**SDCC Independent Study of Electricity and Magnetism**

**Week 3**
**Circuit Components: Resistors, Light bulbs, and Batteries**

**Instructor: Edward Price**
**Email: edward@physics.ucsd.edu**
**Phone: (858)-534-2268**

**Objective:** Explore the microscopic nature of circuit components, including wires, resistors, light bulbs, and batteries, and see how the microscopic properties of these components determine their behavior in circuits.

## Outline

### Insulators vs. conductors

Need to confine/guide charges in a circuit
Charges are mobile in metals, not in insulators
Atomic picture of metal: ionic lattice and 'free' electrons
Number of free electrons/ion depends on metal

### Current flow in a conductor

Voltage exerts a force on charges
In a metal the electrons can move
Current is charge/time
**Demo: resistor model**
Defects in metal scatter electrons
Scattering leads to a 'speed limit' for electrons
Increasing voltage gives more current: **V= I R**
**In class question: how would the resistance change if the demo resistor were longer? What if it were wider?**
R is resistance, increases with length of conductor, decreases with area **R = rL/A**
Resistivity (ρ) is the intrinsic resistance of the conductor
**In class question: What determines the resistivity?**
Resistivity decreases as # of $e^-$/ion, time between collisions increases
**In class question: What determines the time between collisions? (Temperature, impurities, defects)**
A resistor can be a long piece of wire, or a shorter material with a bigger resistivity

### Dissipation

Electrons that collide with ions lose energy
The ions gain energy
Ions can release energy by emitting light (photons)
This is the basis for an incandescent light bulb

**Demo: homemade light bulb**
**In class question: What happens when the current is increased? What happens when the voltage is increased?**
**How are these interpreted in the microscopic model?**
Increased current excites more atoms/time, so the bulb gets brighter
Increased voltage means the electrons give more energy to the ions, so the bulb gets brighter
Power: **P=IV**
**In class question: What happens to the electrons after collisions? Are they used up? What happens to the energy the electrons had before the collisions?**

## Batteries

We have seen that electrons are free in metals
Batteries use a chemical reaction to drive electrons from one place to another
This can only happen if the electrons have a way to get from place to place
By putting a resistor or light bulb in the path of the electrons, the battery can be used to do work
**Demo: Make penny and nickel batteries in class**
**In class question: What combinations give the highest voltage?**
Both Ni and Cu want to get rid of electrons, but Ni more so than Cu
Electrons will flow between dissimilar metals
**In class question: How does the voltage change as you increase the number of coins in the stack? What does this indicate about batteries connected in series?**

## Questions

**1a)** Based on the discussion about how the resistance of a conductor increases when the conductor length increases, and decreases when the conductor's area increases, what do you think happens when you connect two resistors one after the other (in other words, in series)? In particular, does the total resistance of the combination increase or decrease? What happens when you connect them side by side (in parallel)?

**2)** A thin wire (about 0.1 mm in diameter) would have to be about 13 meters (42 feet) long to have a resistance of 1000 Ohms. Yet very small resistors with much larger resistances are commonly used in electronics. In what way do the materials these resistors are made of differ from metals like copper, and how does that lead to such high resistances?

**3a)** Briefly describe how a fluorescent bulb works.
**3b)** Which is hotter, an incandescent light bulb or a fluorescent one? (Be careful not to burn yourself!) Which type of bulb do you think is more efficient, and why?

**4)** What limits the amount of current a battery can provide? (This is a tough one, do the best you can.)