1 In this experiment, you will investigate an electrical circuit.

(a) You have been provided with two metre rules, **F** and **G**, with wires of different diameter attached.

(i) The diameter of the wire attached to **F** is d_F.
Using the micrometer, measure and record d_F.

No zero error
d_{F1} = 0.229 mm, d_{F2} = 0.231 mm; d_{ave} = 0.230 mm

d_F = ...0.230 mm.............. [2]

(ii) Set up the circuit as shown in Figure 1.1.

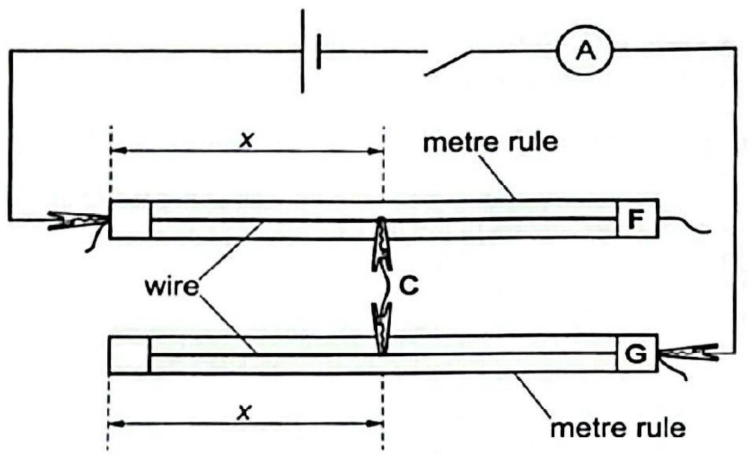


Fig. 1.1

Position connecting lead **C** so that distance x is 50.0 cm on both rules.
Close the switch. The ammeter reading is I.
Record x and I.

x = ...50.0 cm..............

I = ...90.6 mA..............
[2]

Open the switch.

(b) Vary *x* and repeat **(a)(ii).**
Present your results clearly.

x / cm	I / mA	$(1/I)$/ A^{-1}
10.0	81.1	12.33
25.0	85.0	11.76
50.0	95.5	10.47
65.0	94.0	10.64
80.0	95.5	10.47
90.0	97.7	10.24

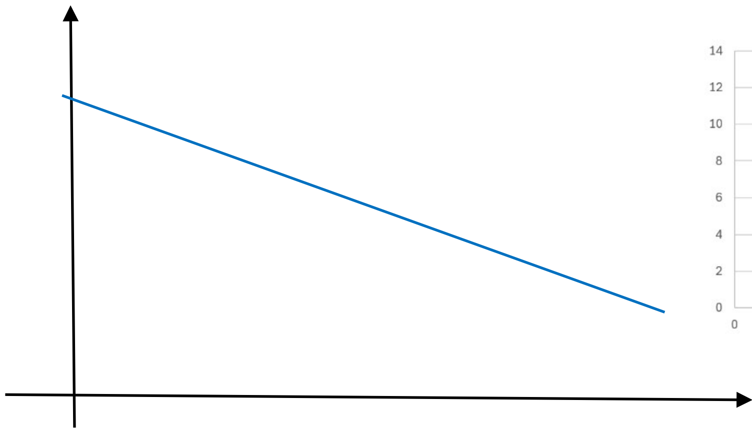
[3]

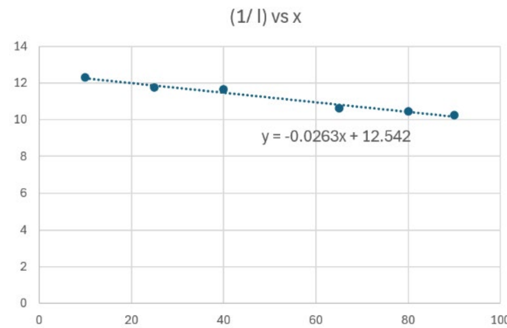
(c) The quantities I and x are related by the expression:

$$\frac{1}{I} = Px + Q$$

where *P* and *Q* are constants.

Plot a suitable graph using a spreadsheet to determine *P* and *Q*.
Sketch the graph in the space below. Write down the equation of the trendline.





Refer to Prelim_ datasetforceext answer.

$(1/ I)$ / A^{-1} Plot graph of against x, where gradient = P and y-intercept = Q

x / cm

12.542

0

$(1/ I)$ = -0.0263 x + 12.542

P = -0.0263 A^{-1} cm^{-1}

Q = 12.5 A^{-1}

[3]

(d) It is suggested that:

$$\frac{P}{Q} = \frac{\left(\frac{d_G^2}{d_F^2} - 1\right)}{L}$$

Where d_G is the diameter of the wire attached to **G** and L = 1.000 m.
Determine a value for d_G.
Show your working.

d_G = 2.5398 x 10^{-4} m = 0.254 mm (to 3 s.f.)

{ Note: actual d_G measured using digital MSG = 0.190 mm }

d_G = 0.254 mm [2]

[Total: 12 marks]

2 In this experiment, you will investigate stretched rubber bands.

(a) Set up the apparatus as shown in Fig. 2.1.

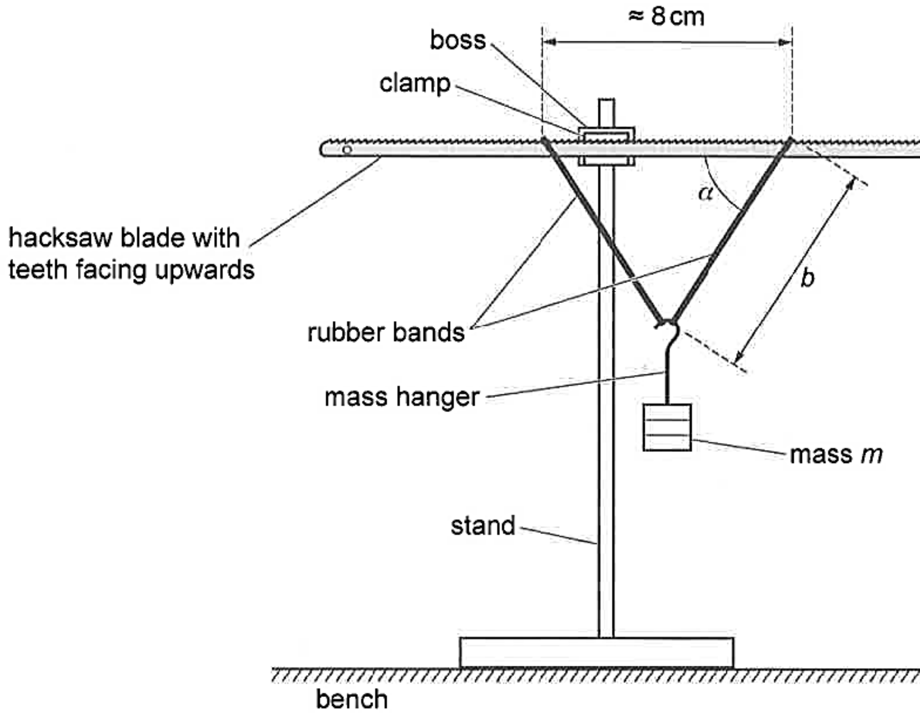


Fig. 2.1

Clamp the hacksaw blade with its teeth facing upwards.

Place the rubber bands on the blade so that the tops of the rubber bands are approximately 8 cm apart. You may wish to use some of the Blu-Tack to secure the tops of the rubber bands on the blade.

Suspend mass *m* from the rubber bands where *m* = 300 g. Record *m*.

m = ...300 g..................

The angle between **one** of the rubber bands and the hacksaw blade is *α*, as shown in Fig. 2.1. The length of **one** of the stretched rubber bands is *b*.

Measure and record *α* and *b*.

$\alpha_1 = 73°$ $\alpha_2 = 73°$; $\alpha_{ave} = 73°$

$b_1 = 10.5$ cm $b_2 = 10.5$ cm; $b_{ave} = 10.5$ cm

α = ...73°..................

b = ...10.5 cm..................

[2]

(b) Change *m* to 200 g.

Adjust the position of the tops of the rubber bands on the blade so that *b* has the same value as in **(a)**.

Record *m*.

m = ...200 g..........

Measure and record α.

$\alpha_1 = 42°$ $\alpha_2 = 42°$

α = ...42°..........

[1]

(c) It is suggested that

$$\sin \alpha = Cm$$

where *C* is a constant.

Use your values from **(a)** and **(b)** to determine two values of *C*.

$C_1 = \; = 3.19\ \text{kg}^{-1}$

$C_2 = \; = 3.35\ \text{kg}^{-1}$

first value of *C* = ...$3.19\ \text{kg}^{-1}$..........

second value of *C* = ...$3.35\ \text{kg}^{-1}$..........

[2]

(d) It is suggested that:

$$C = \frac{g}{2ek}$$

where *e* is the extension of the rubber band with extended length *b, k* is the force constant of this rubber bands and the acceleration of free fall $g = 9.81\ \text{ms}^{-2}$.

Determine a value for *k*. Show your working.

Initial length of rubber band = 8.5 cm (to be measured)
Extension *e* = 10.5 – 8.5 = 2.0 cm

$C_{ave} = \; = 3.27\ \text{kg}^{-1}$

Thus, $k = \; = 75.0\ \text{N kg}^{-1}$

k = ...$75.0\ \text{N m}^{-1}$ or kg s^{-2}..........

[3]

(e) Suggest one significant source of error in this experiment.

In the measurement of angle *α,* uncertainty arises due to the unsteadiness of the hand when holding the protractor.
In the measurement of length *b,* uncertainty arises due to the unsteadiness of the hand when holding the rule.
In the measurement of angle *α*, uncertainty arises as the positioning of protractor is hindered by the clamp.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………… [1]

(f) A materials engineer is characterising the performance of a high-grade industrial material that does not obey Hooke's Law.

The measured Force-Extension data for the loading cycle only is **recorded in the digital file: Prelim_datasetforceext.excel**

Imagine you are the engineer.

(i) Use the engineer's data to estimate the total work done during the loading phase.

Refer to Prelim_ datasetforceext answer

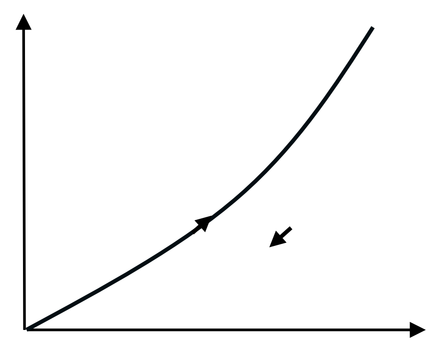
work done = ……5.06…………………………J [1]

(ii) Explain how you obtained the value of the total work done.

Area under the graph of force against extension.

……………………………………………………………………………………[1]

(iii) When a sample of the material is tested for its mechanical properties, it is subjected to a force that gradually increases to a maximum value (loading), and then is smoothly decreased back to zero (unloading), as illustrated in the figure below.



force

extension

loading

unloading

It is observed that the unloading curve does not retrace the loading curve, forming a distinct closed loop. Explain the physical significance of this closed loop.

The area enclosed between the 2 curves represents the energy dissipated as thermal energy (heat) within the material during one complete cycle of loading and unloading.

[1]

Note: Area under Loading Curve represents total work done on material by the stretching force to deform it; Area under Unloading Curve represents work done by material as it returns to its original length (mechanical energy recovered).

(iv) The loading curve of the material is modeled by the equation:

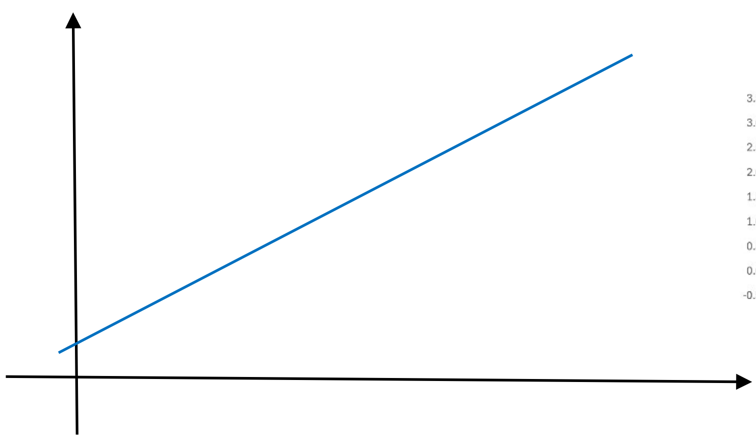
$$F = A\,(e^{Bx} - 1)$$

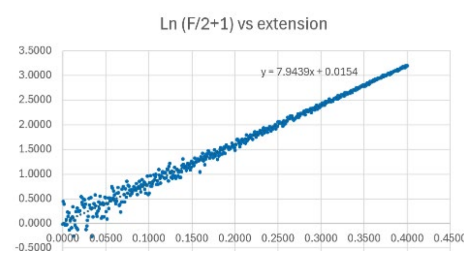
where:

- F is the loading force applied to the material,
- x, measured in metres, is the extension of the material,
- A is a constant equal to 2.0 N,
- B is a constant.

Plot a suitable linear graph using the dataset to determine *B.*

Sketch the graph in the space below. Write down the equation of the trendline.





Refer to Prelim_ datasetforceext answer.

ln (F/2 + 1)

x /m

0.0154

Plot graph of against , where gradient =
= gradient = 7.94 (as given by excel trendline eqn) (3 sf)
Acceptable range of : 6.4 – 9.5

0

$\ln(F/2 + 1) = 7.9439\,x + 0.0154$

B = ……………………………. 7.94 m^{-1} [2]

[Total: 14 marks]

3 This experiment concerns a coupled pendulum system.

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

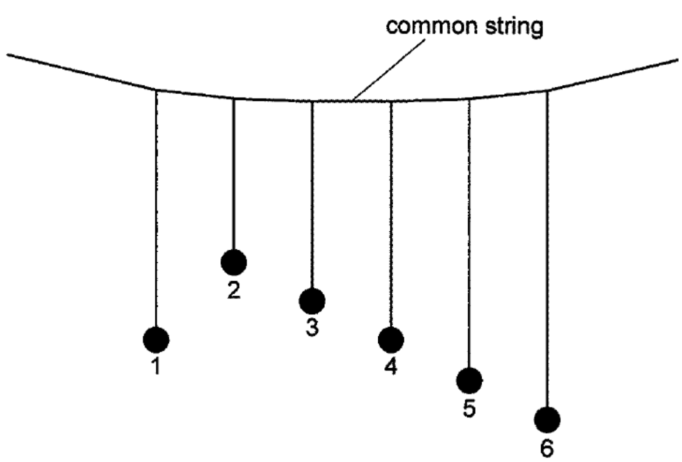


Fig. 3.1

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

You will investigate how these properties affect the behaviour of a coupled pendulum system:

- The distance between 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 Figure 3.2. Place the loops of the common string on the rods of the clamps. The distance x between the pendulum strings is shown.

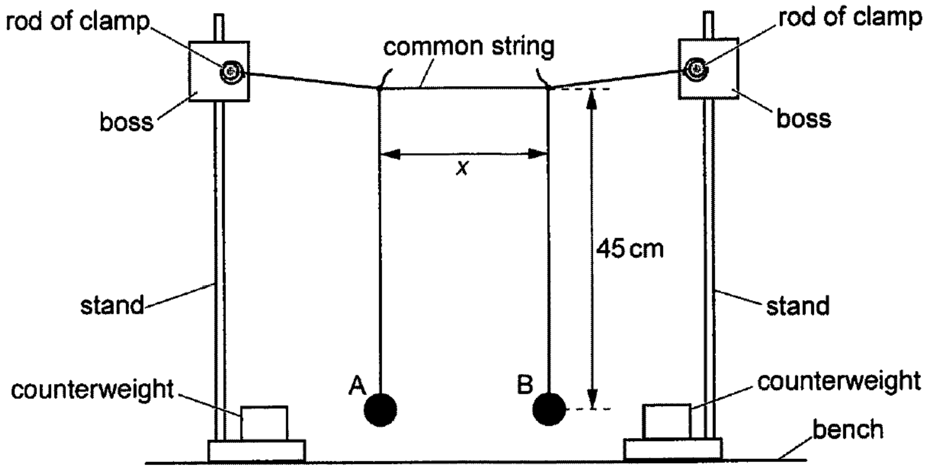


Fig. 3.2

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*.

$_1$ = 15.0, x_2 = 15.0; x_{ave} = 15.0

x = ...15.0.............. cm [1]

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.

Measure and record *t*.

t_1 = 24 s, t_2 = 28 s, t_{ave} = 26 s

Case 1: difference between readings t_1 & t_2 $\leq$ 1.0 s	**Case 2**: difference between readings t_1 & t_2 > 1.0 s
Δt = 0.5 s or less i.e. Challenging condition: **Δt = 3 to 5 times of smallest div** **= 0.3 s to 0.5 s**	Δt > 0.5 s i.e. Very challenging condition **Δt = ½ of range of values of *t*** **= ½ (t_2 - t_1)**

t = ...26............... s [1]

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

%uncertainty = x 100% = x 100% = 19 %

percentage uncertainty in t = ……… 19 % ……… [1]

(iii) It is also possible to determine t using B. The time $2t$ is the time between releasing A and B stopping for the first time.

Discuss whether this second method of determining t is better or worse than the method used in **(a)(i).**

econd method is better, because percentage uncertainty is reduced.

…………………………………………………………………………………………………

……………………………………………………………………………………………[2]

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

x / cm	t_1 / s	t_2 / s	t_{ave} / s
5.0	15	17	16
15.0	24	28	26
25.0	34	30	32

Tabulate these results. Include the results from **(a)(i)**.

Max range is 20 cm, penalised if range less than 15 cm (ie. 75%)

[2]

(ii) Comment on the trend in your results.

t increases as x increases.

…………………………………………………………………………………………………….

………………………………………………………………………………………..….[1]

(c) In part **3(d),** you will use a certain **value of *x***. Choose **one** value of x from the values in **3(b)(i)** to use.

State and explain your choice of x.

25.0 cm.

For greatest x, value of t is also greatest, resulting in lowest percentage uncertainty of t

…………………………………………………………………………………………………….

…………………………………………………………………………………………….……[1]

(d) For the arrangement shown in Figure 3.2, adjust the positions of the pendulums to make x equal to the value chosen in **(c)**.

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_1 = 50 s, t_2 = 52 s, t_{ave} = 51 s

t = ………51……………….. s [1]

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

t increases as tension increases

……..……………………………………………………………………………………………………
.

……..………………………………………………………………………………………..….[1
]

(e) The distance y is the difference in length between the two pendulums, as shown in Figure 3.3 for a chosen value of x.

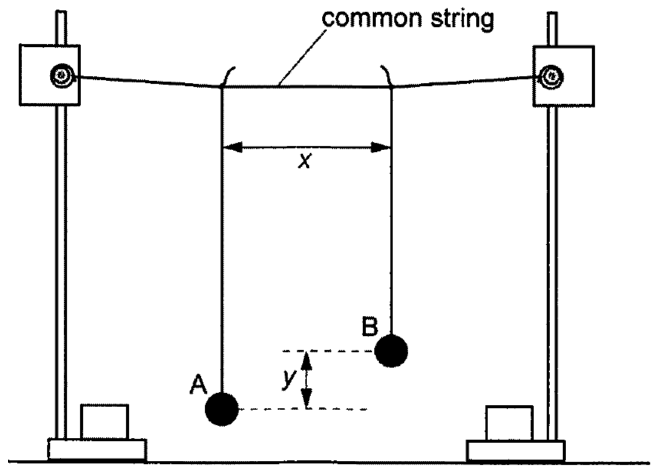


Figure 3.3

Table 3.1 shows data for y and t.

Table 3.1

***y* / cm**	4.0	8.0
***t* / s**	31	12

(i) It is suggested that:

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

where k is a constant.

Use the values from Table 3.1 to determine **two** values of k.

$k = t\,y$,

when y = 4.0 cm and t = 31 s, k = 120 s cm

when y = 8.0 cm and t = 12 s, k = 96 s cm, first value of k = 20 s cm

second value of k = 6 s cm

[2]

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

The number of sf for *k* should be the same as the number of sf of the quantity with the least number of sf, which is both *t* and *y* at 2 sf. Thus, *k* is given to 2 sf.

[1]

(iii) State whether the results of the experiment support the relationship suggested in **(e)(i)**.

Justify your conclusion by referring to your answer in **3(a)(ii)**.

If x 100% > 19 % (ans in (a)(ii)), the results do not support the suggested relationship.

x 100% = x 100% = 22 % which is > 19 %

Hence, the results do not support the suggested relationship.

[1]

(f) Figure 3.4 shows two pendulums of equal length. The pendulum bobs consist of a number of slotted masses.

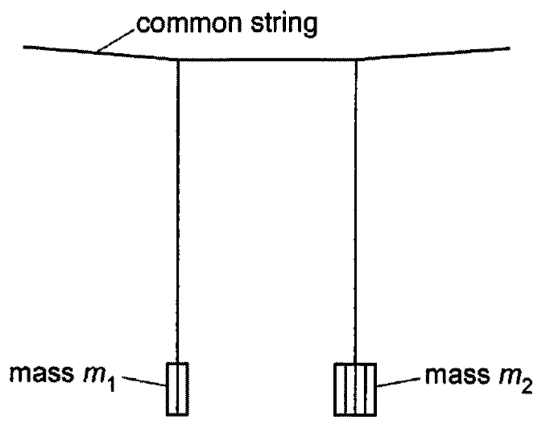


Figure 3.4

In an investigation, mass m_1 is fixed at 40 g, mass m_2 is varied and t is measured.

Table 3.2 shows data for m_2 and t.

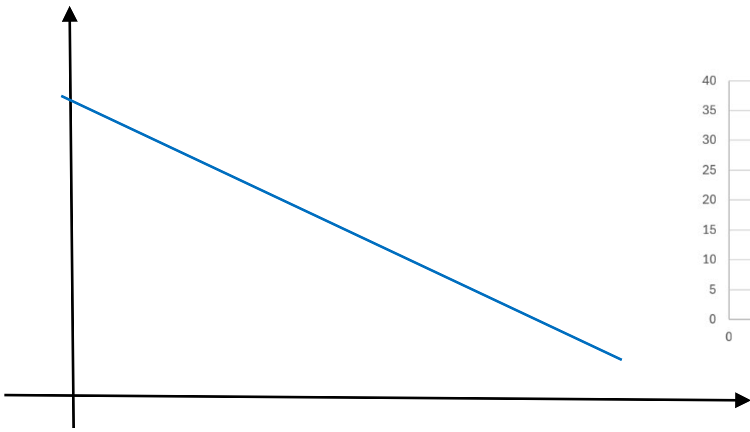
Table 3.2

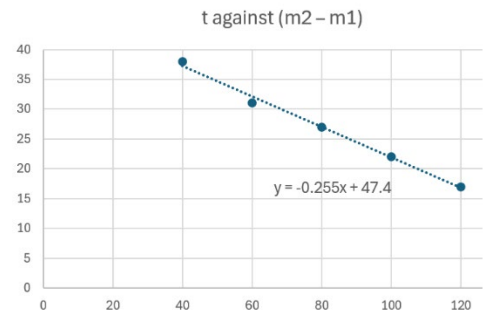
m_2 / g	80	100	120	140	160
t / s	38	31	27	22	17
($m_2 - m_1$) / g	40	60	80	100	120

Complete Table 3.2.

Plot the graph of t against ($m_2 - m_1$) using a spreadsheet to determine t when the two masses are equal.

Sketch the graph in the space below. Write down the equation of the trendline.





t / s

Refer to Prelim_ datasetforceext answer.

$(m_2 – m_1)$ / g

Plot graph of against m_2 - m_1 ,

47.4

where y-intercept = 47.4 (i.e. when m_1 = m_2)

0

t = -0.255 $(m_2 – m_1)$ + 47.4

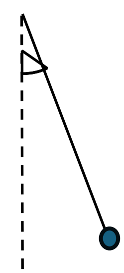
t = 47.4 ………………………………… s
(no other accepted ans)

[4]

(g) It is suggested that the time *t* for one complete energy transfer (i.e. the time between releasing A and A stopping for the first time) between the two pendulums in **(a)** is <u>independent</u> of the initial release angle (. Describe an investigation to determine if this relationship is valid.

Include in your plan:

- details of the measurements
- how you might use the results to show the validity of the relationship



Procedure:

(

A diagram OR description stating the measurement of the initial angle (i.e. the displacement of pendulum A from the vertical) using a protractor. [1]

Side view of pendulum A

Front view of pendulums A & B

States how is varied (e.g. use a protractor placed behind the pendulum string to set the bob at different initial angles). [1]

Then release the bob from rest. Measure the time *t* from releasing bob A and A stopping for the first time using a <u>stopwatch</u>. Description of set-up with video camera with timer in view, with frame-by-frame playback to note the time is acceptable. [1]

Repeat measurement of *t* for at least 10 sets of by releasing bob at different initial angles. [1]

Analysis:

States to plot a graph of *t* against . If the graph is a **horizontal straight line** (zero gradient), the time *t* is independent of ; if the gradient is non-zero, the relationship is invalid (i.e. not independent). [1]

………

………

………

………

………

………[5]

[Total: 24 marks]

APPARATUS LIST FOR PRELIM PRACTICAL 2026

<table>
<tr>
<td>Q1</td>
<td>
[Source: N2025 P4 Q1]

1. 1.5 V dry cell in a battery holder
2. Switch
3. Two metre rules each with a millimetre scale (see Fig. 1.1)
4. 110 cm of 34 swg constantan wire (see Fig. 1.1)
5. 110 cm of 36 swg constantan wire (see Fig. 1.1)

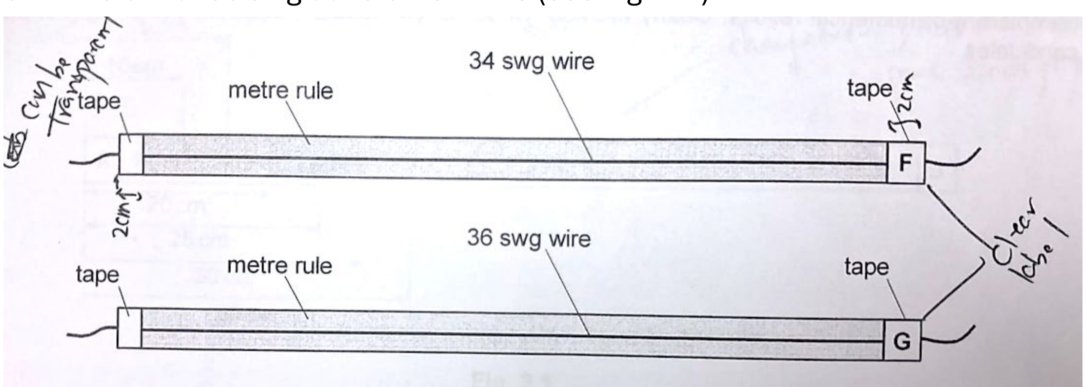
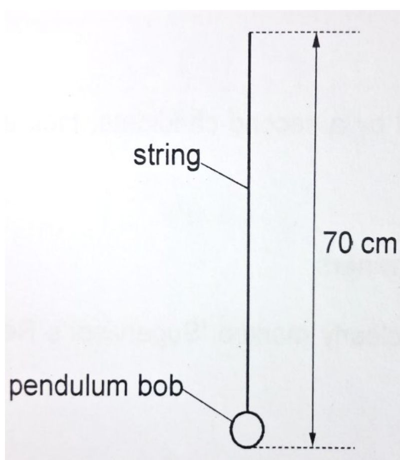


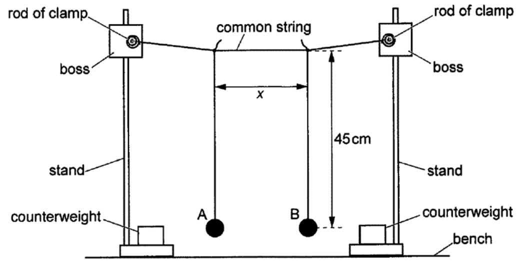
Fig. 1.1

{Wire should be attached to the metre rule as shown above. The metre rule with the 34 swg wire attached should be labelled F, and the other metre rule with the 36 swg wire should be labelled G.}

6. Digital ammeter (set to 200 mA range)
</td>
</tr>
</table>

	7. Five connecting leads with crocodile clips at both ends 8. Micrometer screw gauge (**shared** basis)
Q2	**[Source: N2024 P4 Q2]** 1. Retort stand 2. Boss 3. Clamp 4. Hacksaw blade x1 5. 30 cm ruler 6. Protractor 7. Two thin rubber bands **[need to be replaced every shift]** 8. 100 g mass hangar 9. Two 100 g slotted masses 10. Blu-tack (small blob)
Q3	**[Source: N2019 P4 Q3]** 1. Two retort stands 2. Two clamps 3. Two bosses 4. Two pendulum bobs made of plasticine (See Fig. 3.1) **[need to be replaced every shift]**  **Fig. 3.1** {Note: the bobs should be made of plasticine, each of mass 10 g, rolled into a sphere. Attach each of the bobs to a length of string (70 cm) as shown}

5. Thick string (length 60 cm) with a loop at EACH end. The loops should have a circumference of about 4 cm. {This is called the 'common string' in the question} **[need to be replaced every shift]**



6. Stopwatch
7. Metre rule
8. 30 cm ruler
9. Two small bricks of approximate mass 700 g to act as counterweights

Summary of items to be changed every shift:

Question 1	NIL
Question 2	1. Two thin rubber bands
Question 3	1. Two pendulum bobs made of plasticine 2. Thick string (length 60 cm) with a loop at EACH end.

Question sources:

1. 2025 Alevel P4 Q1 (Electricity)

2. 2024 Alevel P4 Q2 (Rubber band)(and **include Big Data** qn - area under curve)

3. 2019 Alevel P4 Q3 (Coupled pendulums) (and **include planning** qn)