AP Physics Ch 19 Old Book Notes

19-1 Electric Current

Current and Charge Movement
→ Electricity did not become an integral part of our daily lives until scientists learned to control the movement of electric charge, known as **Current.**

Current is the rate of charge movement:
→ A **current** exists whenever there is a **net movement** of electric charge through a medium.

→ The **current** is the rate at which these charges move through the cross section of the wire. If ΔQ is the **amount of charge that passes through this area in a time interval**, Δt. Then the current, I, is the **ratio of the amount of charge to the time interval**.

Electric Current

$$I = \Delta Q / \Delta t$$

$$\text{Electric current} = \frac{\text{charge passing through a given area}}{\text{Time interval}}$$

→ The SI unit for current is the ***Ampere, A***. One ampere is equivalent to **one coulomb** of charge passing through a cross-sectional area in a time internal of **one second**
(1A = 1C/s).

Sample Problem 19A: Relating Current and Charge--The amount of charge that passes through the filament of a certain light bulb in **2.00 s** is **1.67 C**. Determine the **current** in the light bulb.

$$I = \Delta Q/\Delta t \rightarrow I = \frac{1.67\ C}{2.00\ s} = 0.835\ A$$

Sample: **Practice 19A, Problem # 1, pg. 695** → How many electrons pass through the filament of the light bulb in Sample Problem 19A during the 2.00 s time interval?

$$N = \frac{\Delta Q}{(1.60 \times 10^{19}\ C/electron)} = \frac{1.67\ C}{(1.60 \times 10^{19}\ C/electron)} = 1.04 \times 10^{19}\ electrons$$

Conventional current is defined in terms of positive charge movement.

→ The **moving charges** that make up a current **can be positive, negative, or a combination of the two**. In a **common conductor**, such as copper, **current is due** to the **motion of negatively charged electrons**.

→ The protons are **relatively fixed** inside the nucleus of the atom.

→ Body fluids and salt water are able to conduct electric charge because they contain **charged atoms** called ***ions***. Because they can move through a solution easily, **dissolved ions can be charge carriers**. A solute that consists of charge carriers is called an *electrolyte*.

→ **When you turn on the switch, an electric** field is established in the wire. This field, which sets **electric charges in motion**, travels through the wire at
nearly **3.00×10^8 m/s**. The **charges** themselves, however, **do not travel** nearly this quickly.

***Drift Velocity* is the net velocity of charge carriers.**

→ When a **potential difference** is applied across the conductor, an **electric field is set up inside** the conductor. The **force due to that field** sets the ***electrons in motion***, thereby **creating a current**.

→ The energy transferred from the **electrons to the metal atoms** during the collision increases the **vibrational energy** of the atoms, and the **conductor's temperature increases**.

→ Despite the internal collisions the individual **electrons move slowly** along the conductor in a **direction opposite the electric field**, ***E***, with a velocity known as the **drift velocity**, v_{drift}.

Drift speeds are relatively small.

→ The **electric field**, on the other hand, **reaches electrons throughout the wire** at a **speed approximately equal to the *speed of light***.

Sources and Types of Current:

→ When a **potential difference is applied** across the conductor, **free electrons** will **move slowly** from a **higher electric potential to a lower electric potential**. Thus, a **difference in potential maintains current in a circuit**.

Batteries and Generators supply energy to charge carriers.

→ **Batteries** convert chemical energy to **electrical potential** energy.

→ As charge carriers collide with the atoms of a device, such as a **light bulb or a heater**, their **electrical potential energy is converted into kinetic energy**. Note that **electrical energy**, **not charge**, is "used up" in this process.

→ ***Generators convert mechanical energy into electrical energy***. One type of generator converts the kinetic energy of falling water into electrical energy.

Current can be Direct or Alternating.

→ There are two different types of current: **direct current** (***dc***) and **alternating current**, (***ac***). In **direct current**, charges **move in only one direction**. In **alternating current**, the **motion of charges continuously changes** in the forward and reverse directions.

→ Consider a light bulb connected to a battery. The **positive terminal** of the battery has a **higher electric potential** than the negative terminal has, **charge carriers always move in one direction**. Because the potential difference between the terminals of a battery is fixed, ***batteries always generate a direct current***.

→ There is no net motion of the charge carriers in alternating current; they simply vibrate back and forth.

→ If the alternating current were reversed to slowly, you would notice flickering in lights and similar effects in other appliances. ***(Remind me to perform the 60 cycles per second DEMONSTRATIN!)*** To eliminate this flickering problem, alternating current is made to change direction rapidly. In the United States, alternating current oscillates 60 times every second. Thus, its frequency is 60 Hz.

→ The current supplied to your home by power companies is alternating current rather than direct current.

19-2 Resistance

Behaviors of Resistors:

→ Potential difference is not the only factor that determines the current in the light bulb. The materials that make up the connecting wires and the bulb' s filament also affect the current in the bulb.

→ The **impedence of the motion of charge** through a conductor is the conductor's resistance. ***Resistance*** is defined as the **ratio of potential difference to current**.

Resistance

$R = \Delta V / I$ ***resistance = potential difference over current.***

The SI unit for resistance, the ***ohm***, Ω, is ***equal to volts per ampere***.

Resistance is constant over a range of potential differences.

→ **Ohm's Law –** Resistance is constant over a wide range of applied potential differences.

→ It is common practice to express Ohm's Law as $\Delta V = IR$, where R is understood to be independent of ΔV.

Ohm's Law does not hold for all materials.

→ Ohm's Law describes a behavior that is valid only for certain materials.

→ Materials that do not function according to Ohm's law are said to be ***non-ohmic***.

→ One common semiconducting device that is non-ohmic is the ***diode***. Its **resistance is small for currents in one direction** and **large for currents in the reverse** direction. **Diodes are used in circuit boards** to control the direction of current.

Resistance depends on length, cross-sectional area, material, and temperature.

→ Electron collisions affect the motion of charges somewhat as a force of internal friction would.

Resistors can be used to control the amount of current in a conductor.

→ The current in a wire can be decreased by replacing the wire with one of higher resistance. The same effect can be accomplished by making the wire longer or by connecting a resistor to the wire. A ***resistor*** is a simple electrical element that provides a specified resistance.

Sample Problem 19B, pg. 702: All electrical devices are required to have identifying plates that specify their electrical characteristics. The plate on a certain steam iron states that the current in the iron is **6.4 A** when the iron is connected across a potential difference of 120 V. **What is the resistance** of the steam iron?

$$R = \Delta V/I = \frac{120\ V}{6.4\ A} = 19\ \Omega$$

Sample Practice Problem 19B, pg. 703, # 3: Find the current in the following appliances when they are connected across a potential difference of 120 V.

a) a stereo with a resistance of 65 Ω. $I = \Delta V / R = 120\ V / 65\ \Omega = 1.8\ A$

b) a hot plate with a resistance of 48 Ω $I = \Delta V / R = 120\ V / 48\ \Omega = 2.5\ A$

c) a microwave oven with a resistance of 20.0 Ω. $I = \Delta V/R = 120V/20.0\ \Omega = 6.0\ A$

Salt water and perspiration lower the body's resistance.

The Carbon Microphone uses varying resistance.

Superconductors have no resistance below a critical temperature.

→ There is a class of materials that **have zero resistance** below a certain temperature, called the **critical temperature**. These materials are known as ***superconductors***.

→ **Copper, silver, and gold** which are excellent conductors, **do not** exhibit superconductivity.

19-3 Electric Power

Energy Transfer

Electric Power is the rate of conversion of electrical energy.

→**Power** is described as the **rate at which work is done**. **Electric Power is the rate at which charge carriers do work**. Put another way, electric power is the **rate at which charge carriers convert electrical potential energy to nonelectrical forms of energy**.

$P = W/\Delta t = \Delta PE/\Delta t$

Potential difference is defined as the change in potential energy per unit of charge.

$\Delta V = \Delta PE/q$ ***can be rewritten as*** → $\Delta PE = q\Delta V$

Electric Power

$P = I\Delta V$ → ***electric power = current x potential difference***

→ ***The SI*** unit of power is the ***watt, W***. When considering the dissipation of electrical energy being converted to other forms of energy per second.

→ The conversion of **electrical energy to internal energy** in a material of resistance ***R*** is called ***joule heating***. It is also often referred to as an ***I^2R loss***.

Sample Problem 19C, pg. 710: An electric space heater is connected across a **120 V** outlet. The heater dissipates **3.5 kW** of power in the form of electromagnetic radiation and heat. **Calculate the resistance** of the heater.

$P = (\Delta V)^2/R$ → $R = (\Delta V)^2/P = (120\ V)^2/(3.5 \times 10^3 W) = 4.1\ \Omega$

Electric companies measure energy consumed in kilowatt-hours.

→ Electric power is the rate of energy transfer.

→ The ***kilowatt-hour*** is defined in **terms of power**. ***One kilowatt-hour (kW·h) is the energy delivered in 1 h at the constant rate of 1 kW.***

→ $\frac{1\ kW{\cdot}h}{} \left|\frac{1 \times 10^3\ W}{1\ kW}\right| \frac{60\ min}{1\ h} \left|\frac{60\ s}{1\ min}\right. = 3.6 \times 10^6\ W \cdot s = 3.6 \times 10^6\ J$

Sample Problem 19D, pg. 712: How much does it cost to operate a **100.0 W** light bulb for **24 h** if electrical energy costs **$ 0.080 per kW·h**?

Energy $= P\Delta t = (.1000\ kW)(24\ h) = 2.4\ kW{\cdot}h$

Cost $= (2.4\ kW{\cdot}h)(\$\ 0.080/kW{\cdot}h) = \$\ 0.19$

Electrical Energy is transferred at high potential differences to minimize energy loss.