Section Summary

20.1 Magnetic Fields, Field Lines, and Force

- All magnets have two poles: a north pole and a south pole. If the magnet is free to move, its north pole orients itself toward the geographic North Pole of Earth, and the south pole orients itself toward the geographic South Pole of Earth.
- A repulsive force occurs between the north poles of two magnets and likewise for two south poles. However, an attractive force occurs between the north pole of one magnet and the south pole of another magnet.
- A charged particle moving through a magnetic field experiences a force whose direction is determined by the right-hand rule.
- An electric current generates a magnetic field.
- Electromagnets are magnets made by passing a current through a system of wires.

20.2 Motors, Generators, and Transformers

- Electric motors contain wire loops in a magnetic field. Current is passed through the wire loops, which forces them to rotate in the magnetic field. The current is reversed every half rotation so that the torque on the loop is always in the same direction.
- Electric generators contain wire loops in a magnetic field. An external agent provides mechanical energy to force the loops to rotate in the magnetic field, which produces an AC voltage that drives an AC current through the loops.
- Transformers contain a ring made of magnetic material and, on opposite sides of the ring, two windings of wire wrap around the ring. A changing current in one wire winding creates a changing magnetic field, which is trapped in the ring and thus goes through the second winding and induces an emf in the second winding. The voltage in the second winding is proportional to the ratio of the number of loops in each winding.
- Transformers are used to step up and step down the voltage for power transmission.
- Over long distances, electric power is transmitted at high voltage to minimize the current and thereby minimize the Joule losses due to resistive heating.

20.3 Electromagnetic Induction

- **Faraday's law of induction** states that a changing magnetic flux that occurs within an area enclosed by a conducting loop induces an electric current in the loop.
- **Lenz' law** states that an induced current flows in the direction such that it opposes the change that induced it.