20–4 Force on Charge Moving in Magnetic Field

9. (I) Alpha particles of charge $q = +2e$ and mass $m = 6.6 \times 10^{-27}\,\text{kg}$ are emitted from a radioactive source at a speed of $1.6 \times 10^{7}\,\text{m/s}$. What magnetic field strength would be required to bend them into a circular path of radius $r = 0.25\,\text{m}$?

10. (I) Determine the magnitude and direction of the force on an electron traveling $8.75 \times 10^{5}\,\text{m/s}$ horizontally to the east in a vertically upward magnetic field of strength 0.75 T.

11. (I) Find the direction of the force on a negative charge for each diagram shown in Fig. 20–51, where $\vec{\mathbf{v}}$ (green) is the velocity of the charge and $\vec{\mathbf{B}}$ (blue) is the direction of the magnetic field. (⊗ means the vector points inward. ⊙ means it points outward, toward you.)

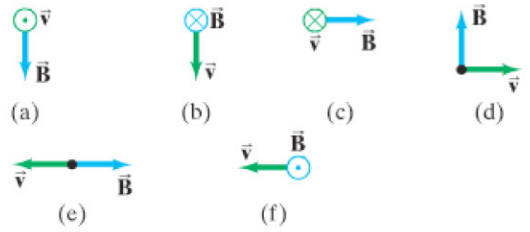

FIGURE 20–51 Problem 11.

12. (I) Determine the direction of $\vec{\mathbf{B}}$ for each case in Fig. 20–52, where $\vec{\mathbf{F}}$ represents the maximum magnetic force on a positively charged particle moving with velocity $\vec{\mathbf{v}}$.

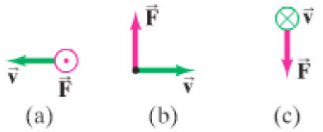

FIGURE 20–52 Problem 12.

13. (I) An electron is projected vertically upward with a speed of $1.70 \times 10^{6}\,\text{m/s}$ into a uniform magnetic field of 0.350 T that is directed horizontally away from the observer. Describe the electron's path in this field.

14. (II) A 5.0-MeV (kinetic energy) proton enters a 0.20-T field, in a plane perpendicular to the field. What is the radius of its path?

15. (II) An electron experiences the greatest force as it travels $2.9 \times 10^{6}\,\text{m/s}$ in a magnetic field when it is moving northward. The force is upward and of magnitude $7.2 \times 10^{-13}\,\text{N}$. What are the magnitude and direction of the magnetic field?

16. (II) What is the velocity of a beam of electrons that go undeflected when passing through perpendicular electric and magnetic fields of magnitude $8.8 \times 10^{3}\,\text{V/m}$ and $3.5 \times 10^{-3}\,\text{T}$, respectively? What is the radius of the electron orbit if the electric field is turned off?

17. (II) A doubly charged helium atom whose mass is $6.6 \times 10^{-27}\,\text{kg}$ is accelerated by a voltage of 2100 V. (*a*) What will be its radius of curvature if it moves in a plane perpendicular to a uniform 0.340-T field? (*b*) What is its period of revolution?

18. (II) A proton (mass m_p), a deuteron $(m = 2m_\text{p},\ Q = e)$, and an alpha particle $(m = 4m_\text{p},\ Q = 2e)$ are accelerated by the same potential difference V and then enter a uniform magnetic field $\vec{\mathbf{B}}$, where they move in circular paths perpendicular to $\vec{\mathbf{B}}$. Determine the radius of the paths for the deuteron and alpha particle in terms of that for the proton.

19. (II) Show that the time T required for a particle of charge q moving with constant speed v to make one circular revolution in a uniform magnetic field $\vec{\mathbf{B}}\ (\perp \vec{\mathbf{v}})$ is

$$T = \frac{2\pi m}{qB}.$$

[*Hint:* see Example 20–5 and Chapter 5.]

20. (II) A particle of charge q moves in a circular path of radius r in a uniform magnetic field B. Show that its momentum is $p = qBr$.

21. (II) A particle of mass m and charge q moves in a circular path in a magnetic field B. Show that its kinetic energy is proportional to r^2, the square of the radius of curvature of its path.

22. (II) Show that the angular momentum of the particle in Problem 21 is $L = qBr^2$ about the center of the circle.

23. (III) A 3.40-g bullet moves with a speed of 160 m/s perpendicular to the Earth's magnetic field of $5.00 \times 10^{-5}\,\text{T}$. If the bullet possesses a net charge of $13.5 \times 10^{-9}\,\text{C}$, by what distance will it be deflected from its path due to the Earth's magnetic field after it has traveled 1.00 km?

24. (III) Suppose the Earth's magnetic field at the equator has magnitude $0.40 \times 10^{-4}\,\text{T}$ and a northerly direction at all points. Estimate the speed a singly ionized uranium ion ($m = 238\,\text{u},\ q = e$) would need to circle the Earth 5.0 km above the equator. Can you ignore gravity?

25. (III) A proton moving with speed $v = 2.0 \times 10^{5}\,\text{m/s}$ in a field-free region abruptly enters an essentially uniform magnetic field $B = 0.850\,\text{T}$ $(\vec{\mathbf{B}} \perp \vec{\mathbf{v}})$. If the proton enters the magnetic field region at a 45° angle as shown in Fig. 20–53, (*a*) at what angle does it leave, and (*b*) at what distance x does it exit the field?

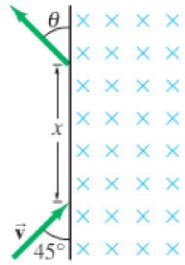

FIGURE 20–53 Problem 25.

20–5 and 20–6 Magnetic Field of Straight Wire, Force Between Two Wires

26. (I) A jumper cable used to start a stalled vehicle carries a 65-A current. How strong is the magnetic field 6.0 cm away from it? Compare to the Earth's magnetic field.

27. (I) If an electric wire is allowed to produce a magnetic field no larger than that of the Earth $(0.55 \times 10^{-4}\,\text{T})$ at a distance of 25 cm, what is the maximum current the wire can carry?

28. (I) In Fig. 20–54, a long straight wire carries current I out of the page toward you. Indicate, with appropriate arrows, the direction of $\vec{\mathbf{B}}$ at each of the points C, D, and E in the plane of the page.

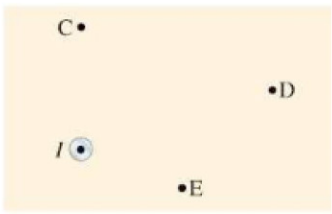

FIGURE 20–54 Problem 28.

29. (I) A vertical straight wire carrying an upward 24-A current exerts an attractive force per unit length of $8.8 \times 10^{-4}\,\text{N/m}$ on a second parallel wire 7.0 cm away. What current (magnitude and direction) flows in the second wire?

30. (I) Determine the magnitude and direction of the force between two parallel wires 35 m long and 6.0 cm apart, each carrying 25 A in the same direction.