Civics Group 20S	Index Number	Name

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2021
Preliminary Examination

PHYSICS

9749/04

Paper 4 Practical

19 August 2021

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed on the Confidential Instructions.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group 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.

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	
1	/15
2	/ 6
3	/22
4	/12
Total	/55

This question paper consists of **20** printed pages including this page.

1 In this experiment, you will investigate combinations of resistors in an electrical circuit.

Fig. 1.1 shows how resistors of resistance 68.0 Ω can be arranged to give different values of total resistance *R*.

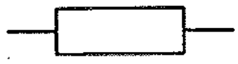
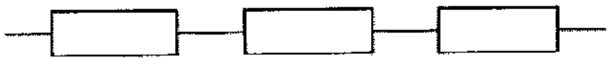
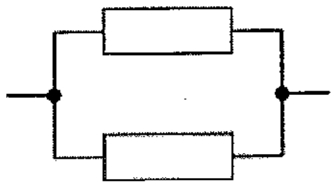
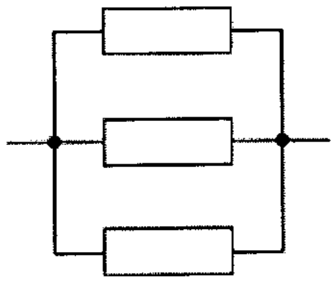
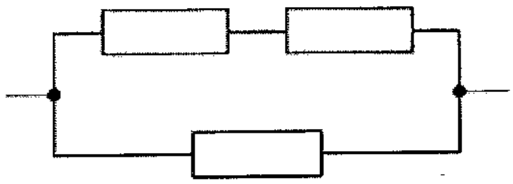
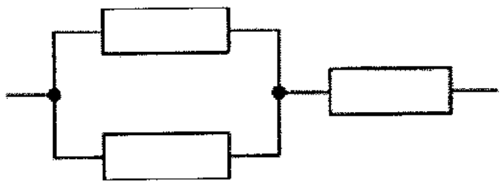
resistor arrangement	*R* / Ω
	68.0
	136
	204
	34.0
	22.7
	45.3
	102

Fig. 1.1

(a) Set up the circuit as shown in Fig. 1.2 with a resistor of resistance 68.0 Ω between F and G.

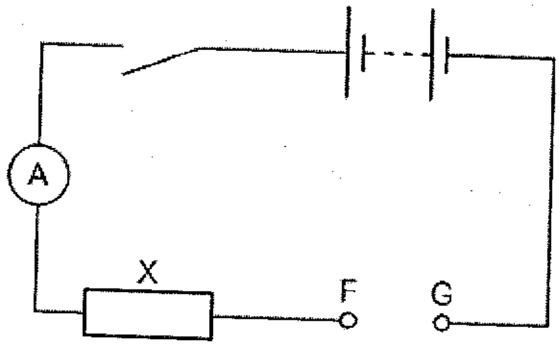


Fig. 1.2

Record the total resistance R between F and G.

R = ... Ω

Close the switch.

Record the ammeter reading I.

I = ... A

Open the switch.

[1]

(b) Use six different arrangements of the 68.0 Ω resistors to provide six different total resistances between F and G.

For each arrangement, record R and I in a table.

[5]

(c) It is suggested that the quantities I and R are related by the equation

$$\frac{1}{I} = \frac{R}{E} + \frac{X}{E}$$

where E is the electromotive force (e.m.f.) of the power supply and X is the resistance of resistor X.

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

E = ...

X = ...

[4]

[3]

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

....

....

.... [1]

(e) The experiment is repeated using a power supply with double the e.m.f.

On the graph grid on page 5, sketch a second graph to represent the new results. Label this graph G. [1]

2 In this experiment, you will experience the equilibrium of a metre rule.

(a) (i) You have been provided with a metre rule with two springs attached.

The distance between one end of the metre rule and the string is L, as shown in Fig. 2.1.

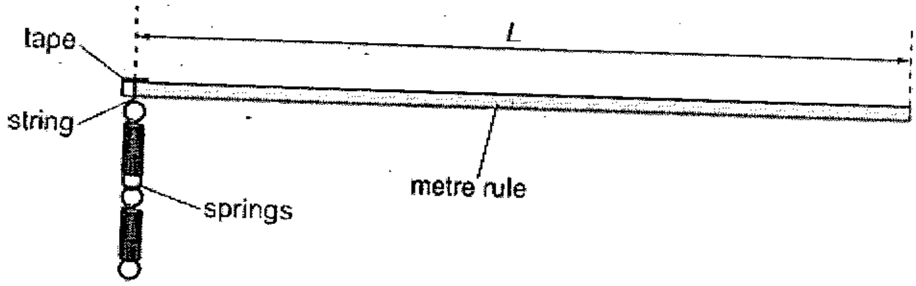


Fig. 2.1

Measure and record L.

L = ... [1]

(ii) Calculate $\frac{L}{n}$ where $n = 3$.

$\frac{L}{n}$ = ... [1]

(b) Set up the apparatus as shown in Fig. 2.2.

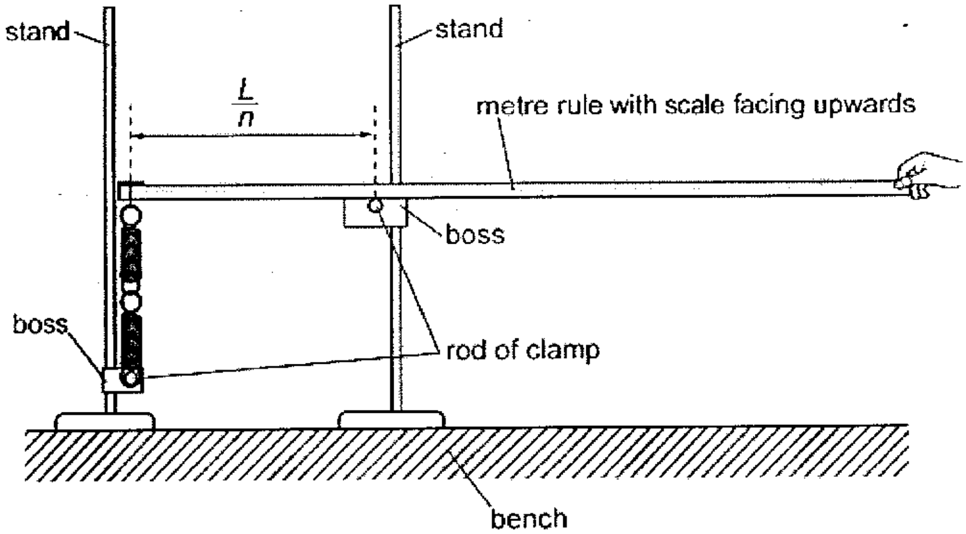


Fig. 2.2

Adjust the apparatus until the horizontal distance between the centres of the rods of the clamps is equal to your value of $\frac{L}{n}$.

Adjust the heights of the bosses so that the rule is horizontal and the springs are vertical and **unstretched** when the rule is held in position.

Gradually release the rule by lowering your hand. The rule will tilt.

The angle between the rule and the horizontal is θ, as shown in Fig. 2.3.

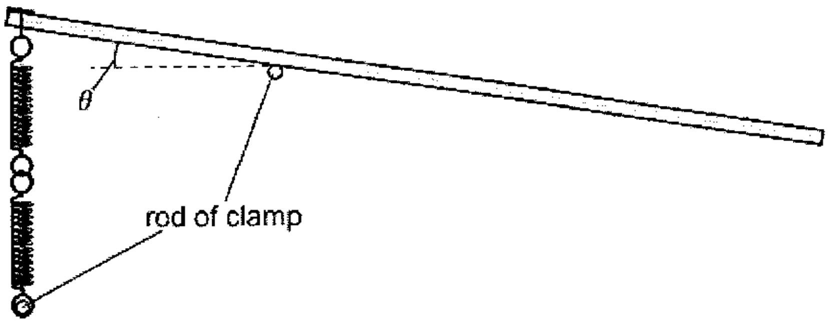


Fig. 2.3

Measure and record θ.

θ = ... ° [1]

(c) Theory suggests that

$$\frac{\sin\theta}{\frac{n^2}{2}-n} = \frac{Mg}{kL}$$

where

- M is the mass of the metre rule given on the card
- k is the spring constant of the spring system
- $g = 9.81\ \text{m s}^{-2}$.

Determine a value for k.

k = ... [1]

(d) **(i)** State one significant source of error in the experiment.

....

....

.... [1]

(ii) Suggest one improvement that could be made to the experiment and explain how this addresses the error identified in **(d)(i)**. You may suggest the use of other apparatus or a different procedure.

....

....

.... [1]

3 This experiment concerns a coupled pendulum system.

Fig. 3.1 shows six pendulums 1, 2, 3, 4, 5 and 6 connected to a common string.

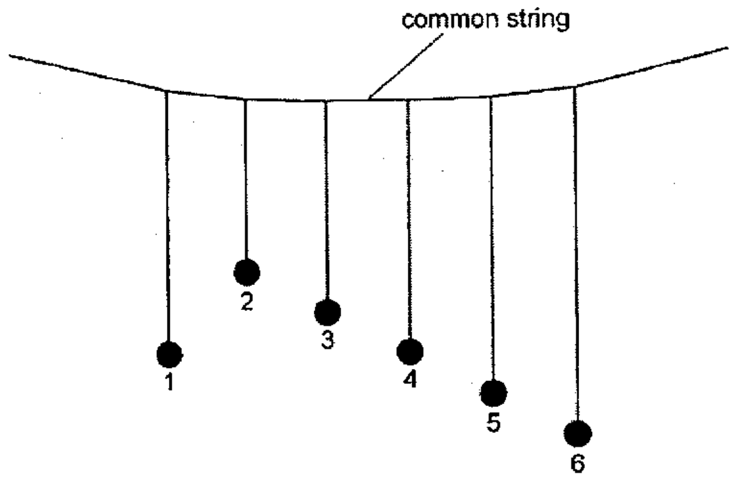


Fig. 3.1

When pendulum 1 is set swinging, the other pendulums move.

You will investigate how the following properties affect the behaviour of a coupled pendulum system.

- the distance between the pendulums
- the tension in the common string
- the difference in pendulum lengths
- the mass of the pendulum bobs

(a) **(i)** Set up two pendulums A and B, as shown in Fig. 3.2. Place the loops of the common string on the rods of the clamps. The distance x between the pendulum strings is shown.

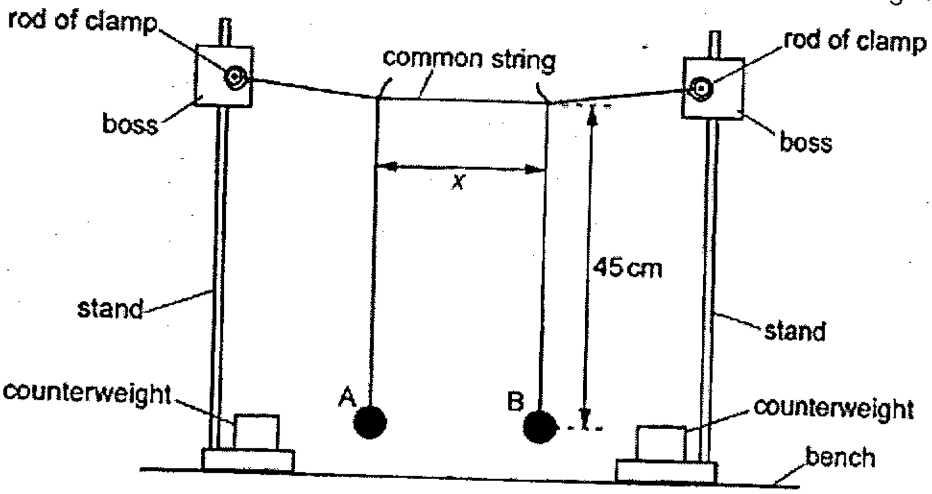


Fig. 3.2

Adjust the distance between the stands so that the common string is taut but **not** as taut as possible.

Adjust the knots until each pendulum has a length equal to 45 cm and x is approximately 15 cm.

Measure and record x.

x = ... cm

Pull pendulum A towards you, perpendicular to the plane containing both pendulums. Release the pendulum. Pendulum A will swing then pendulum B will start to swing. After some time A will stop swinging while B carries on swinging.

The time t is the time between releasing A and A stopping for the first time.
You can also find time t using B. The time $2t$ is the time between releasing A and B stopping for the first time.

Measure and record t.

t = ... [2]

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

percentage uncertainty in t = ... [1]

(b) **(i)** Repeat **(a)(i)** for at least two more values of x in the range of 5 cm to 25 cm. Tabulate these results. Include the results from **(a)(i)**.

[2]

(ii) Comment on the trend in your results.

....

....

.... [1]

(iii) In the following experiments you will use the **same value of *x*** throughout.

Choose **one** value of x from the values in **(b)(i)** to use in the following experiments. Record your choice of x.

x = ... cm

Explain your choice of x.

....

....

.... [1]

(c) **(i)** For the arrangement shown in Fig. 3.2, adjust the positions of the pendulums to make x equal to the value chosen in **(b)(iii)**.

Gently move the stands apart so that the common string is as taut as possible without the stands falling over. This will increase the tension in the common string.

Measure and record t.

t = ...

(ii) Comment on the effect of t of increasing the tension in the common string.

....

....

.... [1]

(iii) Describe, using a diagram, how you could use a spring to investigate the effect of tension in the common string on t.

You may suggest the use of any additional apparatus commonly found in a school physics laboratory.

....

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.... [4]

(d) Keep *x* equal to the value chosen in **(b)(iii)**.
The distance *y* is the difference in length between the two pendulums, as shown in Fig. 3.3.

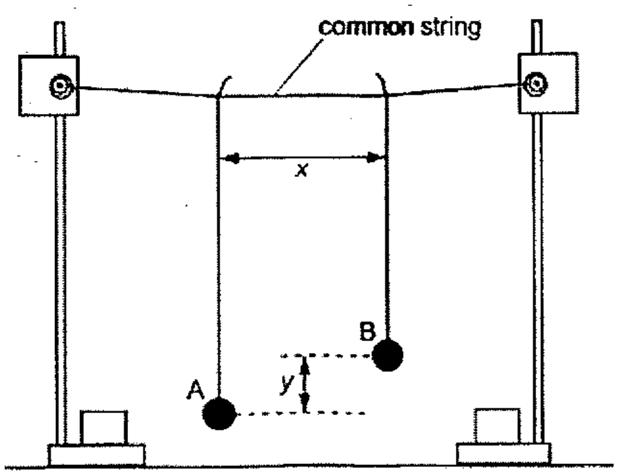

Fig. 3.3

(i) Reduce the length of pendulum B until *y* is approximately 4 cm.

Measure and record *y* and *t*.

y = ... cm

t = ... [1]

(ii) Reduce the length of pendulum B until *y* is approximately 8 cm.

Measure and record *y* and *t*.

y = ... cm

t = ... [1]

(iii) It is suggested that

$$t = \frac{k}{y}$$

where k is a constant.

Use your values from **(d)(i)** and **(d)(ii)** to determine two values of k.

first value of k = ...

second value of k = ...

[2]

(iv) Justify the number of significant figures given in your values of k.

....

....

....

.... [1]

(v) State whether the results of your experiment support the relationship suggested in **(d)(iii)**.

Justify your conclusion by referring to your answer in **(a)(ii)**.

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.... [1]

(e) Fig. 3.4 shows two pendulums of equal lengths. The pendulum bobs consist of a number of slotted masses.

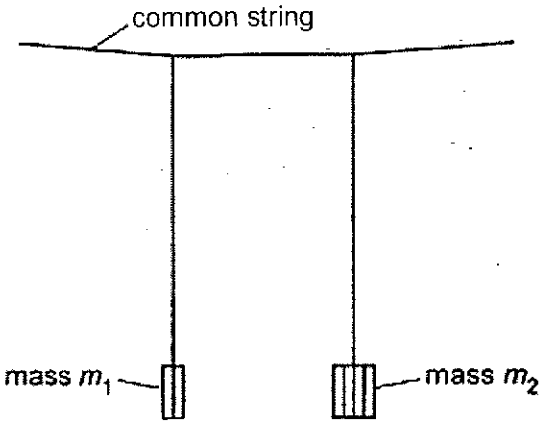
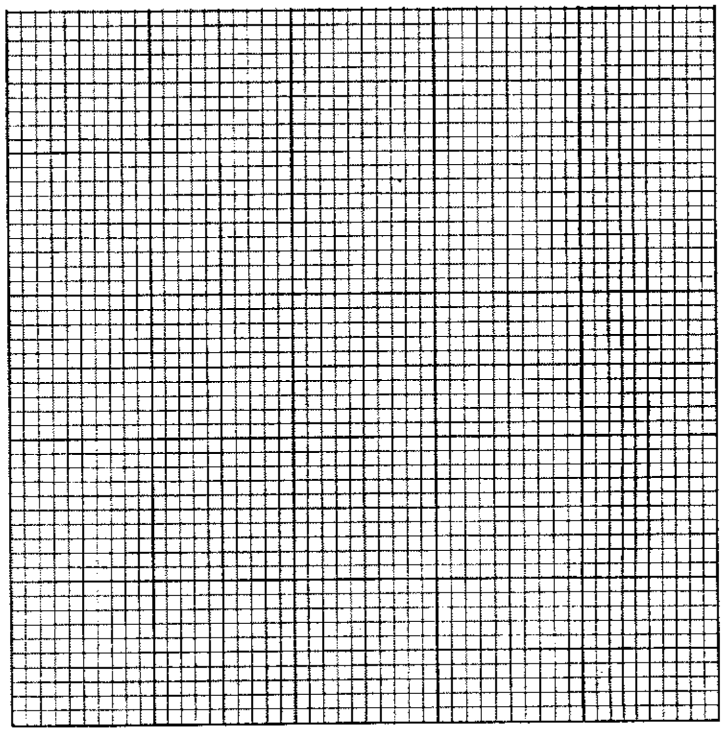


Fig. 3.4

In an investigation, the mass m_1 is fixed at 40 g. The mass m_2 is varied.
The following results for m_2 and t are recorded.

m_2/g	80	100	120	140	160
t/s	37.78	31.07	26.86	22.33	16.88
($m_2 - m_1$)/g					

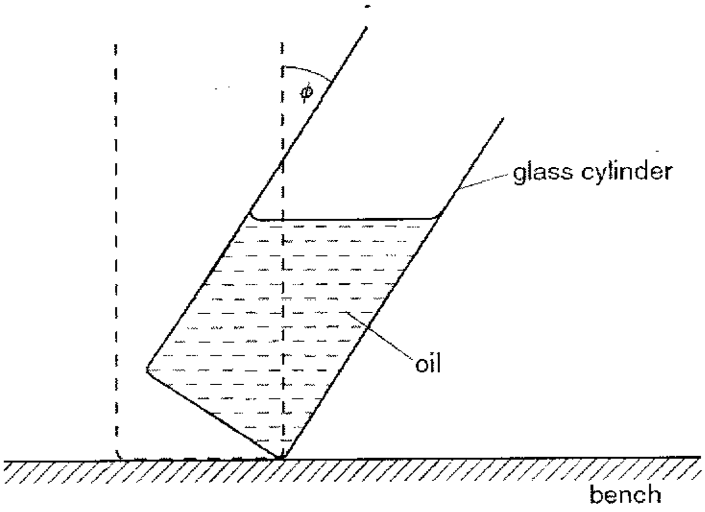
(i) Plot t against ($m_2 - m_1$) on the grid and draw the straight line of best fit. [2]



(ii) Use your graph to determine the time *t* when the two masses are equal.

t = ... [2]

4 A student is investigating the angle at which a glass cylinder containing oil topples, as shown below.



A cylinder of diameter d containing a mass m of oil can be tilted through a maximum angle of Φ from the vertical before it topples.

It is suggested that the relationship between d, m and Φ is

$$\tan \Phi = k\, d^{p} m^{q}$$

where k, p and q are constants.

You are provided with several glass cylinders of different diameters. Design a laboratory experiment to determine the values of p and q.

In your account you should pay particular attention to the following

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

Diagram

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[12]

END OF PAPER

Mark scheme for 2021 SAJC Prelim P4 Q1

No	Marking Point	Score
(a)	Measurement and Observation ☐ Recorded R as 68.0 Ω (accept 68 Ω) ☐ Recorded I to the nearest 0.1 x 10^{-3} A (do not allow changing of prefix) ☐ Value of I in the range 30.0 – 50.0 mA	/1
(b)	Tabulation ☐ At least 6 sets of readings of R and I ☐ Correct trend of decreasing I with increasing R {1 mark for 5 sets, zero mark for 4 or less sets. Deduct up to 2 marks if student requires assistance.}	/2
	Minus mark for poor presentation: • No table (including border must be drawn) • Table lines not drawn using ruler • Poor presentation of data in table (e.g. Show working in table)	-1
	Range of data ☐ Must use R = 204 Ω and R = 22.7 Ω	/1
	Column Heading ☐ Each column heading must contain a quantity and a unit: R/Ω, I/mA and $(\frac{1}{I})$ /mA^{-1}. ☐ Presentation of quantity and unit must conform to accepted scientific convention ☐ No split table	
	Raw data: Precision of recording ☐ All values of I to nearest 0.1 mA {200 mA range setting}	/1
	Calculated quantity: Precision & consistency All values of $(\frac{1}{I})$ recorded consistently to same number of sf as I or, consistently 1 more sf.	/1
	Calculated quantity: Accuracy of calculation All values of $(\frac{1}{I})$ calculated correctly	
(c)	Graph: Scale, Size & Axes ☐ Sensible scales, no awkward scales (eg 3 units into 10 small squares) ☐ Plotted pts occupy at least ½ the graph grid in both x & y directions ☐ Axes labelled with the quantity & unit ☐ Successive scale markings: no more than 20 small squares apart.	/1
	Plotting of Points ☐ ALL observations in table must be plotted ☐ Accurate to within half a small square. ☐ Thickness of plots (ie the crosses, 'x') ≤ half a small square	/1

	<u>Best fit line & Anomaly</u> ☐ Straight line drawn with approx. equal number of points on either side of line (anomalous point not considered). ☐ Line not be kinked/disjointed or thicker than half a small square ☐ Anomalous plot <u>clearly indicated</u> (eg by a circle or labelled.) {Rule of thumb: A plot is considered anomalous if it is > 4 mm from line of best fit.} <u>Minus</u> mark for poor quality: ☐ Straight line NOT within ±4 Ω of all plotted points (Allow 1 anomalous plot only)	/1 -1
	<u>Determination of Gradient</u> ☐ Read-off for 2 points accurate to half a small square in both x and y directions ☐ Hypotenuse of triangle > half length of line drawn ☐ No obscurity of the 2 points used for gradient calculation. {Hence triangle must not be drawn too near a data plot.}	/1
	<u>Determination of y-intercept</u> ☐ Y-intercept calculated using a <u>point on the line</u> {not from the table} & value of gradient. {Allow reading off the y-intercept if x-axis starts from zero }	/1
	<u>Linearisation of Equation</u> ☐ Stated explicitly: E = 1 / gradient OR gradient = 1 / E ☐ Stated explicitly: X = E x (y-intercept) OR y-intercept = X / E OR X = y-intercept / gradient	/1
	☐ Unit for E: V (do not allow Ω A) ☐ Unit for X: Ω (do not allow V A^{-1}) ☐ Value of E between 1 and 6 V ☐ Values of E and X written to appropriate sf	/1
(d)	☐ Stated the anomalous point (if any) with justification based on best fit line. ○ No anomaly as all plots lie close to best fit line OR ○ <u>(xxx , yyy)</u> is anomalous as it lies far from best fit line	/1
(e)	☐ Gradient is half of the first graph (allow 10% error) ☐ Smaller y-intercept than the first graph	/1
	Total	**15**

Mark scheme for 2021 SAJC Prelim P4 Q2

No	Marking Point	Score
(a)(i)	Measurement and Observation ☐ Recorded L to the nearest mm with unit ☐ Value of L within the range 98.5 – 99.5 cm	/1
(a)(ii)	☐ Correct calculation of L / n ☐ Recorded to correct no. of s.f. (3 s.f.)	/1
(b)	Measurement and Observation ☐ Recorded two values of θ to the nearest degree ☐ Value within the range of 0° - 20°	/1
(c)	☐ Correct calculation of k with consistent unit ☐ Within the range 5 – 30 N m^{-1} (allow kg s^{-2})	/1
(d)(i)	One significant source of uncertainty in this experiment A. The hand holding the protractor may move, affecting value of θ B. The rule slips on the rod of clamp, affecting value of L/n C. It is difficult to know when rule is horizontal, affecting value of θ D. It is difficult to hold one end of the rule and adjust the other end at the same time, affecting value of θ	/1
(d)(ii)	The corresponding improvement that could be made to reduce uncertainty A. Mount the protractor on a block OR use another ruler and use trigonometry to determine θ B. Use adhesive tape on the rod C. Use spirit level OR another rule to ensure horizontal D. Use a third stand and clamp to hold the free end of the rule	/1
	Total	**6**

Mark scheme for 2021 SAJC Prelim P4 Q3

<table>
<tr><th>No</th><th>Marking Point</th><th>Score</th></tr>
<tr><td>(a)(i)</td><td><u>Measurement and Observation</u>
□ Recorded x to the nearest 0.1 cm
□ Value of x within the range 14.5 – 15.5 cm

□ Recorded 2 values of t and average to nearest s (do not allow 1 dp)</td><td>/1

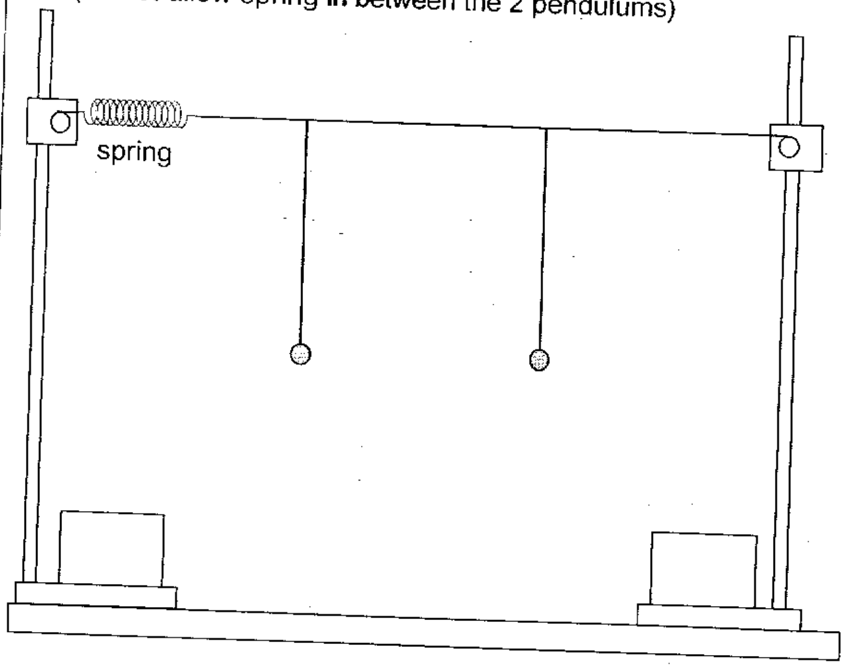
/1</td></tr>
<tr><td>(a)(ii)</td><td>□ Estimate Δt = 1 s to 5 s
□ Calculated percentage uncertainty, $\frac{\Delta t}{t}$ x 100% = ... and recorded to 1 or 2 sf. {No mark for 3 sf.} (do not allow 1 dp for Δt and t)</td><td>/1</td></tr>
<tr><td>(b)(i)</td><td>□ Tabulate 3 sets of results with column heading
<table>
<tr><th>x / cm</th><th>t_1 / s</th><th>t_2 / s</th><th>t / s</th></tr>
<tr><td>5.0</td><td></td><td></td><td></td></tr>
<tr><td>15.0</td><td></td><td></td><td></td></tr>
<tr><td>25.0</td><td></td><td></td><td></td></tr>
</table>
{Deduct up to 1 mark if student requires assistance.}

□ Range of x ≥ 15 cm

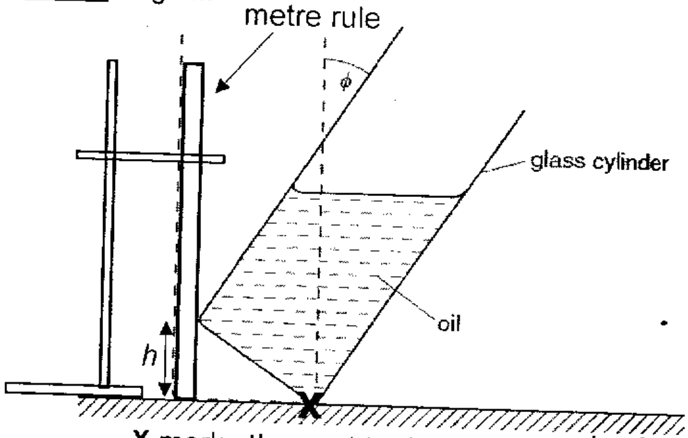
<u>Minus</u> mark for poor presentation:

No table (including border must be drawn)
Table lines not drawn using ruler
Poor presentation of data in table (e.g. Show working in table)
</td><td>/1

/1</td></tr>
<tr><td>(b)(ii)</td><td>□ t increases as x increases</td><td>/1</td></tr>
<tr><td>(b)(iii)</td><td>□ Choose the greatest value of x
□ For greatest x, value of t is also greatest, resulting in <u>lowest percentage uncertainty of t</u></td><td>/1</td></tr>
<tr><td>(c)(ii)</td><td>□ t increases as tension increases</td><td>/1</td></tr>
</table>

(c)(iii)	□ Labelled diagram showing spring attached to one end of common string (do not allow spring in between the 2 pendulums)  <u>Procedure:</u> □ Using a rule, measure length L_o of spring before attaching to common string and length L of spring after setting up as shown in diagram. □ Determine extension $e = L_o - L$. □ Repeat measurement of t for 10 sets of e by changing the distance between the 2 retort stands. <u>Analysis:</u> □ Since T is directly proportional to e. □ Plot a graph of lg t against lg e.	/1 /1 /1 /1
(d)(i)	□ Recorded y to the nearest 0.1 cm □ Value of y within the range 3.5 – 4.4 cm □ Recorded 2 values of t and average to nearest s	/1
(d)(i)	□ Recorded y to the nearest 0.1 cm □ Value of y within the range 7.5 – 8.4 cm □ Recorded 2 values of t and average to nearest s	/1
(d)(iii)	□ Calculated correctly **two** values of k □ With correct unit (s cm) and recorded to 2 or 3 sf.	/1 /1
(d)(iv)	□ The number of sf for k should be the same as (or one more than) the number of sf of the quantity with the <u>least number of sf</u>, <u>which is y</u>, which is 2 sf.	/1

(d)(v)	□ Calculated correctly $\frac{\lvert k_1-k_2 \rvert}{k_{ave}}$ x 100% □ Use the percentage uncertainty of (a)(ii) as the criterion □ Concluded that results do not support the suggestion if $\frac{\lvert k_1-k_2 \rvert}{k_{ave}}$ x 100% > percentage uncertainty of (a)(ii) OR □ Concluded results support the suggestion if $\frac{\lvert k_1-k_2 \rvert}{k_{ave}}$ x 100% $\leq$ percentage uncertainty of (a)(ii)	/1
(e)(i)	□ All 5 points plotted accurate to half a small square □ Sensible scales, no awkward scales (eg 3 units into 10 small squares) □ Plotted pts occupy at least ½ the graph grid in both x & y directions □ Axes labelled with the quantity & unit □ Successive scale markings: no more than 20 small squares apart.	/1
	□ Straight line drawn with approx. equal number of points on either side of line	/1
(e)(ii)	□ Calculated gradient = -0.253 s g^{-1} (accept ±0.01, with correct unit) □ Calculated y-intercept = 47.2 s (accept ±2, with correct unit)	/1
	□ When two masses are equal, t = y-intercept	/1
	Total	**22**

Answer	Mark	Remarks
Identification and control of variables		
Dependent Variable: Φ, maximum angle from vertical before the cylinder topples Independent Variable: m, mass of oil in the cylinder Constants: d, diameter of the cylinder **and** Dependent Variable: Φ, maximum angle from vertical before the cylinder topples Independent Variable: d, diameter of the cylinder Constants: m, mass of oil in the cylinder	1	
Diagram		
Labelled diagram  X marks the spot to tilt cylinder	1	
Procedures		
Using the <u>electronic balance</u>, measure the mass of an empty cylinder, m_o.	1	
Pour an amount of oil into cylinder and measure the mass, m_f. The mass of oil in the cylinder, <u>$m = m_f - m_o$</u>.	1	
Mark a point on bench (**x**) and <u>slowly (gently/gradually)</u> tilt the cylinder of oil until the cylinder is <u>just about to topple</u>.	1	
Measure the angle Φ using protractor mounted on a retort stand with the centre marking aligned with the point (**x**) marked on the bench, **OR** At the point when the cylinder is just about to topple, measure the height of the raised edge of the cylinder, h, using a metre rule. The angle Φ is equal to $\sin^{-1}h$/(external diameter of the cylinder).	1	
For the second experiment, measure the internal diameter d of the cylinder using the <u>internal (inside) jaws of the vernier callipers</u>.	1	

Repeat measurements for 10 sets • Vary the mass *m* by pouring different volumes of oil • Vary the diameter *d* by using different cylinders	0	
Analysis		
When varying temperature *m* $\lg(\tan\Phi) = \lg(k\ d^p) + qm$ Plot $\lg(\tan\Phi)$ vs *m*, the gradient is q.	1	
When varying temperature *d* $\lg(\tan\Phi) = \lg(k\ q^m) + pd$ Plot $\lg(\tan\Phi)$ vs *d*, the gradient is p.	1	
Safety		
Wear gloves to handle the cylinder to prevent skin irritation if the oil spilled onto the hand, Use tray (or lid to cover cylinder or cloth to absorb oil) to prevent the spilling of oil Place padding (or items with cushioning effects) to prevent glass cylinder breaking if fallen	1	1 mark for safety
Good Details / Accuracy		
Place sandpaper (or any rough material) on the bench to prevent sliding of the cylinder	1	2 marks for accuracy
Repeat measurements of *d* in different directions and take average to reduce random errors	1	
Use of video with slow motion/frame by frame playback to determine Φ	1	
Perform a preliminary experiment to establish an approximate angle Φ before redoing the experiment by positioning the cylinder near Φ for fine-tuning.	1	
Use large protractor with higher precision to reduce percentage uncertainty	1	
Total marks	**12**	