Chapter 19

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. If the magnitude of the magnetic force on the wire equals the weight of the wire, then $BI\ell\sin\theta = w$, or $B = w/I\ell\sin\theta$. The magnitude of the magnetic field is a minimum when $\theta = 90°$ and $\sin\theta = 1$. Thus,

$$B_{min} = \frac{w}{I\ell} = \frac{1.0\times10^{-2}\text{ N}}{(0.10\text{ A})(0.50\text{ m})} = 0.20\text{ T}$$

and (a) is the correct answer for this question.

2. The electron moves in a horizontal plane in a direction of 35° N of E, which is the same as 55° E of N. Since the magnetic field at this location is horizontal and directed due north, the angle between the direction of the electron's velocity and the direction of the magnetic field is 55°. The magnitude of the magnetic force experienced by the electron is then

$$F = |q|vB\sin\theta = (1.6\times10^{-19}\text{ C})(2.5\times10^{6}\text{ m/s})(0.10\times10^{-4}\text{ T})\sin 55° = 3.3\times10^{-18}\text{ N}$$

The right-hand rule number 1 predicts a force directed upward, away from the Earth's surface for a positively charged particle moving in the direction of the electron. However, the *negatively charged* electron will experience a force in the opposite direction, downward *toward* the Earth's surface. Thus, the correct choice is (d).

4. The magnitude of the magnetic field at distance r from a long straight wire carrying current I is $B = \mu_0 I/2\pi r$. Thus, for the described situation,

$$B = \frac{(4\pi\times10^{-7}\text{ T}\cdot\text{m/A})(1\text{ A})}{2\pi(2\text{ m})} = 1\times10^{-7}\text{ T}$$

making (d) the correct response.

5. Since the proton follows a semicircular path, not a helical path, it entered perpendicularly to the field. A charged particle moving perpendicular to a magnetic field experiences a centripetal force of magnitude $F_c = mv^2/r = qvB$ and follows a circular path of radius $r = mv/qB$. The speed of this proton must be

$$v = \frac{qBr}{m} = \frac{(1.6\times10^{-19}\text{ C})(0.050\text{ T})(1.0\times10^{-3}\text{ m})}{1.67\times10^{-27}\text{ kg}} = 4.8\times10^{3}\text{ m/s}$$

and choice (e) is the correct answer.

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

2. It should point straight down toward the surface of the Earth.

12. Near the poles the magnetic field of Earth points almost straight downward (or straight upward), in the direction (or opposite to the direction) the charges are moving. As a result, there is little or no magnetic force exerted on the charged particles at the pole to deflect them away from Earth.

PROBLEM SOLUTIONS

19.1 Remember that the direction of the magnetic force exerted on the negatively charged electron is opposite to the direction predicted by right-hand rule number 1. The magnetic field near the Earth's equator is horizontal and directed toward the north. The magnetic force experienced by a moving charged particle is always perpendicular to the plane formed by the vectors representing the magnetic field and the particle's velocity.

(a) When the velocity of a positively charged particle is downward, right-hand rule number 1 predicts a magnetic force toward the east. Hence, the force experienced by the negatively charged electron (and also the deflection of its velocity) is directed $\boxed{\text{toward the west}}$.

(b) When the particle moves northward, its velocity is parallel to the magnetic field, and it will experience $\boxed{\text{zero force and zero deflection}}$.

(c) The direction of the force on the negatively charged electron (and the deflection of its velocity) will be $\boxed{\text{vertically upward}}$.

(d) The direction of the force on the negatively charged electron (and the deflection of its velocity) will be $\boxed{\text{vertically downward}}$.

19.3 Since the particle is positively charged, use the right-hand rule number 1. In this case, start with the fingers of the right hand in the direction of $\vec{\mathbf{v}}$ and the thumb pointing in the direction of $\vec{\mathbf{F}}$. As you start closing the hand, the fingers point in the direction of $\vec{\mathbf{B}}$ after they have moved 90°. The results are

(a) $\boxed{\text{into the page}}$ (b) $\boxed{\text{toward the right}}$ (c) $\boxed{\text{toward bottom of page}}$

19.13 From $F = BIL\sin\theta$, the magnetic field is

$$B = \frac{F/L}{I\sin\theta} = \frac{0.12\ \text{N/m}}{(15\ \text{A})\sin 90^\circ} = \boxed{8.0\times10^{-3}\ \text{T}}$$

The direction of $\vec{\mathbf{B}}$ must be $\boxed{\text{the }+z\text{-direction}}$ to have $\vec{\mathbf{F}}$ in the $-y$-direction when $\vec{\mathbf{I}}$ is in the $+x$-direction.

19.15 Use the right-hand rule number 1, holding your right hand with the fingers in the direction of the current and the thumb pointing in the direction of the force. As you close your hand, the fingers will move toward the direction of the magnetic field. The results are

(a) $\boxed{\text{into the page}}$ (b) $\boxed{\text{toward the right}}$ (c) $\boxed{\text{toward the bottom of the page}}$

19.17 $F = BIL\sin\theta = (0.300\ \text{T})(10.0\ \text{A})(5.00\ \text{m})\sin(30.0^\circ) = \boxed{7.50\ \text{N}}$

19.43 Treat the lightning bolt as a long, straight conductor. Then, the magnetic field is

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(1.00\times10^{4}\ \text{A})}{2\pi(100\ \text{m})} = 2.00\times10^{-5}\ \text{T} = \boxed{20.0\ \mu\text{T}}$$

19.47 From $B = \mu_0 I/2\pi r$, the required distance is

$$r = \frac{\mu_0 I}{2\pi B} = \frac{(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(20\ \text{A})}{2\pi(1.7\times10^{-3}\ \text{T})} = 2.4\times10^{-3}\ \text{m} = \boxed{2.4\ \text{mm}}$$

19.55 (a) The magnetic force per unit length on each of two parallel wires separated by the distance d and carrying currents I_1 and I_2 has the magnitude

$$\frac{F}{\ell}=\frac{\mu_0 I_1 I_2}{2\pi d}$$

In this case, we have

$$\frac{F}{\ell}=\frac{\left(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A}\right)(1.25\ \text{A})(3.50\ \text{A})}{2\pi\left(2.50\times10^{-2}\ \text{m}\right)}=\boxed{3.50\times10^{-5}\ \text{N/m}}$$

(b) The magnetic forces two parallel wires exert on each other are attractive if their currents are in the same direction and repulsive if the currents flow in opposite directions. In this case, the currents in the two wires are in opposite directions, so the forces are $\boxed{\text{repulsive}}$.