Magnetic Fields 2

1.

Fig. 2.1 shows the circular path described by a helium nucleus in a region of uniform magnetic field in a vacuum.

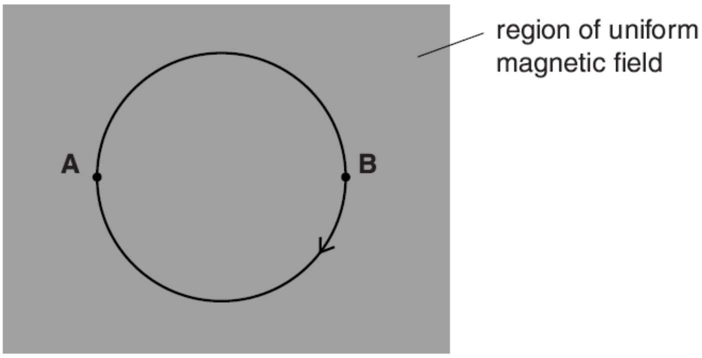

Fig. 2.1

The direction of the magnetic field is perpendicular to the plane of the paper. The magnetic flux density of the magnetic field is 0.20 mT. The radius of the circular path is 15 cm. The helium nucleus has charge + 3.2×10^{-19} C and mass 6.6×10^{-27} kg.

(a) Explain why the helium nucleus

(i) travels in a circular path

....

.... **[1]**

(ii) has the same kinetic energy at **A** and **B**.

....

....

.... **[1]**

(b) Calculate the magnitude of the momentum of the helium nucleus.

momentum = ... kg m s^{-1} **[3]**

(c) Calculate the kinetic energy of the helium nucleus.

kinetic energy = ... J **[2]**

(d) A uniform electric field is now also applied in the region shaded in Fig. 2.1. The direction of this electric field is from **left** to **right**. Describe the path now followed by the helium nucleus in the electric and magnetic fields.

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.... **[2]**

2.

A nitrogen atom is initially stationary at point **P** in Fig. 5.1, midway between two large horizontal parallel plates in an evacuated chamber. The nitrogen atom becomes charged. There is an electric field between the plates. Ignore any effects of gravity.

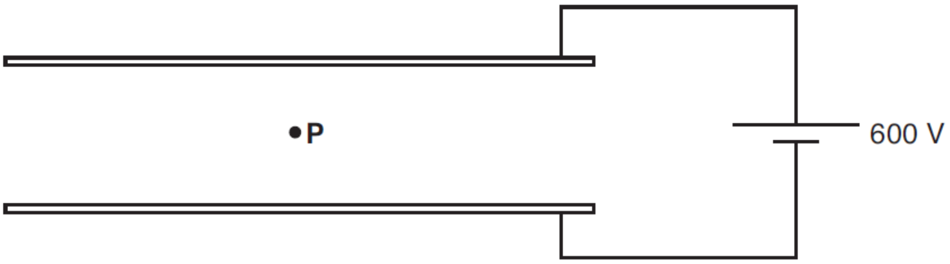

Fig. 5.1

(a) The direction of the electric force on the nitrogen ion is vertically downwards. State with a reason the sign of the charge on the ion.

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....[1]

(b) The voltage between the plates is 600 V. At the instant that the ion, charge 1.6×10^{-19} C and mass 2.3×10^{-26} kg, reaches the lower plate, show that

(i) the kinetic energy of the ion is 4.8×10^{-17} J

[2]

(ii) the speed of the ion is 6.5×10^{4} m s^{-1}.

[2]

(c) The electric field strength between the plates is 4.0×10^{4} N C^{-1}. Calculate the separation of the plates.

separation = ... m [2]

(d) The ion passes through a hole in the lower plate at a speed of 6.5×10^{4} m s^{-1}. It enters a region of uniform magnetic field of flux density 0.17 T perpendicularly into the plane of Fig. 5.2.

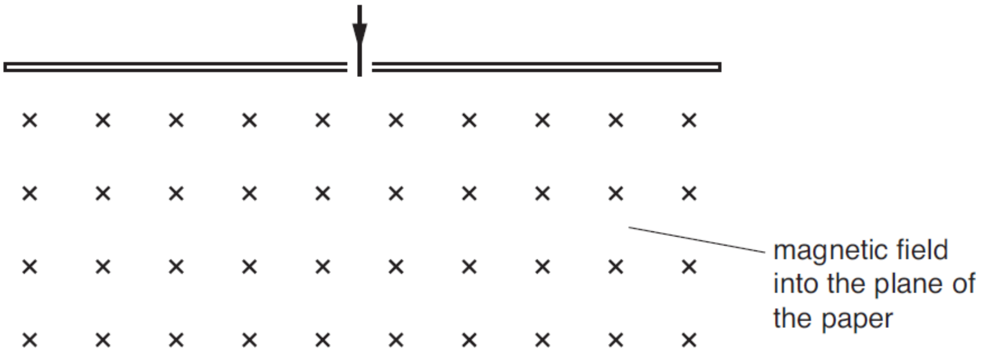

Fig. 5.2

(i) Sketch on Fig. 5.2 the semicircular path taken by the ion. [1]

(ii) Calculate how far from the hole the ion will collide with the plate. Use data from **(b)**.

distance = ... m [5]

3.

(a) Fig. 2.1 shows a horizontal current-carrying wire placed in a uniform magnetic field.

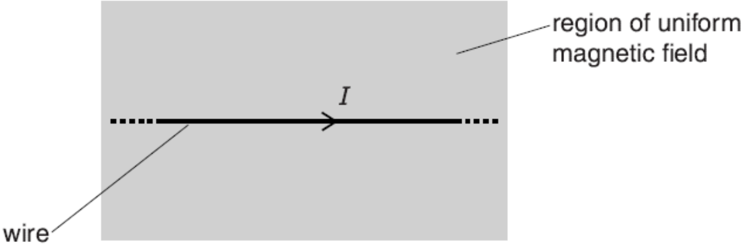

Fig. 2.1

The magnetic field of flux density 0.070 T is at right angles to the wire and into the plane of the paper. The weight of a 1.0 cm length of the wire is 6.8×10^{-5} N. The current I in the wire is such that the vertical upward force on the wire due to the magnetic field is equal to the weight of the wire.

(i) Calculate the current I in the wire.

I = ... A **[2]**

(ii) Suggest why it would be impossible for overhead cables carrying an alternating current to float in the Earth's magnetic field.

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.... **[1]**

(b) A charged particle enters a region of uniform magnetic field. Fig. 2.2 shows the path of this particle.

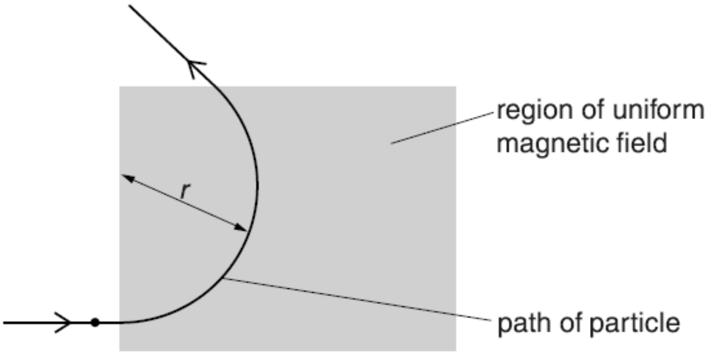

Fig. 2.2

The direction of the field is perpendicular to the plane of the paper. The magnetic field has flux density B. The particle has mass m, charge Q and speed v. The particle travels in a circular arc of radius r in the magnetic field.

(i) Derive an equation for the radius r in terms of B, m, Q and v.

[2]

This question continues on the next page.

(ii) A thin aluminium plate is now placed in the magnetic field. Fig. 2.3 shows the path of an unknown charged particle.

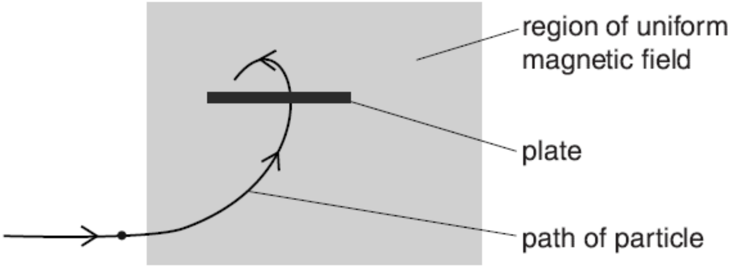

Fig. 2.3

The particle loses some of its kinetic energy as it travels through the plate. The initial radius of the path of the particle before it enters the plate is 4.8 cm. After leaving the plate the final radius of the path of the particle is 1.2 cm.

Calculate the ratio

$$\frac{\text{initial kinetic energy of particle}}{\text{final kinetic energy of particle}}\ .$$

ratio = ... **[2]**

Question 4 is on the next page.

4.

(a) State Faraday's law of electromagnetic induction.

....

.... **[1]**

(b) Fig. 5.1 shows a magnet being moved towards the centre of a flat coil.

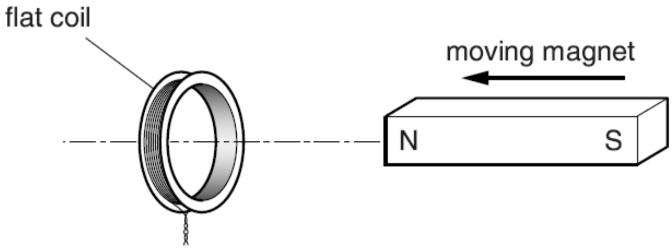

Fig. 5.1

A current is induced in the coil. Use ideas about energy conservation to state and explain the polarity of the face of the coil nearer the magnet.

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.... **[1]**

(c) Fig. 5.2 shows the magnetic field from the north pole of a vertically held bar magnet.

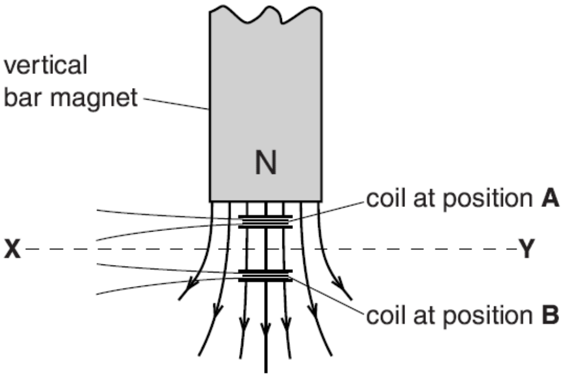

Fig. 5.2

(i) A small flat coil is placed at **A**. The coil is moved downwards from position **A** to position **B**. The plane of the coil remains horizontal between these two positions. Explain why there is no induced e.m.f. across the ends of the coil.

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.... **[1]**

(ii) Fig. 5.3 is a graph showing how the magnetic flux density *B* varies along the horizontal line **XY** in Fig. 5.2.

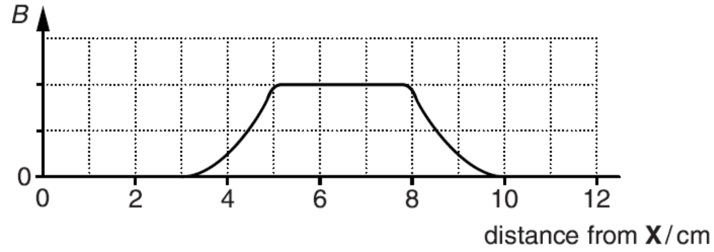

Fig. 5.3

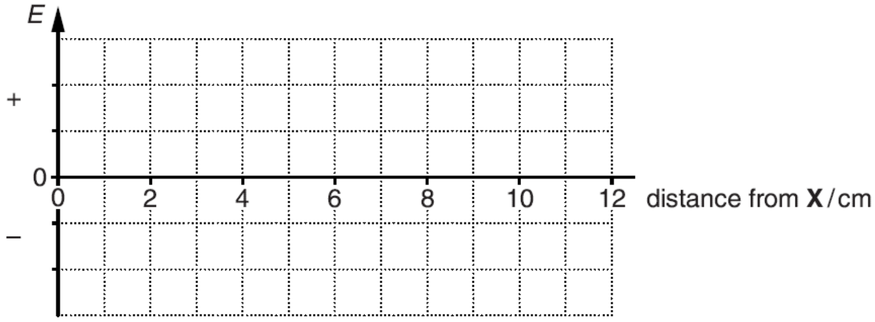

Fig. 5.4

The same small flat coil from **(i)** is moved at a constant speed from **X** to **Y**. The plane of the coil remains horizontal between **X** and **Y**.

On the axis provided in Fig. 5.4, sketch a graph to show the variation of the induced e.m.f. *E* across the ends of the coil with distance from **X**. **[3]**

5.

(a) State Lenz's law.

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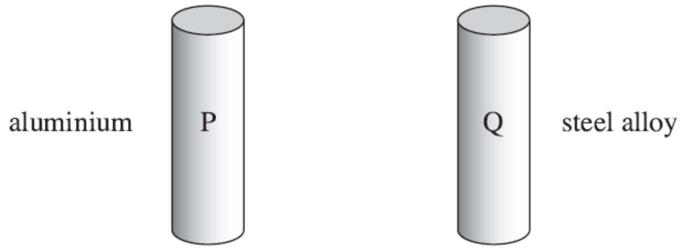
(2 marks)

(b) **Figure 4** shows two small, solid metal cylinders, **P** and **Q**.
P is made from aluminium. **Q** is made from a steel alloy.

Figure 4



(b) (i) The dimensions of **P** and **Q** are identical but **Q** has a greater mass than **P**. Explain what material property is responsible for this difference.

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(1 mark)

(b) (ii) When **P** and **Q** are released from rest and allowed to fall freely through a vertical distance of 1.0 m, they each take 0.45 s to do so. Justify this time value and explain why the times are the same.

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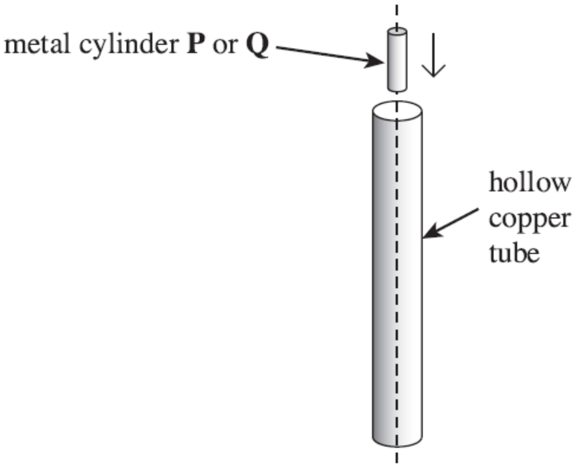
(2 marks)

(c) The steel cylinder **Q** is a strong permanent magnet. **P** and **Q** are released separately from the top of a long, vertical copper tube so that they pass down the centre of the tube, as shown in **Figure 5**.

Figure 5



The time taken for **Q** to pass through the tube is much longer than that taken by **P**.

(c) (i) Explain why you would expect an emf to be induced in the tube as **Q** passes through it.

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(2 marks)

(c) (ii) State the consequences of this induced emf, and hence explain why **Q** takes longer than **P** to pass through the tube.

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(3 marks)

(d) The copper tube is replaced by a tube of the same dimensions made from brass. The resistivity of brass is much greater than that of copper. Describe and explain how, if at all, the times taken by **P** and **Q** to pass through the tube would be affected.

P: ....

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Q: ....

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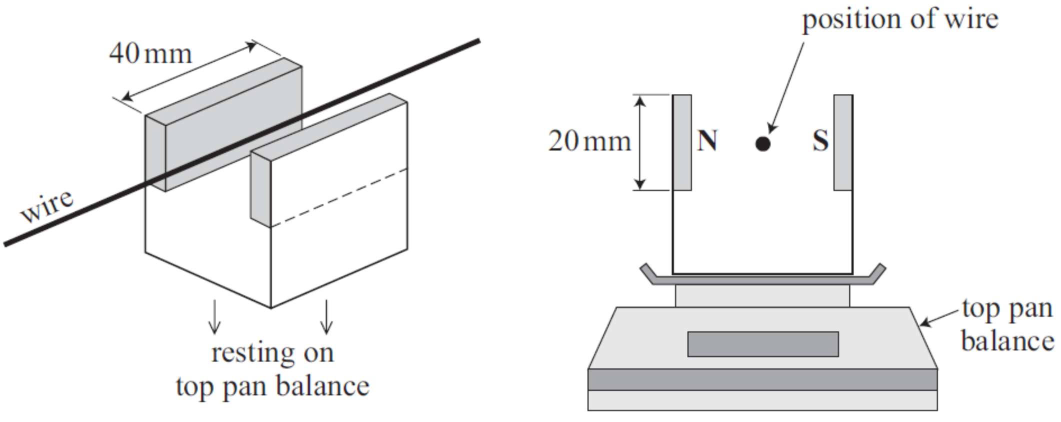
(3 marks)

6.

A uniform magnetic field is produced by mounting two flat magnets on a U-shaped iron frame, so that the north and south poles are facing, as shown in **Figure 3**. The flux density of the magnetic field is 45 mT and may be assumed to act only over the area of the pole faces, which measure 40 mm by 20 mm. This magnet arrangement rests on the pan of a top pan balance.

Figure 3



front view

(a) A horizontal wire is placed in the centre of the magnetic field and aligned to make it perpendicular to the flux lines. When a current is passed through the wire, the balance reading increases by 1.4×10^{-3} kg.

Calculate the current in the wire.

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(2 marks)

(b) The wire is disconnected from the current source and its ends are connected to a sensitive voltmeter. When the wire is moved rapidly, vertically upwards across the whole magnetic field, cutting all of the flux lines perpendicularly, the voltmeter gives a reading.

Calculate

(b) (i) the magnetic flux change experienced by the wire during its movement completely across the magnetic field,

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(b) (ii) the time taken for the wire to pass completely across the magnetic field, assuming it is moved at constant speed, if the voltmeter reads 0.15 mV.

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(5 marks)

7.

A single-turn square coil of side 0.050 m is placed in a magnetic field of flux density B of magnitude 0.026 T.

(a) The coil is placed in three different orientations to the field as shown in Fig. 6.1(a), (b) and (c).

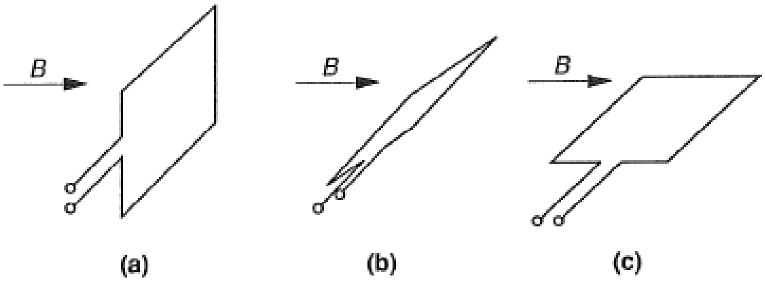

Fig. 6.1

In Fig. 6.1(a), the plane of the coil is perpendicular to the field. In (b), it is at 45° to the field and in (c), it is parallel to the field. Calculate the value, giving a suitable unit, of the magnetic flux linking the coil for the position shown in

(i) Fig. 6.1(a)

magnetic flux = ...unit......... [3]

(ii) Fig. 6.1(b)

magnetic flux = ...unit......... [1]

(iii) Fig. 6.1(c).

magnetic flux = ...unit......... [1]

(b) The coil is rotated in the magnetic field to generate an e.m.f. across its ends. The graph of the variation of e.m.f. with time is shown in Fig. 6.2.

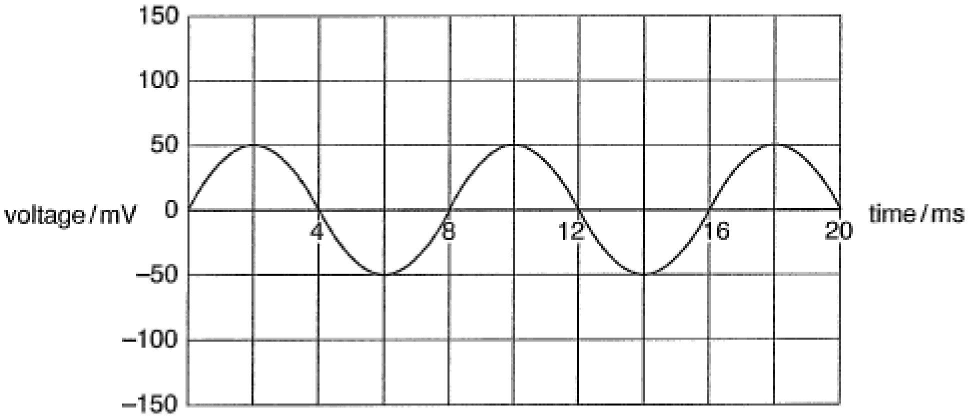

Fig. 6.2

(i) On Fig. 6.2 mark, with an **X**, a point on the graph at a time when the flux linking the coil is a maximum. [1]

(ii) Give your reasoning for your choice of position **X**.

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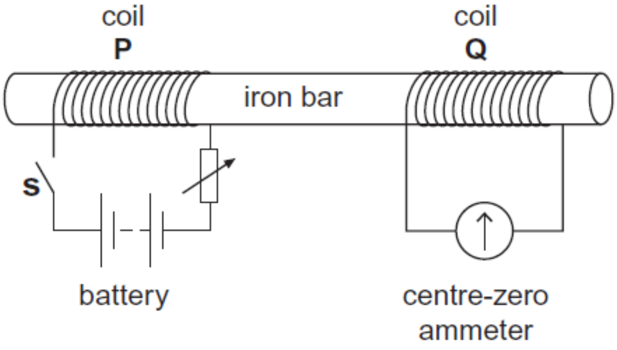
....[2]

(iii) The rate of rotation of the coil is doubled. On Fig. 6.2 draw a graph showing at least two cycles of the e.m.f. now generated across the ends of the coil. [3]

8.

(a) **Figure 5** shows two coils, **P** and **Q**, linked by an iron bar. Coil **P** is connected to a battery through a variable resistor and a switch **S**. Coil **Q** is connected to a centre-zero ammeter.

Figure 5



(a) (i) Initially the variable resistor is set to its minimum resistance and **S** is open. Describe and explain what is observed on the ammeter when **S** is closed.

[3 marks]

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(a) (ii) With **S** still closed, the resistance of the variable resistor is suddenly increased. Compare what is now observed on the ammeter with what was observed in part (a)(i). Explain why this differs from what was observed in part (a)(i).

[2 marks]

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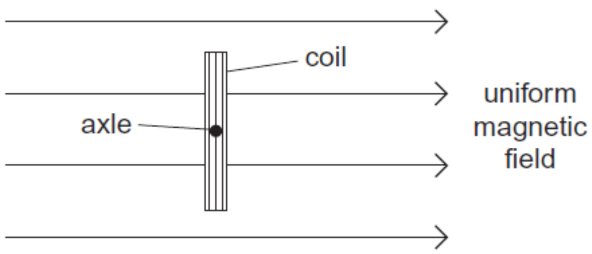
(b) **Figure 6** shows a 40-turn coil of cross-sectional area $3.6 \times 10^{-3}\ \text{m}^2$ with its plane set at right angles to a uniform magnetic field of flux density $0.42\ \text{T}$.

Figure 6



(b) (i) Calculate the magnitude of the magnetic flux linkage for the coil.
State an appropriate unit for your answer.

[2 marks]

flux linkage .... unit ....

(b) (ii) The coil is rotated through 90° in a time of $0.50\ \mathrm{s}$.
Determine the mean emf in the coil.

[2 marks]

mean emf V