



CANDIDATE
NAME

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9702/31

May/June 2024

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You will be allowed to work with the apparatus for a maximum of 1 hour for each question.
- You should record all your observations in the spaces provided in the question paper as soon as these observations are made.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].

For Examiner's Use	
1	
2	
Total	

This document has **12** pages.

You may not need to use all of the materials provided.

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

You have been provided with a metre rule with a wire attached. You have also been provided with six identical resistors. Four of the resistors are connected in series and attached to a wooden block. The other resistors are labelled X and Z.

- (a) • Set up the circuit shown in Fig. 1.1.

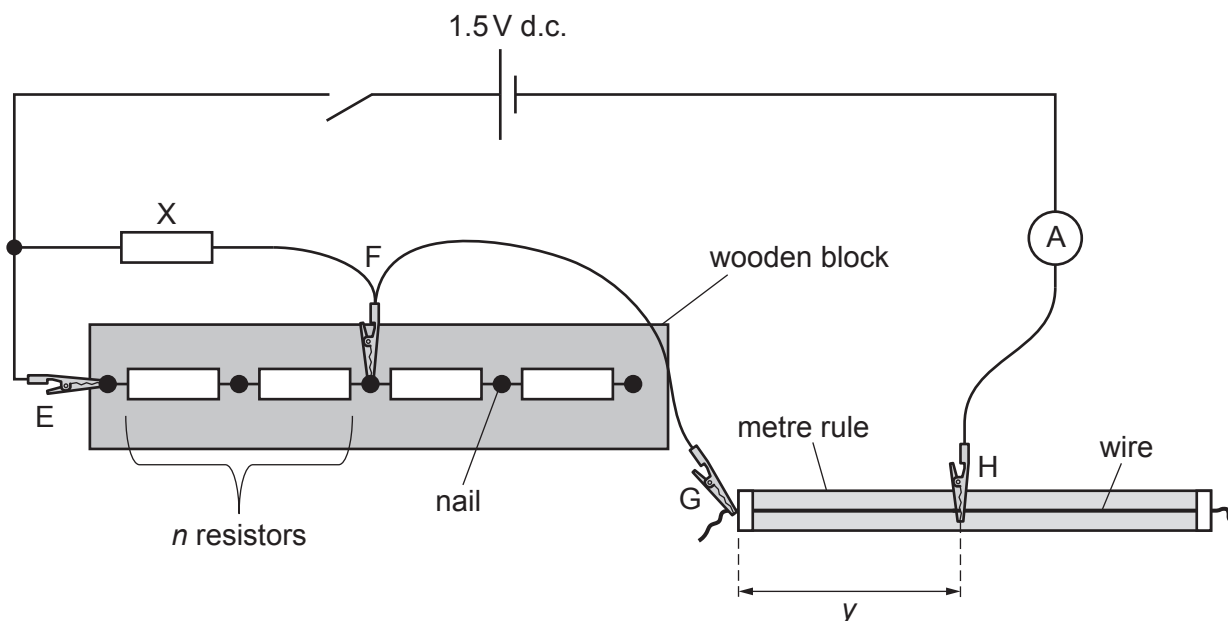


Fig. 1.1 (not to scale)

- E, F, G and H are crocodile clips.

n resistors on the wooden block are connected in parallel with X. Connect F so that $n = 2$, as shown in Fig. 1.1.

- The distance between G and H is y . Attach H to the wire so that y is approximately 50 cm.
- Close the switch.
- Record n , y and the ammeter reading I .

$n =$

$y =$

$I =$

- Open the switch.

[2]

- (b) • Connect Z as shown in Fig. 1.2.

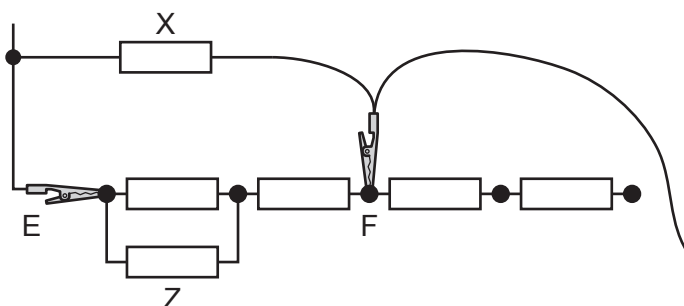


Fig. 1.2

When Z is connected in parallel with the first of the resistors on the block, the total value of n is reduced by 0.5.

For the arrangement in Fig. 1.2, the value of n is 1.5.

- Close the switch.
- Change the position of H on the wire until the value of I is as close as possible to your value in (a).
- Record n and y .

$n =$

$y =$

- Open the switch.
- Disconnect Z.

[1]

- (c) Vary n by changing the position of F and connecting and disconnecting Z.

For each value of n , change the position of H until the value of I is as close as possible to your value in (a).

Repeat until you have six sets of values of n and y . Include your values from (a) and (b).

Record your results in a table. Include values of $\frac{n}{n+1}$ to two significant figures in your table.

[8]

- (d) (i) Plot a graph of y on the y -axis against $\frac{n}{n+1}$ on the x -axis.

[3]

- (ii) Draw the straight line of best fit.

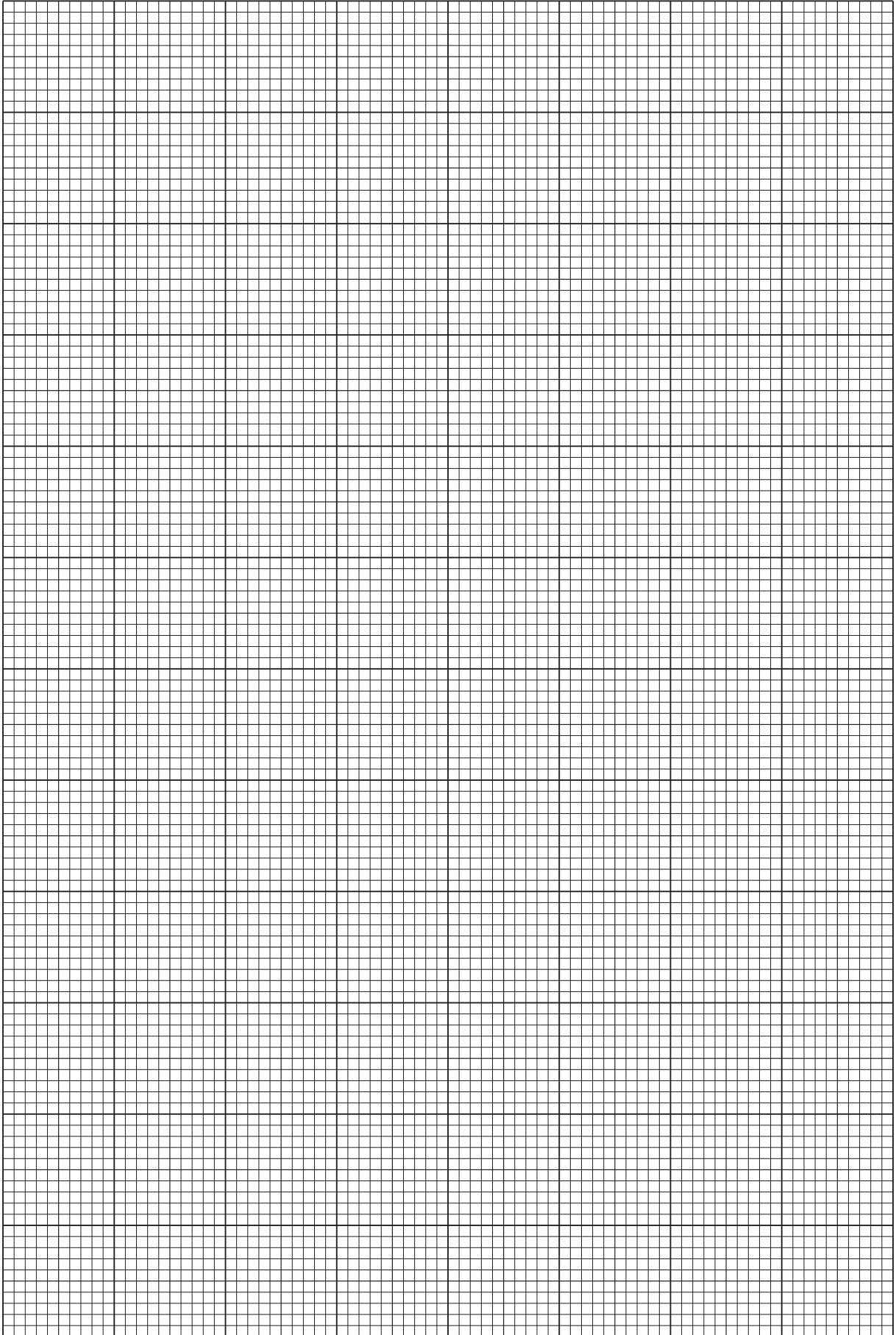
[1]

- (iii) Determine the gradient and y -intercept of this line.

gradient = ...

y -intercept = ...

[2]



- (e) It is suggested that the quantities y and n are related by the equation

$$y = -\frac{Pn}{n+1} + Q$$

where P and Q are constants.

Using your answers in (d)(iii), determine the values of P and Q .
Give appropriate units.

$$P = \dots\dots\dots$$

$$Q = \dots\dots\dots$$

[2]

- (f) Theory suggests that

$$\frac{P}{Q} = \frac{X}{C}$$

where the resistance X of resistor X is 12Ω and C is the resistance of the whole circuit.

Use your values in (e) to determine a value for C .

$$C = \dots\dots\dots \Omega \text{ [1]}$$

[Total: 20]

You may not need to use all of the materials provided.

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

(a) (i) The length of the rod is L , as shown in Fig. 2.1.

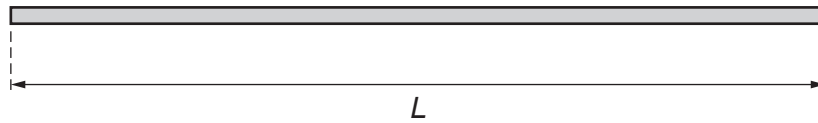


Fig. 2.1

Measure and record L .

$L =$ [1]

(ii) The mass of the rod is M .

Measure and record M .

$M =$ [1]

(iii) Calculate S , where

$$S = \frac{ML^2}{12}.$$

$S =$ [1]

(iv) Justify the number of significant figures that you have given for your value of S .

.....

 [1]

- (b) (i) • Wrap one end of the copper wire tightly three times around the centre of the rod, as shown in Fig. 2.2.

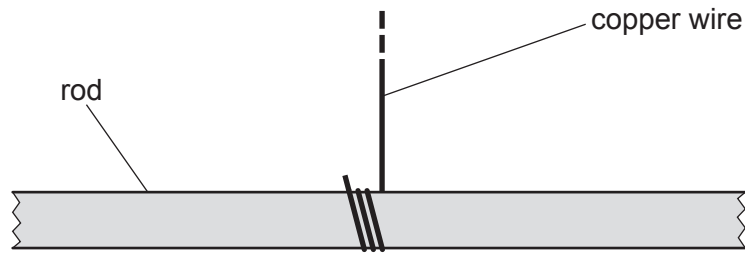


Fig. 2.2

- Slide a 50 g slotted mass onto each end of the rod.
- Record the mass m on **one** end of the rod.

$m = \dots\dots\dots$ g

- Adjust the positions of the masses so that they are equally spaced from the centre of the rod and their centres are approximately 3 cm apart, as shown in Fig. 2.3. You may need to use some of the adhesive putty to keep the masses in position.

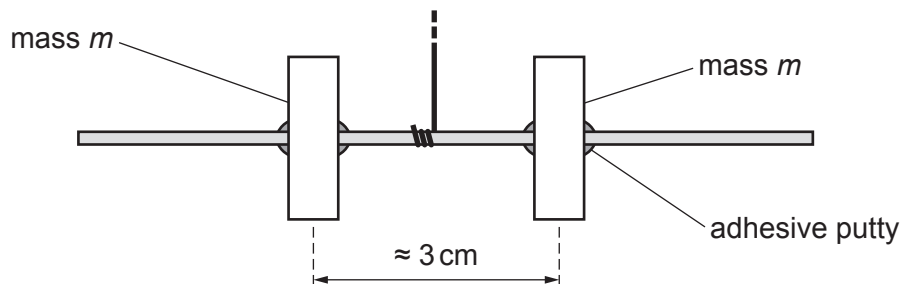


Fig. 2.3

- Set up the apparatus as shown in Fig. 2.4.

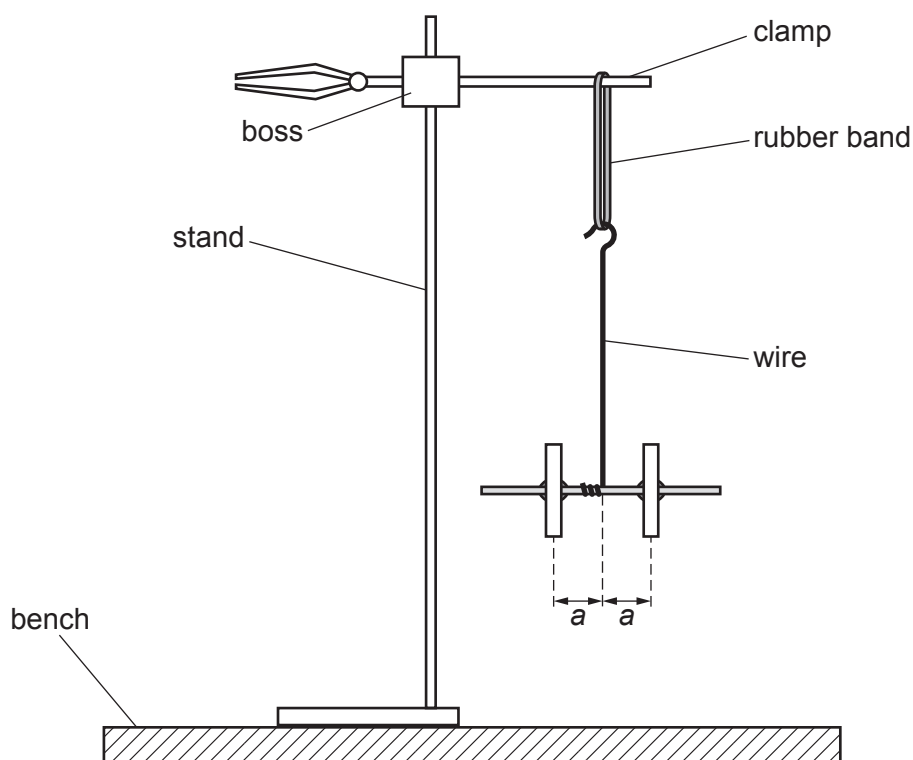


Fig. 2.4

- Make a hook in the wire and place the hook on the rubber band.
- The distance between the centre of each mass and the wire is a .

Adjust the position of the masses until the rod is parallel to the bench and each mass is the same distance a from the wire.

- Measure and record a .

$a =$ [1]

- (ii) Estimate the percentage uncertainty in your value of a . Show your working.

percentage uncertainty = ... % [1]

- (c)
- Rotate the rod horizontally through 90° .
 - Release the rod. The rod will oscillate.
 - Take measurements to determine the period T of these oscillations.

$T = \dots\dots\dots$ [2]

- (d)
- Remove the hook from the rubber band.
 - Remove the 50 g masses from the rod.
 - Place the 10 g masses on the rod so that their centres are approximately 9 cm apart.
 - Record m .

$m = \dots\dots\dots$ g

- Place the hook on the rubber band.
- Adjust the position of the masses until the rod is parallel to the bench and each mass is the same distance a from the wire.
- Measure and record a .

$a = \dots\dots\dots$

- Repeat (c).

$T = \dots\dots\dots$ [2]

- (e) It is suggested that the relationship between T , S , a and m is

$$T^2 = k(S + a^2m)$$

where k is a constant.

Using your data, calculate two values of k .

first value of k = ...

second value of k = ... [1]

- (f) It is suggested that the percentage uncertainty in the values of k is 10%.

Using this uncertainty, explain whether your results support the relationship in (e).

.....

 [1]

- (g) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

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[4]

- (ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

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[Total: 20]

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Cambridge International AS & A Level

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PHYSICS

9702/32

Paper 3 Advanced Practical Skills 2

May/June 2024

2 hours

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You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

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

- (a)** • Connect the circuit shown in Fig. 1.1.

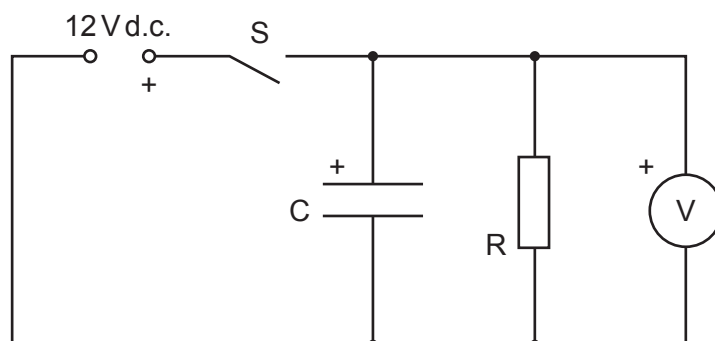


Fig. 1.1

- **Ensure that the polarities of the power supply, component C and the voltmeter are as shown in Fig. 1.1.**
- Close switch S for a short time and then open it.
- Watch the voltmeter reading as it reduces.

When the voltmeter reading passes a value V_S of 8.00 V, start the stop-watch.

When the voltmeter reading passes a value of 7.00 V, stop the stop-watch.

- Record the starting value V_S and the time T for the voltmeter reading to fall by 1.00 V.

$V_S =$

$T =$
[2]

- (b) Choose another starting value V_S . Close S for a short time and then open it. Measure the time T for the voltmeter reading to fall by 1.00 V from the starting value V_S .

Repeat until you have six sets of values of V_S and T .

Record your results in a table. Include values of $\frac{1}{T}$ in your table.

[10]

- (c) (i) Plot a graph of $\frac{1}{T}$ on the y -axis against V_S on the x -axis.

[3]

- (ii) Draw the straight line of best fit.

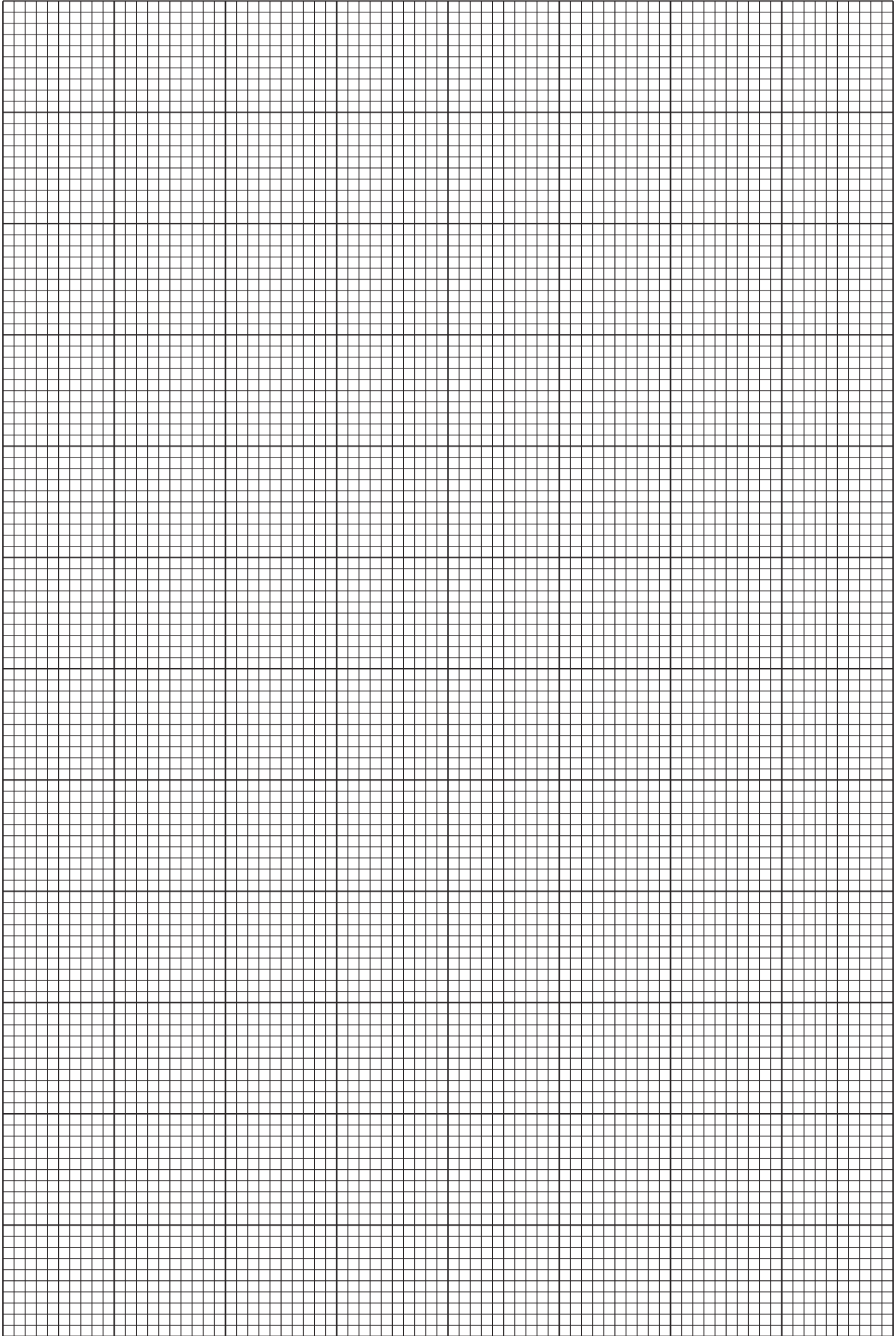
[1]

- (iii) Determine the gradient and y -intercept of this line.

gradient = ...

y -intercept = ...

[2]



(d) It is suggested that the quantities V_S and T are related by the equation

$$\frac{1}{T} = aV_S + b$$

where a and b are constants.

Using your answers in (c)(iii), determine the values of a and b .

Give appropriate units.

$a =$

$b =$
[2]

[Total: 20]

You may not need to use all of the materials provided.

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

- (a) (i)**
- Assemble the apparatus as shown in Fig. 2.1.
 - Adjust the apparatus so that the wooden rod is parallel to the bench and the spring is vertical.

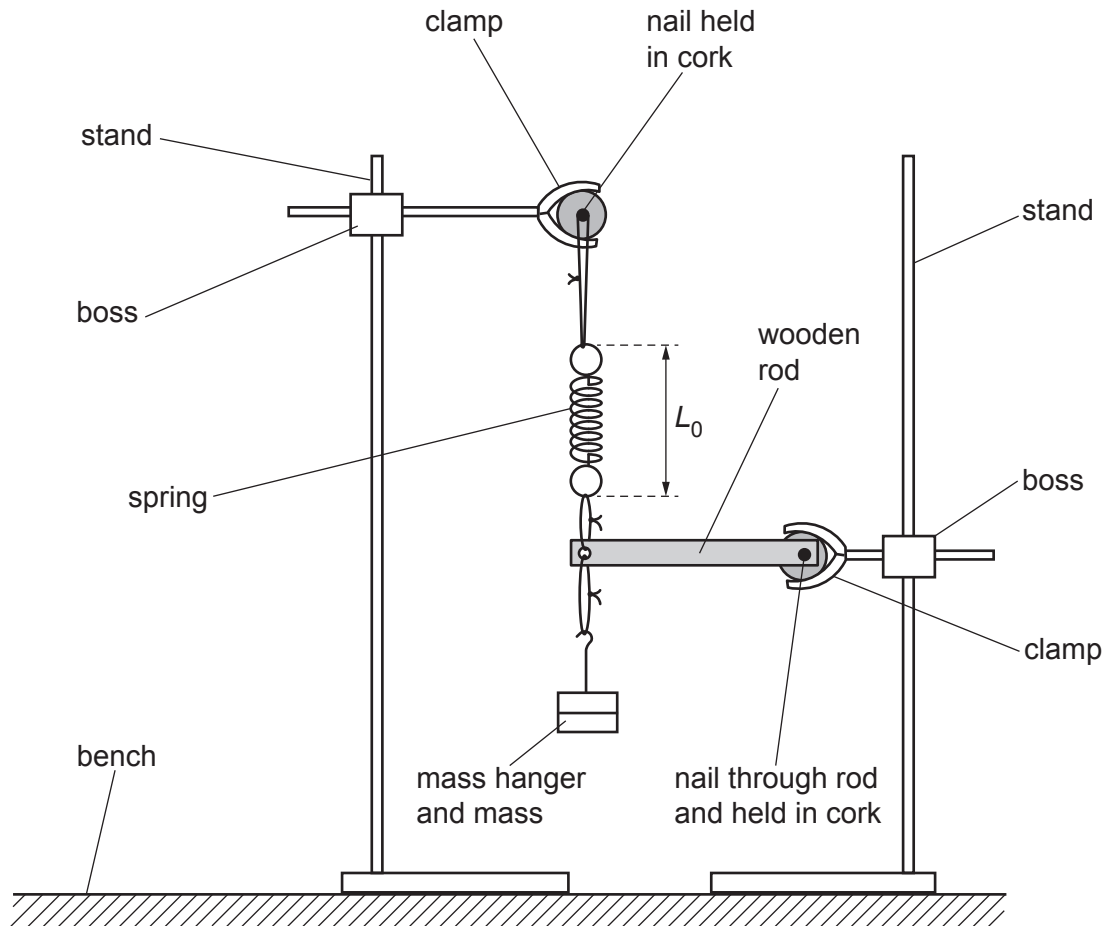


Fig. 2.1 (not to scale)

- The distance between the ends of the spring is L_0 , as shown in Fig. 2.1.
Measure and record L_0 .

$L_0 = \dots\dots\dots$ m [1]

- (ii) • Pull the mass hanger down a short distance and then release it. The mass hanger will oscillate.
- Take measurements to find the period T of the oscillations.

$T = \dots\dots\dots$ [2]

- (iii) • Calculate the value of the spring constant k using

$$k = \frac{\alpha\pi^2}{T^2}$$

where $\alpha = 0.800$ kg.

$k = \dots\dots\dots \text{Nm}^{-1}$

- Justify the number of significant figures that you have given for your value of k .

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[1]

- (b) (i) • Move the stand supporting the spring away from the other stand and add the plumb line, as shown in Fig. 2.2.

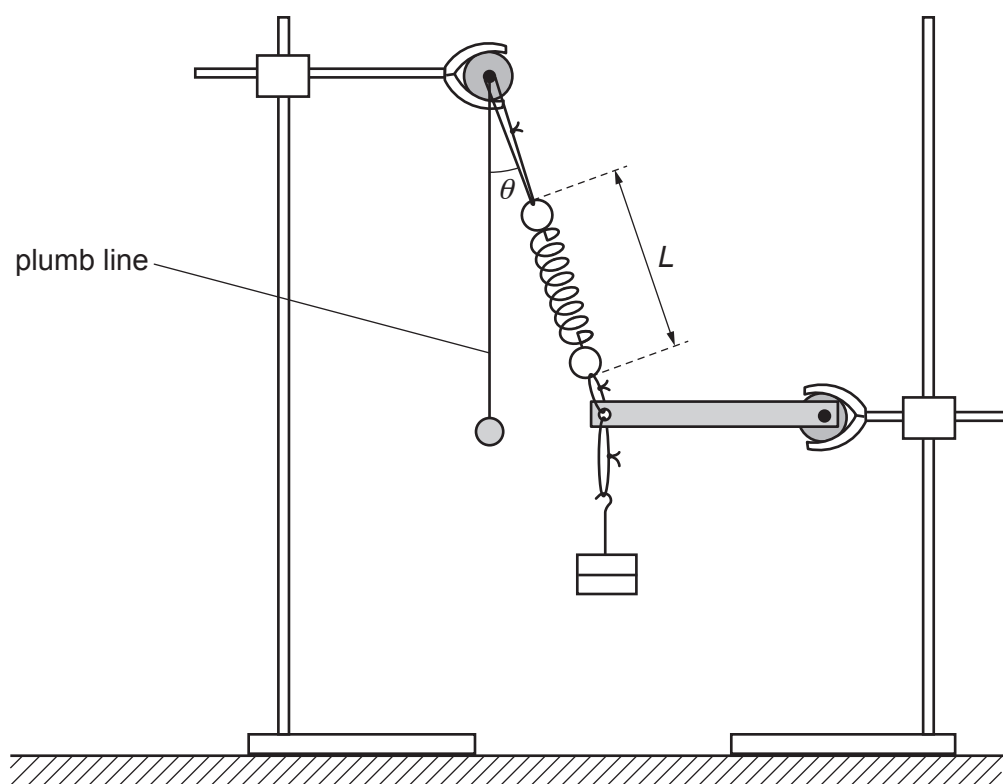


Fig. 2.2 (not to scale)

- Adjust the apparatus so that the angle θ between the spring and the vertical is approximately 20° and the wooden rod is parallel to the bench, as shown in Fig. 2.2.
- The new distance between the ends of the spring is L , as shown in Fig. 2.2.

Measure and record L .

$L = \dots\dots\dots$ m

- Measure and record θ .

$\theta = \dots\dots\dots^\circ$
[2]

- (ii) Estimate the percentage uncertainty in your value of θ . Show your working.

percentage uncertainty = $\dots\dots\dots\%$ [1]

(iii) Repeat (b)(i) using an angle θ of approximately 45° .

$L = \dots\dots\dots$ m

$\theta = \dots\dots\dots^\circ$
[3]

(c) It is suggested that the relationship between L and θ is

$$k(L - L_0) + B = \frac{D}{\cos \theta}$$

where $B = 2.0\text{ N}$ and D is a constant.

Using your data, calculate two values of D .

first value of $D = \dots\dots\dots$

second value of $D = \dots\dots\dots$
[1]

(d) It is suggested that the percentage uncertainty in the values of D is 10%.

Using this uncertainty, explain whether your results support the relationship in (c).

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

- (e) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

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[4]

- (ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

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[4]

[Total: 20]

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Cambridge International AS & A Level

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PHYSICS

9702/33

Paper 3 Advanced Practical Skills 1

May/June 2024

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

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- You should show all your working and use appropriate units.

INFORMATION

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You may not need to use all of the materials provided.

- 1 In this experiment, you will investigate a balanced metre rule.

You have been provided with a metre rule and some masses.

- (a) • Place the masses on the rule as shown in Fig. 1.1.

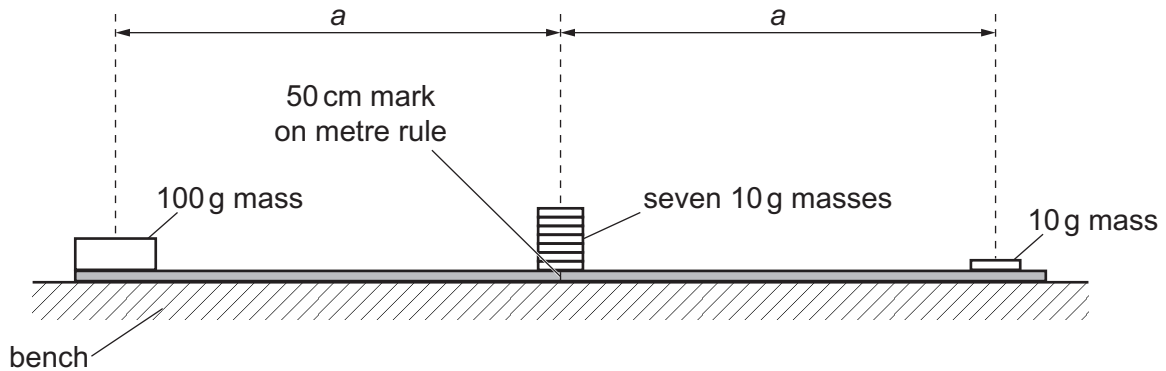


Fig. 1.1

- Place the 100 g mass at one end of the rule.
- The distance between the centre of the 100 g mass and the 50 cm mark on the rule is a .
Measure and record a .
 $a = \dots\dots\dots$
- Place a 10 g mass so that its centre is distance a from the 50 cm mark on the rule.
- Secure this mass in place using the adhesive putty. **This mass must remain in place throughout the experiment.**
- Place seven 10 g masses so that their centres are above the 50 cm mark on the rule.

[1]



- (b)
- Transfer n of the 10 g masses, where $n = 4$, from the centre of the rule onto the 10 g mass near the end of the rule.
 - Carefully place the rule and masses on the pivot as shown in Fig. 1.2.

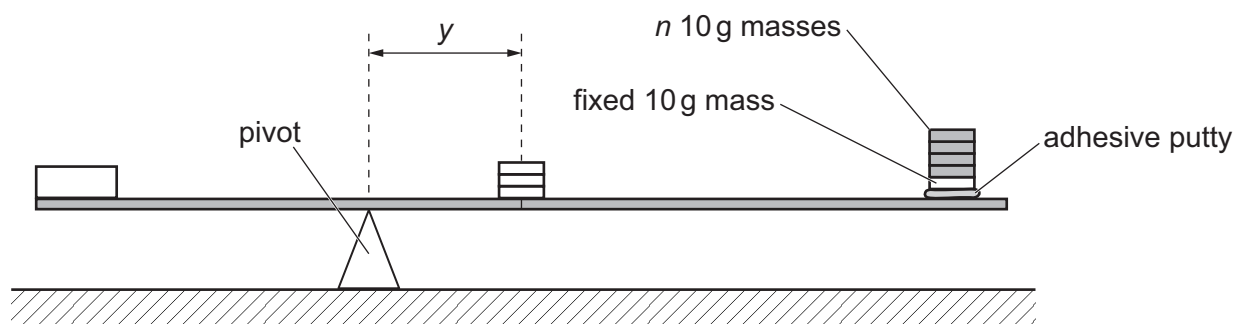


Fig. 1.2

- Adjust the position of the rule on the pivot until the rule is balanced.
- The distance between the pivot and the 50 cm mark on the rule is y .

Record n and y .

$n =$

$y =$

- Remove the rule from the pivot and place it on the bench.
- Return the n 10 g masses to the 50 cm mark.

[1]





- (c) Change n by moving some of the 10 g masses from the centre of the rule onto the 10 g mass near the end of the rule and determine y .

Repeat until you have six sets of values of n and y .

Record your results in a table.

Include values of $\frac{1}{n}$ and $\frac{y}{n}$ to three significant figures.

[9]

- (d) (i) Plot a graph of $\frac{y}{n}$ on the y -axis against $\frac{1}{n}$ on the x -axis.

[3]

- (ii) Draw the straight line of best fit.

[1]

- (iii) Determine the gradient and y -intercept of this line.

gradient = ...

y -intercept = ...

[2]







- (e) It is suggested that the quantities y and n are related by the equation

$$\frac{y}{n} = \frac{P}{n} - Q$$

where P and Q are constants.

Using your answers in (d)(iii), determine the values of P and Q .
Give appropriate units.

$$P = \dots\dots\dots$$

$$Q = \dots\dots\dots [2]$$

- (f) Theory suggests that

$$P = \frac{9Ma}{18M + R}$$

where $M = 10\text{ g}$ and R is the mass of the rule.

Determine the value of R .

$$R = \dots\dots\dots \text{ g } [1]$$

[Total: 20]



You may not need to use all of the materials provided.

2 In this experiment, you will investigate the properties of a rubber band.

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

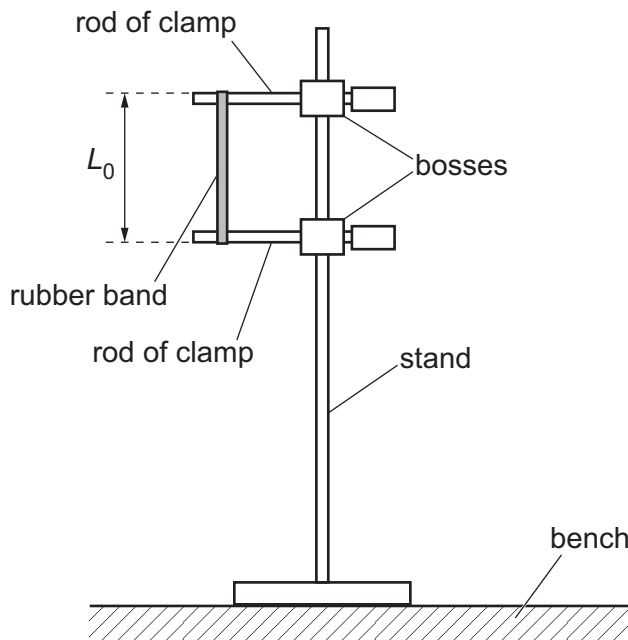


Fig. 2.1

- The rubber band should be straight but not stretched.

The distance between the ends of the rubber band is L_0 , as shown in Fig. 2.1.

Measure and record L_0 .

$L_0 = \dots\dots\dots$ [1]

(ii) Estimate the percentage uncertainty in your value of L_0 . Show your working.

percentage uncertainty = $\dots\dots\dots$ % [1]





- (b) The width of the unstretched rubber band is w_0 and its thickness is t , as shown in Fig. 2.2.

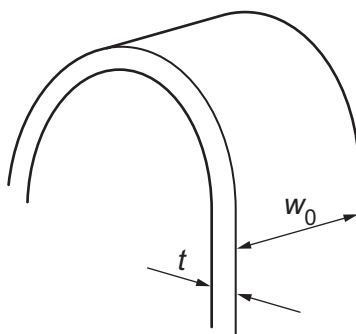


Fig. 2.2

Measure and record w_0 and t .

$w_0 =$

$t =$

[2]

- (c) (i) • Increase the distance between the clamps until the distance between the ends of the rubber band is approximately $1.5L_0$.
- The distance between the ends of the rubber band is L .

The width of the rubber band is w .

Measure and record L and w .

$L =$

$w =$

[1]

- (ii) Calculate ΔL and Δw , where $\Delta L = L - L_0$ and $\Delta w = w_0 - w$.

$\Delta L =$

$\Delta w =$

[1]

- (iii) Justify the number of significant figures that you have given for your value of ΔL .

.....

.....

..... [1]





- (d) • Increase the distance between the clamps until the distance between the ends of the rubber band is approximately $2L_0$.

- Measure and record L and w .

$L =$

$w =$

- Repeat (c)(ii).

$\Delta L =$

$\Delta w =$

[2]

- (e) It is suggested that the relationship between Δw and ΔL is

$$\frac{\Delta L}{\Delta w} = k$$

where k is a constant.

Using your data, calculate two values of k .

first value of $k =$

second value of $k =$

[1]





- (f) It is suggested that the percentage uncertainty in the values of k is 25%.

Using this uncertainty, explain whether your results support the relationship in (e).

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..... [1]

- (g) The approximate force F acting on the rubber band is given by

$$F = \frac{2Et k w_0 \Delta w}{L_0}$$

where the Young modulus E of rubber is $1.0 \times 10^6 \text{ N m}^{-2}$.

Use your second value of k and your value of Δw from (d) to determine a value for F .

$F = \dots\dots\dots \text{ N [1]}$





(h) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

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(ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

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Cambridge International AS & A Level

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PHYSICS

9702/34

Paper 3 Advanced Practical Skills 2

May/June 2024

2 hours

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1 In this experiment, you will investigate the equilibrium position of a pulley system.

- (a) • Assemble the apparatus as shown in Fig. 1.1 with the rods of the stands approximately 50 cm apart.

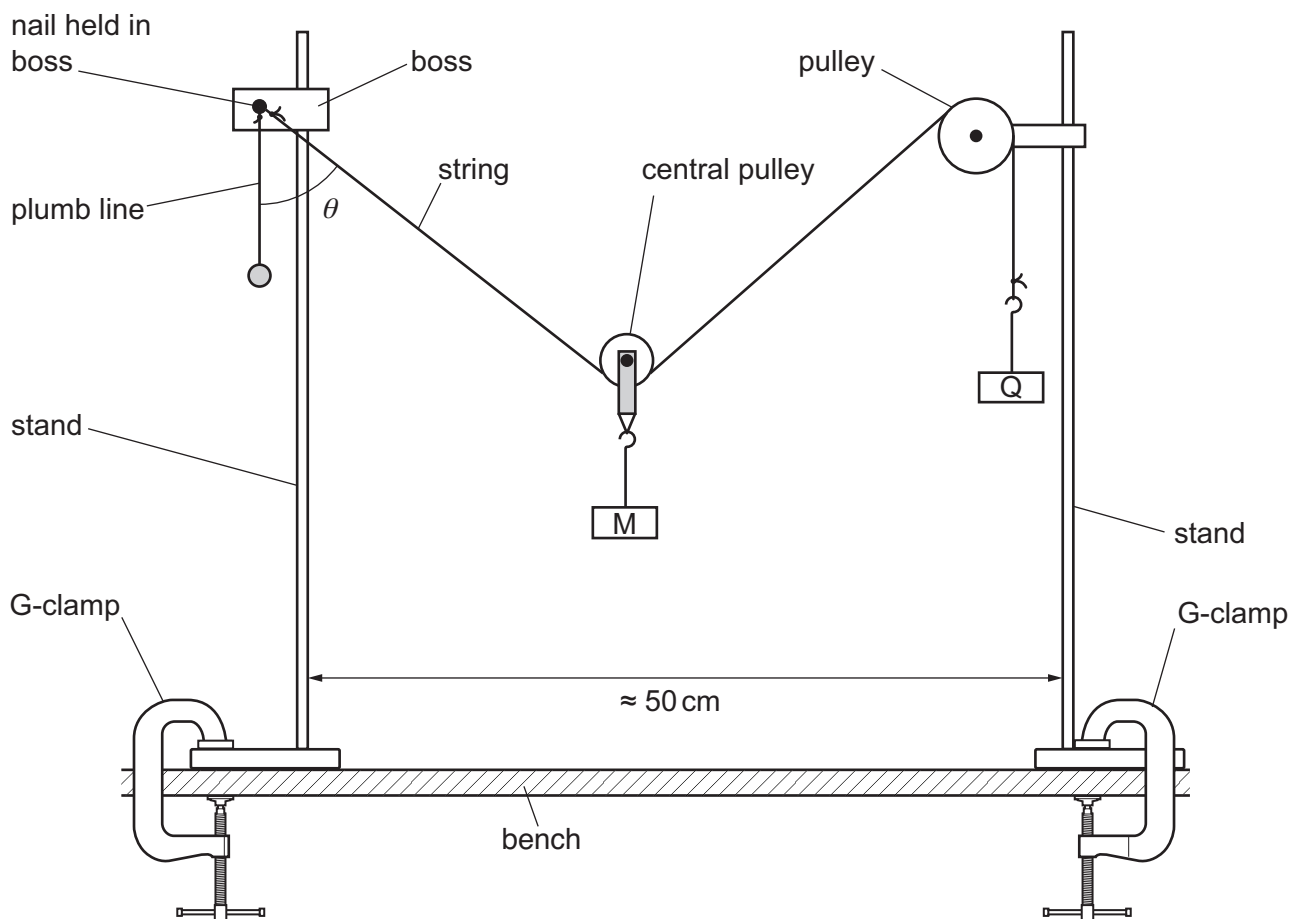


Fig. 1.1

- Adjust the pulley fixed to the stand so that the top of the pulley is approximately 60 cm above the bench.
- Adjust the boss holding the nail so that the nail is approximately 60 cm above the bench.





- Use some of the slotted masses to add a mass of 70 g to Q.
- The mass added to Q is x . Record the value of x .

$x = \dots\dots\dots$ g

- The angle between the plumb line and the string is θ , as shown in Fig. 1.1.

Measure and record θ .

$\theta = \dots\dots\dots$ °

- Carefully remove the slotted masses from Q.

[1]





- (b) By using different numbers of slotted masses, vary x . For each value of x , measure θ .

Repeat until you have six sets of values of x and θ .

Record your results in a table. Include values of $\frac{1}{\cos \theta}$ in your table.

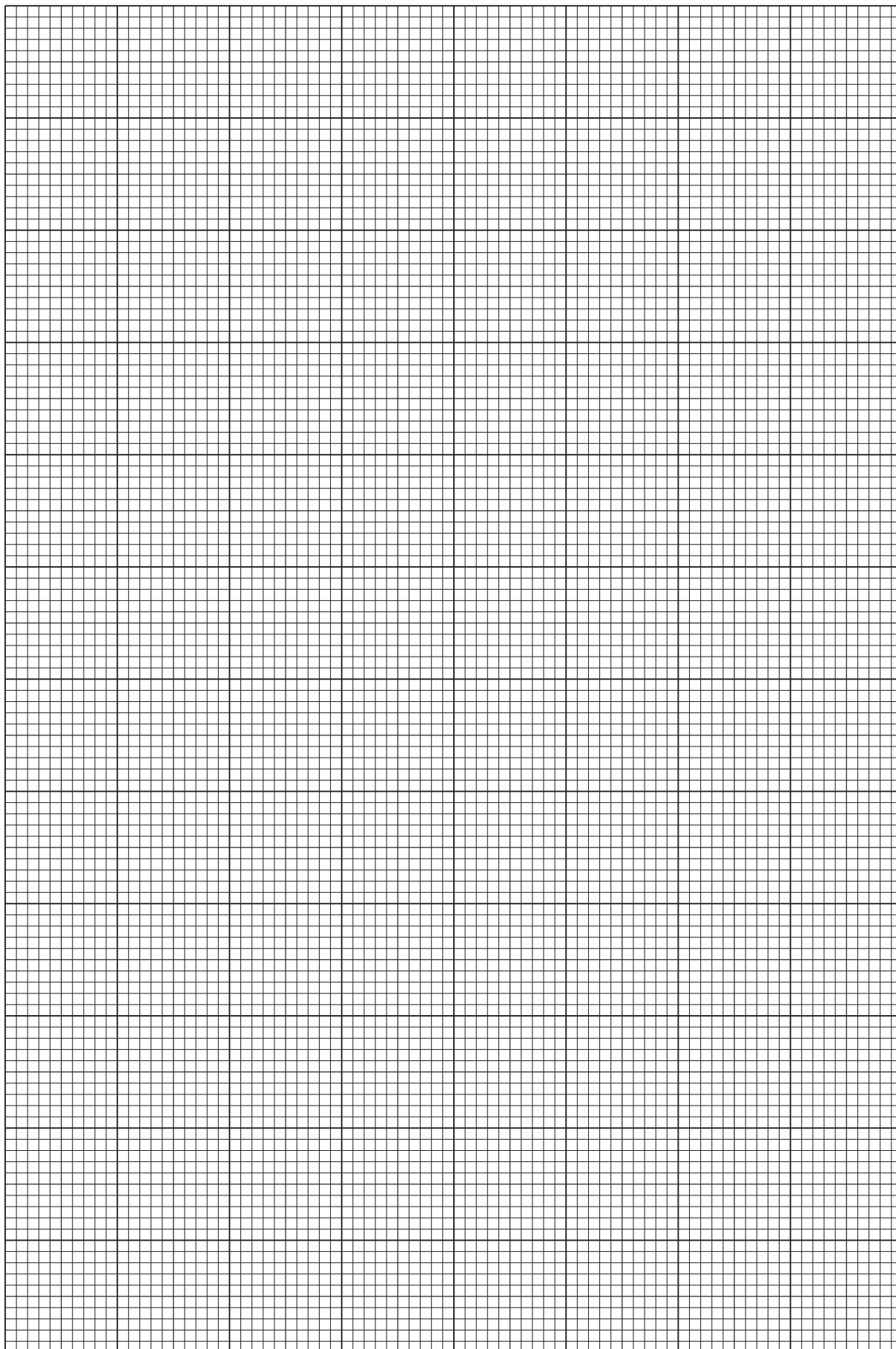
- (c) (i) Plot a graph of $\frac{1}{\cos \theta}$ on the y -axis against x on the x -axis. [10]
- (ii) Draw the straight line of best fit. [3]
- (iii) Determine the gradient and y -intercept of this line. [1]

gradient = ...

y -intercept = ...

[2]







(d) It is suggested that the quantities θ and x are related by the equation

$$\frac{1}{\cos \theta} = ax + b$$

where a and b are constants.

Use your answers in (c)(iii) to determine the values of a and b .
Give appropriate units.

$$a = \dots\dots\dots$$

$$b = \dots\dots\dots$$

[2]

(e) The mass of M is M and the mass of Q is Q .

The constants a and b are related to M and Q by

$$a = \frac{2}{M} \text{ and } b = \frac{2Q}{M}.$$

Calculate values for M and Q .

$$M = \dots\dots\dots \text{ g}$$

$$Q = \dots\dots\dots \text{ g}$$

[1]

[Total: 20]



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7

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You may not need to use all of the materials provided.

2 In this experiment, you will investigate the effect of air resistance on a spinning card.

- (a) (i) • Assemble the apparatus as shown in Fig. 2.1, with the washer and plastic tube over the nail.

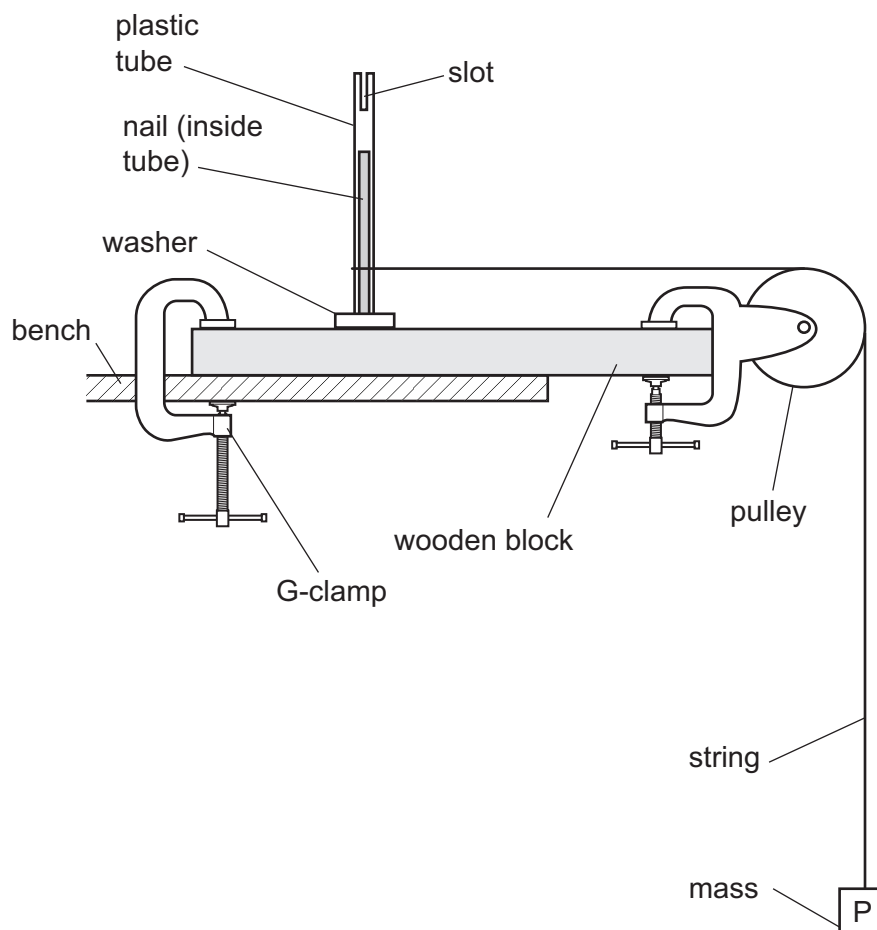


Fig. 2.1

- Rotate the plastic tube so that P rises until it just touches the pulley.
- Release the plastic tube so that P falls.
- Measure and record the time T_0 for P to reach the end of its fall.

$T_0 = \dots\dots\dots$ [2]



(ii) Estimate the percentage uncertainty in your value of T_0 . Show your working.

percentage uncertainty = ... % [1]

(b) (i) Fig. 2.2 shows card A.

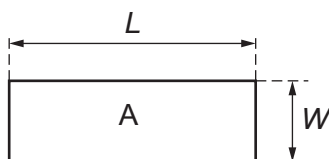


Fig. 2.2

Measure and record the length L and the width W of the card, as shown in Fig. 2.2.

$L =$

$W =$ [1]

- (ii)
- Insert the card centrally into the slot at the top of the plastic tube with its length horizontal. If necessary, use a small piece of adhesive putty to fix it securely in the slot.
 - Rotate the plastic tube so that P rises until it just touches the pulley.
 - Release the plastic tube and measure the time T for P to reach the end of its fall.

$T =$ [2]





(c) Repeat (b) using the card marked B.

$L =$

$W =$

$T =$

[3]

(d) It is suggested that the relationship between T , T_0 , L and W is

$$k(T - T_0) = L^2 W$$

where k is a constant.

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

first value of $k =$

second value of $k =$

[1]

(ii) Justify the number of significant figures that you have given for your values of k .

.....

.....

..... [1]





(e) It is suggested that the percentage uncertainty in the values of k is 15%.

Using this uncertainty, explain whether your results support the relationship in (d).

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.....

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..... [1]





- (f) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

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[4]

- (ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

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[4]

[Total: 20]

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PHYSICS

9702/35

Paper 3 Advanced Practical Skills 1

May/June 2024

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You will be allowed to work with the apparatus for a maximum of 1 hour for each question.
- You should record all your observations in the spaces provided in the question paper as soon as these observations are made.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].

For Examiner's Use	
1	
2	
Total	

This document has **12** pages.

You may not need to use all of the materials provided.

1 In this experiment, you will investigate the motion of a loaded metre rule.

(a) • Set up the apparatus as shown in Fig. 1.1.

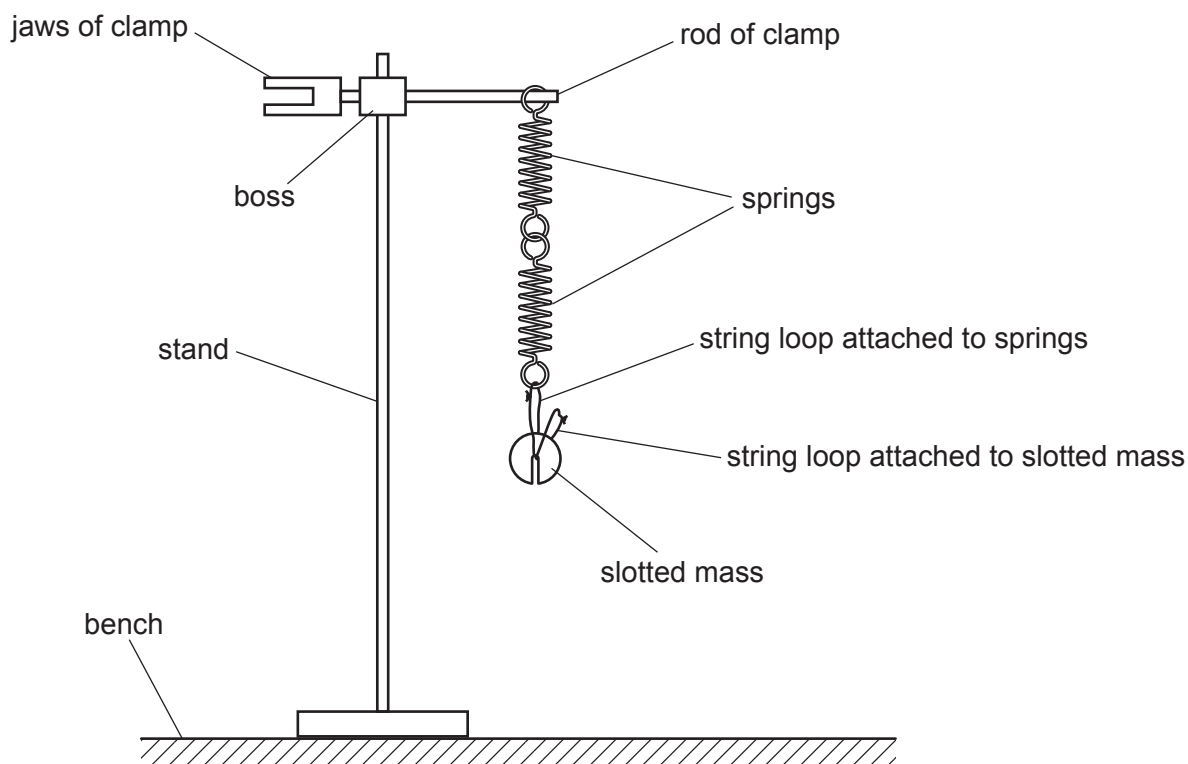


Fig. 1.1

- Place the slotted mass in the string loop attached to the springs.
- Pull the slotted mass downwards through a small distance.
- Release the mass. The mass will oscillate.
- Determine the period T_0 of the oscillations of the mass.

$T_0 = \dots\dots\dots$

- Remove the slotted mass from the string loop attached to the springs.

[2]

- (b) • Set up the apparatus as shown in Fig. 1.2.

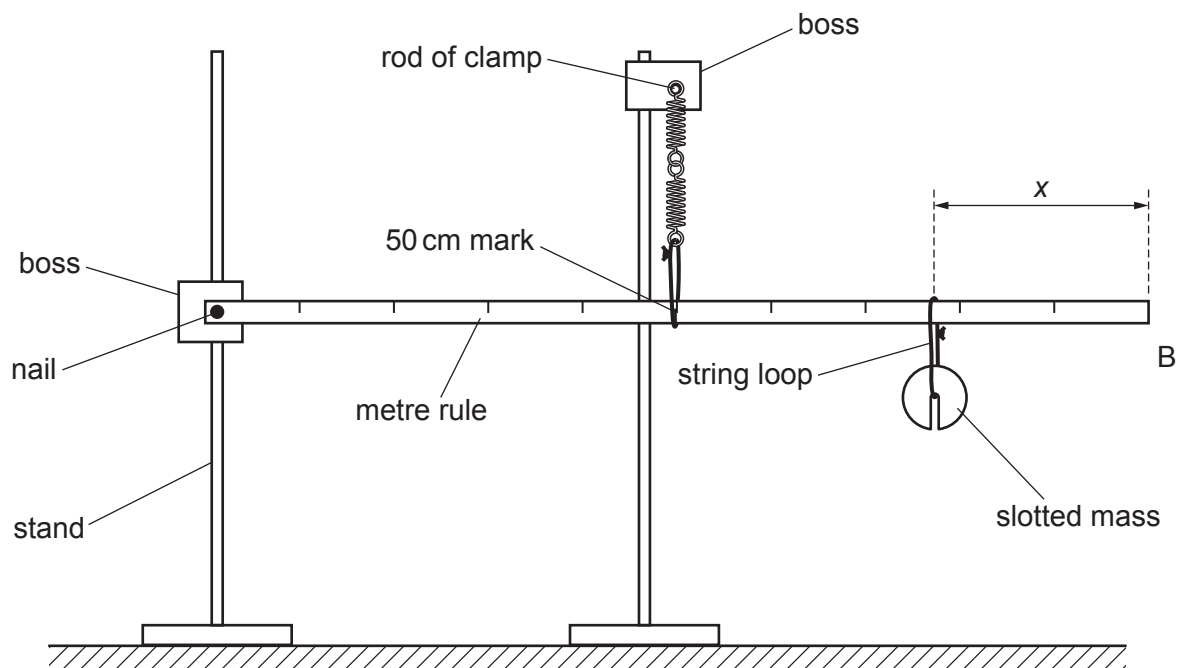


Fig. 1.2

- Position the string loop attached to the springs at the 50 cm mark on the rule. **This string loop must remain in this position throughout the experiment.**
- The distance between the string loop supporting the slotted mass and the end B of the rule is x .

Position the mass so that x is approximately 20 cm.

- Adjust the apparatus so that the rule is parallel to the bench and the springs are vertical.
- Record x .

$x =$

- Pull B downwards through a small distance.
- Release B. The rule will oscillate.
- Determine the period T of the oscillations of the rule.

$T =$

[1]

- (c) Change x by moving the mass along the rule. For each value of x , adjust the apparatus so that the rule is parallel to the bench and the springs are vertical, then determine T .

Repeat until you have six sets of values of x and T with x in the range $10\text{ cm} \leq x \leq 40\text{ cm}$.

Record your results in a table. Include values of $(T - T_0)^2$ in your table.

[9]

- (d) (i) Plot a graph of $(T - T_0)^2$ on the y -axis against x on the x -axis.

[3]

- (ii) Draw the straight line of best fit.

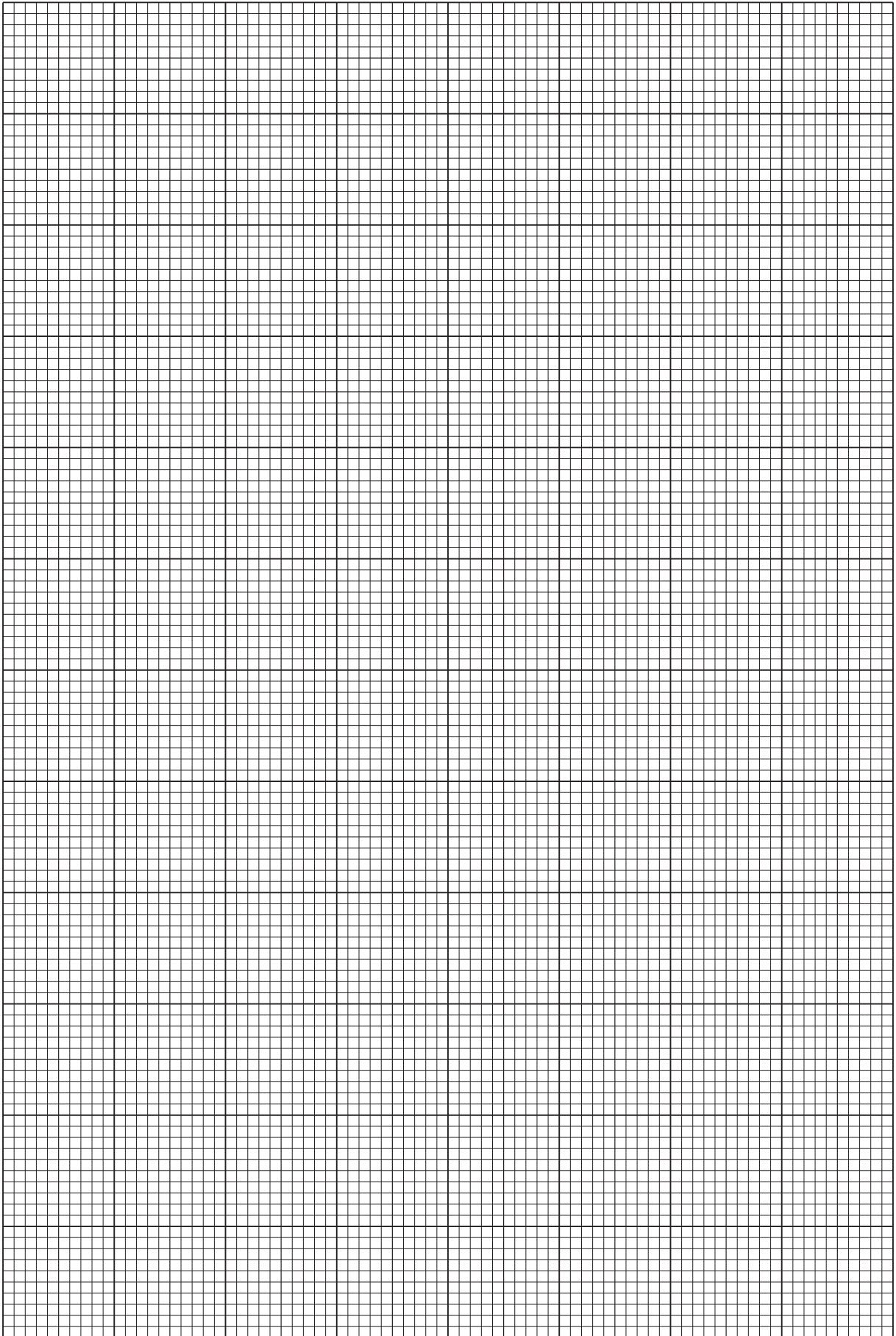
[1]

- (iii) Determine the gradient and y -intercept of this line.

gradient = ...

y -intercept = ...

[2]



- (e) It is suggested that the quantities T , T_0 and x are related by the equation

$$(T - T_0)^2 = -Px + Q$$

where P and Q are constants.

Using your answers in (d)(iii), determine the values of P and Q .
Give appropriate units.

$P =$

$Q =$

[2]

[Total: 20]

You may not need to use all of the materials provided.

- 2** In this experiment, you will investigate the optical properties of glass jars.

You have been provided with two glass jars A and B, each containing water. Each jar has a lid.

- (a)** The diameter of jar A is D , as shown in Fig. 2.1.

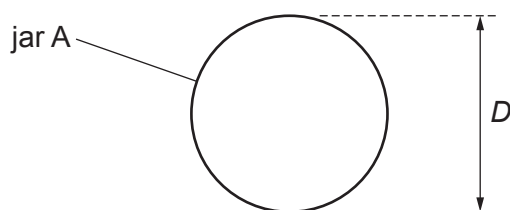


Fig. 2.1

Measure and record D .

$D =$ [1]

- (b) (i) • Hold the nail next to jar A, as shown in Fig. 2.2.

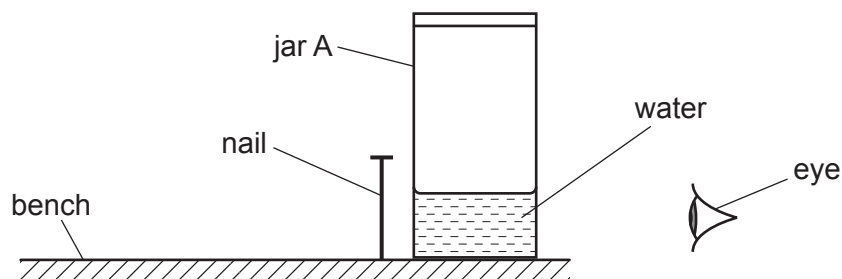


Fig. 2.2

- Close one eye and look at the nail **through the water**.

The bottom of the nail seen through the water will appear to be wider than the top of the nail, as shown in Fig. 2.3.

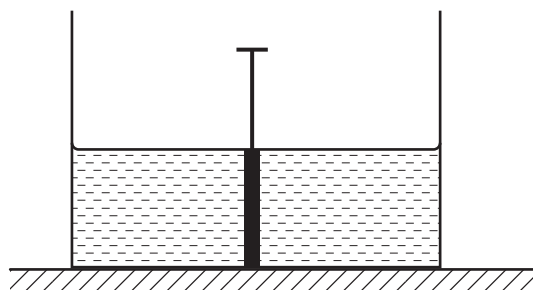


Fig. 2.3

- Move the nail away from the jar. The bottom of the nail will appear to become wider until it suddenly disappears. Hold the nail at this point.
- The distance between the nail and jar A is y , as shown in Fig. 2.4.

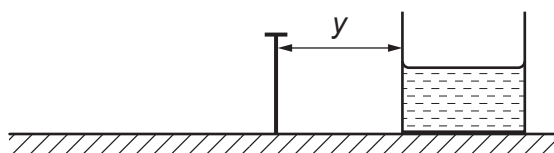


Fig. 2.4

Measure and record y .

$y =$ [2]

- (ii) Estimate the percentage uncertainty in your value of y . Show your working.

percentage uncertainty = ... % [1]

- (iii) The radius r of jar A is given by

$$r = \frac{D}{2}.$$

Calculate $(r + y)$.

$(r + y) =$ [1]

- (c) Repeat (a), (b)(i) and (b)(iii) using jar B.

$D =$

$y =$

$(r + y) =$ [3]

- (d) It is suggested that the relationship between r and y is

$$\frac{(r + y)}{r} = k$$

where k is a constant.

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

first value of k = ...

second value of k = ... [1]

- (ii) Justify the number of significant figures that you have given for your values of k .

.....

 [1]

- (e) It is suggested that the percentage uncertainty in the values of k is 20%.

Using this uncertainty, explain whether your results support the relationship in (d).

.....

 [1]

- (f) • View the nail through the lens as shown in Fig. 2.5.

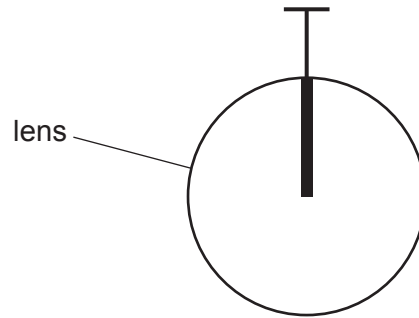


Fig. 2.5

- Increase the distance between the nail and the lens until the bottom of the nail seen through the lens disappears.
- Measure and record the distance y between the nail and the surface of the lens.

$y =$

- Use your second value of k to determine a value of r for the lens.
Give an appropriate unit.

$r =$

[1]

- (g) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

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- (ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

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[Total: 20]

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