Particles from Space

Revised AH Physics 2014

7. The Sun is constantly losing mass through nuclear fusion. Particles also escape from the corona as shown in Figure 7A. This stream of particles radiating from the Sun is known as the Solar wind and its main constituent, by mass, is protons.

Figure 7A

(*a*) Astronomers estimate that the Sun loses mass at a rate of $1{\cdot}0 \times 10^9\,\mathrm{kg\,s^{-1}}$. This rate has been approximately constant through the Sun's lifetime of $4{\cdot}6 \times 10^9$ years.

Estimate the mass lost by the Sun in its lifetime as a percentage of its current mass. **2**

(*b*) A proton in the solar wind has energy of 3·6 MeV.

(i) Calculate the velocity of this proton. **3**

(ii) The proton enters the magnetic field around the Earth at an angle of 50° as shown in Figure 7B. The magnetic field strength is $58\,\mu\mathrm{T}$.

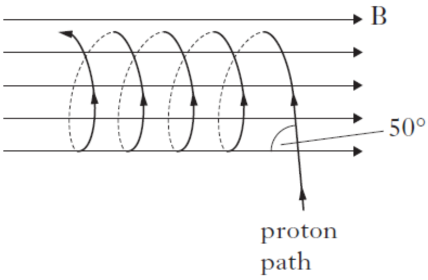

Figure 7B

(A) Explain the shape of the path followed by the proton in the magnetic field. **2**

(B) Calculate the radius of curvature of this path. **3**

(iii) An antiproton of energy 3·6 MeV enters the same region of the Earth's magnetic field at an angle of 30° to the field.

Describe **two** differences in the paths taken by the antiproton and the original proton. **2**

(12)

9. (*a*) A proton moving at constant speed v enters a uniform magnetic field of induction B as shown in Figure 9A.

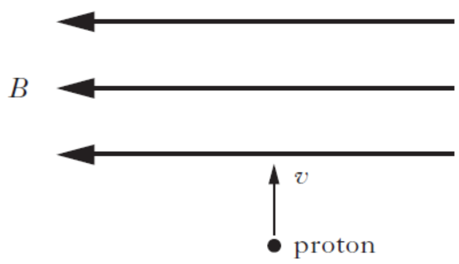

Figure 9A

Within the field the proton follows a circular path of radius r.

(i) Explain why the proton follows a circular path. **1**

(ii) Show that the radius of the path r is given by

$$r = \frac{1 \cdot 05 \times 10^{-8} v}{B}.$$ **2**

(*b*) Another proton moving at the same speed v enters the magnetic field at an angle θ to the magnetic field lines as shown in Figure 9B.

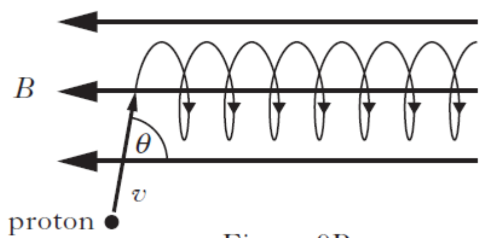

Figure 9B

Explain the shape of the path followed by this proton in the magnetic field. **2** (*c*) The solar wind is a stream of charged particles, mainly protons and electrons, released from the atmosphere of the Sun. Many of these particles become trapped by the magnetic field of the Earth.

Some of the trapped particles move back and forth in helical paths between two ***magnetic mirror points***. The path followed by one particular proton is shown in Figure 9C.

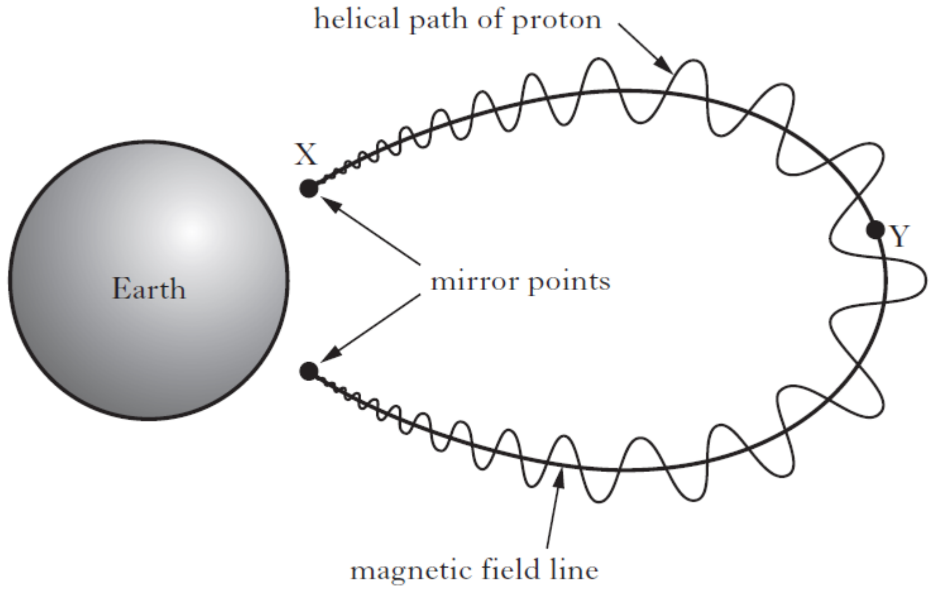

Figure 9C

The speed of the proton remains constant at $1{\cdot}2 \times 10^7\,\text{m s}^{-1}$ as it travels along its helical path from one magnetic mirror point to the other.

(i) The proton oscillates between the two mirror points with a frequency of 4·0 Hz. Calculate the distance that the proton travels in moving from one mirror point to the other. **3**

(ii) Explain why the radius of the helical path followed by the proton increases as it moves from point X to point Y as shown in Figure 9C. **1**

(iii) At point X the radius of curvature of the helix for this proton is $1{\cdot}0 \times 10^4\,\text{m}$. Calculate the strength of the Earth's magnetic field at this point. **2**

(11)

9. A particle with charge q and mass m is travelling with constant speed v. The particle enters a uniform magnetic field at 90° and is forced to move in a circle of radius r as shown in Figure 9.

The magnetic induction of the field is B.

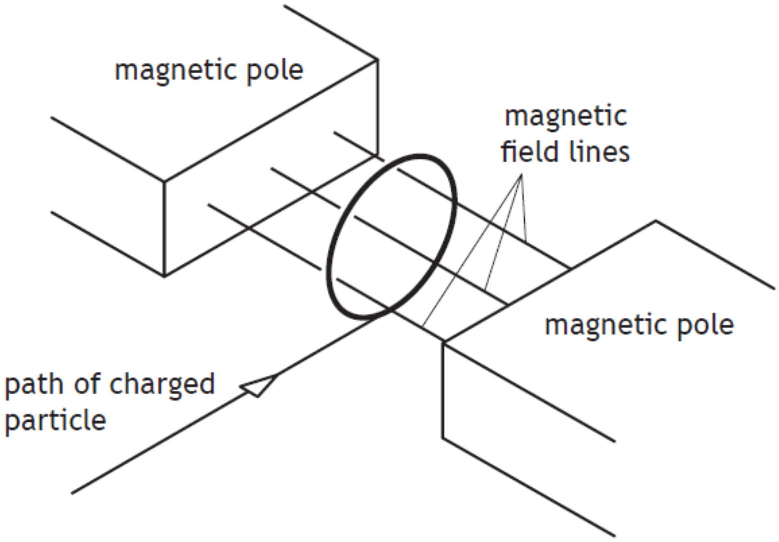

Figure 9

(a) Show that the radius of the circular path of the particle is given by

$$r = \frac{mv}{Bq}$$

2

(b) In an experimental nuclear reactor, charged particles are contained in a magnetic field. One such particle is a deuteron consisting of one proton and one neutron.

The kinetic energy of each deuteron is 1·50 MeV.

The mass of the deuteron is $3{\cdot}34 \times 10^{-27}$ kg.

Relativistic effects can be ignored.

(i) Calculate the speed of the deuteron. **4**

(ii) Calculate the magnetic induction required to keep the deuteron moving in a circular path of radius 2·50 m. **2**

(b) (continued) **MARKS**

(iii) Deuterons are fused together in the reactor to produce isotopes of helium.

$^{3}_{2}He$ nuclei, each comprising 2 protons and 1 neutron, are present in the reactor.

A $^{3}_{2}He$ nucleus also moves in a circular path in the same magnetic field.

The $^{3}_{2}He$ nucleus moves at the same speed as the deuteron.

State whether the radius of the circular path of the $^{3}_{2}He$ nucleus is greater than, equal to or less than 2·50 m.

You must justify your answer. **2**