RIVER VALLEY HIGH SCHOOL
JC2 PRELIMINARY EXAM

H2 PHYSICS 9749
PAPER 4

17 AUG 2021

2 HRS 30 MIN

CANDIDATE NAME					
CENTRE NUMBER	S				
CLASS	2	0	J		

INDEX NUMBER				

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, class and index number above.

Candidates answer on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

SHIFT
LABORATORY

FOR EXAMINERS' USE	
1	/20
2	/ 10
3	/ 13
4	/ 12
TOTAL	**/ 55**

This document consists of **20** printed pages.

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1 In this question you will determine the density of water by immersing a mass suspended by a spring into a beaker of water.

(a) Set up the apparatus as shown in Fig. 1.1. The pointers A and B should be attached to each end of the spring. The pointer A should also be attached to the paper clip. The pointer B should be attached to the mass holder. The total mass of the holder and the masses should be 200 g.

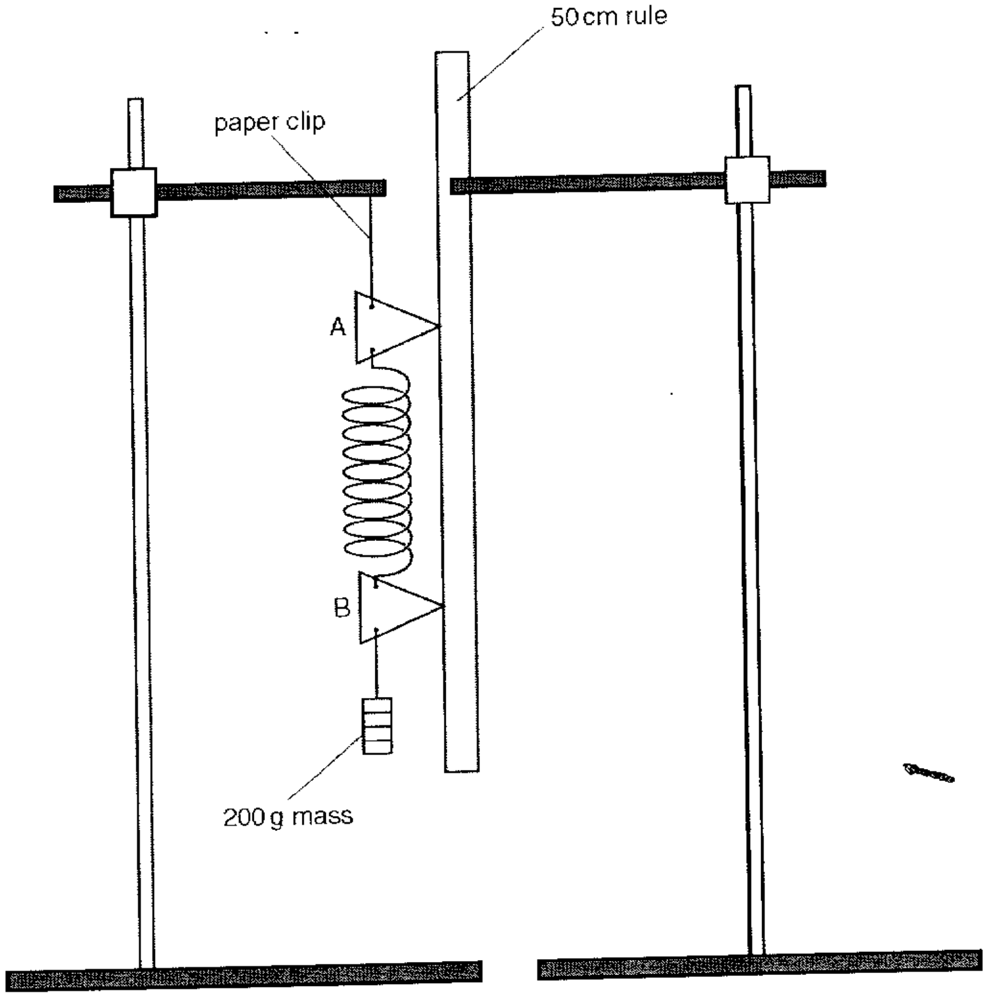

Fig. 1.1

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(i) Measure and record the reading $r_{B,200}$ from pointer B.

$r_{B,200}$ = ...

(ii) Add a further mass of 100 g to the mass holder.

Measure and record the new reading $r_{B,300}$ from pointer B.

$r_{B,300}$ = ... [1]

(iii) Hence, determine the extension e of the spring when an additional force of 0.981 N is applied to the spring.

e = ... [1]

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(b) Use your answers from **(a)** to determine a value for spring constant k of the spring. You may assume that the spring obeys Hooke's law. Please leave your answer in SI units.

k = ... [1]

(c) **(i)** Use the vernier calipers to measure the diameter D of one of the masses.

D = ... [1]

(ii) Determine the percentage uncertainty in the measurement of the diameter D of the mass.

percentage uncertainty in D = ... [1]

(iii) Calculate the cross-sectional area A of the mass. Ignore the slot that is cut into the mass. Please leave your answer in SI units.

A = ...

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(d) **(i)** Put all of the masses onto the mass holder so that the spring supports a total mass of 300 g. This mass should remain constant for the rest of the experiment.

Measure and record the readings from the pointers A and B and hence calculate a value for the length l between the pointers.

reading from pointer A = ...

reading from pointer B = ...

l = ...

[1]

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(ii) Place a beaker of water under the mass as shown in Fig. 1.2. Adjust the position of the boss so that part of the mass is immersed in the water as shown in Fig. 1.2.

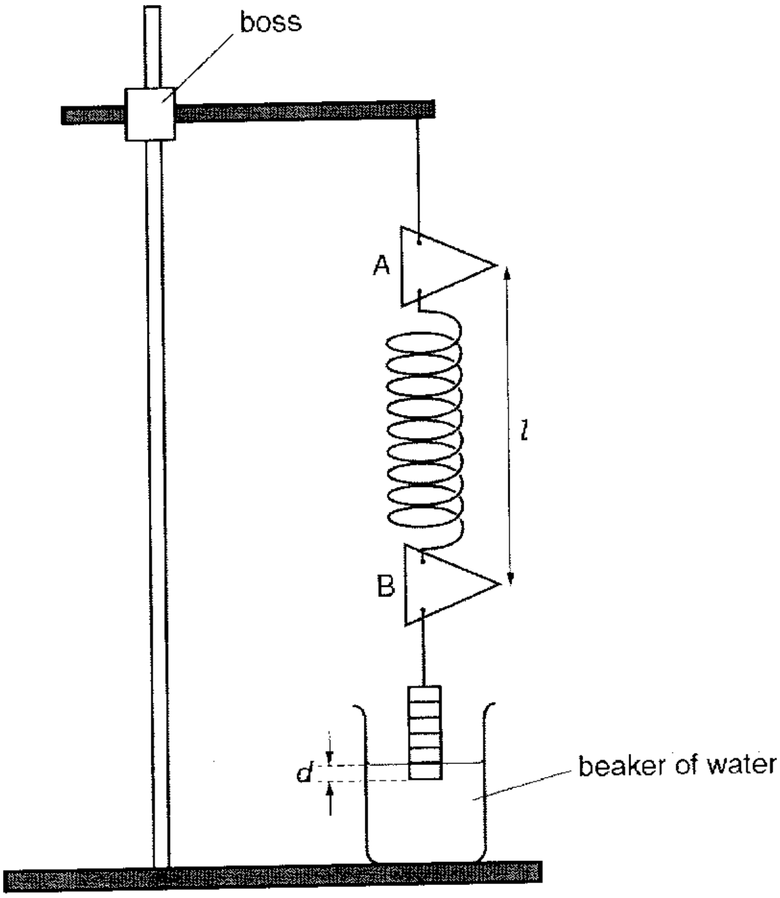

Fig. 1.2

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(iii) Make and record measurements to determine the depth *d* of the submerged part of the mass and the length *l* between the pointers.

d = ...

l = ... [1]

(iv) Adjust the position of the boss and repeat **(iii)** until you have six sets of readings for *d* and *l*. Record all your readings in a table in the space below.

[6]

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(e) Theory suggests that l and d are related by the equation

$$l = -\frac{\rho_w A g d}{k} + c\,.$$

where ρ_w is the density of water, g is the acceleration of free fall and c is a constant.

Plot a suitable graph in order to determine values for density of water ρ_w and the constant c.

ρ_w = ...

c = ... [4]

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[3]

[Total: 20]

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2 In this experiment, you will investigate how the rotational motion of an object depends on its mass m.

(a) **(i)** Suspend the mass hanger from the rubber band, as shown in Fig. 2.1.

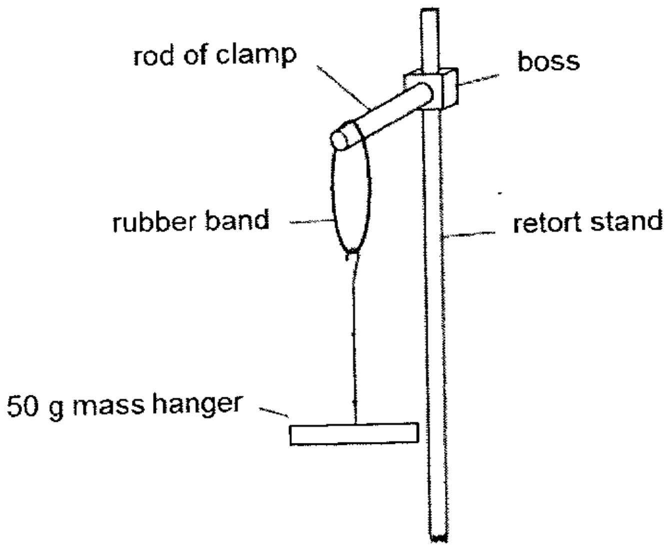

Fig. 2.1

(ii) Hold the mass hanger and slowly twist it horizontally through 90°.

(iii) Release the hanger and watch its movement.
The hanger completes one torsional oscillation by moving as shown in Fig. 2.2.

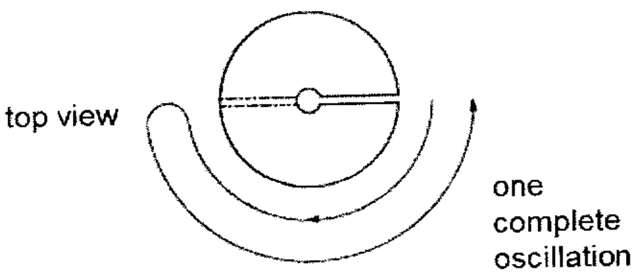

Fig. 2.2

The time taken for one complete oscillation is T.
Determine the value for T.

T = ... [2]

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(b) Repeat **(a)** using the slotted masses until the total mass is 300 g. Complete Fig. 2.3.

m / kg	number of oscillations, N	time for N oscillations		T / s	T^2 / s^2
		t_1 / s	t_2 / s		

Fig. 2.3 [2]

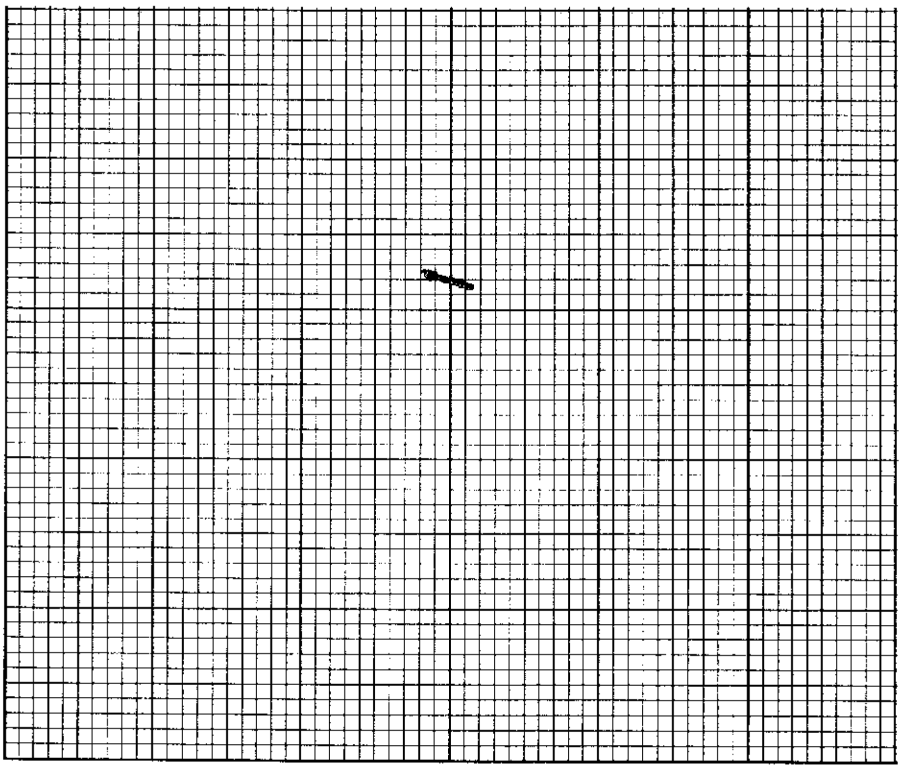
(c) For an oscillating mass it is suggested that the relationship between T and m is

$$T^2 = mk$$

where k is a constant.

(i) Using your data in Fig. 2.3, plot T^2 against m, in Fig. 2.4.

T^2 / s^2



[3]

m / kg

Fig. 2.4

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(ii) Hence determine the gradient of the plotted graph in Fig. 2.4. You may ignore the unit of the gradient.

gradient = ... [2]

(d) Describe one source of uncertainty or limitation of the procedure for this experiment.

....

....

....

....

.... [1]

[Total: 10 marks]

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3 In this experiment you will investigate how the current in a wire depends on the length of the wire. You will use the results of your experiment to determine a value for the resistivity of the material of the wire.

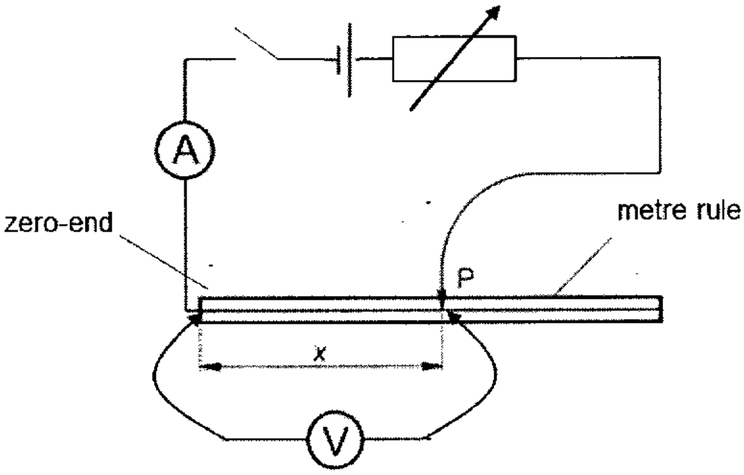

Fig. 3.1

(a) Set up the circuit shown in Fig. 3.1. Connect the ammeter using a connecting lead with crocodile clips to the zero-end of the metre rule.

(b) Adjust the rheostat to give an output voltage of 0.40 V. Place the connecting lead P onto the wire near the centre.

Measure and record the length x and the current I.

x = ...

I = ... [1]

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(c) Complete the table of given in Fig. 3.2.

x/m	I/A	lg (I/A)	lg (x/m)
0.250	0.1438		
0.300	0.1203		
0.350	0.1033		
0.400	0.0915		
0.450	0.0810		

[2]

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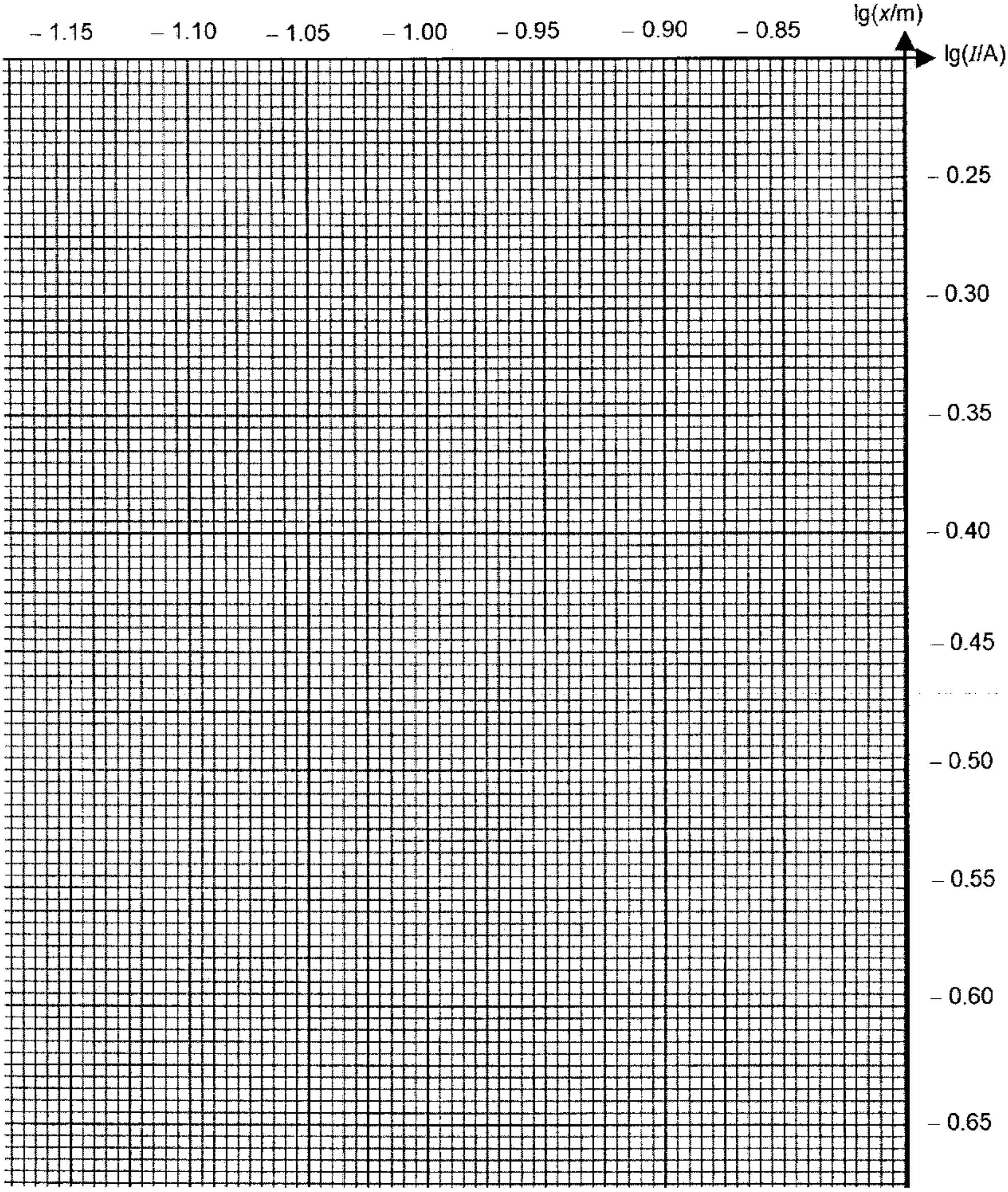
(d) (i) Complete the graph of lg (x/m) against lg (I/A) and draw the line of best fit.

[1]



(ii) Determine the gradient and y-intercept of this line.

gradient = ...

y-intercept = ... [2]

(e) x and I are related by a simple power law of the form $x = kI^n$, where n and k are constants. Use your answers from **(d)(ii)** to find the values of k and n. You need not be concerned with the units of these quantities.

k = ...

n = ... [2]

(f) A simple theoretical treatment of this circuit gives $k = \frac{VA}{\rho}$ where V is the potential difference across the wire, A is the cross sectional area of the wire and ρ is the resistivity of the material of the wire.

(i) Use a micrometer screw gauge to measure the diameter of the wire.

diameter of wire = ... [1]

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(ii) Determine the cross sectional area A of the wire in m^2.

A = ... m^2 [1]

(iii) Determine the percentage uncertainty of A.

percentage uncertainty = ... [2]

(iv) Use your answers from **(e)** and **(f)** to determine a value for ρ.

ρ = ... [1]

[Total: 13 marks]

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4 The efficiency η of a lamp may be expressed as

$$\eta = \frac{\text{light energy emitted}}{\text{electrical energy input}}$$

The efficiency can be determined by measuring the amount of wasted energy produced by the lamp in the form of thermal energy. The efficiency is calculated using

$$\eta = 1 - \frac{\text{thermal energy}}{\text{electrical energy input}}$$

The efficiency is thought to depend on the potential difference V across the lamp. The relation between the efficiency and the potential difference may be written in the form

$$\eta = aV^b$$

where a and b are constants.

You are provided with a filament lamp of low potential difference and a beaker of water that is to be used in the determination of the thermal energy produced by the lamp. You may also use any other standard laboratory apparatus usually found in a college physics laboratory.

Design an investigation to determine the relation between η and V.

You should draw a labelled diagram to show the arrangement of your apparatus.
In your account you should pay particular attention to

- **(a)** the equipment you would use,
- **(b)** the procedure to be followed,
- **(c)** the control of variables,
- **(d)** how the thermal energy is measured,
- **(e)** any precautions that would be taken to improve the accuracy and safety of the equipment.

Diagram

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[Total: 12 marks]

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Give details of the practical shift and laboratory where appropriate in the boxes provided.

SHIFT
LABORATORY

Write in dark blue or black pen on both sides of the paper.
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Answer **all** questions.

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1	/20
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3	/ 13
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TOTAL	/ 55

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1 In this question you will determine the density of water by immersing a mass suspended by a spring into a beaker of water.

(a) Set up the apparatus as shown in Fig.1.1. The pointers A and B should be attached to each end of the spring. The pointer A should also be attached to the paper clip. The pointer B should be attached to the mass holder. The total mass of the holder and the masses should be 200 g.

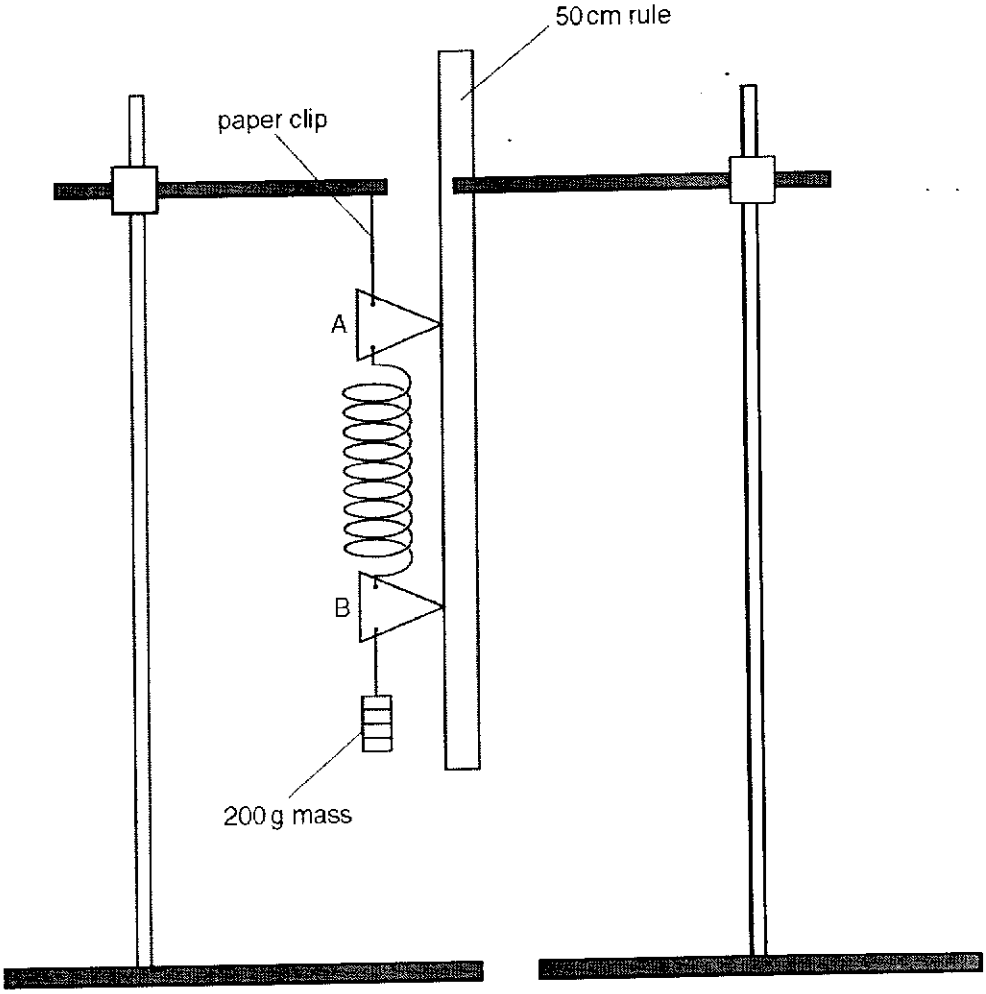

Fig. 1.1

(i) Measure and record the reading $r_{B,200}$ from pointer B.

precise to ½ mm (one reading) or 1 mm (suspended), appropriate unit

$r_{B,200}$ = 23.95 cm

(ii) Add a further mass of 100 g to the mass holder.

Measure and record the new reading $r_{B,300}$ from pointer B.

precise to ½ mm (one reading) or 1 mm (suspended), appropriate unit

$r_{B,300}$ = 19.85 cm

[1]

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(iii) Hence, determine the extension e of the spring when an additional force of 0.981 N is applied to the spring.

correct calculation of $e = r_{B,300} - r_{B,200}$ = 29.95 - 19.85 = 4.1 cm
$\Delta e = \Delta r_{B,300} + \Delta r_{B,200}$ = 1 or 2 mm
precise to 1 or 2 mm, appropriate unit

Accept range 3.6 to 4.5 cm

e = 4.1 cm [1]

(b) Use your answers from **(a)** to determine a value for spring constant k of the spring. You may assume that the spring obeys Hooke's law.
Please leave your answer in SI units.

$k = 0.981/x$ = 0.981 / 0.041 = 23.927 N m^{-1}

sf of k follows sf of e, SI units : N m^{-1}

Ignore any negative signs. Do not allow fractions. Condone kg s^{-2}

k = 23.9 N m^{-1} [1]

(c) **(i)** Use the vernier callipers to measure the diameter D of one of the masses.

Repeated readings = 3.18 cm, 3.17 cm, 3.17 cm
precise to 0.1 mm, appropriate unit

Accept value 2.85 mm to 3.51 mm

D = 3.17 cm [1]

(ii) Determine the percentage uncertainty in the measurement of the diameter D of the mass.

ΔD (either 0.1 mm – fairly stable measurement or 0.2 mm – masses not perfectly round).

correct calculation, 1 or 2 sf $\frac{0.1 \text{ mm}}{31.7 \text{ mm}} \times 100\% = 0.3\%$

percentage uncertainty in D = 0.3 % [1]

(iii) Calculate the cross-sectional area A of the mass.
Ignore the slot that is cut into the mass.
Please leave your answer in SI units.

$A = \pi D^2/4$ $\frac{\pi\ 0.0317^2}{4} = 7.8923 \times 10^{-4}\ m^2$

correct calculation, sf of A follows sf of D, m^2
**Since no mark is allocated here, there is no ecf for calculation of density.

A = $7.89 \times 10^{-4}\ m^2$

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(d) **(i)** Put all of the masses onto the mass holder so that the spring supports a total mass of 300 g. This mass should remain constant for the rest of the experiment.

Measure and record the readings from the pointers A and B and hence calculate a value for the length *l* between the pointers.

readings from pointers precise to ½ or 1 mm, appropriate unit
length *l* precise to nearest mm, appropriate unit, correct calculation

Accept range 18.0 cm to 20.0 cm.

reading from pointer A = 39.90 cm

reading from pointer B = 19.85 cm

l = 20.0 cm

[1]

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(ii) Place a beaker of water under the mass as shown in Fig. 1.2. Adjust the position of the boss so that part of the mass is immersed in the water as shown in Fig. 1.2.

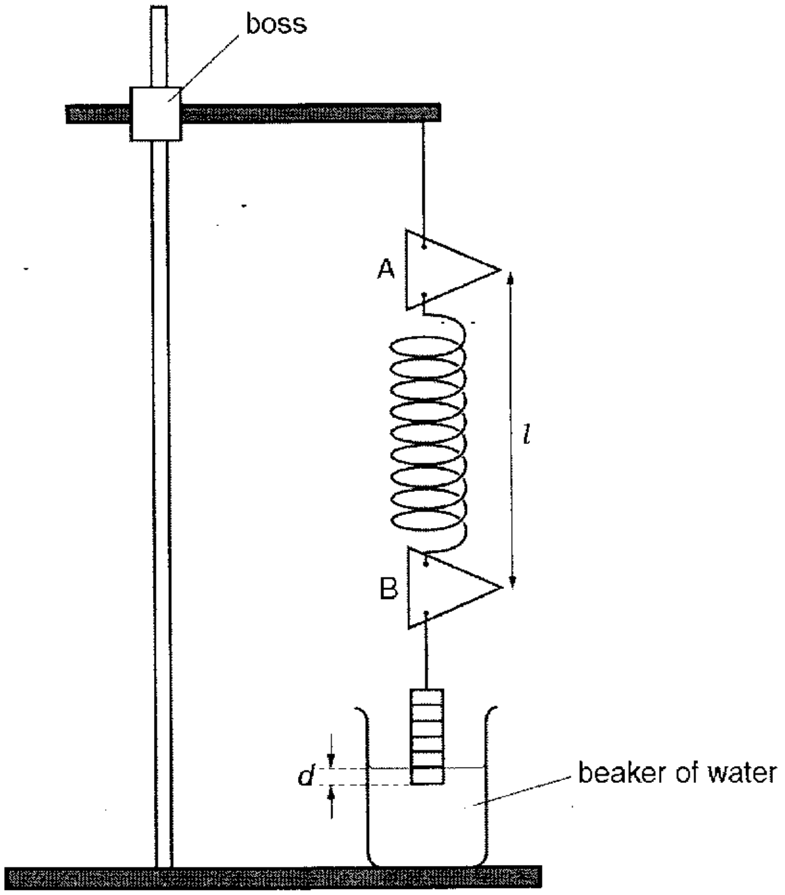

Fig. 1.2

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(iii) Make and record measurements to determine the depth *d* of the submerged part of the mass and the length *l* between the pointers.

depth *d* precise to 1 mm, appropriate unit
length *l* precise to 1 mm, appropriate unit

36.90 - 17.20 = 19.7 cm *d* = 1.0 cm

l = 19.7 cm

(iv) Adjust the position of the boss and repeat **(iii)** until you have six sets of readings for *d* and *l*. Record all your readings in a table in the space below.

6 sets of readings – 2 marks
correct column headings, symbol / unit – 1 mark
correct precision – 1 mark
correct sf – 1 mark
correct calculation – 1 mark (no mark if no raw data i.e. A and B readings)

d / cm	A / cm	B / cm	l / cm
1.0	36.90	17.20	19.7
2.0	36.15	16.75	19.4
2.5	35.20	15.90	19.3
3.0	34.80	15.60	19.2
3.5	34.20	15.20	19.0
4.5	33.20	14.50	18.7

[6]

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(e) Theory suggests that l and d are related by the equation

$$l = -\frac{\rho_w Agd}{k} + c\,.$$

where ρ_w is the density of water, g is the acceleration of free fall and c is a constant.

Plot a suitable graph in order to determine values for density of water ρ_w and the constant c.

Plot a graph of l (y-axis) against d (x-axis). – 1 mark

Gradient calculation – 1 mark:
Δ used must be greater than half the length of the drawn line.
Check the read-offs (must be correct to half a small square).
Ratio must be correct (i.e. Δ y/ Δ x and not Δ x/ Δ y).

ρ_w found using gradient with appropriate units – 1 mark

c found using y-intercept with appropriate unit – 1 mark

gradient = -0.28136 (no unit)
y-intercept = 19.847 cm

$$\rho_w = -\frac{k\,(\text{gradient})}{Ag} = -\frac{23.927\ (-0.28136)}{7.8923\times10^{-4}\ (9.81)}$$

= 870 kg m^{-3}

ρ_w = 870 kg m^{-3}

c = 19.8 cm

[4]

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2 In this experiment, you will investigate how the rotational motion of an object depends on its mass m.

(a) **(i)** Suspend the mass hanger from the rubber band, as shown in Fig. 2.1.

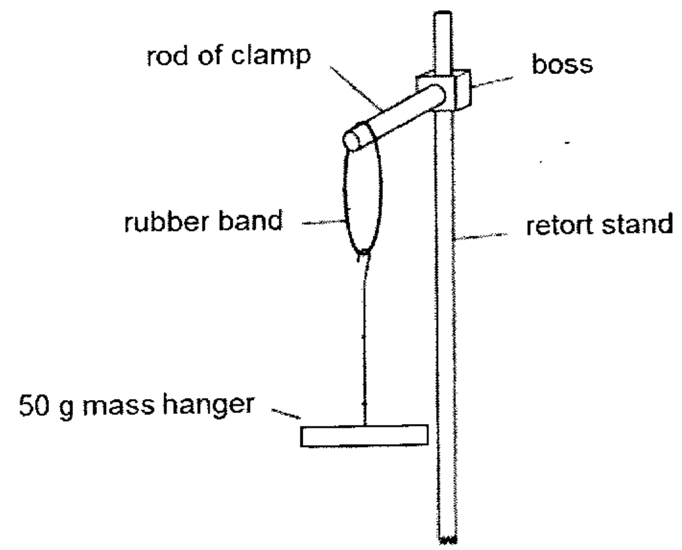

Fig. 2.1

(ii) Hold the mass hanger and slowly twist it horizontally through 90°.

(iii) Release the hanger and watch its movement.
The hanger completes one torsional oscillation by moving as shown in Fig. 2.2.

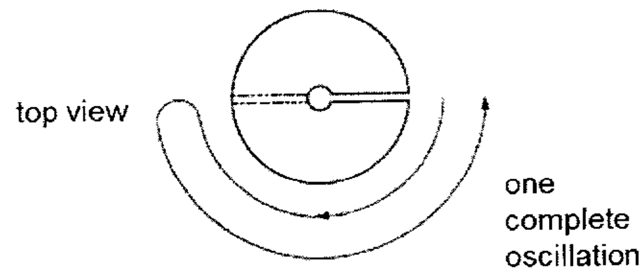

Fig. 2.2

The time taken for one complete oscillation is T.
Determine the value for T.

t >10s and s.f. of processed value to follow s.f. of raw data (1 to 2 d.p.) Evidence of repeated reading and accuracy of T (0.8s to 1.5s)

T = ... [2]

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(b) Repeat **(a)** using the slotted masses until the total mass is 300 g. Complete Fig. 2.3.

m / kg	number of oscillations, N	time for N oscillations		T / s	T^2 / s^2
		t_1 / s	t_2 / s		

All 6 values of T taken successfully, t >10s
$T_6 > T_5 > T_4 > T_3 > T_2 > T_1$ and accuracy of T (T_6 should not exceed 5.0s)

All T^2 values calculated correctly and appropriate s.f. (s.f. of T should be appropriate.)

m/kg	N	t1/s	t2/2	T/s	T^2/s^2
0.050	20	22.23	22.19	1.111	1.233
0.100	14	21.68	21.49	1.542	2.377
0.150	11	21.98	22.40	2.017	4.069
0.200	8	20.32	21.18	2.594	6.728
0.250	8	22.50	23.44	2.871	8.244
0.300	6	20.78	20.75	3.461	11.98

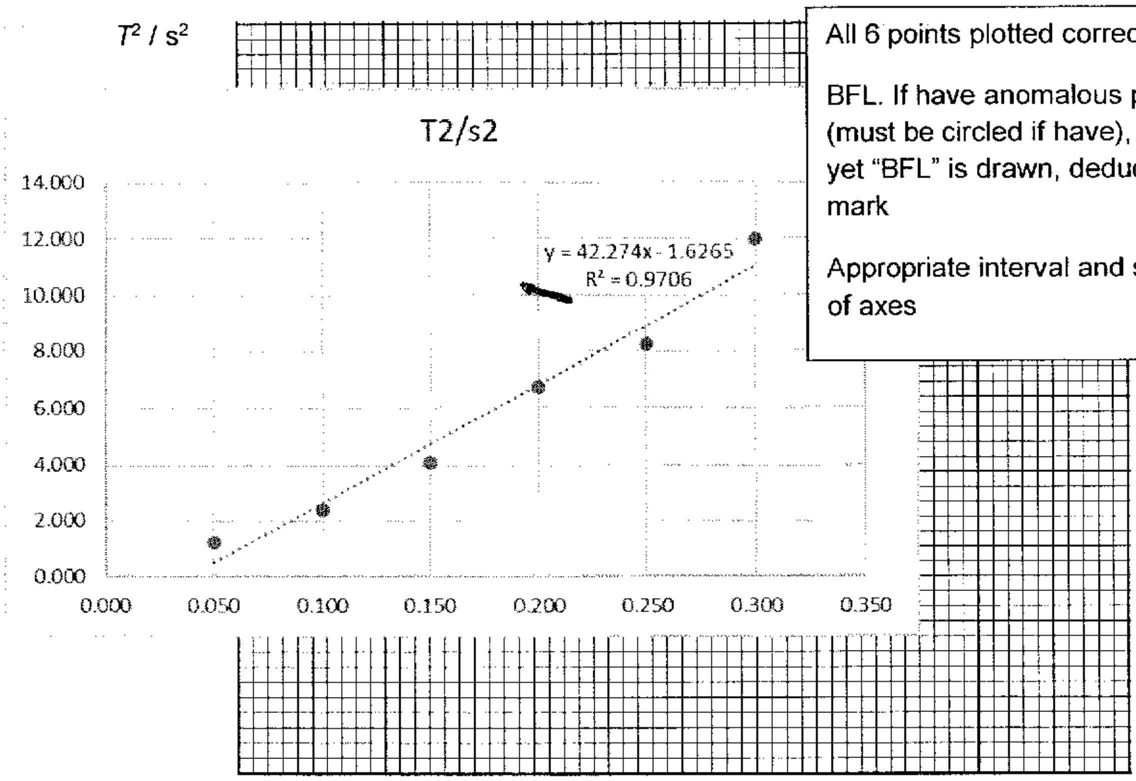
Fig. 2.3 [2]

(c) For an oscillating mass it is suggested that the relationship between T and m is

$$T^2 = mk$$

where k is a constant.

(i) Using your data in Fig. 2.3, plot T^2 against m, in Fig. 2.4.



All 6 points plotted correctly

BFL. If have anomalous point (must be circled if have), and yet "BFL" is drawn, deduct this mark

Appropriate interval and scale of axes

[3]

Fig. 2.4

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(ii) Hence determine the gradient of the plotted graph in Fig. 2.4. You may ignore the unit of the gradient.

determination of gradient using $\frac{dT^2}{dm}$, gradient

coordinates shown on graph

Calculation to be correct

gradient = (8.4 – 4.0) / (0.28 – 0.15) = 33.8

gradient = ... [2]

(d) Describe one source of uncertainty or limitation of the procedure for this experiment.

Any one of the following:

1. Oscillation not in one plane only.
2. Difficult to determine the end/start of oscillation.
3. Difficult to turn through 90° each time.

If want to state vertical oscillations being pronounced, need to mention heavy masses

Student should not fault the equipment stability when describing uncertainty or limitation. If equipment not stable, could have raised concern during exam.

Description of uncertainty of limitation could indicate incorrect experimental technique or procedure (e.g. out-of-range T). Mark not awarded if answer found to be so.

[1]

[Total: 10 marks]

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3 In this experiment you will investigate how the current in a wire depends on the length of the wire. You will use the results of your experiment to determine a value for the resistivity of the material of the wire.

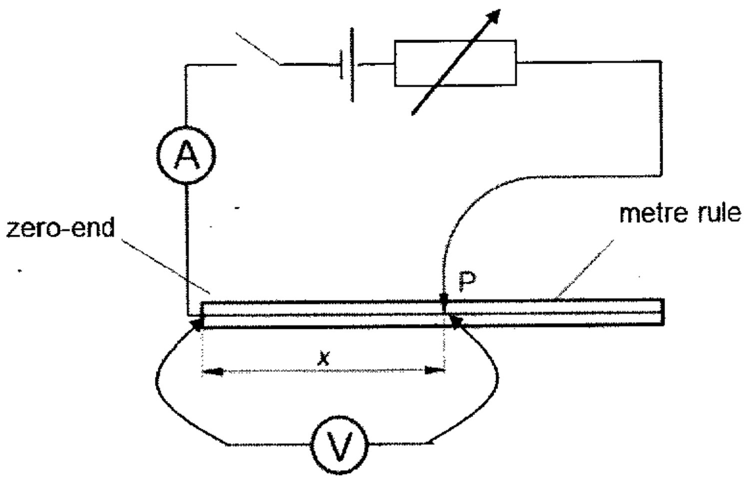

Fig. 3.1

(a) Set up the circuit shown in Fig. 3.1. Connect the ammeter using a connecting lead with crocodile clips to the zero-end of the metre rule.

(b) Adjust the rheostat to give an output voltage of 0.40 V. Place the connecting lead P onto the wire near the centre.

Measure and record the length x and the current I.

It is not wise to quote a length of e.g. 30.0 cm when the instruction clearly stated to "place the connecting lead ... near the centre"

As the DMMs are pre-set, the unit readable for current should be mA. This is a test of candidate's ability to read-off and quote the correct unit based on the apparatus.

Allowable range: 0.480 to 0.520 m, 48.0 to 52.0 cm

x = ...

I = ... Allowable range: 70.0 to 80.0 mA Only accept mA unit .... [1]

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(c) Complete the table of given in Fig. 3.2.

x/m	I/A	lg (I/A)	lg (x/m)
0.250	0.1438		
0.300	0.1203		
0.350	0.1033		
0.400	0.0915		
0.450	0.0810		

[2]

x/m	I/A	lg (I/A)	lg (x/m)
0.250	0.1438	-0.8422	-0.602
0.300	0.1203	-0.9197	-0.523
0.350	0.1033	-0.9859	-0.456
0.400	0.0915	-1.039	-0.398
0.450	0.0810	-1.092	-0.347
0.500	0.0720	-1.143	-0.301

Correct d.p., raw data entered correctly

Correct calculation, s.f.

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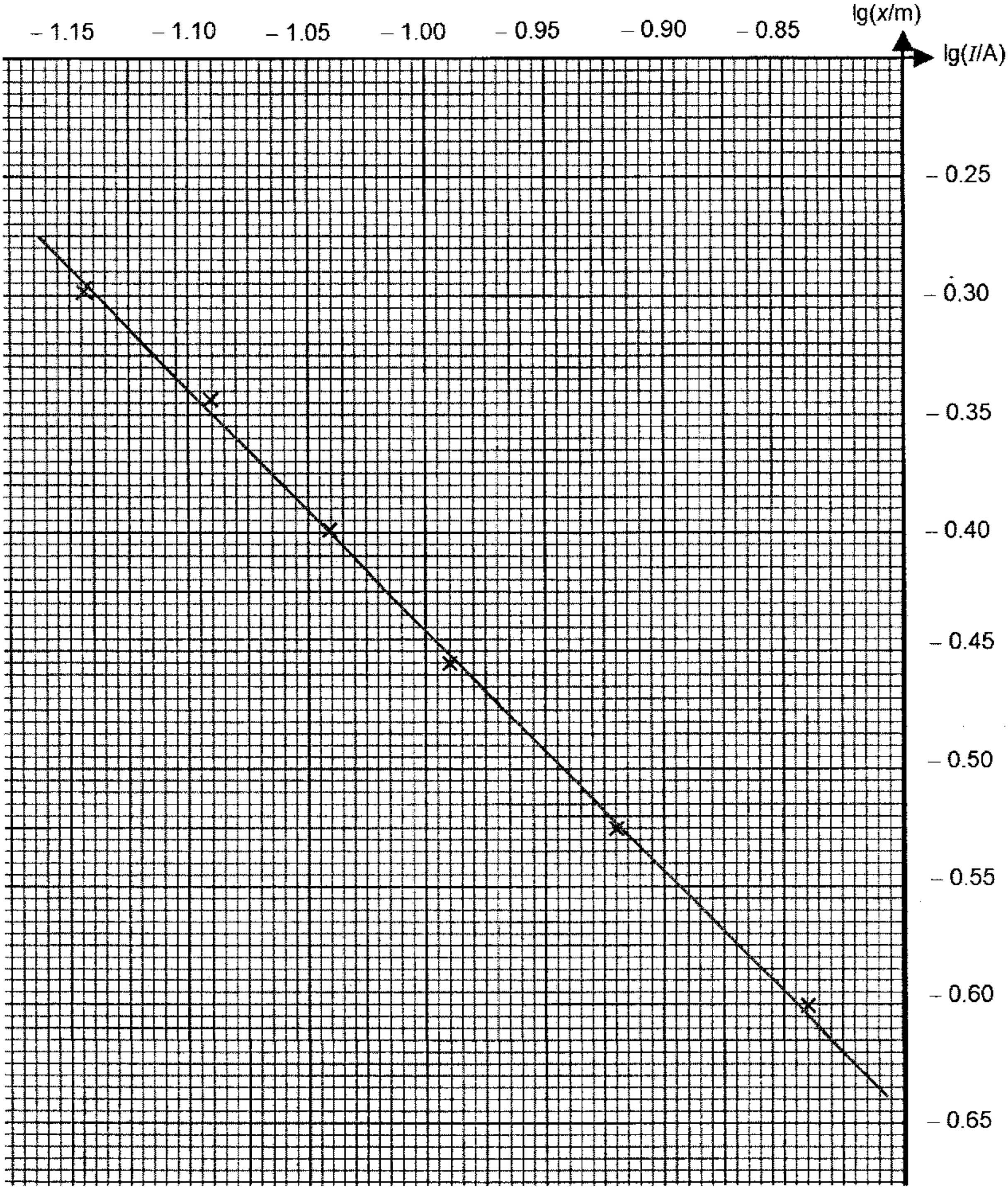
(d) (i) Complete the graph of lg (x/m) against lg (I/A) and draw the line of best fit.



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(ii) Determine the gradient and y-intercept of this line. [1]

Gradient:
$\Delta y/\Delta x$, gradient coordinates, gradient triangle at least 50%, value must be negative, around – 1.0 (to 2 s.f.), ignore units

Y-intercept:
False y-intercept (cannot read-off from graph), correct substitution of a point on the BFL into y = mx + c. Allow e.c.f from calculation of gradient. Value around – 1.4 to – 1.6.

gradient = ...

y-intercept = ... [2]

(e) x and I are related by a simple power law of the form $x = kI^n$, where n and k are constants. Use your answers from **(d)(ii)** to find the values of k and n. You need not be concerned with the units of these quantities.

lg x = nlg I + lg k
Value for n from gradient. Allow e.c.f. from (d)(ii). n = – 1.0
Value for k (from $10^{\text{y-intercept}}$). Allow e.c.f from (d)(ii). k = 0.0355.

k = ...

n = ... [2]

(f) A simple theoretical treatment of this circuit gives $k = \frac{VA}{\rho}$ where V is the potential difference across the wire, A is the cross sectional area of the wire and ρ is the resistivity of the material of the wire.

(i) Use a micrometer screw gauge to measure the diameter of the wire.

Correct range 0.21 mm to 0.25 mm, 0.021 cm to 0.025 cm (10% error)

Actual is 0.23 mm (SWG 34 constantan)

Correct precision

Repeated readings

diameter of wire = ... [1]

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(ii) Determine the cross sectional area A of the wire in m^2.

correct formula, correct calculation, correct s.f.

$A = \pi(D/2)^2 = \pi(0.00023/2)^2 = 4.15 \times 10^{-8}$ m^2

Acceptable range: 3.5 → 4.9 × 10^{-8} m^2

A = ... m^2 [1]

(iii) Determine the percentage uncertainty of A.

Correct formula, correct absolute uncertainty
correct calculation, correct s.f.

$A = \pi(D/2)^2 \rightarrow \Delta A/A \times 100\% = 2\Delta D/D \times 100\% = 2(0.01/0.23) \times 100\% = 8.7\%$
$\Delta D = 0.01$ mm
Do not allow if use $2\Delta r/r$ directly, as instrument and measurements made for diameter, unless algebraic conversion is sufficiently shown

Acceptable range: 8 → 10%

percentage uncertainty = ... [2]

(iv) Use your answers from **(e)** and **(f)** to determine a value for ρ.

$k = VA / \rho$

$\rho = VA / k = (0.40)(4.15 \times 10^{-8}) / (0.0355) = 4.7 \times 10^{-7}$ Ω m (tech spec = 4.9×10^{-7} Ω m)

Acceptable range: based on student's data but must be within reasonable order of magnitude 10^{-7} Ω m

Other forms of units not accepted as context is resistivity.

ρ = ... [1]

[Total: 13 marks]

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4 The efficiency η of a lamp may be expressed as

$$\eta = \frac{\text{light energy emitted}}{\text{electrical energy input}}$$

The efficiency can be determined by measuring the amount of wasted energy produced by the lamp in the form of thermal energy. The efficiency is calculated using

$$\eta = 1 - \frac{\text{thermal energy}}{\text{electrical energy input}}$$

The efficiency is thought to depend on the potential difference V across the lamp. The relation between the efficiency and the potential difference may be written in the form

$$\eta = aV^b$$

where a and b are constants.

You are provided with a filament lamp of low potential difference and a beaker of water that is to be used in the determination of the thermal energy produced by the lamp. You may also use any other standard laboratory apparatus usually found in a college physics laboratory.

Design an investigation to determine the relation between η and V.

You should draw a labelled diagram to show the arrangement of your apparatus.
In your account you should pay particular attention to

- **(a)** the equipment you would use,
- **(b)** the procedure to be followed,
- **(c)** the control of variables,
- **(d)** how the thermal energy is measured,
- **(e)** any precautions that would be taken to improve the accuracy and safety of the equipment.

Diagram

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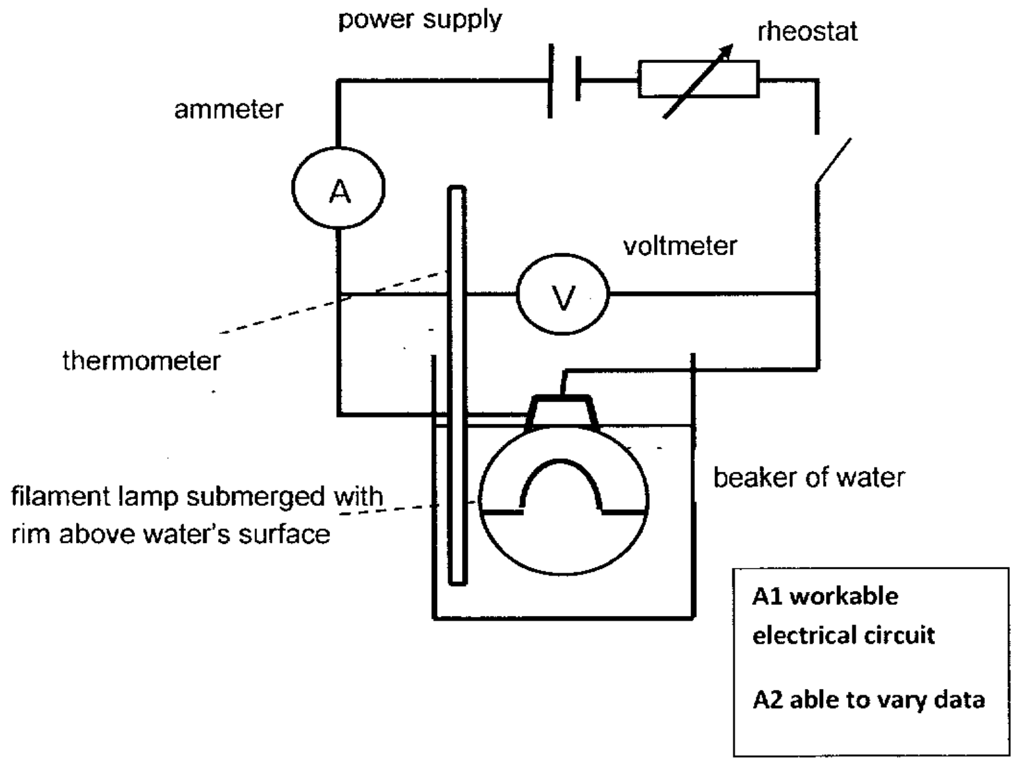
4



(a) **Independent variable**: Potential difference V across the lamp.
Dependent variable: Rise in temperature $\Delta\theta$ of the water, current I flowing through the lamp **A3**
Control variables: mass of water m, time t that the filament lamp was turned on.

(b) **Procedures**

1. Set up the apparatus as shown in the diagram.
2. Do preliminary readings to find range of voltages that will cause significant change in temperature of the water.
3. Measure the mass of water m using a mass balance. **B1**
4. Measure the initial temperature of the water θ_i with a thermometer. **B2**
5. Close the switch and adjust the rheostat. Measure the potential difference V across the lamp using a voltmeter and start the stopwatch. **B3**
6. Measure and record the value of the current I from the ammeter.
7. After time t, open the switch to stop the power supply.
8. Determine the highest temperature θ_f that the water reaches and calculate the change in temperature using $\Delta\theta = \theta_f - \theta_i$. **B4**
9. Repeat steps 2 – 7 for 6 different values of V by adjusting the rheostat and record down the corresponding values of I and $\Delta\theta$. **B5**

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10. Calculate η using the expression

$$\eta = 1 - \frac{\text{thermal energy}}{\text{electrical energy input}} = 1 - \frac{mc\Delta\theta}{VIt}$$ **B6**

11. Since $\eta = aV^b$, $\lg\eta = b\lg V + \lg a$

Plot lg η against lg V, if a straight line is obtained, the gradient is given by *b* and y-intercept by lg *a*. **B7**

(c) **Safety**: **C1**

- Use of gloves or tongs when adjusting the lamp or moving the hot beaker.
- Make sure that only the bulb is submerged and not the wires as there could be short circuited.

Accuracy: **C2**

- Cover the beaker to prevent thermal energy loss to the surroundings.
- Stir the water to ensure the temperature is uniform.

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