1)

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

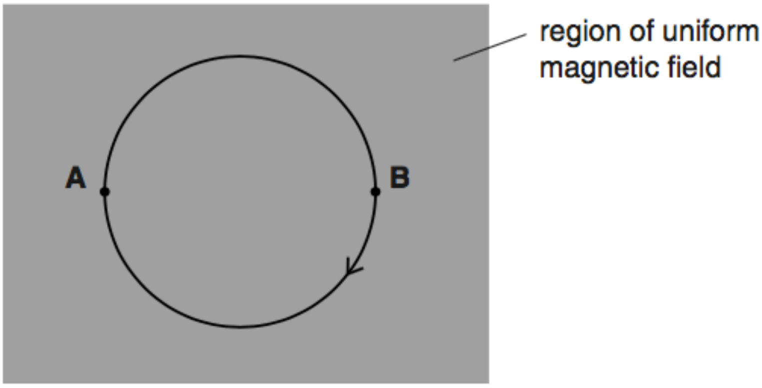


**Fig. 2.1**

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 $+3.2 \times 10^{-19}$ C and mass $6.6 \times 10^{-27}$ kg.

**(a)** Explain why the helium nucleus

**(i)** travels in a circular path

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.............................................................................................................................. **[1]**

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

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.............................................................................................................................. **[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]**

**[Total: 9]**

2)

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

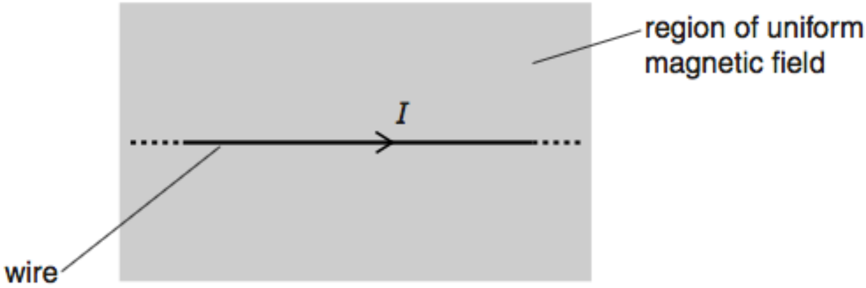


**Fig. 2.1**

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 $6.8 \times 10^{-5}$ 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.

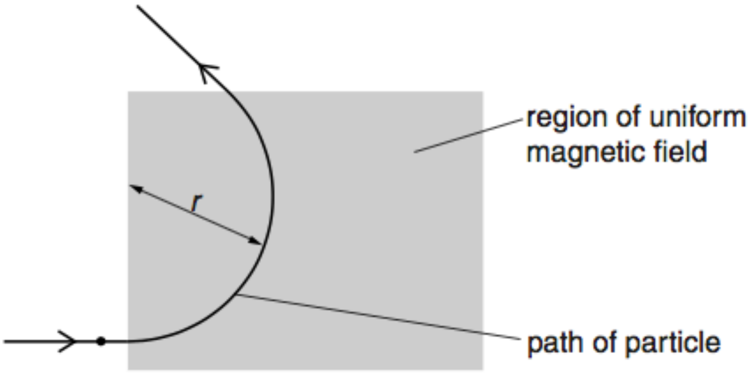


**Fig. 2.2**

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.

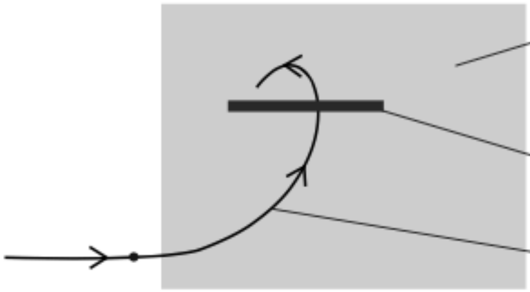


**Fig. 2.3**

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]**

3)

Fig. 3.1 shows part of an accelerator used to produce high-speed protons. The protons pass through an evacuated tube that is shown in the plane of the paper.

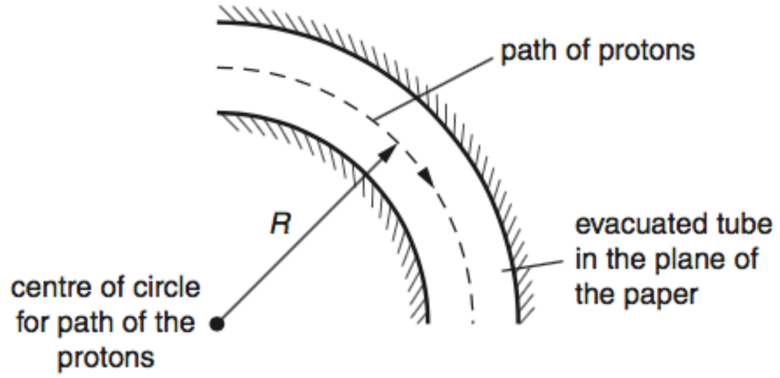


**Fig. 3.1**

The protons are made to travel in a circle of radius *R* by a magnetic field of flux density *B*.

**(a)** State clearly the direction of the magnetic flux density *B* that produces the circular motion of the protons.

............................................................................................................................................ **[1]**

**(b)** Show that the relationship between the velocity *v* of the protons and the radius *R* is given by $v = \frac{BQR}{m}$ where *Q* and *m* are the charge and mass of a proton respectively.

**[1]**

**(c)** Calculate the magnetic flux density *B* of the magnetic field needed to keep protons in a circular orbit of radius 0.18 m. The time for one complete orbit is $2.0 \times 10^{-8}$ s.

*B* = ...................................................... T **[3]**

**(d)** Explain why the magnetic field does not change the speed of the protons.

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.................................................................................................................................. **[2]**

**[Total: 7]**

4)

**(a)** Define *torque of a couple.*

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**(b)** Fig. 2.1 shows a current-carrying square coil placed in a uniform magnetic field.

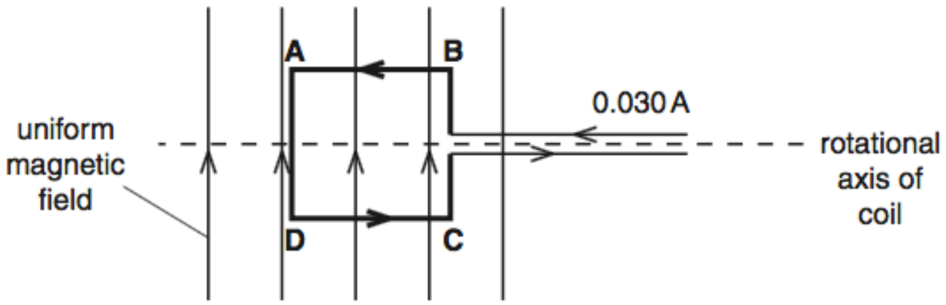


**Fig. 2.1**

The length of each side of the coil is 0.015 m. The plane of the coil is parallel to the magnetic field. The magnetic field is at right angles to the section **AB** of the coil and has magnetic flux density 0.060 T. The current in the coil is 0.030 A.

**(i)** Use Fleming's left-hand rule to determine the direction of the force on section **AB** of the coil.

.......................................................................................................................................... **[1]**

**(ii)** The current-carrying coil will rotate because it experiences a torque. With the coil in the position shown in Fig. 2.1, calculate

**1** the force experienced by the length **AB**

force = ........................................................N **[1]**

**2** the torque experienced by the coil.

torque = ................................................ N m **[2]**

**(c)** Fig. 2.2 shows the path of a positive ion of oxygen-16 inside a mass spectrometer.

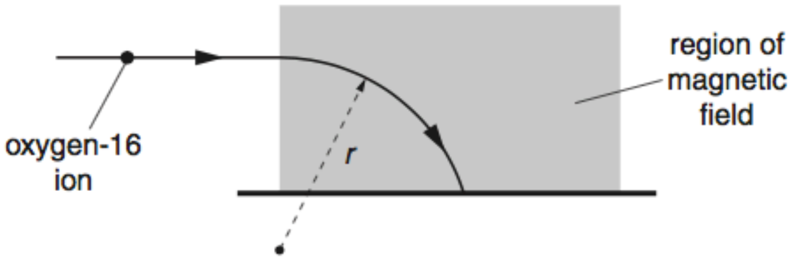


**Fig. 2.2**

The shaded area in Fig. 2.2 represents a region of uniform magnetic field of flux density 0.14 T. The direction of the magnetic field is out of the plane of the paper. The ion has a speed of $4.5 \times 10^{6}\,\text{m s}^{-1}$ and it enters the region at right angles to the magnetic field. While the ion is in the magnetic field, it describes a circular arc of radius *r*. The force experienced by the ion in the magnetic field is $2.0 \times 10^{-13}$ N.

**(i)** Calculate the charge *Q* of the ion.

*Q* = ........................................................C **[2]**

**(ii)** The mass of the ion is $2.7 \times 10^{-26}$ kg. Calculate the radius *r* of the circular path.

*r* = ...................................................... m **[3]**

**(iii)** In Fig. 2.2, the oxygen-16 ion is replaced by an oxygen-18 ion. The oxygen-18 ion has the same speed and charge. Explain why this ion describes an arc of greater radius.

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**[Total: 12]**

5)

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

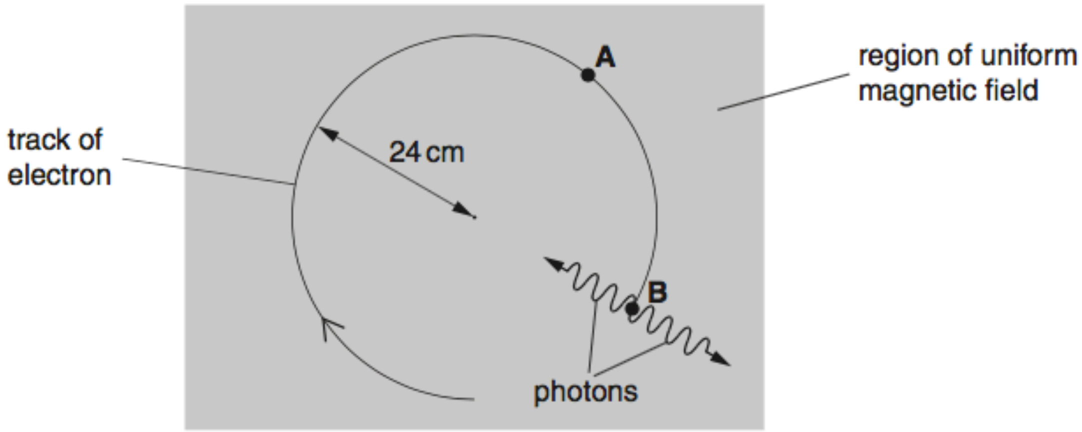


**Fig. 2.1**

The magnetic field is perpendicular to the plane of Fig. 2.1. The speed of the electron is $6.0 \times 10^7\,\text{m}\,\text{s}^{-1}$ 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.

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**(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]**

6)

Fig. 3.1 shows a section through a mass spectrometer.

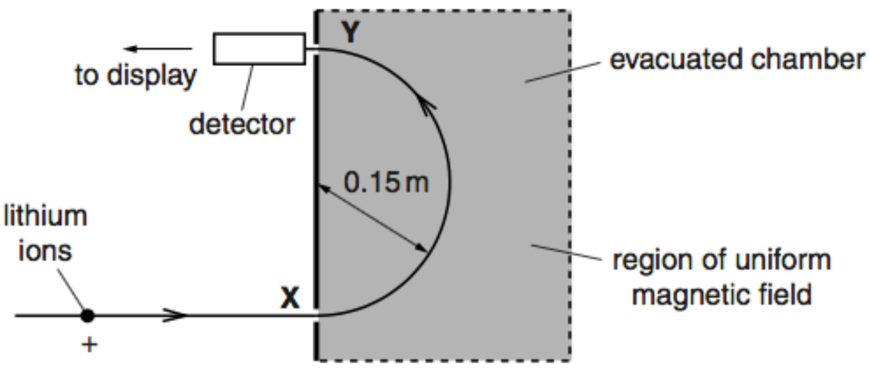


**Fig. 3.1**

A beam of positive lithium ions enter the evacuated chamber through the hole at **X**. The ions travel through a region of uniform magnetic field. The magnetic field is directed vertically into the plane of the diagram. The ions exit and are detected at **Y**.

**(a)** Name the rule that may be used to determine the direction of the force acting on the ions.

.............................................................................................................................. **[1]**

**(b)** Explain why the speed of the ions travelling from **X** to **Y** in the magnetic field does not change despite the force acting on the ions.

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.............................................................................................................................. **[1]**

**(c)** The lithium-7 ions are detected at **Y**. All the ions have the same speed, $4.0 \times 10^5\,\mathrm{m\,s^{-1}}$ and charge, $+1.6 \times 10^{-19}\,\mathrm{C}$. The radius of the semi-circular path of the ions in the magnetic field is 0.15 m. The mass of a lithium-7 ion is $1.2 \times 10^{-26}\,\mathrm{kg}$.

**(i)** Calculate the force acting on a lithium ion as it moves in the semi-circle.

force = ...................................................... N **[2]**

**(ii)** Calculate the magnitude of the magnetic flux density $B$.

$B$ = ..................................................... T **[2]**

**(iii)** The current recorded by the detector at **Y** is $4.8 \times 10^{-9}$ A. Calculate the number of lithium-7 ions reaching the detector per second.

number per second = ................................................... $s^{-1}$ **[2]**

**(d)** Fig. 3.2 shows the variation of current $I$ in the detector with magnetic flux density $B$.

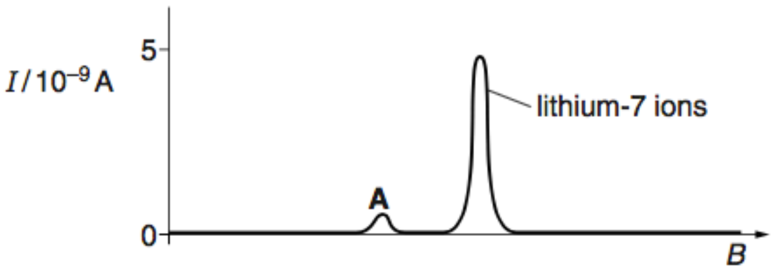


**Fig. 3.2**

The peak **A** is due to ions of another isotope of lithium. These ions have the same speed and charge as the lithium-7 ions. Explain the significance of the 'height' and position of peak **A**.

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**[Total: 10]**