

## 2

- 1 A hammer is often used to force a nail into wood. The faster the hammer moves, the deeper the nail moves into the wood.

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This can be represented in a laboratory by a mass falling vertically onto a nail.

It is suggested that the depth  $d$  of the nail in the wood (see Fig. 1.1) is related to the velocity  $v$  of the mass at the instant it hits the nail by the equation

$$d = kv^n$$

where  $k$  and  $n$  are constants.

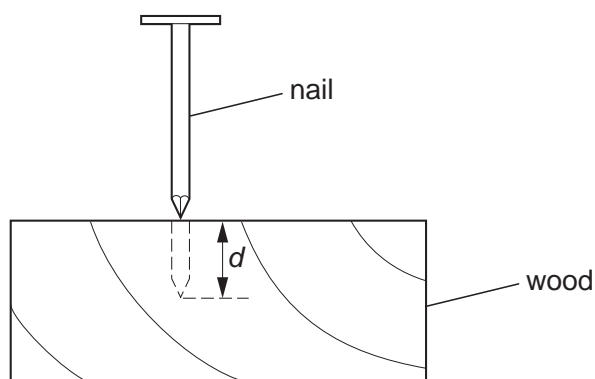


Fig. 1.1

Design a laboratory experiment to investigate the relationship between  $v$  and  $d$  so as to determine a value for  $n$ . You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

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

[15]

**Diagram**

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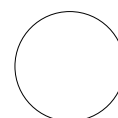
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<b>For Examiner's Use</b>	Defining the problem	Methods of data collection	Method of analysis	Safety considerations	Additional detail



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- 2 The reactance  $X_c$  of a capacitor is defined as

$$X_c = \frac{V_0}{I_0}$$

where  $V_0$  is the peak voltage across the capacitor and  $I_0$  is the peak current through the capacitor.

An experiment is carried out to investigate how the reactance of a capacitor varies with the frequency  $f$  of the a.c. supply to the capacitor.

The equipment is set up as shown in Fig. 2.1.

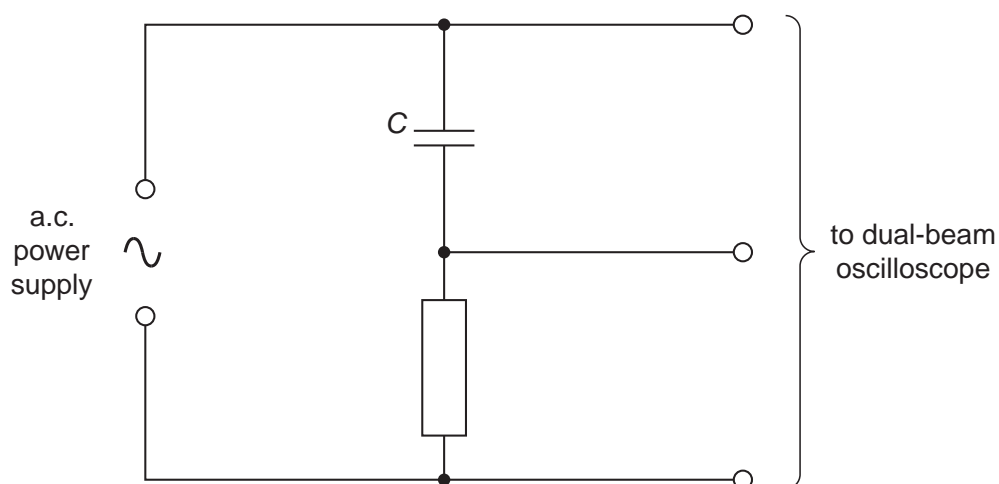


Fig. 2.1

The dual-beam oscilloscope is used to determine values of  $V_0$  and  $I_0$ .

Question 2 continues on the next page.

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It is suggested that  $X_c$  and  $f$  are related by the equation

$$X_c = \frac{1}{2\pi fC}$$

where  $C$  is the capacitance of the capacitor.

- (a) A graph is plotted with  $X_c$  on the  $y$ -axis and  $\frac{1}{f}$  on the  $x$ -axis. Express the gradient in terms of  $C$ .

gradient = ..... [1]

- (b) Values of  $f$ ,  $V_0$  and  $I_0$  are given in Fig. 2.2.

$f/\text{Hz}$	$V_0/\text{V}$	$I_0/10^{-3}\text{A}$	$\frac{1}{f}/10^{-3}\text{s}$	$X_c/\Omega$
220	$5.0 \pm 0.2$	$15 \pm 0.2$		
250	$5.0 \pm 0.2$	$17 \pm 0.2$		
300	$5.0 \pm 0.2$	$21 \pm 0.2$		
350	$5.0 \pm 0.2$	$24 \pm 0.2$		
400	$5.0 \pm 0.2$	$28 \pm 0.2$		
450	$5.0 \pm 0.2$	$31 \pm 0.2$		

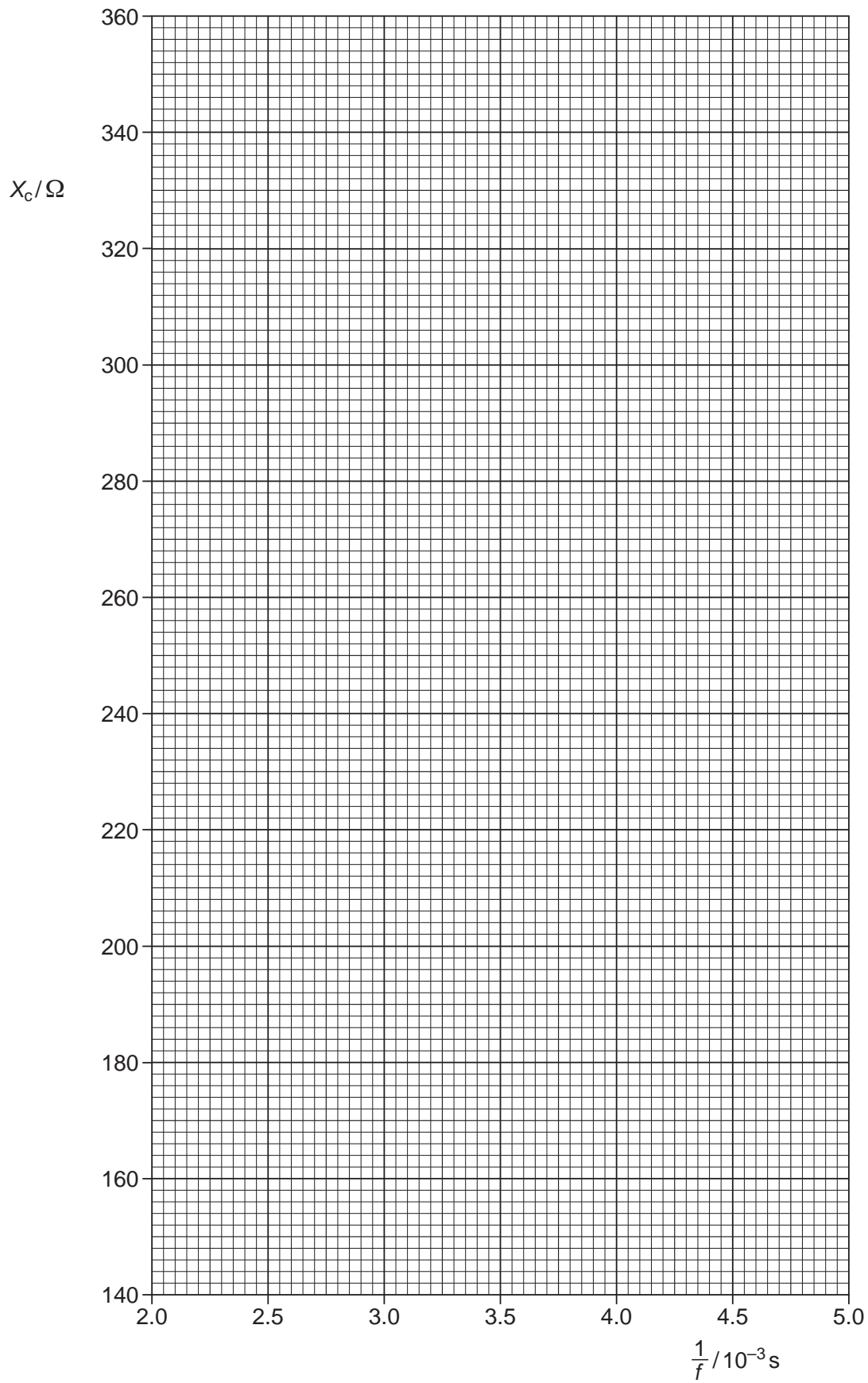
**Fig. 2.2**

Calculate and record values of  $\frac{1}{f}$  and  $X_c$  in Fig. 2.2. Include the absolute uncertainties in  $X_c$ . [3]

- (c) (i) Plot a graph of  $X_c/\Omega$  against  $\frac{1}{f}/10^{-3}\text{s}$ . Include error bars for  $X_c$ . [2]
- (ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]
- (iii) Determine the gradient of the line of best fit. Include the uncertainty in your answer.

gradient = ..... [2]

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- (d) Using your answer to (c)(iii), determine the value of  $C$ . Include the absolute uncertainty in your value and an appropriate unit.

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$$C = \dots\dots\dots [3]$$

- (e) The time constant  $\tau$  is defined as  $\tau = CR$  where  $R$  is the total resistance of the circuit.

- (i)  $C$  is placed in a circuit with total resistance  $220\text{ k}\Omega$ . Determine the value of  $\tau$ .

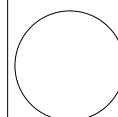
$$\tau = \dots\dots\dots \text{ s } [1]$$

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- (ii) The percentage uncertainty in the total resistance of the circuit is  $\pm 10\%$ . Determine the percentage uncertainty in  $\tau$ .

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

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