CANDIDATE NAME								
CIVICS GROUP	2	3	-			REGISTRATION NUMBER		

PHYSICS

9749/04

Paper 4 Practical

15th September 2023

1 hour 30 minutes

Candidates answer on the Question Paper.
Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration 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 an 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 of the practical shift and laboratory, where appropriate, in the boxes provided.

Shift
Laboratory

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.

For Examiner's Use	
1	**14**
2	**19**
Total	**33**

This document consists of **11** printed pages and **1** blank page.

1 In this experiment, you will investigate the behaviour of a system in static equilibrium.

(a) **(i)** Determine the mass of one paper clip.

Mass of 10 paper clips = $\frac{10.37 + 10.36}{2} = 10.37$ g

Mass of 1 paper clip = $\frac{10.37}{10} = 1.037$ g

mass of one paper clip = 1.037 g [2]

(ii) You are provided with two strings.

Connect two mass hangers with the shorter string and place them on both sides of a pulley. The mass hangers should balance each other's weight and hang in equilibrium.

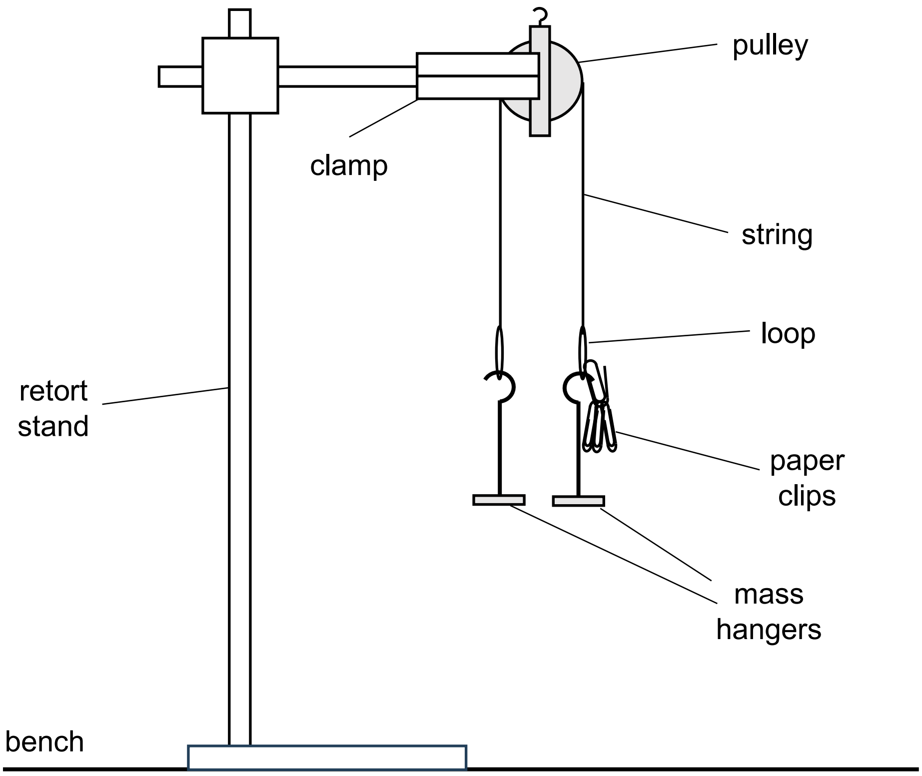

Fig 1.1

Add paper clips, one by one, to one side as shown in Fig. 1.1 until the pulley starts to rotate. Record the minimum number of paper clips that is required to cause the pulley to rotate.

Average number of paper clips = $\frac{6 + 6}{2} = 6$

number of paper clips = 6 [1]

(b) Using the longer string, set up the apparatus as shown in Fig. 1.2.
Mass *m* and *M* are provided by a 50 g mass hanger and a pendulum bob, respectively.

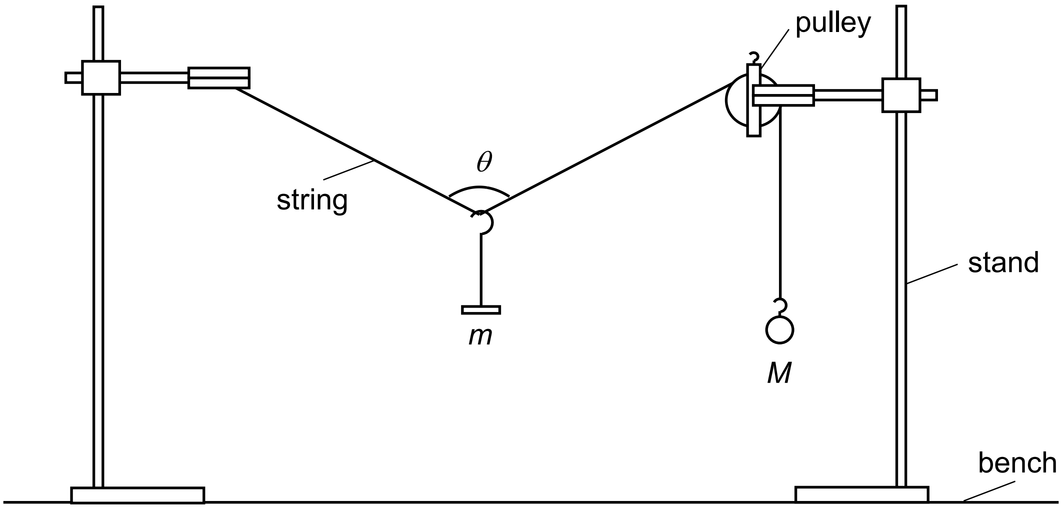

Fig 1.2

(i) Adjust the position of *m* along the string until the angle θ is symmetrical about the vertical axis.

Measure and record θ.

θ_1 / °	θ_2 / °	$\langle\theta\rangle$ / °
145	144	145

θ = ...145°...... [1]

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

$$\frac{\Delta\theta}{\langle\theta\rangle}\times 100\% = \frac{5^\circ}{145^\circ}\times 100\%$$
$$= 3.4\%$$

percentage uncertainty in θ = ...3.4%...... [1]

(c) *M*, *m* and θ are related by the expression

$$2M\cos\frac{\theta}{2} = m.$$

(i) Calculate the value of *M*.

$$M = \frac{m}{2\cos\frac{\theta}{2}}$$

$$= \frac{50}{2\cos\left(\frac{145^\circ}{2}\right)} = 83 \text{ g}$$

M = 83 g [1]

(ii) Using your values in **(a)(ii)** and **(b)(ii)**, estimate the maximum value of *M*.

$$M_{max} = \frac{m}{2\cos\frac{\theta_{max}}{2}} + \text{uncertainty due to friction in axle of pulley}$$

$$= \frac{50}{2\cos\left(\frac{150^\circ}{2}\right)} + 6(1.037) = 103 \text{ g}$$

maximum *M* = 103 g [1]

(iii) Repeat **(b)(i)** for *m* = 100 g.

θ_1 / °	θ_2 / °	$\langle\theta\rangle$ / °
103	105	104

θ = 104° [1]

(d) It is suggested that

$$m^2 = k(1+\cos\theta)$$

where k is a constant.

(i) Use your values from **(b)(i) and (c)(iii)** to determine two values of k.

$$k = \frac{m^2}{1+\cos\theta}$$

$$k_1 = \frac{50^2}{1+\cos 145^\circ} = 1.38\times 10^4 \text{ g}^2$$

$$k_2 = \frac{100^2}{1+\cos 104^\circ} = 1.32\times 10^4 \text{ g}^2$$

first value of k = 1.38×10^4 g^2 ....

second value of k = 1.32×10^4 g^2 .... [2]

(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)**.

$$\%\text{ difference in } k = \frac{1.38-1.32}{1.32}\times 100\% = 4.5\%$$

Since percentage difference in k (4.5%) is larger than the percentage uncertainty in θ (3.4%), the results do not support the suggested relationship.

.... [2]

(e) **(i)** Suggest a significant source of error in the measurement of θ.

Accepted sources of error
i) Difficult to measure θ accurately, using a protractor held in one's hand, because of unsteady hands.d
ii) Friction present in the ball bearings of the pulley causes the setup to be stable over a range of θ.
iii) The hook of the hanger makes it impossible to place the protractor close to the setup. This affects the measurement of θ.
iv) Difficult to gauge where the vertical axis is. This makes it difficult to ensure that θ is symmetrical about the vertical axis.
v) The hook of the hanger is too thick, making the origin of the angle difficult to judge.

.... [1]

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

Corresponding improvement
i) Clamp the protractor with a retort stand, so that it is stable.
ii) Lubricate the axle of the pulley.
iii) Tie the hanger to a piece of string.
iv) Use a plumb line to indicate the vertical axis.
v) Suspend the hanger with a piece of string.

.... [1]

[Total: 14 Marks]

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2 In this experiment, you will investigate how the period of oscillation of a bent metal wire varies with the angle between the straight parts of the wire

(a) **(i)** Make a sharp bend in the wire at its centre so that the angle θ between the straight parts of the wire is about 140° as shown in Fig. 2.1.

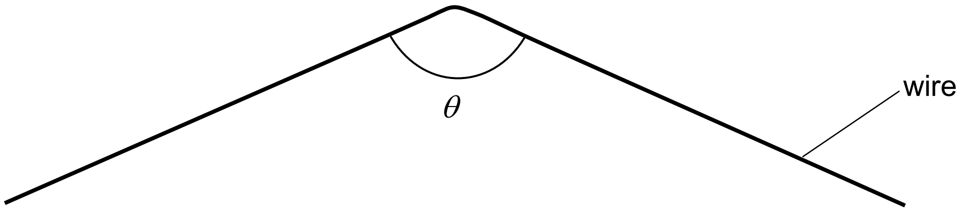


Fig 2.1

(ii) Measure and record θ.

θ_1 / °	θ_2 / °	$\langle\theta\rangle$ / °
140	139	140

θ = 140° .... [1]

(b) **(i)** Secure the cork using the clamp so that the pin is mounted horizontally.

Suspend the wire from the pin so that the arrangement is as shown in Fig. 2.2.

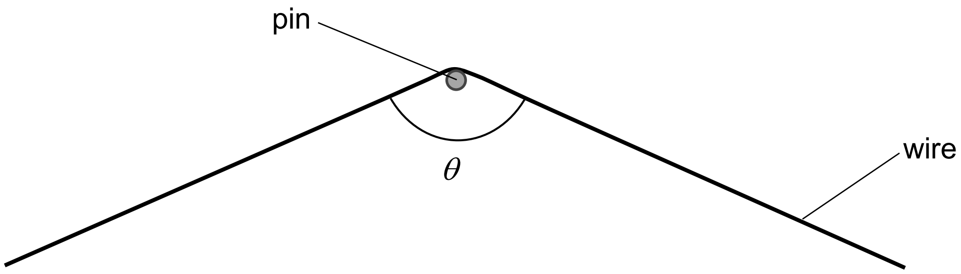


Fig 2.2

(ii) Displace the wire from its equilibrium position and release it so that it performs small oscillations in a vertical plane, as shown in Fig. 2.3.

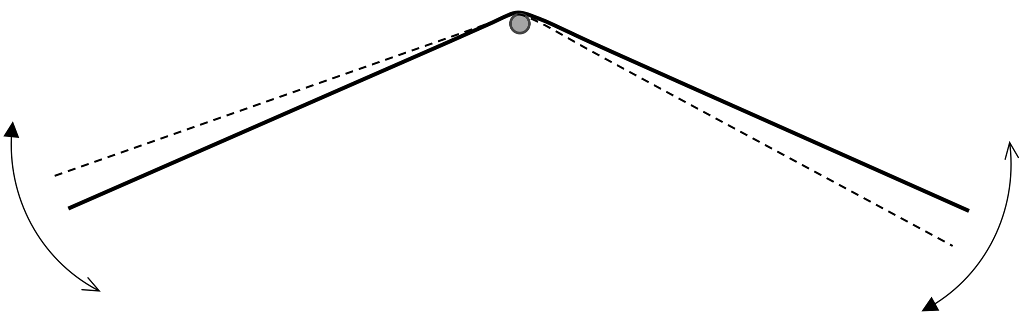


Fig 2.3

(iii) Make and record measurements to determine the period T of these oscillations.

Let number of oscillations be N

N	t_1 / s	t_2 / s	$\langle t \rangle$ / s	T / s
20	25.59	25.44	25.52	1.276

T = 1.276 s .... [1]

(c) Remove the wire from the pin. Change the value of θ by gently bending the wire. The new value of θ should be in the range $30° \le \theta \le 140°$.

Repeat **(b)** until you have six sets of readings for θ and T.

Record your results in a table. Include values of $\frac{1}{T^4}$ and cos θ in your table of results.

Let number of oscillations be N

θ / °	N	t_1 / s	t_2 / s	$\langle t \rangle$ / s	T / s	$\frac{1}{T^4}$ / s^{-4}	$\cos(\theta / °)$
140	20	25.59	25.44	25.52	1.276	0.3775	-0.766
120	20	21.58	21.56	21.57	1.079	0.7391	-0.500
100	25	23.57	23.52	23.55	0.9418	1.271	-0.174
70	30	25.06	24.96	25.01	0.8337	2.070	0.34
60	30	24.22	24.80	24.51	0.8170	2.244	0.50
40	30	22.91	22.68	22.80	0.7598	3.000	0.77

[7]

(d) **(i)** The quantities T and θ are related by the equation

$$\frac{1}{T^4} = A\cos\theta + B$$

where A and B are constants.

Plot a suitable graph to determine the values of A and B.

Plot of $\frac{1}{T^4}$ / s^{-4} against $\cos(\theta / °)$ gives a straight line graph with gradient A / s^{-4} and y-intercept B / s^{-4}.

Gradient = $\frac{2.5750 - 0.5000}{0.70 - (-0.68)} = 1.50$

A = gradient
= 1.50 s^{-4}

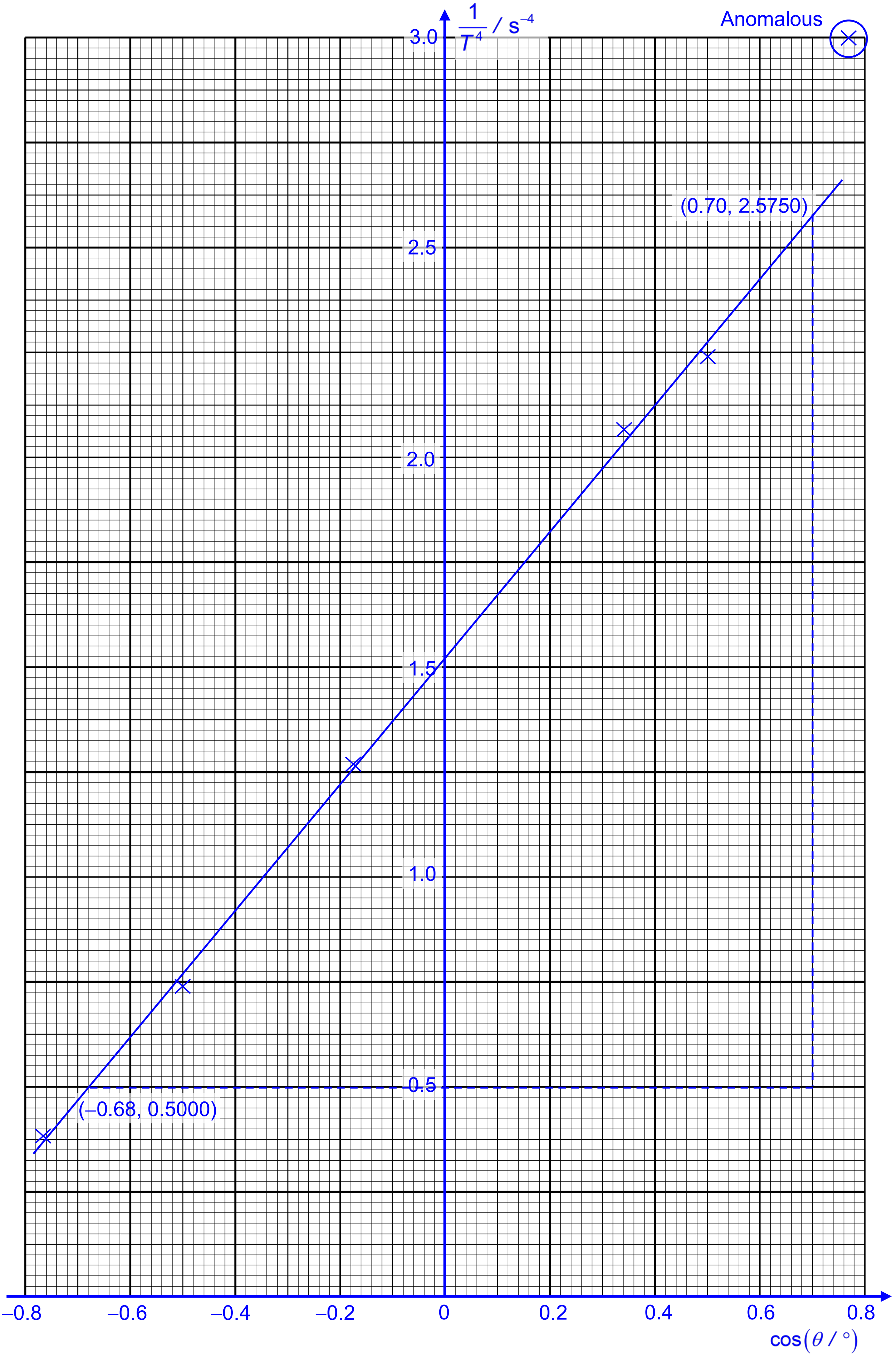
From graph, y-intercept = 1.5250

B = 1.5250 s^{-4}

A = 1.50 s^{-4}

B = 1.5250 s^{-4}

[4]



$\frac{1}{T^4}$ / s^{-4}
Anomalous
(0.70, 2.5750)
(–0.68, 0.5000)
3.0
2.5
2.0
1.5
1.0
0.5
–0.8
–0.6
–0.4
–0.2
0
0.2
0.4
0.6
0.8
$\cos(\theta / °)$

[3]

(ii) Comment on any anomalous data or results that you may have obtained.

There is an anomalous point at (0.77, 3.0000).

It does not follow the trend of the best fit line.

It lies significantly far from the best fit line relative to the other points. [1]

(e) A theoretical treatment of this oscillator shows that

$$A = \frac{1}{2}\left(\frac{3g}{4\pi^2 L}\right)^2$$

where L is the total length of the wire and g is the acceleration of free fall.

By making one further measurement, and using the results of your experiment, calculate a value for g.

L_1 / cm	L_2 / cm	$\langle L \rangle$ / cm
39.9	40.1	40.0

$$g = \frac{4}{3}\pi^2 L\sqrt{2A}$$

$$= \frac{4}{3}\pi^2(40.0\times10^{-2})\sqrt{2(1.50)}$$

$$= 9.12 \text{ m s}^{-2}$$

g = 9.12 m s^{-2} [2]

[Total: 19 Marks]