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.

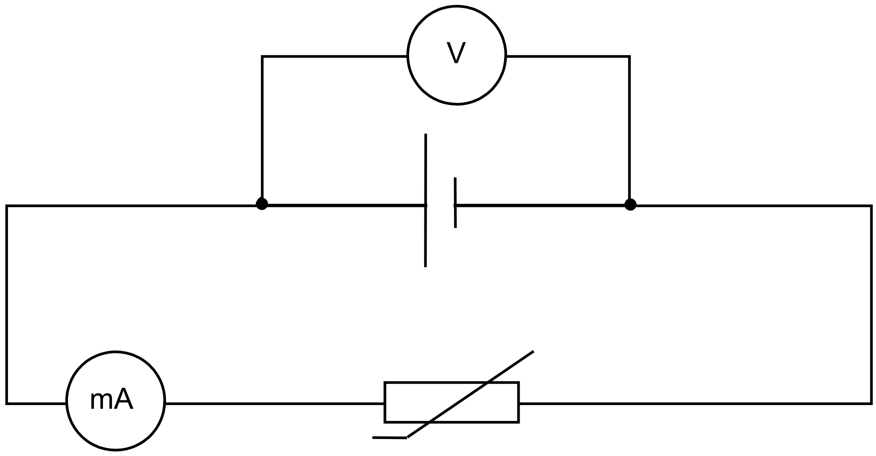


Fig. 1.1

(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 ^{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 ^{0}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 ^{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]

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

For Examiner's Use

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.

A2	
A3	
A4	
A5	

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

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 $A = -6.18$

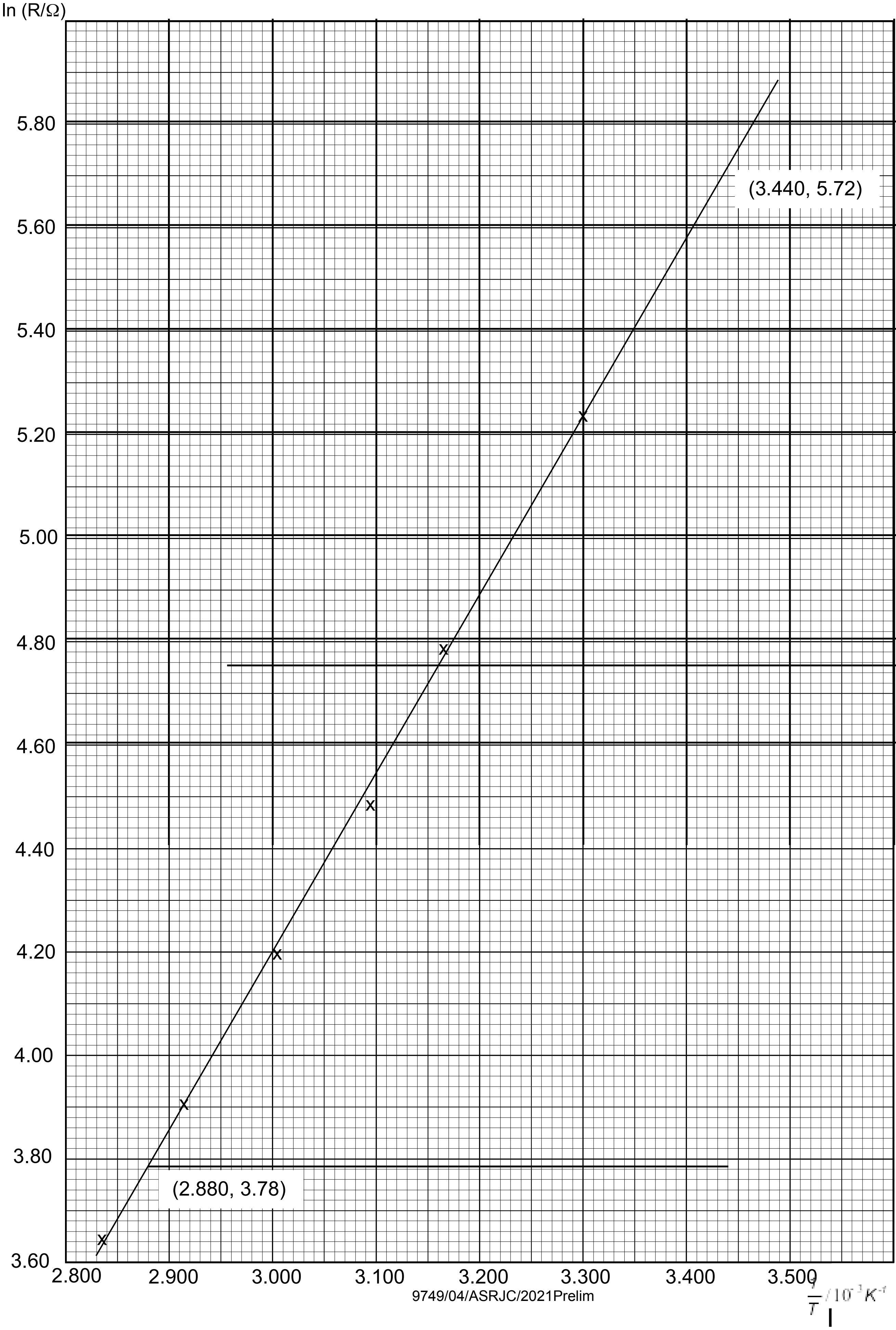
$A = e^{-6.18}$

$= 2.07 \times 10^{-3}$ Ω

E = ... 4.77×10^{-20} J

2.07×10^{-3} Ω

A = ……..………………



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.

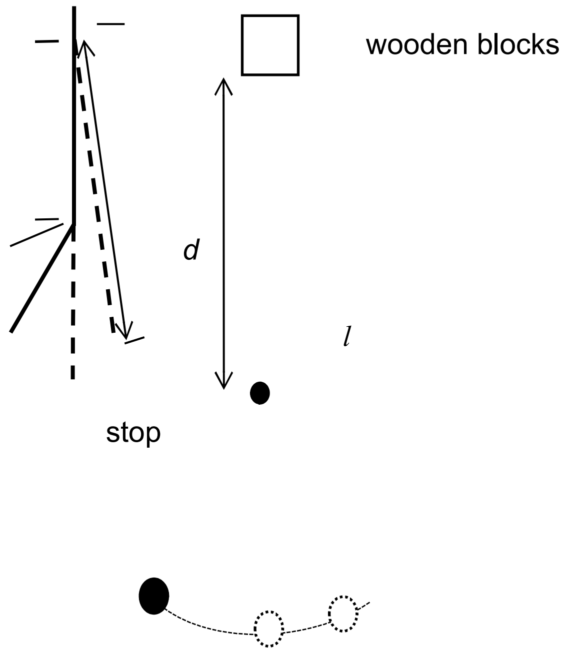


Fig. 2.1

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 s

M2	
A1	

T = ……1.42 s………………..…… [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 m s $^{-2}$.

(i) Calculate k.

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

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

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

k = 9.41……………………….. 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.

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.

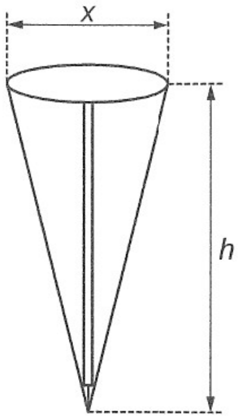


Fig. 3.1

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

$h = \dfrac{12.6 + 13.0}{2} = 12.8$ 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 = $\dfrac{0.5}{3.4} \times 100\%$ = 15 %

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

A1

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.

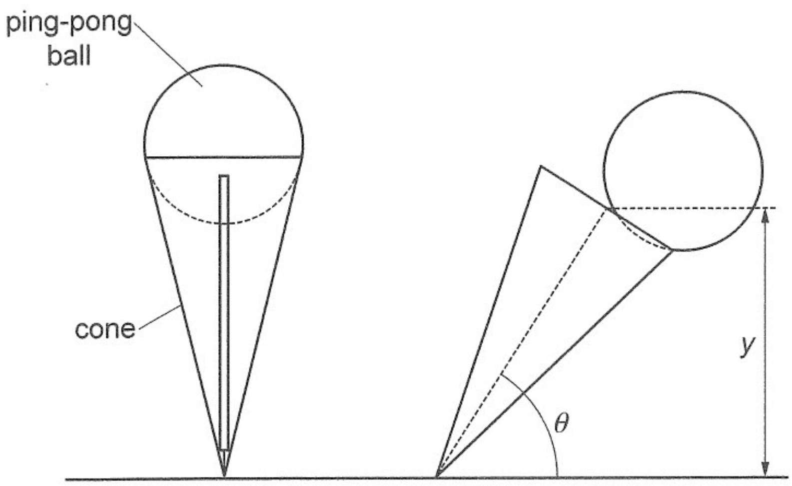


Fig. 3.2 **Fig. 3.3**

Measure and record θ and y.

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

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

θ = ...45°......

y = ...9.7 cm......

[2]

M2	
M3	

(ii) Calculate tan θ.

$\tan 45^\circ = 1.0$

tan θ = ...1.0...... [1]

A2	

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

Cut around the outline and assemble this cone.

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

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

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

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

$y = \dfrac{9.1 + 9.3}{2} = 9.2$ 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 $\tan\theta = \dfrac{ky}{hx}$ 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.

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

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

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

first value for k = ...4.5 cm......

second value for k = ...6.6 cm......

[1]

A3	

(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 $k \le$ 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

For Examiner's Use

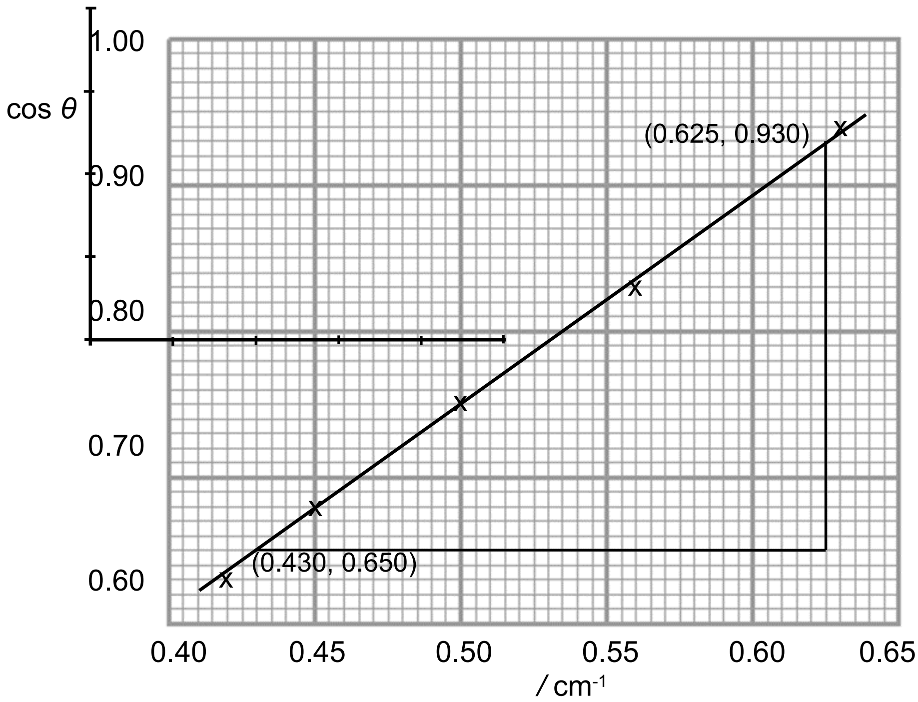
radii r.

The results are shown in the table.

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

r/ cm	$\frac{1}{r}$ / cm^{1}	θ/ °	cos θ
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.

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

A7

(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]

For

A9

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 $\theta = 60^\circ$.

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 $\theta = 60^\circ$. This will be the minimum height of a cone that they could make.

[5]

PL1

PL2

PL3

PL4

PL5

[Total: 21 marks]