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.

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.

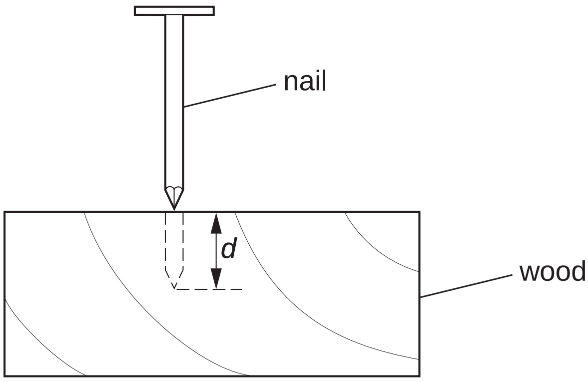

Fig. 1.1

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

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of the data,

(e) the safety precautions to be taken.

[15]

Diagram

For Examiner's Use

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For Examiner's Use

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

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.

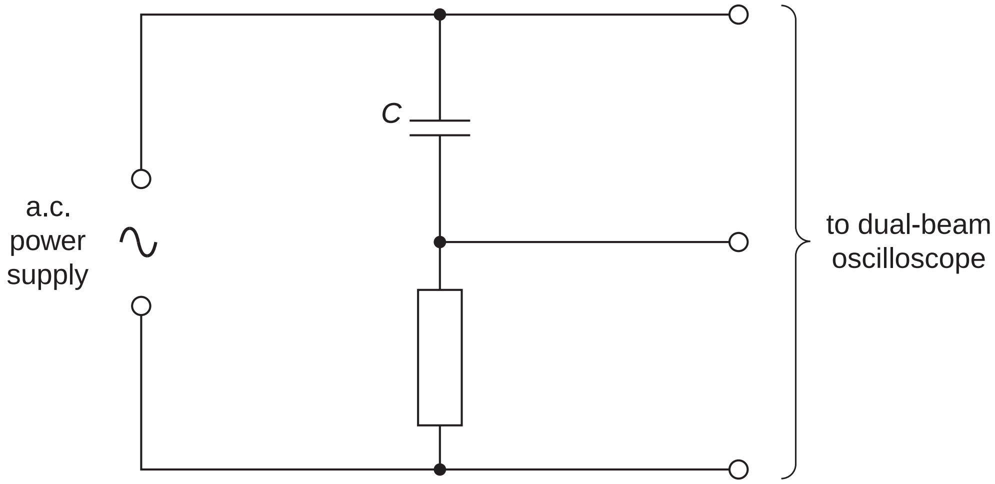

Fig. 2.1

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

Fig. 2.2

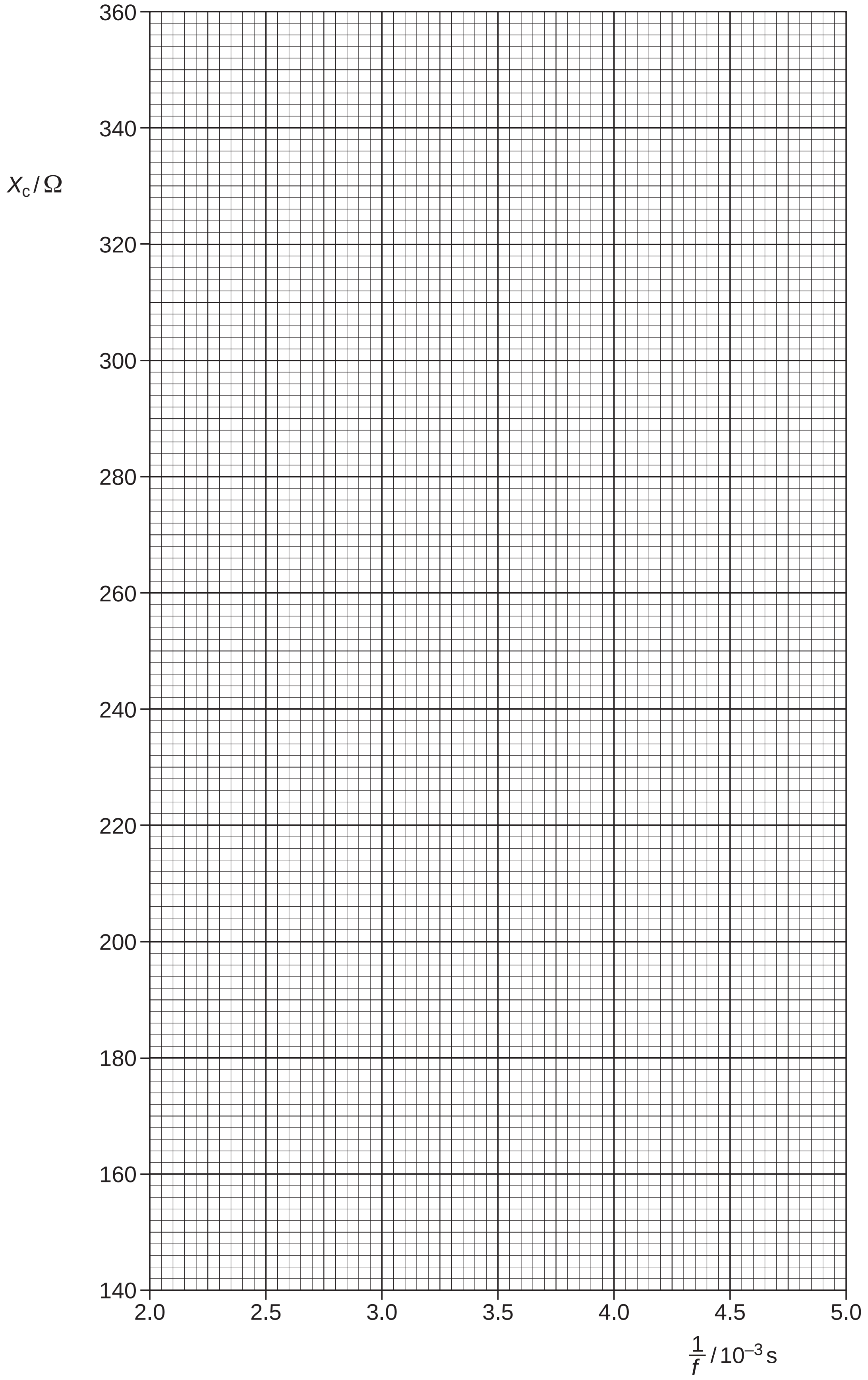
Calculate and record values of $\frac{1}{f}$ and X_c in Fig. 2.2. Include the absolute uncertainties in X_c. [3]

(c) (i) Plot a graph of X_c / Ω against $\frac{1}{f}$ / 10^{-3} 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 = ... [3]

(e) The time constant τ 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 kΩ. Determine the value of τ.

τ = ... s [1]

(ii) The percentage uncertainty in the total resistance of the circuit is ±10%. Determine the percentage uncertainty in τ.

percentage uncertainty = ... % [1]