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Centre number

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Candidate number

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A-level PHYSICS

Paper 3 Section A

Tuesday 17 June 2025

Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 70 minutes on this section.

Materials

For this paper you must have:

- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do **all** rough work in this book. Cross through any work you do not want to be marked.
- Show **all** your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 45.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
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TOTAL	



J U N 2 5 7 4 0 8 3 A 0 1

Section A

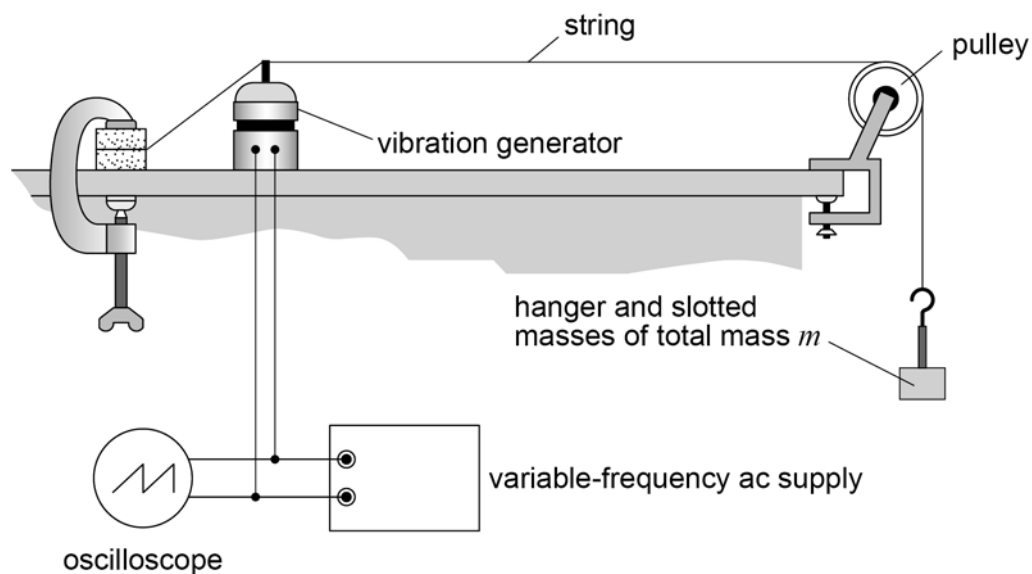
Answer **all** questions in this section.

0	1
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This question is based on an investigation into how the frequency of the first-harmonic stationary wave on a string varies with tension (required practical activity 1).

Figure 1 shows the arrangement for this investigation.

Figure 1



The tension in the string is equal to the weight mg of the total mass m tied to the string.

The frequency is changed until the first-harmonic stationary wave appears on the string. This frequency f is determined using the oscilloscope.

The process is repeated for different values of m .



0 1 . 1 Identify **two** control variables for the arrangement shown in **Figure 1**.

You may annotate **Figure 1** as part of your answer.

[2 marks]

1 *Mass per unit length (μ) of the string.*

2 *Length L of the string between the vibration generator and the pulley.*

0 1 . 2 The total mass m is made from a mass hanger and up to three slotted masses.

One 20 g, one 50 g and one 100 g slotted mass are provided.
The hanger has a mass of 100 g.

The hanger must not be removed from the string.

Which statement is correct?

Tick (✓) **one** box.

[1 mark]

m has a maximum range of 170 g.

☒

m has a maximum of 7 different values.

☐

m values are evenly distributed across the range.

☐

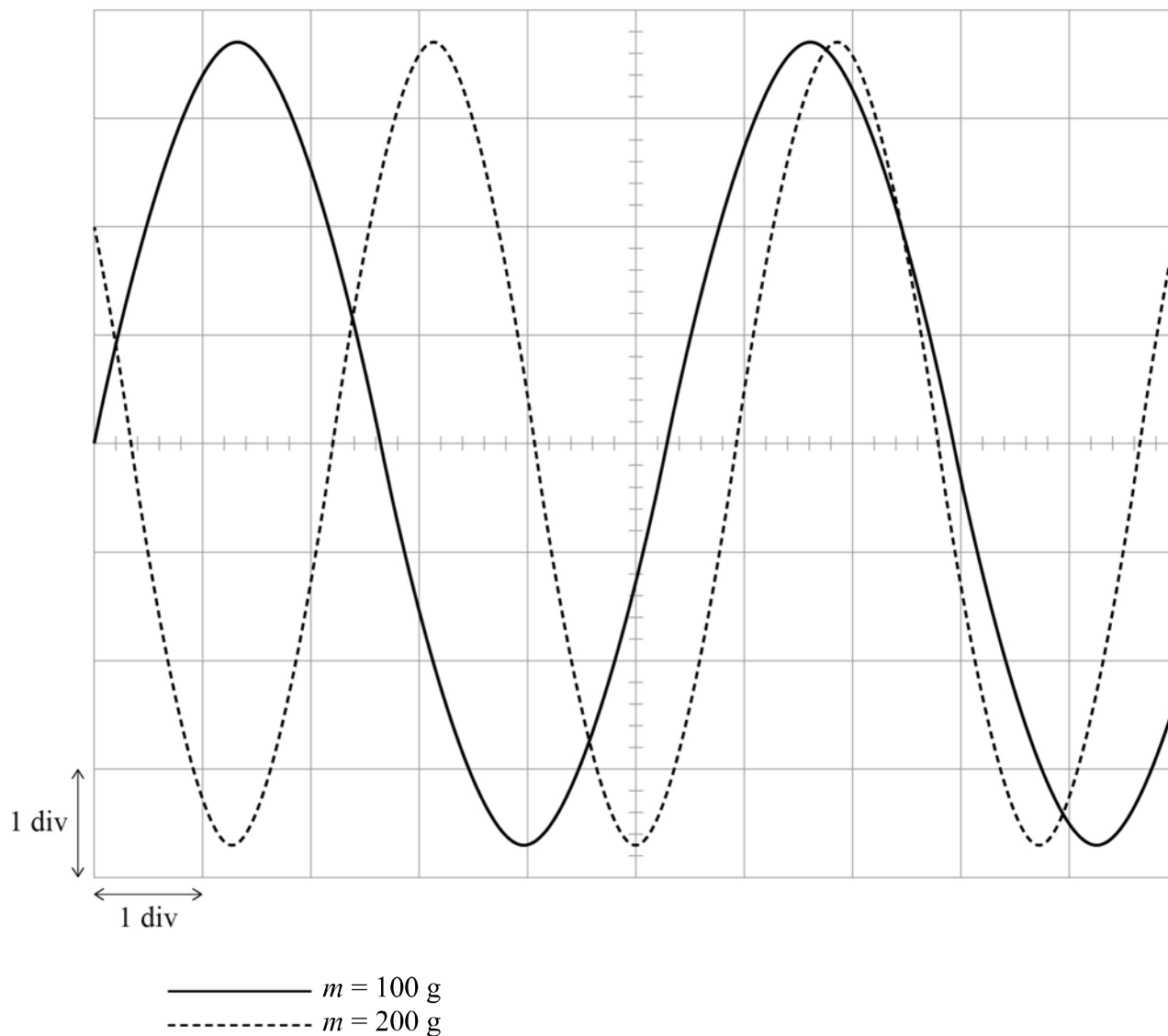
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The frequency f is calculated using the waveform displayed on the oscilloscope.
Figure 2 shows the waveforms displayed on the oscilloscope when $m = 100 \text{ g}$ and
 when $m = 200 \text{ g}$.

Figure 2



The y -voltage gain setting is 5 V div^{-1} .
 The time-base setting is 20 ms div^{-1} .

0 1 . 3

Determine V_{rms} , the root mean square voltage of the ac supply.

[2 marks]

$$\text{Peak-to-peak} = 7.4 \text{ div, so } V_{\text{peak}} = 3.7 \text{ div} \times 5 \text{ V div}^{-1} = 18.5 \text{ V}$$

$$V_{\text{rms}} = V_{\text{peak}} / \sqrt{2} = 18.5 / \sqrt{2} = 13.08 \text{ V}$$

$$V_{\text{rms}} = \underline{13.1} \text{ V}$$

0 1 . 4

Determine the period of the waveform on **Figure 2** when $m = 100 \text{ g}$.

[1 mark]

$$\text{One cycle} = 5.27 \text{ div; } T = 5.27 \times 20 \text{ ms div}^{-1} = 105.4 \text{ ms}$$

$$\text{period} = \underline{105} \text{ ms}$$

0 1 . 5

Deduce whether **Figure 2** shows the expected result of doubling m from 100 g to 200 g.

[2 marks]

$$m = 200 \text{ g: one cycle} = 3.73 \text{ div, } T_{200} = 3.73 \times 20 = 74.6 \text{ ms}$$

$$f_{100} = 1 / 0.1054 = 9.49 \text{ Hz} \quad f_{200} = 1 / 0.0746 = 13.4 \text{ Hz}$$

$$\text{Expected: } f = (1/2L)\sqrt{(mg/\mu)}, \text{ so } f \propto \sqrt{m}$$

$$\text{Doubling } m \text{ should multiply } f \text{ by } \sqrt{2} = 1.41 \text{ (and divide } T \text{ by } \sqrt{2})$$

$$\text{Ratio from Figure 2: } T_{100} / T_{200} = 105.4 / 74.6 = 1.41$$

$$(f_{200} / f_{100} = 13.4 / 9.49 = 1.41)$$

The ratio 1.41 is equal to $\sqrt{2}$, so Figure 2 is consistent with doubling m :

it does show the expected result.

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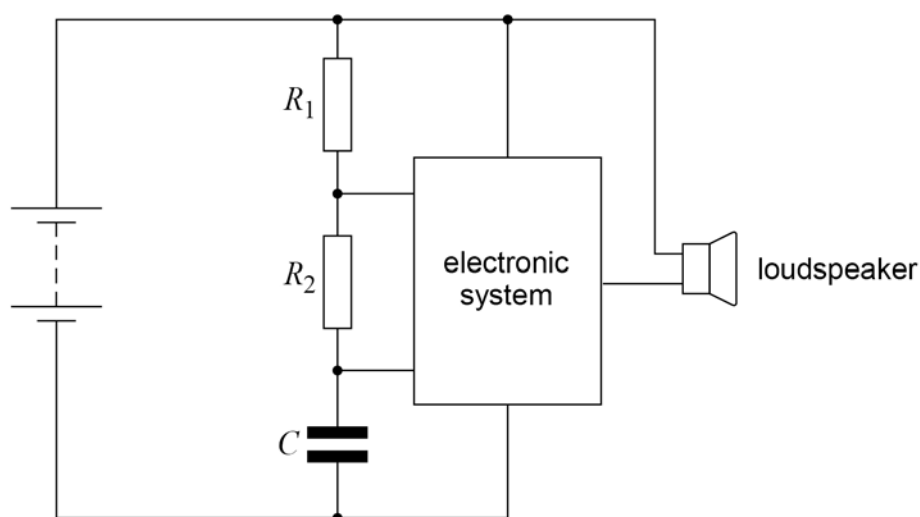


0 2

Figure 3 shows a circuit that causes a loudspeaker to emit 'clicks' at a constant rate. The time T between successive clicks depends on the resistances R_1 and R_2 and the capacitance C .

You do not need to know any details about the electronic system.

Figure 3



A student uses a stopwatch to determine T .

Table 1 shows the student's repeated measurements of $20T$.

Table 1

$20T / \text{s}$	$20T / \text{s}$	$20T / \text{s}$	$20T / \text{s}$	$20T / \text{s}$
19.22	18.91	19.36	19.04	19.45



0 2 . 1 Suggest why the student measures $20T$.

[1 mark]

Timing 20 oscillations spreads the stop-start (reaction time) error over 20 periods, so it reduces the percentage uncertainty in T (reduces the effect of random error).

0 2 . 2 Suggest why the student repeats their measurements of $20T$.

[1 mark]

To check for anomalies in $20T$ (e.g. miscounting cycles), so that any anomalous reading can be identified and rejected.

0 2 . 3 Determine the percentage uncertainty in the student's result for T . Assume that all the data in **Table 1** are valid.

[2 marks]

$$\begin{aligned} \text{mean } 20T &= (19.22 + 18.91 + 19.36 + 19.04 + 19.45) / 5 \\ &= 95.98 / 5 = 19.196 \text{ s} \approx 19.20 \text{ s, so } T = 0.960 \text{ s} \end{aligned}$$

$$\begin{aligned} \text{uncertainty in } 20T &= \text{half the range} = (19.45 - 18.91) / 2 = 0.27 \text{ s} \\ (\text{uncertainty in } T &= 0.0135 \text{ s}) \end{aligned}$$

$$\% \text{ uncertainty} = 0.27 / 19.196 \times 100 = 1.41 \%$$

percentage uncertainty in T = 1.4 %

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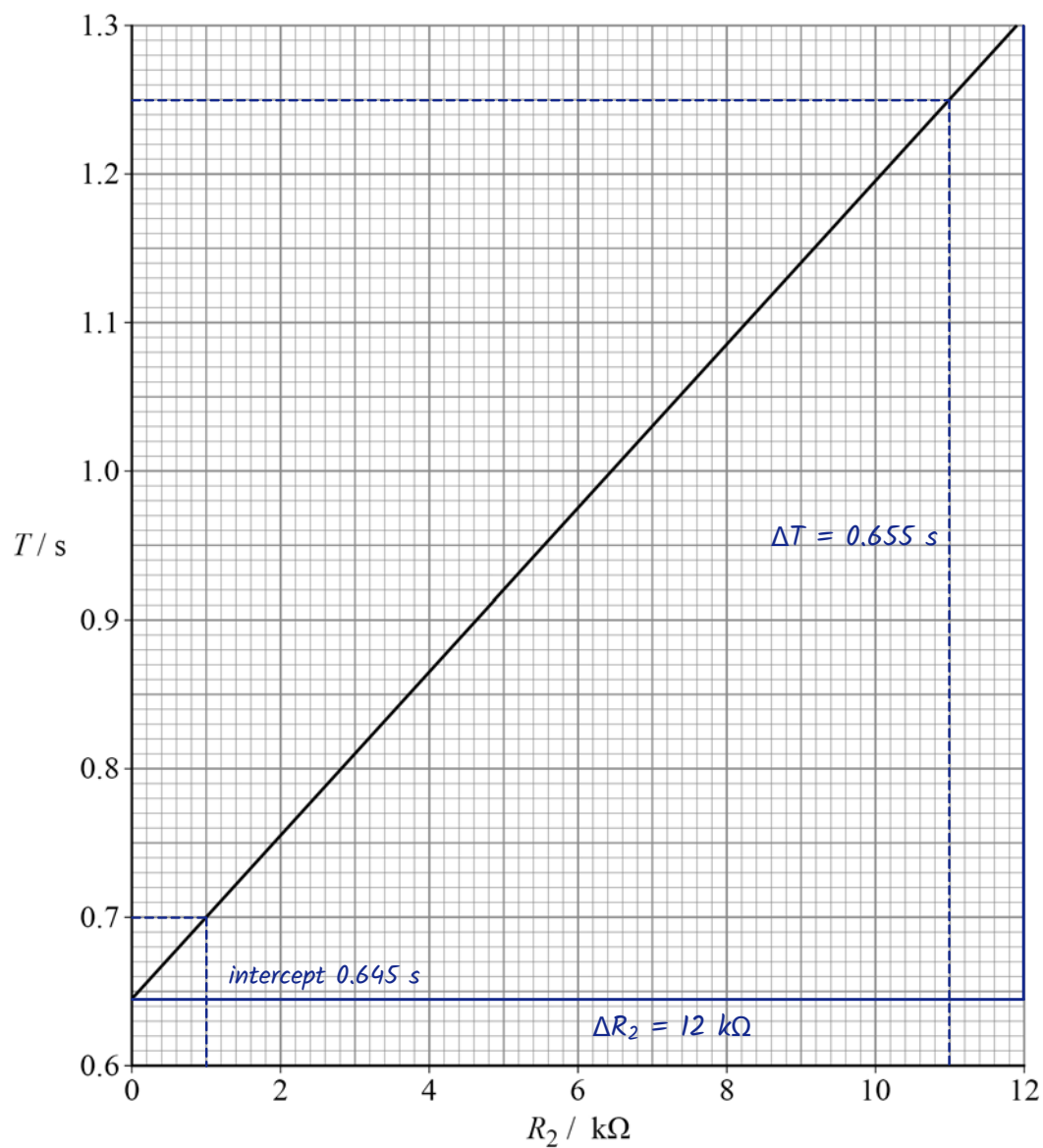


The student determines T for different values of R_2 .

The values of R_1 and C are not changed.

The student produces the graph in **Figure 4**.

Figure 4



0 2 . 4

It can be shown that

$$T = (R_1 + 2R_2)C \ln 2$$

Determine C and R_1 .**[5 marks]**

$T = 2C \ln 2 \times R_2 + R_1 C \ln 2$, so a graph of T against R_2 is a straight line
with gradient $= 2C \ln 2$ and intercept $= R_1 C \ln 2$

$$\begin{aligned} \text{gradient} &= \Delta T / \Delta R_2 = (1.30 - 0.645) / (12 \times 10^3) \\ &= 0.655 / 12\,000 = 5.46 \times 10^{-5} \text{ s } \Omega^{-1} \end{aligned}$$

$$\begin{aligned} C &= \text{gradient} / (2 \ln 2) = 5.46 \times 10^{-5} / (2 \times 0.693) \\ &= 3.94 \times 10^{-5} \text{ F} \end{aligned}$$

$$\text{intercept } (R_2 = 0): T = 0.645 \text{ s} = R_1 C \ln 2$$

$$\begin{aligned} R_1 &= 0.645 / (3.94 \times 10^{-5} \times 0.693) \\ &= 2.36 \times 10^4 \Omega \end{aligned}$$

$$\begin{aligned} C &= \underline{3.9 \times 10^{-5}} \text{ F} \\ R_1 &= \underline{2.4 \times 10^4} \Omega \end{aligned}$$

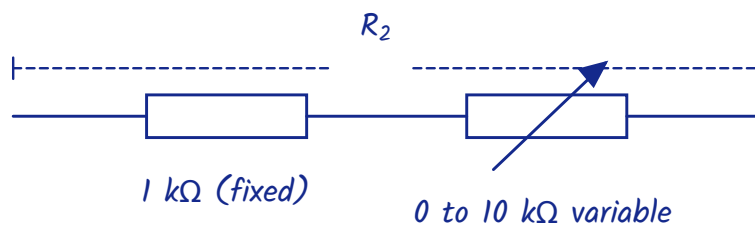
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0 2 . 5

The student has access to a range of fixed and variable resistors. The student wants to modify the circuit in **Figure 3** so that T can be varied continuously from a minimum of 0.70 s to a maximum of 1.25 s.

Show how the student can achieve this by combining two resistors to make R_2 . You should use information from **Figure 4**.

[3 marks]



From Figure 4: $T = 0.70$ s when $R_2 = 1.0$ kΩ and $T = 1.25$ s when $R_2 = 11$ kΩ.

So R_2 must vary continuously from a minimum of 1 kΩ to a maximum of 11 kΩ (a range of 10 kΩ).

Use one fixed 1 kΩ resistor in series with one 10 kΩ variable resistor.

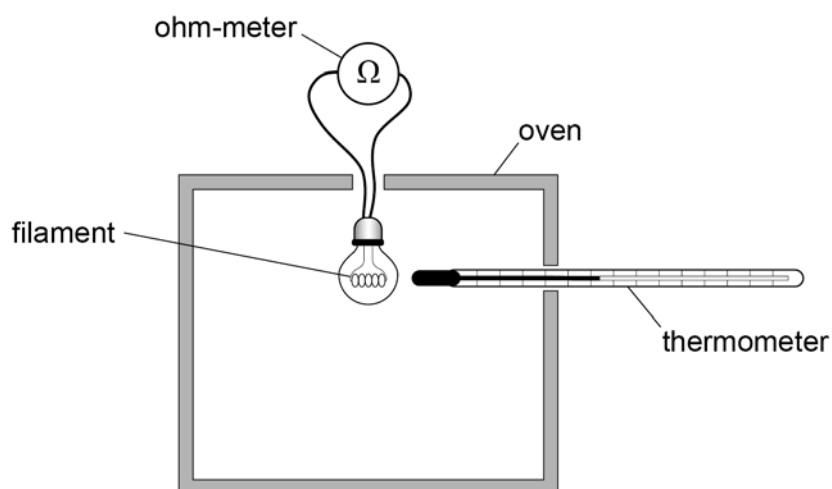
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0 3

Figure 5 shows apparatus to investigate how the resistance R of a lamp filament varies with the absolute temperature T of the filament.

Figure 5



The lamp is inside an oven.

The oven temperature is increased to a steady value.

The filament is at the same temperature as the inside of the oven.

The temperature T in kelvin is determined using the thermometer.

An ohm-meter is connected to the filament to determine R at temperature T .

The oven temperature is increased to new steady values and further readings of T and R are recorded.

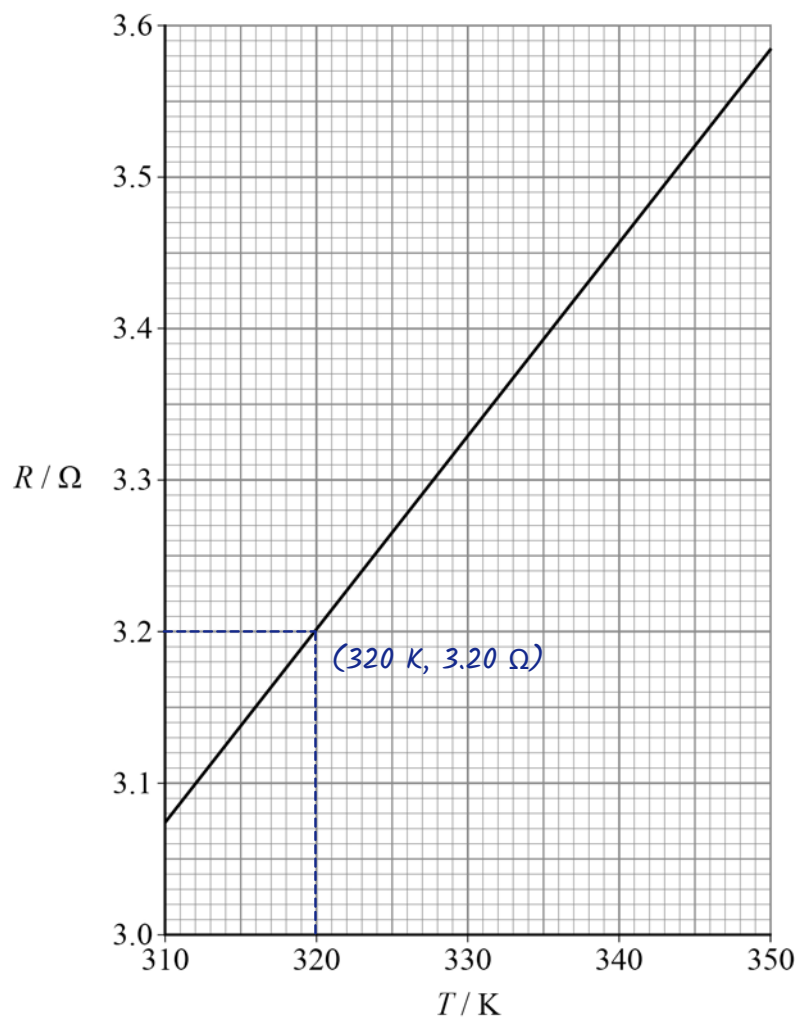
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Figure 6 shows the variation of R with T .

Figure 6



It can be shown that:

$$\frac{R - R_0}{R_0} = \alpha(T - T_0)$$

where:

R_0 is the resistance of the filament at temperature T_0

α is a constant.



0 3 . 1

Determine α using the graph in **Figure 6**.
State an appropriate SI unit for your answer.

$$R_0 = 2.83 \, \Omega \text{ when } T_0 = 291 \, \text{K}$$

[3 marks]

From Figure 6: $R = 3.20 \, \Omega$ when $T = 320 \, \text{K}$

$$\alpha = (R - R_0) / (R_0(T - T_0))$$

$$= (3.20 - 2.83) / (2.83 \times (320 - 291))$$

$$= 0.37 / (2.83 \times 29) = 0.37 / 82.07$$

$$= 4.51 \times 10^{-3} \, \text{K}^{-1}$$

$$\alpha = \underline{4.51 \times 10^{-3}} \quad \text{unit} = \underline{\text{K}^{-1}}$$

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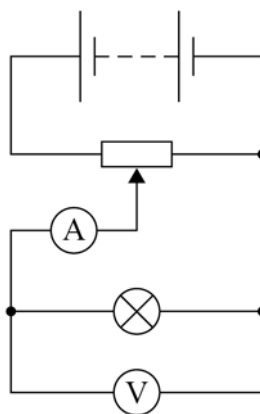
In a different investigation, a student investigates how the electrical power P transferred in the same filament lamp varies for values of T greater than 800 K.

The student assumes that α is constant for all values of T .

Figure 7 shows the circuit that the student uses.

The temperature of the filament is controlled by the energy supplied to it from the battery.

Figure 7



0 3 . 2

Explain how the ammeter and voltmeter readings are used to determine values of P and T .

[2 marks]

P Power $P = V \times I$: multiply the voltmeter reading V by the ammeter reading I .

T Find $R = V / I$, then use $T = (R - R_0) / (\alpha R_0) + T_0$ with $R_0 = 2.83 \, \Omega$, $T_0 = 291 \, \text{K}$ and α from 03.1.



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For a steady value of T , $P = P_1 + P_2$

where:

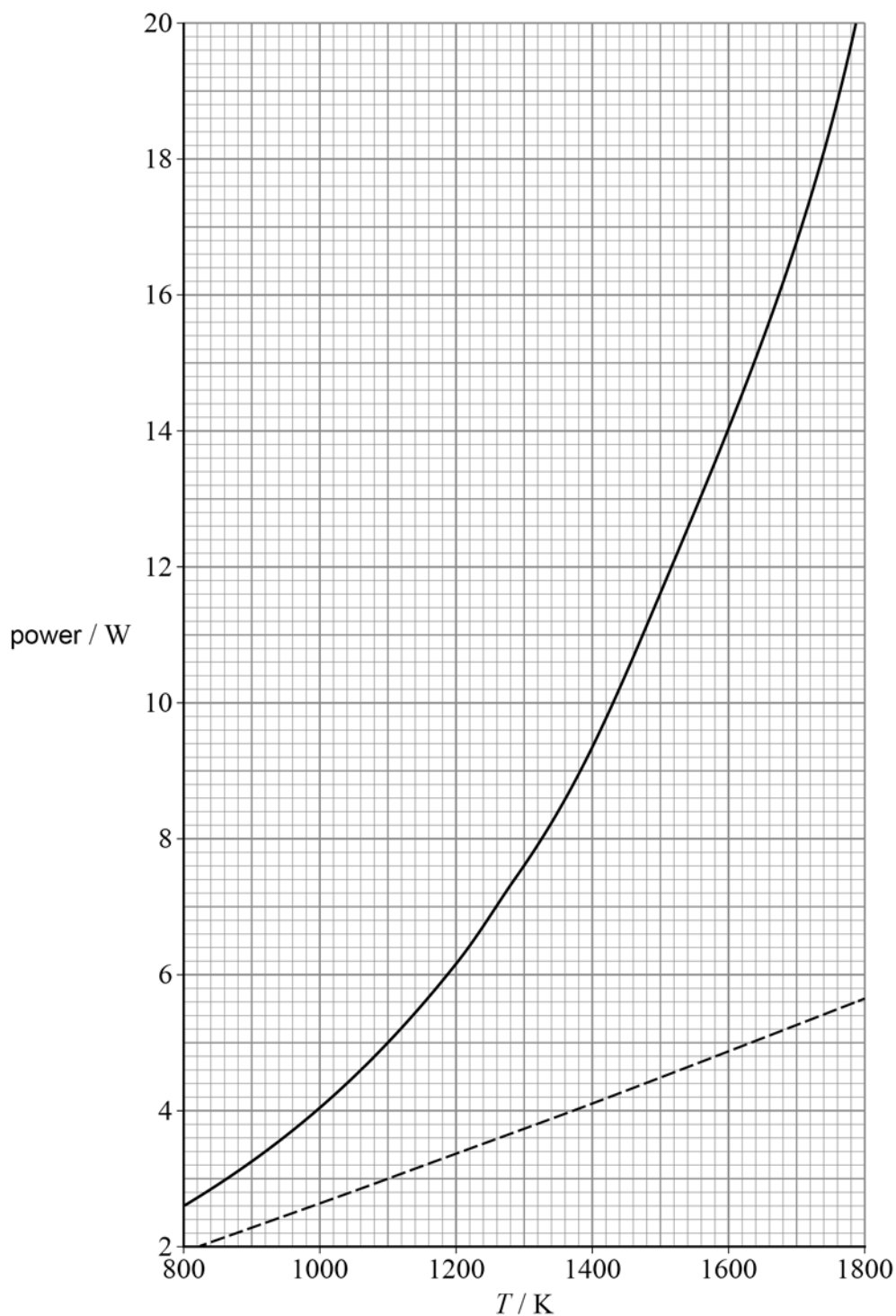
P_1 is the rate of heat transfer from the filament by radiation

P_2 is the rate of heat transfer from the filament by all other processes.

In **Figure 8**:

- the solid line shows how P varies with T
- the dashed line shows how P_2 varies with T .

Figure 8



0 3 . 3

Complete **Table 2**.**[3 marks]****Table 2**

T / K	P / W	P_1 / W	P_2 / W
960	3.7	1.2	2.5
1100	5.0	2.0	3.0
1370	8.8	4.8	4.0
1680	16.2	11.0	5.2

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0 3 . 4 It can be shown that $P_1 \propto T^n$ where n is an integer.

Determine n .

In your answer you should:

- use **Table 3** to organise the data you will plot
- plot a suitable graph on **Figure 9**.

[5 marks]

Table 3

T / K	P_1 / W	$\log (T / \text{K})$	$\log (P_1 / \text{W})$
960	1.2	2.982	0.079
1100	2.0	3.041	0.301
1370	4.8	3.137	0.681
1680	11.0	3.225	1.041

$$P_1 = kT^n, \text{ so } \log P_1 = n \log T + \log k$$

Graph of $\log P_1$ against $\log T$ is a straight line of gradient n

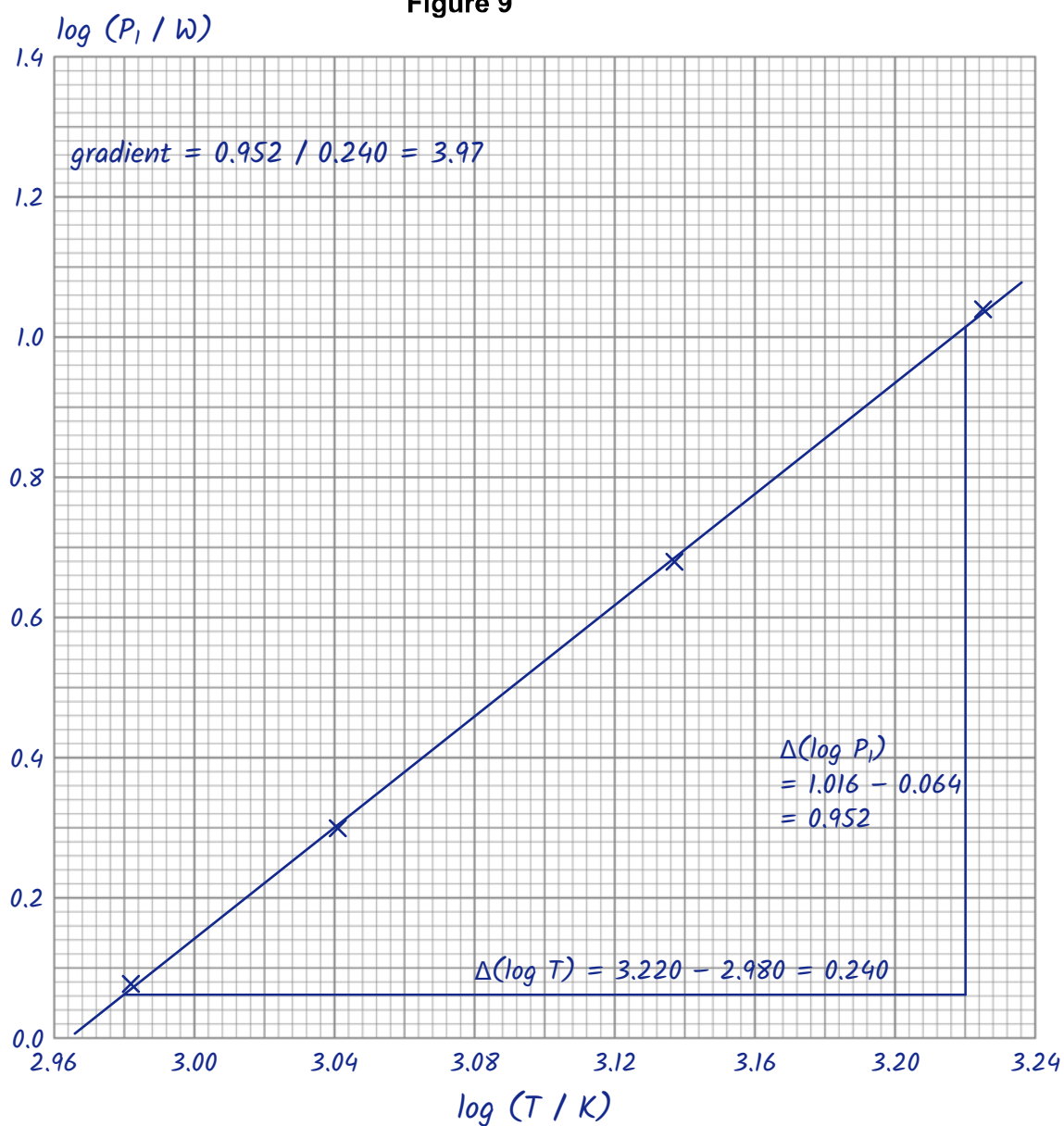
$$\begin{aligned} \text{gradient} &= \Delta(\log P_1) / \Delta(\log T) = (1.016 - 0.064) / (3.220 - 2.980) \\ &= 0.952 / 0.240 = 3.97 \end{aligned}$$

n is an integer, so $n = 4$

$$n = \underline{\quad 4 \quad}$$



Figure 9



Turn over for the next question

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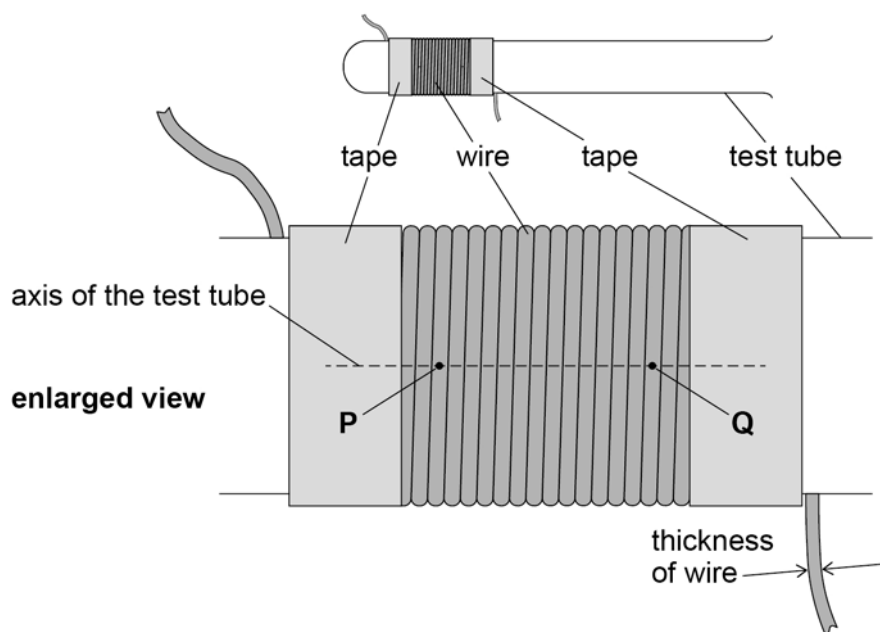


0 4

This question is about the vertical oscillations of a test tube in a liquid.

Figure 10 shows some wire wound tightly around a test tube. The ends of the wire are secured with tape.

Figure 10

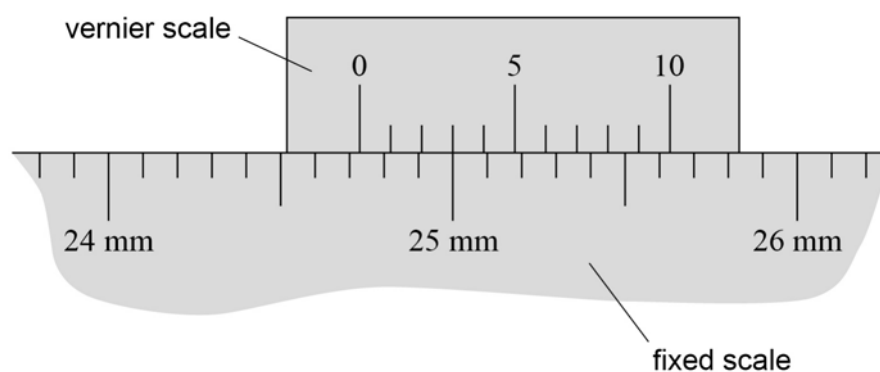


P and **Q** are points marked on the wire, as shown in the enlarged view in **Figure 10**. A travelling microscope with a vernier scale is used to measure the distance between **P** and **Q**.

The microscope reading at **P** is 9.26 mm.

Figure 11 shows the microscope reading at **Q**.

Figure 11



0 4 . 1

Show that the wire has a thickness of approximately 1.2 mm.

[2 marks]

$$\text{Reading at Q} = 24.70 + 0.03 = 24.73 \text{ mm}$$

$$PQ = 24.73 - 9.26 = 15.47 \text{ mm}$$

There are 13 turns of wire between P and Q

$$t = 15.47 / 13 = 1.19 \text{ mm } (\approx 1.2 \text{ mm})$$

0 4 . 2

The external diameter of the test tube is 18.0 mm.

Deduce the length of wire between P and Q.

[3 marks]

$$\text{Diameter to the centre of the wire} = 18.0 + 1.19 = 19.19 \text{ mm}$$

$$\text{Circumference of one turn} = \pi \times 19.19 = 60.29 \text{ mm}$$

$$\text{Length} = 13 \text{ turns} \times 60.29 \text{ mm} = 783.7 \text{ mm}$$

length of wire = 784 mm

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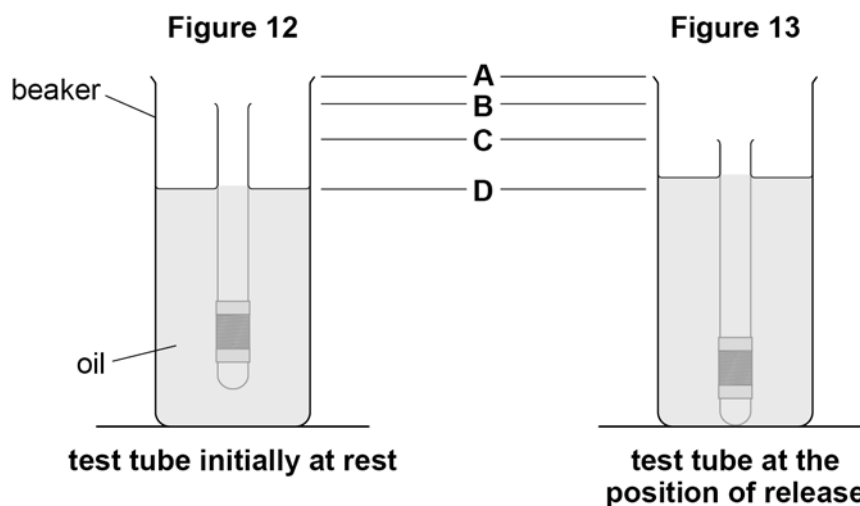


A student investigates vertical oscillations of the test tube in a liquid.

Figure 12 shows the test tube and wire floating at rest in a beaker of dark-coloured oil.

The part of the test tube below the surface cannot be seen clearly through the oil.

The test tube is then pushed downwards as far as possible, as shown in **Figure 13**.



The test tube is now released from the position shown in **Figure 13**.

The test tube oscillates vertically with simple harmonic motion of period T .

0 4 . 3

A horizontal fiducial mark is used to reduce uncertainty in the measurement of T .

The fiducial mark is to be placed level with one of the positions **A**, **B**, **C** or **D** shown in **Figures 12** and **13**.

Identify the correct position for the fiducial mark.

Go on to explain why you chose this position.

[2 marks]

position = B

The top of the test tube passes level with B when it is moving fastest (maximum kinetic energy), so the transit time past the mark is least and the instant it passes is judged most precisely.



0 4 . 4

When the total mass of the test tube, wire and tape is constant, it can be shown that:

$$T \propto \frac{1}{\sqrt{\text{density of the liquid}}}$$

When the test tube oscillates in the oil, T is 0.587 s.

The density of the oil is $8.49 \times 10^2 \text{ kg m}^{-3}$.

The test tube is cleaned and placed in an identical beaker containing milk.

When the test tube oscillates in the milk, T is 0.534 s.

Determine the density of the milk.

[2 marks]

$$T \propto 1/\sqrt{\rho}, \text{ so } T^2\rho \text{ is constant: } T_{oil}^2 \rho_{oil} = T_{milk}^2 \rho_{milk}$$

$$\rho_{milk} = \rho_{oil} \times T_{oil}^2 / T_{milk}^2 = 849 \times 0.587^2 / 0.534^2$$

$$= 292.5 / 0.2852 = 1026 \text{ kg m}^{-3}$$

$$\text{density} = \underline{1.03 \times 10^3} \text{ kg m}^{-3}$$

0 4 . 5

Due to damping, only a small number of oscillations occurs after the test tube is released.

The student wants to produce a greater number of oscillations for a particular liquid **without** changing T .

State and explain **two** ways in which the apparatus can be modified to achieve this.

[3 marks]

1 Add more oil to the beaker (increase the depth) so the test tube can be pushed down further, giving a larger initial displacement / amplitude.

This gives the system more initial energy, so more oscillations occur before they die away.

2 Use a wider beaker (larger diameter), filled with oil to at least the same depth, so the walls are further from the test tube.

This reduces the drag (fluid resistance) on the tube, so less energy is lost per cycle; T is unchanged.

12

END OF QUESTIONS



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2 8



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