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- 2 A small thin rectangular slice of semiconducting material has width a and thickness b and carries a current I . The current is due to the movement of electrons. Each electron has charge $-e$ and mean drift velocity v . A uniform magnetic field of flux density B is perpendicular to the direction of the current and the top face of the slice as shown in Fig. 2.1.

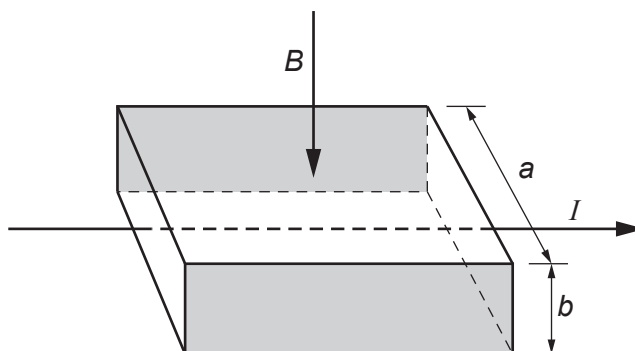


Fig. 2.1

- (a) As soon as the current is switched on, the moving electrons in the current are forced towards the shaded rear face of the slice where they are stored. This causes the shaded faces to act like charged parallel plates. Each electron in the current now experiences both electric and magnetic forces. The resultant force on each electron is now zero.

Write the expressions for the electric and magnetic forces acting on each electron and use these to show that the magnitude of the potential difference V between the shaded faces is given by

$$V = Bva.$$

[3]

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(b) Here are some data for the slice in a particular experiment.

number of conducting electrons per cubic metre, $n = 1.2 \times 10^{23} \text{ m}^{-3}$

$a = 5.0 \text{ mm}$

$b = 0.20 \text{ mm}$

$I = 60 \text{ mA}$

$B = 0.080 \text{ T}$

Use this data to calculate

(i) the mean drift velocity v of electrons within the semiconductor

$v = \dots\dots\dots \text{ ms}^{-1}$ [3]

(ii) the potential difference V between the shaded faces of the slice.

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

- (c) The slice is mounted and used as a measuring instrument called a Hall probe. A cell is connected to provide the current in the slice. The potential difference across the slice is measured by a separate voltmeter.

A student wants to measure the magnetic flux density between the poles of two magnets mounted on a steel yoke as shown in Fig. 2.2. The magnitude of the flux density is between 0.02T and 0.04T.

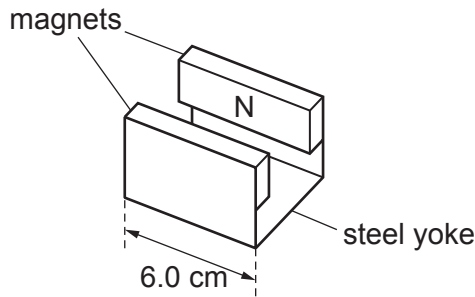


Fig. 2.2

- (i) Suggest **one** reason why this Hall probe is **not** a suitable instrument to measure the magnetic flux density for the arrangement shown in Fig. 2.2.

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- (ii) Another method of measuring the magnetic flux density for the arrangement shown in Fig. 2.2 is to insert a current-carrying wire between the poles of the magnet. Explain how the magnetic flux density can be determined using this method and discuss which measurement in the experiment leads to the greatest uncertainty in the value for the magnetic flux density.

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- 5 (a) A magnet rotates inside a shaped soft iron core. A coil is wrapped around the iron core as shown in Fig. 5.1. The coil is connected to an oscilloscope.

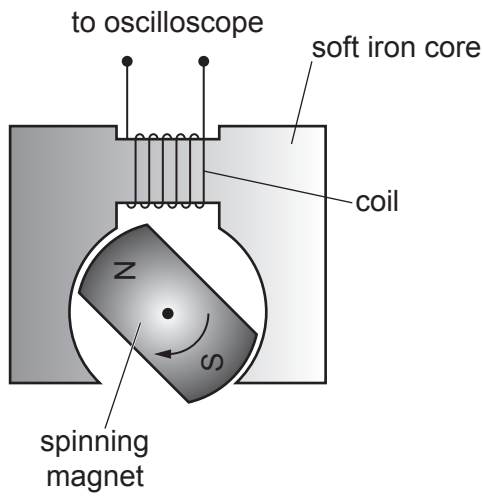


Fig. 5.1

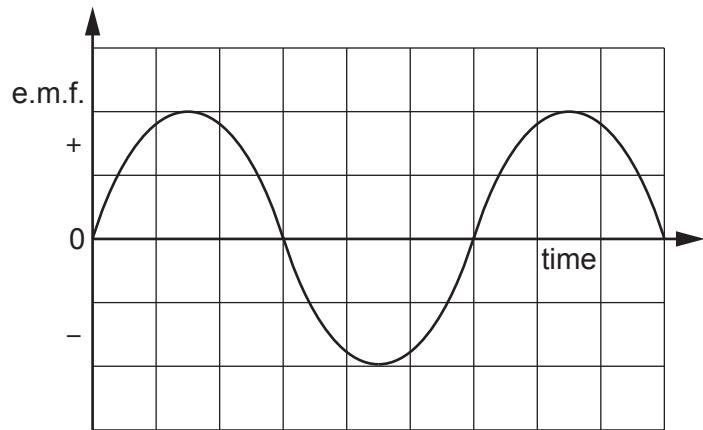


Fig. 5.2

The spinning magnet induces an e.m.f. in the coil. A graph of the e.m.f. displayed on the oscilloscope screen is shown in Fig. 5.2.

- (i) Explain the shape of the graph in terms of the magnetic flux linking the coil.

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- (ii) On Fig. 5.3 sketch a graph of the magnetic flux linkage of the coil against time. The variation of the induced e.m.f. across the coil is shown as a dotted line. [1]

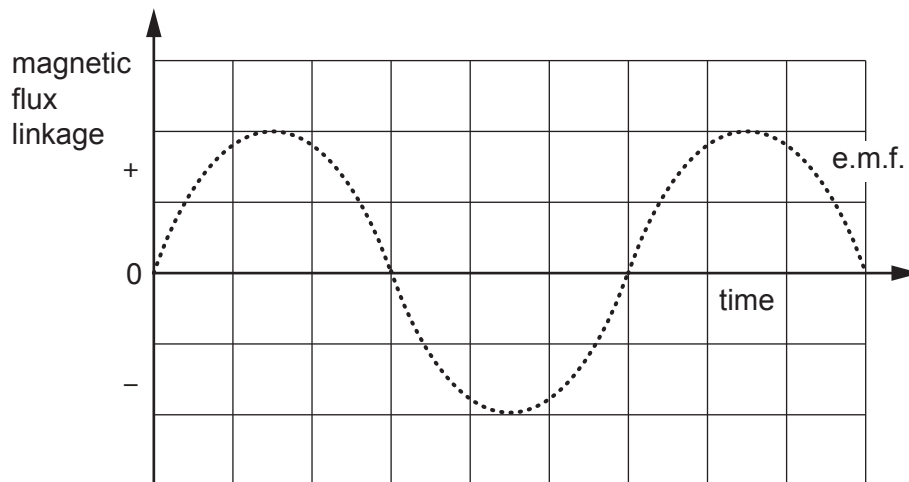


Fig. 5.3

Question 5 is continued on page 14.

- (iii) The coil shown in Fig. 5.1 has 150 turns. The maximum induced e.m.f. V_0 across the coil is 1.2V when the magnet is rotating at 24 revolutions per second.

Calculate the maximum **magnetic flux** through the coil using the equation

$$V_0 = 2\pi \times (\text{frequency}) \times (\text{maximum magnetic flux linkage})$$

Give a unit with your answer.

maximum flux = unit [2]

- (b)* A student is given a transformer with coils **X** and **Y**, as shown in Fig. 5.4.

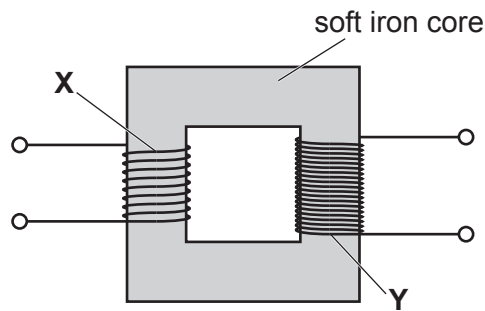


Fig. 5.4

The student is intending to investigate how the maximum induced e.m.f. V_0 in coil **Y** depends on the frequency f of the alternating current in coil **X**.

The changing magnetic flux density in coil **X** induces an e.m.f. in coil **Y**. Faraday's law indicates that the maximum induced e.m.f. V_0 should be directly proportional to f .

Describe how you would investigate the suggested relationship between V_0 and f in the laboratory using these coils. In your description include all of the equipment used and how you would analyse the data collected.

Use the space below to draw a suitable diagram.

3 Fig. 3.1 shows the design of a 'mechanical' torch.

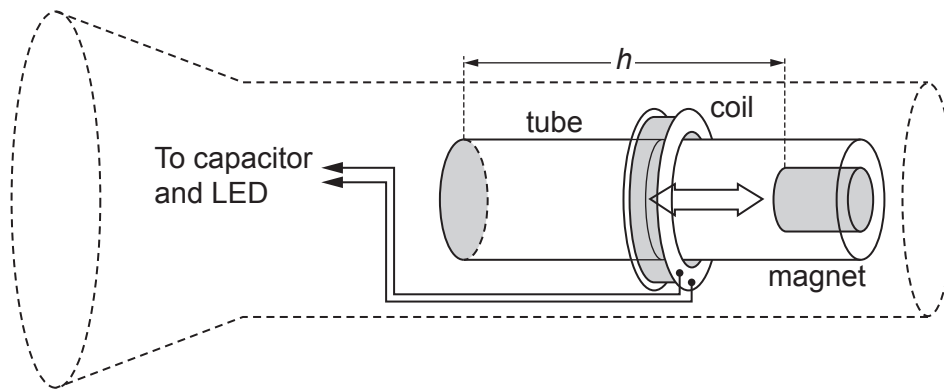


Fig. 3.1

There is no battery in the torch. Instead, when the torch is inverted, the magnet falls a short vertical distance h through the coil of wire, as shown in Fig. 3.2. This induces an electromotive force (e.m.f.) across the ends of the coil. The e.m.f. is used to store charge in a capacitor, which lights a light-emitting diode (LED) when it discharges.

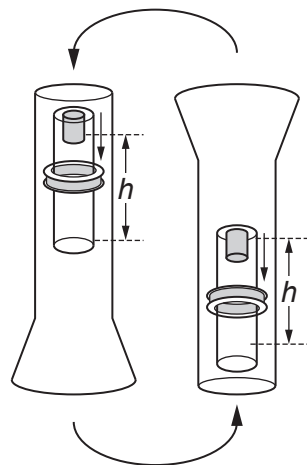


Fig. 3.2

Fig. 3.3 shows the variation with time of the e.m.f. generated as the magnet falls the distance h .

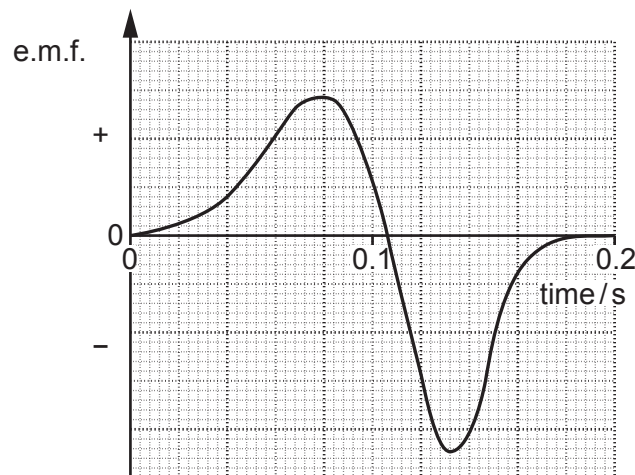


Fig. 3.3

(a) Explain the shape of the curve in Fig. 3.3.

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..... [3]

(b) When the torch is inverted, the pulses of e.m.f. shown in Fig. 3.3 cause a capacitor of capacitance 0.12 F to become charged.
Each positive **and** each negative pulse adds 9.0×10^{-3} C to the charge stored in the capacitor.

(i) The torch is inverted 80 times.

Calculate the total energy stored in the capacitor.

total energy = J [3]

(ii) When the torch is switched on, the energy stored in the capacitor lights a 50 mW LED.

Estimate the time for which the LED lights.

time = s [1]

Additional answer space if required

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Question 4 continues on page 12

(b) The electromagnetic induction hob is shown in **Fig. 4.1**.

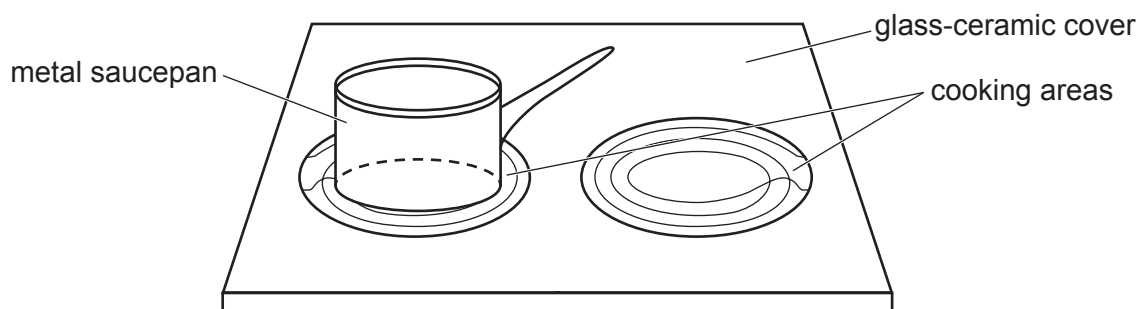


Fig. 4.1

Each cooking area has a coil below the glass-ceramic cover. When switched on, the coils carry a high-frequency **alternating** current.

A metal saucepan is placed above one of the coils. A large alternating current is induced in the saucepan base, and this causes the saucepan to heat up.

(i) **Fig. 4.2** shows one of the coils at a time when the current is in the direction indicated by the arrows.

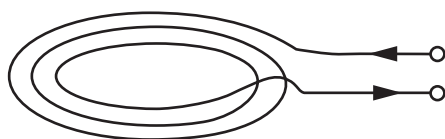


Fig. 4.2

On **Fig. 4.2**, sketch the magnetic field pattern for the current-carrying coil. [2]

- (ii) **Fig. 4.3** shows the path of the large alternating current induced in the metal base of the saucepan.

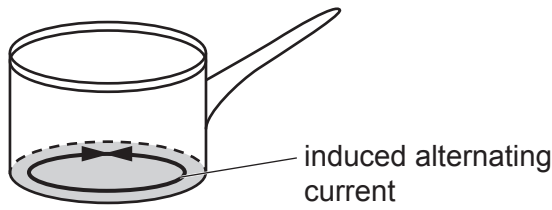


Fig. 4.3

Explain the origin of this large current.

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- (iii) Explain why it would be safe for a person to place a hand on the cooking area before the saucepan is put onto it.

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The force F is removed.

- (i) Calculate the magnitude of the block's initial acceleration at the instant that the force F is removed.

Assume that the spring is not extended beyond its limit of proportionality.

acceleration = ms^{-2} [3]

- (ii) The block now moves with simple harmonic motion.

Calculate the frequency of this motion.

frequency = Hz [3]

- (ii) The frequency of the vibration generator is now varied between 0.5 Hz and 5.0 Hz.

Suggest how the amplitude and frequency of the oscillations of **L** will change as the frequency of the generator is varied.

You may draw a diagram to support your answer.

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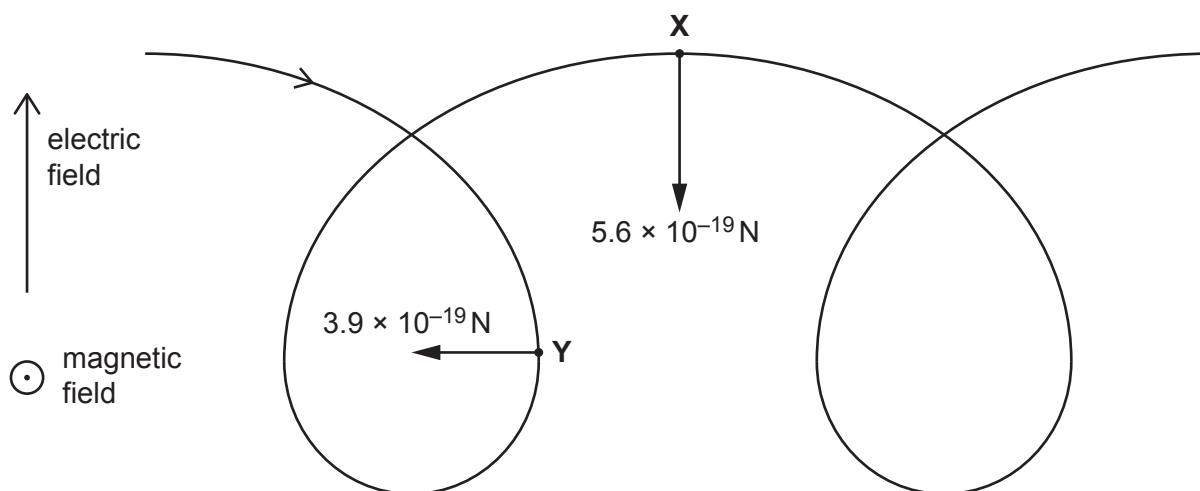
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- 6 The figure below shows the path of a proton moving in a region occupied by both an electric field and a magnetic field.

The direction of the electric field lines is perpendicular to the direction of the magnetic field lines.



The uniform electric field is directed upwards, with electric field strength $E = 0.90 \text{ NC}^{-1}$.

The uniform magnetic field is directed out of the plane of the paper, with magnetic flux density $B = 5.0 \times 10^{-5} \text{ T}$.

At point X the proton is moving horizontally to the right. The magnitude of the **magnetic** force at X is $5.6 \times 10^{-19} \text{ N}$.

At point Y the proton is moving vertically downwards. The magnitude of the **magnetic** force at Y is $3.9 \times 10^{-19} \text{ N}$.

The **electric** forces acting on the proton at X and Y are **not** shown in the figure.

- (a) Show that the magnitude of the constant **electric** force acting on the proton is about 10^{-19} N .

[1]

(b)

- (i) Suggest why the **magnetic** force acting on the proton has a different magnitude at X than at Y.

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- (ii) At **X**, the motion of the proton is instantaneously equivalent to motion in a circle at a constant speed.

Calculate the radius of this circular motion.

radius = m [4]

- (iii) 1 Calculate the magnitude of the resultant force on the proton at **Y**.

resultant force = N [2]

- 2 Explain why the motion of the proton at **Y** is **not** instantaneously equivalent to motion in a circle at a constant speed.

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END OF QUESTION PAPER