Chapter 20

1. (a) What is the magnitude of the force per meter of length on a straight wire carrying an 8.40-A current when perpendicular to a 0.90-T uniform magnetic field? (b) What if the angle between the wire and field is 45.0°?

(a) Use Eq. 20-1 to calculate the force with an angle of 90° and a length of 1 meter.
\[ F = ILB \sin \theta \rightarrow \frac{F}{l} = IB \sin \theta = (8.40 \text{ A})(0.90 \text{ T}) \sin 90° = 7.56 \text{ N/m} \]

(b) \[ \frac{F}{l} = IB \sin \theta = (8.40 \text{ A})(0.90 \text{ T}) \sin 45.0° = 5.34 \text{ N/m} \]

9. 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 magnitude field strength would be required to bend them into a circular path of radius \( r = 0.25 \text{ m} \)?

In this scenario, the magnetic force is causing centripetal motion, and so must have the form of a centripetal force. The magnetic force is perpendicular to the velocity at all times for circular motion.
\[ F_{\text{max}} = qvB = \frac{mv^2}{r} \rightarrow B = \frac{mv}{qr} = \frac{(6.6 \times 10^{-27} \text{ kg})(1.6 \times 10^7 \text{ m/s})}{2(1.60 \times 10^{-19} \text{ C})(0.25 \text{ m})} = 1.32 \text{ T} \]

10. 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 \( 0.75 \text{ T} \).

The maximum magnetic force as given in Eq. 20-4 can be used since the velocity is perpendicular to the magnetic field.
\[ F_{\text{max}} = qvB = (1.60 \times 10^{-19} \text{ C})(8.75 \times 10^5 \text{ m/s})(0.75 \text{ T}) = 1.05 \times 10^{-13} \text{ N} \]

By the right hand rule, the force must be directed to the [North].

26. 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.

We assume the jumper cable is a long straight wire, and use Eq. 20-6.
\[ B_{\text{cable}} = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7} \text{ Tm/A})(65 \text{ A})}{2\pi (6.0 \times 10^{-2} \text{ m})} = 2.17 \times 10^{-4} \text{ T} \]

Compare this to the Earth’s field of \( 5 \times 10^{-5} \text{ T} \).
\[ \frac{B_{\text{cable}}}{B_{\text{Earth}}} = \frac{2.167 \times 10^{-4} \text{ T}}{5 \times 10^{-5} \text{ T}} = 4.33, \text{ so the field of the cable is about 4 times that of the Earth.} \]
Note: In WebAssign, they chose a much smaller current (15.0 A) so $B_{\text{cable}}$ comes out to be less than $B_{\text{Earth}}$. The second part of the question in WebAssign says: “What percentage of the Earth's magnetic field ($5.00 \times 10^{-5} \text{T}$) is this?”

43. Two long wires are oriented so that they are perpendicular to each other. At their closest, they are 20.0 cm apart (Fig. 20-59). What is the magnitude of the magnetic field at a point midway between them if the top one carries a current of 20.0 A and the bottom one carries 5.0 A?

The magnetic fields created by the individual currents will be at right angles to each other. The field due to the top wire will be to the right, and the field due to the bottom wire will be out of the page. Since they are at right angles, the net field is the hypotenuse of the two individual fields.

$$B_{\text{net}} = \sqrt{\left( \frac{\mu_0 I_{\text{top}}}{2\pi r_{\text{top}}} \right)^2 + \left( \frac{\mu_0 I_{\text{bottom}}}{2\pi r_{\text{bottom}}} \right)^2} = \frac{\mu_0}{2\pi} \sqrt{I_{\text{top}}^2 + I_{\text{bottom}}^2} = \frac{4\pi \times 10^{-7} \text{T} \cdot \text{m/A}}{2\pi \left( \frac{0.100 \text{m}}{0.100 \text{m}} \right)} \sqrt{(20.0 \text{A})^2 + (5.0 \text{A})^2}$$

$$= 4.12 \times 10^{-5} \text{T}$$

49. A 30.0-cm long solenoid 1.25 cm in diameter is to produce a field of 0.385 T at its center. How much current should the solenoid carry if it has 975 turns of the wire?

Use Eq. 20-8 for the field inside a solenoid.

$$B = \mu_0 I N / l \quad \rightarrow \quad I = \frac{\mu_0 N B}{l} = \frac{(0.385 \text{T})(0.300 \text{m})}{(4\pi \times 10^{-7} \text{T} \cdot \text{m/A})(975)} = 94.3 \text{A}$$

54. A single square loop of wire 22.0 cm on a side is placed with its face parallel to the magnetic field between the pole pieces of a large magnet. When 6.30 A flows in the coil, the torque on it is 0.325 m·N. What is the magnetic field strength?

If the face of the loop of wire is parallel to the magnetic field, the angle between the perpendicular to the loop and the magnetic field is 90°. Use Eq. 20-10 to calculate the magnetic field strength.

$$\tau = NIAB \sin \theta \quad \rightarrow \quad B = \frac{\tau}{NI \sin \theta} = \frac{0.325 \text{m} \cdot \text{N}}{(1)(6.30 \text{A})(0.220 \text{m})^2 \sin 90^\circ} = 1.07 \text{T}$$
60. Protons move in a circle of radius 5.10 cm in a 0.566-T magnetic field. What value of electric field could make their paths straight? In what direction must it point?

The radius and magnetic field values can be used to find the speed of the protons. The electric field is then found from the fact that the magnetic force must be the same magnitude as the electric force for the protons to have straight paths.

\[ qvB = \frac{mv^2}{r} \rightarrow v = \frac{qBr}{m} \quad F_e = F_B \rightarrow qE = qvB \rightarrow \]

\[ E = vB = qB^2 r/m = \frac{(1.60 \times 10^{-19} \text{ C})(0.566 \text{ T})^2 (5.10 \times 10^{-2} \text{ cm})}{1.67 \times 10^{-27} \text{ kg}} = 1.57 \times 10^6 \text{ V/m} \]

The direction of the electric field must be perpendicular to both the velocity and the magnetic field, and must be in the opposite direction to the magnetic force on the protons.