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## 9702/51

May/June 2023

**1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

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

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].

This document has 8 pages.

- 1 A wooden cube of mass  $A$  is placed on an inclined plane. The cube is attached to a cylinder of mass  $B$  using string that passes over a pulley, as shown in Fig. 1.1.

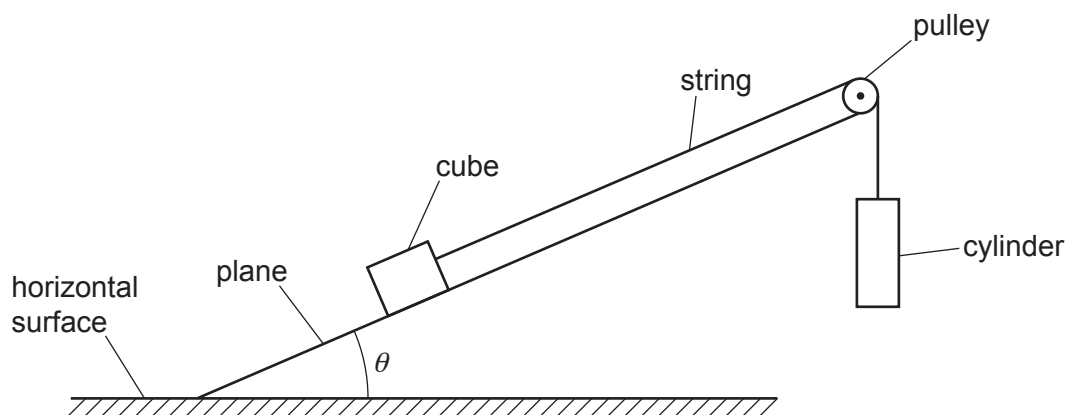


**Fig. 1.1** (not to scale)

The angle between the plane and the horizontal surface is  $\theta$ . Initially the cylinder is held at rest.

The cylinder is released. The time for the cylinder to fall a distance  $d$  is  $t$ .

It is suggested that  $t$  is related to  $\theta$  by the relationship

$$\frac{2d}{t^2} = -\frac{AH \sin \theta}{(A + B)} - \frac{KA}{(A + B)}$$

where  $H$  and  $K$  are constants.

Plan a laboratory experiment to test the relationship between  $t$  and  $\theta$ .

Draw a diagram showing the arrangement of your equipment.

Explain how the results could be used to determine values for  $H$  and  $K$ .

In your plan you should include:

- the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken.

**Diagram**

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- 2 A student investigates the discharge of capacitors in the circuit shown in Fig. 2.1.

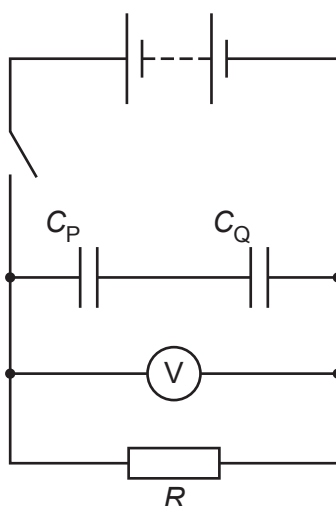


**Fig. 2.1**

The capacitors have capacitances  $C_P$  and  $C_Q$ .

The student closes the switch to charge the capacitors and then records the maximum reading  $V_0$  on the voltmeter.

The switch is opened and a stop-watch is started. The capacitors discharge through the resistor and the reading on the voltmeter decreases. When the reading on the voltmeter is  $V$  the time  $t$  is recorded. The discharge of the capacitors is repeated and the mean time  $T$  is calculated.

The experiment is repeated for different values of  $C_P$  and  $C_Q$ .

For each combination of  $C_P$  and  $C_Q$ , the combined capacitance  $C$  is calculated.

It is suggested that  $C$  and  $T$  are related by the equation

$$\ln \left( \frac{V}{V_0} \right) = - \frac{T}{CR}$$

where  $R$  is the resistance of the resistor.

- (a) A graph is plotted of  $T$  on the  $y$ -axis against  $C$  on the  $x$ -axis.

Determine an expression for the gradient.

gradient = ..... [1]

(b) Values of  $C_P$ ,  $C_Q$  and  $t$  are given in Table 2.1.

**Table 2.1**

| $C_P/10^{-4}\text{F}$ | $C_Q/10^{-4}\text{F}$ | $C/10^{-4}\text{F}$ | $t/\text{s}$ | $t/\text{s}$ | $T/\text{s}$ |
|-----------------------|-----------------------|---------------------|--------------|--------------|--------------|
| 2.2                   | 1.5                   |                     | 12.9         | 14.5         |              |
| 2.2                   | 3.3                   |                     | 21.1         | 19.7         |              |
| 2.2                   | 5.6                   |                     | 23.7         | 24.9         |              |
| 3.3                   | 1.5                   |                     | 15.3         | 16.9         |              |
| 5.6                   | 1.5                   |                     | 19.0         | 17.6         |              |
| 5.6                   | 3.3                   |                     | 30.9         | 32.1         |              |

The relationship between  $C$ ,  $C_P$  and  $C_Q$  is

$$C = \frac{C_P C_Q}{C_P + C_Q}.$$

Calculate and record values of  $C/10^{-4}\text{F}$  and  $T/\text{s}$  in Table 2.1.  
Include the absolute uncertainties in  $T$ .

[2]

(c) (i) Plot a graph of  $T/\text{s}$  against  $C/10^{-4}\text{F}$ .  
Include error bars for  $T$ .

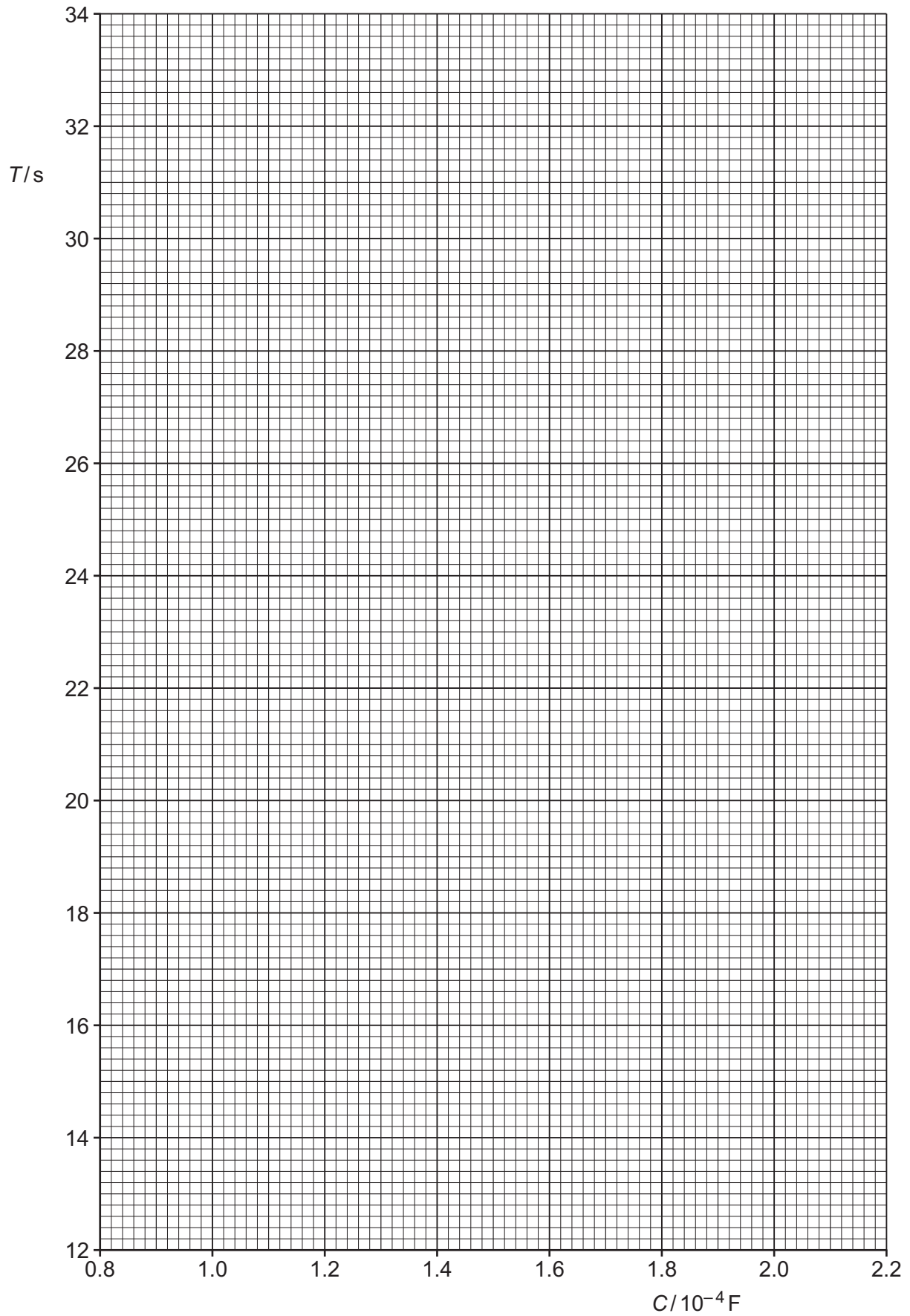
[2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Label both lines.

[2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

gradient = ..... [2]



- (d) The values of  $V_0$  and  $V$  are:

$$V_0 = (4.8 \pm 0.1) \text{ V}$$

$$V = (2.4 \pm 0.1) \text{ V}$$

Calculate  $\ln\left(\frac{V}{V_0}\right)$ . Include the absolute uncertainty in  $\ln\left(\frac{V}{V_0}\right)$ .

$$\ln\left(\frac{V}{V_0}\right) = \dots\dots\dots [1]$$

- (e) (i) Using your answers to (a), (c)(iii) and (d), determine the value of  $R$ . Include an appropriate unit.

$$R = \dots\dots\dots [2]$$

- (ii) Determine the percentage uncertainty in  $R$ .

$$\text{percentage uncertainty in } R = \dots\dots\dots \% [1]$$

- (f) The experiment is repeated. Determine the value of  $C$  that gives a value of  $T$  of 60.0 s. Include the absolute uncertainty in your answer.

$$C = \dots\dots\dots \text{ F } [2]$$

[Total: 15]



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## 9702/52

May/June 2023

**1 hour 15 minutes**

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No additional materials are needed.

- Answer **all** questions.
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This document has 8 pages.

- 1 Two coils, P and Q, are placed close to each other, as shown in Fig. 1.1.

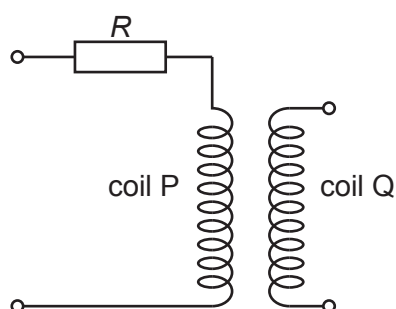


**Fig. 1.1**

A resistor of resistance  $R$  is connected in series with coil P.

A changing magnetic flux of frequency  $f$  in coil P causes an electromotive force (e.m.f.)  $E$  to be induced across the terminals of coil Q.

It is suggested that  $E$  is related to  $R$  by the relationship

$$E = 2\pi f M \left( \frac{V}{R + k} \right)$$

where  $V$  is the potential difference across the resistor and coil P, and  $k$  and  $M$  are constants.

Plan a laboratory experiment to test the relationship between  $E$  and  $R$ .

Draw a diagram showing the arrangement of your equipment.

Explain how the results could be used to determine values for  $k$  and  $M$ .

In your plan you should include:

- the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken.

**Diagram**

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- 2 A student investigates how the volume of a gas varies with its temperature. Air is trapped in a transparent cylinder of diameter  $d$  with a movable piston as shown in Fig. 2.1.

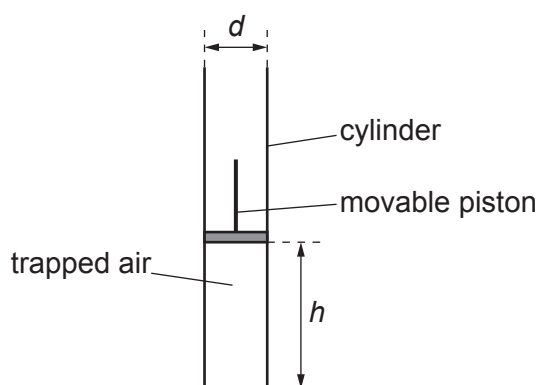


**Fig. 2.1**

The distance between the base of the cylinder and the bottom of the piston is  $h$ .

The trapped air is heated by placing the cylinder in water of temperature  $\theta$ . The increase in temperature of the trapped air causes the piston to move. When the piston stops moving, the value of  $h$  is measured.

For each value of  $h$ , the volume  $V$  of the trapped air is calculated.

The experiment is repeated for different values of  $\theta$ .

It is suggested that  $V$  and  $\theta$  are related by the equation

$$pV = Yk(\theta + Z)$$

where  $k$  is the Boltzmann constant,  $p$  is the atmospheric pressure, and  $Y$  and  $Z$  are constants.

- (a) A graph is plotted of  $V$  on the  $y$ -axis against  $\theta$  on the  $x$ -axis.

Determine expressions for the gradient and  $y$ -intercept.

gradient = .....

$y$ -intercept = .....

[1]

(b) Values of  $\theta$  and  $h$  are given in Table 2.1.

**Table 2.1**

| $\theta/^\circ\text{C}$ | $h/\text{mm}$  | $V/10^{-5}\text{m}^3$ |
|-------------------------|----------------|-----------------------|
| 23                      | $62.4 \pm 0.1$ |                       |
| 35                      | $65.2 \pm 0.1$ |                       |
| 48                      | $68.1 \pm 0.1$ |                       |
| 62                      | $70.9 \pm 0.1$ |                       |
| 73                      | $73.3 \pm 0.1$ |                       |
| 88                      | $76.1 \pm 0.1$ |                       |

The value of  $d$  is  $(27.9 \pm 0.1)\text{mm}$ .

The volume  $V$  is calculated using the relationship

$$V = \frac{\pi d^2 h}{4}.$$

Calculate and record values of  $V/10^{-5}\text{m}^3$  in Table 2.1.

Include the absolute uncertainties in  $V$ .

[2]

(c) (i) Plot a graph of  $V/10^{-5}\text{m}^3$  against  $\theta/^\circ\text{C}$ . Include error bars for  $V$ .

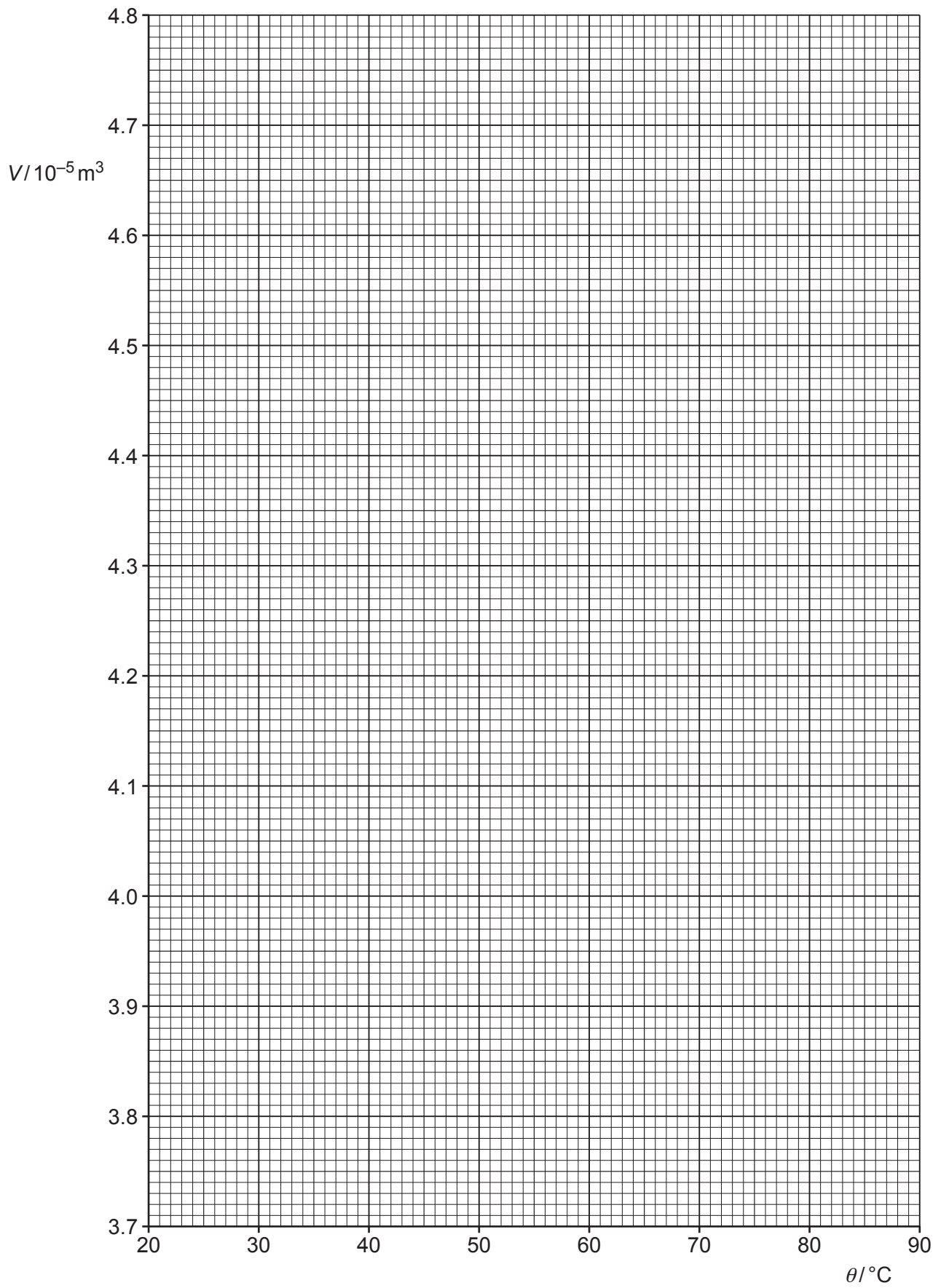
[2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Label both lines.

[2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

gradient = ..... [2]



- (iv) Determine the  $y$ -intercept of the line of best fit. Include the absolute uncertainty in your answer.

$y$ -intercept = ..... [2]

- (d) (i) Using your answers to (a), (c)(iii) and (c)(iv), determine the values of  $Y$  and  $Z$ . Include appropriate units.

Data:  $p = (1.01 \pm 0.01) \times 10^5 \text{ Pa}$   
 $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

$Y = \dots\dots\dots$

$Z = \dots\dots\dots$  [2]

- (ii) Determine the percentage uncertainty in  $Y$ .

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

- (e) The experiment is repeated. Determine the temperature  $\theta$  that gives a value of  $h$  of 60.0 mm.

$\theta = \dots\dots\dots^\circ\text{C}$  [1]

[Total: 15]



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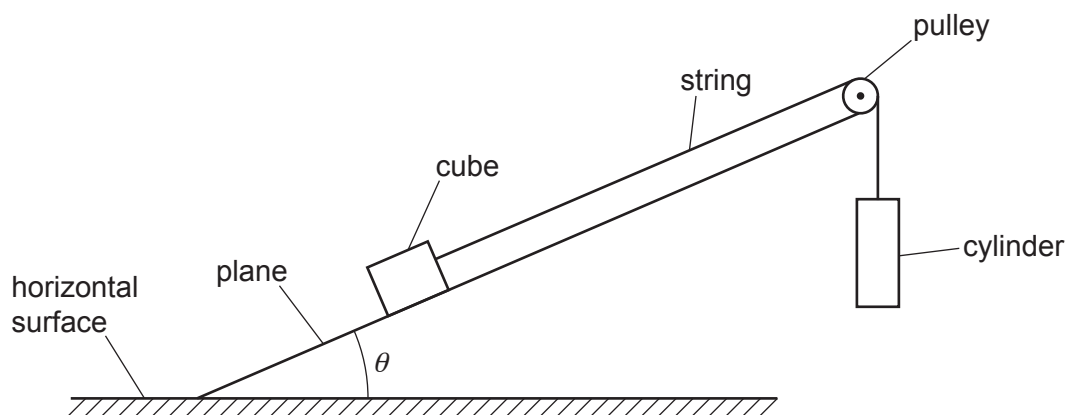


**Fig. 1.1** (not to scale)

The angle between the plane and the horizontal surface is  $\theta$ . Initially the cylinder is held at rest.

The cylinder is released. The time for the cylinder to fall a distance  $d$  is  $t$ .

It is suggested that  $t$  is related to  $\theta$  by the relationship

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where  $H$  and  $K$  are constants.

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**Diagram**

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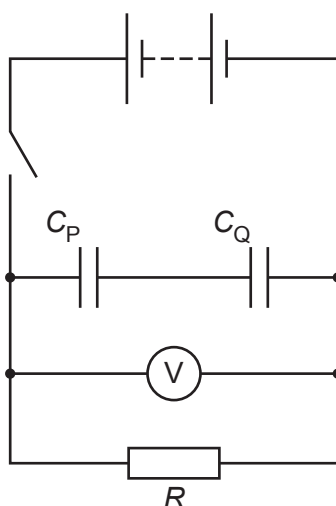


**Fig. 2.1**

The capacitors have capacitances  $C_P$  and  $C_Q$ .

The student closes the switch to charge the capacitors and then records the maximum reading  $V_0$  on the voltmeter.

The switch is opened and a stop-watch is started. The capacitors discharge through the resistor and the reading on the voltmeter decreases. When the reading on the voltmeter is  $V$  the time  $t$  is recorded. The discharge of the capacitors is repeated and the mean time  $T$  is calculated.

The experiment is repeated for different values of  $C_P$  and  $C_Q$ .

For each combination of  $C_P$  and  $C_Q$ , the combined capacitance  $C$  is calculated.

It is suggested that  $C$  and  $T$  are related by the equation

$$\ln \left( \frac{V}{V_0} \right) = - \frac{T}{CR}$$

where  $R$  is the resistance of the resistor.

- (a) A graph is plotted of  $T$  on the  $y$ -axis against  $C$  on the  $x$ -axis.

Determine an expression for the gradient.

gradient = ..... [1]

(b) Values of  $C_P$ ,  $C_Q$  and  $t$  are given in Table 2.1.

**Table 2.1**

| $C_P/10^{-4}\text{F}$ | $C_Q/10^{-4}\text{F}$ | $C/10^{-4}\text{F}$ | $t/\text{s}$ | $t/\text{s}$ | $T/\text{s}$ |
|-----------------------|-----------------------|---------------------|--------------|--------------|--------------|
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| 2.2                   | 3.3                   |                     | 21.1         | 19.7         |              |
| 2.2                   | 5.6                   |                     | 23.7         | 24.9         |              |
| 3.3                   | 1.5                   |                     | 15.3         | 16.9         |              |
| 5.6                   | 1.5                   |                     | 19.0         | 17.6         |              |
| 5.6                   | 3.3                   |                     | 30.9         | 32.1         |              |

The relationship between  $C$ ,  $C_P$  and  $C_Q$  is

$$C = \frac{C_P C_Q}{C_P + C_Q}.$$

Calculate and record values of  $C/10^{-4}\text{F}$  and  $T/\text{s}$  in Table 2.1.  
Include the absolute uncertainties in  $T$ .

[2]

(c) (i) Plot a graph of  $T/\text{s}$  against  $C/10^{-4}\text{F}$ .  
Include error bars for  $T$ .

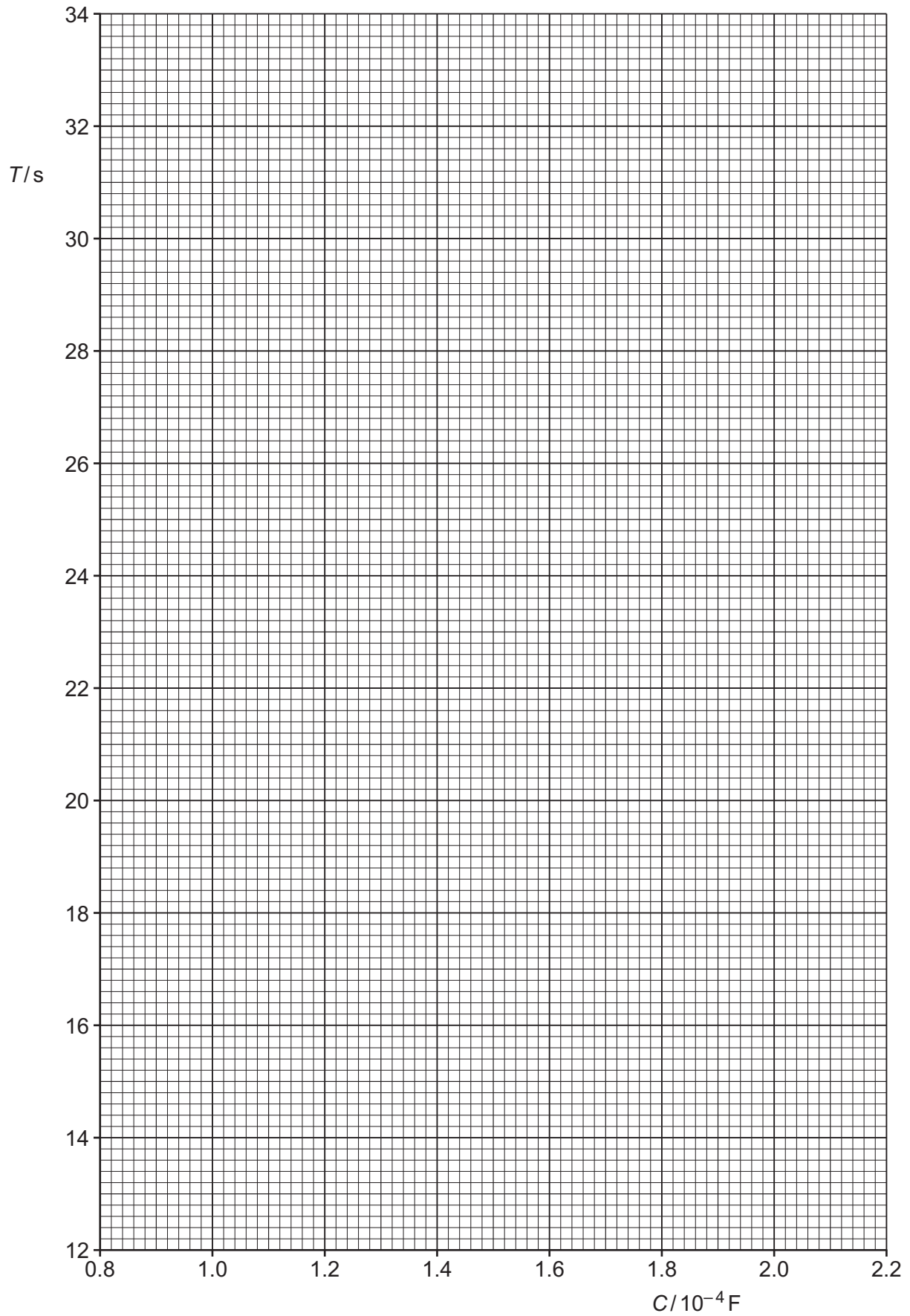
[2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Label both lines.

[2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

gradient = ..... [2]



- (d) The values of  $V_0$  and  $V$  are:

$$V_0 = (4.8 \pm 0.1) \text{ V}$$

$$V = (2.4 \pm 0.1) \text{ V}$$

Calculate  $\ln\left(\frac{V}{V_0}\right)$ . Include the absolute uncertainty in  $\ln\left(\frac{V}{V_0}\right)$ .

$$\ln\left(\frac{V}{V_0}\right) = \dots\dots\dots [1]$$

- (e) (i) Using your answers to (a), (c)(iii) and (d), determine the value of  $R$ . Include an appropriate unit.

$$R = \dots\dots\dots [2]$$

- (ii) Determine the percentage uncertainty in  $R$ .

$$\text{percentage uncertainty in } R = \dots\dots\dots \% [1]$$

- (f) The experiment is repeated. Determine the value of  $C$  that gives a value of  $T$  of 60.0 s. Include the absolute uncertainty in your answer.

$$C = \dots\dots\dots \text{ F } [2]$$

[Total: 15]