

Chapter 37 Electromagnetic Induction

Summary

THE BIG IDEA : Magnetism can produce electricity, and electricity can produce magnetism.

37.1 Electromagnetic Induction

- ✓ Electric current can be produced in a wire by simply moving a magnet into or out of a wire coil.
- Voltage is induced by the relative motion of a wire with respect to a magnetic field. The amount of voltage induced depends on how quickly the magnetic field lines are traversed by the wire. Very slow motion produces hardly any voltage at all. Quick motion induces a greater voltage.
- The greater the number of loops of wire that move in a magnetic field, the greater are the induced voltage and the current in the wire.
- Work is done in pushing a magnet into a loop of wire. That's because the induced current in the loop creates a magnetic field that repels the approaching magnet.
- The force that you exert on the magnet multiplied by the distance that you move the magnet is your input work. This work is equal to the energy expended (or possibly stored) in the circuit to which the coil is connected.
- The phenomenon of inducing voltage by changing the magnetic field around a conductor is **electromagnetic induction**.

37.2 Faraday's Law

- ✓ Faraday's law states that the induced voltage in a coil is proportional to the product of the number of loops, the cross-sectional area of each loop, and the rate at which the magnetic field changes within those loops.
- The amount of current produced by electromagnetic induction depends not only on the induced voltage but also on the resistance of the coil and the circuit to which it is connected.

37.3 Generators and Alternating Current

- ✓ Whereas a motor converts electrical energy into mechanical energy, a generator converts mechanical energy into electrical energy.
- A machine that produces electric current by rotating a coil within a stationary magnetic field is called a **generator**. It is essentially the opposite of a motor.
- When the loop of wire of a simple generator is rotated in the magnetic field, there is a change in the number of magnetic field lines within the loop. The voltage induced by the generator alternates, and the current produced is alternating current (AC).

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37.4 Motor and Generator Comparison

- ✓ **Moving charges experience a force that is perpendicular to both their motion and the magnetic field they traverse.**
- The motor effect occurs when a current-carrying wire moves through a magnetic field, and the wire is deflected.
- In the generator effect, a wire with no current is moved downward through a magnetic field. The electrons in the wire experience a force along the wire, resulting in a current.
- The electrical part of a hybrid automobile's engine is both a motor and a generator.

37.5 Transformers

- ✓ **A transformer works by inducing a changing magnetic field in one coil, which induces an alternating current in a nearby second coil.**
- Consider a pair of coils, side by side. The primary (input) coil is connected to a battery, and the secondary (output) is connected to a galvanometer. As soon as the switch is closed in the primary and current passes through its coil, a current occurs in the secondary also—even though there is no material connection between the two coils.
- If an alternating current is used to power the primary, the rate of the magnetic field changes is equal to the frequency of the alternating current, creating a transformer. A **transformer** is a device for increasing or decreasing voltage through electromagnetic induction.
- A step-up transformer has a greater number of turns on the secondary than on the primary.
- A step-down transformer has fewer turns on the secondary than on the primary.
- The relationship between primary and secondary voltages with respect to the relative number of turns is: primary voltage divided by number of primary turns equals secondary voltage divided by number of secondary turns.
- The rate at which energy is transferred from the primary to the secondary in a transformer is the power.

37.6 Power Transmission

- ✓ **Almost all electric energy sold today is in the form of alternating current because of the ease with which it can be transformed from one voltage to another.**
- Power is transmitted great distances at high voltages and correspondingly low currents, a process that otherwise would result in large energy losses owing to heating of the wires.
- Power may be carried from power plants to cities at about 120,000 volts or more, stepped down to 2400 volts in the city. Most household use requires around 120 volts.

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37.7 Induction of Electric and Magnetic Fields

- ✓ A magnetic field is created in any region of space in which an electric field is changing with time.
- Faraday's law states that an electric field is created in any region of space in which a magnetic field is changing with time. The magnitude of the created electric field is proportional to the rate at which the magnetic field changes. The direction of the created electric field is at right angles to the changing magnetic field.
 - If electric charge happens to be present where the electric field is created, this charge will experience a force.
 - British physicist James Clerk Maxwell advanced a counterpart to Faraday's law, in which the roles of electric and magnetic fields are interchanged. The magnitude of the created magnetic field is proportional to the rate at which the electric field changes. The direction of the created magnetic field is at right angles to the changing electric field.

37.8 Electromagnetic Waves

- ✓ An electromagnetic wave is composed of oscillating electric and magnetic fields that regenerate each other.
- Electromagnetic waves move outward from a vibrating charge. No medium is required. At any point on the wave, the electric field is perpendicular to the magnetic field, and both are perpendicular to the direction of motion of the wave.
 - Electromagnetic waves move at the speed of light—no matter what the frequency or wavelength or intensity of the radiation.
 - In an electromagnetic wave, the changing electric field induces a magnetic field. The changing magnetic field acts back to induce an electric field.
 - Light is simply electromagnetic waves with frequencies in the range of 4.3×10^{14} to 7×10^{14} vibrations per second. Radiation of any frequency would propagate at the same speed as light.
 - Radio waves are radiation which can be generated by causing electric charges to move up and down an antenna.