Name: ______________________________ (   )   Class: 21 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2021 JC2 Preliminary Exam

PHYSICS Higher 2 **9749/04**

Paper 4 Practical **30 Aug 2021**

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 index number and class in the spaces provided above.
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.

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	
Paper 4 (55 marks)	
1	
2	
3	
4	
Total (55 marks)	

For Examiner's Use

Question 1 begins on the next page.

For Examiner's Use

1 In this experiment, you will investigate how the resistance R of a thermistor varies with its temperature θ.

(a) Construct the circuit shown in Fig. 1.1.

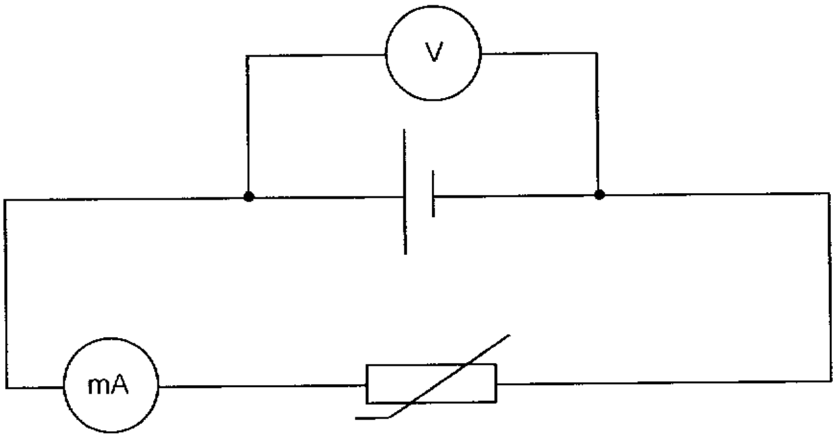


Fig. 1.1

(b) Immerse the thermistor in a beaker of water. Measure and record the current I, potential difference V and temperature θ.

I = ...

V = ...

θ = ...[1]

M1

(c) **(i)** Arrange the apparatus so that the water may be heated. **Use the stand and clamp to ensure that the wires connected to the thermistor are kept well away from the source of heating.**

(ii) Use the heating apparatus to raise the temperature of the water by about 10 °C.

After the temperature has stabilized, measure and record the new values of I, V and θ.

I = ...

V = ...

θ = ...

(iii) Repeat **(c)(ii)** for θ varying from room temperature to 80 °C.

Tabulate these results. Include the results from **(b)**, **(c)(ii)**, all the values of R, where $R = V / I$, and all the values of thermodynamic temperature T, where $T = \theta + 273$.

For Examiner's Use

M2	
P1	
P2	
P3	
A1	

[6]

(d) The formula which relates R and T is

$$R = Ae^{\frac{E}{kT}}$$

where A is a constant, E is an energy characteristic of the thermistor, and $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$.

Plot a suitable graph to determine values for E and A.

A2	
A3	
A4	
A5	

E = ...

A = ...

[7]

For Examiner's Use

P4	
P5	
P6	

(e) Comment on any anomalous data or results you may have obtained. Explain your answer.

For Examiner's Use

....

....

....[1]

M3

[Total: 15 marks]

For Examiner's Use

Question 2 begins on the next page.

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

(a) Set up the apparatus as shown in Fig. 2.1. The length *l* of the pendulum is approximately 70 cm. As the pendulum oscillates, a stop shortens the effective length *l* by an amount *d*.

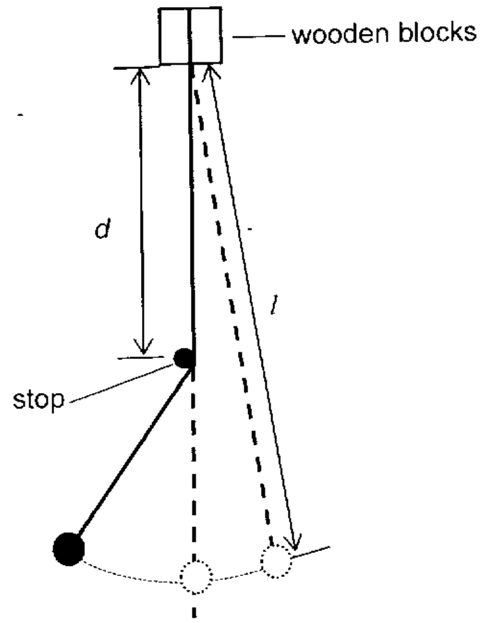


Fig. 2.1

Mount the wooden rod horizontally so that it acts as a stop half-way down the pendulum. The stop should *just touch* the string when the pendulum rests in a vertical plane.

(b) **(i)** Measure and record the value of *l*.

l = ...

(ii) Measure and record the value of *d*.

d = ... [1]

M1	

(iii) Gently displace the pendulum so that it performs small oscillations in a vertical plane perpendicular to the stop.

Make and record measurements to determine the period *T* of these oscillations.

M2	
A1	

T = ... [2]

For Examiner's Use

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

$$T = -\frac{\pi^2}{k}\left(\frac{d}{T}\right) + 2\pi\sqrt{\frac{l}{g}}$$

where *k* and *l* are constants, and $g = 9.81 \text{ m s}^{-2}$.

(i) Calculate *k*.

k = ... m s^{-2} [2]

A2	
A3	

(ii) It is not accurate to draw a conclusion for the value of *k* based on only one reading as in **c(i)**. It is a good practice to determine *k* graphically.

Using the same apparatus, describe how you would obtain further measurements, and the graph that you would plot to determine *k*.

....

....

....

....

....

....[2]

A4	
A5	

[Total: 7 marks]

For Examiner's Use

3 In this experiment, you will model the stability of a scoop of ice cream in a cone.

(a) **(i)** Measure and record the diameter x and the height h of the cone, as shown in Fig. 3.1.

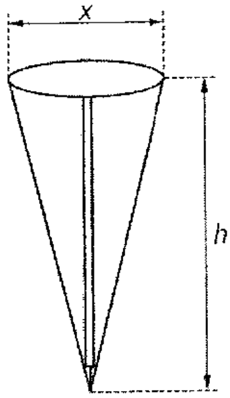


Fig. 3.1

x = ...

h = ...[1]

M1

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

percentage uncertainty = ...% [1]

A1

(b) **(i)** Place the ping-pong ball in the cone, as shown in Fig. 3.2.

For Examiner's Use

Tilt the cone until the ping-pong ball falls out, as shown in Fig. 3.3.
The angle between the bench and the **centre** line of the cone is θ.
The height of the top of the centre line above the bench is y.

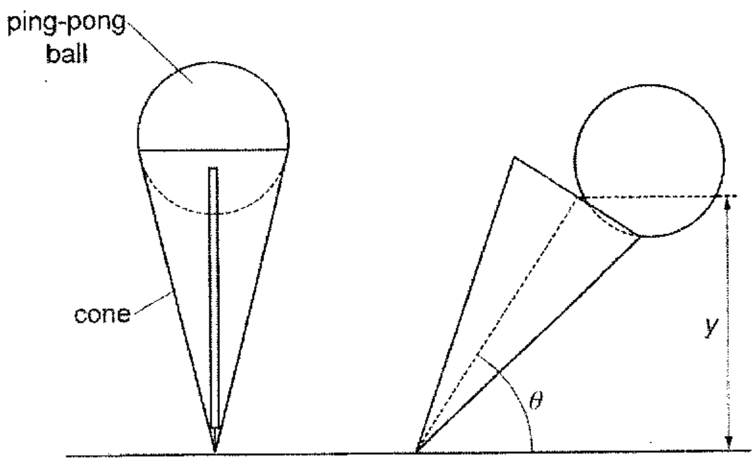


Fig. 3.2 **Fig. 3.3**

Measure and record θ and y.

θ = ...

y = ... [2]

M2	
M3	

(ii) Calculate $\tan\theta$.

$\tan\theta$ = ... [1]

A2	

[Turn Over

For Examiner's Use

(c) **(i)** You have been provided with a sheet of paper with the outline of another cone.

Cut around the outline and assemble this cone.

(ii) Repeat **(a)(i)** and **(b)**.

x = ...

h = ...

θ = ...

y = ...

$tan\ \theta$ = ... [2]

M4	
M5	

(d) It is suggested that $\tan\theta = \frac{ky}{hx}$ where k is a constant.

(i) Use your values from **(a)(i)**, **(b)** and **(c)(ii)** to determine two values for k.
Give your values for k to an appropriate number of significant figures.

first value for k = ...

second value for k = ... [1]

A3	

For Examiner's Use

(ii) State whether the results of your experiment support the suggested relationship. Justify your conclusion by referring to your value in **(a)(ii)**.

....

....

....

....

.... [1]

A4

(e) **(i)** Suggest **two** significant sources of error in this experiment.

1 ....

....

....

....

2 ....

....

....

....

[2]

A5

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

....

....

....

....[1]

A6

(f) The experiment is repeated using a cone with fixed dimensions and spheres of different radii r.

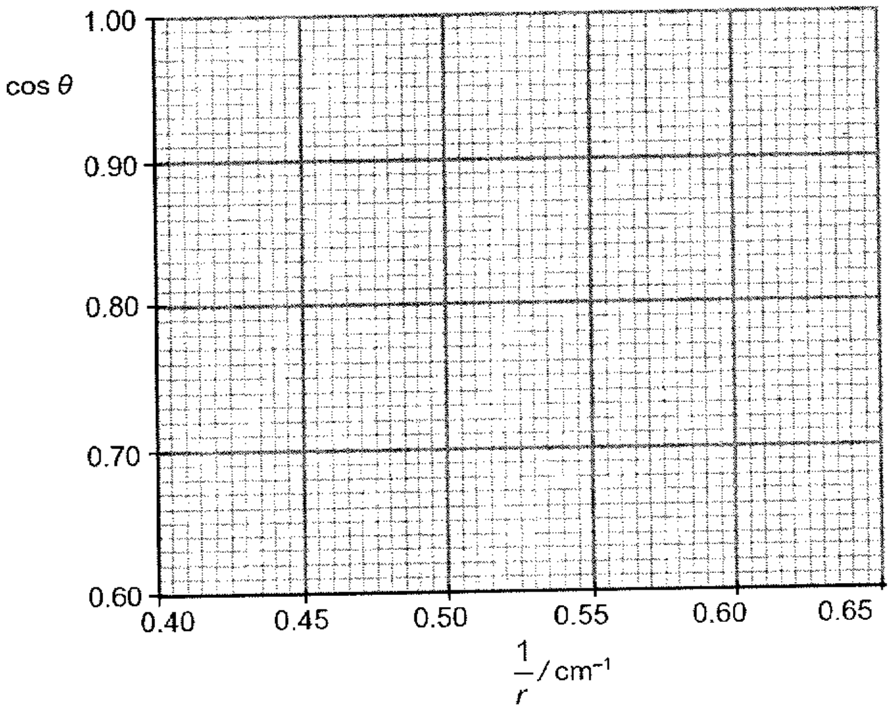
For Examiner's Use

The results are shown in the table.

Values of $\frac{1}{r}$ and $\cos\theta$ are included.

r/ cm	$\frac{1}{r}$/ cm^{-1}	θ/ °	$\cos\theta$
1.6	0.63	20	0.94
1.8	0.56	34	0.83
2.0	0.50	41	0.75
2.2	0.45	47	0.68
2.4	0.42	51	0.63

(i) Plot the points on the grid and draw the straight line of best fit.



[1]

P1

(ii) Determine the y-intercept of the line.

A7

A8

y-intercept = ... [2]

(iii) Use your answer in **(f)(ii)** to state whether cos θ is inversely proportional to r.

....

....[1]

For Examiner's Use

A9	

(g) An ice-cream cone manufacturer uses cones of height 10 cm and diameter 6 cm. These are used for ice-cream scoops which are the same size as tennis balls.

They wish to reduce the height of the cones but the scoop must still be stable when $\theta = 60°$.

Plan an investigation to find the minimum height of a cone that they could make.

Your account should include:

- your experimental procedure
- details of the table of measurements with appropriate units
- how you would find the minimum height.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....[5]

PL1	
PL2	
PL3	
PL4	
PL5	

[Total: 21 marks]

4 The motion of a small cube on a turntable connected to an electric motor is shown in Fig. 4.1.

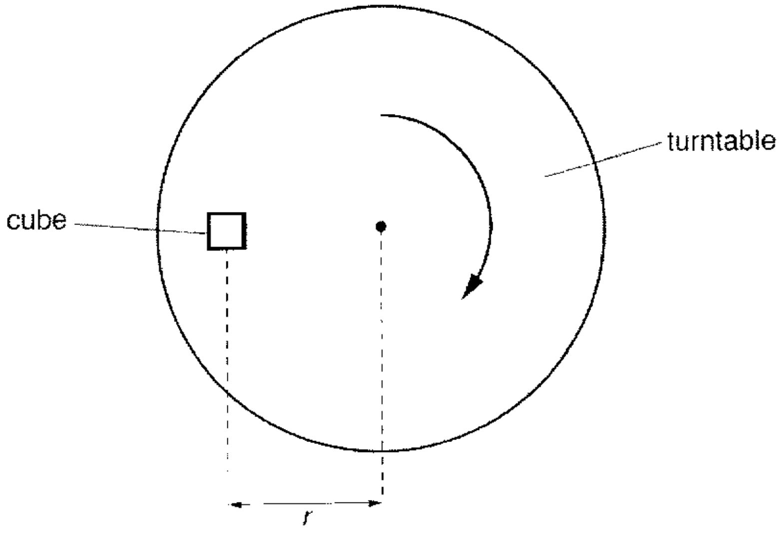


Fig. 4.1

The cube is placed at a distance r from the centre of the turntable. A student suggested that the maximum frequency f of the turntable for which the cube does not move relative to the turntable depends on r and mass m of the cube.

The relation between f, r and m may be written in the form

$$f = Kr^p m^q$$

where K, p and q are constants.

You are provided with a number of cubes of different sizes of the same material.
Design an experiment to determine the values of K, p and q.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to

(a) the equipment you would use
(b) the procedure to be followed
(c) how you would vary the frequency of the turntable
(d) the control of variables
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

For Examiner's Use

....

....

....

....

....

....

....

....

....

....

....

....

....

....

For Examiner's Use

....[12]

[Total: 12 marks]

BLANK PAGE

BLANK PAGE

For Examiner's Use

1 In this experiment, you will investigate how the resistance R of a thermistor varies with its temperature θ.

(a) Construct the circuit shown in Fig. 1.1.

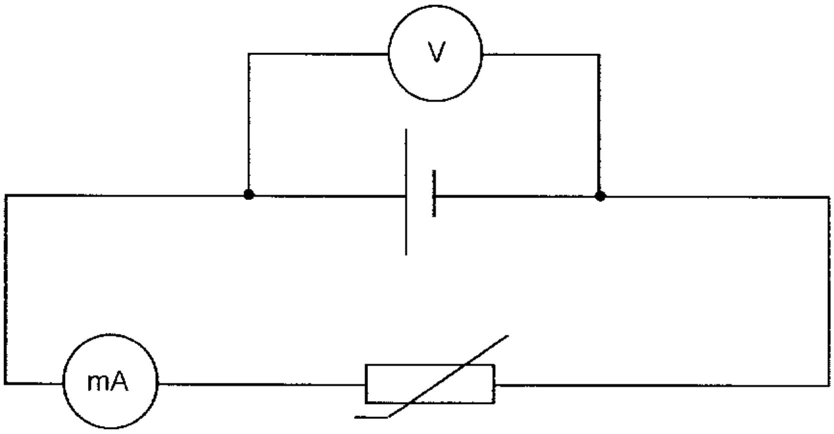


Fig. 1.1

(b) Immerse the thermistor in a beaker of water. Measure and record the current I, potential difference V and temperature θ.

I = 11.1 mA

V = 2.08 V

θ = 30.0 °C [1]

M1

(c) **(i)** Arrange the apparatus so that the water may be heated. **Use the stand and clamp to ensure that the wires connected to the thermistor are kept well away from the source of heating.**

(ii) Use the heating apparatus to raise the temperature of the water by about 10 °C.

After the temperature has stabilized, measure and record the new values of I, V and θ.

I = 17.4 mA

V = 2.08 V

θ = 43.0 °C

(iii) Repeat **(c)(ii)** for θ varying from room temperature to 80 °C.

Tabulate these results. Include the results from **(b)**, **(c)(ii)**, all the values of R, where $R = V / I$, and all the values of thermodynamic temperature T, where $T = \theta + 273$. [6]

For Examiner's Use

θ / °C	V / V	I / mA	R / Ω	T / K	ln (R/ Ω)	$\frac{1}{T}$ / 10^{-3} K^{-1}
30.0	2.08	11.1	187	303.0	5.23	3.300
43.0	2.08	17.4	120	316.0	4.79	3.165
50.0	2.08	23.5	88.5	323.0	4.48	3.096
60.0	2.08	31.6	65.8	333.0	4.19	3.003
70.0	2.07	41.9	49.4	343.0	3.90	2.915
80.0	2.07	54.3	38.1	353.0	3.64	2.833

M2	
P1	
P2	
P3	
A1	

(d) The formula which relates R and T is

$$R = Ae^{\frac{E}{kT}}$$

where A is a constant, E is an energy characteristic of the thermistor, and $k = 1.38 \times 10^{-23}$ J K^{-1}.

Plot a suitable graph to determine values for E and A.

[7]

$$R = Ae^{\frac{E}{kT}}$$

$$\ln R = \frac{E}{k}\left(\frac{1}{T}\right) + \ln A$$

Plot a graph of ln R against $1/T$ where gradient = E/k, and y-intercept = ln A.

$$\text{Gradient} = \frac{5.72 - 3.78}{(3.440 - 2.880) \times 10^{-3}} = 3.46 \times 10^{3}$$

Hence $E = 3.46 \times 10^{3} \times 1.38 \times 10^{-23} = 4.77 \times 10^{-20}$ J

Substituting (3.440×10^{-3}, 5.72) into y = mx + c:

y-intercept c = $5.72 - 3.46 \times 10^{3} (3.440 \times 10^{-3}) = -6.18$

ln $A = -6.18$

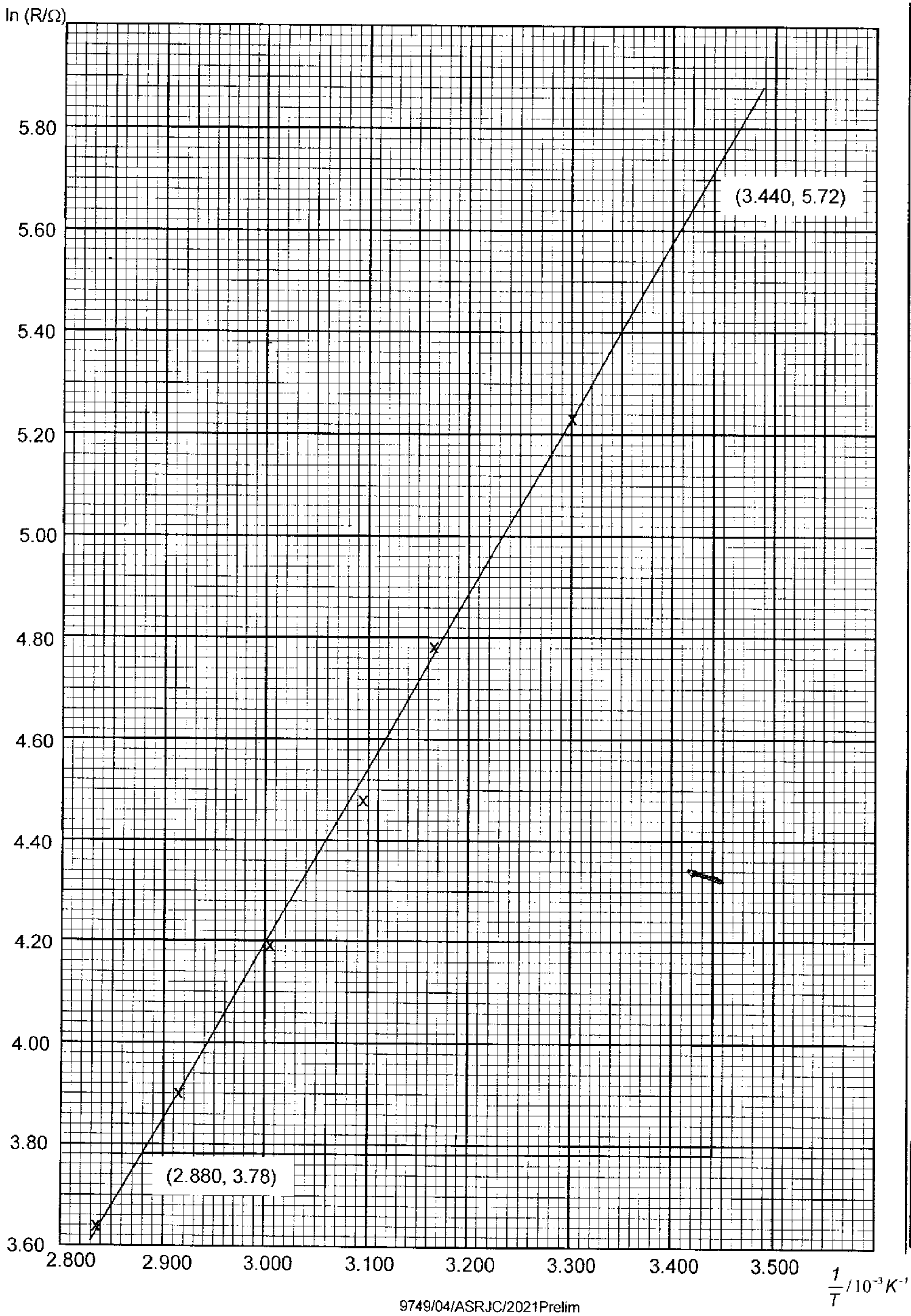
$A = e^{-6.18}$

$= 2.07 \times 10^{-3}$ Ω

A2	
A3	
A4	
A5	

E = 4.77 × 10^{-20} J

A = 2.07 × 10^{-3} Ω



For Examiner's Use

P4	
P5	
P6	

(e) Comment on any anomalous data or results you may have obtained. Explain your answer.

There are no anomalous data as all the plotted points lie close to the best fit line.

[1]

M3	

[Total: 15 marks]

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

For Examiner's Use

(a) Set up the apparatus as shown in Fig. 2.1. The length l of the pendulum is approximately 70 cm. As the pendulum oscillates, a stop shortens the effective length l by an amount d.

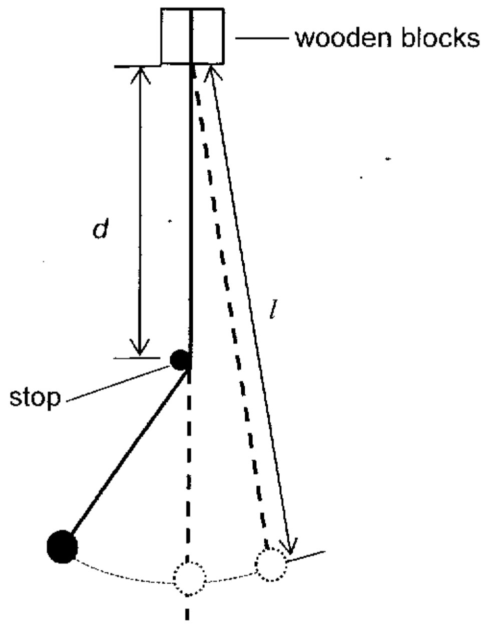


Fig. 2.1

Mount the wooden rod horizontally so that it acts as a stop half-way down the pendulum. The stop should *just touch* the string when the pendulum rests in a vertical plane.

(b) **(i)** Measure and record the value of l.

l = 0.700 m

(ii) Measure and record the value of d.

d = 0.350 m [1]

M1	

(iii) Gently displace the pendulum so that it performs small oscillations in a vertical plane perpendicular to the stop.

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

$$T = \frac{t_1 + t_2}{2N}$$

$$= \frac{28.5 + 28.3}{2(20)}$$

$$= 1.42 \text{ s}$$

T = 1.42 s [2]

M2	
A1	

For Examiner's Use

(c) The quantities d and T are related by the equation

$$T = -\frac{\pi^2}{k}\left(\frac{d}{T}\right) + 2\pi\sqrt{\frac{l}{g}}$$

where k and l are constants, and $g = 9.81 \text{ m s}^{-2}$.

(i) Calculate k.

$$k = \frac{\pi^2 d}{T\left(2\pi\sqrt{\frac{l}{g}} - T\right)}$$

$$= \frac{\pi^2 (0.350)}{1.42\left(2\pi\sqrt{\frac{0.700}{9.81}} - 1.42\right)}$$

$$= 9.41 \text{ m s}^{-2}$$

A2	
A3	

k = 9.41 .... m s^{-2} [2]

(ii) It is not accurate to draw a conclusion for the value of k based on only one reading as in **c(i)**. It is a good practice to determine k graphically.

Using the same apparatus, describe how you would obtain further measurements, and the graph that you would plot to determine k.

Repeat the experiment with different d by changing the position of the wooden rod to obtain 6 sets of d and T.

Plot a graph of T against $\frac{d}{T}$ (where gradient = $-\frac{\pi^2}{k}$ and y-intercept = $2\pi\sqrt{\frac{l}{g}}$),

Determine gradient of the graph and find k using $k = -\frac{\pi^2}{gradient}$.

A4	
A5	

[2]

[Total: 7 marks]

3 In this experiment, you will model the stability of a scoop of ice cream in a cone.

For Examiner's Use

(a) **(i)** Measure and record the diameter x and the height h of the cone, as shown in Fig. 3.1.

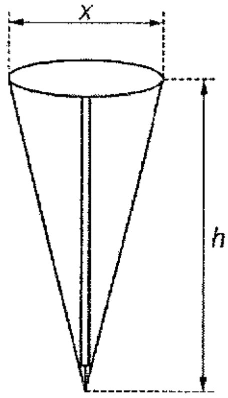


Fig. 3.1

$$x = \frac{3.3 + 3.5}{2} = 3.4 \text{ cm}$$

$$h = \frac{12.6 + 13.0}{2} = 12.8 \text{ cm}$$

x = ...3.4 cm..........

h = ...12.8 cm.......... [1]

M1

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

percentage uncertainty of $x = \frac{0.5}{3.4} \times 100\% = 15\ \%$

percentage uncertainty = ...15.......... % [1]

A1

[Turn Over

For Examiner's Use

(b) **(i)** Place the ping-pong ball in the cone, as shown in Fig. 3.2.

Tilt the cone until the ping-pong ball falls out, as shown in Fig. 3.3.
The angle between the bench and the **centre** line of the cone is θ.
The height of the top of the centre line above the bench is y.

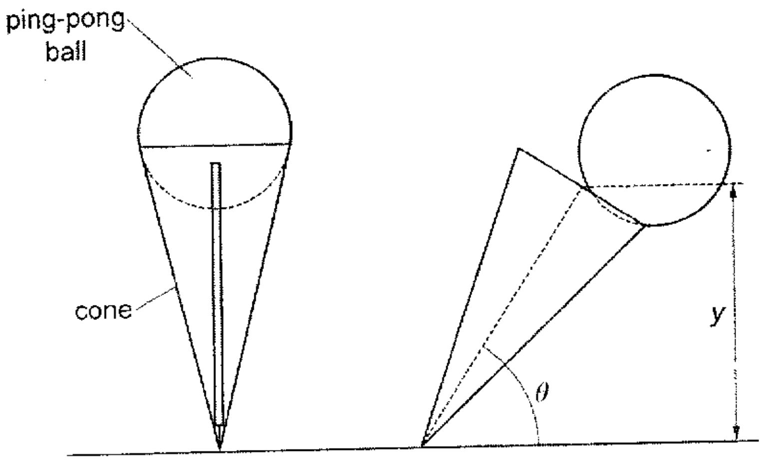


Fig. 3.2 **Fig. 3.3**

Measure and record θ and y.

$$\theta = \frac{44° + 46°}{2} = 45°$$

$$y = \frac{9.9 + 9.5}{2} = 9.7 \text{ cm}$$

θ = ...45°......

y = ...9.7 cm...... [2]

M2	
M3	

(ii) Calculate tan θ.

tan 45° = 1.0

tan θ = ...1.0...... [1]

A2	

(c) **(i)** You have been provided with a sheet of paper with the outline of another cone.

For Examiner's Use

Cut around the outline and assemble this cone.

(ii) Repeat **(a)(i)** and **(b)**.

$$x = \frac{2.6 + 3.2}{2} = 2.9 \text{ cm}$$

$$h = \frac{10.2 + 11.0}{2} = 10.6 \text{ cm}$$

$$\theta = \frac{58^\circ + 67^\circ}{2} = 63^\circ$$

$$y = \frac{9.1 + 9.3}{2} = 9.2 \text{ cm}$$

tan 63° = 2.0

x = 2.9 cm

h = 10.6 cm

θ = 63°

y = 9.2 cm

$\tan\theta$ = 2.0

[2]

M4	
M5	

(d) It is suggested that $\tan\theta = \frac{ky}{hx}$ where k is a constant.

(i) Use your values from **(a)(i)**, **(b)** and **(c)(ii)** to determine two values for k. Give your values for k to an appropriate number of significant figures.

$$k = \frac{hx\tan\theta}{y}$$

first value for $k = \frac{(12.8)(3.4)\tan 45^\circ}{9.7} = 4.5 \text{ cm}$

second value for $k = \frac{(10.6)(2.9)\tan 63^\circ}{9.2} = 6.6 \text{ cm}$

first value for k = 4.5 cm

second value for k = 6.6 cm

[1]

A3	

[Turn Over

For Examiner's Use

(ii) State whether the results of your experiment support the suggested relationship. Justify your conclusion by referring to your value in **(a)(ii)**.

The criterion for the relationship to be valid is percentage difference in $k \leq$ percentage uncertainty in x.

Percentage difference in $k = \dfrac{6.6-4.5}{4.5} \times 100\% = 47\%$

Since the percentage difference in k is larger than percentage uncertainty in x, the relationship is not valid. [1]

A4

(e) **(i)** Suggest **two** significant sources of error in this experiment.

1 It is difficult to maintain the position of the tilted cone while measuring angle and height after the ball is dropped, thus affecting values of θ and y.

2 It is difficult to measure y accurately as the ruler is not vertical, affecting values of y.

[2]

A5

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

Clamp the protractor and ruler with retort stands, and measure angle and height after the ball is dropped.

[1]

A6

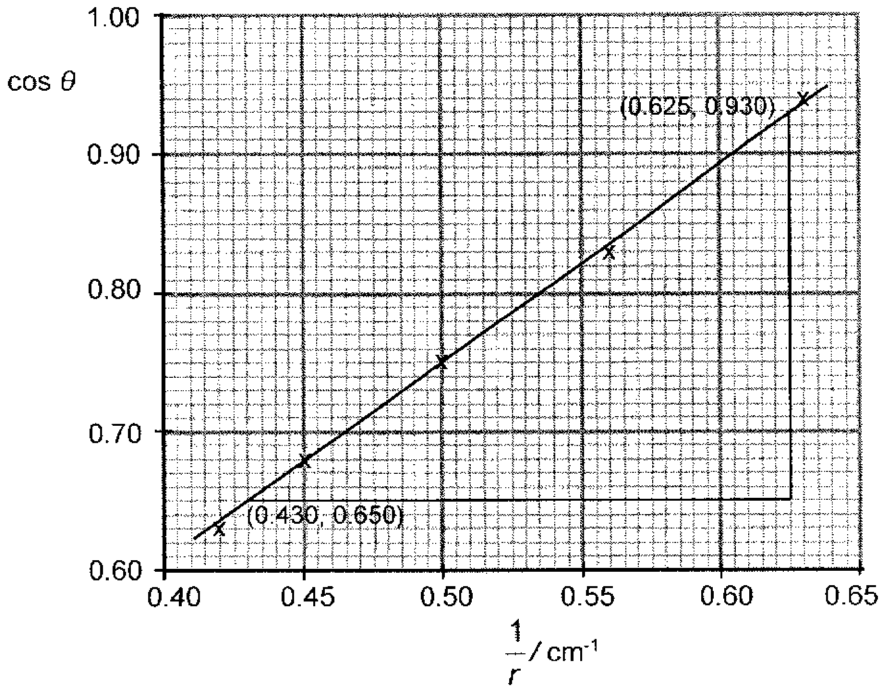
(f) The experiment is repeated using a cone with fixed dimensions and spheres of different radii r.

The results are shown in the table.

Values of $\frac{1}{r}$ and $\cos\theta$ are included.

r/ cm	$\frac{1}{r}$ / cm^{-1}	θ/ °	$\cos\theta$
1.6	0.63	20	0.94
1.8	0.56	34	0.83
2.0	0.50	41	0.75
2.2	0.45	47	0.68
2.4	0.42	51	0.63

(i) Plot the points on the grid and draw the straight line of best fit.



[1]

P1

(ii) Determine the y-intercept of the line.

$$\text{Gradient} = \frac{0.930 - 0.650}{0.625 - 0.430} = \frac{0.280}{0.195} = 1.44$$

Substitute (0.625, 0.930) into y = mx + c, where c is the y-intercept

c = 0.930 – 1.44(0.625)

= 0.030

y-intercept = ... [2]

0.030

A7

A8

[Turn Over

For Examiner's Use

(iii) Use your answer in **(f)(ii)** to state whether cos θ is inversely proportional to r.

Since y-intercept is not zero, cos θ is not inversely proportional to r.

[1]

A9

(g) An ice-cream cone manufacturer uses cones of height 10 cm and diameter 6 cm. These are used for ice-cream scoops which are the same size as tennis balls.

They wish to reduce the height of the cones but the scoop must still be stable when $\theta = 60°$.

Plan an investigation to find the minimum height of a cone that they could make.

Your account should include:

- your experimental procedure
- details of the table of measurements with appropriate units
- how you would find the minimum height.

1. Keep the diameter of the cones constant at 6 cm (by fixing the arc length of the cone outline).
2. Vary the height h of the cone (using different lengths for the lateral side of the cone outline. Ensure that the final heights of the cone obtained are less than 10 cm). Place a tennis ball in a cone and tilt the cone until the ball falls out. Measure the angle θ between the bench and the centre line of the cone. Repeat with the other cones to obtain θ for different values of h.
3. Record the reading in a table with headings:

h / cm	θ_1 / °	θ_2 / °	$\theta = (\theta_1 + \theta_2) / 2$ θ / °

4. Plot a graph of h against θ and draw the best fit line.
5. Read off the value of h for $\theta = 60°$. This will be the minimum height of a cone that they could make.

[5]

PL1 PL2 PL3 PL4 PL5

[Total: 21 marks]

2021 JC2 Prelim Paper 4 Question 1 MS

Q1	Answer	Mark	Code
(b)	***Measurement of I*, V and θ** Values of I, V and θ measured to the correct unit within appropriate range.	1	**M1**
(c)	***Set up apparatus from a circuit diagram and follow of written instructions*** • Award 2 marks if the student has successfully collected 6 or more sets of data (I, V and θ), without assistance/intervention. • Award 1 mark if student has successfully collected 5 sets of data (I, V and θ), without assistance/intervention. • Award zero mark if student has successfully collected 4 or fewer sets of data (I, V and θ), without assistance/intervention. • Deduct 1 mark if student requires some assistance/intervention but has been able to do most of the work independently. Indicate the nature of any assistance. • Deduct 2 marks if student has been unable to collect data without substantial assistance/intervention. Minimum mark for **M2** = 0.	2	**M2**
(c)	***Layout: Column headings (raw data & calculated quantities: I*, V, θ, T, R, ln R, 1/T*)*** Each column heading must contain an appropriate quantity and a unit. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit i.e. solidus is expected.	1	**P1**
(c)	***Table of results: raw data (appropriate degree of precision)*** All values of I, V, θ to the correct precision.	1	**P2**
(c)	***Table of results: calculated quantities (appropriate no. of significant figures)*** For each calculated value of T, R, ln R and $1/T$, the number of s.f. should be the same (or one more) as the number of s.f. in the raw data.	1	**P3**
(c)	***Table of results: calculated quantities*** Correctly calculated values of calculated quantities. Allow one slip computation.	1	**A1**
(d)	***Linearising Equation*** Linearising equation and deriving expressions that equate gradient to E/k and y-intercept to ln A.	1	**A2**
(d)	***Graph: Layout, choice of scale and labeling of axes*** Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Axes must be labelled with the quantity which is being plotted.	1	**P4**
(d)	**Graph: plotting of points** All observations must be plotted. Check any 3 points and put ticks if correct. Work to an accuracy of half a small square.	1	**P5**

Q1	Answer	Mark	Code
(d)	**Graph: trend line and ability to draw best fit line** Straight line of best fit – judge by scatter of points about the candidate's line. There must be a fair scatter of points either side of the line.	1	**P6**
(d)	***Interpretation of graph – gradient*** Gradient – the hypotenuse of the Δ must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square.	1	**A3**
(d)	***Interpretation of graph – intercept*** y-intercept must be read off to the nearest half small square or determined from y = mx + c using a point on the line.	1	**A4**
(d)	***Interpretation of graph – values of E and A*** Values of E and A calculated correctly with units.	1	**A5**
(e)	*Identification of anomaly* *Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise, comment of absence of anomalous data.*	*1*	*M3*

JC2 Prelim Question 2 MS

Q2	*Answer*	Mark	Code
(b)(ii)	***Measurement of d*** Value of *d* to the nearest mm with correct unit and correct range	1	**M1**
(b)(iii)	***Evidence of repeated readings*** Repeated timings for a value of *d*, with *t*>10 s	1	**M2**
(b)(iii)	***Calculated quantity T*** Correct calculation of *T* to 3 s.f.	1	**A1**
(c)(i)	***Calculated quantity k*** Correct substitution of *d*, *T*, *l* and *g* to calculate *k*	1	**A2**
(c)(i)	***Calculated quantity k*** Correct calculation of *k* value with appropriate s.f.	1	**A3**
(c)(ii)	***Determine k by plotting a graph*** Repeat the experiment with different *d* by changing the position of the wooden rod to obtain 6 sets of *d* and *T* Correct graph plotted	1	**A4**
(c)(ii)	***Determine k by plotting a graph*** Correct method to find *k* graphically.	1	**A5**

JC2 Prelim Question 3 MS

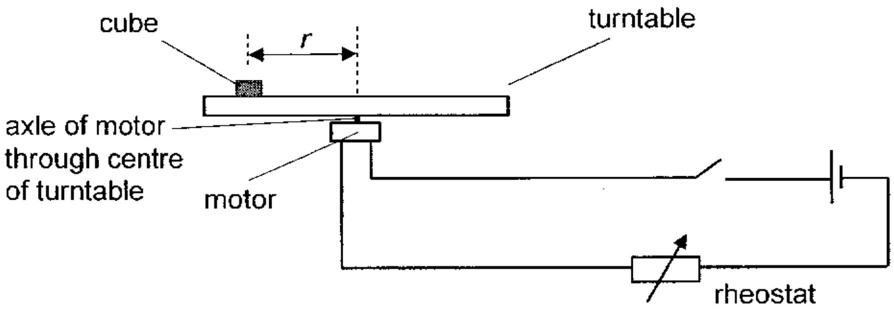
Q3	Answer	Mark	Code
(a)(i)	***Measurement of x and h*** Value of *x* and *h* measured to the nearest 1 mm with unit.	1	M1
(a)(ii)	***Estimating uncertainties*** Sensible value of Δ*x* (e.g. 0.2 cm to 0.5cm). Percentage uncertainty in *x* calculated correctly to 2 s.f.	1	A1

Q3	Answer	Mark	Code
(b)(i)	***Measurement of θ and y*** Value of θ measured to the nearest 1°. Value of y measured to the nearest 1 mm with unit. Evidence of repeated readings of θ and *y*.	1 1	M2 M3
(b)(ii)	***Calculation of tan θ*** Value calculated correctly with appropriate s.f.	1	A2
(c)(ii)	***Measurement of x, h, θ and y*** Record of readings *x*, *h*, θ and *y*. θ in **(c)(ii)** > θ in **(b)(i)**.	1 1	M4 M5
(d)(i)	***Calculation of k values*** Correct calculation of *k* values with appropriate s.f. and units.	1	A3
(d)(ii)	***Validation of relationship*** Draw conclusion based on stated criterion e.g. not obeyed because % difference in *k* more than % uncertainty in *x*.	1	A4
(e)(i)	***Sources of error*** 1. Difficult to maintain the position of the tilted cone while measuring angle and height after the ball is dropped, affecting values of θ and *y*. 2. Difficult to measure *y* accurately with positioning reason (e.g. ruler is not vertical), affecting values of *y*. 3. Difficult to measure *x* as the cone changes shape easily, affecting values of *x*.	any 2 1 1	A5
(e)(ii)	***Improvement*** 1. Clamp the protractor and ruler with retort stands, and measure angle and height after the ball is dropped. OR Hold the cone using the clamp of the retort stand. Rotate the clamp to drop the ball and tighten the boss after the ball is dropped. Measure angle and height after the ball is dropped 2. Hang a plumbline using a retort stand to check that ruler is vertical.	1	A6
(f)(i)	***Graph : plotting of points and best-fit line*** Points correctly plotted. Straight line of best fit – judge by scatter of points about the candidate's line. There must be a fair scatter of points on either side of the line.	1	P1
(f)(ii)	***Graph : gradient*** Gradient – the hypotenuse of the Δ must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. ***Graph : y-intercept*** y-intercept must be determined from y = mx + c using a point on the line.	1 1	A7 A8

Q3	Answer	Mark	Code
(f)(iii)	***Drawing conclusion*** Correct conclusion based on whether the y-intercept obtained in **(f)(ii)** is zero.	1	A9
(g)	***Planning*** Diameter of the cone, x, is kept constant Height of the cone, h is varied and corresponding readings for θ taken (where θ is the angle of cone tilted until the ball falls out). Table with correct headings (e.g h / cm, θ / °) Plot a graph of h against θ and draw the best fit curve Accept other suitable graphs e.g. $\theta = kh^x$ Read off the value of h which gives $\theta = 60°$	1 1 1 1 1	PL1 PL2 PL3 PL4 PL5

Prelim P4 Q4 Suggested Solutions and Mark Scheme

Diagram



Experiment (i) *f* vs *r*

Dependent variable	Independent variables	Control variables
What? Frequency of rotation, f	Distance from centre of turntable to centre of mass, r	• mass of cube, m
How? Stopwatch Take timing t for N turns. Period, $T = t/N$ $f = N/t$ Vary by adjusting rheostat	Half metre rule moving the cube to a different position	• electronic balance • use the same cube

Experiment (ii) *f* vs *m*

Dependent variable	Independent variables	Control variables
What? Frequency of rotation, f	mass of cube, m	• Distance from centre of turntable to centre of mass, r
How? Stopwatch Take timing t for N turns. Period, $T = t/N$ $f = 1/T$ Vary by adjusting rheostat	electronic balance using cubes of different sizes / mass	• Mark on turntable fixed position

Procedure

1. **How f varies with r, keeping m constant**
2. Set up the apparatus as shown. Ensured the motor is securely clamped using a retort stand.
3. Measure and record *r* using a half metre rule.
4. Measure and record *m* using an electronic balance.
5. Close the switch to spin the turntable. Adjust the variable resistor in the circuit to increase the frequency of rotation until the cube moves relative to the turntable.
6. Measure and record time t for N number of complete rotations of the turntable using a stopwatch.
7. Calculate period T, using T = t/N.
8. Calculate f = 1/T.
9. Repeat the experiment with different *r* by moving the cube to a different position to obtain 6 sets of readings of ***r* and *f*.**

10. **How f varies with m, keeping r constant**
11. Repeat the experiment by using cubes of different sizes / mass to obtain 6 sets of readings of ***m* and *f*.**

Analysis

Given that $f = K\,r^p\,m^q$ where *K, p and q* are constants,

Experiment (i)

$\lg f = p \lg r + \lg (K\,m^q)$

Plot a graph of lg *f* against lg *r*.

If the graph is a straight line, p is the gradient and $\lg (K\,m^q)$ is the y-intercept.

Calculate the gradient to find *p*.

Experiment (ii)

$\lg f = q \lg m + \lg (K\,r^p)$

Plot a graph of lg *f* against lg *m*.

If the graph is a straight line, *q* is the gradient and $\lg (K\,r^p)$ is the y-intercept.

Calculate the gradient to find *q*.

Using the values of *p* from experiment (i) and constant *r*, substitute into y-intercept, $c = \lg (K\,r^p)$

$K = 10^c / r^p$

Control of Variables

1. For experiment (i), ensure m is the constant by using the same cube.
2. For experiment (ii), ensure r is the constant by marking the position of the cube on the turntable.

Accuracy and Safety

1. Take preliminary readings to find suitable values of *r* and *m* to obtain measurable values of *t*.
2. Wait for turntable to rotate steadily before increasing frequency **OR** gradual or incremental or slowly increase in frequency.
3. Use a spirit level to check that turntable is horizontal.
4. Put a mark on the cube to ensure distance *r* is measured to centre of the cube.
5. Measure two or more diameters, take average and halved its value to determine centre the turntable.
6. Take two readings of *t* for each *r* and *m* and find average *f* to reduce random error.
7. Use safety screen as a protection against the cube in case it spins off the turntable.

[Total: 12]

Q4	Code

Design/Diagram	
Labelled diagram showing power supply connected to motor (two leads) under turntable with axle through the centre of turntable, and a variable resistor in series.	D1
Procedure	
Measure and record the distance *r* using ruler and mass *m* using an electronic balance.	P1
Increase the frequency until the cube moves (relative to turntable).	P2
Workable method to determine the period of rotation e.g. stopwatch, lightgate attached to timer/datalogger or stroboscope.	P3
How to vary *m* and *r* to get 6 sets of data of *m* and *r*	P4
Control of variables	
Method to keep *r* and *m* constant.	C1
Analysis	
Plot a graph of lg *f* against lg *r* and equate *p* to gradient	G1
Plot a graph of lg *f* against lg *m* and equate *q* to gradient.	G2
$K = 10^c / r^p$ or $10^{c - p \lg r}$ or $10^c / m^q$ or $10^{c - q \lg m}$	G3
Accuracy and Safety (max 3 = 2A + 1S)	
Take preliminary readings to find suitable values of *r* and *m* to obtain measurable values of *f*.	A1
Wait for turntable to rotate steadily before increasing frequency **OR** gradual or incremental or slowly increase in frequency.	A2
Use a spirit level to check that turntable is horizontal.	A3
Method to ensure *r* is measured to the centre of the cube.	A4
Method to determine the centre of the turntable.	A5
Repeat experiment for each *r* and *m* and find average *f*.	A6
Use slow motion video / playback frame-by-frame to determine period more accuracy.	A8
Mark position of cube on turntable to better determine if cube has moved.	A9
Use safety screen as a protection against the cube as it spins off the turntable.	S1