Name: ______________________________ (   )   Class: 24 /_____

ANDERSON SERANGOON JUNIOR COLLEGE

2024 JC2 Preliminary Examination

PHYSICS Higher 2 — 9749/04

Paper 4 Practical — **Monday 26 August 2024**

2 hours 30 minutes

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

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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 mark 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)	

This document consists of **15** printed pages and **1** blank page.

1 In this experiment, you will investigate the motion of a sphere launched from a ramp.

(a) Set up the apparatus as shown in Fig. 1.1. Adjust the height of the clamp so that the launch angle ϕ is approximately 15°. **Do not bend the ramp throughout the experiment**.

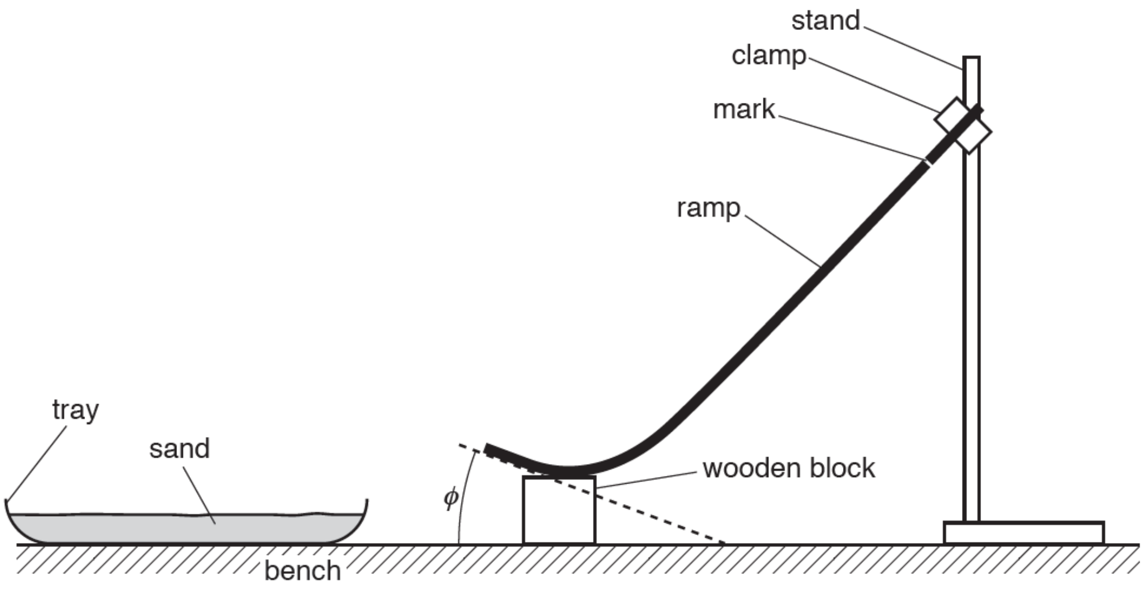


Fig. 1.1 (not to scale)

(b) **(i)** Measure and record ϕ, as shown in Fig. 1.1.

ϕ = 15° ....[1]

M1

(ii) Measure and record the height h_1 of the mark above the bench, as shown in Fig. 1.2.

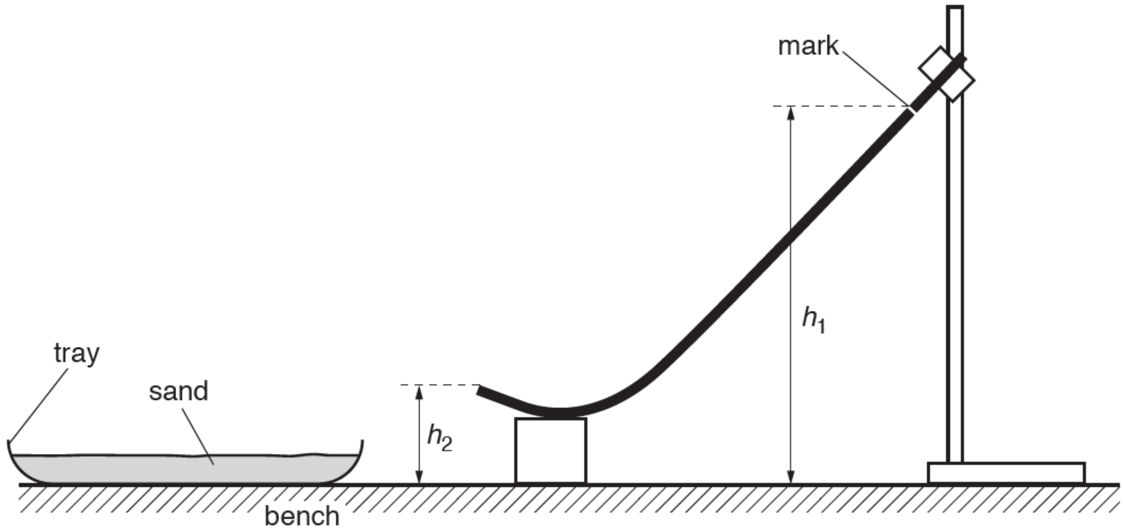


Fig. 1.2 (not to scale)

h_1 = 0.280 m ....

(iii) Measure and record the height h_2 of the end of the ramp, as shown in Fig. 1.2.

For Examiner's Use

h_2 = 0.085 m ....[1]

M2

(iv) Calculate the speed v of the sphere when it leaves the ramp using the expression

$$v = \sqrt{2g(h_1 - h_2)}$$

where g = 9.81 m s^{-2}.

$$v = \sqrt{2(9.81)(0.280 - 0.085)}$$
$$= 1.96 \text{ m s}^{-1}$$

v = 1.96 m s^{-1} ....[1]

A1

(c) Justify the number of significant figures you have given for your value of v.

Since the number of s.f. for ($h_1 - h_2$) is 3, hence v is 3 s.f..

.... [1]

P1

(d) **(i)** Place the sphere on the ramp at the mark. Release the sphere.

(ii) Measure and record the horizontal distance R from the end of the ramp to the landing position of the sphere, as shown in Fig. 1.3.

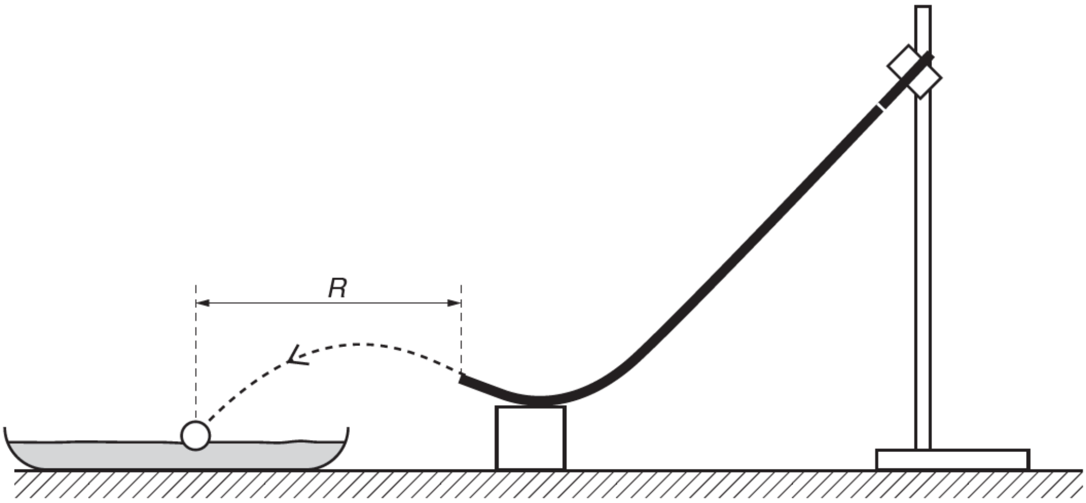


Fig. 1.3 (not to scale)

$$R = \frac{R_1 + R_2}{2}$$
$$= \frac{0.230 + 0.250}{2}$$
$$= 0.240 \text{ m}$$

M3
M4

R = 0.240 m .... [2]

(e) Estimate the percentage uncertainty in your value of R.

percentage uncertainty = $\dfrac{0.01}{0.24} \times 100\%$
= 2.1 %

percentage uncertainty = 2.1 % .... [1]

For Examiner's Use

A2

(f) By lowering the clamp, increase the launch angle ϕ to approximately 25°. Repeat **(b)** and **(d)** using the sphere.

ϕ = 25° ....

h_1 = 0.210 m ....

h_2 = 0.089 m ....

$v = \sqrt{2(9.81)(0.210 - 0.089)}$
$= 1.54 \text{ m s}^{-1}$

v = 1.54 m s^{-1} ....

$R = \dfrac{0.185 + 0.195}{2}$
$= 0.190 \text{ m}$

M5

M6

R = 0.190 m ....[2]

(g) It is suggested that the relationship between R, v and ϕ is

$$R = k\,v\cos\phi$$

where k is a constant.

For Examiner's Use

(i) Using your data, calculate two values of k.

$$k = \frac{R}{v\cos\phi}$$

first k

$$k = \frac{0.240}{1.96\cos 15^\circ} = 0.126\,\text{s}$$

second k

$$k = \frac{0.190}{1.54\cos 25^\circ} = 0.136\,\text{s}$$

first value of k = 0.126 s ....

second value of k = 0.136 s .... [1]

A3

(ii) Explain whether your results support the suggested relationship.

Percentage difference in k = $\frac{\Delta k}{k} \times 100\% = \frac{0.136 - 0.126}{0.126} \times 100\% = 7.9\%$

The criterion is percentage difference in k ≤ percentage uncertainty in R.

Since the % difference in k value is more than the % uncertainty in R, the suggested relationship is not valid. ....[1]

A4

(iii) It is not accurate to draw a conclusion based on only two readings as in **g(ii)**. Suggest a way the method can be changed.

Take 6 sets of readings by varying ϕ and plot a graph of R against $v\cos\phi$ to test the relationship. If the graph is a straight line passing through the origin, the relationship is valid. ....[1]

A5

(h) **(i)** State one significant source of error in this experiment.

It is difficult to measure R as the sphere rolls after landing / the landing mark is unclear. This will affect the accuracy of R.

.....[1]

For Examiner's Use

A6

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

Use sticky surface (e.g. duct tape) to stop rolling/ dye on ball to mark paper/ clay to show landing mark so as to improve the accuracy of R.

.....[1]

A7

(i) A student is investigating the motion of a sphere launched horizontally from the ramp with a range of different speeds v.

It is suggested that the square of the horizontal distance R from the end of the ramp to the landing position of the sphere is directly proportional to v.

Plan an investigation on this relationship using the **same apparatus**.

Your account should include your experimental procedure, control of variables, and how you would use your results to test the relationship.

1. Decrease the launch angle ϕ to zero by raising the clamp and making sure that the shorter part of ramp is lying flat on the wooden block.
2. Fix the clamp position to keep ϕ constant throughout the experiment.
3. Vary the speed v by releasing the sphere at different position on the ramp / at different height h_1 to obtain 6 sets of readings of v and R.
4. Plot a graph of R^2 against v. If the graph is a straight line passing through the origin, the relationship is valid.

.....[4]

PL1

PL2

PL3

PL4

[Total: 18]

2 In this experiment, you will investigate the oscillation of a rod.

For Examiner's Use

(a) Assemble the apparatus as shown in Fig. 2.1. Set the distance x between the supporting strings to about 8 cm. Each spring should be vertical and the metal rod should be parallel to the bench.

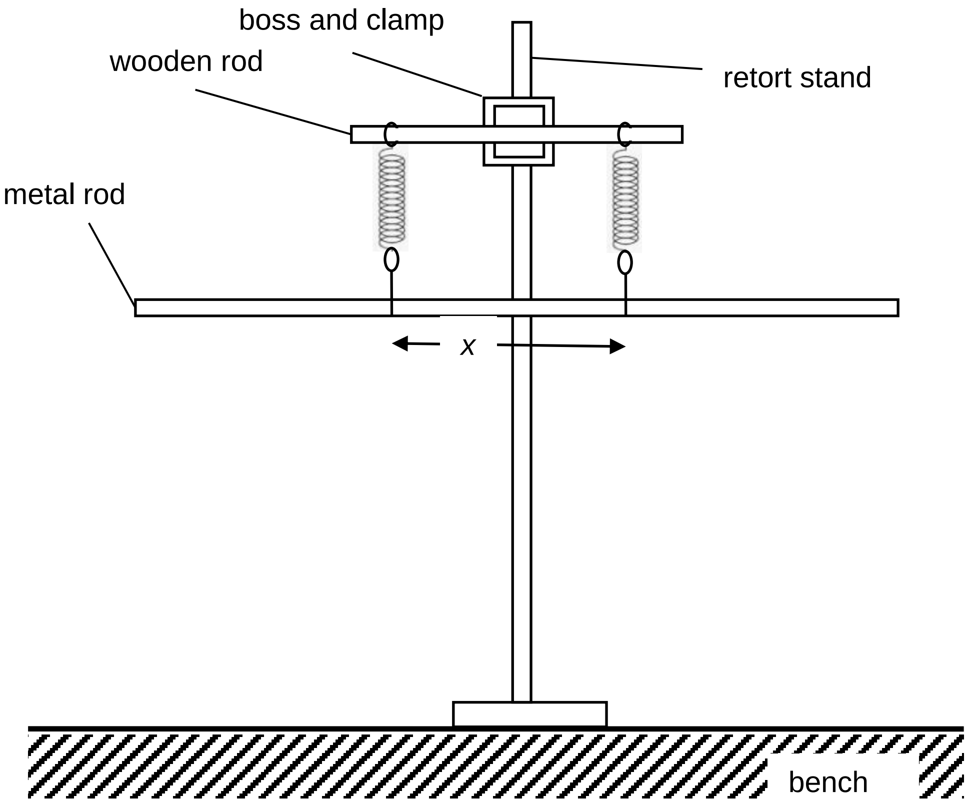


Fig. 2.1

Measure and record x.

$$x = \frac{7.9 + 8.0}{2} = 8.0 \text{ cm}$$

x = ...8.0 cm........ [1]

M1

For Examiner's Use

(b) Lift one end of the metal rod a short distance and push the other end of the metal rod down a short distance. Release the rod so that it oscillates with a rocking motion, as shown in Fig. 2.2.

Fig. 2.2

(c) Take measurements to determine the period *T* of the oscillation.

$N = 7$

$t_1 = 12.1$ s

$t_2 = 12.6$ s

$$T = \frac{\frac{12.1+12.6}{2}}{7} = 1.76 \text{ s}$$

T = ...1.76 s............ [2]

M2	
A1	

(d) The equation that relates *T* and x for this oscillator is

$$T = \frac{k}{x}$$

where *k* is a constant.

Calculate *k*.

$$k = Tx$$
$$= 1.76 \times 8.0$$
$$= 14 \text{ cm s}$$

k = ...14 cm s............ [2]

A2	
A3	

[Total: 5]

3 In this experiment, you will investigate how the current through a milliammeter varies as the resistance of a resistor is changed.

For Examiner's Use

(a) Set up the circuit as shown in Fig. 3.1.

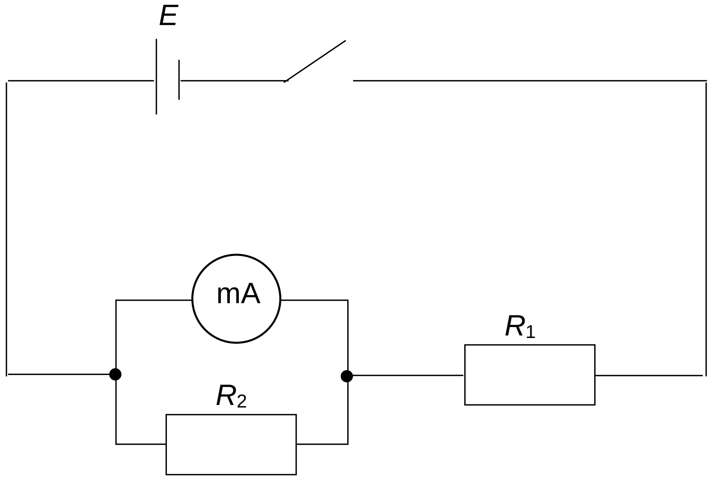


Fig. 3.1

(b) The resistor of resistance R_2 can be made using any combination of the resistors provided. The resistance of each resistor is 100 Ω.

(c) Set the value of R_2 to 100 Ω and close the switch. Record the current I through the digital milliammeter.

I = ...2.43 x 10^{-3}...A [1]

M1	

(d) Change the value of R_2 and repeat step **(c)** to obtain further sets of values for R_2, and the corresponding values of I.

R_2 / Ω	I / 10^{-3}A	$\frac{1}{R_2}$ / 10^{-3} Ω^{-1}	$\frac{1}{I}$ / A^{-1}
33.3	2.43	30.0	411
50.0	2.65	20.0	377
66.7	2.78	15.0	360
100	2.90	10.0	345
150	3.02	6.67	331
200	3.08	5.00	325
300	3.13	3.33	319

For Examiner's Use

M2	
M3	
P1	
P2	
P3	
A1	

[7]

(e) It is suggested that I and R_2 are related by the equation,

$$\frac{1}{I} = \frac{k}{R_2} + C$$

where k and C are constants.

Plot a suitable graph to determine values of k and C.

Plot a graph of $\frac{1}{I}$ against $\frac{1}{R_2}$ where k is the gradient and C is the y-intercept.

gradient = $\frac{410.0 - 320.0}{(29.5 - 4.5) \times 10^{-3}} = 3600$

k = 3600 A^{-1} Ω

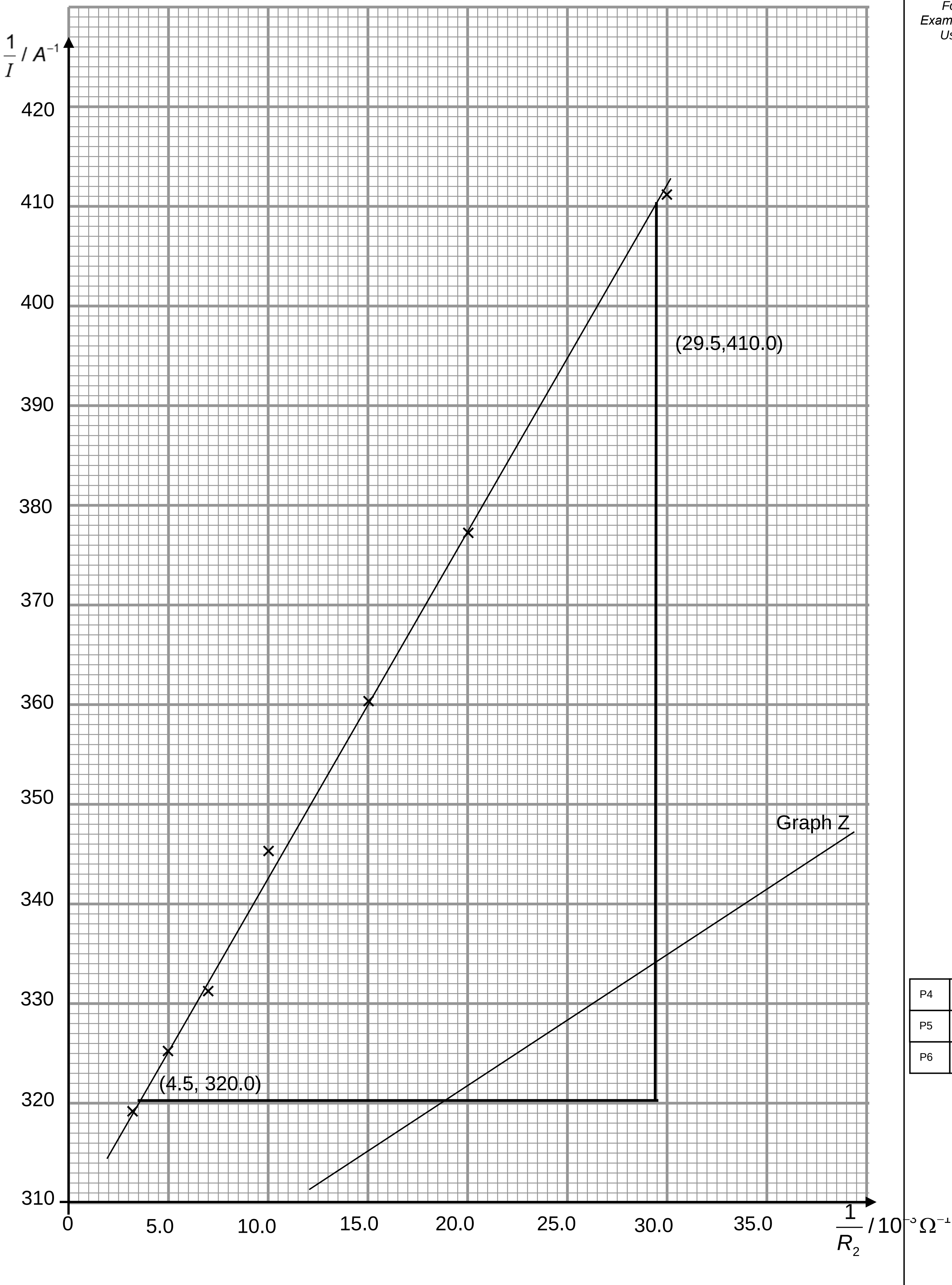
Substitute (29.5 x 10^{-3}, 410.0) into y = mx+c,
y-intercept, c = 410.0– (3600 × 29.5×10^{-3})
= 303
C = 303 A^{-1}

k = 3600 A^{-1} Ω

C = 303 A^{-1}

[7]

A2	
A3	
A4	
A5	



For Examiner's Use

P4	
P5	
P6	

For Examiner's Use

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

There is no anomalous point as all the points are close to the best fit line. ....

....[1]

M4

(ii) Measure and record a value of the e.m.f. E of the power supply using the digital voltmeter.

E = ...1.51 V......[1]

M5

(g) Theory suggests that $k = \dfrac{R_1 S}{E}$

where S is the resistance of the digital milliammeter.

Given that R_1 = 470 Ω, together with your answers to **(e)** and **(f)(ii)**, determine a value for S.

$$k = \frac{R_1 S}{E}$$

$$S = \frac{kE}{R_1} = \frac{3600\ (1.51)}{470} = 11.6\ \Omega$$

A6

S = ...11.6 Ω...... [1]

(h) C is inversely proportional to E.

On the graph grid on page 11, sketch a second graph to represent the results if E is increased. Label this graph Z.

[2]

A7

A8

[Total: 20]

Question 4 begins on the next page.

For Examiner's Use

4 Springs can be made from metal wires of thickness t, with cross-sectional area A, as shown in Fig. 4.1.

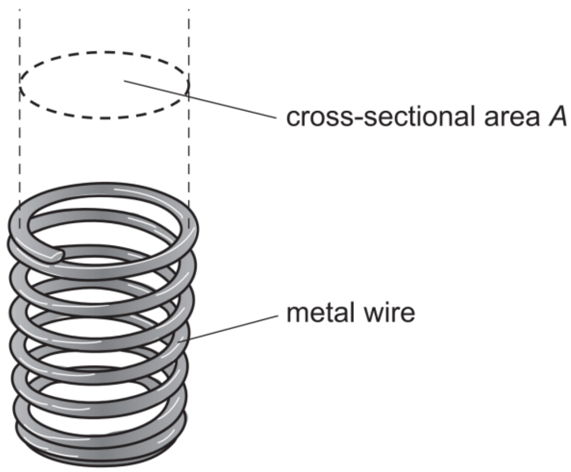


Fig. 4.1

The spring constant k is given by the equation:

$$k = \frac{Ct^P}{A^Q}$$

where C, P and Q are constants.

You are given springs of different A and t.

Design a laboratory experiment to determine the constants P and Q.

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 k would be determined
(d) the control of variables
(e) any precautions that should be taken to improve the accuracy of the experiment.

Diagram

For Examiner's Use

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For Examiner's Use

[12]

[Total: 12]

2024 ASRJC JC2 Prelim P4 MS

Q1	Answer	Mark	Code
(b)(i) **MMO**	***Measurement of ϕ*** ϕ in range 10° to 20°, with unit and to nearest degree.	1	**M1**
(b)(ii) **MMO**	***Measurement of h_1 and h_2*** Values of h_1 and h_2 to nearest mm.	1	**M2**
(b)(iv) **ACE**	***Calculation of v*** Correct calculation of *v* with correct unit.	1	**A1**
(c) **PDO**	***Calculated quantities (appropriate no. of significant figures)*** Justification based on number of significant figures in ($h_1 - h_2$). *Note: no credit if ans in b(iv) not in 3.s.f.*	1	**P1**
(d)(ii) **MMO**	***Measurement of R*** Value of *R* to nearest mm Evidence of repeat readings of *R*.	1 1	**M3** **M4**
(e) **ACE**	***Estimating uncertainties*** Percentage uncertainty in *R* calculated correctly to 2 s.f using sensible value of ΔR (e.g. 2 mm ≤ ΔR ≤ 10 mm). *Note: If ΔR = 10 mm, then R has to be recorded to 2 d.p in metre for d(ii)*	1	**A2**
(f) **MMO**	***Measurement of second values*** ϕ in range 20° to 30°. Second values of h_2 greater than first h_2. Second values of h_1 less than first h_1. Second *R* less than first *R*.	1 1	**M5** **M6**
(g)(i) **ACE**	***Calculation of k*** Two values of *k* calculated correctly with unit and appropriate s.f. *Note: k has to be recorded to* 2 s.f. or 3 s.f.	1	**A3**
(g)(ii) **ACE**	***Conclusion*** Valid conclusion relating to the calculated values of *k*, testing against a criterion	1	**A4**
(g)(iii) **ACE**	***Modification*** Take 6 sets of readings <u>and</u> plot a graph of *R* against $v \cos\phi$. If the graph is a straight line passing through the origin, the relationship is valid.	1	**A5**
(h)(i) **ACE**	***Sources of errors*** 1. It is difficult to measure *R* as the sphere rolls after landing / the landing mark is not clear/distinct. This will affect the accuracy of *R*. 2. It is difficult to measure R as the ruler was placed above the sand tray, causing parallax error. This will affect the accuracy of *R*. 3. It is difficult to measure ϕ as the ramp in contact with the block is curve/ the alignment of the zero marking of protractor is uncertain. This will affect the accuracy of ϕ. 4. It is difficult to release marble from same position each time as alignment of the lowest point of the sphere on the mark is uncertain. This will affect the accuracy of h_1.	1	**Any 1** **A6**

[Turn Over

Q1	Answer	Mark	Code
(h)(ii) **ACE**	***Improvement*** 1. Use sticky surface (e.g. duct tape) to stop rolling/ dye on ball to mark paper/ clay to show landing mark so as to improve accuracy of *R.* 2. Place a pin vertically at the edge of the depression in the sand tray (due to landing of the marble) as a guide to measure *R* using the ruler. 3. Hold <u>ruler</u> as tangent so as to improve accuracy of ϕ. 4. Use a card as a stop on ramp to ensure marble is released from same position	1	**A8**
(i)	***Planning*** 1. Decrease the launch angle ϕ to zero by <u>raising</u> the height of clamp. 2. <u>Fix the clamp position</u> to keep ϕ constant throughout the experiment. 3. Vary the speed *v* by releasing the sphere at different position on the ramp /different height h_1 to obtain 6 sets of readings *v* and *R*. 4. Plot a graph of R^2 against *v*. If the graph is a straight line passing through the origin, the relationship is valid.	1 1 1 1	PL1 PL2 PL3 PL4

Q2	Answer	Mark	Code
(a) **MMO** **ACE**	***Measurement of x*** *x* given to nearest 1 mm with correct units. [acceptable range: 7.8 cm to 8.2 cm]	1	**M1**
(C) **MMO** **ACE**	***Determination of T*** Evidence of repeated reading of raw time for *N* oscillations more than 10.0 s. *Correct calculation of T* to the s.f. of raw time with units. [acceptable range: 1.60 s to 1.90 s]	1 1	**M2** **A1**
(d) **ACE**	***Calculation of k*** Correct calculation of *k* to lowest sf of raw data. Correct units of *k.*	1 1	**A2** **A3**

Q3	Answer	Mark	Code
(c) **MMO**	***Measurement of I*** Value of I with precision to 0.01 mA	1	**M1**
(d) **MMO**	***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 (R_2, I), without assistance/intervention. • Award 1 mark if student has successfully collected 5 sets of data (R_2, I), without assistance/intervention.	2	**M2**

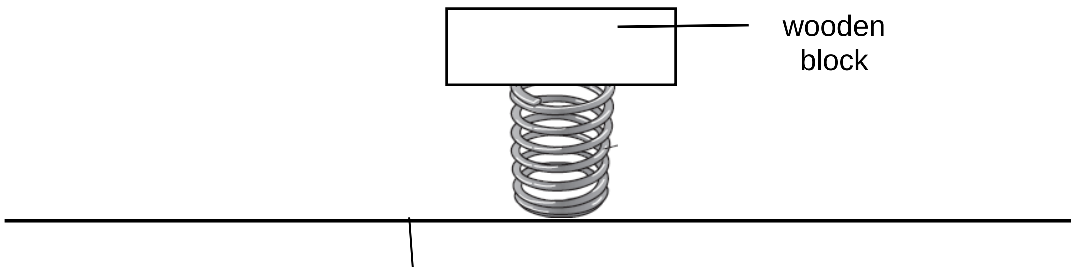
Q3	Answer	Mark	Code
	• Award zero mark if student has successfully collected 4 or fewer sets of data (R_2, I), without assistance/intervention. • Deduct 1 mark if student requires some assistance/intervention but has been able to do most of the work independently. Indicate the nature of any assistance. • Deduct 2 marks if student has been unable to collect data without substantial assistance/intervention. Minimum mark for **M2** = 0.		
(d) **MMO**	***Values of R_2*** Correct values of R_2 (ie: 33.3, 50.0, 66,7, 100, 150, 200, 300)	1	**M3**
(d) **PDO**	***Layout: Column headings (raw data & calculated quantities: R_2, I, 1/R_2, 1/I)*** 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**
(d) **PDO**	***Table of results: raw data (appropriate degree of precision)*** All I *values* to nearest 0.01 mA.	1	**P2**
(d) **PDO**	***Table of results: calculated quantities (appropriate no. of significant figures)*** For each calculated value of R_2,1/R_2 and 1/I, the number of s.f. should be the same or one more than the number of s.f. in the raw data.	1	**P3**
(d) **ACE**	***Table of results: calculated quantities*** Correctly calculated values of 1/R_2 and 1/I. *Note: No marks if 1/R_2 and / or 1/I not present.* *Check all 1/R_2 values and 3 random 1/I values.*	1	**A1**
(e) **ACE**	***Linearising Equation*** Linearising equation and deriving expressions that equate e.g. gradient to *k* and y-intercept to *C*.	1	**A2**
(e) **PDO**	***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**
(e) **PDO**	**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**
(e) **PDO**	**Graph: trend line and ability to draw best fit line** Straight line of best fit – judge by scatter of points about the student's line. There must be a fair scatter of points on either side of the line, and in each half of the line there should be roughly the same number of points above as below.	1	**P6**

Q3	Answer	Mark	Code
(e) **ACE**	***Interpretation of graph – gradient*** Gradient – the hypotenuse of the triangle must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Check for $\Delta y/\Delta x$ (do not allow $\Delta x/\Delta y$).	1	**A3**
(e) **ACE**	***Interpretation of graph – intercept*** y-intercept – must be read off to <u>nearest half</u> a small square or determined from $y = mx + c$ using a point on the line.	1	**A4**
(e) **ACE**	***Drawing conclusion*** Values of k and C calculated correctly with units and appropriate s.f.	1	**A5**
(f)(i) **MMO**	***Identification of anomaly*** Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise, comment of absence of anomalous data.	1	**M4**
(f)(ii) **MMO**	***Measurement of E*** E measured to the correct precision with unit.	1	**M5**
(g) **ACE**	***Calculation of S*** S calculated with correct substitution of values (E from f(ii) and k value from (e) and R_1).	1	**A6**
(h) **ACE**	***Interpretation of graph – underlying principles*** When E increases, the gradient decrease and y-intercept decrease	1 1	**A7** **A8**

Suggested Solution to Q4

Independent variable	**Dependent variables**	**Control variables**
What? (i) *t* (ii) *A*	*k*	(i) *A* (ii) *t*
How? (i) Measure with micrometer screw gauge. Vary by choosing springs of different *t*. (ii) Measure diameter *D* of spring, calculate A = π D^2 / 4. Vary by choosing springs of different *A*.	Load with mass *m* and measure compression *x* Calculate $k = mg / x$	(iii) choose springs of the same *A* (iv) choose springs of the same *t*

Diagram



Procedure

Experiment 1: *k* vs *A*

1. Select springs of the same thickness t_0 but different cross-sectional area *A*.
2. Measure and record the thickness t_0 of the spring using a micrometer screw gauge.
3. Measure and record the diameter *D* of the spring using vernier calipers.
4. Calculate *A* using $A = \pi D^2 / 4$.
5. Measure and record the mass *m* of a wooden block using an electronic balance.
6. Measure and record the initial length of the spring, l_o using half-metre rule.
7. Load the spring with the wooden block and measure the new length, *l* with a half-metre rule.
8. Calculate *x* using the difference between *l* and l_o.
9. Calculate *k* using $k = mg / x$, where *g* is 9.81 m s^{-2}.
10. Repeat experiment using springs of same t_0 but different *D* to obtain 6 sets of data of *D* and *k*.

Experiment 2: *k* vs *t*

1. Repeat the experiment as before but using springs of the same D_0 but different *t* to obtain 6 sets of data of *t* and *k*.

Control of variables

Expt 1: Keep t_0 constant by selecting springs of the same t_0 measuring with a micrometer screwgauge.
Expt 2: Keep A_0 constant by selecting springs of the same D_0 measuring with a vernier calliper.

Analysis

Expt 1: Plot a graph of lg *k* against lg *A* and find the gradient. *Q* = – gradient.
Expt 2: Plot a graph of lg *k* against lg *t* and find the gradient. *P* = gradient.

Accuracy and Safety

1. Take preliminary readings to determine the range of *t, D* and *m* to obtain suitably wide range of extension.
2. Repeat measurement of *D* in different directions and take the average value.
3. Repeat measurement of *t* along the wire and take the average value.
4. Measure the external diameter and internal diameter of the spring and take the average.
5. Clamp the ruler vertically parallel to spring / use of fiducial line / use set square to ensure orientation/reduce parallex error.
6. Avoid using loads with too large mass to prevent the spring from breaking / deforming / losing elasticity.
7. Use safety goggles to prevent injury to eyes from spring slipping off under the mass and flying into the air.
8. Use cushion / sand box / any appropriate method to prevent injury when the load falls.

Q4 Planning (12 marks)

Diagram		
D1	Labelled diagram showing the arrangement of spring and mass to cause compression/extension. Labelled bench and appropriate support need to be shown too.	[1]
Procedure		
P1	Measure t using micrometer screw gauge/vernier caliper. Measure diameter D using metre rule/vernier caliper.	[1]
P2	Measure mass m using electronic balance or measure weight using Newton meter or use slotted masses of known mass.	[1]
P3	Measure extension/compression of spring as <u>difference</u> between the length of the spring before and after loading using a ruler.	[1]
P4	Repeat experiment <u>using/choosing springs</u> of different t to obtain <u>6 readings of t and k.</u> Repeat experiment <u>using/choosing springs</u> of different A (or D) to obtain <u>6 readings of A (or D) and k</u>.	[1]
Control		
C1	Keep t constant by using springs of same t while varying D.	[1]
C2	Keep A (or D) constant by using springs of same A (or D) while varying t.	[1]
Analysis $\lg k = \lg Ct^P - Q \lg A$ $\lg k = p \lg t + \lg \dfrac{C}{A^Q}$		
G1	Plot a graph of lg k against lg A and equate Q to **negative** of the gradient.	[1]
G2	Plot a graph of lg k against lg t and equate P to the gradient.	[1]
Additional detail and safety 3A OR 2A + 1S)		
A1	Take preliminary readings to determine the range of t, D and m to obtain suitably wide range (or measurable values) of extension.	[1]
A2	Repeat measurement of D in different directions and take the average value.	[1]
A3	Repeat measurement of t along the wire and take the average value.	[1]
A4	Measure the external diameter and internal diameter of the spring and take the average.	[1]
A5	Calculate $A = \pi D^2 / 4$	[1]
A6	Calculate $k = mg / x$ or F / x	[1]
A7	Detail points relating to measuring extension, e.g. clamping ruler vertically parallel to spring, use of fiducial line, or set square to ensure orientation/reduce parallex error, etc	[1]
A8	Avoid using loads with too large mass to prevent the spring from breaking / deforming / losing elasticity.	[1]
S1	Use safety goggles to prevent injury to eyes from spring slipping off under the mass and flying into the air.	[1]
S2	Use cushion / sand box / any appropriate method to prevent injury when the load falls.	[1]