YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CG		INDEX NO	

PHYSICS

Marking Scheme

9749/04

Paper 4 Practical

26 Aug 2021

2 hours 30 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces 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, highlighters, glue or correction fluid/tape.

Answer **all** questions.

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, where appropriate, in the boxes provided.

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

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	**/16**
2	**/ 6**
3	**/21**
4	**/12**
Total	**/55**

This document consists of **17** printed pages and **3** blank pages.

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1 In this experiment you will investigate an electrical circuit.

You are provided with several groups of resistors connected in parallel.

(a) Assemble the circuit as shown in Fig. 1.1

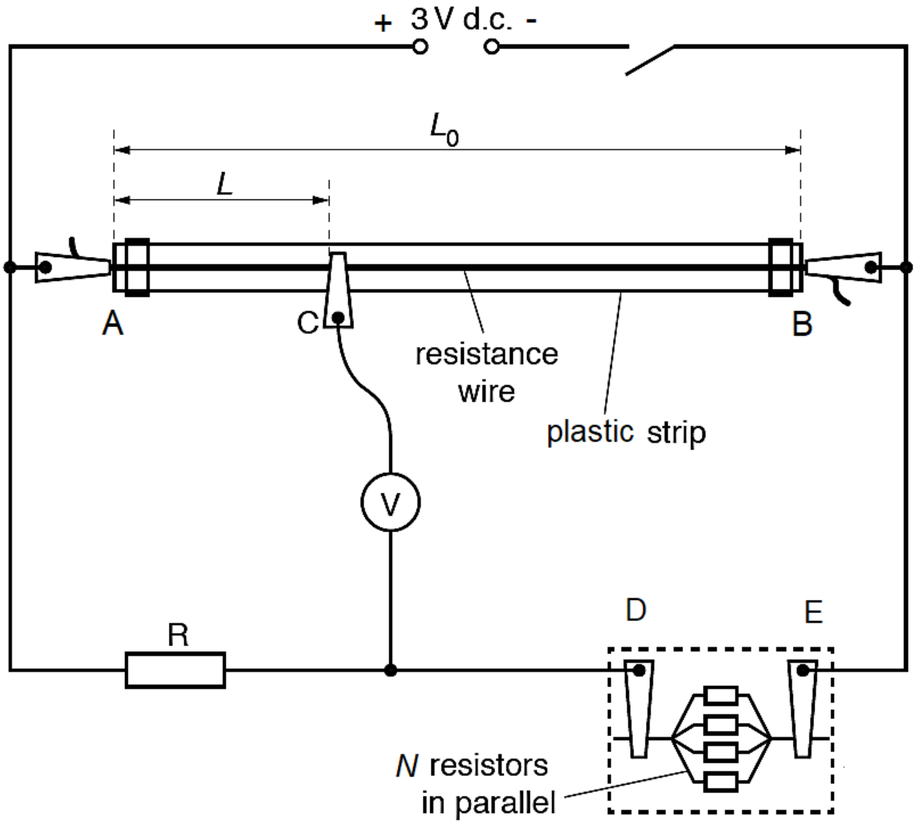


Fig. 1.1

A, B, C, D and E are crocodile clips.

Measure and record the length L_o of the resistance wire between the ends of A and B, as shown in Fig. 1.1.

- to nearest mm with units
- 0.580 m $\leq L_o \leq$ 0.620 m **[1]**

L_o = 60.0 cm (0.600 m) [1]

(b) **(i)** Select from the groups of resistors connected in parallel, *N=4* and connect it across D and E as shown in Fig.1.1.

(ii) Close the switch. Move C along the wire until the voltmeter reading is zero.

Measure and record the distance L between A and C when the voltmeter reading is zero, as shown in Fig. 1.1.

- nearest mm with units
- L depends on N and is less than L_o **[1]**

L = 16.8 cm (0.168 m) [1]

Open the switch.

(c) Select a different group of resistors and repeat **(b)(ii)** until you have at least six sets of values of N and L.

Record your results in a table.

Include values of $\frac{1}{N}$ and $\frac{1}{L}$ in your table of results.

N	L / m		
2	0.098	0	
3	0.141	0	
4	0.168	0	
5	0.196	0	
6	0.220	0	
7	0.245	0	
8	0.262	0	

- Award 2 mk if collected 6 or more sets of data wo assistance. Award 1 mk if collected 5 sets of data wo assistance. Zero if less than 5 sets. **[2]**
- Column headings must contain a quantity and a unit where appropriate eg $\frac{1}{L}$ / m^{-1} **[1]**
- Raw values for L must be given to nearest mm (precision) **[1]**
- Number of s.f. for calculated values should be same or one more than that for L. **[1]**
- Correct calculation for 1/N and 1/L. **[1]**
- Allow for one miscalculation.

[6]

(d) **(i)** It is suggested that the quantities L and N are related by the equation

$$\frac{1}{L} = \frac{a}{N} + b$$

where a and b are constants.

Plot a suitable graph to determine a and b. Give appropriate units.

A graph of $\frac{1}{L}$ against $\frac{1}{N}$ is plotted with the gradient equals to a and the y-intercept equals to b.

Gradient = $\frac{(9.40 - 4.20)}{(0.450 - 0.150)} = 17.3\ \text{m}^{-1}$

$\Rightarrow$ $a = 17.3\ \text{m}^{-1}$

- Correct linearising of equation. Not necessarily to be that given above **[1]**
- The hypotenuse of the gradient triangle must be greater than half the length of the drawn line of best fit. Gradient points are read off accurate to half a small square. **[1]**
- Zero mark for above if gradient obtained from plotting reverse axis (x-y graph)
- Calculation for gradient is correct. Value for a is in 3 s.f. with correct units (m^{-1} or cm^{-1}) **[1]**

Determining the y-intercept

Substituting (0.450, 9.40) into $y = ax + b$

$9.40 = (17.3)(0.450) + b$

$b = 1.62\ \text{m}^{-1}$

- Either correct read off (with ½ small square precision) from y-intercept ($1/N = 0$) or by calculation using substitution into $y=ax + b$.
- Value for b is correctly calculated, in 3 .s.f and with correct unit. ECF allowed. **[1]**
- Zero mark if use data point not on the line of best fit for substitution.

a = 17.3 m^{-1}

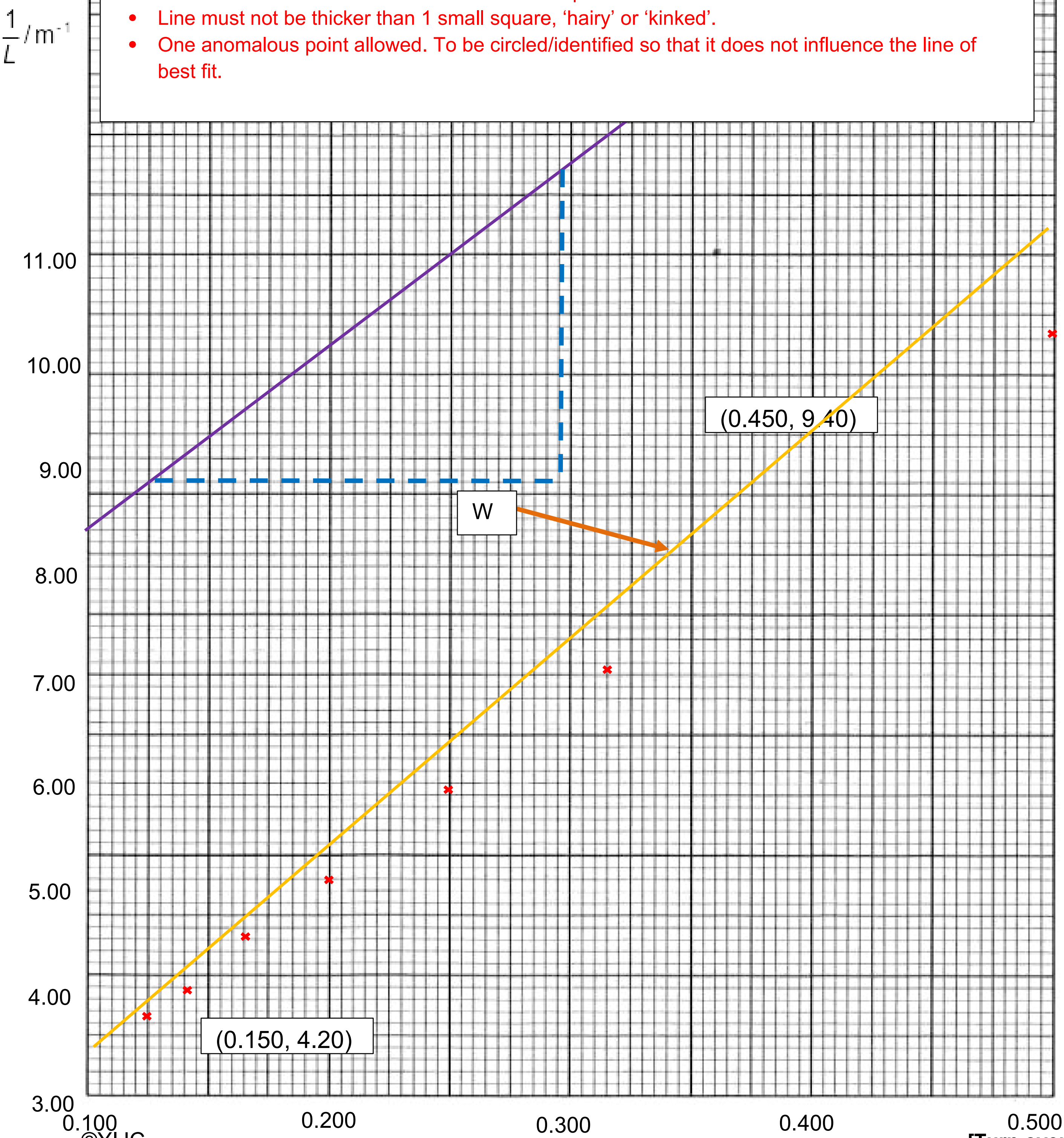
b = 1.62 m^{-1}

[7]

Axes [1]
- Axes are clearly labelled with units
- Sensible scales (no awkward scale eg 3:10)
- Scales chosen so that plotted points occupy at least 4 by 6 big squares.
- Scale markings should not be more than 2 big squares apart.

Plotting of points [1]
- Number of plotted points tally with observed data in table.
- Diameter of plotted points $\leq$ half a small square.
- Plots accurate to half a small square in both x and y direction.

Quality of best fit line [1]
- Reasonable line of best fit with even scatter of points.
- Line must not be thicker than 1 small square, 'hairy' or 'kinked'.
- One anomalous point allowed. To be circled/identified so that it does not influence the line of best fit.



(e) Without taking further readings, sketch a line on your graph grid to show the results you would expect if the experiment was repeated with the wire across AB replaced by one with the same length but with a **larger resistance per unit length**.

Label this line W. [1]

[Total : 16]

- The line W is the **same as the original** line plotted **[1]**
- The line MUST be labelled to show the same line is expected. No mark if line is not labelled clearly.

  No need for explanation.
- The potential difference across the length of wire AB is the same. Thus, the potential divider principle remains the same regardless of the resistance. The potential ratio is the same.

When p.d. = 0, by potential divider principle.

$$\frac{L}{L_o} = \frac{R}{R + \frac{10R}{N}} = \frac{1}{1 + \frac{10}{N}} \Rightarrow \frac{1}{L} = \frac{1}{L_o}\left(1 + \frac{10}{N}\right) = \frac{10}{NL_o} + \frac{1}{L_o}$$

In theory, since L_o = 0.60 m

$b = 1/L_o = 1/0.60 = 1.67\ \text{m}^{-1}$

$a = 10/L_o = 10/0.60 = 16.7\ \text{m}^{-1}$

Changing the resistance AB of same length does not impact the graph as L_o is still the same.

2 In this experiment, you will investigate the oscillatory motion of a loaded metre rule supported at one end by a spring.

(a) Secure the cork in the clamp so that the pin is mounted horizontally. Suspend one end of the rule from the pin by passing the pin through the hole in the rule. The rule should be able to pivot around the pin.

The other end of the metre rule has a spring attached to it through a small loop of string at the 0.5 cm mark. Hook the other end of the spring to the rod of another clamp as shown in Fig. 2.1.

The clamps should be adjusted so that the rule is approximately horizontal.

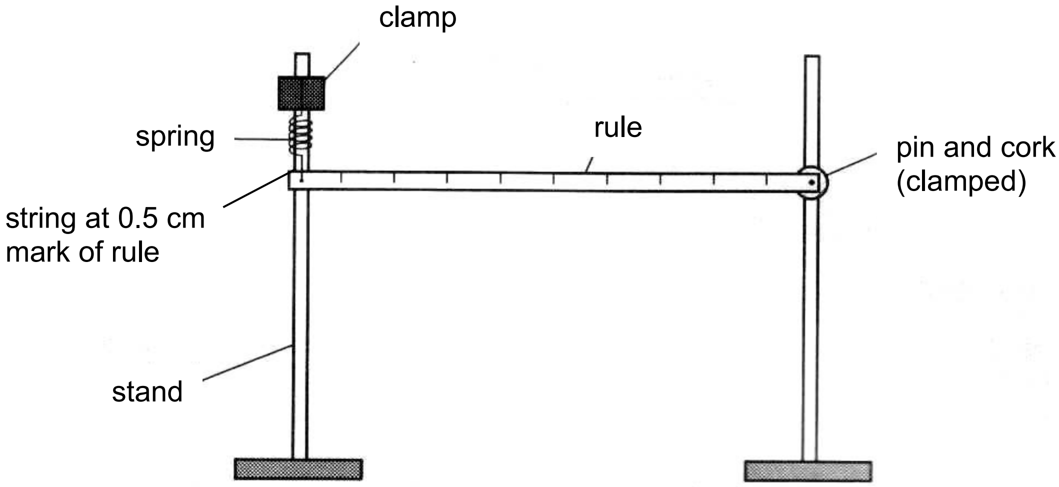


Fig. 2.1

(b) Hang the loop of string onto the rule to suspend a mass of 350 g a distance d from the pin as shown in Fig 2.2. The mass should be about halfway along the rule. Adjust the position of the clamps to make the rule approximately horizontal again.

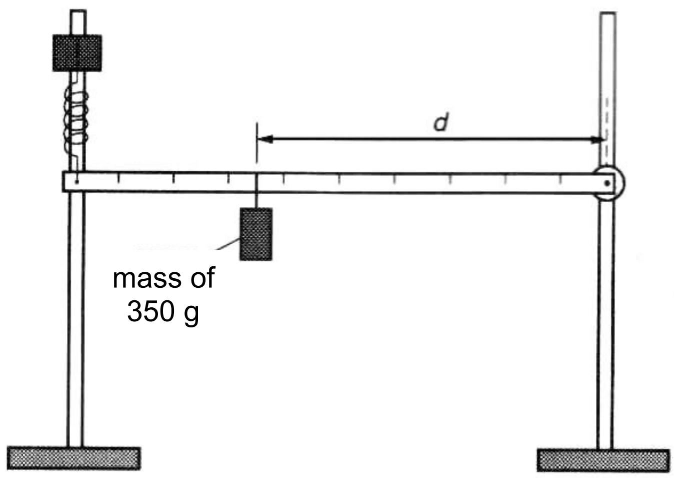


Fig. 2.2

(c) **(i)** Based on the scale on the metre rule, record the position of the loop attached to the hanging mass, X_A.

Record the position of the pin, X_B.

- nearest mm with units
- Both X_A and X_B to be correct
- 0.400 m <= X_A <= 0.600 m **[1]**

X_A = 0.500 m

X_B = 0.995 m OR 0.005 m

[1]

(ii) Determine *d*.

d = (0.500 – 0.005) = 0.495 m
OR
d = (0.995 – 0.500) = 0.495 m

- nearest mm with units
- 0.395 m <= d <= 0.595 m **[1]**

d = 0.495 m [1]

(d) Gently displace the end of the rule so that it performs small oscillations in a vertical plane.

Determine the period *T* of the oscillations.

N = 60
t_1 = 28.82 s
t_2 = 28.05 s
t_{ave} = 28.44 s

$T = t_{ave}$ / N = 28.44 / 60
= 0.4739 s

- repeated readings for t
  correct precision of stopwatch (2 dp)
  t > = 20 s **[1]**
- T correctly calculated to 4 sf with units **[1]**

T = 0.4739 s [2]

(e) The equation that relates *T* and *d* for this oscillator is

$$T^2 = \frac{4\pi^2}{kL^2}(Md^2 + C)$$

where k is 28.0 N m^{-1}, M is the mass of the load, L is 1.000 m and C is a constant.

Calculate *C*.

$$T^2 = \frac{4\pi^2}{kL^2}(Md^2 + C)$$

- C correctly calculated to the least sf of raw values **[1]**
- Correct units for C **[1]**

Substituting,

$$(0.4739)^2 = \frac{4\pi^2}{(28.0)(1.000)^2}[(0.350)(0.495)^2 + C]$$

C = 0.0735 kg m^2

C = 0.0735 kg m^2 [2]

[Total: 6]

3 In this experiment you will investigate the magnetic field produced by an electric current.

You are provided with two sets of a wire coiled around a plastic channel. One set is longer than the other.

Choose the **longer** plastic channel and set it on the raised board as shown in Fig. 3.1.

(The raised board placed on a pair of wooden blocks is necessary to reduce the effects of the magnetic materials under the table top.)

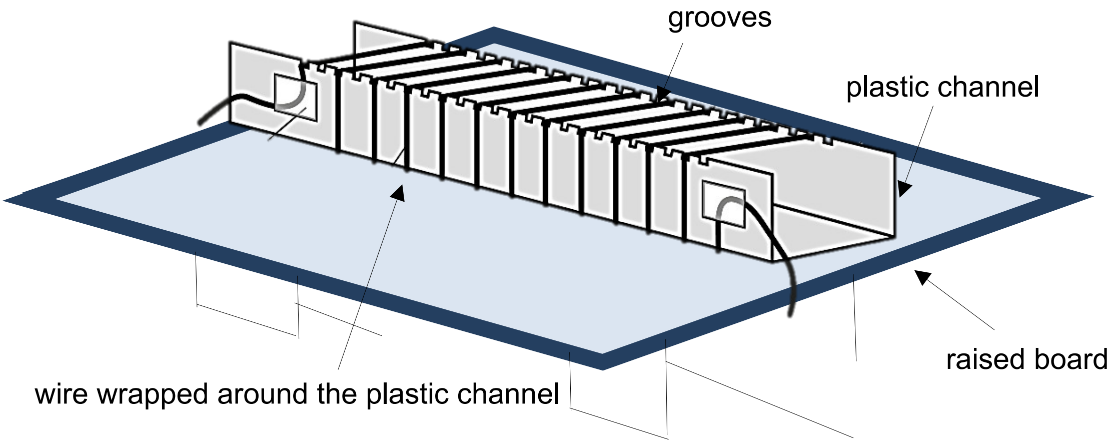


Fig. 3.1

(a) Count and record the number of **complete** turns N of wire in the coil.

N = ...9..............

(b) Slide the compass into the plastic channel so that it lies flat on the red circle in the middle of the coil. The coil is to be placed on the raised board.

Connect the circuit as shown in Fig. 3.2.

Rotate the plastic channel until the arrow of the compass is perpendicular to the channel, as shown in Fig. 3.2.

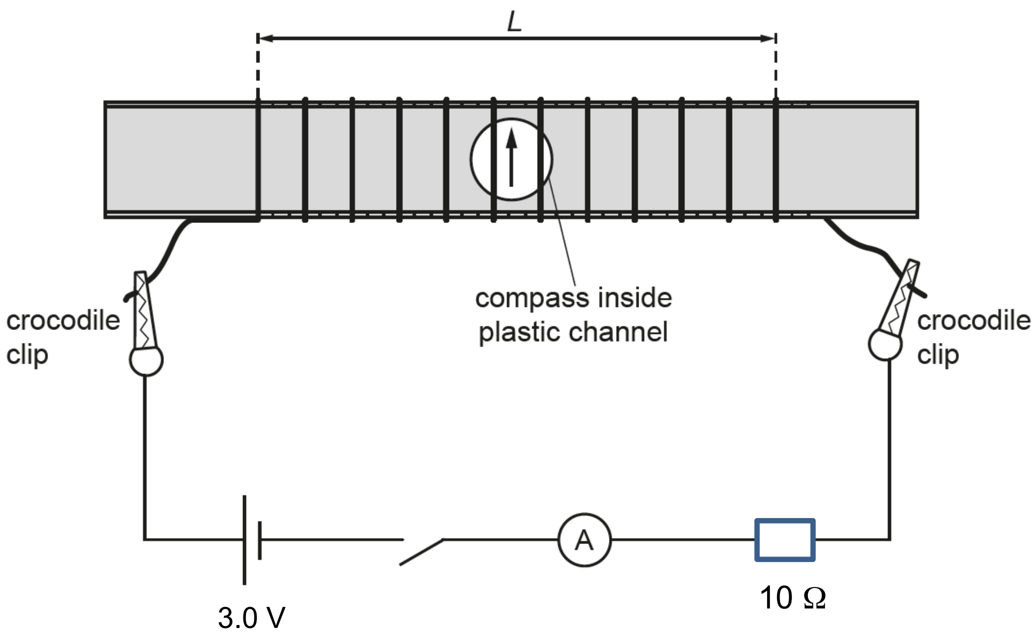


Fig. 3.2

The distance between the first and last turns of wire is L, as shown in Fig.3.2.

Measure and record L.

Value of L to nearest mm, with unit in range 15.5 to 16.5 cm. **[1]**

16.0 cm or 0.160 m

L = ... [1]

(c) Close the switch. The compass arrow will rotate through an angle θ.

Measure and record θ. $\theta = (10° + 12°)/2 = 11°$

Value of raw θ stated to nearest 2 degrees.
Average θ can be to the nearest degree.
Allowed range $4° \leq \theta \leq 16°$. Take average of repeated measurements.
[1]

θ = ...11 o

Record the ammeter reading I. ½ (103.4 + 101.5) = 102.5 mA

Value of I with unit to nearest 0.1 mA.
Take average of repeated measurements **[1]**

I = ...102.5 mA................

Open the switch.

[2]

(d) **(i)** Estimate the percentage uncertainty in your value of θ.

$$\frac{\Delta\theta}{\theta}\% = \frac{4}{10} \times 100 = 40\%$$

Absolute uncertainty is 4° to 8° as the compass is small.
Percentage uncertainty correctly obtained. **[1]**

40%

percentage uncertainty = ... [1]

(ii) Suggest one significant source of uncertainty in this experiment.

As indicated by above, the most significant source of uncertainty is in the measurement of the angle of deflection of compass needle. The smallest division of the scale is 2°. **[1]**

Other sources of uncertainty: Current (not much), parallax error (because needle is not over the scale).

.... [1]

(iii) Suggest an improvement that could be made to the experiment to reduce the uncertainty identified in **(d)(ii)**.

You may suggest the use of other apparatus or a different procedure.

....

....

We can improve the measurement of the angle of deflection (reduce the uncertainty of the scale) by placing the compass on a sheet of paper and make marking on it to

...... [1]

(e) Calculate the value of B using

$$B = \frac{\mu_o N I}{L}$$

where $\mu_o = 1.26 \times 10^{-6}$ N A^{-2}.

$$B = \frac{(1.26 \times 10^{-6})(9)(102.5 \times 10^{-3})}{0.160}$$

$= 7.26 \times 10^{-6}$ T (or N A^{-1} m^{-1})

Correct calculation for B. **[1]**

B = ... N A^{-1} m^{-1} [1]

(f) Disconnect the crocodile clips and remove the compass.

Place the compass inside the middle of the **shorter** plastic channel as shown in Fig.3.3.

Reattach the crocodile clips.

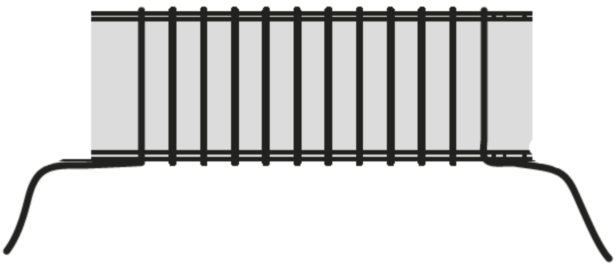


Fig. 3.3

Repeat steps **(a)**, **(b)**, **(c)** and **(e)**.

N = ...9...............

L = ...8.0 cm...............

$$\theta = \frac{22+22}{2} = 22^{\circ}$$

$$I = \frac{100.5+100.3}{2} = 100.4\ \text{mA}$$

θ = ...22..........o

I = ...100.4 mA..........

Value of raw θ with precision 2°, Angle must be greater than (c).
Take average of repeated measurements.
ECF if penalised before **[1]**
Same for current **[1]**

$$B = \frac{(1.26\times10^{-6})(9)(100.4\times10^{-3})}{0.080}$$

$= 1.42\times10^{-5}$ T (or N A^{-1} m^{-1})

Correct calculation for B **[1]**

B = ...1.42×10^{-5}.......... N A^{-1} m^{-1}

[3]

(g) It is suggested that the relationship between θ and B is

$$\tan\theta = \frac{B}{k}$$

where k is a constant.

(i) Using your data, calculate two values of k.

First value for k

$$k = \frac{7.26\times10^{-6}}{\tan 11^{\circ}} = 3.7\times10^{-5}\ \text{T}$$

Second value for k

$$k = \frac{1.42\times10^{-5}}{\tan 22^{\circ}} = 3.5\times10^{-5}\ \text{T}$$

Two values of k calculated correctly with unit **[1]**
ECF allowed

first value of k = ...

second value of k = ...

[1]

(ii) Justify the number of significant figures you have given for your values of *k*.

The values for *k* are expressed in 2 s.f. because the least significant figures among the values in θ, *L* and *I* is 2.

.... [1]

(iii) State whether the results of your experiment support the suggested relationship. Justify your conclusion by referring to your answers in **(d)(i)**.

Method 1

Percentage difference = $\left(\dfrac{3.7 - 3.5}{3.5}\right)\times 100 = 5.7\%$

This is less than the 40% uncertainty listed in (d)(i). Therefore, the relation is valid.

Method 2

Percentage uncertainty = $= \dfrac{\frac{1}{2}range}{average} = \left(\dfrac{3.7 - 3.5}{3.7 + 3.5}\right)\times 100 = 2.8\%$

This is less than the 40% uncertainty listed in (d)(i). Therefore, the relation is valid.

[1]

(h) In an investigation, the compass is inserted into a certain plastic channel where the relation between the angle of deflection θ and the current *I* in the wire is related by the equation.

$$\tan\theta = \frac{\mu_o n I}{B_E}$$

where

μ_o = 1.26 $\times$ 10^{-6} N A^{-2}

n = number of turns per unit length = 1200 per metre.

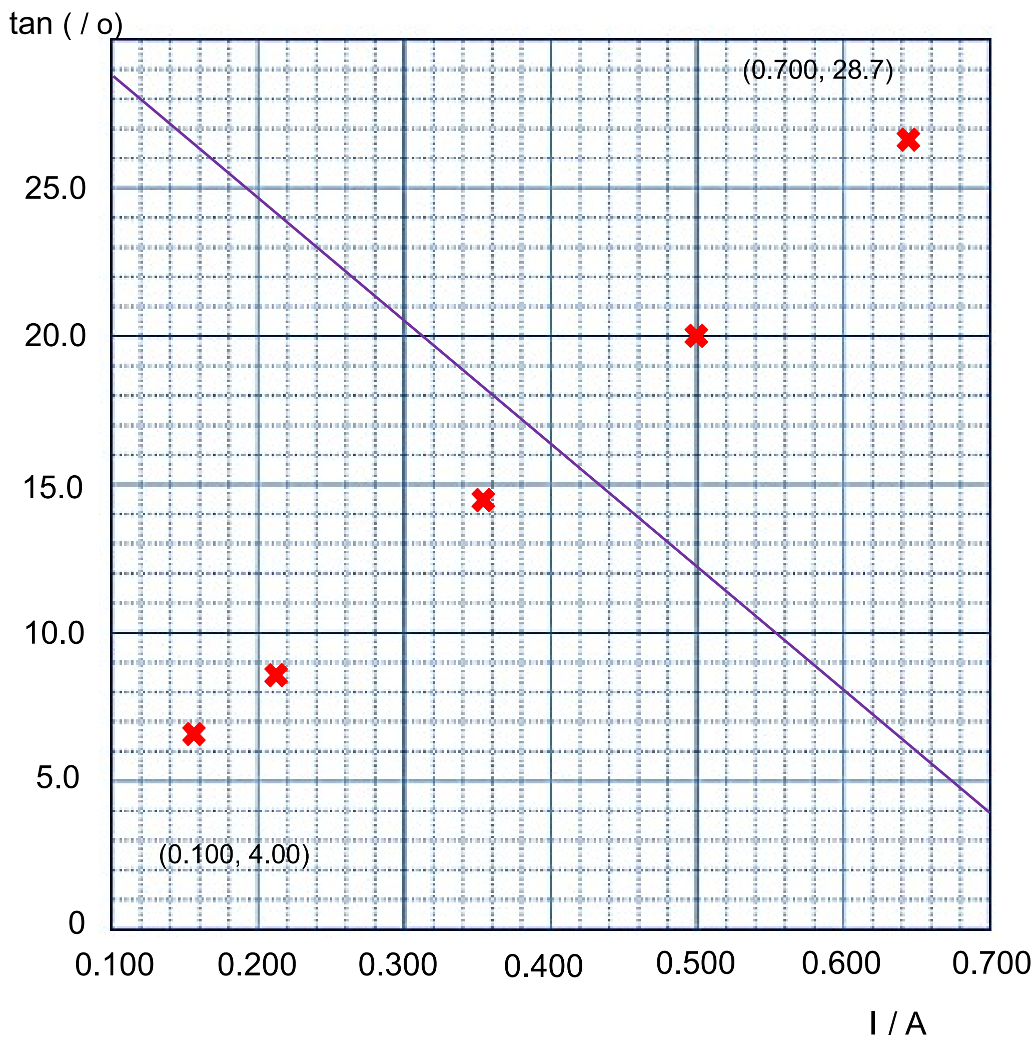
B_E = the horizontal component of the Earth's magnetic flux density.

The following results for *I* and tanθ were recorded.

I / A	0.156	0.209	0.357	0.572	0.648
tan (θ / °)	6.37	8.54	14.6	23.4	26.5

(i) Plot tanθ against *I* on the grid and draw the straight line of best fit. [1]

Points accurately plotted to ½ small square precision.
Line of best fit with even scattering of points **[both satisfied - 1]**



(ii) Use your graph to determine the value of B_E, the horizontal component of the Earth's magnetic flux density.

Gradient = $\dfrac{(28.7 - 4.0)}{(0.700 - 0.100)}$ = 41.7

$$\frac{\mu_o n}{B_E} = gradient \quad \Rightarrow \quad \frac{(1.26\times10^{-6})(1200)}{B_E} = 41.167$$

$B_E = 3.67\times10^{-5}$ T = 36.7 μT

Relating the equation to gradient **[M1]**

Correct substitution of data, gradient correctly obtained (updated) **[M1; do not accept substitution of a single set of coordinates]**

Correct calculation of Earth's magnetic flux density horizontal component **[A1]**

B_E = ……………………………… N A^{-1} m^{-1} [3]

(i) The experiment in **(h)** is repeated. Instead of using a magnetic compass to determine the magnetic flux density at the centre of the current carrying solenoid, a Hall probe is to be used.

Plan an investigation using the same set of apparatus to verify the relationship between the magnetic flux density B at the centre of the solenoid and the current I in the solenoid given as

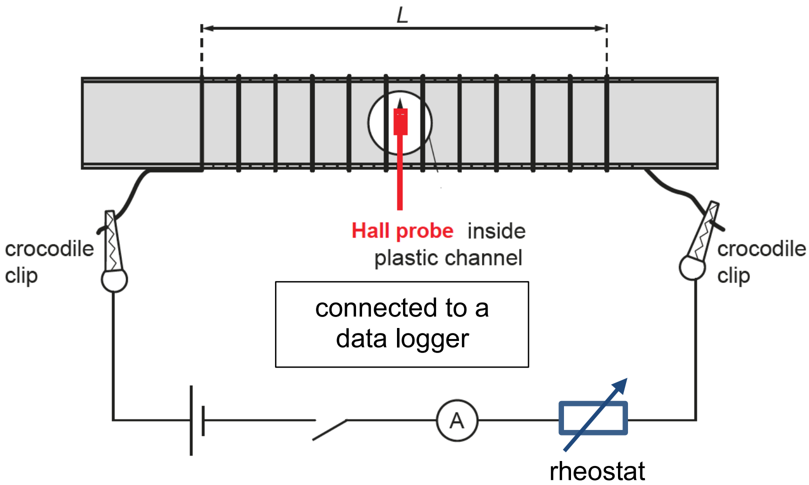
$$B = \mu_o n I$$

where n is the number of turns per unit length along the solenoid.

Your account should include:

- your experimental procedure (with a circuit diagram)
- managing the controlled variables
- details of how the Hall probe is used
- how the above relation is verified

You may suggest the use of any additional apparatus commonly found in a school physics laboratory.



Reference to be made to the diagram student draws. The written description should complement the diagram which must include a **rheostat** (or some ways to vary the current and the **Hall probe** inserted inside the solenoid).

Arrangement [1]

Similar to the instruction in **(b)**, the solenoid is firstly orientated such that the compass needle is perpendicular to the solenoid. This is to offset the Earth's magnetic field.

The setup shows the Hall probe placed inside the solenoid where the compass used to be.

Control of variables [1]

- The number of turns per unit length of the coil is fixed.
- The orientation of the solenoid is fixed.

Procedure with Hall probe [1]

To vary the current, a **rheostat** is connected in series with the circuit. The current is measured using an ammeter while the magnetic flux density B using the calibrated Hall probe. The Hall probe has to be orientated **normally** to the solenoid's magnetic field. The probe should be connected to a data logger.

Verifying the relation [1]

A graph of B against I is plotted. If a straight line passing through the origin is obtained, the relation is verified.

....

....

.... [4]

[Total: 21]

4 A student wishes to investigate the surface texture of a new coating material.

The material is spray coated onto the surface of a circular disk and attached to the axle of a motor at its centre. A small object is then placed onto the disk at a distance r from the centre and the motor is started to rotate the disk about its centre as shown in Fig. 4.1.

When the static friction between the surface of the coating and the object is exceeded, the object is observed to start slipping off the coated surface. This happens when the maximum angular speed, ω, of the disc is reached before slippage is observed.

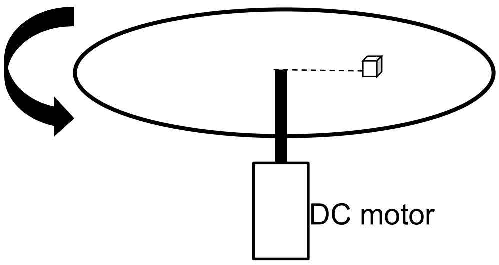


Fig. 4.1

The student suggested that the relationship between the maximum angular speed of the disc, ω, the mass of the object, m, and its distance from the centre of the disc, r, may be expressed in the form

$$\omega = Am^x r^y$$

where A, x and y are constants.

You are provided with a DC motor and a controller to adjust the rotational speed of the motor. You may also use any of other equipment usually found in a physics laboratory.

Design an experiment to determine the values of x and y.

Draw a diagram showing the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use and measurements to be taken,

(c) the procedure to be followed,

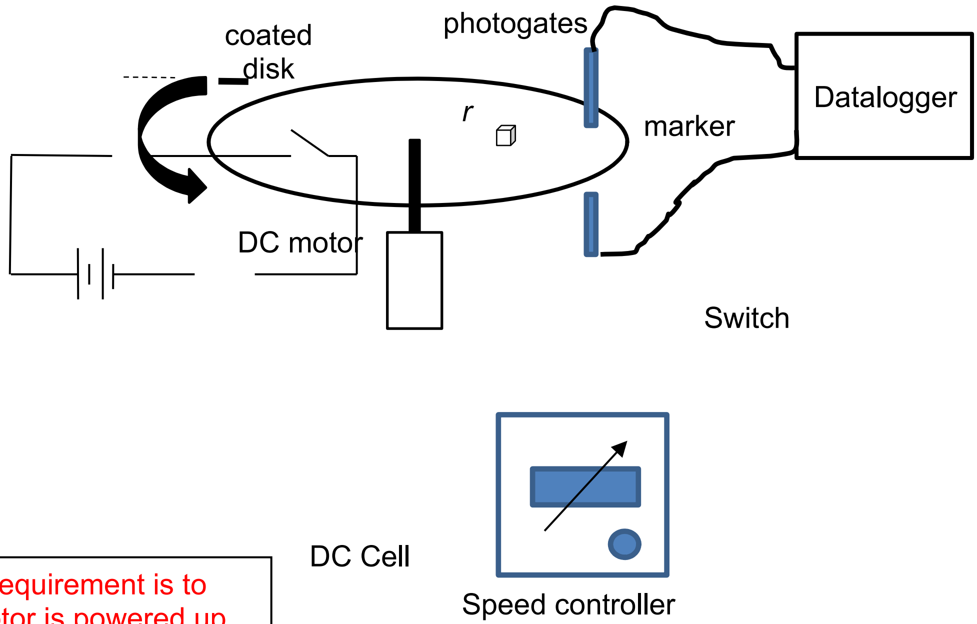
(d) how you would determine the maximum angular speed, ω, of the disc,

(e) the analysis of the data,

(f) any precautions that would be taken to improve the accuracy and safety of the experiment.

<u>Suggested Mark scheme for planning question 4</u>

Diagram



[D1] – Minimum requirement is to show how DC motor is powered up and how rotation speed is adjusted and measured

S/No	Description
1	**<u>Defining the problem (AIM)</u> [A1] for identifying dependant, independent and control variables for both sets of experiments** The aim of the experiment is to find the unknowns *x* and *y* in the relationship $\omega = A\, m^x\, r^y$ The dependent variable is the angular speed ω of the coated disk. There are two independent variables – mass of the small object *m* and the distance of the object from the centre of the disk *r*. Thus, two sets of experiments that are to be carried out (1) Determining ω by varying *r* (with *m* kept constant) (2) Determining ω by varying *m* (with *r* kept constant)

	The other factors to be controlled are • Use a similar DC motor, coated disk and same object shape throughout the 2 sets of experiments to maintain the same surface interface conditions between object and disk.
2	**Method of data collection (PROCEDURE)** **EXPT 1 – To determine the value of *y*** a) Cut out a small slit marker on the circular disk as shown in the diagram above. Attach a pair of photogates across the slit marker so that light from the photogates can pass through the open slit. Connect the photogates to a datalogger. The datalogger is capable of measuring the angular speed of the disk. b) Place a small object of mass m, at a distance r from the centre of the disk. c) The mass, m is measured by a top-pan balance and the distance r is measured by a 30 cm ruler) **[P1]** d) Turn on the switch and slowly increase the speed of the DC motor by adjusting the speed controller. Stop increasing the speed once the mass starts to slip on the coated surface. **[P1]** e) Record the angular speed ω from the datalogger. **(a)&(e)[P1]** f) Using the same mass, repeat steps 2(b) to 2(e), 5 more times to obtain different datasets for ω and r each time increasing r by by a short distance from the centre of the disk. *(procedure to keep m the same and vary r is necessary in the repeat statement)* **[P1]** **EXPT 2 – To determine the value of *x*** g) Select a fixed distance r throughout this 2nd set of experiments. h) Conduct the experiment as per Expt 1, 2(b) to 2(e) to obtain the first data set of ω and m. i) Repeat steps 2(g) to 2(h), 5 more times to obtain different datasets for ω and m each time by increasing the mass m by using different objects. *(procedure to keep r the same and vary m is necessary in the repeat statement)* **[P1]**
3	**Method of analysis (ANALYSIS)** **EXPT 1 [N1]** Linearizing the equation gives $\lg \omega = y \lg r + \lg (A m^x)$. Plot a graph of $\lg \omega$ against $\lg r$. – GRAPH 1. The constant y will be the gradient and the y-intercept will be $\lg (A m^x)$. **EXPT 2 [N1]** Linearizing the equation gives $\lg \omega = x \lg m + \lg (A r^y)$ Plot a graph of $\lg \omega$ against $\lg m$. – GRAPH 2. The constant x will be the gradient and the y-intercept will be $\lg(A r^y)$.

4	**Safety considerations (SAFETY)** S1: To ensure safety, wear safety goggles in case the object slips and flies off the high speed rotating disk and injures the eye. S2: Ensure that the rotating disc is horizontal by checking it with a spirit level gauge so that there will not be imbalance when the small object is placed on it. S3: Place proper shielding around the setup, to prevent mass from hitting nearby observers when it slips off the rotating disc. S4: Any other valid safety points
5	**Reliability considerations (RELIABILITY)** R1: Ensure that *r* is measured from the centre of rotating disc to centre of mass for a more accurate reading of *r*. R2: Show understanding of reducing random error in experiment: Take a few readings of ω for each *m* or *r* and take the average value. R3: Ensure that the object is small but of high density, so that slippage occur only at sufficiently high revolution speeds to minimize random error when taking speed measurements. R4: Increase the speed of the rotating disc slowly to allow sufficient time for the rotation speed to reach steady state before the next speed increment. This allows for more accurate reading of ω. R5: Any other valid reliability points **(Safety and reliability statements max 3 marks) – either 1S & 2R or 2S & 1R**

[Total: 12]