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

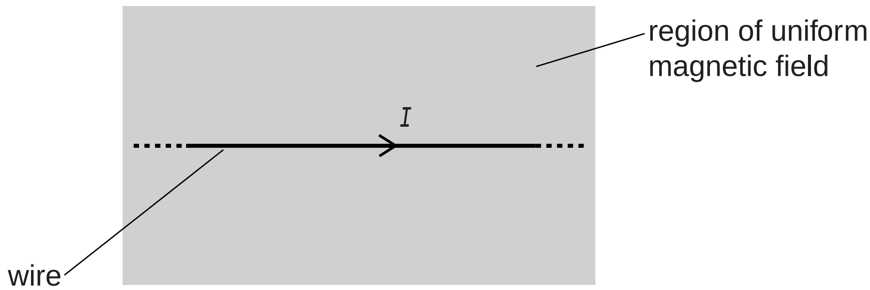

Fig. 2.1

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.

....

.... **[1]**

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

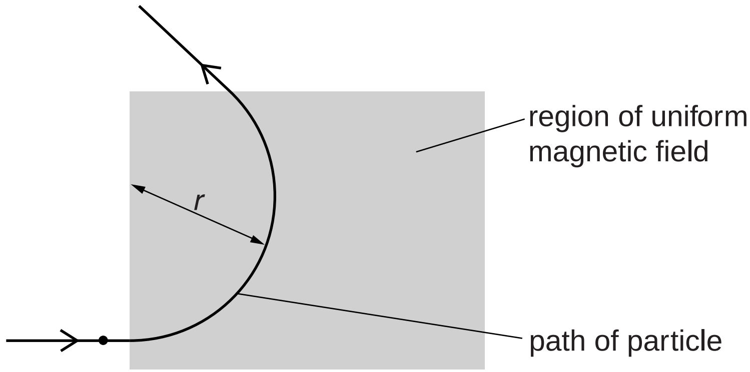

Fig. 2.2

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]

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

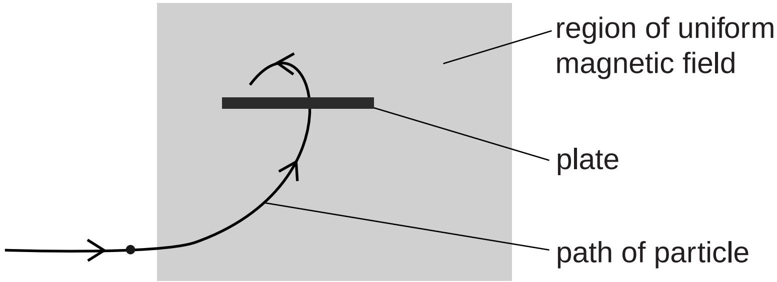

Fig. 2.3

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]**

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

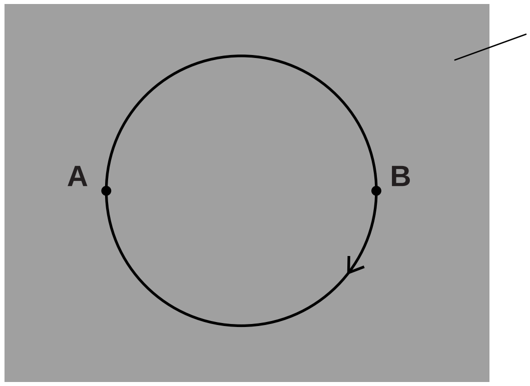

Fig. 2.1

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.

....

....

....

.... **[2]**

[Total: 9]

3 **(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.

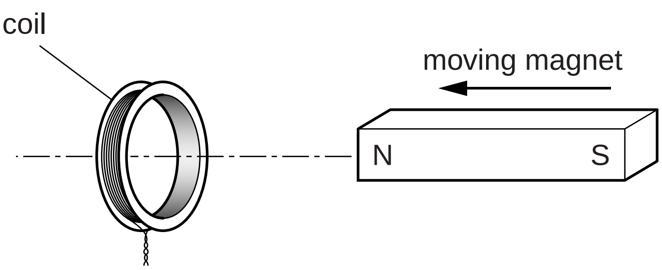

Fig. 5.1

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.

....

....

.... **[1]**

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

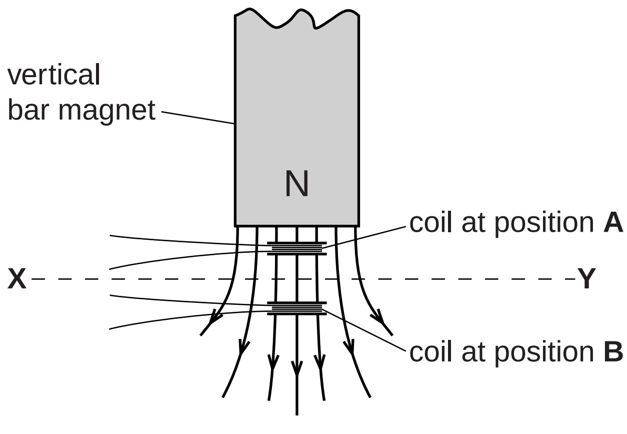

Fig. 5.2

(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.

....

....

.... **[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.

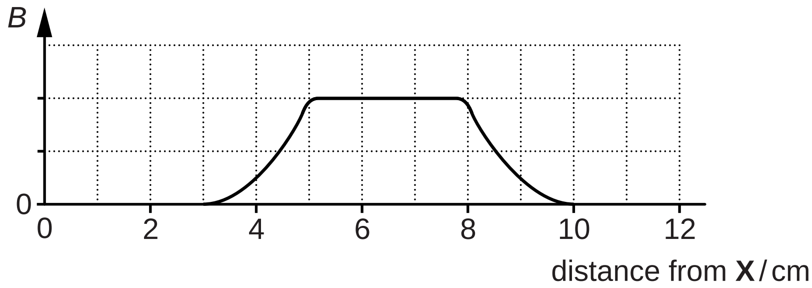

Fig. 5.3

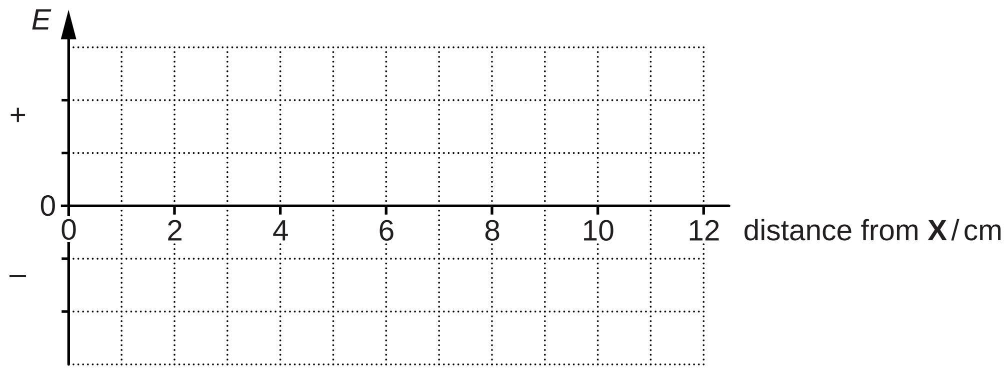

Fig. 5.4

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]**

[Total: 6]

4 Fig. 3.1 shows an arrangement used to accelerate electrons.

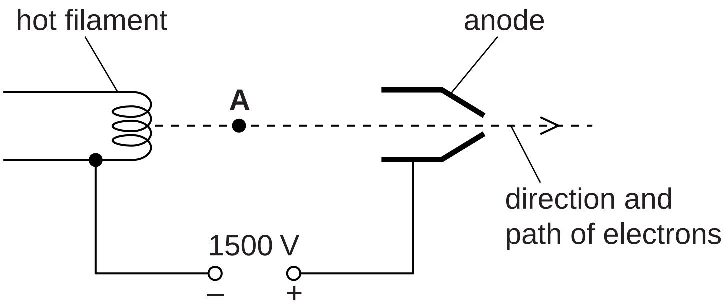

Fig. 3.1

(a) Draw an arrow on Fig. 3.1 to show the direction of the electric field at point **A**. **[1]**

(b) The potential difference between the filament and the anode is 1500 V. The speed of an electron at the filament is negligible.

(i) Determine the kinetic energy in electronvolts (eV) of an electron at the anode.

kinetic energy = ... eV **[1]**

(ii) Calculate the speed v of an electron at the anode.

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

(c) The electrons from the arrangement shown in Fig. 3.1 enter a region of space occupied by both uniform electric and magnetic fields, as shown in Fig. 3.2.

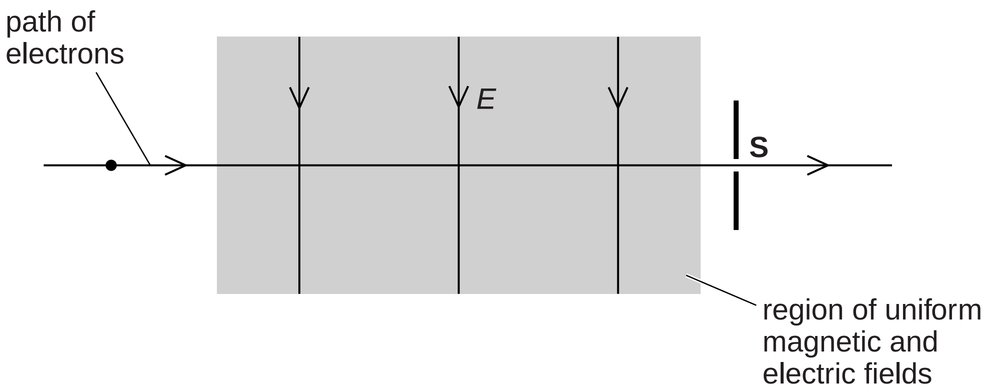

Fig. 3.2

The electric field strength of the electric field is E and its direction is shown in Fig. 3.2. The magnetic flux density of the magnetic field is B. The direction of the magnetic field is perpendicular to E and directed into the plane of the paper. B is increased until all the electrons pass through the slit **S** at a particular speed v. The path of the electrons is now horizontal as shown.

(i) Derive an expression for v in terms of E and B.

[2]

(ii) The magnetic flux density is increased further. The electric field strength is unchanged. Describe and explain what happens to the path of the electrons.

....

....

....

.... **[2]**

[Total: 9]

5 **(a)** Define *magnetic flux*.

....

....

.... **[1]**

(b) Fig. 4.1 shows a solenoid connected to a battery and the magnetic field through it when the switch **S** is closed.

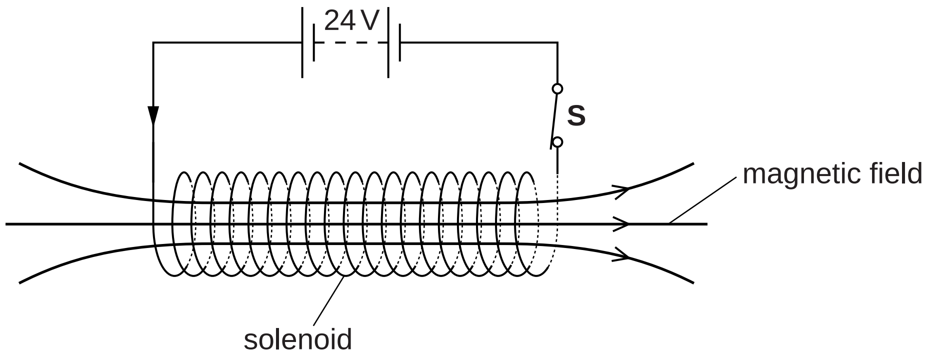

Fig. 4.1

(i) The battery has an e.m.f. of 24 V and negligible internal resistance. The solenoid is made from copper wire. The wire has radius 4.6×10^{-4} m and total length 130 m. The resistivity of copper is $1.7 \times 10^{-8}\ \Omega$ m. Calculate the current in the solenoid.

current = ... A **[3]**

(ii) A tiny electrical spark is created between the contacts of the switch **S** as it is opened. The spark is produced because an e.m.f. is induced across the ends of the solenoid by the collapse of the magnetic flux linked with the solenoid.

The initial magnetic flux density within the solenoid is 0.090T and may be assumed to be uniform. The solenoid has 1100 turns and cross-sectional area $1.3 \times 10^{-3}\,m^2$.

The average e.m.f. induced across the ends of the solenoid is 150V. Estimate the time taken for the magnetic flux to collapse to zero.

time = ... s **[3]**

[Total: 7]

6 Fig. 2.1 shows the circular track of an electron moving in a uniform magnetic field.

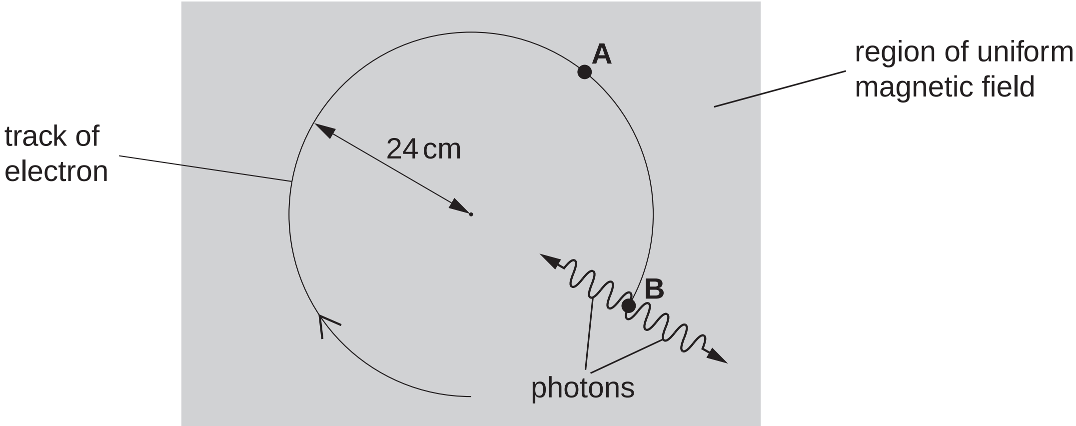

Fig. 2.1

The magnetic field is perpendicular to the plane of Fig. 2.1. The speed of the electron is $6.0 \times 10^{7}\,\mathrm{m\,s^{-1}}$ and the radius of the track is 24 cm. At point **B** the electron interacts with a stationary positron.

(a) **(i)** On Fig. 2.1, draw an arrow to show the force acting on the electron when at point **A**. Label this arrow **F**. **[1]**

(ii) Explain why this force does not change the speed of the electron.

....

....

.... **[1]**

(b) Calculate the magnitude of the force F acting on the electron due to the magnetic field when it is at **A**.

F = ... N **[2]**

(c) Calculate the magnetic flux density of the magnetic field.

magnetic flux density = ... T **[2]**

(d) At point **B**, the electron and the positron annihilate each other. A positron has a positive charge and the same mass as the electron. The particles create two gamma ray photons. Calculate the wavelength of the gamma rays assuming the kinetic energy of the electron is negligible.

In your answer, you should make your reasoning clear.

wavelength = ... m **[3]**

[Total: 9]