H2 Physics Revision Topic : Electromagnetism

Structured Questions Name: ____________________

1

(a) Wire A is a long current-carrying low resistance wire that passes through and is normal to the horizontal plane as shown in Fig. 5.1. *d* is the horizontal distance away from wire A.

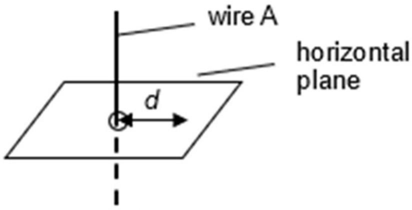

Fig. 5.1

The magnetic field due to the Earth and wire A are B_E and B_W respectively. A miniaturized compass is placed at d = 0.8 cm due East of wire A as shown in Fig. 5.2. At this position, B_W is slightly larger than B_E.

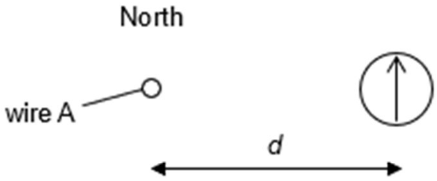

Fig. 5.2

(i) When the current in the wire A is switched off, there is no change in the angle of deflection of the compass.

State the direction of the current in the wire A as shown in Fig. 5.2.

....[1]

1

(ii) The compass is replaced by a magnetic field sensor connected to a datalogger. By varying d, the resultant magnetic field B at that position is obtained.

Fig. 5.3 shows the variation of B against $\frac{1}{d}$.

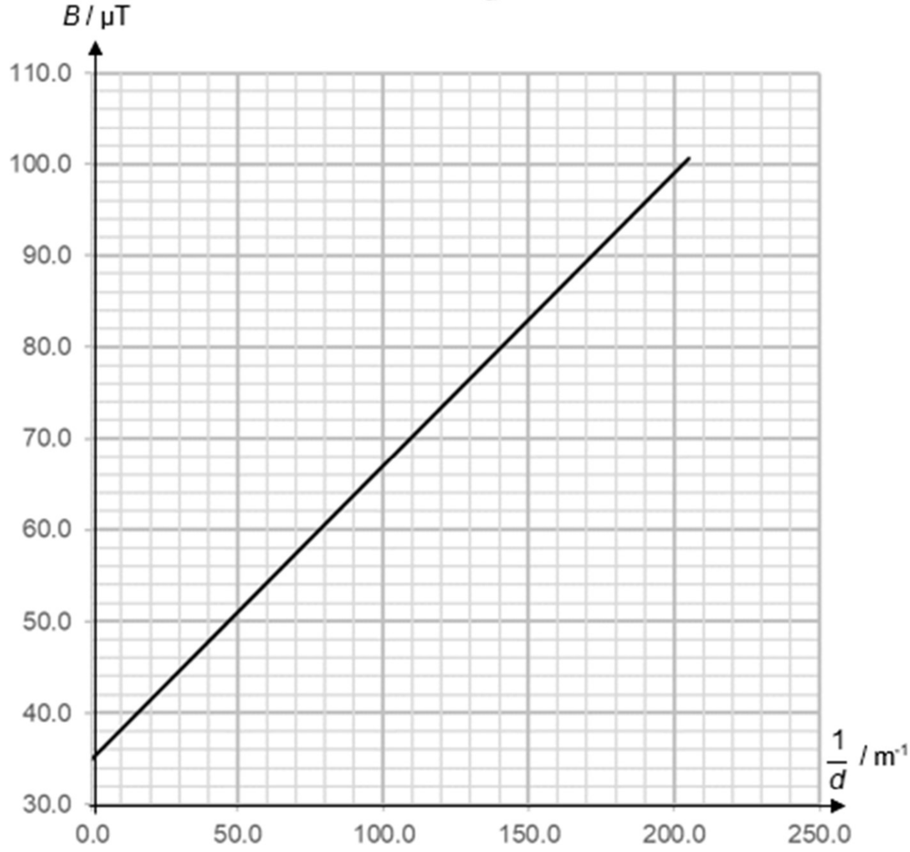

Fig. 5.3

1. B_E is the value of the y-intercept in Fig. 5.3. State the magnitude of B_E.

B_E = ... μT [1]

2. Explain why the y-intercept is the magnitude of B_E.

....

....

.... [1]

1

3. Using your answer in **(a)(ii)1.** and Fig. 5.3, determine the current in the wire A, I_W.

I_W = ... A [3]

(iii) Another current carrying wire, wire B, is placed parallel to wire A and at d = 0.8 cm due South of it as shown in Fig. 5.4. The direction of current in wire B points into the page.

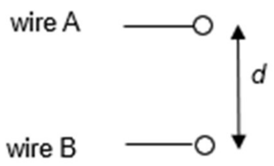

Fig. 5.4

On Fig. 5.4, draw the resultant magnetic force that acts on wire A and the resultant magnetic force that acts on wire B. Label the forces F_A and F_B respectively.

[1]

1

(b) A copper disc spins freely between the poles of an unconnected electromagnet as shown in Fig. 5.5.

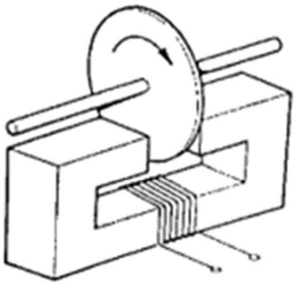

Fig. 5.5

Describe and explain what will happen to the speed of rotation of the disc when a direct current is switched on in the electromagnet.

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.... [4]

2 **(a)** A current-carrying rigid copper wire AB is held horizontally between the pole pieces of two magnets, as shown in Fig. 8.1.

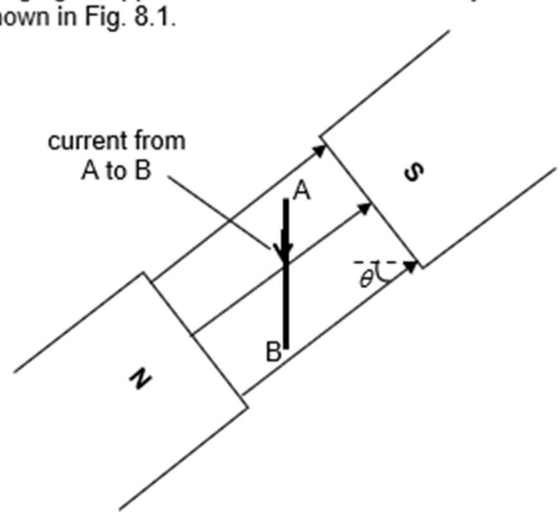

Fig. 8.1

(i) By reference to Fig. 8.1, state and explain the direction of the force by wire AB on the magnets.

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....[2]

(ii) The angle θ is varied from 0 ° to 60 ° by rotating the magnet in the horizontal plane. Describe the changes in the force on the wire.

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....[2]

2

(b) The magnet in **(a)** is fixed in position at $\theta = 0\,°$ such that its magnetic field is perpendicular to wire AB. The magnetic flux density between the poles of the magnet is 0.45 T. The current in the copper wire is now switched off.

The wire is moved at constant speed of 5.0 m s^{-1} vertically out of the plane to cut the region of magnetic field.

(i) The movement of the wire causes conduction electrons in the wire to experience magnetic force.

Show that the magnetic force acting on an electron is 3.6×10^{-19} N.

[1]

(ii) The magnetic force in **(b)(i)** causes conduction electrons in the wire to move, creating a potential difference across the ends of wire AB.

State and explain which end of the wire is at a higher potential.

....

....

....[2]

(iii) The conduction electrons will move until the potential difference across the ends of wire AB is large enough such that the electrons in the wire reach an equilibrium.

1. Explain why electrons in the wire reach an equilibrium.

....

....

....[2]

2. With reference to **(b)(i)**, calculate the electric field strength generated across the ends of the wire AB.

electric field strength = ... N C^{-1} [2]

2

3. The length of the wire within the region of field is 0.20 m. Using the answer in **(b)(iii)2.**, calculate the induced e.m.f across wire AB.

induced e.m.f = ... V [1]

(c) A 2.0 cm square copper frame is moving on a smooth surface with a constant speed of 1.0 cm s^{-1} towards two uniform magnetic fields, as shown in Fig. 8.2.

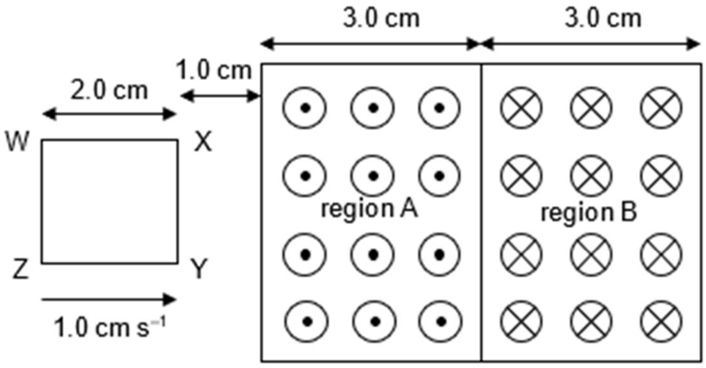

Fig. 8.2

An external force F is applied on the frame when necessary to ensure that the frame moves at a constant speed. The position of the frame in Fig. 8.2 is taken to be at t = 0 s.

The magnetic field in region A is directed out of the paper while the magnetic field in region B is directed into the paper. The magnetic flux density of both fields is 1.0 T. The resistance of the frame is 8.0×10^{-4} Ω.

A short instant later, the side XY of the frame enters region A.

(i) Explain why an external force F is necessary to maintain the constant speed of the frame as it enters region A.

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....[3]

2

(ii) Determine the magnitude of the external force F at this instant.

F = ... N [3]

(iii) On Fig. 8.3, sketch the variation of external force F with time t, from t = 0 s till the frame completely emerges from region B. The graph for region A has been drawn. Values on F axis are not required.

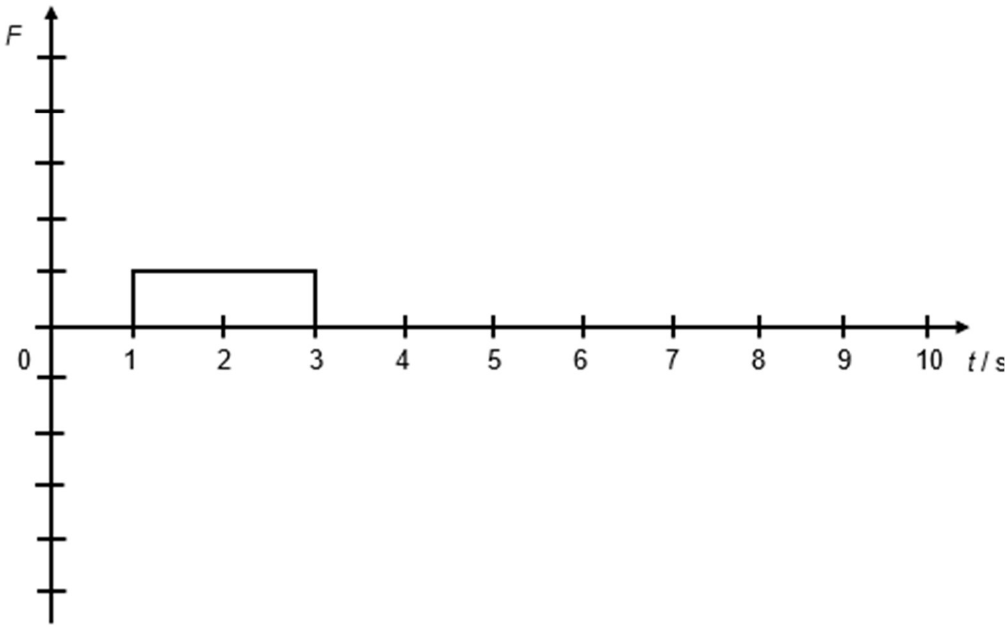

Fig. 8.3

[2]

[Total: 20]

3 A cyclotron is a device used to accelerate ions to very high speeds. Fig. 7.1 shows a top-view diagram of a cyclotron. It is composed of two hollow, semi-circular electrodes called "Dees". The "Dees" are encased inside a vacuum chamber and exposed to a perpendicular uniform magnetic field. An ion source lies in between the "Dees" at point A. An alternating voltage supply is connected across the "Dees" such that the voltage changes between +*V* and -*V* after a constant time duration.

During operation, the voltage supply produces an alternating electric field in the small gap between the "Dees". This is to ensure that the ions are accelerated each time they cross the gap. On entering the "Dees", the uniform magnetic field causes the ions to move in a circular path. As the ions speed up, they travel in ever larger circles within the "Dees". Once the ions reach a sufficiently large speed, they exit through an outlet in one of the "Dees" which is aimed at a target.

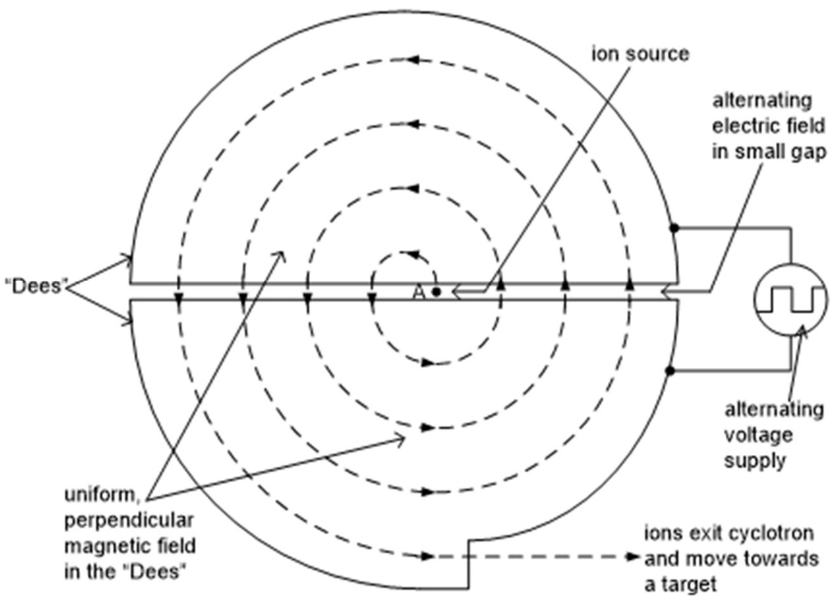

Fig. 7.1

At any time when an ion of mass *m* and charge *q* accelerates across the small gap, the potential difference between the "Dees" is *V*. The ion then travels in a circular path in the "Dees" where a uniform magnetic field of flux density *B* is applied perpendicularly.

3 **(a)** Show that the time T for the ion to complete one revolution in the cyclotron is independent of the radius of its circular path r.

State an assumption you made.

[3]

(b) A helium nucleus of mass 6.68 x 10^{-27} kg and charge $2e$ (where e is the elementary charge) is accelerated in the cyclotron by applying an alternating potential difference of 450 V across the "Dees". The magnetic flux density through the "Dees" is 0.850 T.

(i) Calculate the time T to complete one revolution for the helium nucleus.

T = ……………………s [2]

(ii) Determine the frequency f of the alternating voltage supply so that the helium nucleus is accelerated each time it crosses the gap between the "Dees". Explain your answer.

f = ……………………Hz [2]

(iii) Explain why the expression for the gain in kinetic energy of the helium nucleus after one revolution is $4eV$.

……………………………………………………………………………………………

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4 A small circular conducting wire loop of diameter 3.0 cm is placed inside a larger flat circular loop of diameter 20.0 cm. Current is supplied to the larger loop via a battery and a variable resistor.

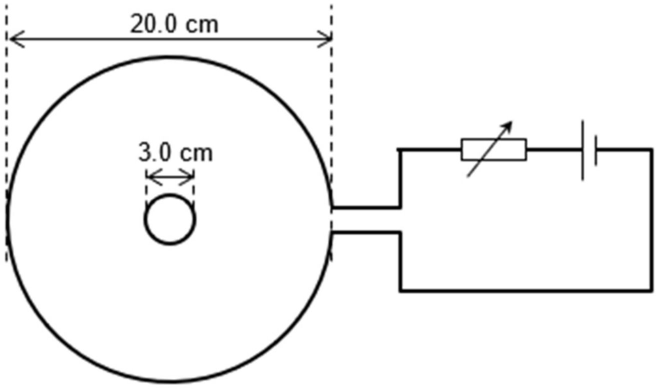

Fig. 5.1

(a) Explain why a current is momentarily detected in the small loop when the resistance of the variable resistor is increased.

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.... [2]

(b) Explain whether the induced current in the small loop flows in a clockwise or anti-clockwise direction as the resistance of the variable resistor is increased.

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.... [2]

(c) Calculate the magnetic flux density at the centre of the large loop when the current is 2.0 A.

magnetic flux density = ... T [1]

4 **(d)** **(i)** The current in the large loop is reduced from 2.0 A to 1.0 A in a time of 0.25 s at a constant rate. Given that the resistance of the small loop is 1.5 Ω, calculate the average current induced in the small loop.

average current = ... A [3]

(ii) State the assumption you made to simplify the calculation in **(d)(i)**.

....

.... [1]

(e) The smaller wire loop is now replaced with a loop of the same dimensions made from an electrical insulator.

Explain why there is no current flowing in this insulating loop when the experiment is repeated.

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.... [2]

[Total: 11]

5 **(a)** Define *magnetic flux density* of a magnetic field.

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....[2]

(b) Fig. 6.1 shows a solenoid of length 50.0 cm and 1000 turns. It is connected in a circuit in series with a horizontal rectangular loop ABCD, where AB = 20.0 cm and BC = 4.0 cm. The loop is freely pivoted about the axis XY.

When there is no current, the loop is balanced without the use of any rider. When a current of 3.0 A flows as shown in Fig. 6.1, a rider of mass 0.40 g is needed to restore balance.

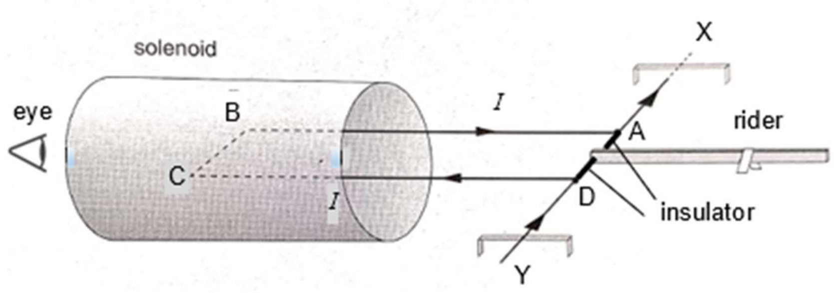

Fig. 6.1

(i) State and explain whether the direction of the current in the solenoid is clockwise or anticlockwise as viewed by the eye.

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....

....[2]

(ii) Calculate the magnetic flux density in the solenoid.

magnetic flux density = ... T [2]

5

(iii) Determine the magnetic force acting on side BC.

force = ... N [1]

(iv) Determine the distance of the rider from the axis XY when balance is restored.

distance = ... cm [2]

6 An electron having charge – q and mass m is accelerated from rest in a vacuum through a potential difference V.

The electron then enters a region of uniform magnetic field of magnetic flux density B, as shown in Fig. 7.1.

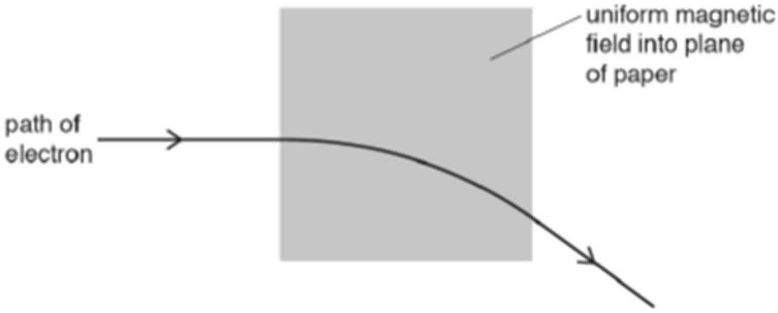

Fig. 7.1

The direction of the uniform magnetic field is into the plane of the paper.
The velocity of the electron as it enters the magnetic field is normal to the magnetic field.
The radius of the circular path of the electron in the magnetic field is r.

(a) Explain why the path of the electron in the magnetic field is the arc of a circle.

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.... [3]

(b) Show that the magnitude p of the momentum of the electron as it enters the magnetic field is given by

$$p = \sqrt{2mqV}$$

[2]

6 **(c)** The potential difference V is 120 V. The radius r of the circular arc is 7.4 cm.
Determine the magnitude of the magnetic flux density B.

B = ... T [3]

[Total: 8]

7 A long vertical rectangular frame, of width of 2.0 m, consists of a 2.0 Ω resistor and conducting wires of negligible resistance. The frame is placed in a uniform magnetic field of flux density 0.35 T. The magnetic field is directed into the plane of the frame.

A horizontal metal rod of mass 0.15 kg and negligible resistance slides along the frame downwards, as shown in Fig. 6.1. The metal rod remains in electrical contact with the frame throughout its motion.

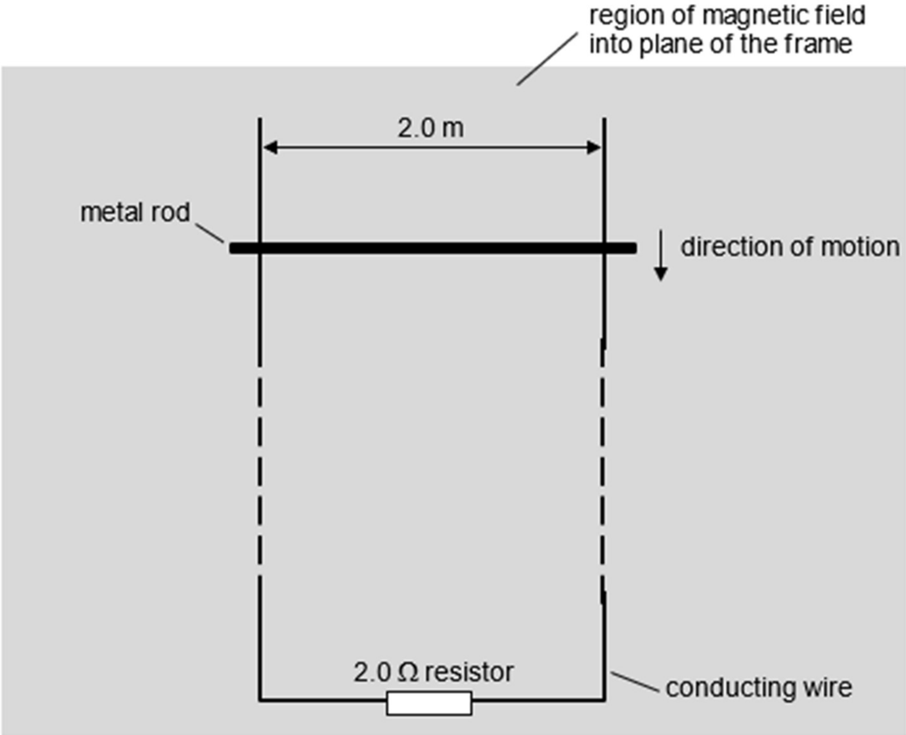

Fig. 6.1

(a) Explain why a magnetic force acts on the metal rod.

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.... [3]

7

(b) State and explain the direction of the magnetic force.

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....

.... [2]

(c) Determine the highest speed the metal rod can reach. Assume that friction and air resistance are negligible.

speed = ... $m\ s^{-1}$ [4]

8 **(a)** Define magnetic flux density.

....

.... [1]

(b) Fig. 6.1 shows two parallel metal plates P and Q placed in a vacuum. P is connected to a positive potential and Q is connected to earth such that a uniform electric field of field strength 500 N C^{-1} is set up in the region between the plates.

A uniform magnetic field is also set up in the region between the plates.

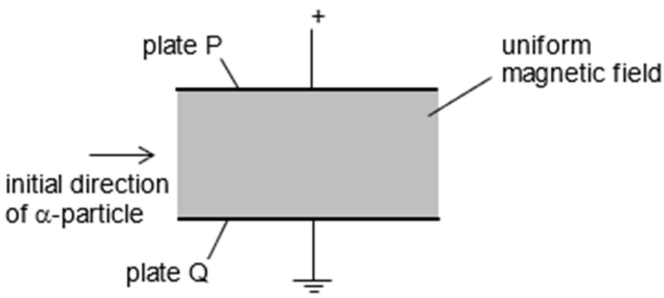

Fig. 6.1

An α-particle of charge +2e, mass 6.64×10^{-27} kg and kinetic energy 120 eV enters the region between the plates at right angles to the electric field. The α-particle travels through the region without any deflection.

(i) State and explain the direction of the magnetic field.

....

....

....

.... [2]

(ii) Show that the electric force on the α-particle is 1.6×10^{-16} N.

[1]

8 **(iii)** Calculate the speed of the α-particle.

speed = ... $m\,s^{-1}$ [2]

(iv) Determine the flux density *B* of the magnetic field.

B = ... T [2]

(v) A proton travels along the same initial path with a kinetic energy of 120 eV. Describe and explain the initial deflection of the proton between the plates.

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.... [3]

9 **(a)** State what is meant by *a magnetic field*.

....

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.... [2]

(b) A 'bus bar' is a metal bar which can used to conduct a large electric current. In a test, two bus bars, X and Y, of length 0.90 m are clamped at either end parallel to each other on a base board, as shown in Fig. 5.1.

When a constant current of 12 kA is carried by each bus bar, they exert a force of 200 N on each other.

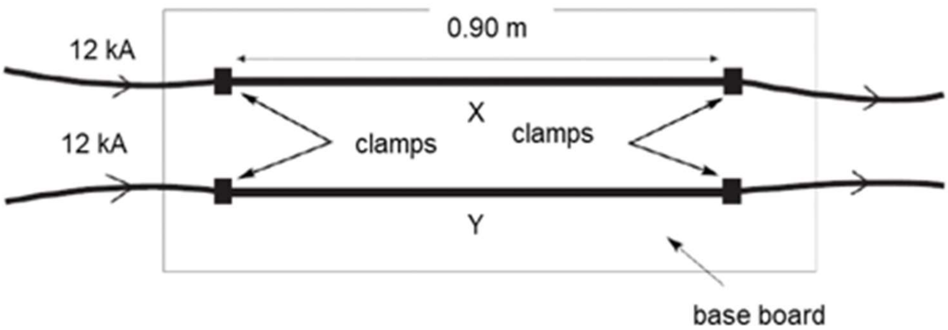

Fig. 5.1

(i) Calculate the magnetic flux density due to the current in one bus bar at the position of the other bus bar.

magnetic flux density = ... T [2]

(ii) Calculate the magnitude of the force on each bus bar if X carried a current of 6.0 kA and Y carried a current of 12 kA in the same direction.

magnetic force on X = ... N

magnetic force on Y = ... N [2]

9 **(c)** A small circular coil of cross sectional area 1.7×10^{-4} m^2 contains 250 turns of wire. The plane of the coil is placed parallel to and a distance x from the pole of a magnet as shown in Fig. 5.2.

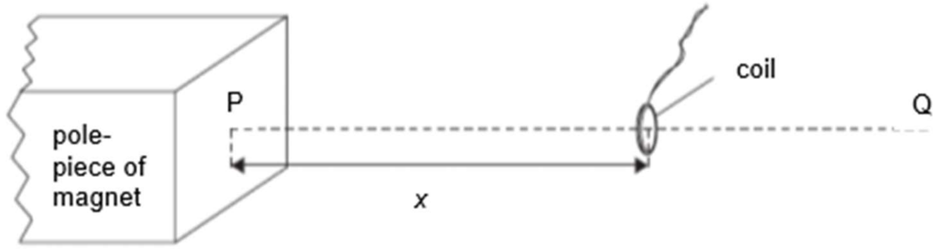

Fig. 5.2

PQ is a line that is normal to the pole piece. The variation with distance x along line PQ of the mean magnetic flux density B in the coil is shown in Fig. 5.3.

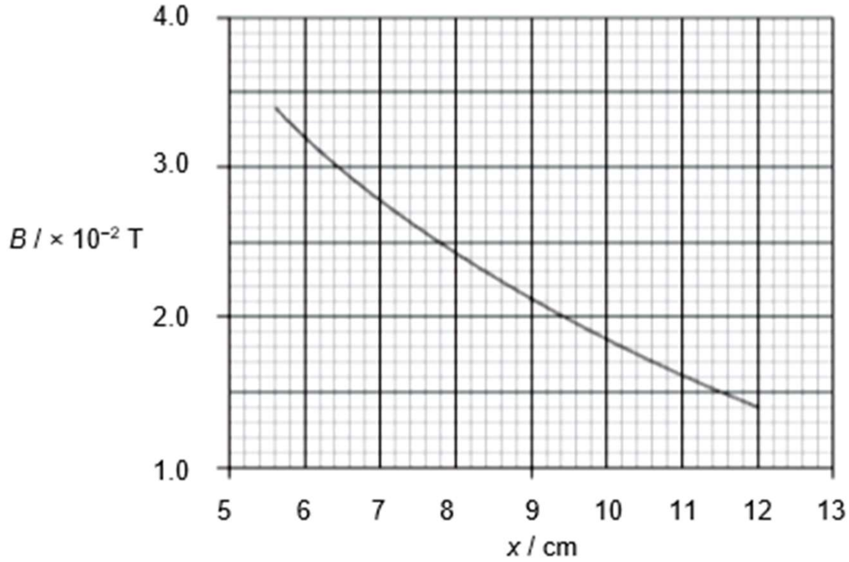

Fig. 5.3

(i) For the coil situated a distance 6.0 cm from the pole piece of the magnet,

1. State the mean magnetic flux density in the coil.

mean magnetic flux density = ………………… T [1]

2. Calculate the magnetic flux linkage through the coil.

magnetic flux linkage = ………………… Wb-turns [2]

9

(ii) The coil is moved along PQ so that the distance *x* changes from 6.0 cm to 12.0 cm in a time of 0.35 s.

1. Determine the change in magnetic flux linkage through the coil.

change in magnetic flux linkage = ………………… Wb-turns [2]

2. State Faraday's law of electromagnetic induction and hence calculate the mean e.m.f. induced in the coil.

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mean e.m.f. induced = ………………… V [2]

(iii) Use Lenz's law to explain why work has to be done to move the coil along the line PQ.

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…………………………………………………………………………………… [2]