PHYS 2212

Look over
Chapter 26 sections 1-7
Examples 3, 7

PHYS 1112

Look over
Chapter 18 sections 1-5, 8
over examples 1, 2, 5, 8, 9,

GOOD THINGS TO KNOW

1) How to find a current in a wire.
2) What the Current Density and Draft Speed are.
3) What Resistance is.
4) How to use Ohm's Law
5) How to find the Power used in a circuit.

MOVING CHARGES

So far we have been dealing with electrostatics (charges that are not moving). Now we want to focus on **Electric Currents**, charges in motion.

There are electric currents flowing all around us like the currents in household wiring or the tiny nerve currents that regulate muscular activity.

ELECTRIC CURRENT

If we insert a battery into a conducting loop then the loop is no longer at a single potential. Electric fields then act inside the material exerting forces on the conduction electrons, causing them to move, and thus establishing a current.

DEFINITION OF CURRENT

If we could count how much charge (q) passes through a section of our conducting loop in an amount of time (Δt) then we can define the average current as:

$$i_{ave} = \frac{\Delta q}{\Delta t}$$

If we want to the instances current we can let Δt get very small and we get:

$$i = \frac{dq}{dt}$$

UNITS OF CURRENT

The SI unit for current is the Coulomb per second, also called the an **Ampere (A):**

$$1\ ampere = 1\,A = 1\,\frac{C}{s}$$

The ampere is an SI base unit; the coulomb is defined in terms of the ampere.

The ampere is named after the French physicist André Marie Ampère

CURRENT IS NOT A VECTOR

Current is not a vector but we will often represent current with an arrow to indicate the direction the current is moving.

When current is split at a junction the current in the branches must add up to yield the magnitude of the current in the original conductor so:

$$i_0 = i_1 + i_2$$

DIRECTION OF CURRENT

The charge carriers in conductors are electrons. The electric field forces them to move from the negative terminal to the positive terminal of the battery. For historical reasons we use the following convention:

A current arrow is drawn in a direction in which positive charge carriers would move, even if the actual charge carriers are negative and moving in the opposite direction.

CURRENT DENSITY

The current density ***J*** is a vector quantity that as the same direction as the electric field through a surface and has a magnitude J equal to the **current per unit area** through an element of that surface.

$$\vec{J} = \frac{i}{A} \text{ in the direction of } \vec{E}$$

DRIFT SPEED

When a conductor does not have a current through it, its conducting electrons move randomly, with no net motion in any direction. When the conductor does have a current through it, these electrons actually still move randomly but now they tend to drift with a **Drift Speed** v_d in the direction opposite that of the applied electric field that causes the current.

DRAFT SPEED AND CURRENT DENSITY

In typical household wiring electron drift speeds are perhaps 10^{-5} or 10^{-4} m/s while the random motion speeds are around 10^{6} m/s.

The drift speed and the current density are related by:

$$\vec{J} = (ne)\vec{v}_d$$

Where n is the number of charge carriers per unit volume

EXAMPLE 1

1) In the Bohr model of the hydrogen atom, an electron in the lowest energy state follows a circular path at a distance of 5.29×10^{-11} m from the proton.
a) What is the speed of the electron?
b) What is the effective current associated with this orbiting electron?

RESISTANCE DEFINED

If we apply the same potential difference (V) between the ends of similar rods of two different metals, very different currents (i) will result.

If we where to graph the voltage (V) .vs. the current (i) we will get a straight line for most materials. The slope of this line is the resistance.

$$V = Ri \quad \text{or} \quad R = \frac{V}{i}$$

UNITS OF RESISTANCE

The SI unit for resistance is the Volt per Ampere. This combination occurs so often that we give it a special name the Ohm (Ω).

$$1\,Ohm = 1\,\Omega = 1\frac{V}{A}$$

A conductor whose function in a circuit is to provide a specified resistance is called a **Resistor**.

We represent a resistor in a circuit diagram with the symbol 

RESISTIVITY

If instead of the current i through the conductor the resistor, we deal with the current density J then instead of the resistance R of the object we deal with the **Resistivity** ρ of the material as defined as:

$$\rho = \frac{E}{J}$$

The unit for resistivity is the Ω·m.

So we can write: $\vec{E} = \rho \vec{J}$

We will often speak of the conductivity σ of a material as: $\sigma = \frac{1}{\rho}$

OHMS' LAW

Ohm's law is an assertion that the current through a device is always directly proportional to the potential difference applied to the device:

$$V = iR$$

A conducting device obeys Ohm's law when resistance of the device is independent of the magnitude and polarity of the applied potential difference.

POWER IN ELECTRIC CIRCUIT

In the figure the power supplied by the battery is the work it does per unit time, that is:

$$P = \frac{W}{t}$$

But the work done within the battery is done by chemical means, and its final result is to move a positive charge *q* from the negative terminal inside the battery to the positive terminal within the battery. That is the charge *q* had to be "lifted" from the point of zero potential to the point of higher potential *V* within the battery.

POWER

The power supplied by the battery is then:

$$P = \frac{W}{t} = \frac{qV}{t}$$

$$P = iV$$

Power supplied to the circuit = Power consumed in the circuit

JOULE HEATING

If a circuit contains only a resistor, then the voltage across the resistor is given by V=iR. Therefore, the power consumed or dissipated in the resistor is:

$$P = iV = i(iR) = i^2R$$

EXAMPLE 2

2) A high voltage transmission line carries 1000 A starting at 700 kV for a distance of 100 mi. If the resistance in the wire is 0.500 Ω/mi, what is the power loss due to resistive losses?