H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CLASS		TUTOR'S NAME	
CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS 9749/04

19 August 2024

Paper 4 Practical

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name, class, tutor's name, Centre number and index number 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 a HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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 or if you do not use appropriate units.

Give details on 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	
2	
3	
4	
Total	**/ 55**

1 In this experiment, you will investigate the resistivity of a constantan wire.

(a) **(i)** Connect the circuit as shown in Fig. 1.1 with the switch open.

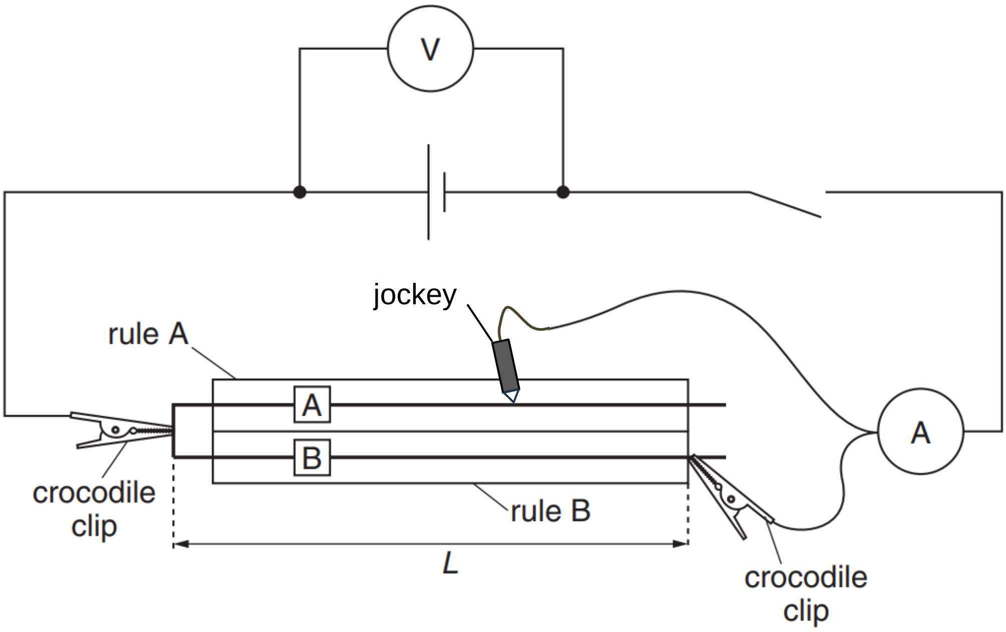


Fig. 1.1

The wire on rule B should be connected by a crocodile clip at each end.

L is the length of wire between the crocodile clips.

(ii) With the switch open, record the voltmeter reading *V*.

1.4 V- 1.6V
Correct range, units and dp

V = 1.583 V

(b) **(i)** Measure and record the length *L*.

L = 1.050 m

1.02m – 1.07m
Correct range, units and dp [1].
Either one wrong is 0m

Examiners' comments:
Students must measure the length carefully. The correct range needs to be given.

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

ΔL = 0.2 – 0.5 cm

Percentage uncertainty = $\frac{\Delta L}{L} \times 100\% = \frac{0.3}{105} \times 100\% = 0.3\%$

1 or 2 sf [1].

percentage uncertainty = 0.3 %
[1]

Examiners' comments:
Many are able to calculate the percentage error. Common error is the wrong choice of ΔL.

(c) **(i)** Close the switch. Place jockey on the wire on rule A at a distance x from the end of the rule, as shown in Fig. 1.2. The value of x should be about 40 cm.

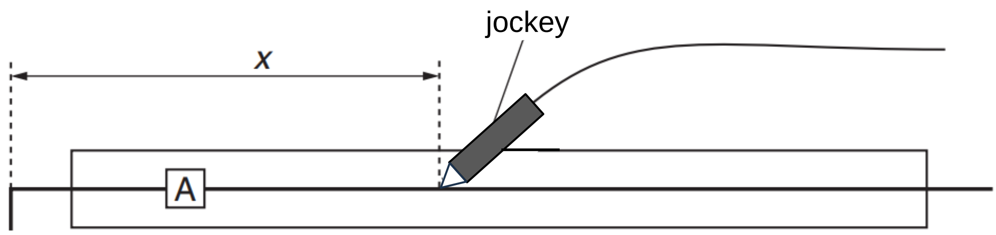


Fig. 1.2

(ii) Measure and record the distance *x* and the ammeter reading I.

x = 40.0 cm

I = 0.33 A

(iii) Remove the jockey from the wire on rule A and open the switch.

(d) Repeat **(c)** for further values of *x* and the corresponding values of I.

x/ cm	*I* / A	$\frac{1}{x}$ / cm $^{-1}$
20.0	0.51	0.0500
30.0	0.40	0.0333
40.0	0.33	0.0250
50.0	0.30	0.0200
60.0	0.23	0.0167
70.0	0.21	0.0143
80.0	0.19	0.0125

Examiners' comments:
Some readings of I are not possible, which shows that the experiment was set up wrongly.
Many did not maximise the range of the wire.
Most are able to write the table correctly.

6 or more sets of data collected without assistance/ intervention [1]
Each column heading *x*, *I* and 1/*x*, is a quantity and has a unit [1]
All values of *x* and *I* to the correct values, d.p. AND correct s.f. for 1/*x* [1]

[3]

(e) Theory suggests that I and x are related by the expression

$$I = \frac{P}{x} + Q$$

where P and Q are constants.

Plot a suitable graph to determine the values of P and Q.

A graph of I is plotted against $1/x$, with gradient equals to P and y-intercept equals to Q.

gradient = $\frac{0.5000-0.1950}{0.0470-0.0100}$ = 8.24 A cm

P = 8.24 A cm

y-intercept = 0.500 – 8.24 (0.0470) = 0.113 A

Q = 0.113 A

y-intercept correctly read off to the nearest half small square

OR correctly determined from y = mx + c using a point on the line [1]

Distance between points chosen for gradient calculation > half length of drawn line

AND gradient read-offs accurate to half a small square AND gradient calculated correctly [1]

Values of P and Q calculated correctly with units [1]

Examiners' comments:

- Sf and dp rules should always be applied in calculations.
- The number of dps of readings off a 5-scale should reflect the uncertainty of ½ of the smallest square
  For example: 1 division : 5 → uncertainty = ½ × (5 / 10 squares) = 0.3 (1 sf)

P = ...

Q = ... [3]

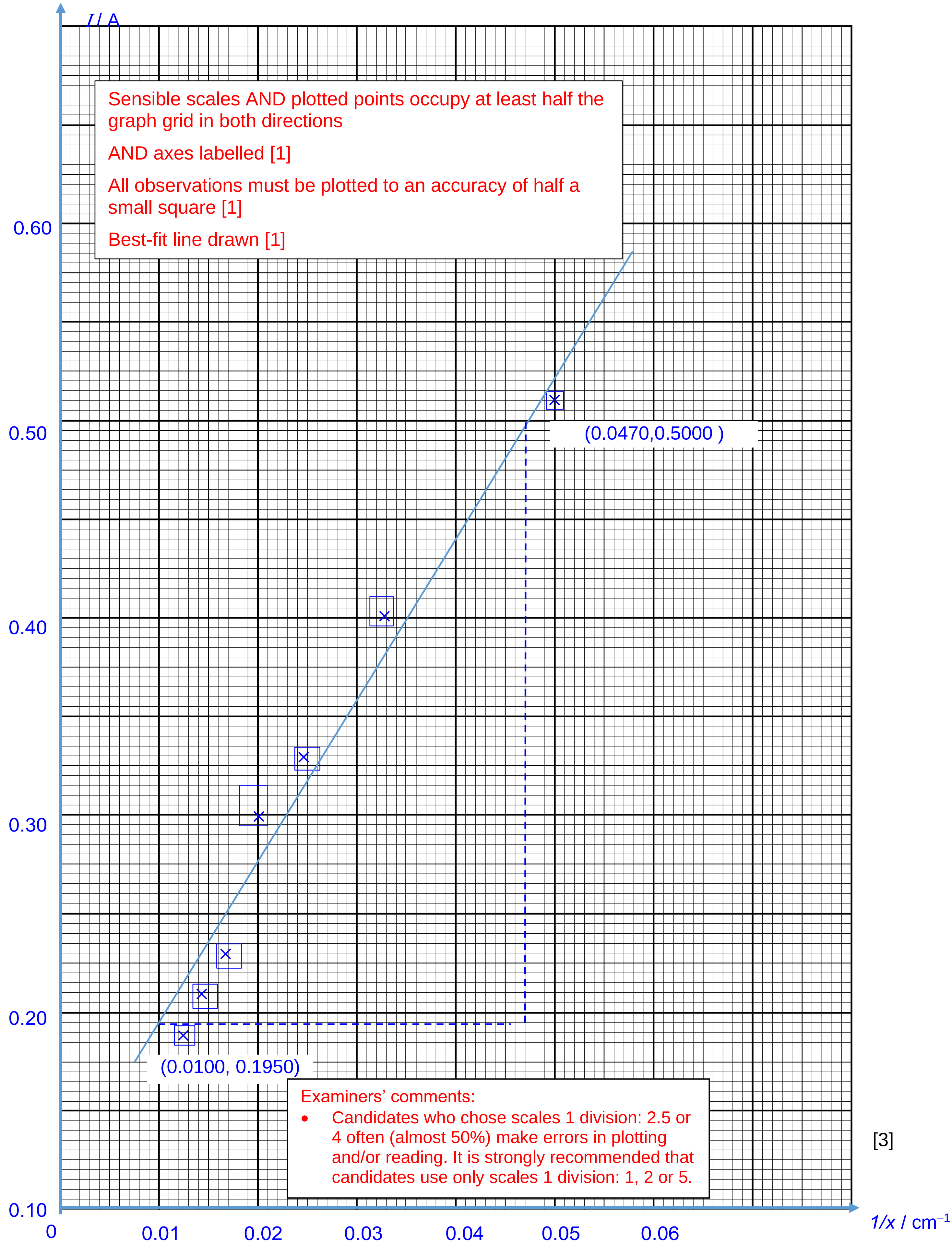
(f) The experiment is repeated with a battery of larger value of e.m.f.

Sketch a line on your graph grid used in **(e)** to show the expected result.

Label this line W. [1]

[Total: 12]

Larger y-int [B1]
Ignore the gradient (which should be the same).



Sensible scales AND plotted points occupy at least half the graph grid in both directions

AND axes labelled [1]

All observations must be plotted to an accuracy of half a small square [1]

Best-fit line drawn [1]

Examiners' comments:

- Candidates who chose scales 1 division: 2.5 or 4 often (almost 50%) make errors in plotting and/or reading. It is strongly recommended that candidates use only scales 1 division: 1, 2 or 5.

[3]

2 In this experiment, you will investigate the oscillations of a torsional pendulum.

Set up the provided apparatus as shown in Fig 2.1. Adjust the lengths of the strings such that the red markings on the strings lie just below the disc B, and secure the strings to disc B using the binder clips provided. Place **four** 50g masses on the centre of disc A in a vertical stack

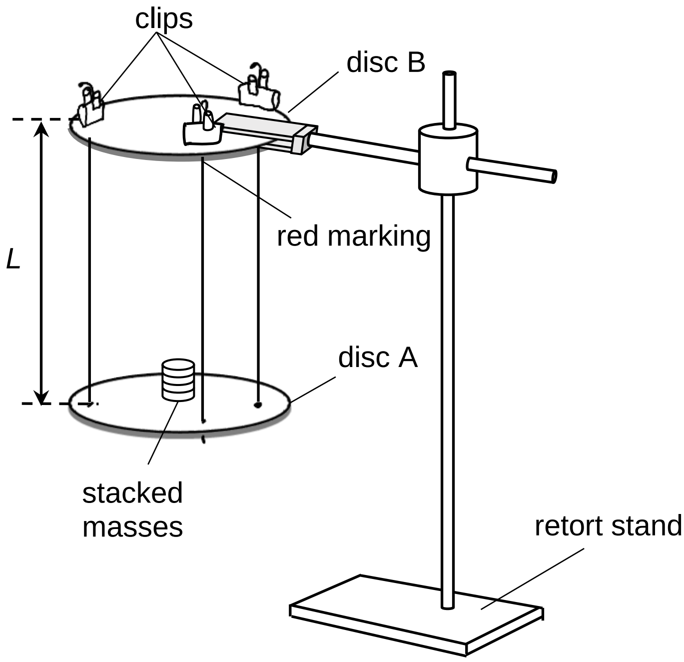


Fig 2.1 (Front view)

(a) Measure and record the distance *L* between the two discs.

Examiners' comments:
Some readings of L are not possible, which shows that the experiment was set up wrongly.

1 dp of cm, 49 cm < L < 52 cm B1

L = ...50.5.... cm [1]

(b) Displace disc A by a small angle about the centre of the disc. Release the disc so that it performs torsional oscillations in the horizontal plane about its centre. (See Fig. 2.2.)

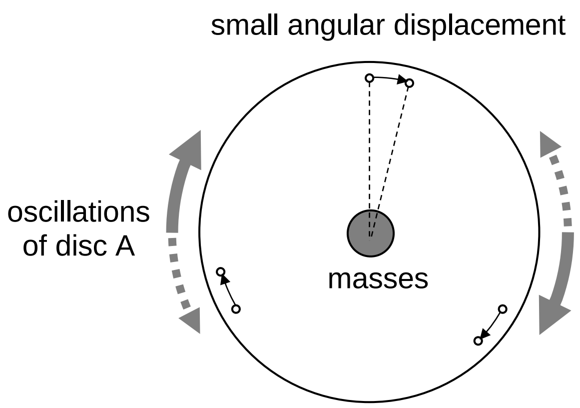


Fig. 2.2 (Top view)

Make measurements to determine the frequency f of the oscillations

Time for 30 oscillations $t = \dfrac{15.00 + 15.12}{2} = 15.06$ s

$f = 1/T = \dfrac{30}{15.06} = 1.992$ Hz

Repeated measurements B1
Time greater than 10 s B1
Correct calculation of f B1

f = 1.992 Hz [3]

(c) Make further measurements to determine the mass M required at the centre of disc A such that the frequency f of the oscillations is 1.50 Hz. Show your working clearly.

M / g	N	t_1/s	t_2/s	T/s	f/Hz
200	30	15.00	15.12	0.5020	1.992
150	25	13.90	13.96	0.5572	1.795
100	25	15.81	15.76	0.6314	1.584
50	20	15.08	15.08	0.7540	1.326

At least 2 more sets of data B1

Closest values of M used B1

Interpolation to obtain M B1

$$\frac{1.50 - 1.326}{M - 50} = \frac{1.584 - 1.326}{100 - 50} \rightarrow M = 83.7 \text{ g}$$

Examiners' comments:
If interpolation is to be made, the extra readings to be taken should be in between 1.50 Hz.
It is good to see many had taken additional readings but many just give a mass without explaining in details.

M = 83.7 g [3]

etermine the value of M for f = 5.00 Hz using the method in **(c)**.

Oscillations are too fast such that it will be very difficult to keep an accurate count of the number of oscillations.

Reason related to high frequency and human limitation B1

[1]

[Total: 8]

Examiners' comments:
There is no measurement of period in (c). Hence, the error should not be linked to period.

3 A flywheel is a mechanical device that uses the conservation of angular momentum to store rotational energy.

In this experiment, you will investigate the properties of a flywheel modelled by a slotted mass system.

(a) **(i)** Measure and record the diameter D_1 of the 100 g slotted mass.

1st reading of $D_1 = 3.5$ cm

2nd reading of $D_1 = 3.5$ cm

$\langle D_1 \rangle = 3.5$ cm

D_1 = 3.5 (3.4 to 3.6) cm [1]

evidence of repeated readings and D_1 recorded to nearest 0.1 cm and within 3.4 cm to 3.6 cm

Examiners' comments: Measurement of diameter of a circular/spherical object must be repeated.

(ii) Calculate C using

$$C = M_1 D_1^2$$

where M_1 = 0.100 kg.

$$C = M_1 D_1^2$$
$$= (0.100)(3.5)^2$$
$$= 1.2 \text{ kg cm}^2$$

C = 1.2 kg cm^2 [1]

correct calculation of C with units

(iii) Justify the number of significant figures that you have given for your value of C.

Number of significant figures (s.f.) for C is based on the least s.f. of M_1 and D_1, which is 2 s.f. [1]

Examiners' comments: Sf of the two variables must be compared to arrive at an answer. M_1 is not a constant and is already pre-measured with 3 sf.

(iv) Insert the plastic straw into the slot of the slotted mass, as shown in Fig. 3.1.

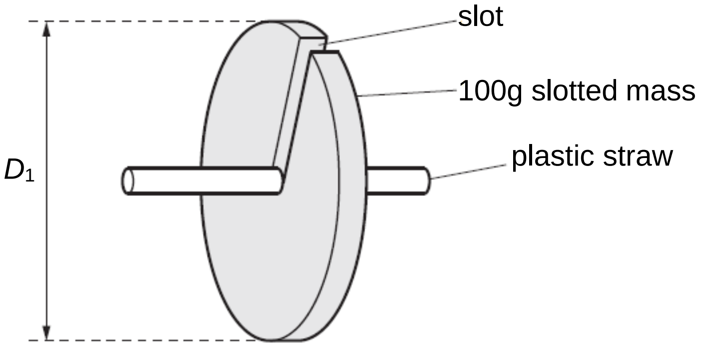


Fig. 3.1

(v) Assemble the apparatus in Fig. 3.2.

Loop one end of the string around one end of the straw and **pass the rest of the string through the slot of the slotted mass** and down to the floor, as shown in Fig. 3.2.

Hook the mass hanger onto the other end of the string loop and then adjust the height of the flywheel until the mass hanger is just touching the floor and the rod is horiztonal.

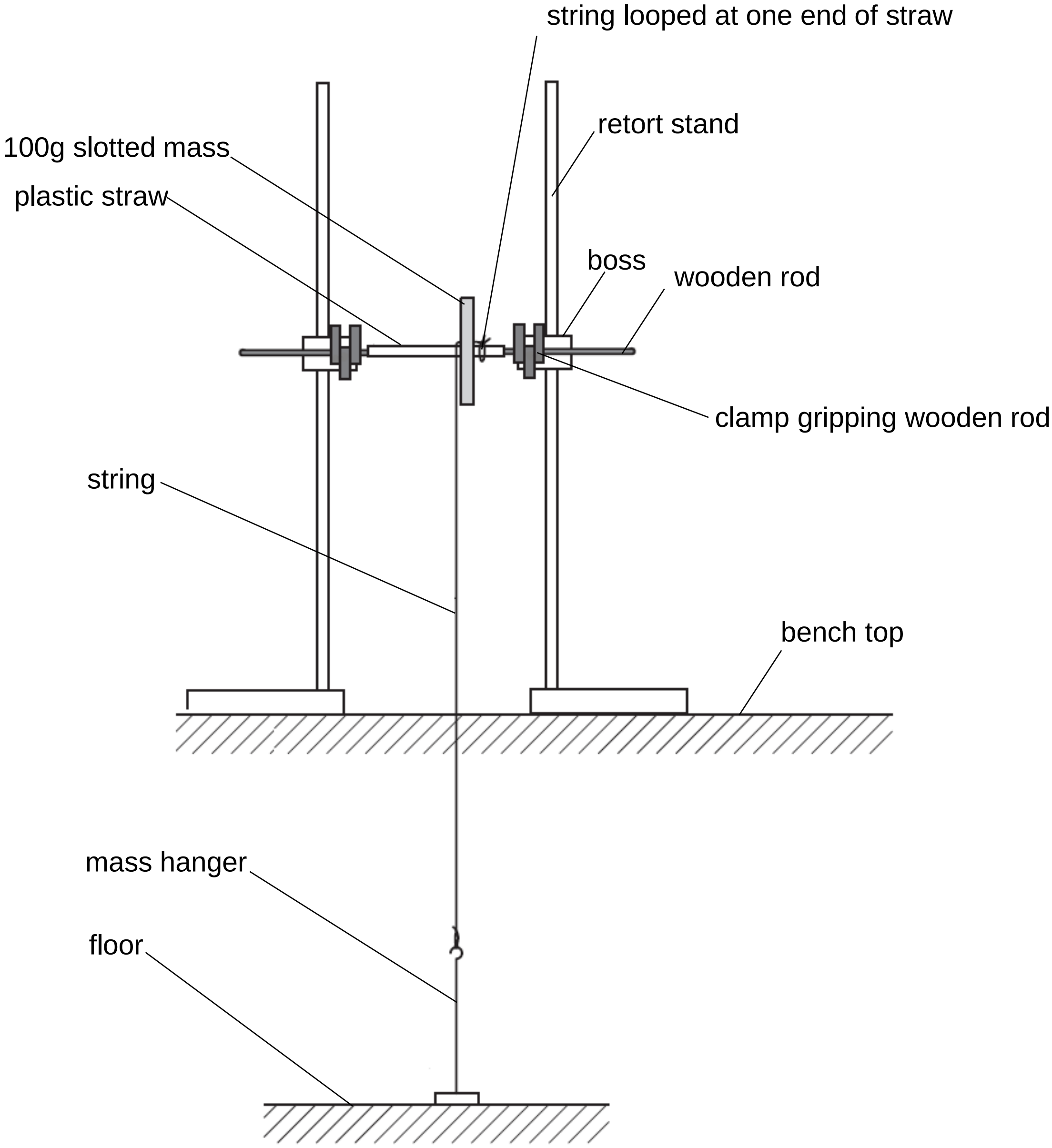


Fig. 3.2

(vi) Rotate the slotted mass 20 times so that the string is wound around the straw, as shown in Fig. 3.3.

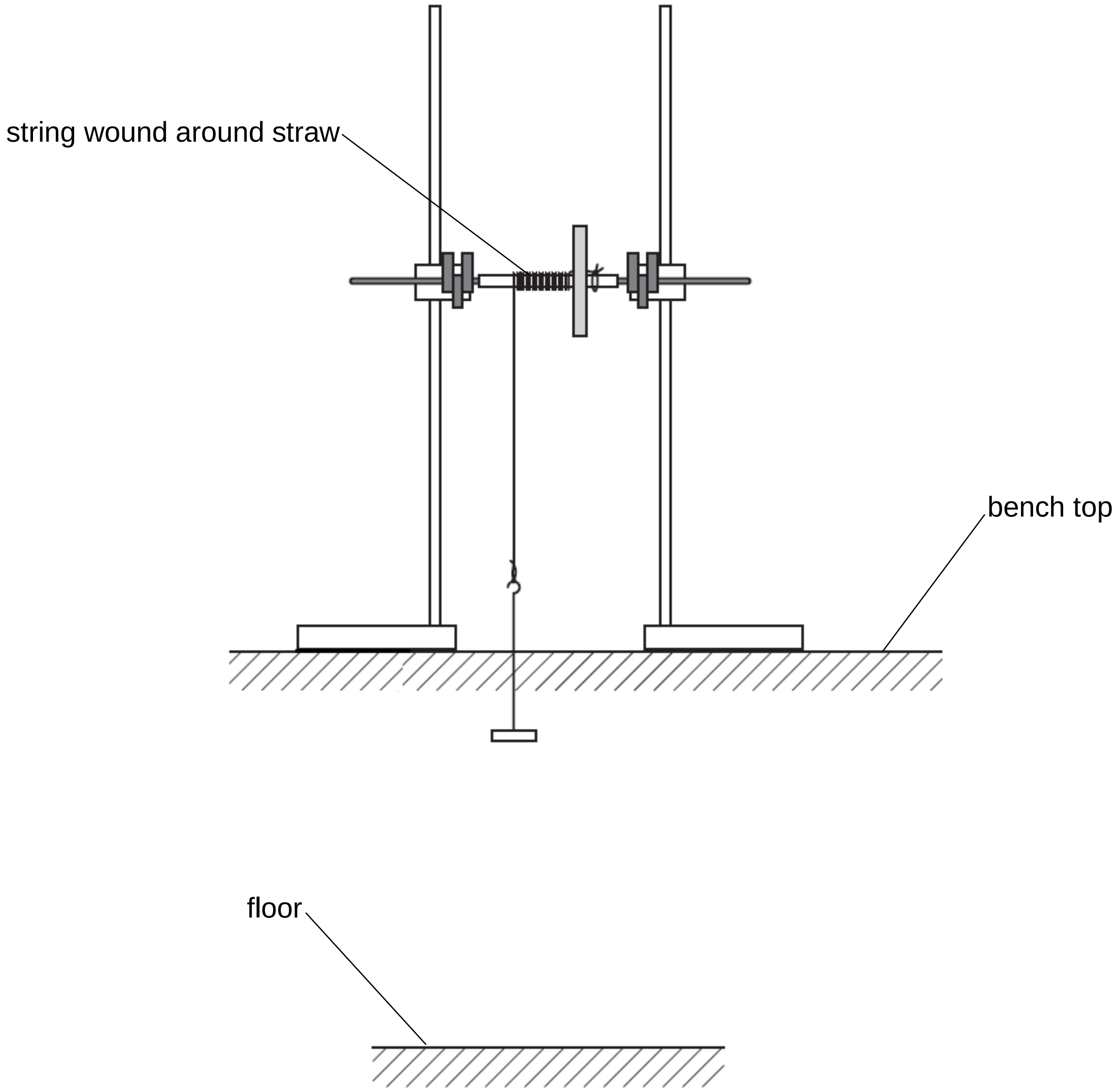


Fig. 3.3

Release the slotted mass and take measurements to determine the time *t* for the mass hanger to reach the floor.

1st reading of $t = 1.82$ s

2nd reading of $t = 1.84$ s

$\langle t \rangle = 1.83$ s

t = 1.83 s [2]

evidence of repeated readings
***t* to nearest 0.01 s, with unit**

Examiners' comments:
All time interval should be repeated.

(b) (i) Using **all** the modelling clay, mould the modelling clay to form a ring of uniform thickness around the outside of the slotted mass, as shown in Fig. 3.4. Ensure that the modelling clay is securely attached to the slotted mass so that it does not fall off when rotating.

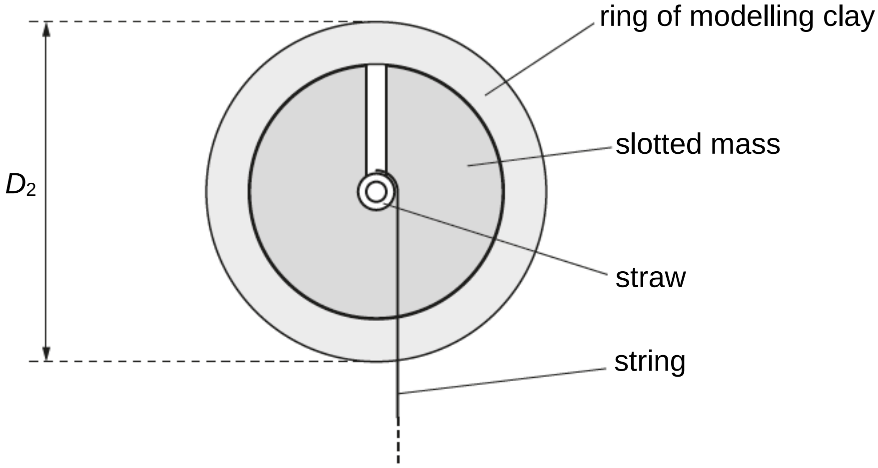


Fig. 3.4

Measure and record the outer diameter D_2 of the ring of modelling clay and slotted mass, as shown in Fig. 3.4.

1st reading of $D_2 = 8.2$ cm
2nd reading of $D_2 = 8.4$ cm
$\langle D_2 \rangle = 8.3$ cm

D_2 = 8.3 cm [1]

D_2 > D_1 and recorded to nearest 0.1 cm, repeated reading

(ii) Estimate the percentage uncertainty in your value of D_2.

$$\frac{\Delta D_2}{D_2} \times 100\% = \frac{0.3}{8.3} \times 100\%$$
$$= 3.6\ \%$$

0.2 cm ≤ ΔD_2 ≤ 0.5 cm
% uncertainty correct to 1 or 2 s.f.

percentage uncertainty = 3.6 % [1]

(iii) Calculate C using

$$C = (M_1 + M_2)D_1^2 + M_2 D_2^2$$

where the mass of the modelling clay, M_2 = 0.100 kg.

$$C = (M_1 + M_2)D_1^{\,2} + M_2 D_2^{\,2}$$
$$= (0.100 + 0.100)(3.5)^2 + (0.100)(8.3)^2$$
$$= \ 9.3 \text{ kg cm}^2$$

C = 9.3 kg cm^2 [1]

correct calculation of *C* and units

(iv) Rotate the slotted mass 20 times so that the string is wound around the straw, as shown in Fig. 3.3.

Release the slotted mass and take measurements to determine the time t for the mass hanger to just touch the floor.

$$\text{1st reading of } t = 5.38 \text{ s}$$
$$\text{2nd reading of } t = 5.46 \text{ s}$$
$$\langle t \rangle = 5.42 \text{ s}$$

t = 5.42 s [2]

value of *t* seen, with unit
new value of *t* is greater than first *t*

(c) (i) It is suggested that the relationship between t and C is

$$t^2 = kC$$

where k is a constant.

Using your data, calculate two values of k.

$$k_1 = \frac{t^2}{C} = \frac{1.83^2}{1.2} = 2.8 \text{ s}^2 \text{ kg}^{-1} \text{ cm}^{-2}$$

$$k_2 = \frac{t^2}{C} = \frac{5.42^2}{9.3} = 3.2 \text{ s}^2 \text{ kg}^{-1} \text{ cm}^{-2}$$

first value of k = 2.8 s^2 kg^{-1} cm^{-2}

second value of k = 3.2 s^2 kg^{-1} cm^{-2}

two values of *k* calculated correctly and no fractions or 1 s.f. [1]
(circle incorrect unit but don't penalise)

Examiners' comments: Units should be stated.

(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)**.

$$\frac{\Delta k}{k} \times 100\% = \frac{3.2 - 2.8}{2.8} \times 100\%$$
$$= 14\%$$

Since k depends on the uncertainty in C and hence D_2^2, the percentage difference in k of 14% is more than the percentage uncertainty in D_2^2 which is $2 \times 3.6\ \% = 7.2\ \%$, the results do not support the suggested relationship. [1]

Examiners' comments:
In the calculation of k, the quantity C has value of D squared.
Hence for proper comparison, we should apply $2\Delta D$.

(d) **(i)** Suggest **one** significant source of error in this experiment.

1. Difficult to measure t with a reason: difficult to judge when mass hanger reaches the floor / difficult to judge start of descent of mass hanger.
2. Difficult to measure D_2 with a reason: inconsistent thickness of clay layer / thickness of clay varies
3. Difficult to exactly judge 20 turns / difficult to judge number of turns of flywheel
4. Mass hanger does not fall consistently / hanger stops and starts

[1]

(ii) Suggest an improvement that could be made to the experiment to reduce the error identified in **(d)(i)**. You may suggest the use of other apparatus or a different procedure.

1. Use video/record/film the descent of mass hanger **and** timer in view/view frame-by-frame.
2. Hold a roller/board on the modelling clay while flywheel is turned / use a mould in the shape of a ring to preform it
3. Use fiducial marker **and** line up with slot on mass or a marking made on the mass
4. Improved method to allow mass hanger to fall smoothly: use a tube supported at both ends so rotation is more consistent

[1]

Examiners' comments:
Sources of error mentioned without mentioning which direct variable is affected.
Trivial sources of error (eg wooden rod is not level with the bench top) should be avoided. Especially those that conform to good experimental practice.
Avoid need to change apparatus. Examiner would like to see ways to reduce the problem.
Avoid human reaction error. Instead describe the problem eg the time for mass to reach the floor is too fast to be measured properly.

(e) Detach the ring of modelling clay. Using **all** of the clay, re-mould the clay **around** the straw, such that the outer diameter D_3 is approximately that of the 100 g slotted mass. The clay must be in contact with the slotted mass, as shown in Fig. 3.5. **Do not shove the modelling clay into the straw as it can become clogged.**

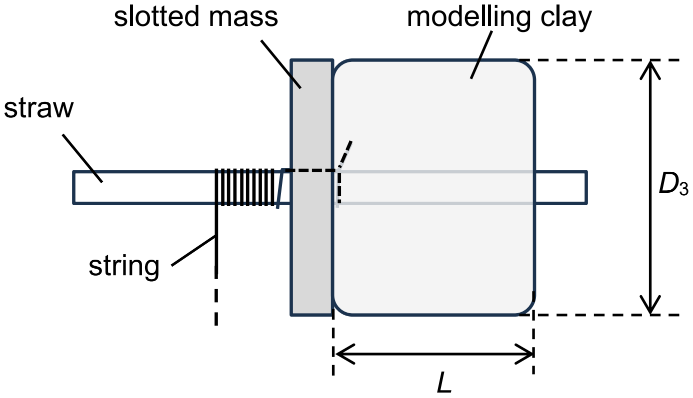


Fig. 3.5

(i) Measure and record the length L and the outer diameter D_3 of the modelling clay.

1st reading of $D_3 = 3.5$ cm

2nd reading of $D_3 = 3.5$ cm

$\langle D_3 \rangle = 3.5$ cm

1st reading of $L = 5.2$ cm

2nd reading of $L = 5.4$ cm

$\langle L \rangle = 5.3$ cm

Examiners' comments:
Some candidates did not take repeated measurements despite L and D_3 not being easily reproducible when measuring again.

L = ...5.3...... cm

D_3 = ...3.5...... cm

$L > D_3$

$3.0 \le D_3 \le 4.0$ [1]

(ii) Rotate the slotted mass 20 times so that the string is wound around the straw, as shown in Fig. 3.3. Release the slotted mass and take measurements to determine the time t for the mass hanger to just touch the floor.

1st reading of $t = 3.32$ s

2nd reading of $t = 3.44$ s

$\langle t \rangle = 3.38$ s

Repeat shown

t (slotted mass) < t < t (clay ring)

t = ...3.38 s...... [1]

Examiners' comments:
Some candidates incorrectly gave 3 d.p. for raw timings.

(iii) Estimate the percentage uncertainty in your time t.

$$\frac{\Delta t}{t} \times 100\% = \frac{0.3}{3.38} \times 100\%$$
$$= 8.9\ \%$$

Absolute uncertainty to 1 s.f.

% uncertainty to 1 or 2 s.f.

0.2s < Δt < 0.5s

percentage uncertainty = ...8.9 %...... % [1]

Examiners' comments:
Many candidates do not know what is the uncertainty in starting and stopping the stopwatch. Many gave a time of < 0.1s. Till now, many candidates are still giving the absolute uncertainty to more than 1 s.f.

(iv) You have been provided with another 100 g slotted mass.

Use these masses and your results in **(e)(ii)** and **(e)(iii)** to determine for a flywheel assembly of diameter D_1, the effect of density and distance between masses, on the time taken t for the mass hanger to reach the floor.

Your account should be presented clearly which includes:

- your experimental procedure
- control of variables
- results
- conclusion.

Mark Code	Description
P1	✓ **P**rocedures in investigating the effect of density ρ on time taken t To compare the timing between a 200g mass-clay flywheel with a 200g mass-mass flywheel OR to compare the timing between a 100g clay only flywheel with a 100g slotted mass flywheel • IGNORE comparison made between flywheels of different masses (for e.g. removing portions of clay or using a 300g mass-clay-mass arrangement) • IGNORE methods to determine density, e.g. ρ = M/V, if the mass M of the arrangement used is not stated clearly
P2	✓ **P**rocedures in investigating the effect of distance of separation x on time taken t To compare the effect of distances between a 200g mass-mass flywheel on timing OR the effect of distances between a 200g mass-clay flywheel on timing • Measurements in distance of separation must be shown clearly, by either considering the distance between 2 slotted masses OR distance between 1 slotted mass and the clay (NOT distance between mass on straw to mass hanger)
R	✓ Tabulation of **R**esults Recordings of raw timings (in table-form OR in working form) for either investigation
A1	✓ First **A**nalysis from the calculation of percentage difference with the result from **(e)(ii)** Workings to show the calculation of percentage difference in k for either investigation
A2	✓ Second **A**nalysis leading to the conclusion by checking with the criterion in **(e)(iii)** Justification whether the results of the experiment support the effect of density and distance of separation on timing by comparing % differences to % uncertainty in t in (e)(iii) ✓
CV	✓ **C**ontrol **V**ariables (CVs) stated clearly The 2 most significant CVs in this experiment are: • diameter of flywheel assembly must be that of a slotted mass (≈3.5 cm) • total mass of 200g for the flywheel to be used throughout for fair comparison • IGNORE other CVs (same length of string, same no. of loops, same mass hanger, same slotted mass, etc)

Suggested Answer:

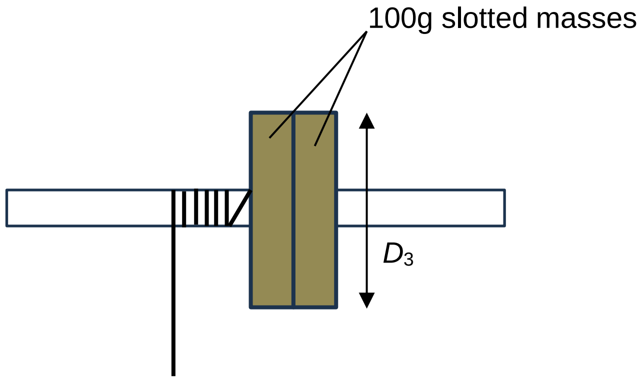


Fig. A

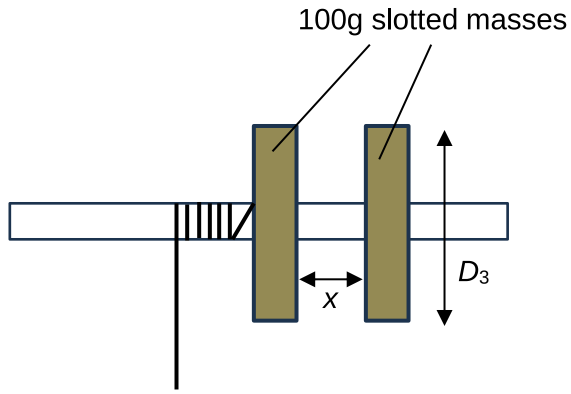


Fig. B

Control variables for both experiments:

- diameter D_3 of flywheel must be 3.5 cm (diameter of slotted mass); using ruler to check,
- total mass of flywheel must be 200g; using electronic balance to check.

1. To investigate the effect of density, use the set up in Fig. 3.5 but replace the 100g clay with the other 100g slotted mass (Fig. A). Ensure that there is no gap between the slotted masses and the total mass of the flywheel is kept at 200g (so that can compare with flywheel in Fig. 3.5).

2. Repeat step (e)(ii) twice to measure the time taken for the mass hanger to reach the floor, using a stopwatch. Calculate the average timing $\langle t \rangle$.

3. To investigate the effect of separation, move one of the slotted mass a distance x apart using ruler to measure (let x = 4cm, Fig. B) and repeat step 2.

4. Tabulate the results as shown.

Flywheel	Total mass/g	Distance of separation, x/cm	t_1 / s	t_2 / s	$\langle t \rangle$ / s
Mass-clay (from eii)	200	0	3.32	3.44	3.38
Mass-mass (Expt. 1)	200	0	3.20	3.20	3.20
Mass-mass (Expt. 2)	200	4.0	3.15	3.19	3.17

5. To check whether the suggested relationship is valid, calculate the percentage difference for each experiment and compare it to the percentage uncertainty in t of 8.9% in part (e)(iii).

$$\text{\% difference in Expt. 1} = \frac{3.38 - 3.20}{3.20} \times 100\% = 5.6\ \%$$

$$\text{\% difference in Expt. 2} = \frac{3.20 - 3.17}{3.17} \times 100\% = 0.94\ \%$$

6. The percentage difference in Expt. 1 (effect of density) is 5.6% < 8.9% and the percentage difference in Expt. 2 (effect of separation) is 0.94% < 8.9%. Hence, my experiments show that there is no effect of density or separation on the timing t.

Examiners' comments:
The mini-planning required students to conduct short investigations to take some results to verify whether there was an effect of density and separation of the masses on the timing. It then required students to compare their results to the previous parts in (e)(ii) and (e)(iii). However, candidates who rote learn neither conducted any investigation nor used the criterion of % uncertainty in (e)(iii) to justify their conclusions – many were still talking about collecting six sets of fictitious readings (when only 1 more slotted mass was provided) and plotting some best-fit line passing through the origin.

Candidates are advised to read the instructions and be prepared for questions of novel situation, where they need to answer in the context of the given question; otherwise they can write lines and lines of answers but not given any credit. Many candidates usually answered one of the two required investigations (of density or separation), probably missing out on the other due to the lack of time or simply not reading the instructions. Better candidates gave clear procedural steps, usually with an organised structure.

Candidates are advised to organise their steps and to give clear headings or signpostings, and to tabulate their results clearly. A few candidates confused the distance of separation to be the vertical length of the string, where they incorrectly hung the 100g mass to the mass hanger and varied the number of loops. These candidates probably did not appreciate the arrangement/mechanism of the flywheel from the previous parts of the question. Most candidates were able to vary the distance of separation between masses correctly, but had difficulties varying the density, usually talking about removing clay to vary the density or using slotted masses of different materials (when only 1 mass was provided). Because of the need to compare their results to the mass-clay flywheel in (e)(ii), few candidates realised that an important CV is to keep the masses and diameter of the flywheel constant at 200g and 3.5 cm respectively for a meaningful comparison throughout.

The maximum induced e.m.f. ε across the coil depends on the mass per unit length μ and the maximum amplitude x_0 of vibration of the metal guitar wire.

The e.m.f. ε is given by:

$$\varepsilon = K\, m^p\, x_0^{\,q}$$

where K, p and q are constants.

Design an experiment to determine the values of p and q.

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

- the equipment you would use,
- the procedure to be followed,
- the control of variables,
- how the maximum induced e.m.f. would be measured,
- any precautions that would be taken to improve the accuracy of the experiment.

Diagram

[12]

End of Paper

Suggested Solution

1. Problem Definition

Experiment 1

Independent variable: Mass per unit length μ of the wire

Dependent variable: Maximum induced e.m.f. ε across the coil

Control variables: Amplitude of vibration of guitar wire

Experiment 2

Independent variable: Maximum amplitude x_0 of vibration of the metal guitar wire

Dependent variable: Maximum induced e.m.f. ε across the coil

Control variables: Mass per unit length μ of the wire

General controls: Tension in the wire, distance *d* of wire placed above the coil, distance between pivots of string, displacement of wire always at mid length

2. Experimental Set-up

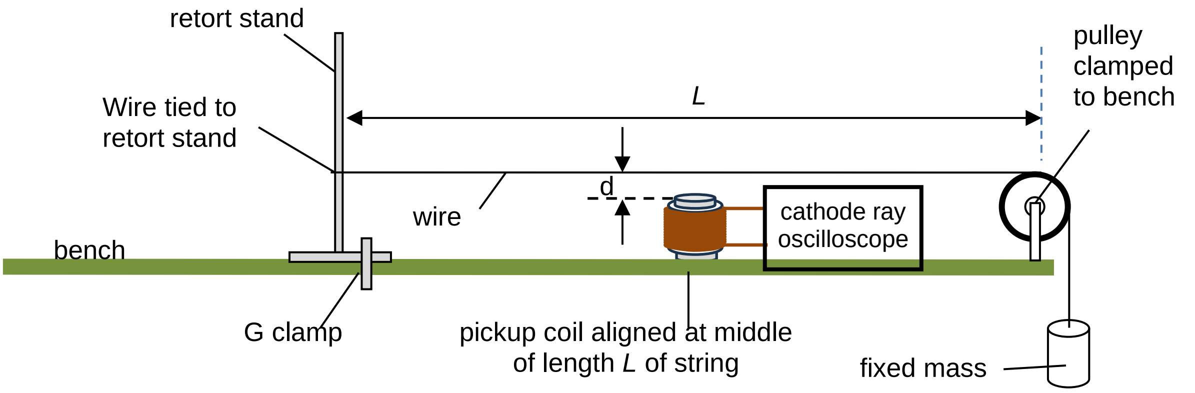


Fig 1. (side view)

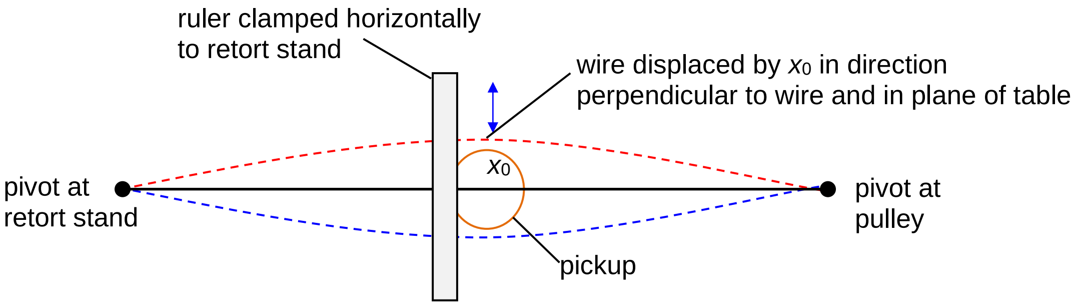


Fig 2 (top view)

3. Procedure

1. Set up the apparatus as shown in Fig. 1.

(a) Tie a wire such that it is horizontal, one end to the retort stand and other end attached to a mass looped about a pulley.
(b) Position pickup below the middle of wire of length L and secure it to the table using tape.
(c) Distance of wire above the pickup is d and length between retort stand and pully is L.
(d) Connect pickup to a cathode ray oscilloscope (c.r.o).
(e) Turn on the c.r.o.

2. Experiment 1: variation of ε with μ, keeping x_0 constant

(a) Measure and record mass m, of wire using an electronic mass balance.
Measure and record length R of wire using a ruler.
Calculate and record mass per unit length $\mu = \dfrac{m}{R}$.
(b) Carry out step 1(a) to (e).
(c) Displace the middle of wire by pulling wire by distance x_0 (in direction perpendicular to wire and in plane of table) as shown in Fig. 2. (need to clearly show / clearly stated direction displaced)
Measure and record x_0 using a ruler.
(d) Release the wire and let it oscillate.
(e) Measure induced e.m.f. ε in pickup coil using a c.r.o.
Record the peak value displayed on the c.r.o.
Or
Maximum induced e.m.f. ε across the coil. Use CRO connect across the wire measure. Read off peak value, note the y-gain. Multiply the peak value with the y-gain to obtain maximum induced e.m.f.
(f) Repeat steps 2(a) to 2(d) for a total of 6 sets of μ and ε each time using wires of increasing μ.
(g) x_0 is kept constant.

3. Experiment 2: variation of ε with x_0, keeping μ constant.
(a) Select one of the wires and record its mass per unit length μ.
(b) Repeat steps 2(b) to 2(e).
(c) Repeat steps 3(a) and 3(b) for a total of 6 sets, each time increasing the distance x_0.
(d) μ is kept constant by using the same wire.

Controls for both experiments
L and d are kept constant by checking with a ruler and readjusting lengths if necessary. Tension in the string is kept constant by using the same fixed mass.

4. Analysis (max 2)

$$\varepsilon = K m^p x_0^{\ q}$$

To determine y from Experiment 1:
$\lg\varepsilon = \lg K + p\lg\mu + q\lg x_0$, where x_0 is constant.
Plot a graph of lg ε against lg μ, such that gradient = p and vertical-intercept = lg K + q lg x_0.

To determine x from Experiment 2:
$\lg\varepsilon = \lg K + p\lg\mu + q\lg x_0$, where μ is constant.
Plot a graph of lg ε against lg x_0 , such that gradient = q and vertical-intercept lg K + p lgμ.

5. Safety Precautions (max 1)

1. Wear safety booths to protect feet from injury from falling masses.
2. Wear safety gogles to protect eyes from snapping wires.

6. Additional Details (max 1)

1. Take preliminary data for a suitable range of x_0 to produce e.m.f. signals that are measurable and distinguishable from each other.
2. Displace wire using a sharp hook edge to allow for better visibility.
3. Measure displacement x_0 using a travelling microscope to allow for better accuracy of the value x_0
4. Place wire directly above the pickup such that wire it bisecting pickup and in line with mid-point of L.
5. Take a screenshot of c.r.o. display to obtain maximum reading for e.m.f. induced.

<u>Mark Scheme for 2024 P4 Q4</u>

1. Detailed Diagram **[max 1]**

1. Workable set-up with equipment supported by retort stands/clamps/table. No levitating objects. [D1]

Comments

Diagram must have positions of instruments. Many students just gave the same sketch given in the question with no supporting equipment.

Please note that diagrams give in QP are the items you will need to **<u>incorporate</u>** into your setup!

The orientation of the coil and the string relative to it, must be correct for mark to be awarded.

2. Procedure **[max 5]**

1. Measuring mass m, length R using ruler, mass using an electronic mass balance [P1]
2. Calculate $\mu = m/R$ [P2]
3. Measuring x_0 using a ruler (displacement shown in diagram or orientation clearly described in words) [P3]
4. Release the wire. [P4]
5. Measure maximum e.m.f. using a c.r.o connected to pickup. [P5]

Comments

A lot missed out in measuring and recording lengths. You are not able to measure the displacement using the vernier / tail of the vernier!!

Voltmeters were not accepted because the response rate is too slow, while CRO you are able to see the time based response. Data loggers not accepted (unless only if connected to a voltage sensor). Voltmeter+data loger not accepted.

Cathode Ray Oscilloscope (C.R.O.). Needs to be spelled out in full and then CRO can be subsequently used for the rest of the answer. We have seen ‘cathode ray oscillator’ before.

Equation for calculating mass per unit length must be shown.

Please do not state something like: "use ruler and displace wire by…..". Your ruler is used to MEASURE the length. Please take note of your expression.
Use terms such as "Measure, Record, Calculate" rather than 'get this value, find this etc."

The question provided metal WIREs, not strings.

Many did not realise that the wire needs to oscillate for the e.m.f. to be induced in the coil.
Students who did not let the wire oscillate, the experimental setup is considered to be incorrect and C1 mark will on not be awarded in this case.

There is no sound produced in this experiment.

3. Control of Variables **[max 2]**

1. To determine p, repeat for total of 6 sets by varying μ and keep x_0 constant [C1]
2. To determine q, repeat for total of 6 sets by varying x_0 and keep μ constant (this mark will only be awarded **only if** P4 is awarded)

1. Tension in wire created by hanging pass attached to wire and hung over a pully + one other control variable [C2]

Comments:
Many students did not mention the number of data sets to obtain, or repeat steps how many times.

For C2 mark to be awarded (Tension in string + and other control varuable: length L of wire, distance d above wire, position of pickup w.r.t. L)

4. Analysis **[max 2]**

1. Plot graph of lg ε against lg μ, stating gradient = p and vertical-intercept = lg K + q lg x_0. [A1]
2. Plot graph of lg ε against lg x_0, stating gradient = q and vertical-intercept lg K + p lgμ. [A2]

Comments:
A very small number of students did not state "plot______ against _______', and/or they flipped the variables to plot.
Please reserved ln functions for exponentials. For this equation you should be using lg.
Some students Plot lg μ against lg ε. In this case the gradient is 1/p instead!

5. Safety Precautions **[max 1]**

1. Wear safety boots to protect feet from injury from falling masses. [S1]
2. Wear safety goggles to protect eyes from snapping wires. [S1]

Comments:
Tell us what do and why. If your statement starts with "do not" chances are you get no credit.

An oscillating string is not going to create that big a p.d. to get someone electrocuted. There should be no current to speak of either.

6. Additional Details **[max 1]**

1. Take preliminary data for range of x_0 to produce e.m.f. signals on the C.R.O. that are measurable and distinguishable from each other. [AD1]
2. Displace wire using a sharp hook edge to allow for better visibility of edge of wire when measuring displacement of the wire. [AD1] [AD1]
3. Measure displacement x_0 using a travelling microscope to allow for better accuracy of the value x_0 [AD1]
4. Place wire directly above the pickup such that wire it bisecting pickup and in line with mid-point of L. [AD1]

Comments:
All equipment are already expected to be on the benches and secured with g-clamps and bricks etc. Those are the basic requirements that must be met for the D1 credit.

Guitar wires don't cut

Other general comments.

- Do not write in prose.
- Planning is as if you are writing a practical worksheet. You are supposed to write statements in an instructional format. Short and sweet.
- All variables used / investigated must be measured with an instrument.
- Even if the question did not explicitly ask for safety, you will still need to write it.
- Even though calculating averages was not awarded credit here, please write it regardless during A level Practical.