NAME: ____ CLASS: _________ INDEX: __________

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

PHYSICS

9749/04

Paper 4: Practical

19 AUG 2022

2 hour 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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 of the practical shift and laboratory where appropriate in the boxes provided.

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

Shift
Laboratory

For Examiner's Use	
1	/ 11
2	/ 14
3	/ 20
4	/ 12
Total	/ 55

This document consists of **12** printed pages and **0** blank page.

[Turn over

1 In this experiment, you will investigate the potential difference across a current-carrying wire.

You have been provided with three wires A, B and C attached onto the respective cards.

(a) Wire A has a diameter *D*.

(i) Without detaching the wire from the card, measure and record *D*.

D = ... [1]

Solution:

D_1 = 0.16 mm
D_2 = 0.16 mm
D = 0.16 mm

1 mark for

- Value for *D* in the range 0.14 mm to 0.16 mm.
- Precision to 0.01 mm.
- Units included.
- Repeated readings.

(b) Set up the circuit shown in Fig. 1.1.

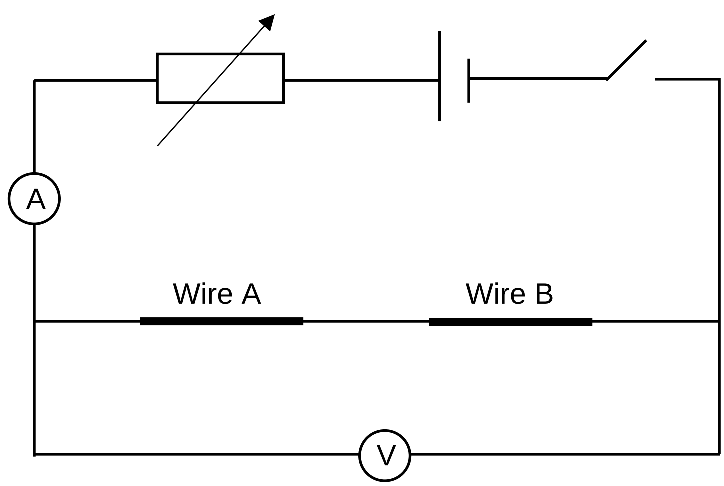


Fig. 1.1

Adjust the rheostat to approximately the middle of its range.

Close the switch.

(i) Record the ammeter reading.

ammeter reading = [1]

Solution:

Ammeter reading = 63.8 mA

1 mark for

- Value in the range 50.0 mA to 100.0 mA.
- Ammeter setting: 0 – 200 mA. Hence precision is to 0.1 mA.
- Units included.

(ii) Record the voltmeter reading.

V = ... [1]

Solution:

Voltmeter reading = 0.529 V

1 mark for

- Value in the range 0.400 V to 1.000 V.
- Voltmeter setting: 0 – 2 V. Hence precision is to 0.001 V.
- Units included.

Open the switch.

(c) **(i)** Wire B has a diameter d.

Measure and record d.

d = ... [1]

Solution:

d_1 = 0.19 mm
d_2 = 0.19 mm
d = 0.19 mm

1 mark for

- Value for d in the range 0.18 to 0.20 mm. (Value of $d > D$ and $d <$ 1 mm.)
- Precision to 0.01 mm.
- Units included.
- Repeated readings.

(ii) The diameter D of Wire A and the diameter d of Wire B are related by G, through

$$G = \frac{D^2 + d^2}{D^2 d^2}$$

Calculate G for Wire A and Wire B.

G = ... [1]

Solution:

$$G = \frac{0.16^{2} + 0.19^{2}}{0.16^{2}\ 0.19^{2}} = 66.8 = 67\ \text{mm}^{-2}$$

1 mark for

- Correct calculation of G using candidate's values of D and d.
- Correct units.

(d) Replace Wire B with Wire C.

Close the switch.

Adjust the rheostat so that the ammeter reading is as close as possible to the reading in **(b)**,

Record the voltmeter reading V.

V = ... [1]

Solution:

0.399 V

1 mark for reading: Second value of V less than first value of V in **(b)(ii)**.

(e) Wire C has a diameter d_C.

(i) Measure and record d_C.

d_C = ...

Solution:

d_1 = 0.27 mm
d_2 = 0.27 mm
d_C = 0.27 mm

(ii) Use the expression in **(c)(ii)** to calculate G for Wire A and Wire C.

G = ... [1]

Solution:

$$G = \frac{0.16^{2} + 0.27^{2}}{0.16^{2}\ 0.27^{2}} = 52.8 = 53\ \text{mm}^{-2}$$

1 mark for

- Correct calculation of G using candidate's values of D and d_C.
- Correct units. Allow ECF.

(f) It is suggested that the relationship V and G is

$$V = kG$$

where k is a constant.

Using your data, calculate two values of k.

first value of k = ...

second value of k = ...

[1]

Solution:

$$k_1 = \frac{V}{G} = \frac{0.529}{67} = 7.9 \times 10^{-3}\,\text{V mm}^2$$

$$k_2 = \frac{V}{G} = \frac{0.399}{53} = 7.5 \times 10^{-3}\ \text{V mm}^2$$

1 mark for

- Correct calculations.
- Appropriate units.

(g) It is suggested that the percentage uncertainty in the values of k is 4%, which is determined from the percentage uncertainty of V and G, as well as other experimental factors.

Using this uncertainty, explain whether your results support the relationship in **(f)**.

[1]

Solution:

Percentage difference $\dfrac{7.90 - 7.53\ \times 10^{-3}}{7.53 \times 10^{-3}} \times 100 = 5\%$

As the percentage difference of the two k values of 5% exceeds the percentage uncertainty of k of 4%, it means that the two values of k are not within experimental uncertainty. Therefore, my results do not support the relationship in **(f)**.

1 mark for

- Calculation of percentage difference between candidate's two k values.
- Comparison of percentage difference with the experimental uncertainty of 4%, leading to a consistent conclusion.

Total [9]

2 In this experiment you will investigate the equilibrium position of a half-metre rule supported by a spring.

(a) Attach the spring tied to the string and the 20 cm length of string to the half-metre rule as shown in Fig. 2.1.

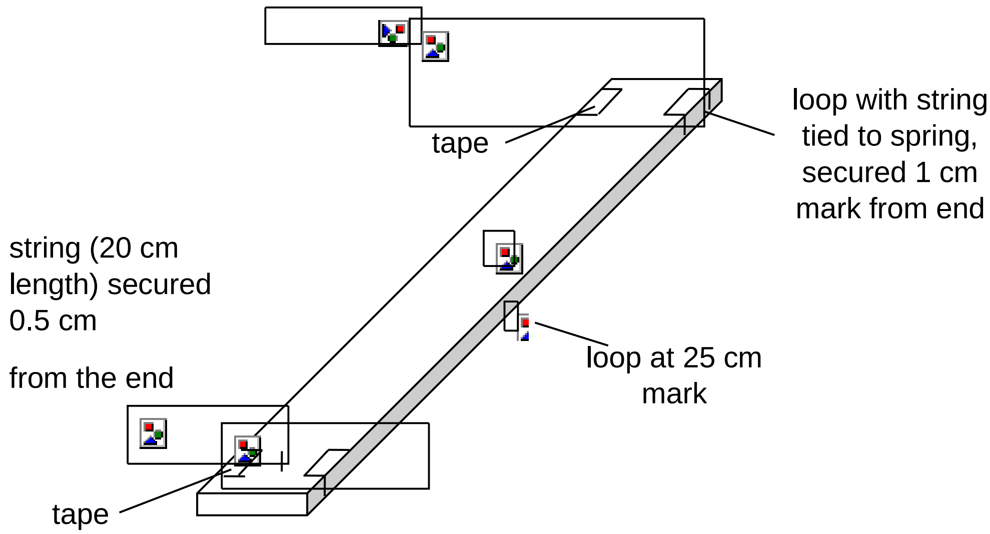


Fig. 2.1

Assemble the apparatus as shown in Fig. 2.2, using a mass of 300 g.

Ensure that the mass hanger and masses are not touching the bench.

The upper string must be parallel to the bench.

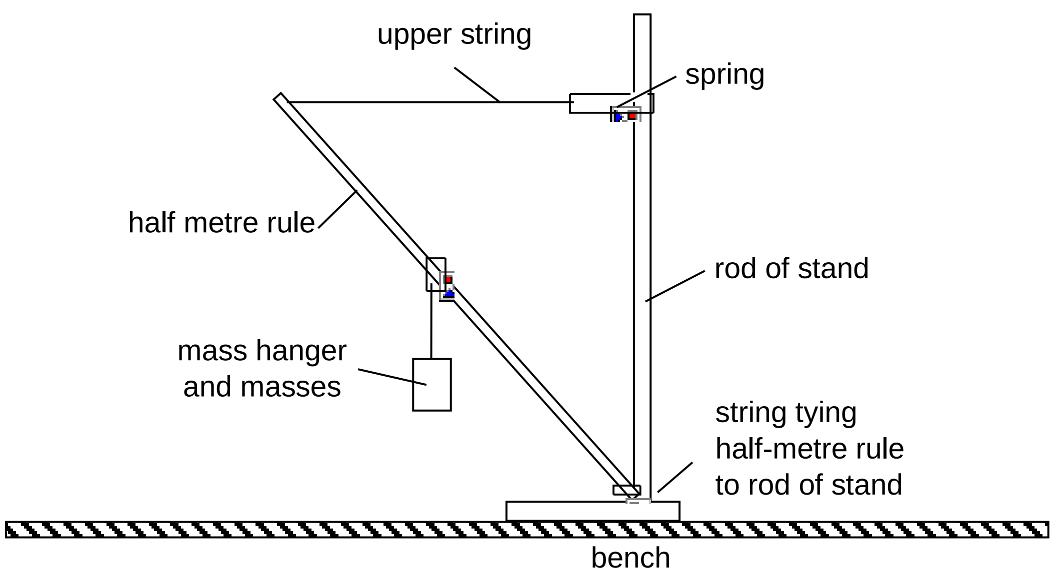


Fig. 2.2

(b) Fig. 2.3 shows the measurements you will take.

Point **A** is where the line of the upper string meets the half-metre rule.

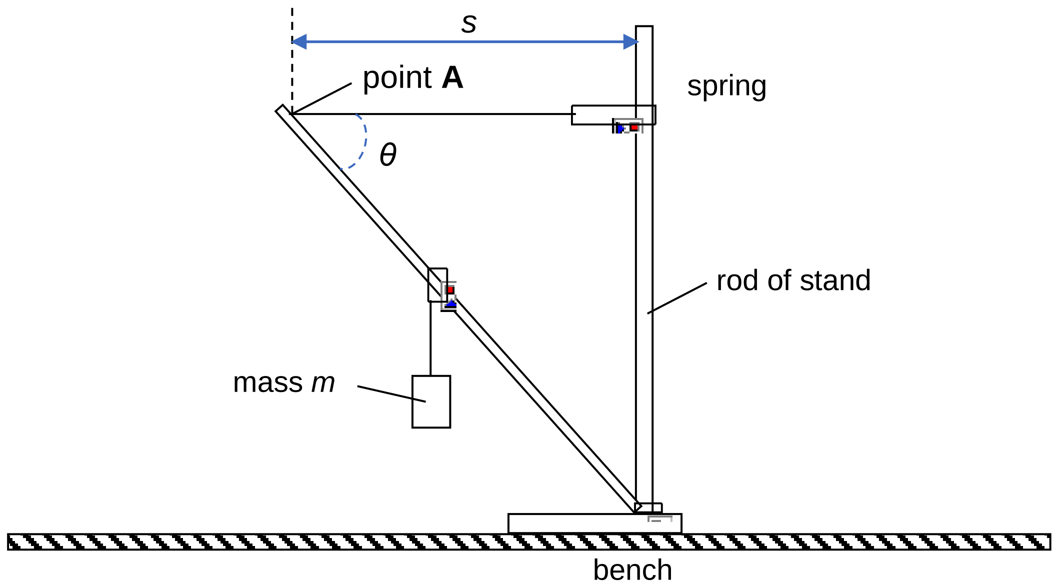


Fig. 2.3

(i) *M* is the mass of the half-metre rule as written on the card on the bench.

State your *M* value.

M = ...

Solution:
63 g

(ii) Record the total mass *m* of the mass hanger and masses.

m = ...

Solution:
300 g

(iii) Measure and record the distance *s* between the rod of the stand and **A**, as shown in Fig. 2.3.

s = ... [1]

Solution:
36.8 cm

1 mark for
- Precision to 0.1 cm
- Units included

(iv) Measure and record the angle θ, as shown in Fig. 2.3.

θ = ... [1]

Solution:
41 °

1 mark for
- Precision to 1°
- Unit included

(c) Change the value of m and repeat **(b)(ii)**, **(b)(iii)**, and **(b)(iv)** to obtain further sets of values of m, s, and θ.

[6]

Solution:

m/g	s_1 /cm	s_1 /cm	s_{ave} /cm	θ_1 /°	θ_2 /°	θ_{ave} /°	(m + M)/g	tan (θ/°)	$\frac{(m+M)}{\tan\theta}$ /g
50	30.2	30.2	30.2	51	51	51	113	1.23	91.9
100	31.1	31.1	31.1	50	50	50	163	1.19	137
150	32.2	32.2	32.2	48	48	48	213	1.11	191
200	33.3	33.3	33.3	47	47	47	263	1.07	246
250	34.8	34.8	34.8	44	44	44	313	0.966	324
300	36.8	36.8	36.8	41	41	41	363	0.869	418
350	39.3	39.3	39.3	38	38	38	413	0.781	529
0 d.p.	**1 d.p.**	**1 d.p.**	**1 d.p.**	**0 d.p.**	**0 d.p.**	**0 d.p.**	**Follow least d.p. of m & M**	**3 s.f. (Follow Special Rule for trigo.)**	**Follow least s.f. of (m+M) & tan θ**

1 mark – at least 6 sets of data without assistance without assistance
1 mark – correct data trend, i.e. as m increases, s increases and θ decreases.
1 mark – repeat readings for both s and θ
1 mark – appropriate column headings, quantity and unit separated, i.e. slash
1 mark – all raw readings have the appropriate precision, i.e. m to 50 g, s to 0.1 cm and θ to 1°
1 mark – calculated values to correct d.p. or s.f. + all values calculated correctly, allowing maximum 2 slips

(d) It is suggested that *m*, *s* and *θ* are related by the expression

$$\frac{m+M}{\tan\theta} = Ps - Q$$

where *P* and *Q* are constants.

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

P = ...

Q = ... [6]

Solution:

Plot a graph of $\frac{(m+M)}{\tan\theta}$ against s. A straight line graph of gradient P and y-intercept -Q is expected.

Gradient = …….. = 48.571 g cm^{-1}
P = Gradient = 48.6 g cm^{-1}

Y-intercept = ….. = -1373.7 g
-Q = Y-intercept
Q = 1370 g

3 marks: Graph

- Axes labelled with Units + Good scale (no odd scales, and graph size at least half the graph grid)
- All points plotted + plotted accurately to half smallest division
- Best-fit straight line drawn

1 mark: Gradient calculation

- Correct gradient formula
- Used 2 coordinates far apart on the best-fit line (separated by at least half the length of the line drawn)
- Read off coordinates accurately to half the smallest division

1 mark: y-intercept

- Correct formula used, or, if able to read off the graph, read off accurately to half the smallest division.
- Read off coordinates from the best-fit line accurately to half the smallest division

1 mark: Determination of P & Q with Units

- Equate gradient to P
- Equate y-intercept to -Q
- Final answer of P & Q to appropriate sig. fig. & units

Total [14]

3 In this experiment, you will investigate the motion of chains of paper clips.

You are provided with two chains of fifteen paper clips with two spheres of modelling clay.

(a) Measure and record the length L of one paper clip as shown in Fig. 3.1.

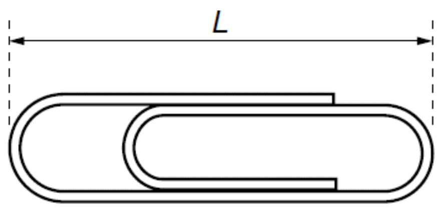


Fig. 3.1

L = ... [1]

Solution:

L = 2.8 cm

1 mark for

- Value for L in the range 2.6 cm to 3.0 cm
- Precision to 0.1 cm
- Units included

(b) Set up the apparatus as shown in Fig. 3.2.

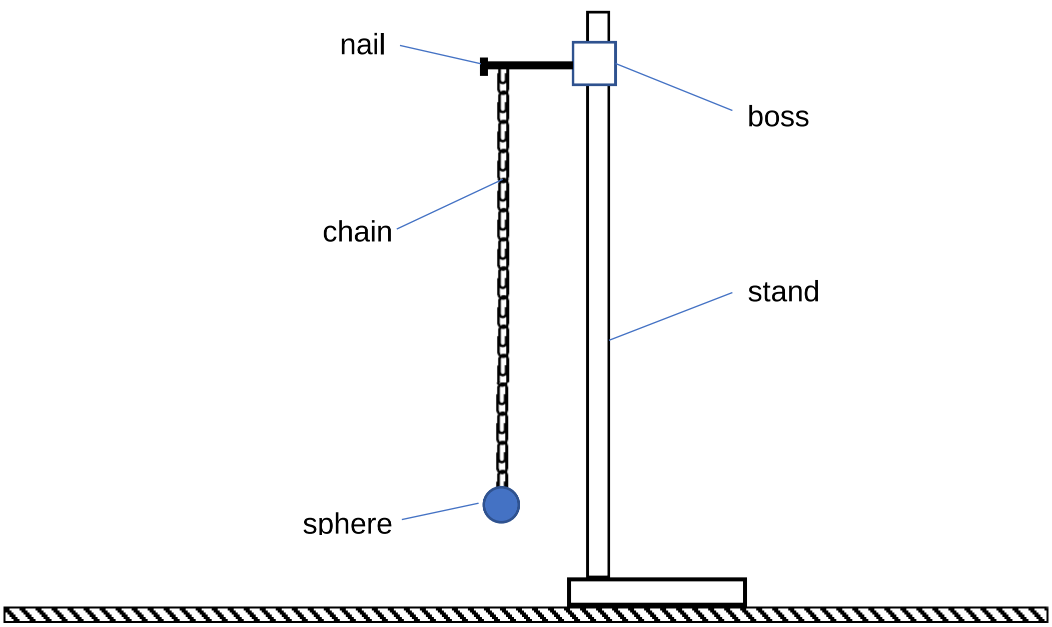


Fig. 3.2

Suspend the chain from the nail. The number *n* of the paper clips below the nail should be 15.

Move the sphere of modelling clay towards you a distance of approximately 5 cm. Release the sphere. The chain will oscillate.

(i) Determine the period *T* of the oscillations.

T = ... [1]

Solution:

For 20 oscillations, total time
t_1 = 24.9 s
t_2 = 24.7 s
t = 24.8 s

T = 24.8 / 20 = 1.24 s

1 mark for
- t greater than 20 s
- Repeated readings of t
- Precision of t to 0.1 s
- Recording of number of oscillations shown
- Correct calculation of T, and correct s.f. for T (3 s.f.)
- Units included for t and T

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

percentage uncertainty of *T* = ... [1]

Solution:

ΔT = 0.03 s

$$\frac{\Delta T}{T} \times 100\% = \frac{0.03}{1.24} \times 100\% = 2\%$$

1 mark for:
- Reasonable estimate of absolute uncertainty of T (accept Δt = 0.2 s to 0.6 s, or equivalently, ΔT = 0.01 s to 0.03 s since T = t/N)
- Final answer to appropriate sig. fig.

(iii) The period of a simple pendulum is

$$T_P = 2\pi\sqrt{\frac{l}{g}}$$

where l is the length of the pendulum.

Taking g = 9.81 m s^{-2}, calculate a value for period of the chain in **(b)(i)**.

T_P = ... [1]

Solution:

$$T_P = 2\pi\sqrt{\frac{15\times 0.028}{9.81}} = 1.3 \text{ s}$$

1 mark for:

- Correctly determine total length of the chains as well as correct calculation of T_P.
- Units included

(iv) Justify the number of significant figures that you have given for your value of T_P in **(b)(iii)**.

[1]

Solution:

1 mark –
T_P is presented to 2 significant figures (s.f.) as the least number of s.f. among l and g used in its calculation is 2 s.f..

(v) It is suggested that the oscillation of the chain in **(b)(i)** is different from the oscillation of a simple pendulum.

State whether your results in **(b)(i)** and **(b)(iii)** support the suggestion.

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

[1]

Solution:

$$\left|\frac{Actual\ period - Theoretical\ period}{Theoretical\ period}\right| x\ 100\% = \left|\frac{1.24 - 1.3}{1.3}\right| x\ 100\% = 5\%$$

The percentage difference between the period values in **(b)(i)** and **(b)(iii)** is about 5% which is more than the estimated percentage uncertainty in T (2%, calculated in (b)(ii)). This suggests that the chain does not oscillate like a simple pendulum.

1 mark for:

- Comparison of percentage difference in the period values of (b)(i) and (b)(iii) with the percentage uncertainty in (b)(ii), and
- leading to a logical conclusion.

(c) Set up two chain pendulums side by side as shown in Fig. 3.3.

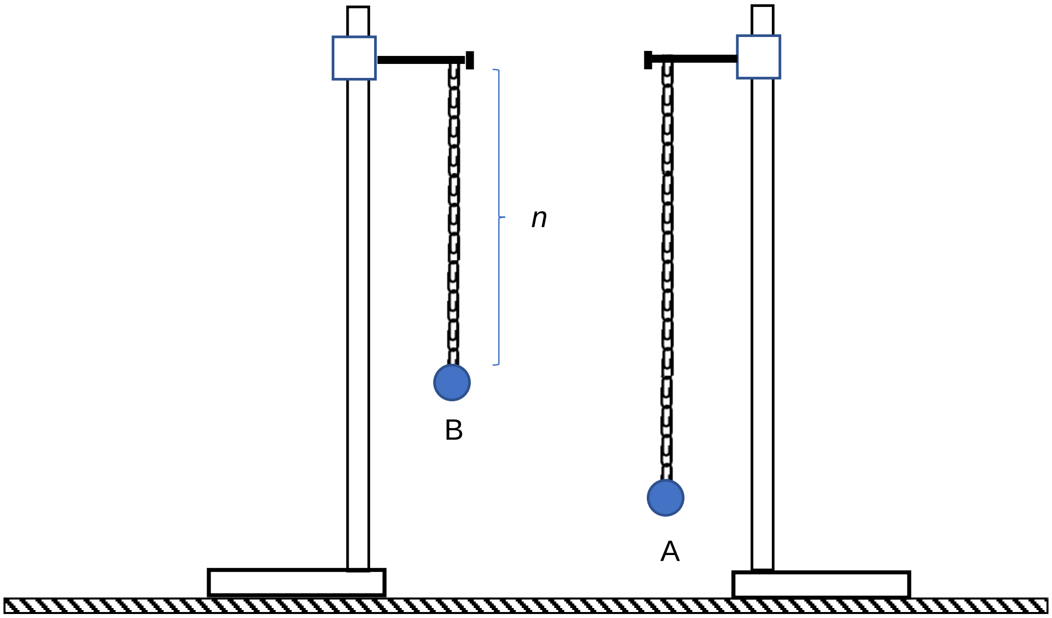


Fig. 3.3

Set chain A with 15 paper clips.

Set chain B with *n* paper clips such that *n* = 7.

Record *n*

n = ...

Solution:
7

(d) Set both pendulums into motion with small oscillations.

Start the stopwatch when the two pendulums are lined up in phase.

Measure the time *t* taken before the next occasion when the two pendulums are in phase again.

t = ... [1]

Solution:

t_1 = 2.8 s
t_2 = 2.8 s
t = 2.8 s

1 mark for

- Value for *t* in the range 2 s to 3 s
- Repeated readings
- Precision to 0.1 s
- Units included

(e) Increase the value of n and repeat **(d)** to obtain further sets of values of t until $n \leq 14$. [3]

Solution:

n	t_1 /s	t_1 /s	t_{ave} /s
14	59.6	60.0	59.8
13	17.9	17.8	17.9
12	10.4	10.6	10.5
11	7.9	7.9	7.9
10	5.4	5.5	5.5
9	4.3	4.3	4.3
8	3.2	3.1	3.2
7	2.8	2.8	2.8

1 mark – correct trend: as n decreases t decreases,
1 mark – at least 8 sets of data for a curve, and for the range of n not smaller than 7.
1 mark – column headings with units, and correct calculation of data

(f) **(i)** Plot t against n on Fig. 3.4. The graph obtained should be a curve. [3]

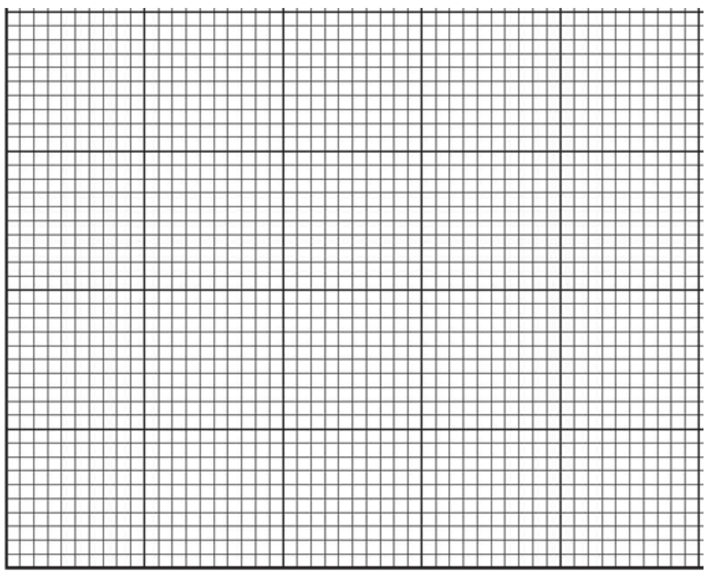


Fig. 3.4

1 mark – Good scale (No odd scale. Size of graph covers at least half the given graph grid)
1 mark – All points plotted, and plotted accurate to ½ smallest division
1 mark – curve drawn as line of best fit.

(ii) Explain why the graph in Fig. 3.4 should not have a value at n = 15. [2]

Solution:

When n = 15, the lengths of both pendulums A and B are the same.

Therefore, their periods are the same and always in phase. Hence, they do not go out of phase then come back in phase, suggesting that there is no such time t at n = 15.

OR accept other reasonable explanations based on students' observation.
e.g. As n increases, the time taken becomes increasingly longer and longer. At n = 15 it will take a very long time such that oscillations of the pendulums die off.

1 mark – Make meaning of n = 15 to the experiment
1 mark – Appropriate reasoning, by theory or by students' observation to having no t value at n = 15.

(g) (i) Theory suggests that

$$t = A\frac{\sqrt{Cn}}{\sqrt{C}-\sqrt{n}}$$

where A and C are constants.

State the graph to plot to obtain a straight line to determine values for constants A and C, assuming that the theory is correct.

[1]

Solution:

$$t = A\frac{\sqrt{Cn}}{\sqrt{C}-\sqrt{n}}$$

$$\frac{1}{t} = \frac{1}{A}\left(\frac{\sqrt{C}-\sqrt{n}}{\sqrt{Cn}}\right)$$

$$\frac{1}{t} = \frac{1}{A}\left(\frac{1}{\sqrt{n}}-\frac{1}{\sqrt{C}}\right)$$

$$\frac{1}{t} = \frac{1}{A}\left(\frac{1}{\sqrt{n}}\right)-\frac{1}{A\sqrt{C}}$$

Plot a graph of $\frac{1}{t}$ as y-axis against $\frac{1}{\sqrt{n}}$ as the x-axis.

1 mark for:

- Correct linearization.

(ii) State expressions for the gradient and y-intercept of the straight line.

[1]

Solution:
Gradient expression:

$$\frac{1}{A}$$

y-intercept expression:

$$-\frac{1}{A\sqrt{C}}$$

1 mark for:

- Correct gradient and y-intercept expressions. Allow ECF from (g)(i).

(h) The physics of the oscillations of a hanging chain without the spherical modelling clay as shown in Fig. 3.5 is studied by Daniel Bernoulli in 1732, which led to the introduction to Bessel Functions.

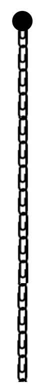


Fig. 3.5

It was theorized that the period T of the oscillations depends on the mass per unit length, which is known as the linear mass density ρ of the chain.

Explain how you would investigate the relationship between the period T of the chain and the linear mass density of the chain.

Your account should include:

- your experimental procedure
- control of variables
- how you would determine the linear mass density ρ of the chain
- how you would use your results to that deduce the relationship of T and ρ.

[4]

Solution:

1. Set up the chain as shown in Fig. 3.5.
2. Measure the mass m of the chain using a weighing balance and the length L of the chain using a metre rule.
3. Calculate the line mass density of the chain by using the equation $\rho = m / L$
4. Displace the loose end of the chain slight and let it oscillate.
5. Measure the period of the oscillations using a stopwatch as performed in step (b)(i)
6. Method to vary m but keep L constant: Repeat steps 2 to 5 by adding more paper clips to the chain, each time adding one more paper clip per loop. (OR adding plasticine uniformly along the length of the chain.) This would keep the length L of the chain constant. Repeat the experiment until 6 sets of measurements were obtained for ρ and T.
7. Assume that the relationship between T and ρ is $T = k\rho^n$
8. Plot a graph of lg T against $lg\ \rho$, with n as the gradient and lg k as the y-intercept.
9. Calculate the gradient and the y-intercept to obtain the values for k and n, thus getting the relationship between T and ρ

1 mark – Method to determine ρ
1 mark – Method to vary mass but keeping L constant
2 marks – Analysis: using a graphical approach to deduce the relationship between T and ρ, such as proposing an appropriate equation relating them.

Total [21]

4 Gases can absorb light of certain wavelengths as observed in the absorption line spectra.

A substance that consists of atoms and molecules may dissolve in water to form a solution which is also observed to absorb light of certain wavelengths.

The amount of light of a particular wavelength after passing through such a solution depends on the concentration *c* of the substance in water. The concentration *c* is defined as the mass of substance dissolved in per unit volume of water.

The intensity I detected from a light source of a particular wavelength after the absorption by the solution is given by the equation

$$I = kc^n L^m$$

where *k*, *n* and *m* are constants. *L* is the path length that the light takes to pass through the solution.

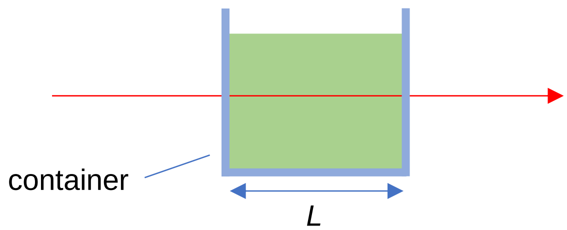


Fig. 4.1

Design an experiment to determine the values of *n* and *m*.

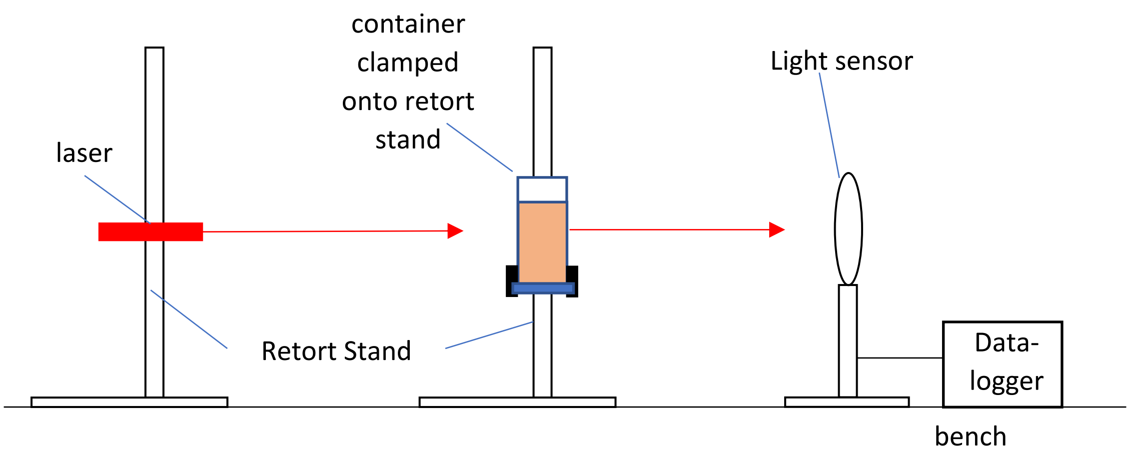
You are provided with containers of different sizes and a monochromatic laser light source. You also provided with the substance to be dissolved in water and the solution absorbs the laser light provided.

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)** how the concentration of the solution and the path lengths are measured
- **(d)** the control of variables
- **(e)** any precautions that should be taken to improve the accuracy and safety of the experiment.

[11]

Diagram:



D1 – Well labelled diagram

Feasibility of setup

<u>1st part: Keeping the path length L constant, varying the concentration c</u>

Independent variable (IV): concentration c
Dependent variable (DV): light intensity I
Controlled variables (CV): path length L, ambient light intensity
Procedure:

1. Set up the experiment as shown in the diagram above.
2. Take one container and measure the path length L using the inner claws of a vernier caliper.
3. Measure 50 cm^3 of water using a measuring cylinder.
4. Measure 10 g of the substance using a weighing balance.
5. Dissolve the 10 g of substance into the 50 cm^3 water. Calculate concentration c of the solution using mass of substance divided by the volume of water, i.e. 10 g / 50 cm^3 = 0.20 g cm^{-3}. Pour the solution into the container.
6. Place the container in the path of the laser light.
7. Measure and record the light intensity I of the laser light after passing through the solution using a photometer or a light sensor connected to a datalogger.
8. Repeat steps 1 to 8 using different concentration c of the solution, by weighing different mass of the substance in step 4 with the same amount of water in step 3, for at least 6 sets of readings. Use the same container to keep L constant.
9. Plot a graph of lg I against lg c.
10. Calculate the gradient of the graph. The gradient of the graph gives the value of n.

IV1 - method of measuring c

VIV1 – Method of varying c while keeping L constant

A1 – Graphical solution

<u>2nd part: Keeping concentration c constant, vary L</u>

P1 – Two experiments with two sets of IV,DV,CV.

Independent variable (IV): path length L
Dependent variable (DV): light intensity I
Controlled variables (CV): concentration c, ambient light intensity

Procedure:

1. **Repeat** step 1 to step 8 of the experiment in part 1, but **each time with a different container to vary the path length *L*, for at least 6 sets** of readings.
2. Add in the **same mass of the same substance and volume of water to get the same concentration *c* of solution**.
3. Plot a graph of lg I against lg L.
4. Calculate the gradient of the graph. The gradient of the graph gives the value of m.

IV2 – Method of measuring L
VIV2 – Method of varying L while keeping c constant
A2 – Graphical solution

Additional Details:

1. Perform a preliminary experiment to determine the amount of substance required and how much water to add such that all substance dissolves in the water. Adjust the concentrations such that an observable trend can be obtained in the actual experiment.
2. (Steps taken to align the laser light)
   a. Measure the height from the surface of the bench to the laser light to check that the laser light is parallel.

AD1

b. When placing the container on the platform, verify that the platform is horizontal by using a spirit level.
c. Rotate the container such that the light intensity measured by the light sensor is the maximum. This ensures that the laser light enters at right angle to the surface of the container.

3. (Steps taken to account for ambient light intensity)
   a. Perform experiment in a dark room / dark box so as to minimize the ambient light intensity from entering the light sensor.
   b. Take the ambient light intensity reading with the light sensor connected to the datalogger in the setup as shown in the figure but without switching on the laser light. Subtract this ambient intensity from the I readings in the above experiments.

Safety:

1. Wear goggles to prevent accidental looking into the laser light.
2. Prepared cloths in case of spills.
3. Wear gloves when handling the substance to prevent touching unknown chemicals with our bare hands.

(Generic safety precautions that are not specific to the nature of the experiment will not be accepted.)

S1 – Any relevant safety precaution