Answers to 2023 JC2 Preliminary Examination Paper 4 (H2 Physics)

Suggested Solutions

<table>
<tr><th>No.</th><th>Solution</th><th>Remark</th></tr>
<tr><td>1(a)</td><td>$x = \frac{15.0+15.0}{2} = 15.0$ cm

Period $T = \frac{20.8+20.7}{2\times 20} = 1.04$ s</td><td>[1]
- for correct measurements with units
- 1 d.p in cm
- repeat
[1]
- 1 or 2 d.p in timing
- repeat
- T in 3 s.f. or 4 s.f. depending on the d.p. of t_1 and t_2
$t \geq 20.0$ s</td></tr>
<tr><td>1(b)</td><td>
<table>
<tr><th rowspan="2">x/cm</th><th rowspan="2">N</th><th colspan="2">Time for N oscillation</th><th rowspan="2">Period T/s</th><th rowspan="2">T^4/s^4</th></tr>
<tr><th>t_1/s</th><th>t_2/s</th></tr>
<tr><td>11.0</td><td>25</td><td>24.2</td><td>24.1</td><td>0.966</td><td>0.871</td></tr>
<tr><td>13.0</td><td>25</td><td>25.1</td><td>25.2</td><td>1.01</td><td>1.04</td></tr>
<tr><td>15.0</td><td>20</td><td>20.8</td><td>20.7</td><td>1.04</td><td>1.17</td></tr>
<tr><td>17.0</td><td>20</td><td>21.4</td><td>21.6</td><td>1.08</td><td>1.36</td></tr>
<tr><td>19.0</td><td>20</td><td>22.1</td><td>22.2</td><td>1.11</td><td>1.52</td></tr>
<tr><td>21.0</td><td>20</td><td>22.9</td><td>22.8</td><td>1.14</td><td>1.69</td></tr>
</table>
</td><td>[1]
- headings and units
- 6 sets of data

[1]
- d.p. of raw data
- $t \geq 20.0$ s

[1] s.f. of processed data

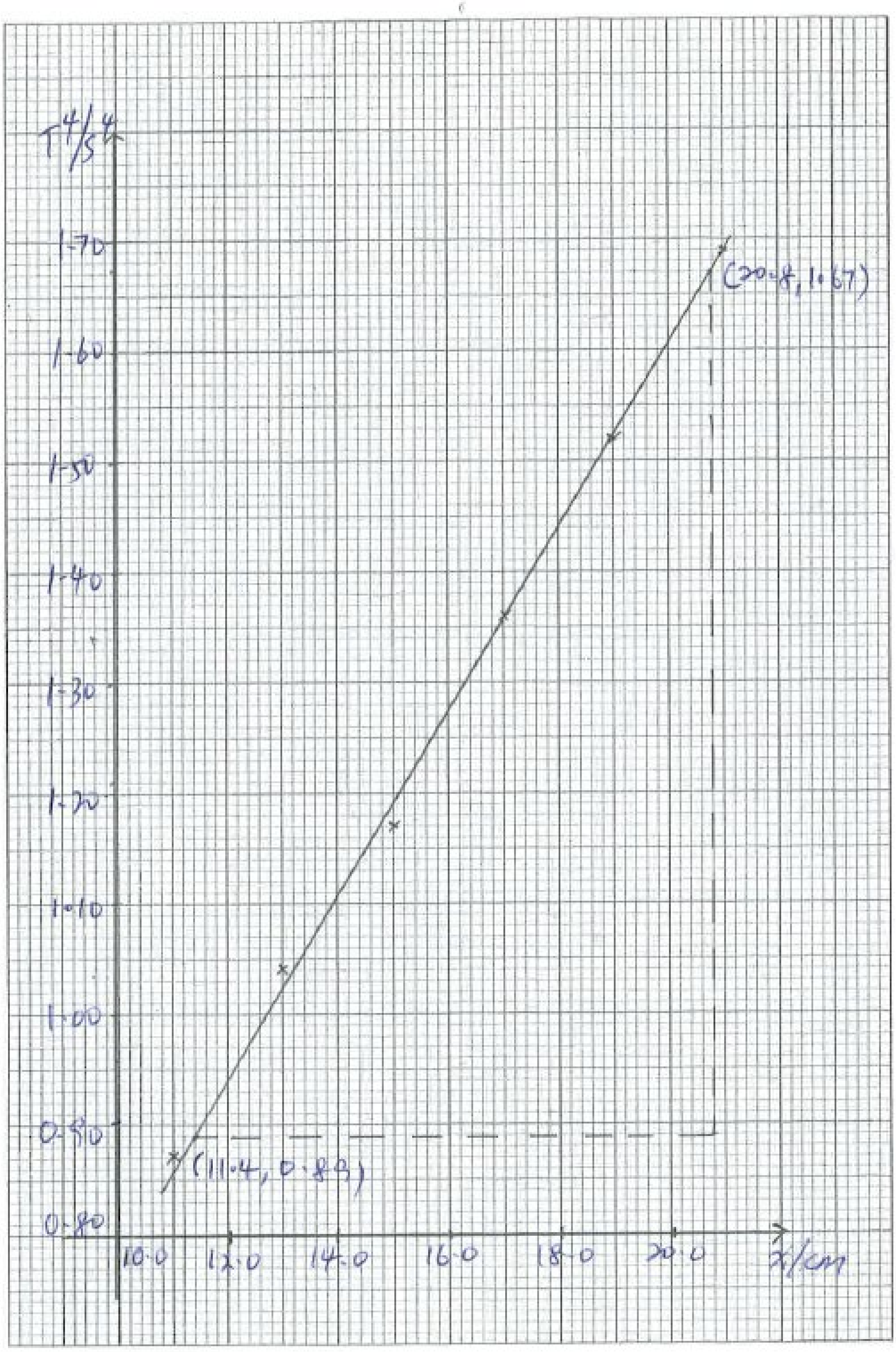
[1] correct calculation, allow 1 slip

Don't accept x = 0 cm. This <u>will not</u> be considered one set of data.</td></tr>
<tr><td>1(c)</td><td>Refer to attached graph.</td><td>[1] axes: units, scale

[1] plotted points accurate to half of smallest division

[1] best fit line</td></tr>
<tr><td>1(c)</td><td>Given $T^4 = Px + Q$
Graph of T^4 vs x is plotted, where P is the gradient and Q is the y-intercept.</td><td>[1]
- Big triangle
- substitution of gradient coordinates
- linearisation</td></tr>
</table>

	Gradient= $\frac{1.67-0.89}{20.8-11.4}=0.0830$ P = 0.0830 s^4 cm^{-1} Substitute $(20.8,1.67)$ into the equation, $1.67=(0.0830)(20.8)+Q$ $Q=-0.0564$ s^4	[1] P calculated correctly with units [1] Q calculated correctly with units



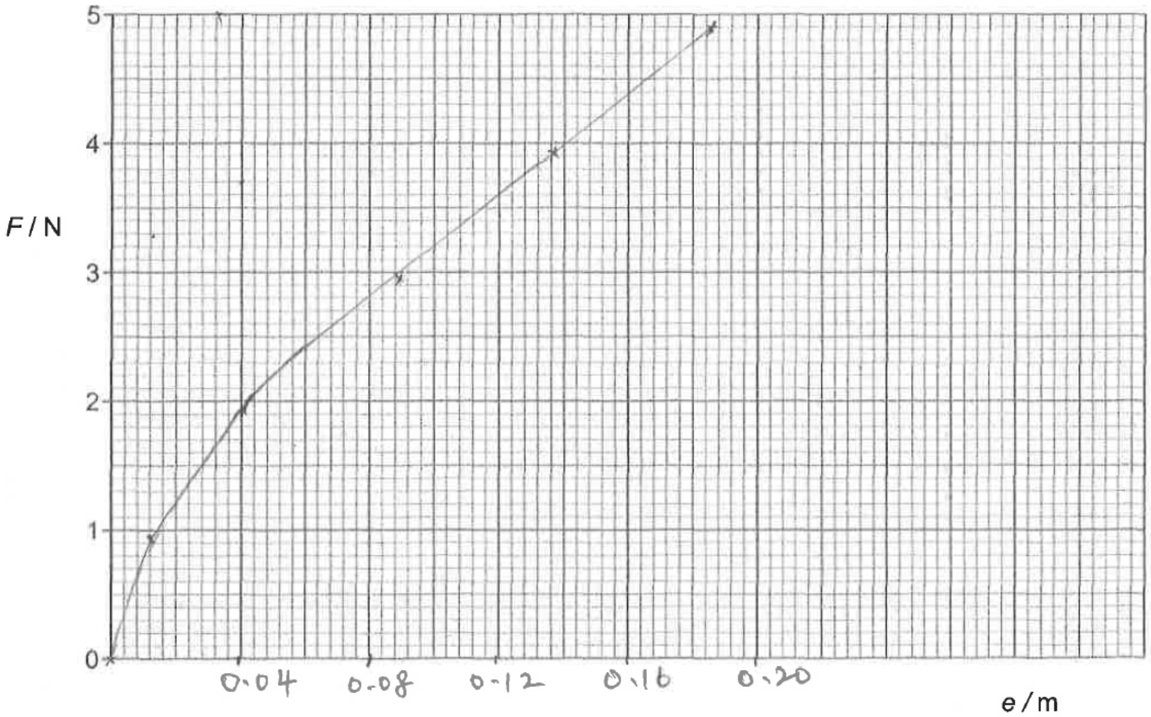
T⁴/s⁴
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
10.0
12.0
14.0
16.0
18.0
20.0
x/cm
(20.8, 1.67)
(11.4, 0.88)

[Total: 12]

No.	Solution	Remarks
2(a)(i)	$L_0 = \dfrac{7.5 + 7.5}{2} = 7.5$ cm	[1] correct measurements with unit and d.p
2(a)(ii)	Volume $V = (1.9\times10^{-3})(1.9\times10^{-3})(2\times7.5\times10^{-2})$ $= 5.42\times10^{-7}$ m^3	[1] ans
2(b)(i)	$L = \dfrac{8.8 + 8.8}{2} = 8.8$ cm Extension e = 8.8 – 7.5 = 1.3 cm = 0.013 m Force $F = 100\times10^{-3} \times 9.81 = 0.981$ N	[1] - both e and F calculated correctly - repeat measurement for L - answer for F in 2 or 3 sig. fig
2(b)(ii)	(see table below)	[1] - headings and units - 6 sets of data (award full credit if m = 0.000 kg not included in the table) [1] - d.p. of raw data - m in 3 d.p - s.f of processed data [1] correct calculation, allow 1 slip
2(b)(iii)	Refer to attached graph.	[1] - plotted points accurate to half of smallest division - best fit curve / line
2(b)(iv)	When the extended length is $2L_0$, the extension e is L_0 = 0.075 m and force F is 2.7 N. Energy stored = area under the graph $= \dfrac{1}{2}(0.013)(0.981) + \dfrac{(0.981 + 1.96)(0.028)}{2}$ $+ \dfrac{(1.96 + 2.7)(0.034)}{2}$ = 0.127 J	[1] correct calculation No marks awarded if best fit curve / line does not pass through origin
2(b)(v)	Energy stored per unit volume $= \dfrac{0.127}{5.41\times10^{-7}}$ $= 2.35\times10^{5}$ J m^{-3}	[1] correct calculation

Table for 2(b)(ii):

m/kg	L/m	e/m	F/N
0.000	0.075	0.000	0.000
0.100	0.088	0.013	0.981
0.200	0.116	0.041	1.96
0.300	0.165	0.090	2.94
0.400	0.212	0.137	3.92
0.500	0.261	0.186	4.91



[1]

No.	Solution	Remarks
3(a)	$D_Y = \frac{4.5 + 4.5}{2} = 4.5$ cm Diameter $d_Y = \frac{0.30 + 0.30}{2} = 0.30$ mm	[1] - correct measurement for D_Y. Accept 4.0 cm to 5.0 cm - repeat [1] - correct measurement for d_Y. Accept 0.25 mm to 0.35 mm - repeat
3(b)(i)	There are 13 turns on cardboard tube Y. $L_Y = 13 \times 2 \times \pi \times r$ $= 13 \times D_Y \times \pi$ $= 13 \times 4.5 \times \pi$ $= 184$ cm	[1] sub [1] ans
3(b)(ii)	$L_Y = 13\pi D_Y$ $\frac{\Delta L_Y}{L_Y} = \frac{\Delta D_Y}{D_Y}$ $\frac{\Delta L_Y}{L_Y} \times 100\% = \frac{\Delta D_Y}{D_Y} \times 100\%$ Hence percentage uncertainty in $L_Y = \frac{0.2}{4.5} \times 100\% = 4.4\%$	[1] for correct percentage uncertainty (1 or 2 s.f.)
3(c)	$R = 15\ \Omega$ $I = 140.6 \times 10^{-3}$ A	[1] - correct R - correct I with d.p
3(d)	see table below	[1] - headings and units - 5 sets of data [1] - d.p, units of raw data - s.f of processed data [1] correct calculation

R/Ω	I/A	IR/V
15	0.1406	2.1
18	0.1329	2.4
22	0.1227	2.7
27	0.1148	3.1
33	0.1128	3.7

<table>
<tr><td>3(e)</td><td>Gradient= $\frac{3.4-2.2}{30-16}=0.0857$
$G=0.0857$ A

Substitute $(30, 3.4)$ into the equation,
$3.4=(0.0857)(30)+H$
$H=0.829$ V

$X_Y=\frac{H}{G}=\frac{0.829}{0.0857}=9.67\ \Omega$</td><td>[1]
- points plotted correctly

- best fit line drawn

[1]
- value of G calculated correctly (with or without unit)

[1] value of X_Y calculated correctly in 2 or 3 sig. fig</td></tr>
<tr><td>3(f)(i)</td><td>D_Z = $\frac{4.5+4.5}{2}=4.5$ cm

Diameter d_Z = $\frac{0.20+0.20}{2}=0.20$ mm (0.15 to 0.25 mm)

$L_Z=\frac{3L_Y}{4}=\frac{3(184)}{4}=138$ cm</td><td>[1]
- correct measurement for D_Z
- Accept 4.0 cm to 5.0 cm
- (repeat)

- correct measurement for d_Z
- Accept 0.15 mm to 0.25 mm
- (repeat)

- correct calculation</td></tr>
<tr><td>3(f)(ii)</td><td><table><tr><td>R/Ω</td><td>I/A</td><td>IR/V</td></tr><tr><td>15</td><td>0.1258</td><td>1.9</td></tr><tr><td>18</td><td>0.1165</td><td>2.1</td></tr><tr><td>22</td><td>0.1079</td><td>2.4</td></tr><tr><td>27</td><td>0.1001</td><td>2.7</td></tr><tr><td>33</td><td>0.0972</td><td>3.2</td></tr></table></td><td>[1]

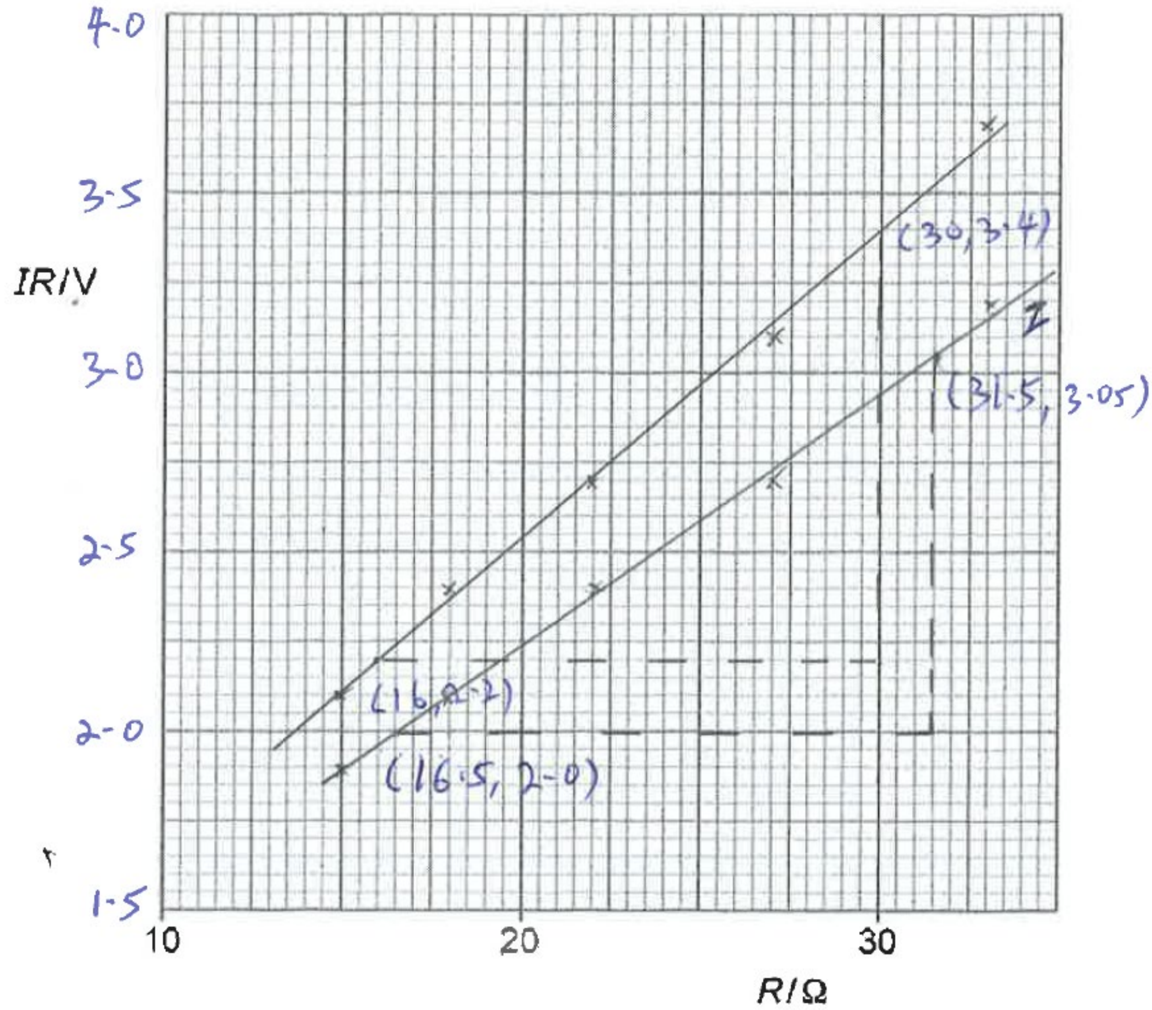
- headings and units

- 5 sets of data

- d.p, units of raw data

- s.f of processed data</td></tr>
</table>

	Gradient= $\dfrac{3.05-2.0}{31.5-16.5}=0.0700$ $G=0.0700$ A Substitute $(31.5, 3.05)$ into the equation, $3.05=(0.0700)(31.5)+H$ $H=0.845$ V $X_Z=\dfrac{H}{G}=\dfrac{0.845}{0.0700}=12.1\ \Omega$	[1] value for X_Z calculated correctly


4.0
3.5
IR/V
3.0
2.5
2.0
1.5
10
20
30
R/Ω
(30, 3.4)
(31.5, 3.05)
Z
(16, 2.2)
(16.5, 2.0)

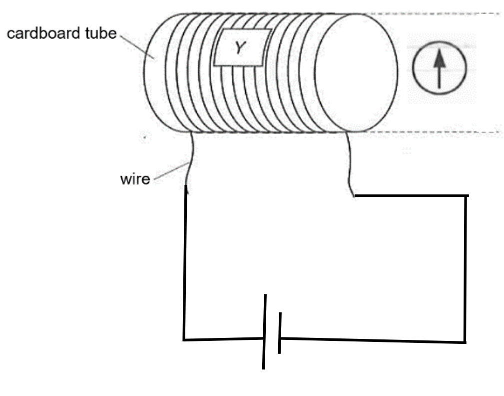
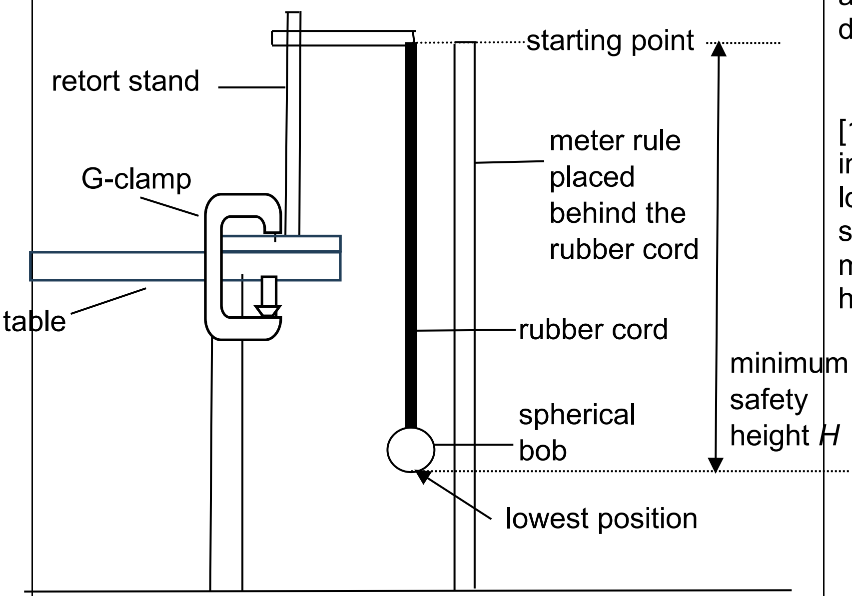
3(f)(iii)	Difference: The calculated value is 12.1 Ω and the measured value is 21.6 Ω. Measured value is higher than the calculated value. Reason: Due to the contact resistance of crocodile clip.	[1] for difference and reason
3(g)(i)	Given $X = \frac{kL}{d^2} \Rightarrow k = \frac{Xd^2}{L}$ First value of *k* (for wire Y) $k_Y = \frac{9.67(0.30 \times 10^{-3})^2}{1.84}$ = 4.73×10^{-7} Ω m Second value of *k* (for wire Z) $k_Z = \frac{12.1(0.20 \times 10^{-3})^2}{1.38}$ = 3.51×10^{-7} Ω m	[1] correct calculation of value of both *k*.
3(g)(ii)	Percentage difference $= \frac{(4.73 - 3.51) \times 10^{-7}}{3.51 \times 10^{-7}} \times 100\% = 35\%$ The percentage difference of 35% between the two k values are higher than the percentage uncertainties of L_Y at 4.4%. As such, the result of my experiment does not support the suggested relationship.	[1] valid evaluation based on comparing percentage difference with percentage uncertainties of L_Y
3(h)(i)	From the equation $B = CnI$, magnetic flux density *B* at each end of the tube depends on *n,* number of turns of wire per unit length. Since tube Y has greater number of turns of wire per unit length than tube Z, tube Y has greater magnetic flux density at its ends.	[1] explanation
3(h)(ii)	 **Fig. 1**	[1] Diagram to show - battery connected directly across the coil - compass placed beside on end of the tube

	 **Fig. 2** **1.** Set up the circuit as shown in Fig. 1 for both tube Y and Z. **2.** The needle of the compass points due north when there is no current flowing in the coil. **3.** Count the number of turns of wires, *N* and measure the length of the tube l and determine $n = \frac{N}{l}$. **4.** The deflection of the needle of the compass as shown in Fig. 2 gives the direction of the resultant magnetic flux density due to the Earth magnetic flux density and the magnetic flux density at the end of the tube. **5.** Measure the angle of deflection using a protractor. The angle of deflection of the compass needle is used to determine the relative field strength. **6.** By comparing the angle of deflection of compass needle for both tube Y and Z will conclude whether tube Y or tube Z has a greater magnetic flux density at its end.	[1] - Distance between compass and coil Y and Z must be constant - Tube Y and Z arranged in East-West direction [1] compare angle of deflection to determine the relative field strength

4

Aim: To investigate how the minimum safety height *H* depends on the mass *M* of the object and the length *L* of the rubber cord.



Experiment 1 – to determine *p*

Independent variable: mass of the spherical bob, *M* measured using the electronic balance.

Dependable variable: minimum safety height *H*, measured using the metre rule.

Controlled variable:
- length of the rubber cord.
- release the sphere at rest from starting point.

Procedure:

a) Set up the apparatus as shown in the diagram above.

b) The retort stand is placed at the edge of the table.

c) One end of the rubber cord is tied securely to the end of the clamp.

d) Measure the length of the rubber cord *L* using a metre rule.

e) Weigh the mass of the spherical bob *M* using the electronic balance.

f) Suspend the spherical bob from the starting point and release. Note the position of the lowest point reached and record the minimum safety height *H* by using the metre rule behind the rubber cord. Minimum safety height is measured from the starting point to the lowest position reached by the spherical bob.

[1] feasible set up and labelled diagram

[1] clear information on lowest position, starting point and minimum safety height

[1] correct variables for Experiment 1

[2] for correct and detailed procedure

[1] mention of apparatus for different measurement
– length of rubber cord,

- mass of spherical bob,

- minimum safety height

	g) Repeat **(f)** at least two times to get an average value of the minimum safety height *H*.	
	h) Repeat **(e)** to **(g)** using spherical bobs of different mass and same length of the rubber cord to get five additional readings of *M* and *H*.	
	i) Based on the equation $H = k\,M^{p}\,L^{q}$, we get $\lg H = p \lg M + \lg(kL^{q})$. Plot a graph of lg *H* against lg *M*, where *p* is the gradient.	[1] correct graph plotted
	Experiment 2 – to determine *q*	
	Independent variable: length of the rubber cord *L*, measured using metre rule.	
	Dependable variable: minimum safety height *H*, measured using the metre rule behind the rubber cord.	[1] correct variable for Experiment 2
	Controlled variable: - mass of the spherical bob. - release the sphere at rest from starting point.	
	j) Repeat **(e)** to **(g)** using rubber cord of different length and same mass of spherical bob to get six readings of *L* and *H.*	
	k) Based on the equation $H = k\,M^{p}\,L^{q}$, we get $\lg H = q \lg L + \lg(kM^{p})$. Plot a graph of lg *H* agains lg *L*, where *q* is the gradient.	[1] correct graph plotted
	Precautions for accuracy:	
	1. Conduct preliminary experiments by using the longest rubber cord and heaviest spherical bob so as to obtain a workable range for *H*.	[2] any 2
	2. Release the spherical bob with no downward velocity. Do not exert any force vertically or horizontally on the sphere upon release of the spherical bob.	
	3. The retort stand is placed at the edge of the table because the extension of the rubber cord can be longer than the height of the retort stand.	
	4. Measure the unstretched length of the rubber cord before releasing the spherical bob of different mass to ensure that the same length of the rubber cord is used for all spherical bobs.	

	Precautions for safety: **1.** Use the G-clamp to clamp the base of the retort stand to stabilize it and prevent the retort stand from toppling. **2.** Place the retort stand at a higher level e.g. on a table so that the spherical bob will not hit the ground (this may cause hazard to others) after the rubber cord has fully extended.	[1] any 1

Apparatus List

Odd Number Bench
Question 1
- Retort stand
- Boss
- Clamp
- Split cork
- Pendulum made from strings and two slotted masses
- Stopwatch
- 30 cm ruler

Question 2
- Retort stand
- Boss head
- Clamp
- 3 x 100 g slotted masses
- Rubber band with dimensions of its cross section written on a card
- 100 g mass hanger
- Four 100 g slotted masses
- 30 cm rule

Even Number bench
Question 3
- Cardboard tube Y, with wire wrapped around it
- Cardboard tube Z, with wire wrapped around it
- Switch
- 1.5 V dry cell in holder
- 0 – 400 mA multimeter
- 0 – 400 Ω multimeter
- One each of the following labelled resistors:
  15 Ω, 18 Ω, 22 Ω, 27 Ω, 33 Ω
- Six connecting wires
- 30 cm ruler
- Micrometer screwgauge (one per 2 candidates)