



Oxford Cambridge and RSA

Wednesday 21 October 2020 – Morning

A Level Physics B (Advancing Physics)

H557/03 Practical skills in physics

Time allowed: 1 hour 30 minutes

You must have:

- the Data, Formulae and Relationships Booklet

You can use:

- a scientific or graphical calculator
- a ruler (cm/mm)



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

Last name

StemUp Model Solution

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION

- The total mark for this paper is **60**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

ADVICE

- Read each question carefully before you start your answer.

SECTION A

Answer **all** the questions.

- 1 This question is about finding the specific thermal capacity of a liquid. An electrical immersion heater connected to a supply unit is placed inside a calorimeter containing a liquid at room temperature, 17°C . The calorimeter, shown in **Fig. 1.1**, has insulated lid, walls and base. The mass of the liquid is $200 \pm 5\text{ g}$. The temperature of the liquid is measured using a digital thermometer at 30-second intervals for 6 minutes.

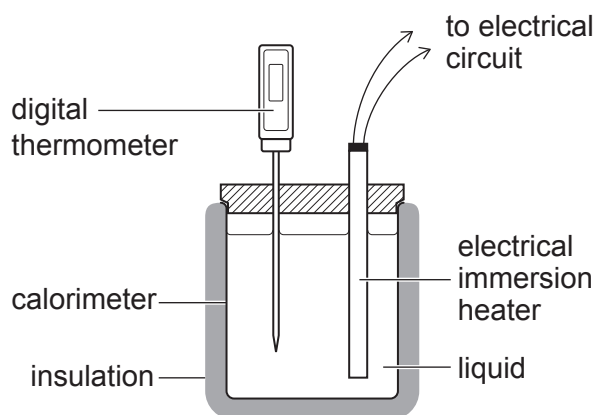
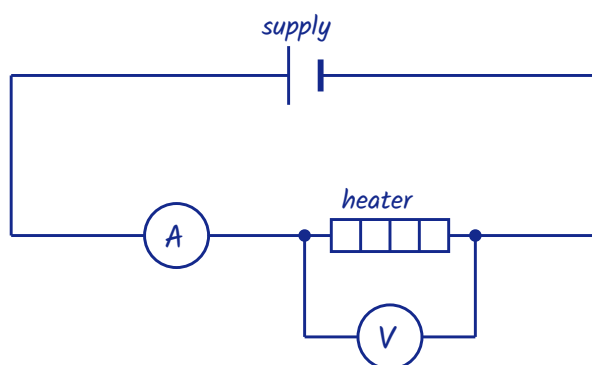


Fig. 1.1

- (a) Suggest an improvement, with a reason, to the experimental design.

Stir the liquid (gently and continuously) during heating.
This ensures the temperature is the same throughout the liquid, so the
thermometer reads the true temperature of all of it. [2]

- (b) (i) Draw a circuit diagram to represent the apparatus used to calculate the power of the electrical heater. This symbol  may be used for the electrical heater.



[2]

- (ii) The following readings were obtained:

potential difference $V = 10.5 \pm 0.2 \text{ V}$
 current $I = 2.3 \pm 0.2 \text{ A}$.

Calculate the power supplied to the heater **per unit mass** of the liquid.
 Include the uncertainty in the value.

$$P = VI = 10.5 \times 2.3 = 24.15 \text{ W}$$

$$P / m = 24.15 / 0.200 = 121 \text{ W kg}^{-1}$$

$$\text{max} = (10.7 \times 2.5) / 0.195 = 137 \text{ W kg}^{-1}$$

$$\text{min} = (10.3 \times 2.1) / 0.205 = 106 \text{ W kg}^{-1}$$

$$\text{uncertainty} = \frac{1}{2} (137 - 106) = 16 \text{ W kg}^{-1} \approx 20 \text{ W kg}^{-1}$$

power per unit mass = ...120..... $\pm$ 20..... W kg^{-1} [4]

(c) Fig. 1.2 shows the temperature–time graph obtained.

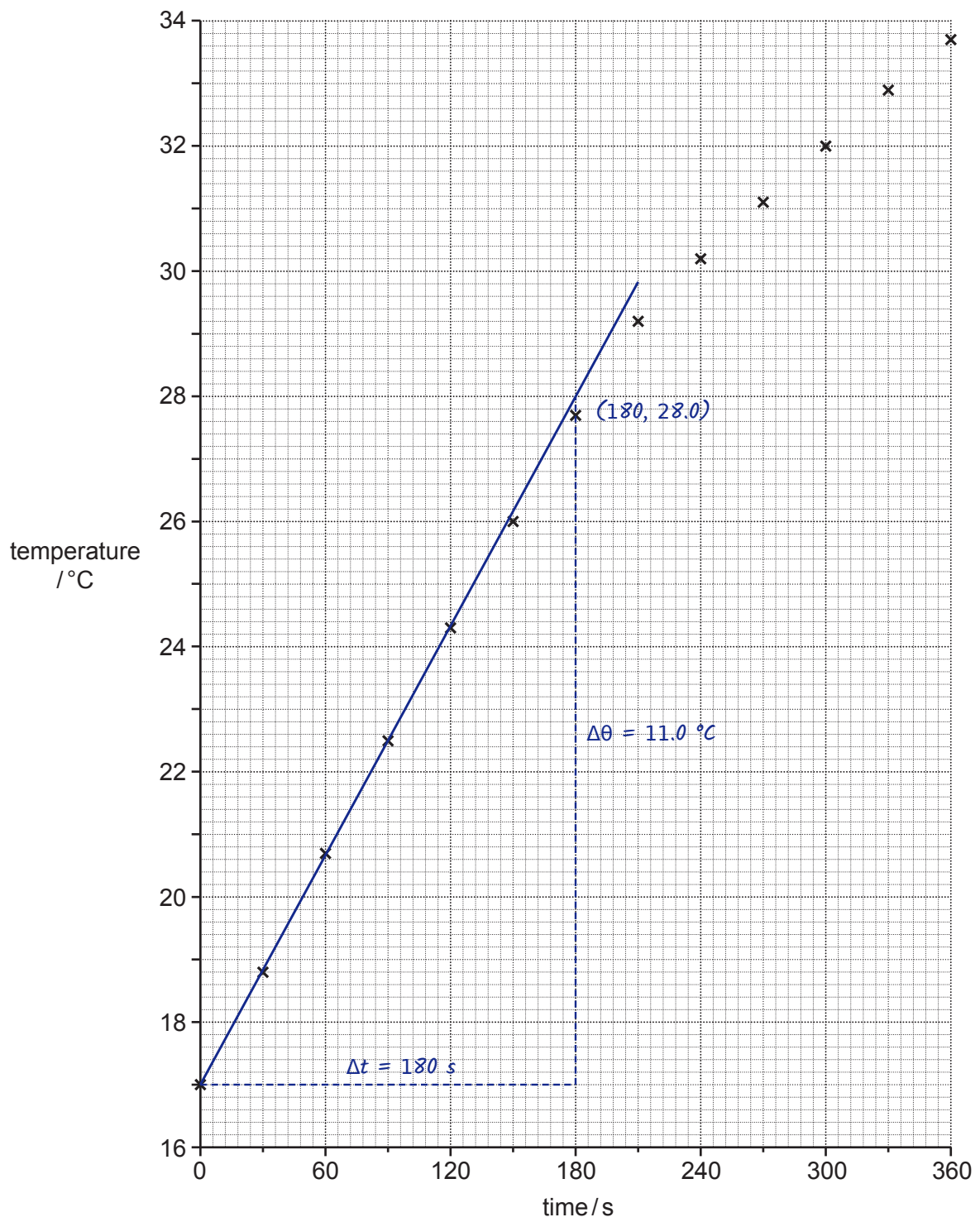


Fig. 1.2

- (i) Explain the shape of the graph in **Fig. 1.2**.

Initially the temperature increases at a constant rate (temperature rise proportional to time) because the power input is constant and negligible heat is lost to the surroundings.
After about 3 minutes the rate of increase of temperature decreases because the temperature difference with the surroundings increases, so thermal energy is lost to the surroundings at a higher rate. [2]

- (ii) Draw a straight line of best fit through the initial linear section of **Fig. 1.2**. [1]

- (iii) Show that the relationship between the gradient of the linear section and the specific thermal capacity, c , takes the form

$$\text{gradient} = \frac{Z}{c}$$

where Z is a constant.

$$\text{energy supplied} = \text{power} \times \text{time: } P\Delta t = mc\Delta\theta$$

$$\text{gradient} = \Delta\theta / \Delta t = P / mc$$

P and m are constant, so $Z = P / m$ is a constant

$$\text{gradient} = Z / c$$

[2]

- (iv) Use the linear part of **Fig. 1.2** to find the specific thermal capacity of the liquid.

from the line: (0 s, 17.0 °C) and (180 s, 28.0 °C)

$$\text{gradient} = (28.0 - 17.0) / (180 - 0) = 0.0611 \text{ } ^\circ\text{C s}^{-1}$$

$$c = (P / m) / \text{gradient} = Z / \text{gradient}$$

$$c = 121 / 0.0611 = 1980 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$c = \dots\dots\dots 2.0 \times 10^3 \dots\dots\dots \text{ J kg}^{-1} \text{ K}^{-1} \text{ [3]}$$

PLEASE DO NOT WRITE ON THIS PAGE

Question 2 begins on page 7

2 This question is about calibrating a light meter to measure the intensity of light emitted by a torch.

(a) Light intensity is measured in W m^{-2} , and can be calculated using the equation

$$\text{Intensity} = \frac{E}{At}$$

where E is the radiant energy passing through a surface in time t and A is the cross-sectional area of the surface.

The beam from a torch, shown in **Fig. 2.1**, has a conical shape. At a distance, x , the intensity of light is L . Show that at a distance of $2x$, the intensity will be reduced to $\frac{L}{4}$.

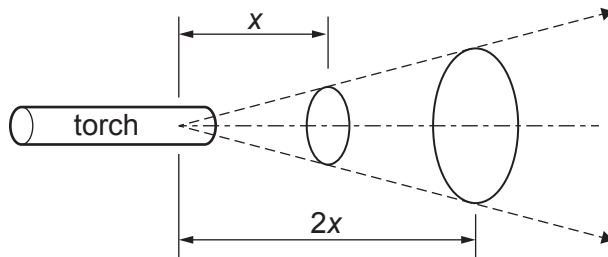


Fig. 2.1

by similar triangles, at $2x$ the beam radius is $2r$

area at $2x = \pi(2r)^2 = 4\pi r^2 = 4A$ (4 times as big)

the same energy E passes through each area in time t :

$$L_{2x} = E / (4At) = \frac{1}{4} \times E / (At) = L / 4$$

[2]

(b) An LDR is placed in a potential divider circuit as shown in **Fig. 2.2**.

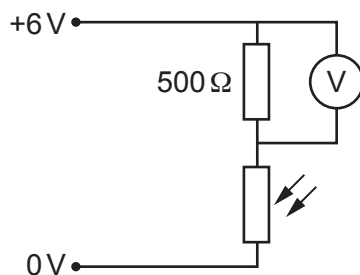


Fig. 2.2

(i) Explain why the output reading on the voltmeter will increase as light intensity increases.

..Increasing light intensity decreases the resistance of the LDR.....

..The total p.d. is constant, so the p.d. across the LDR decreases and the.....

p.d. across the 500 ohm resistor (voltmeter) increases..... [2]

Fig. 2.3 shows a graph of intensity against $\frac{1}{x^2}$.

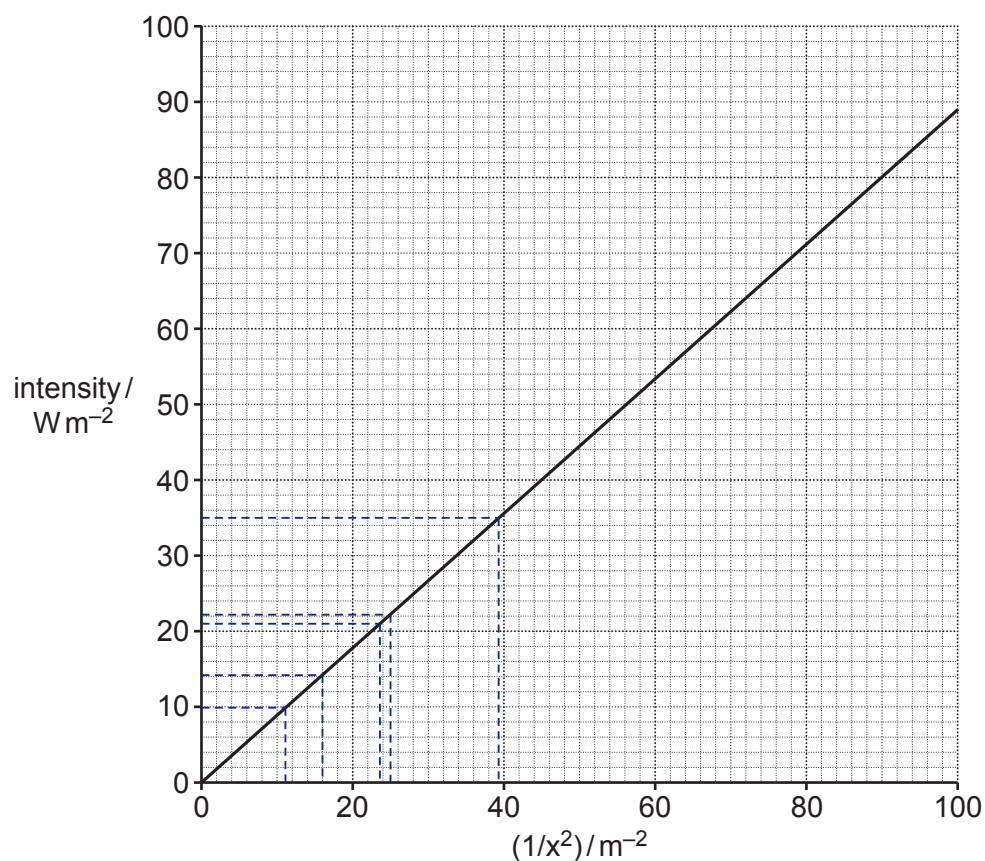


Fig. 2.3

A student collects the data shown in the table below. There was no background illumination present.

Distance/cm	Voltage output/V	Light Intensity/ W m^{-2}
10	5.66	89
20	4.69	22
30	3.75	10
40	2.78	7
50	2.17	3.5

- (ii) Use the graph in **Fig. 2.3** to complete the third column and then plot the points and complete the calibration curve in **Fig. 2.4**. **[3]**

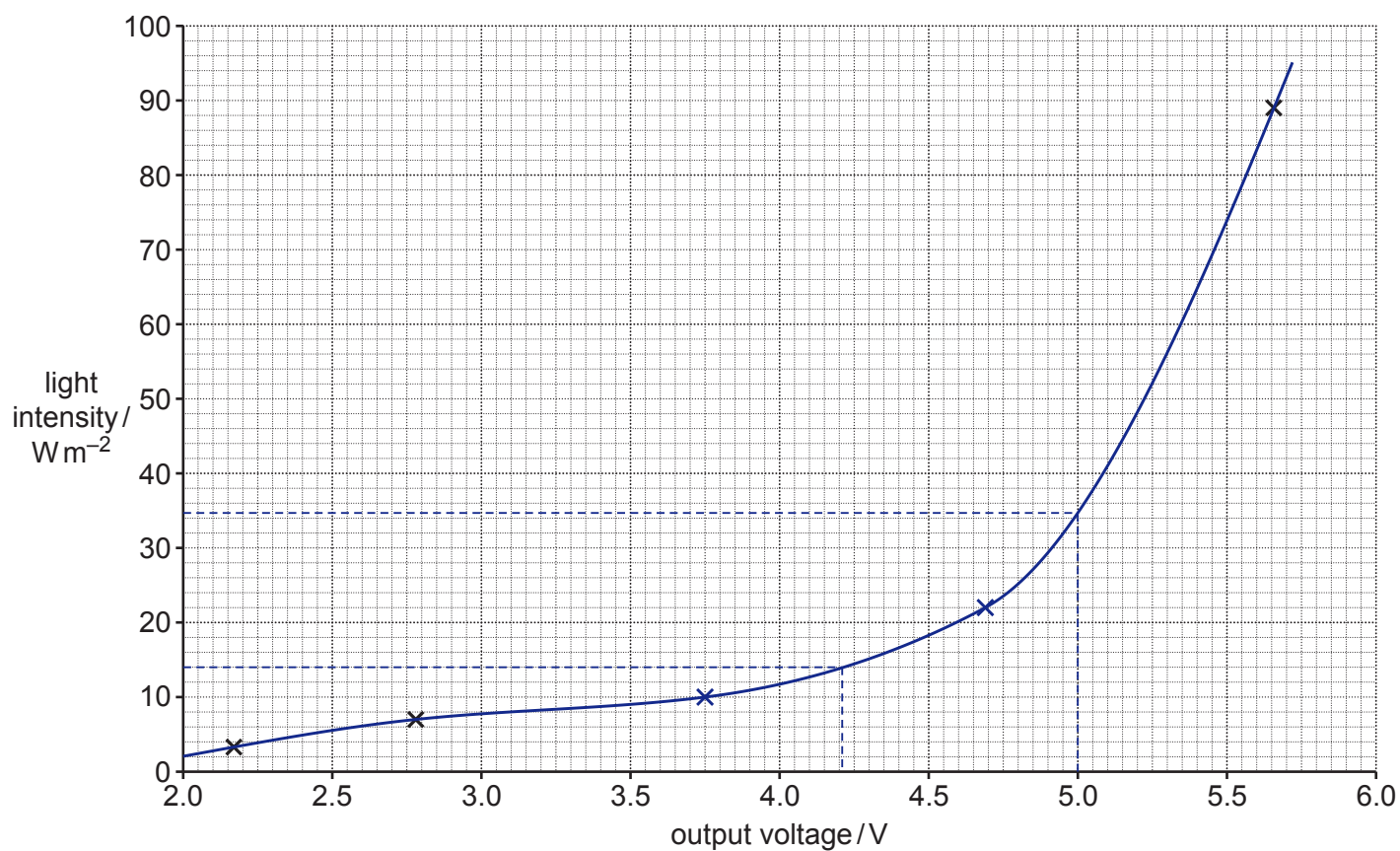


Fig. 2.4

(c)* Use the calibration plots in this question to find the distance of the torch from the light meter in the following two cases:

- the voltmeter in **Fig. 2.2** reads 5.0 V
- the voltmeter in **Fig. 2.2** reads 5.0 V when the torch shines on it in a room with a constant level of background illumination equal to the intensity from the source at a distance of 25.0 cm.

Make your method clear.

Explain how a calibration curve yielding the intensity of the *light from the torch* in the scenario with background illumination would differ from **Fig. 2.4**, the calibration curve of the light incident on the light meter with no background illumination. [6]

Torch alone: from Fig. 2.4, an output of 5.0 V gives an intensity of 35 W m^{-2} . From Fig. 2.3, 35 W m^{-2} gives $1/x^2 = 39 \text{ m}^{-2}$, so $x = 1/\sqrt{39} = 0.16 \text{ m}$ (16 cm).

With background: at 25.0 cm, $1/x^2 = 1/0.250^2 = 16 \text{ m}^{-2}$, so from Fig. 2.3 the background intensity is 14 W m^{-2} .

At 5.0 V the total intensity is still 35 W m^{-2} , so the intensity from the torch = $35 - 14 = 21 \text{ W m}^{-2}$. From Fig. 2.3 this gives $1/x^2 = 24 \text{ m}^{-2}$, so $x = 1/\sqrt{24} = 0.20 \text{ m}$ (20 cm). The torch is further away for the same output because some of the light comes from the background.

Curve for the torch light: intensity from torch = total intensity - background intensity, so every point is 14 W m^{-2} lower; the curve has the same shape but is shifted to the right.

With no light from the torch the total intensity is 14 W m^{-2} , giving an output of 4.2 V on Fig. 2.4, so the new curve crosses the voltage axis at (4.2 V, 0) and passes through (5.0 V, 21 W m^{-2}).

Additional answer space if required

The background light makes the LDR less resistive at every distance, so the output voltage is higher for each x and the torch intensity is less for the same output.

- 3 The speed of sound can be measured using the resonance of air in a tube. A loudspeaker is placed above the open end of a hollow glass tube with the other end immersed in water as shown in Fig. 3.1.

The loudspeaker is connected to a signal generator set at a frequency of 480 Hz with an audible volume. The height of the column of air is changed by moving the glass tube up and down, until maximum volume of sound is heard.

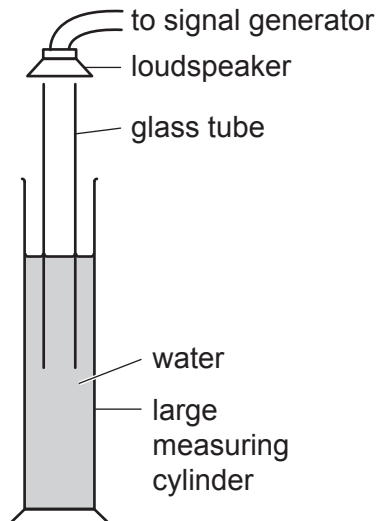


Fig. 3.1

- (a) (i) Explain how a standing wave is formed in the tube.

The sound wave travels down the tube and reflects at the water surface. The incident and reflected waves travel in opposite directions with the same frequency (wavelength) and similar amplitudes, so they superpose. A node forms where they meet in antiphase and an antinode where they meet in phase: a node at the water surface and an antinode at the open end of the tube.

[4]

- (ii) The shortest height of the air column for maximum volume is recorded as L_1 . The air just above the tube is also vibrating and this extends the length of the standing wave by x , the 'end correction', such that:

$$L_1 + x = \frac{\lambda}{4}.$$

Show that:

$$L_1 = \frac{v}{4f} - x$$

$$v = f\lambda \text{ so } \lambda = v / f$$

$$L_1 + x = \lambda / 4 = v / 4f$$

$$\text{so } L_1 = v / 4f - x$$

[1]

- (b) A student records the value of L_1 for different values of frequency and plots a graph of L_1 against $1/\text{frequency}$ as shown in **Fig. 3.2**.

- (i) The gradient of the line is 83 ms^{-1} . Calculate the speed of sound in air. Calculate the percentage uncertainty in your result by taking a 'worst-fit' line from the graph.

$$L_1 = (v / 4)(1 / f) - x, \text{ so gradient} = v / 4$$

$$v = 4 \times 83 = 332 \text{ m s}^{-1}$$

worst-fit lines (dashed) drawn through the error bars on Fig. 3.2:

steepest: (0.00195, 0.146) to (0.00390, 0.320), gradient = 89 m s^{-1}

shallowest: (0.00195, 0.156) to (0.00390, 0.310), gradient = 79 m s^{-1}

uncertainty in gradient = $(89 - 79) / 2 = 5 \text{ m s}^{-1}$

percentage uncertainty = $5 / 83 \times 100 = 6.0 \%$

speed of sound = ...330..... ms^{-1}

percentage uncertainty = ...6.0..... % [4]

- (ii) The end correction is approximately equal to $0.3D$, where D is the diameter of the tube. What is the approximate diameter of the tube used in this experiment?

using (0.0026, 0.205): $L_1 = (v / 4f) - x$

$$0.205 = (330 \times 0.0026 / 4) - x = 0.2145 - x$$

$$x = 0.0095 \text{ m}$$

$$D = x / 0.3 = 0.0095 / 0.3 = 0.032 \text{ m}$$

$D =$ 0.03..... m [2]

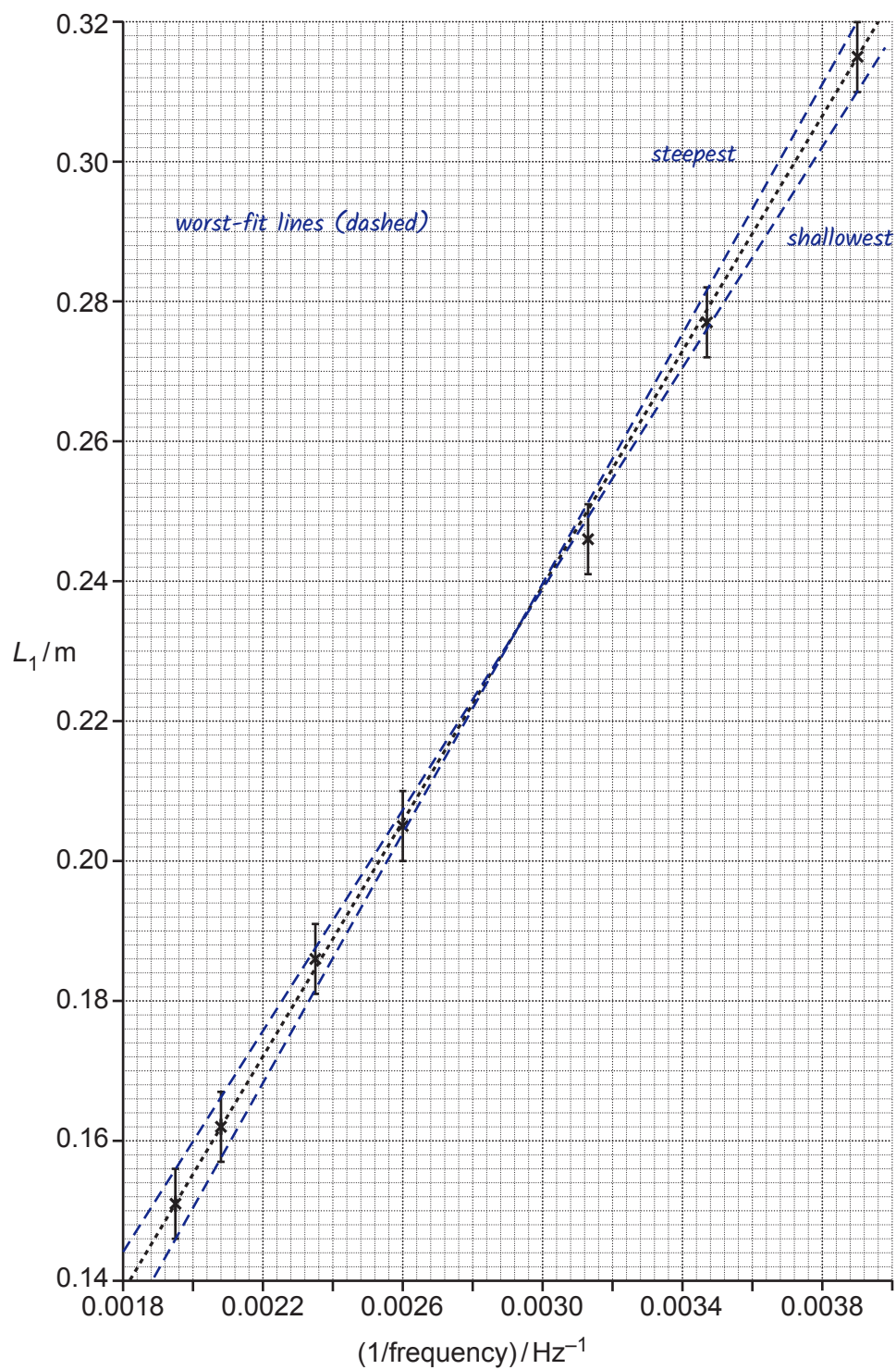


Fig. 3.2

SECTION B

Answer **all** the questions.

- 4 This is a question about transformers. A student performs an experiment to investigate transformers using the apparatus shown in **Fig. 4.1**.

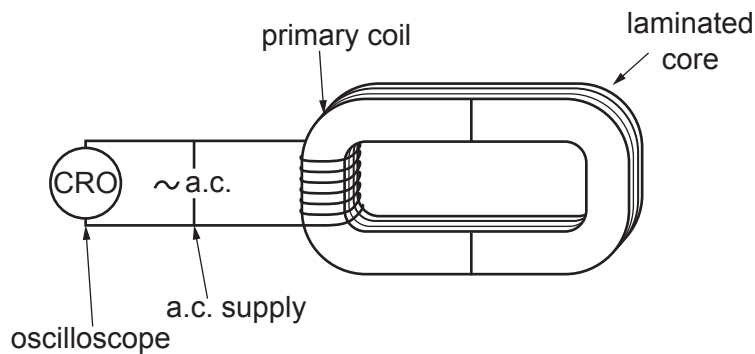


Fig. 4.1

The student connects an oscilloscope as shown in **Fig. 4.1**, to measure the input voltage to the primary coil of the transformer. The screen of the oscilloscope is shown in **Fig. 4.2**:

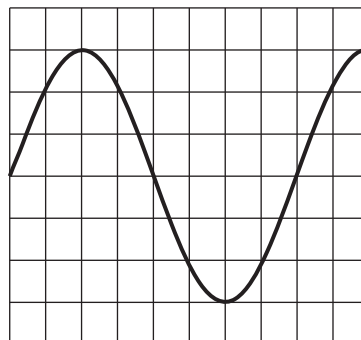


Fig. 4.2

- (a) The oscilloscope has the following settings: 500 mV/div on the vertical scale and 2.5 ms/div on the horizontal scale. Use **Fig. 4.2** to calculate the following values for the input coil:

- (i) peak potential difference V

$$\text{peak} = 3 \text{ div} \times 500 \text{ mV} = 1500 \text{ mV}$$

$$V = \dots\dots\dots 1.5 \dots\dots\dots \text{ V [1]}$$

- (ii) frequency f

$$T = 8 \text{ div} \times 2.5 \text{ ms} = 0.020 \text{ s}, \quad f = 1 / T$$

$$f = \dots\dots\dots 50 \dots\dots\dots \text{ Hz [1]}$$

- (b) A secondary coil is added to the right-hand side of the C-core shown in **Fig. 4.1**.

Fig. 4.3 shows the p.d.s across the primary and secondary coils. The scale settings are unchanged.

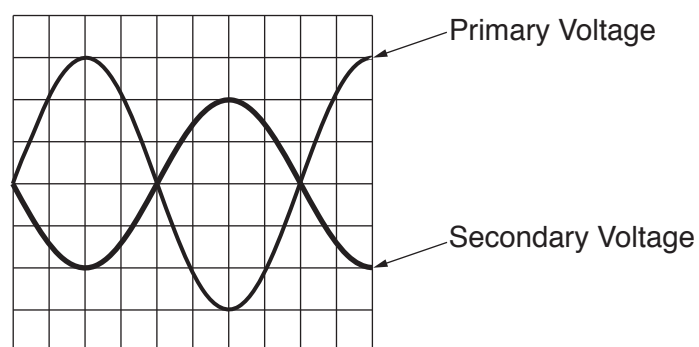


Fig. 4.3

The student suggests that the turns ratio $\frac{N_1}{N_2}$ is $\frac{3}{2}$.

- (i) Use **Fig. 4.3** to explain the student's reasoning.

$$V_1 / V_2 = N_1 / N_2$$

primary peak = 3 div (1.5 V), secondary peak = 2 div (1.0 V)

$$V_1 / V_2 = 1.5 / 1.0 = 3 \text{ div} / 2 \text{ div} = 3 / 2$$

$$\text{so } N_1 / N_2 = 3 / 2$$

[2]

- (ii) The actual ratio of turns for the transformer is $\frac{5}{4}$. Suggest and explain a reason for this difference.

Some magnetic flux leaks out of the core into the air, so less flux links the secondary coil.

The secondary e.m.f. is smaller than expected, so V_1 / V_2 (3/2) is greater than N_1 / N_2 (5/4).

[2]

- (c) The current in the primary coil is I_1 and the current in the secondary coil is I_2 . Show that the maximum current in the secondary coil is given by the relationship

$$\frac{I_1 N_1}{N_2} = I_2.$$

State any assumptions you make.

ideal transformer: power in = power out

$$I_1 V_1 = I_2 V_2 \text{ so } V_1 / V_2 = I_2 / I_1$$

$$\text{and } V_1 / V_2 = N_1 / N_2 \text{ so } N_1 / N_2 = I_2 / I_1$$

$$I_2 = I_1 N_1 / N_2$$

Assumption(s): *the transformer is 100% efficient (ideal), no energy is lost, so*
power input = power output. [2]

- (d) The student alters the turns ratio to $\frac{5}{7}$. N_2 is now 200 turns. The peak output emf is 2.0 V.

The frequency of the supply is unchanged.

- (i) Estimate the maximum flux through the secondary coil.

$$\varepsilon = -N \Delta\phi / \Delta t \text{ so } \Delta\phi = \varepsilon \Delta t / N$$

$$T = 1 / f = 1 / 50 = 0.020 \text{ s}$$

$$\text{flux rises from zero to maximum in } \frac{1}{4} \text{ cycle: } \Delta t = \frac{1}{4} T = 0.0050 \text{ s}$$

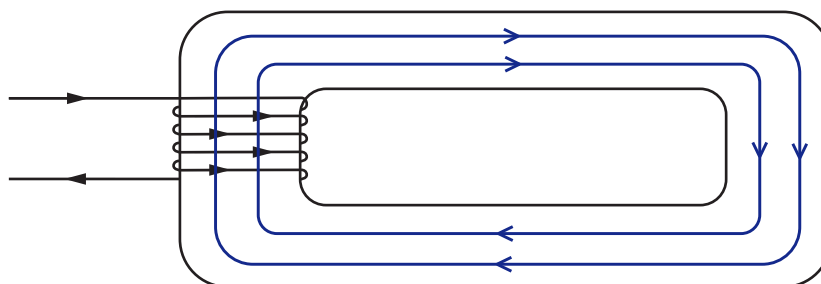
$$\text{maximum flux} \approx \varepsilon \Delta t / N = (2.0 \times 0.0050) / 200$$

$$= 5.0 \times 10^{-5} \text{ Wb}$$

maximum flux = ... 5.0×10^{-5} Wb [3]

The student now uses a different set of C-cores which have a greater overall length.

- (ii) Complete the diagram by adding two lines which represent the flux in the core at the instant shown.



[2]

- (iii) State the effect of increasing the length of the magnetic circuit of the transformer.

It decreases the permeance of the magnetic circuit, so the flux in the core decreases (and so the output voltage decreases).

[1]

Another student has a faulty set of apparatus such that the C-cores do not fully meet on one side as shown in **Fig. 4.4**.

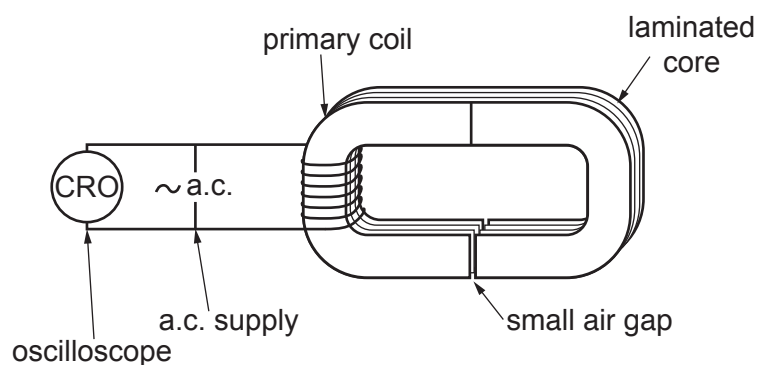


Fig. 4.4

- (iv) Explain how a small air gap affects the magnetic circuit in **Fig. 4.4** and why the core is made of vertically stacked laminated sheets rather than a solid block of iron or horizontally stacked laminated sheets as shown in **Fig. 4.5**. [6]

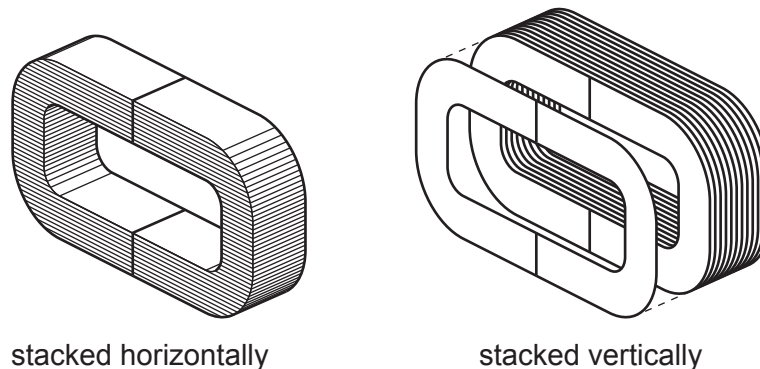


Fig. 4.5

Air has a much lower permeability than iron, so even a small air gap greatly decreases the permeance of the whole magnetic circuit. (Permeance is like conductance in an electric circuit). The flux in the core depends on the permeance, so the flux decreases and less flux links the secondary.

The changing flux induces eddy currents in the iron core. These waste energy as heat and produce a flux that opposes the flux from the primary coil.

Eddy currents flow at right angles to the flux. With vertical laminations the glue between sheets is an electrical insulator, so eddy currents can only flow within the thickness of each thin sheet: high resistance in their direction, so they are much smaller.

A solid block is best for flux but worst for eddy currents. Horizontal laminations still allow large eddy currents and their insulating layers impede the flux; vertical laminations do not impede the flux.

END OF QUESTION PAPER

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