

(iii) unlikely to significantly improve the evidence (don't allow additional readings improve the best-fit line):
when y is small T is very large: **(1)**
it is difficult to judge exactly when the pendulums are moving in phase **(1)**

(6)

[22]

17 ***planning***

(a) sensible key factor e.g. p.d. across paper, that, when varied, leads to the determination of resistance: candidate then goes on to estimate the thickness of the paint layer on strip [only allow direct measurement of resistance if the investigation is of how either width or length of a rectangular strip affects the resistance of the paper] **(1)**

(b) correct measuring instrument given [allow circuit diagram] **(1)**

(c) dimensions of paper constant when resistance measured [to see how a certain dimension influences the resistance, width (if length varied)/length (if width varied)] **(1)**

(d) check that current through paper does not exceed 200 mA **(1)**

(e) sensible qualitative prediction given: thickness can only be estimated due to uncertainty in resistivity **(1)**

(f) thickness of layer (assuming uniform coating) in range 10^{-7} to 10^{-11} m **(1)**

[or (e) sensible qualitative prediction given: $R \propto l$ or $R \propto w^{-1}$]

(g) reasonable physics reasoning given in support: similarity with behaviour of a metallic conductor **(1)**

(h) use of V/I to find R [use of repeated readings to reduce uncertainty in measurement of dimension] **(1)**

(i) calculating possible range of thickness using limiting values of resistivity / assessing the uncertainty in result [plotting graph of results to check relationship] **(1)**

(j) any other sensible measure, e.g. maintain steady temperature **(1)**

[max 8]

18 (a) (i) $W = 2mg \cos\varphi$ $\therefore m = W/(2g \cos\varphi)$✓

The question says show that, so the candidates must write down both steps.

1

(ii) Well drawn straight line of best fit.✓

The line should follow the trend of the points with an even scatter of points on either side of the line.

1

(b) (i) Triangle drawn with smallest side at least 8 cm in length. ✓

Correct readings taken from the line for the triangle ✓

Gradient in the range 0.45 to 0.49 (0.445 to 0.494) quoted to 2 or 3 significant figures ✓

The size of the triangle can be identified from readings taken from the line.
The third mark is independent of the other two: error carried forward for incorrect readings (or for a poor line of best fit) which give a gradient out of range is not allowed.

3

(ii) Candidate's answer for gradient in (b)(i) correctly multiplied by g (expected answer 4.6)✓

N ✓

No s.f. penalty.
The second mark is for the unit and can be awarded if the numerical answer is incorrect.

2

(c) $\delta x\% = 0.2$ and $\delta y\% = 0.5$✓

$\delta(x/y)\% = \delta x\% + \delta y\% = 0.2 + 0.5 = 0.7$ ✓

Use of $\delta(x/y.)^2\% = 2 \times \delta(x/y)(\%)$ ✓

Final answer is (±) 1.4 (%) which automatically gains all three marks

Otherwise

Accept only 1 s.f. for 1^{st} and/or 2^{nd} marks.
The third mark is for the method, not the final answer

3

(d) (i) Systematic errors in measurements are errors which show a pattern or a bias or a trend ✓

Some acceptable alternatives

- ***A systematic error** is one which deviates by a fixed amount from the true value of a measurement*
- *An error which has the same value in all readings*
- *A difference between the true value of a quantity and the indicated value caused by a fault in the measuring device*
- *Accept a good example of systematic error.*

1

(ii) y would be larger✓
because angle θ would be smaller
or
because friction would be opposing the increasing weight of m✓

2

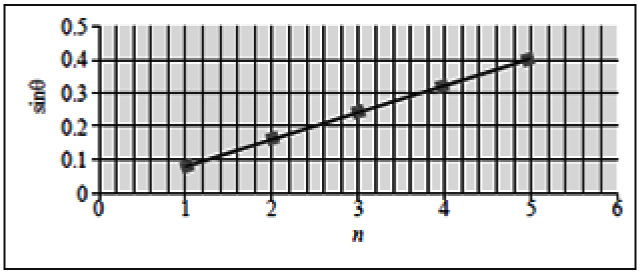
[13]

19 (a)

	x / m	sin θ
1	0.173	0.086
2	0.316	0.156
3	0.499	0.242
4	0.687	0.325
5	0.860	0.395

1

If angles only calculated 1 / 2



at least 4 points plotted correctly **(1)**
best straight line **(1)**
gradient calculated from suitable triangle, 50% of each axis **(1)**
correct value from readings **(1)**
appropriate use of d sin $\theta = n\lambda$ **(1)**
hence N (rulings per metre) = 1.25 × 10^5 m^{-1} (1.1 to 1.4 ok) **(1)**

max 2 / 6 if no graph and more than one data set used correctly, 1 / 6 only one set
if tan calc but plotted as sin, mark as scheme
tan or distance plotted, 0 / 6

max 6

(b) (i) maxima wider spaced [or pattern brighter] **(1)**
sin θ or θ increases with N [or light more concentrated] **(1)**

(ii) maxima spacing less **(1)**
sin θ or θ decreases with λ [or statement] **(1)**

(iii) maxima wider spaced [or pattern less bright] **(1)**
same θ but larger D [or light more spread out] **(1)**

6

(c) (i) waves in phase from **(1)**
any sensible ref to coherence **(1)**
whole number of wavelengths path difference **(1)**

(ii) use of geometry to show that $\sin \theta = \frac{\lambda}{d}$

max 3

[15]

20 ***planning***
(to determine the illumination at points along axis of the lamp)
measure <u>distance from LDR to lamp</u> using <u>metre rule</u> / tape

1

find <u>resistance</u> of LDR using <u>ohmmeter</u> [or <u>VI method</u> explained, or <u>potential divider</u> method explained: must be from diagram]

1

read <u>illumination</u> from (calibration) graph

1

(light meter method, scores 2 / 3; single circuit method or interchanged meters, scores 1 / 3)

diagram:
sensible diagram to include lamp, LDR (light meter) and suitable means of resistance measurement: symbols must be correct

1

distance, d, shown or means to measure it

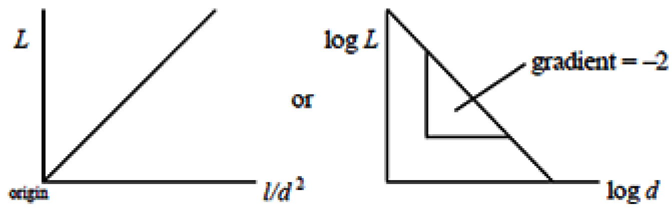
1

check for correct prediction by <u>repeating at different distances</u>

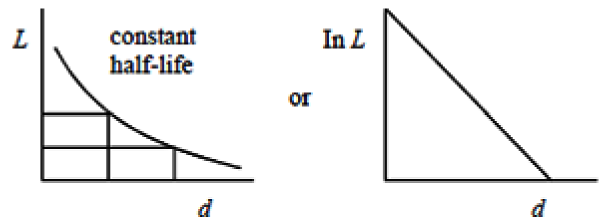
1

plot a suitable graph to test prediction of **either** student,
with <u>method of testing relationship explained</u> **(1)**
(repeated calculations of L / d^2 and check for consistency is acceptable)

possible approaches for student A to test inverse-square variation:



possible approaches for student B to test exponential variation:



control:
eliminate stray illumination by <u>using blackout</u> [or by collimating beam]
(subtracting background illumination not acceptable)
[or maintain intensity of spotlight by <u>use of appropriate circuit</u>]

1

difficulties:
any <u>two</u> of the following: (look for *difficulty* + *how to overcome* = 2)

reduce uncertainty <u>in the graph</u> **(1)**
by taking extra readings where the illumination changes

most rapidly with distance **(1)**

reduce uncertainty in R (V and I) **(1)**

by taking extra readings and <u>averaging</u> **(1)**

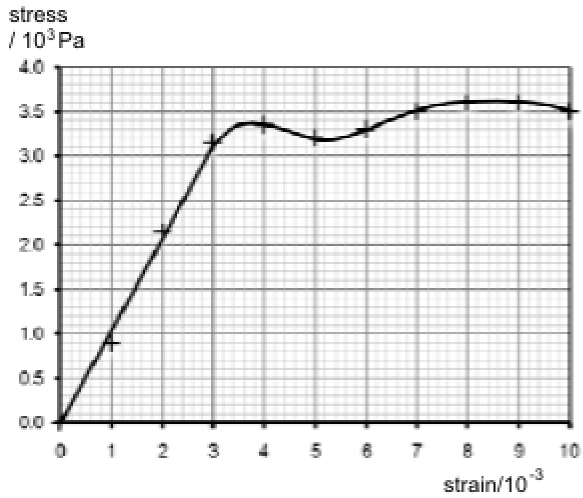
overcome uncertainty in d **(1)**
by measuring from specified point on lamp **(1)**
[ensure that the LDR only moves along axis of the lamp]
[allow any other good relevant physics]

4

(12 possible marks for) max 8

[8]

21 (a)



Suitable scale on both axes (eg not going up in 3s) **and** > ½ space used ✓

≥ points correct (within half a small square) ✓

line is straight up to at least stress = 2.5×10^8 **and** curve is smooth beyond straight section ✓

3

(b) understanding that E = gradient (= $\Delta y/\Delta x$) ✓

allow y/x if line passes through origin

= 1.05×10^{11} (Pa) (allow 0.90 to 1.1) **ecf** from their line in (a) if answer outside this range **and** uses a *y* value ≥ 2 ✓

when values used from table;

- two marks can be scored only if candidates line passes through them
- one mark only can be scored if these points are not on their line

2

(c) correct rearrangement of symbols or numbers ignoring incorrect

powers of ten, eg $A = \frac{FL}{E\Delta L}$ ✓

correct substitution in any correct form of the equation,

eg = $\frac{10(000) \times 3.0}{1.90(\times 10^{11}) \times 1.0(\times 10^{-3})}$ ✓

allow incorrect powers of ten for this mark

= 1.6×10^{-4} ✓ (1.5789) (m^2)

3

[8]

22 (a) 5.31, 6.38 ✓

Exact answers only

1

(b) Both points correctly plotted to the nearest mm✓

Well drawn straight line of best fit.✓

The orange LED point (4.80, 1.54) is anomalous. The line should follow the trend of the points (ignoring the anomalous point) with an even scatter of points on either side of the line.

2

(c) (i) Triangle drawn with smallest side at least 8 cm in length.✓

Correct readings taken from the line for the triangle. ✓

Gradient in range 0.44 to 0.46 (0.435 to 0.464) × 10^{-14} quoted to 2 or 3 significant figures ✓

The size of the triangle can be implied by readings taken from the line.

The third mark is independent of the other two: error carried forward for incorrect readings (or for a poor line of best fit) which give a gradient out of range is not allowed. Unit not required for the mark.

3

(ii) Possible marking points:

The anomalous point makes the value less reliable.✓

(However) the (other) points are close to the line of best fit. Suggesting that the value is reliable. ✓

If the candidate has not ignored the anomalous point when drawing the line of best fit accept:

The points are not close to the line of best fit so the value is not reliable✓

for one mark only

2

(d) (i) Recognition that the gradient = h/e ✓

$h = 0.45 \times 10^{-14} \times 1.60 \times 10^{-19}$ ✓

$= (6.95 \text{ to } 7.44) \times 10^{-34}$ Js ✓

Allow ecf from (c)(i) for <u>second mark</u> (including wrong exponent)

Final answer must be in range, have correct exponent, <u>correct unit</u> and be quoted to 2 or 3 sf

3

(ii) $((7.2 \times 10^{-34} - 6.63 \times 10^{-34}) / 6.63 \times 10^{-34}) \times 100\%$

calculated correctly✓

Allow ecf from (d)(i): expected answer 8.6%

Allow $\dfrac{(7.2 \times 10^{-34} - 6.63 \times 10^{-34}) \times 100\%}{7.2 \times 10^{-34}}$ *giving 7.9%*

No sf penalty

1

(iii) ± 1.1% or + 1%✓

± is required here as it is explicit in the question

1

(iv) %uncertainty in f = 8.6 – 1.1 = 7.5%✓

∴ δf = ± 0.075 × 3.19 × 1014 ✓

= ± 2.39 × 1013 Hz ✓

Allow ecf from (d)(ii)

Final answer: 2 or 3 sf with unit but ± symbol not required

3

16