HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 2

A

CANDIDATE NAME	Suggested Solutions	**CT GROUP**	23S
TUTOR NAME			

PHYSICS

9749/04

Paper 4 Practical

22 August 2024

2 hours 30 mins

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your name, CT group and tutor's name in the boxes at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3.
You are advised to spend approximately 30 minutes on Question 4.

Write your answers in the spaces provided 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.

At the end of the examination, submit sets A, B and C separately.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	**/ 12**
2	**/ 9**
3	**/ 22**
4	**/ 12**
Total	**/ 55**

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1 In this experiment, you will investigate the period of torsional oscillations of a suspended disc with loaded mass.

(a) Set up the apparatus as shown in Fig. 1.1.

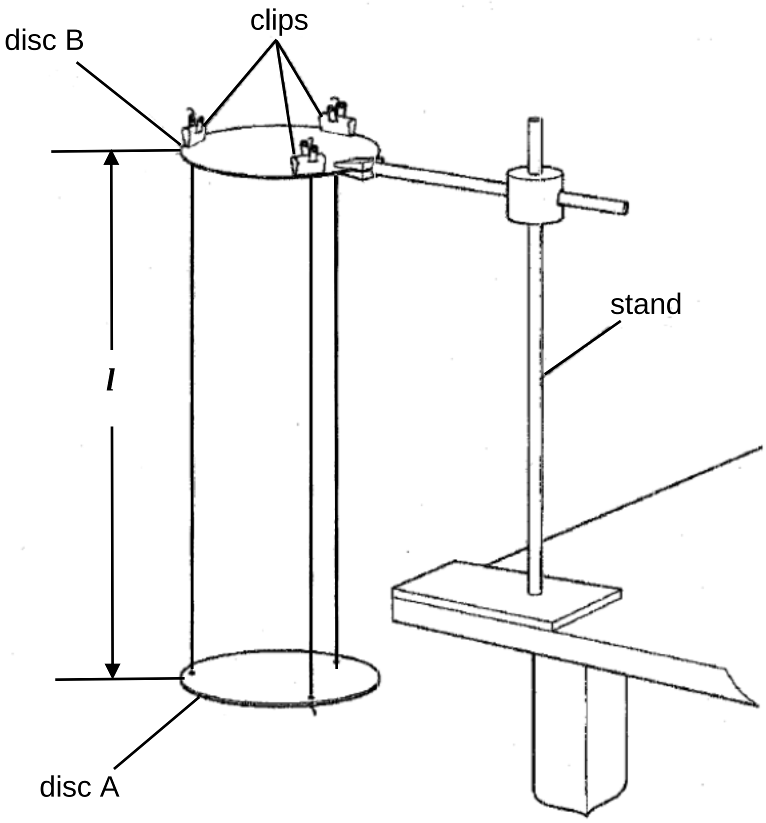


Fig. 1.1

Disc A and disc B have three small holes spaced at regular intervals near the edge. Pieces of string have been threaded through the holes.

Clamp disc B horizontally using two small blocks of wood. Use the clips on disc B to adjust the length l of each string until l is about 100 cm.

Place a 50 g mass in the centre of disc A.

(b) **(i)** Gently rotate disc A through a small angular displacement and release it so that the disc performs torsional oscillations of period *T* in a horizontal plane as shown in Fig. 1.2.

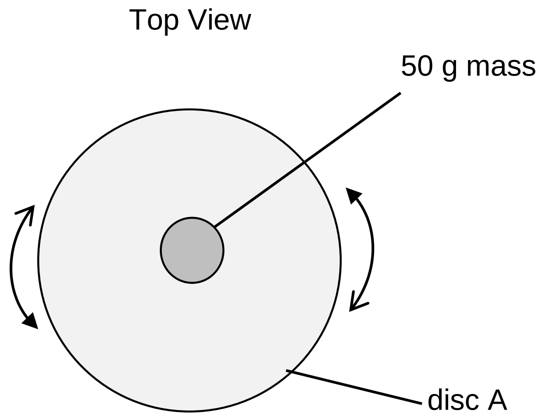


Fig. 1.2

Determine and record *T*.

- Repeated readings of timings t shown
- Calculate T with working

For n = 20 oscillations,
t_1 = 20.0 s
t_2 = 20.2 s

$T = \frac{t_1+t_2}{2n} = \frac{20.0+20.2}{40} = 1.01$ s (3 s.f.)

T = ... [2]

(ii) Repeat **(b)(i)** for different values of mass *m*, by stacking the slotted masses on top of each other, until you have five sets of readings of *T* and *m*.

Present your results clearly.

m / g	No. of oscillations n	Timing for n oscillations		T / s	lg (m / g)	lg (T / s)
		t_1 / s	t_2 / s			
50	20	20.0	20.2	1.01	1.70	0.002
100	30	24.7	24.9	0.827	2.000	-0.083
150	30	21.5	21.4	0.715	2.176	-0.146
200	30	20.0	20.0	0.667	2.301	-0.176
250	35	21.8	22.1	0.627	2.398	-0.234

[4]

- 5 sets of readings
- Timing $t \geq 20$ s
- Column headings: Each column heading must contain a quantity, a unit and a separating mark where appropriate. The presentation of quantity and unit must conform to accepted scientific convention
- Correct precision for raw data and s.f for calculated data

(c) It is suggested that T and m are related by the expression:

$$T = km^n$$

where k and n are constants.

Plot a suitable graph to determine the values of k and n.

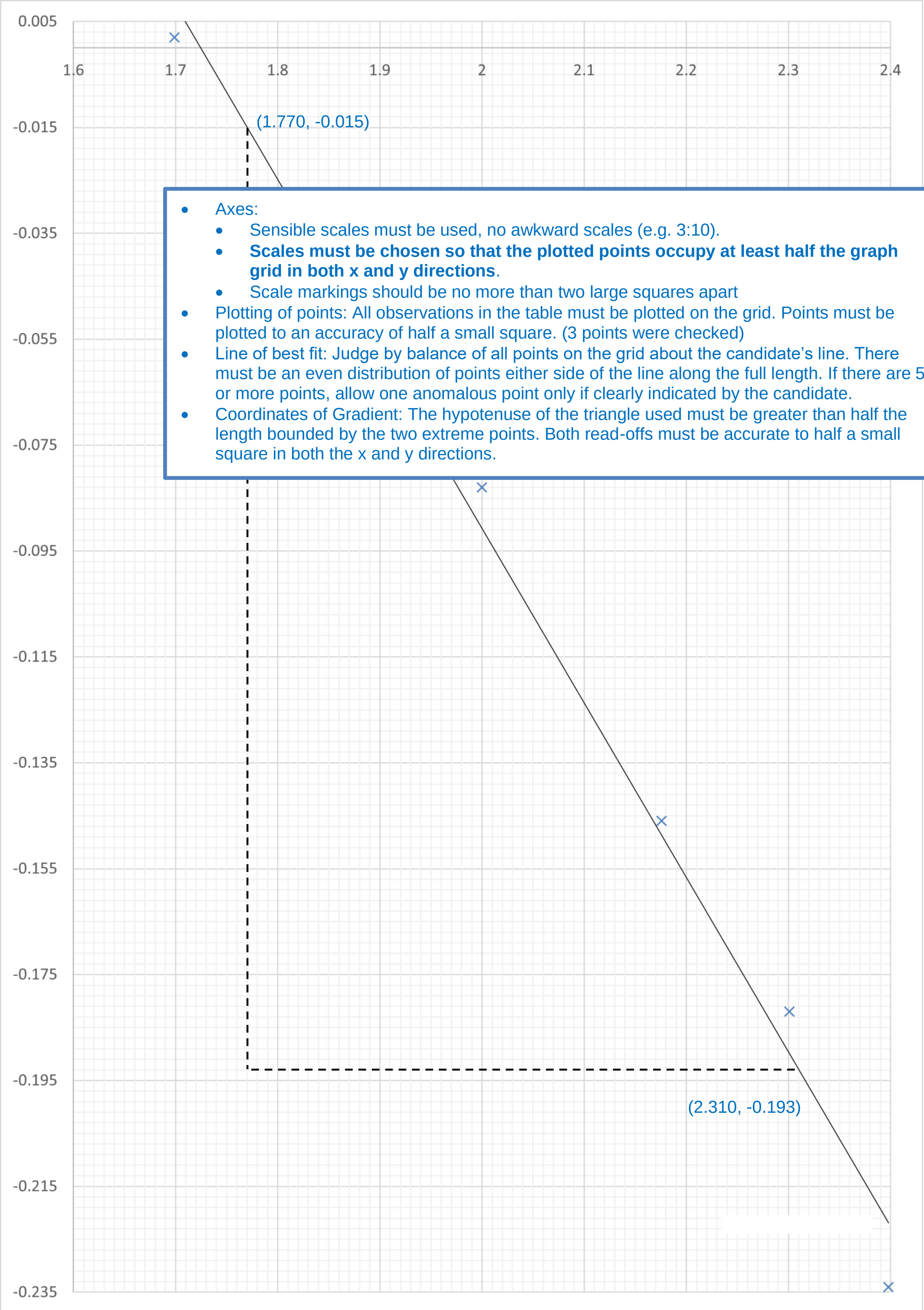
Since lg T = n lg m + lg k
By plotting a graph of lg T vs lg m, a straight line graph should be obtained with gradient = n and y-intercept = lg k

From graph plotted,

Gradient of graph = $\frac{-0.015-(-0.193)}{1.770-2.310}$ = -3.3296 = -3.30 (3 s.f)
(-0.015) = -3.3296 (1.770) + y-intercept
y-intercept = 0.5684

Hence
n = -3.30
lg k = 0.5684
k = 3.70 s g^{-n}
= 3.70 *s* $g^{3.30}$

[6]



- Axes:
  - Sensible scales must be used, no awkward scales (e.g. 3:10).
  - **Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions**.
  - Scale markings should be no more than two large squares apart
- Plotting of points: All observations in the table must be plotted on the grid. Points must be plotted to an accuracy of half a small square. (3 points were checked)
- Line of best fit: Judge by balance of all points on the grid about the candidate's line. There must be an even distribution of points either side of the line along the full length. If there are 5 or more points, allow one anomalous point only if clearly indicated by the candidate.
- Coordinates of Gradient: The hypotenuse of the triangle used must be greater than half the length bounded by the two extreme points. Both read-offs must be accurate to half a small square in both the x and y directions.

2 In this experiment, you will investigate the energy stored in a stretched rubber band.

(a) **(i)** Place the rubber band on the bench so that it is taut without being stretched, as shown in Fig. 2.1.

The length of the rubber band is L_0.

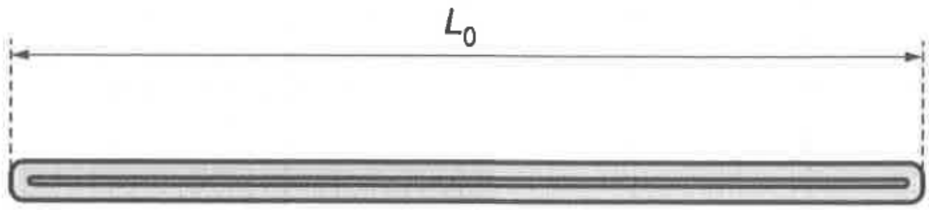


Fig. 2.1

Measure and record L_0 for your rubber band.

- Value of L_0 in the range 7.0 cm to 8.0 cm & (to nearest 0.1 cm or 0.001 m)

L_0 = ...7.5 cm........ [1]

(ii) Use the dimensions given on the card to calculate the volume V of the rubber band.

w = 1.5 mm , h = 1.5 mm

$V = (2 \times 7.5 \times 10^{-2} \times 1.5 \times 10^{-3} \times 1.5 \times 10^{-3})$

- Correct calculation of volume V (e.g. $2 \times L_0 \times w \times h$) (Where w is the width and h is the height of rubber band.)

V = ...3.4×10^{-7} m^3 / 0.34 cm^3........ [1]

(b) **(i)** Set up the apparatus as shown in Fig. 2.2 with the mass hanger suspended from the rubber band.

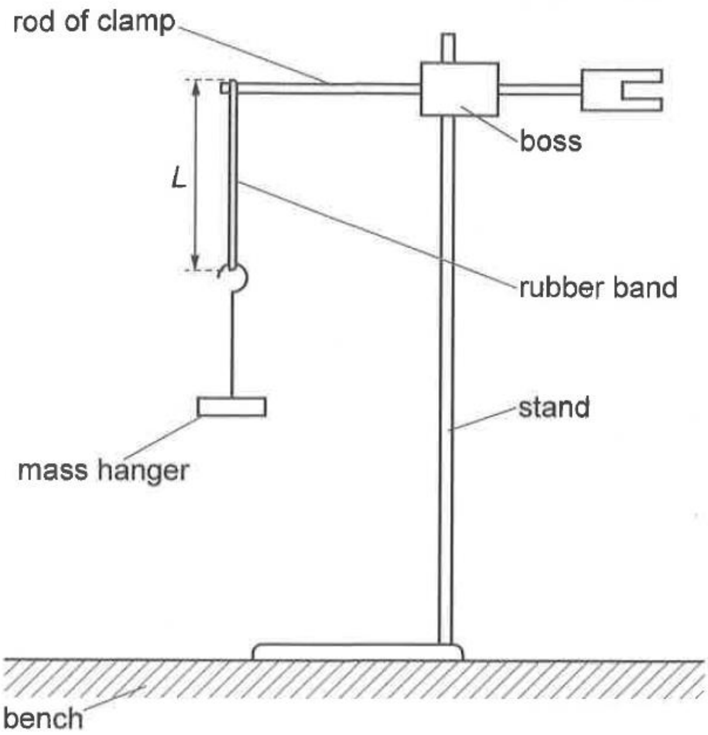


Fig. 2.2

The extended length of the rubber band is L.

Calculate the extension e of the rubber band where:

$$e = L - L_0.$$

e = 8.5 – 7.6 = 0.9 cm
= 0.009 m

Record your answer in metres.

e = ...0.009.......... m

The force F acting on the rubber band is given by:

$$F = mg$$

Where m is the mass, in kg, suspended from the rubber band and g = 9.81 N kg^{-1}.

Calculate and record F.

Both e is calculated correctly and correct precision (0.001 m) and *F* is calculated to correct value and correct s.f. (accept 2 or 3 s.f. as *m* may be read to 2 or 3 s.f)

F = ...F = 0.100 x 9.81 = 0.981 N.......... N
[1]

(ii) Vary *m* and repeat **(b)(i)**.

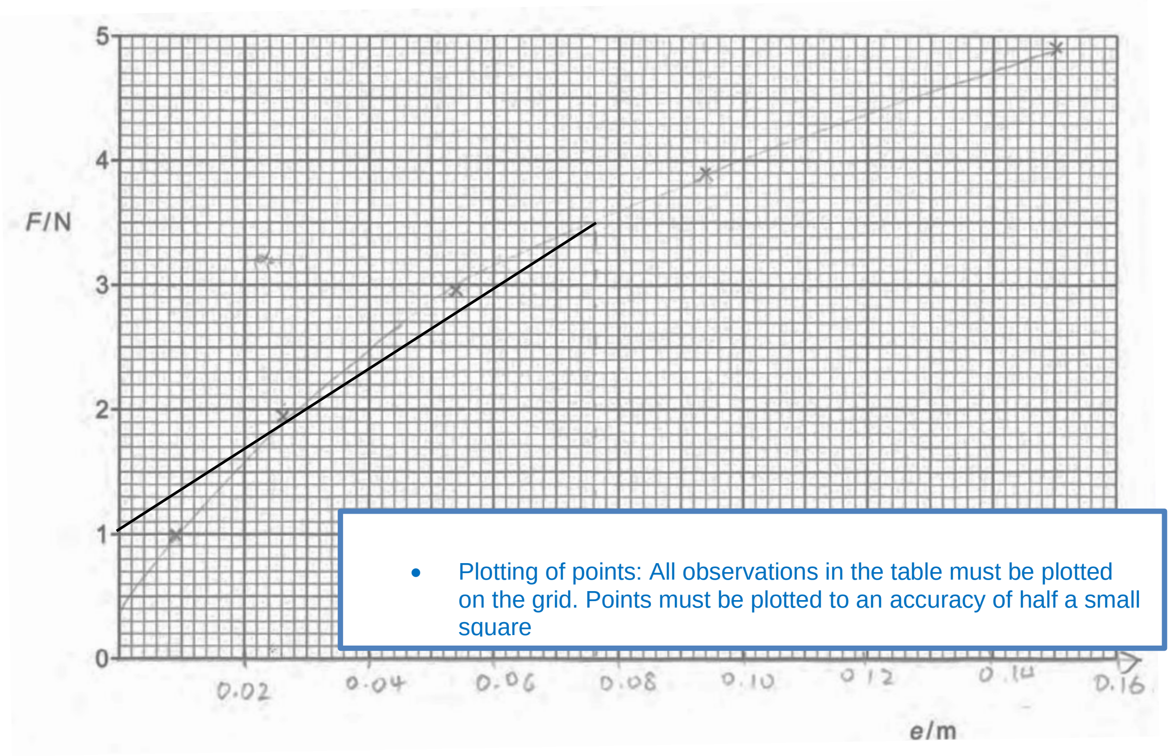
Present your results clearly.

m / g	*L* / m	*e* / m	*F* / N
100	0.085	0.009	0.981
200	0.102	0.026	1.96
300	0.130	0.054	2.94
400	0.170	0.094	3.92
500	0.226	0.150	4.91

[3]

- 5 sets of readings (using 100 g mass intervals not 50 g)
- Column headings: Each column heading (*m, L, e and F*) must contain a quantity, a unit and a separating mark where appropriate. The presentation of quantity and unit must conform to accepted scientific convention
- Correct precision for raw data and s.f for calculated data

(iii) Plot your results on the grid below.



- Plotting of points: All observations in the table must be plotted on the grid. Points must be plotted to an accuracy of half a small square

(iv) The area under the graph represents the approximate energy stored by the rubber band.

Estimate this energy when its extended length $L = 2L_0$.

- Estimate correctly the area under graph up till $e = L_0$

  Show working
  Acceptable range (0.08 to 0.20 J)
  Common mistake is thinking that the $e = 2L_0$

Estimated area = Area under black line

= ½ x (3.5 – 1.0) x 0.076
= 0.095 J

energy stored = ... J [1]

(v) Calculate the energy stored per unit volume, in J m^{-3}, in the rubber band when its extended length $L = 2L_0$.

- Correct calculation of energy stored per unit volume in J m^{-3}. In particular taking note of the correct units.

Energy stored per unit volume = Energy stored / volume
= $0.095 / 3.4 \times 10^{-7}$
= $2.8 \times 10^{5}\ \text{J m}^{-3}$

energy stored per unit volume = ... J m^{-3} [1]

[Total: 9]

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B

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PHYSICS

Paper 4 Practical

Candidates answer on the Question Paper.

No Additional Materials are required.

3 This experiment investigates the properties of a coil of wire.

(a) You have been provided with two cardboard tubes with wire wrapped around them. The diameter of the tube labelled Y is D_Y, as shown in Fig. 3.1. The diameter of the wire is d_Y.

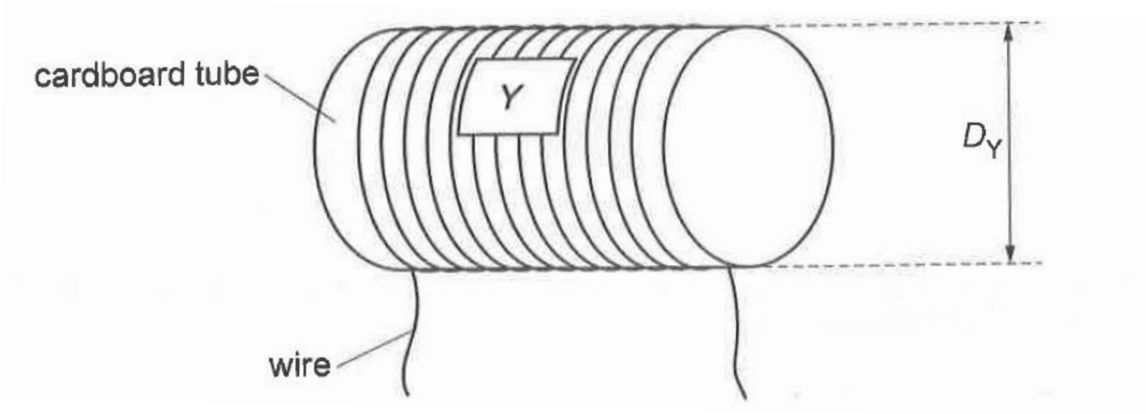


Fig. 3.1

Measure and record D_Y and d_Y.

Average $D_Y = \dfrac{4.4 + 4.5}{2} = 4.5$ cm

- repeated measurement of D_Y
- value of D_Y recorded to nearest 0.1 cm
- 4.0 cm $\leq D_Y \leq$ 4.6 cm

Average $d_Y = \dfrac{0.29 + 0.28}{2} = 0.29$ mm

- repeated measurement of d_Y
- value of d_Y recorded to nearest 0.01 mm
- 0.26 mm $\leq d_Y \leq$ 0.30 mm

D_Y = ... 4.5 .... cm

d_Y = ... 0.29 .... mm [2]

(b) **(i)** The total length of wire is L_Y.

Estimate and record your value for L_Y.

Show your working.

Number of turns of wire round the tube = 14
Circumference of 1 turn = $(\pi)(D_Y)$

$L_Y = 14 \times (\pi)(D_Y)$
$= 14 \times (\pi)(4.5)$
$= 195.72$

- formula to estimate L_Y
- substitution of number into formula
- value of L_Y calculated correctly
- 180 cm $\leq$ L_Y $\leq$ 220 cm
- L_Y express to the nearest cm or tens of cm.

L_Y = ...196.............. cm [2]

(ii) Estimate the percentage uncertainty in your value of L_Y.

$L_Y = 14 \times (\pi)(D_Y)$

$$\frac{\Delta L_Y}{L_Y} = \frac{\Delta D_Y}{D_Y} = \frac{0.2}{4.5} \times 100\% = 4.44\%$$

- 1% < $(\Delta Ly/Ly) \times 100\%$ $\leq$ 10%
- If ΔLy is quoted, it should be to the order of cm and to **1 s.f.**
- Final percentage uncertainty expressed to 1 or 2 s.f.

percentage uncertainty in L_Y = ...4.4 %.............. [1]

(c) Connect the circuit shown in Fig. 3.2 where resistor R has a resistance *R* of 15 Ω.

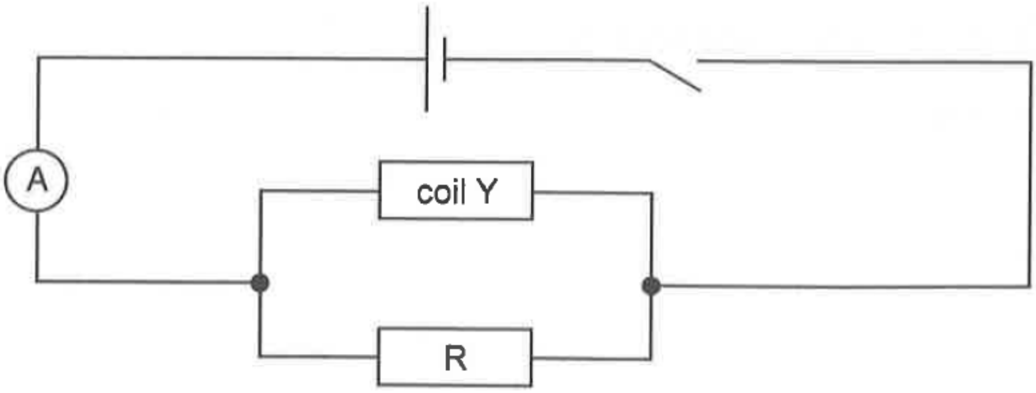


Fig. 3.2

Close the switch.

Note and record *R* and the ammeter reading I.

- value of *R* recorded, measurement via DMM is not required.
- value of *I* recorded to the correct decimal place in A (in this case 4, e.g. 0.1340 A)

R = ...15............ Ω

I = ...136.6 x 10^{-3} or 0.1366...... A

[1]

Open the switch.

Vary *R* and repeat **(c)**.

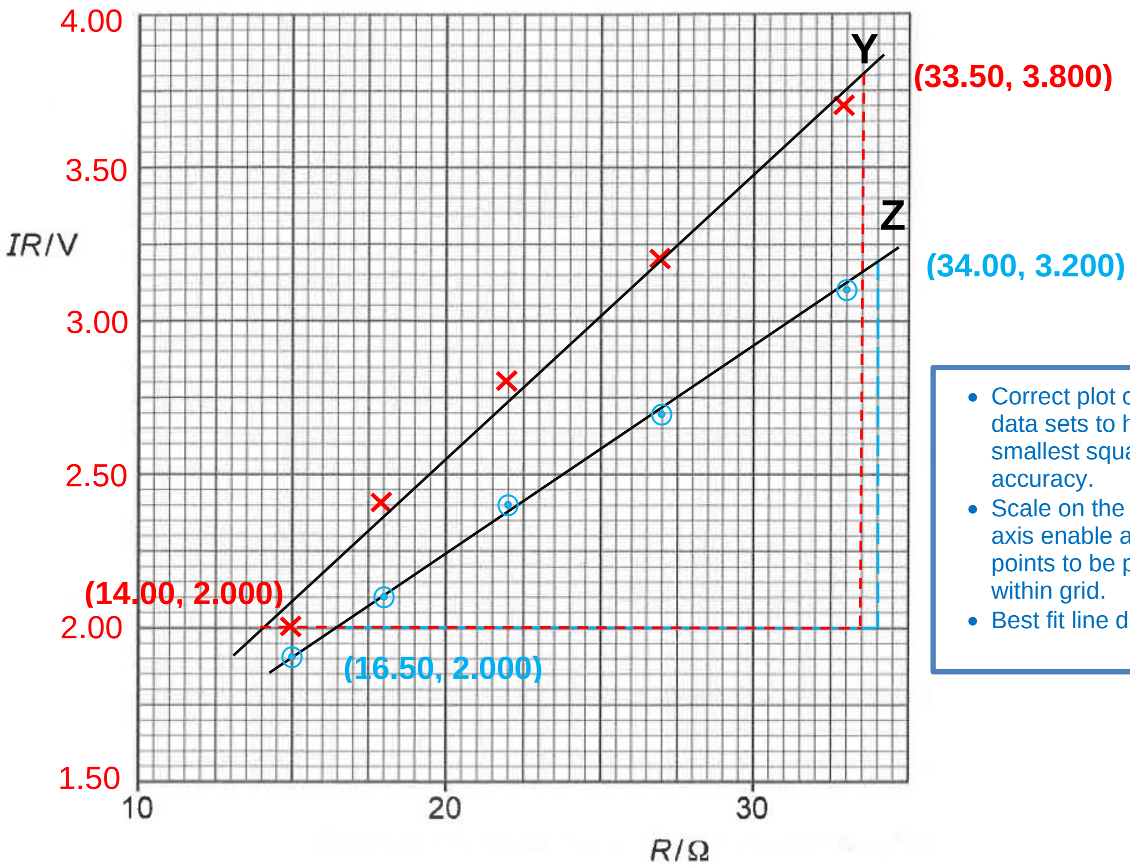
(d) Present your results clearly.

R / Ω	I / A	IR / V
15	0.1366	2.0
18	0.1349	2.4
22	0.1258	2.8
27	0.1186	3.2
33	0.1130	3.7

- a table with correct column headings & units for 5 sets of readings
- no split tables!
- display correct trend (*R* increases, I decreases)
- value of IR calculated correctly and expressed to correct s.f. (In this case the lesser of the two s.f.'s between *R* and I is 2.)

[3]

(e) Plot your results on Fig. 3.3 and label this line Y.



- Correct plot of all data sets to half the smallest square accuracy.
- Scale on the vertical axis enable all data points to be plotted within grid.
- Best fit line drawn.

Fig. 3.3

I and R are related by the expression:

$$IR = GR + H$$

where G and H are constants.

The resistance X_Y of coil Y is given by:

$$X_Y = \frac{H}{G}.$$

Use your graph to determine X_Y.

$$G = \text{gradient} = \frac{3.800 - 2.000}{33.50 - 14.00} = 0.09231$$

- Coordinates of points used for calculating to be read correctly to half the smallest square accuracy
- Correctly calculate Gradient = G,

To find H, substitute (14.00, 2.000) and G into the given expression:

$2.000 = (0.09231)(14.00) + H$

$H = 2.000 - 1.292 = 0.708$

- Correctly deduce y-intercept = H
- Correctly calculate $X_Y = H/G$

$$\therefore X_Y = \frac{0.708}{0.09231} = 7.67\ \Omega$$

X_Y = 7.67 Ω

[3]

(f) The diameter of the tube labelled Z is D_Z. The diameter of the wire is d_Z.

(i) Measure and record D_Z and d_Z.

- Value of D_Z within (and include) 2 mm of D_Y
- Value of d_Z to nearest 0.01 mm.
- 0.17 mm $\leq d_Z \leq$ 0.23 mm.
- Value of L_Z calculated correctly.

Average $D_Y = \dfrac{4.5+4.5}{2} = 4.5$ cm

Average $d_Y = \dfrac{0.21+0.23}{2} = 0.22$ mm

D_Z = ...4.5.......... cm

d_Z = ...0.22.......... mm

The length of wire wrapped around Z is L_Z, where:

$$L_Z = \frac{3L_Y}{4}.$$

$L_Z = \dfrac{3 \times 195.721}{4} = 146.79$ cm = 147 cm

Calculate L_Z.

L_Z = ...147.......... cm [1]

(ii) The resistance of coil Z is X_Z.

Repeat **(c)**, **(d)** and **(e)** to find X_Z.

Plot your results on Fig. 3.3 and label this line Z.

R / Ω	*I* / A	*IR* / V
15	0.1277	1.9
18	0.1175	2.1
22	0.1090	2.4
27	0.1000	2.7
33	0.0932	3.1

G = gradient = $\dfrac{3.200-2.000}{34.00-16.50} = 0.06857$

Find H:

2.000 = (0.06857)(16.50) + H

H = 2.000 – 1.131 = 0.869

$X_Y = \dfrac{0.869}{0.06857} = 12.7\ \Omega$

- A table with correct column headings & units for 5 sets of readings
- At least one of the graphs must be labelled.

Plot of line Z on Fig. 3.3

- At least 3 data points must be within the grid
- Generally below Y graph

X_Z = ...12.7.......... Ω [2]

(iii) Use a digital multimeter to measure X_Z. measured X_Z = 22.8 Ω

Describe any difference between your two values for X_Z and suggest a reason for this difference.

difference The measured value is larger than the calculated value by 10.13 Ω

reason Internal resistance of the cell is not accounted for / not negligible.

[1]

- Need to record the measured value of X_Z.
- Measure value should be compared to be larger than the value of X_Z found in (f)(ii)
- Additional resistance due to internal resistance of battery / heating effect or energy lost within battery.

(g) It is suggested that the resistance of a wire, X, is given by the relationship:

$$X = \frac{kL}{d^2}$$

Where L is the length of the wire, d is the diameter of the wire and k is a constant.

(i) Use your values from **(a)**, **(b)(i)**, **(e)**, **(f)(i)** and **f(ii)** to determine two values of k.

$$k = \frac{xd^2}{L}$$

$$k_Y = \frac{7.67 \times (0.29 \times 10^{-3})^2}{196 \times 10^{-2}} = 3.3 \times 10^{-7}\ \Omega\text{m}$$

$$k_Z = \frac{12.7 \times (0.22 \times 10^{-3})^2}{147 \times 10^{-2}} = 4.2 \times 10^{-7}\ \Omega\text{m}$$

- Two values of k calculated correctly
- values of k expressed to the 2 or 3 s.f.
- correct units of k

first value of k = 3.3×10^{-7} Ωm

second value of k = 4.2×10^{-7} Ωm

[1]

(ii) State whether or not the results of your experiment support the suggested relationship.

Justify your conclusion by referring to your value in **(b)(ii)**.

$$\% \text{ difference in } k = \frac{(4.18\times10^{-7} - 3.29\times10^{-7})}{\left(\dfrac{4.18\times10^{-7} + 3.29\times10^{-7}}{2}\right)} \times 100 = 24\%$$

Since the percentage difference in *k* is greater than the percentage uncertainty in *L* of 4.4 %, the experiment does not support the suggested relationship.

....

- working shown for % difference for *k* or uncertainty of *k*
- reference made to (b)(ii) in calculation of uncertainty
- correct conclusion drawn from above comparison

.... [1]

(h) **(i)** When there is a current I in one of the coils, the magnetic flux density B at each end of the tube along its axis is given by:

$$B = CnI$$

Where C is a constant and n is the number of turns of wire per unit length on the tube.

Without taking further readings, explain whether tube Y or tube Z has a greater magnetic flux density at its ends when the voltage supply is connected directly across the coil.

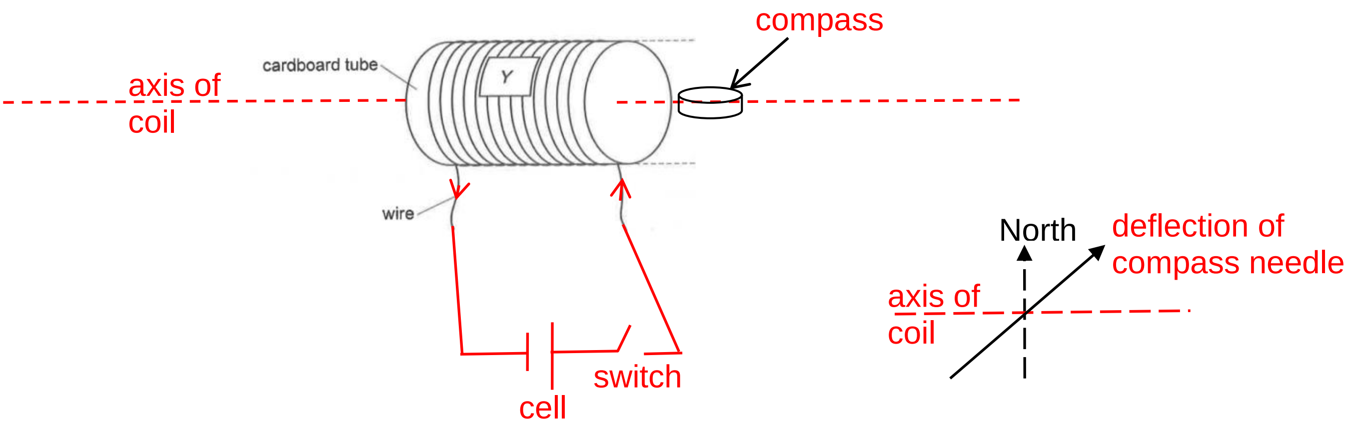
$n_Y > n_Z$, and since $X_Z > X_Y$, $I_Y > I_Z$. Hence the magnetic flux density at the end of tube Y is greater.

- Tube Y produces a greater magnetic flux density
- Tube Y has a greater number of coil per unit length (n)
- Tube Y has a higher current flow (I) through it

.... [1]

(ii)

Describe, using a diagram, how you could check your conclusion in **(h)(i)** using a small compass.



1. Connect the ends of the coil of wire on tube Y to a cell as shown in the diagram.
2. Place a small compass at the centre of the end of tube Y.
3. Ensure the compass needle points towards the North in the direction of the Earth's magnetic field.
4. Orientate tube Y so that the axis of the coil is perpendicular to the compass needle.
5. Close the switch.
6. The magnetic field generated at the end of the coil deflects the needle. Note the angle of deflection of the compass needle from the North.
7. Repeat steps 1 to 6 with the coil on tube Z.

The angle of deflection of the compass needle would be greater for the coil which exerts a stronger magnetic flux density at its end.

....

....

....[3]

[Total: 22]

- Diagram: (1) Correct placement of compass relative to coiled tube.
  (2) Appropriate circuit connected to coils.
- Consideration for Earth's magnetic field
- Repeat experiment for both coils and clear explanation on how to draw conclusion based on proposed experiment

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C

CANDIDATE NAME		**CT GROUP**	**23S**
TUTOR NAME		**SCORE**	

PHYSICS

Paper 4 Practical

Candidates answer on the Question Paper.

No Additional Materials are required.

4 A student is investigating how the boiling point of a salt solution varies with pressure and the density of the salt solution.

It is suggested that the relationship between the Celsius temperature θ at which the water of the solution starts to boil, the air pressure P and the density σ of the salt solution is

$$\theta = k\sigma^{x}P^{y}$$

where k, x and y are constants.

Design a laboratory experiment to determine the values of x and y.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to:

(a) the equipment you would use

(b) the procedure to be followed

(c) the control of variables

(d) any precautions that should be taken to improve the accuracy of the experiment.

Diagram

....

....

....

....

....

Suggested solution

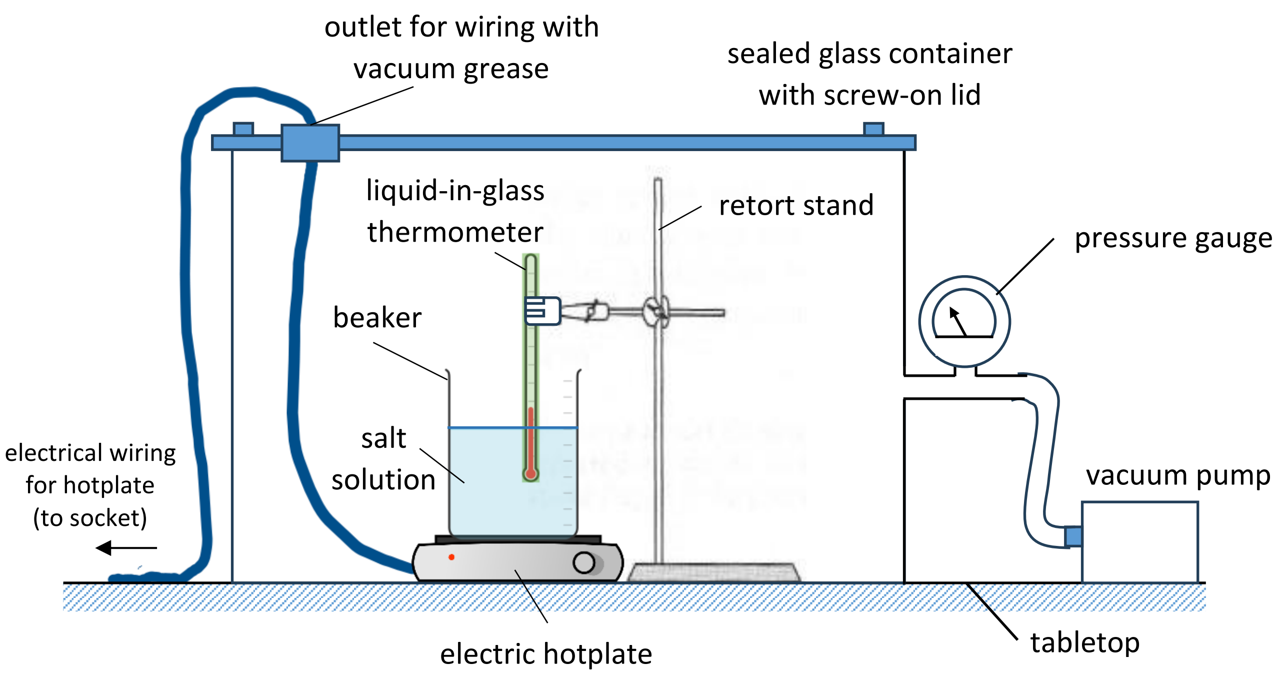

Fig. 1

Aim: The relationship between the Celsius temperature θ at which the water of the solution starts to boil, the air pressure P and the density σ of the salt solution is

$$\theta = k\sigma^x P^y$$

$$\Rightarrow \lg\theta = \lg k + x\lg\sigma + y\lg P$$

Determine x and y.

Experiment 1: Keep P constant, vary σ and determine θ

- *Plot graph of lg θ vs lg σ. If the relationship is valid, the data points will present a straight-line trend. Draw a best-fit straight line and determine gradient = x.*

Experiment 2: Keep σ constant, vary P and determine θ

- *Plot graph of lg θ vs lg P. If the relationship is valid, the data points will present a straight-line trend. Draw a best-fit straight line and determine gradient = y.*

Apparatus and Method to Measure the Various Quantities:

Dependent Variable: θ	*Measured with a liquid-in-glass thermometer.* Salt solution starts to boil when the bubbles move to the top of the solution and the temperature reaches a maximum for a few seconds.
Independent Variable: σ	*Weigh the mass M of the salt solution using the electronic balance. Measure the volume V of the salt solution using a measuring cylinder. Density σ = M/V*
Independent Variable: P	*Measured with the pressure gauge*
Additional controls:	*The type of salt used to make the solution can affect the boiling point. Hence, the salt solution should only be made with distilled water and laboratory-grade salt, e.g. NaCl; keep the same type of salt throughout the experiment.*

Experiment 1: Keep *P* constant, vary σ *to find* θ

1) *Prepare a large amount of salt solution by adding salt to water in a large container. Determine and record the density* σ *of the salt solution to be used and fill the beaker with the salt solution.*
2) *Set up the apparatus as shown in Fig. 1. Record the pressure P indicated*
3) *Switch on the electrical heater and wait for the solution to start to boil. Read off the temperature* θ*.*
4) *Repeat the experiment for Steps 1 to 3 for 10 different values of* σ *while keeping P constant.* σ *can be varied by adding additional salt to the solution in Step 1.*
5) *Plot a graph of lg* θ *vs lg* σ *and determine gradient = x.*

Experiment 2: Keep σ constant, vary *P* to find θ,.

6) *Setup the apparatus as shown in Fig.1.*
7) *Repeat the experiment for steps 1 to 3 by now varying P and keeping* σ *constant. The pressure P can be changed by using the vacuum pump to pump out some of the air each time. Obtain 10 sets of data of different values of P and the corresponding values of* θ*, while keeping* σ *constant.*
8) *Plot a graph of lg* θ *vs lg P and determine gradient = y.*

Additional Details

- *Conduct preliminary experiments to find a suitable range for* σ *and P that will lead to a good variation of measurable values of* θ *.*
- *The pressure P may still change (in Experiment 2) as the water heats and steam builds up, so the P value recorded should be the value when the water boils. Hence, read the value of P at the same time as when* θ *is read.*
- *There is some judgement in deciding when exactly is the point when the solution starts to boil. One way to address this is to repeat the experiment 3 times and take the average of θ for each* σ *(Experiment 1) or each P (Experiment 2). This checks for reproducibility of results as well.*

Safety Precautions

- *Wear protective goggles to protect the eyes from possible implosion of the container when the pressure is reduced.*
- *Handle the hot beakers and thermometers with thermal gloves to protect the hands from accidental burns.*