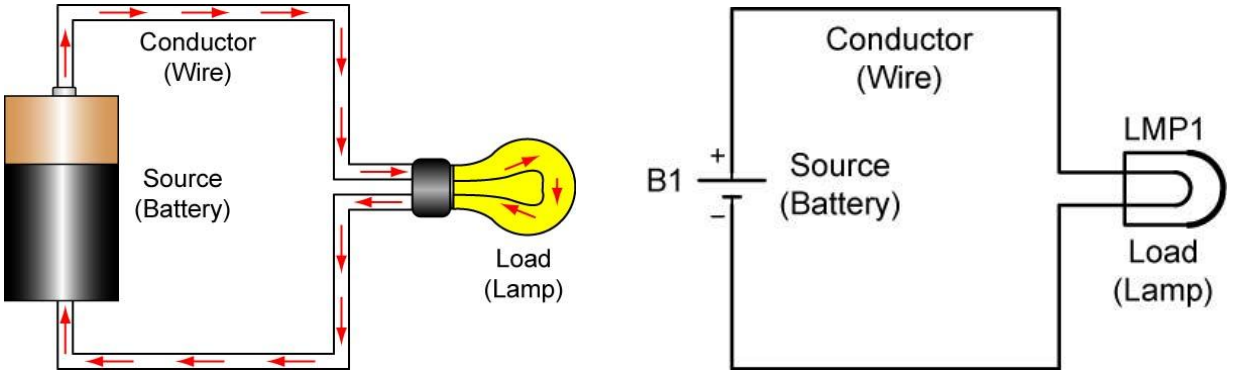
Cornerstone Electronics Technology and Robotics I Week 2
Simple Electrical Circuits and Basic Electrical Terms

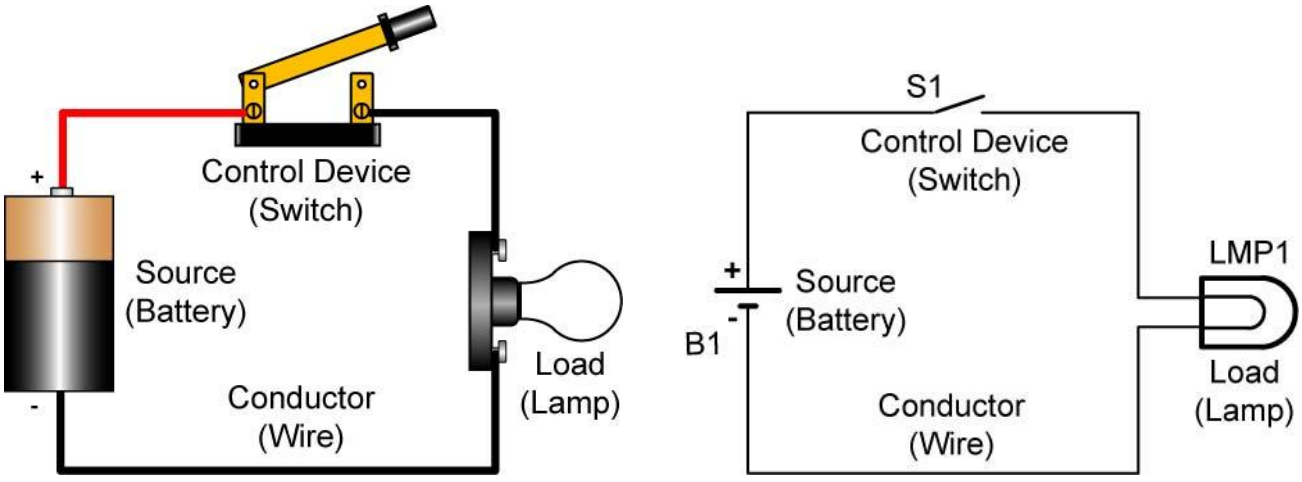
- **Administration:**
  - Prayer
- **Basic Electric Circuit:**
  - An electric circuit provides a path for current flow to perform a useful function such as turning on a light bulb. The current flows from the source of electricity through the circuit components and connections and then back to the source.
  - A basic electric circuit consists of three main parts: source, conductor, and load.



A Simple Electric Circuit **Schematic of the Simple Circuit**

Figure 1: An Example of the Three Main Parts of a Simple Electric Circuit and the Schematic Diagram of the Simple Circuit

  - Another component called a control device can be added to the electric circuit. This new component is not necessary for the circuit to work, but provides a safety and practical function. In the circuit illustrated in Figure 2, the control device is a switch.



Circuit with Control Device **Circuit Schematic with Control Device**

Figure 2: Three Main Electrical Circuit Parts with a Control Device Added

- **Voltage Source**: The voltage source provides an electric potential difference (voltage) causing current to flow through the circuit (Figure 3). The source can be a battery, electrical outlet, solar panel, generator, or even potatoes.

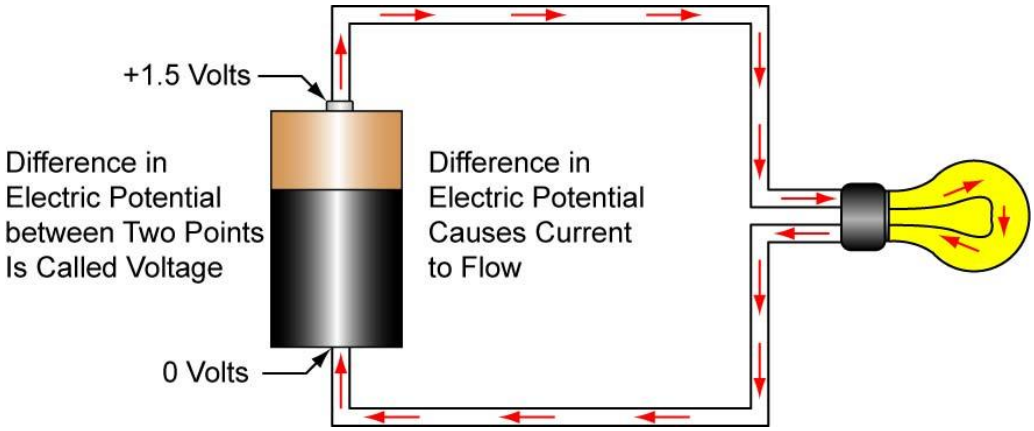


Figure 3: Electric Potential Difference Causes Current to Flow

- **Load**: The load converts the electrical energy to some other form of energy including heat (resistor), light (lamp), motion (motor), or magnetism (linear solenoid) (Figure 5). This is the part of a circuit that performs work.

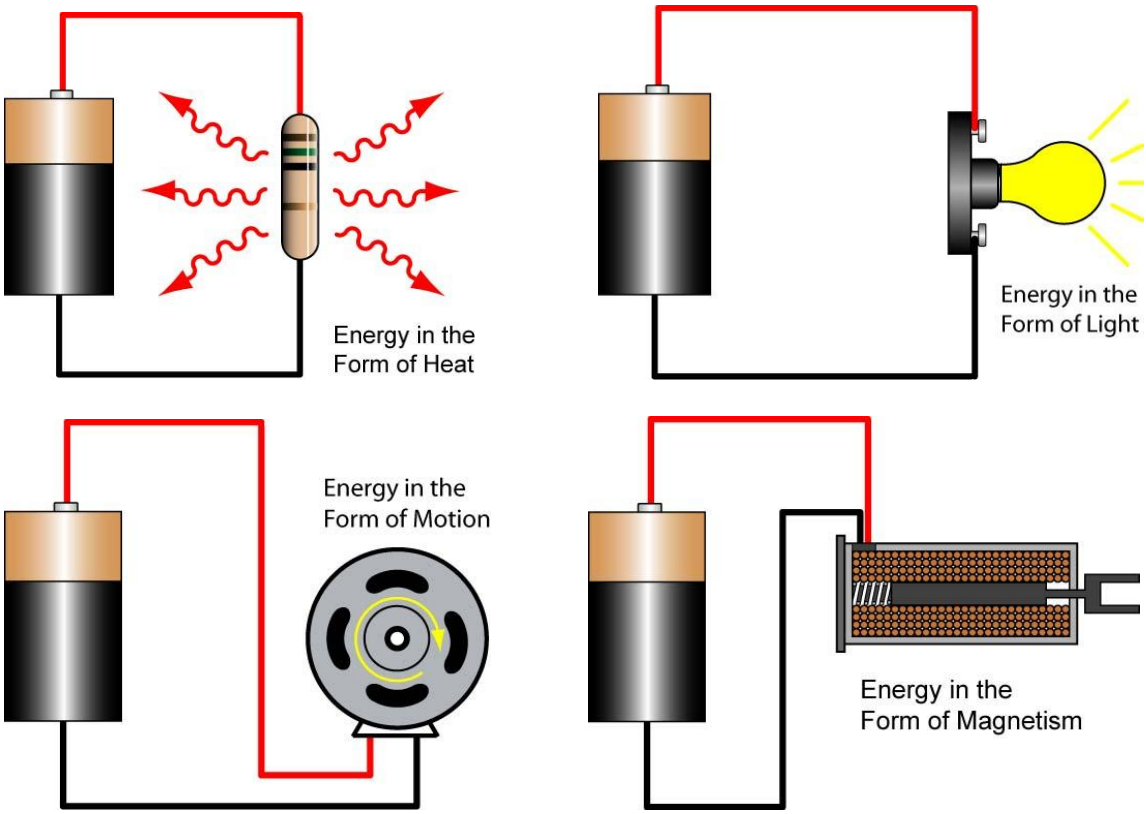


Figure 5: Electrical Energy Converted into Heat, Light, Motion, and Magnetism

- **Conductor:** The conductors are the wires between the source and the load which are made up of a low resistance material through which current can easily flow.
    - The symbol for wire is a line.
- **Control Device:** A control device such as a switch is not required for the circuit to work, but provides a safety and practical function for instance turning a circuit on and off.

Other Control Devices	
Control Device	Function
Fuse	Provides excessive current protection
Relay	Electrically operated switch
Solenoid	Electromagnetic switch that converts current into linear movement

Table 1: Other Control Devices

- **Three Basic Circuit Conditions:**
  - **Open Circuit**, a broken path therefore, no current flow.

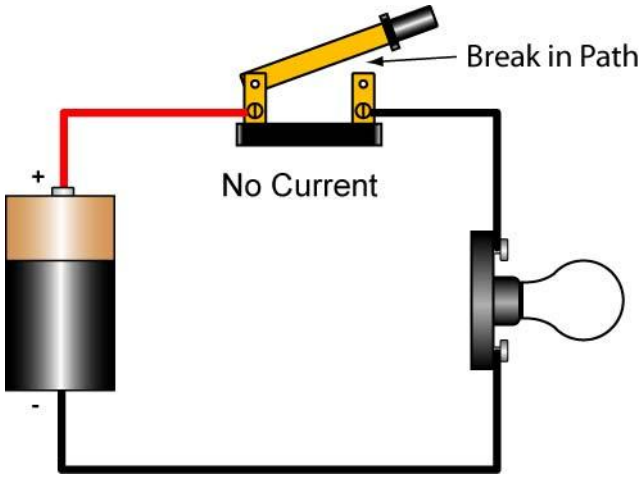


Figure 7: Open Circuit with Broken Path

  - **Closed Circuit**, an unbroken path for current from a source to a load and back to the source. In general, if the circuit works, then it is a closed circuit.

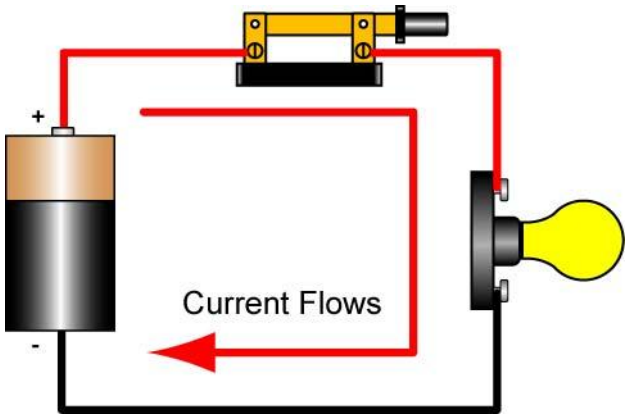


Figure 8: Closed Circuit

  - **Short Circuit**, an unwanted circuit condition where the current bypasses the load causing damage to the circuit.

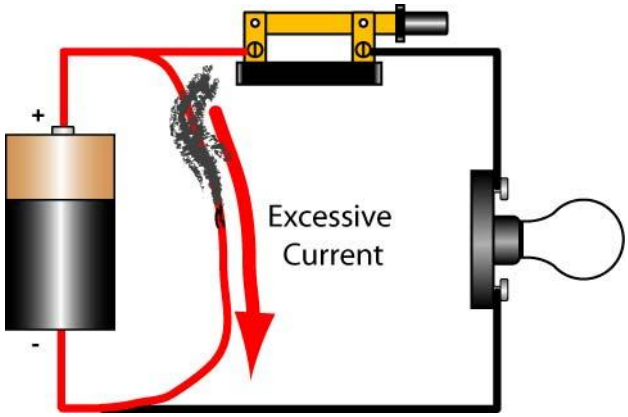


Figure 9: A Short Circuit Can Cause Damage to the Circuit

  - Perform Simple Circuits LAB 1 – Wiring Simple Circuits

- **Terms and Definitions:**
  - **Introduction:** The quantities associated with electricity may be difficult to grasp since we cannot “see” them. However, with the help of electronic instruments, we can observe and measure the effects of these quantities and better understand how they relate to each other.
- **Three Basic Electric Quantities:** The three most basic quantities in electricity are voltage, current, and resistance. To help understand these quantities, an analogy using water can be used. Voltage is equivalent to water pressure, the current is equivalent to water flow, and the resistance is analogous to a restriction in the pipe.
  - **Voltage (Units in Volts, V):** In general terms, voltage or electromotive force can be thought of as a pressure that is exerted on charges which causes them to move or flow in a conductor. More specifically, voltage is the difference in electric potential between two points (Figure 10). Voltage is represented by the letter V or E.

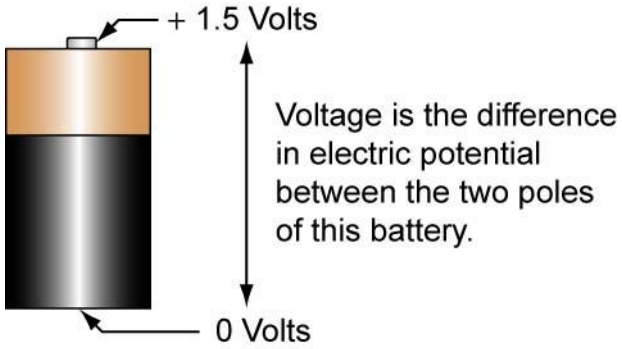


Figure 10: Difference in Electric Potential

The voltage between two points in a circuit is a short name for the electromotive force that would drive an electric current between those two points (Figure 11).

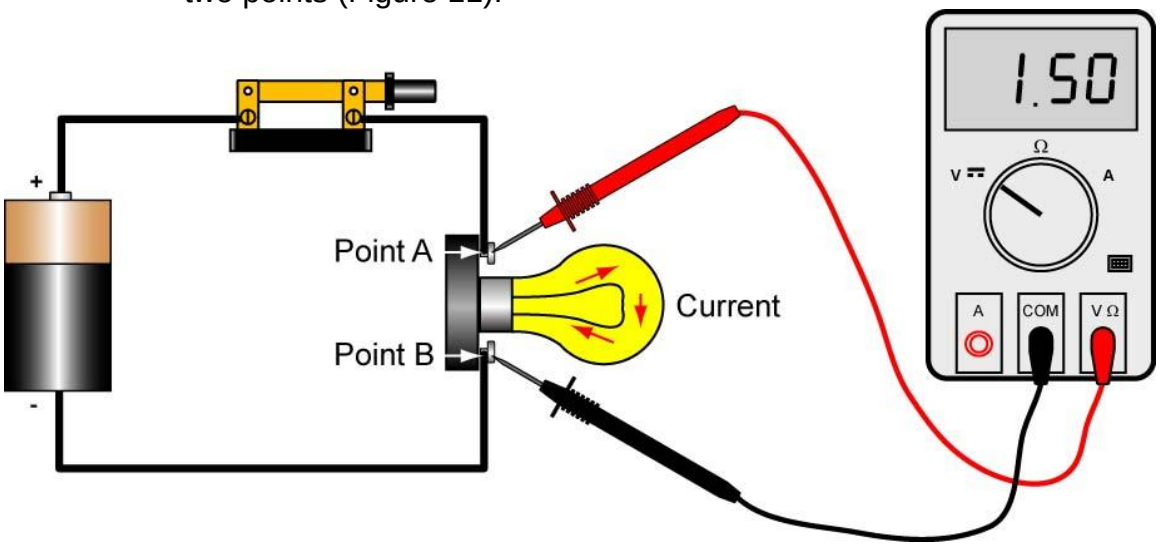


Figure 11: 1.5 Volts Measured between Points A and B Drives the Current between those Points

- If we compare electric current to water flowing through a pipe, then voltage would be analogous to water pressure. If a pipe has the same water pressure at both ends, no water will flow (Figure 12). For water to flow through a pipe, it is necessary to have a difference in water pressure between the two ends of the pipe. With higher water pressure, more water is forced through a pipe in a given time.

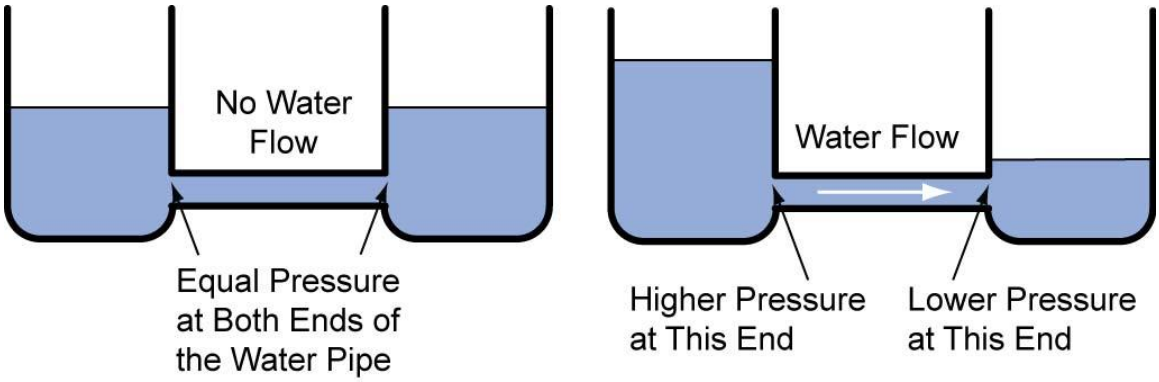


Figure 12: Difference in Pressure Creates Water Flow in a Pipe

Similarly, for electric current to flow, it is necessary to have a difference in electrical potential (measured in volts) between the two ends of a component. See Figure 13.

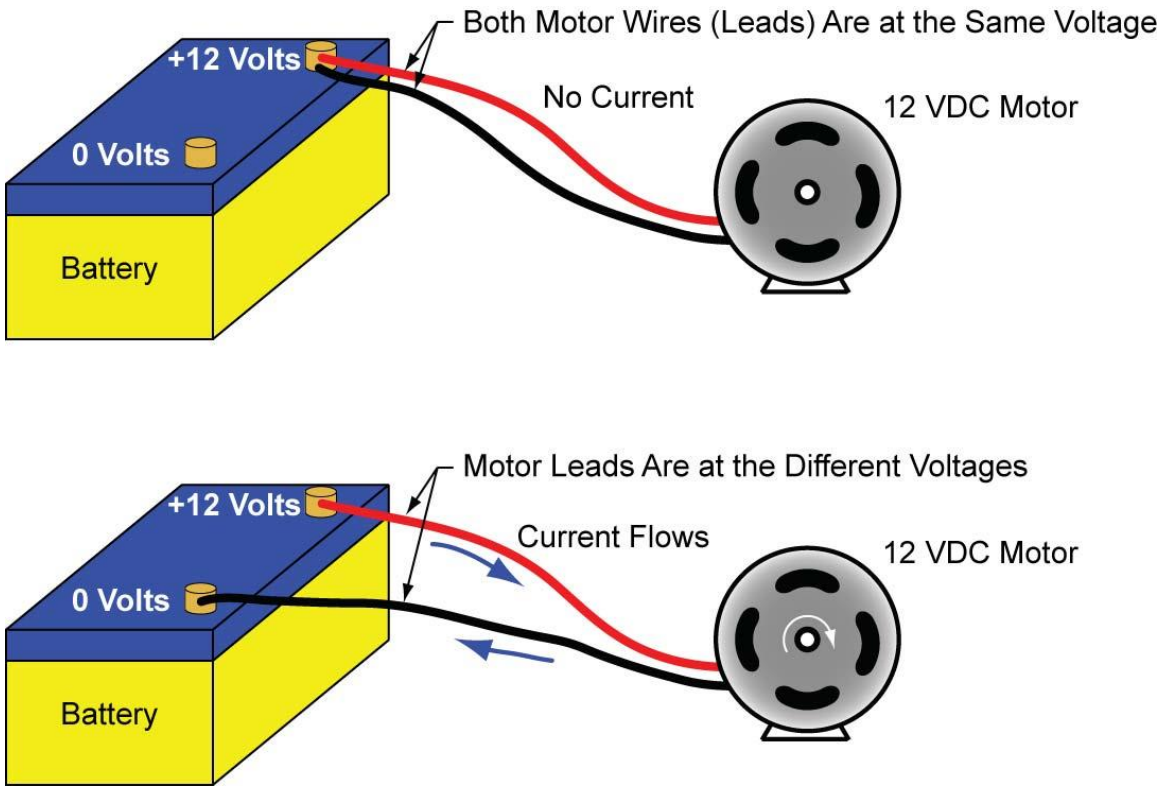
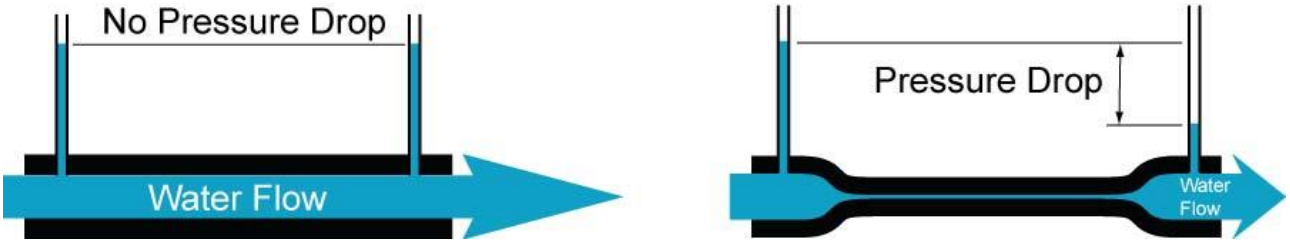


Figure 13: A Difference in Voltage Creates Electrical Current through the Motor

- Also see:
  - http://www.upscale.utoronto.ca/IYearLab/Intros/DCI/Flash/WaterAnalogy.html
  - http://www.mste.uiuc.edu/murphy/WaterTower/default.html
  - http://www.howstuffworks.com/water.htm
- Perform Simple Circuits Lab 2 – Matching Voltage Source to Loads
- **Current (Units in Amperes, A):** In our water analogy, electric current in a conductor corresponds to the flow of water in a pipe. In electrical circuits, current is the flow of electric charge
- passing a given point per unit of time. This charge is often moving electrons. The direction of the current will be covered later in this lesson. Current is represented by the letter I.

Figure 14: Electrical Current in a Conductor

- **Resistance (Units in Ohms, Ω):** Resistance in water flow is represented by a constriction or obstruction that will produce a pressure drop (Figure 15).

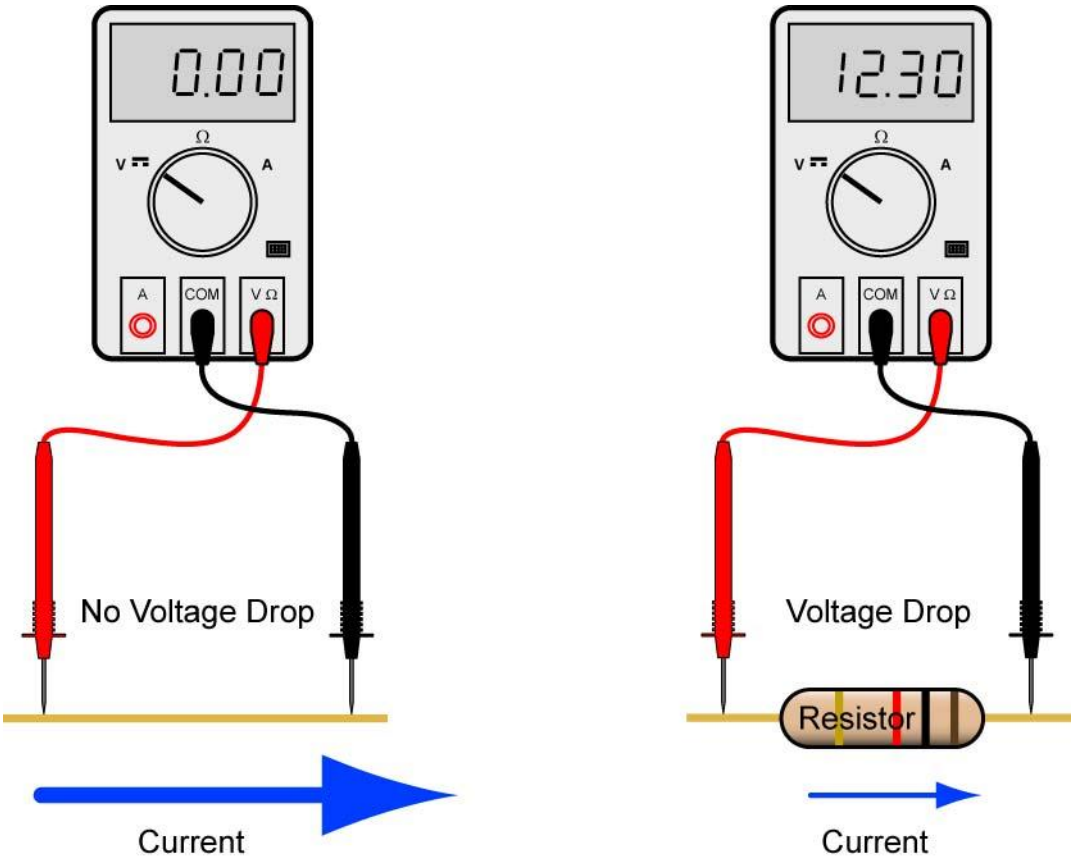


Pipe with No Constriction

Pipe with Severe Constriction and Pressure Drop

Figure 15: A Constriction in a Water Pipe Reduces the Water Flow and Produces a Pressure Drop

Resistance in electrical circuits is the opposition to flow of current which produces a voltage drop. Resistance is represented by a resistor.



Wire with No Resistor **Wire with Resistor and Voltage Drop**

Figure 16: A Resistor in an Electrical Circuit Reduces the Current and Produces a Voltage Drop across the Resistor

Resistance is used to control the amount of voltage and/or current in a circuit. Resistance is represented by the letter R.

- **Conductor**: Conductor is a material that permits the free flow of electric current, i.e., very low resistance.
- **Insulator**: An insulator is a material that does not allow electric current to move freely, i.e., very high resistance. See Figure 17.

Figure 17: Conductor and Insulator in a Wire

- Show examples of conductors and insulators.
- Perform Simple Circuits Lab 3 – Conductivity Tester

- **Types of Electric Current:**
  - **Direct Current (DC)**: Direct current is current that flows in one direction, whether steady or in pulses. Direct current has definite fixed polarity as in a battery. The positive terminal of a battery is labeled by the **+** symbol and the negative terminal is labeled by the **–** symbol (Figure 18).

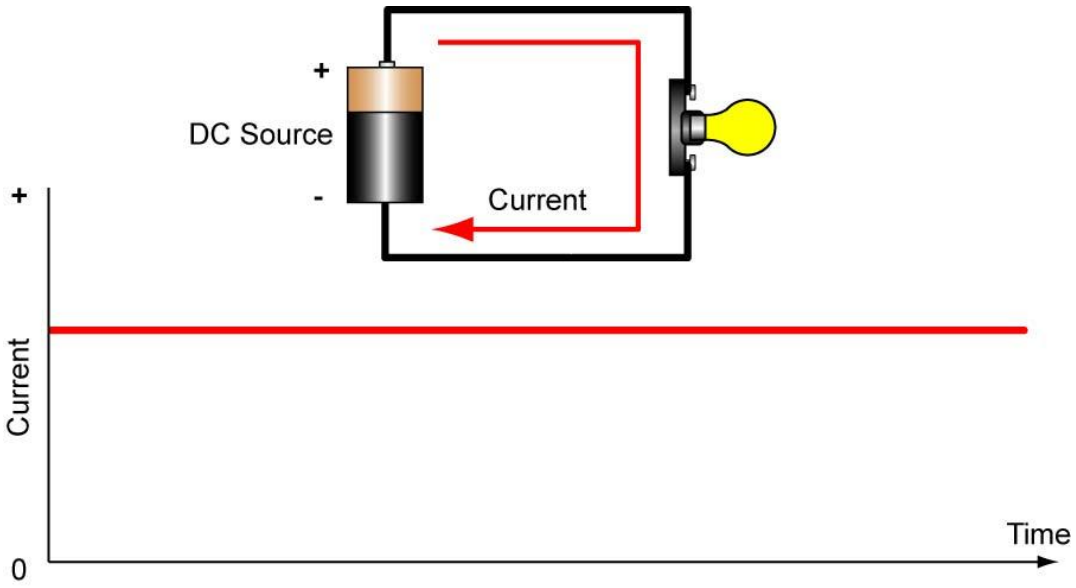


Figure 18: Direct Current Flows in One Direction

  - **Alternating Current (AC)**: Alternating current flows in both directions and has no fixed polarity.

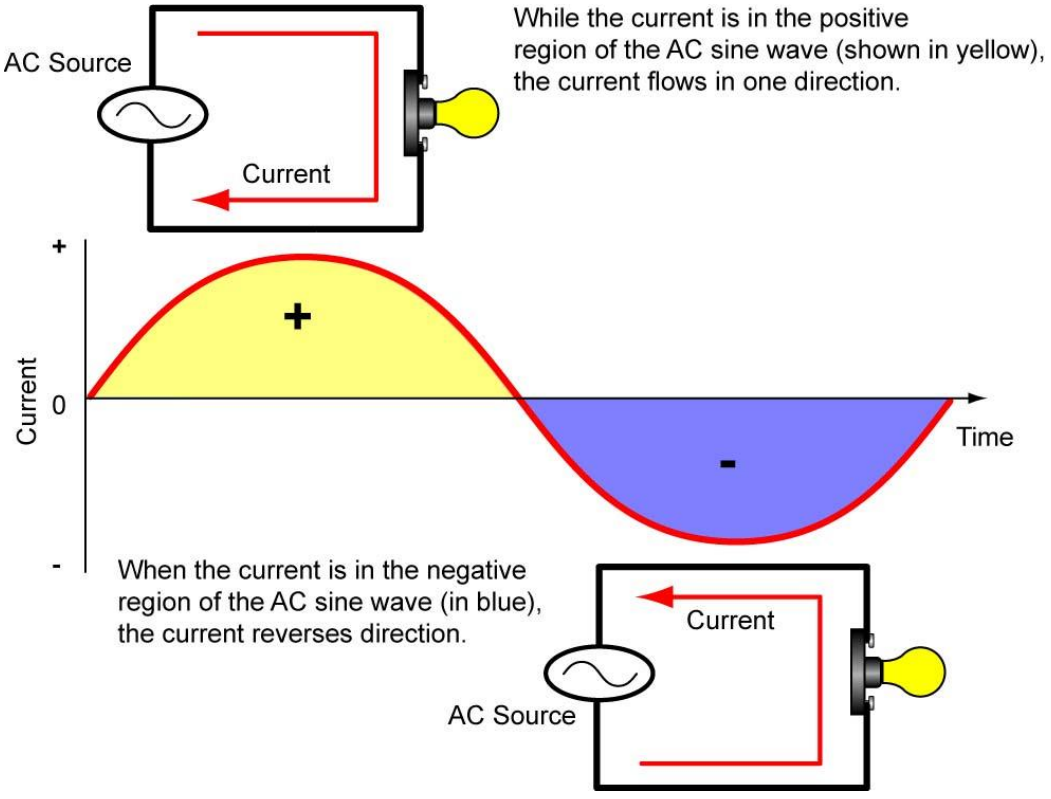


Figure 19: Alternating Current Flows in Both Directions

- **Direction of Current:**
  - **Electron Flow**: Electron flow identifies electrons as the charge carrier for current. Electron flow states that current flows out of the negative terminal (a surplus of negative charge) through the circuit and into the positive terminal (a deficiency of negative charge).

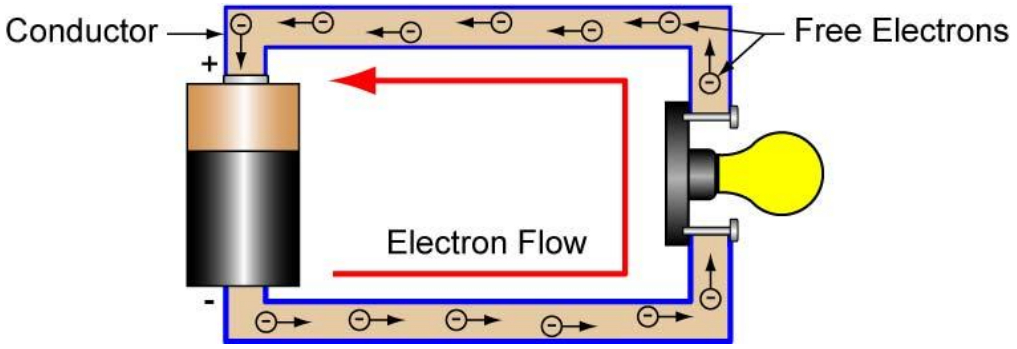


Figure 20: Electron Flow – Current Flow from Negative to Positive

  - **Conventional Current Flow**: An old theory attributed to Ben Franklin that assumes all current consists of moving positive charges. The fact is that the electrical charges moving are typically the negatively charged electrons. Generally it doesn't matter that the assumed electric charge moves in the opposite direction that it actually does because in most cases positive charges flowing one direction is equivalent to negative charges flowing in the opposite direction. Conventional flow concludes that current flows from the positive terminal (a surplus of "positive" charge) through the circuit and into the negative terminal (a deficiency of "positive" charge). Since conventional flow is followed by most electrical engineers, we will use conventional flow to define the direction of current.

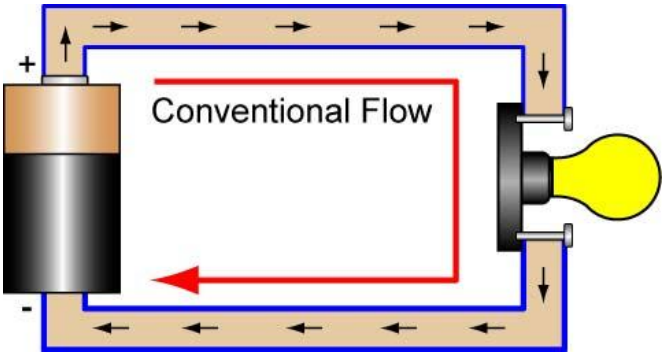


Figure 21: Conventional Flow – Current Flow from Positive to Negative

- **Series and Parallel Circuits:**
  - **Series**: A circuit where the components are connected end to end in a chainlike manner. There is only one pathway for the current to flow. See Figure 22.

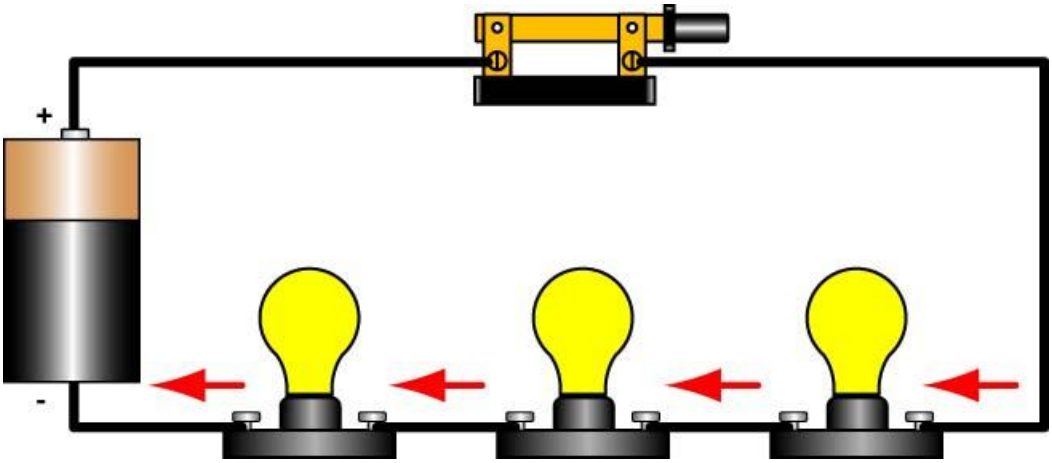


Figure 22: Three Lamps in Series with One Current Pathway

  - **Parallel**: A circuit where two or more components are connected so current can flow through one component without having first to flow through another component. It is a circuit where there are Y's or branching in the wiring. Another way of saying it is that a parallel circuit is one that has more than one pathway for the current to flow.
    - Memory aid: **II** in parallel

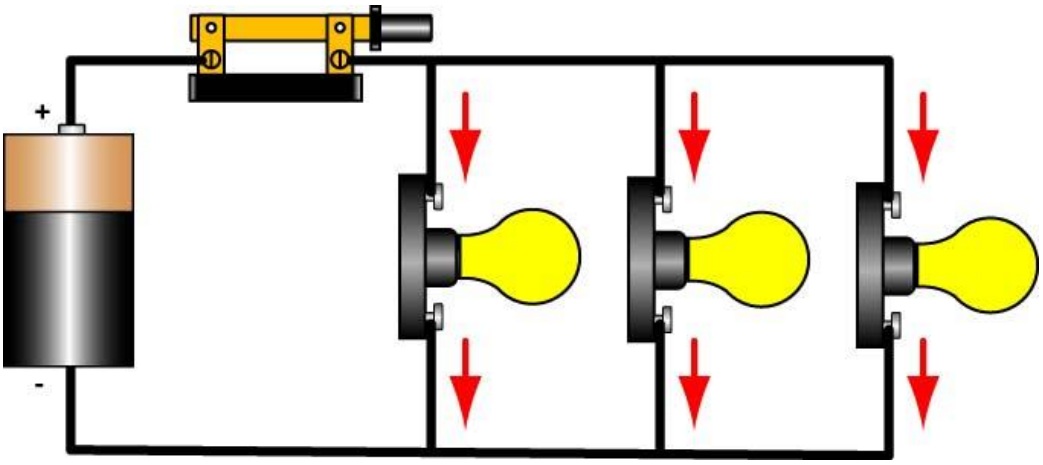
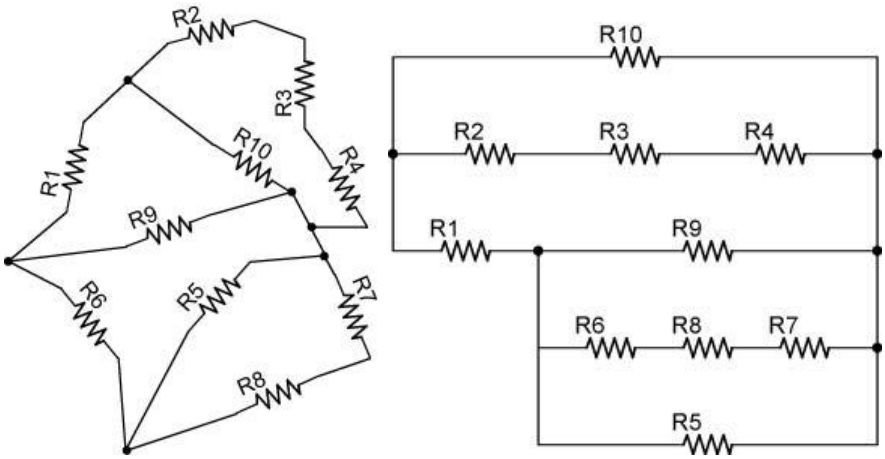


Figure 23: Three Lamps in Parallel with Three Current Pathways

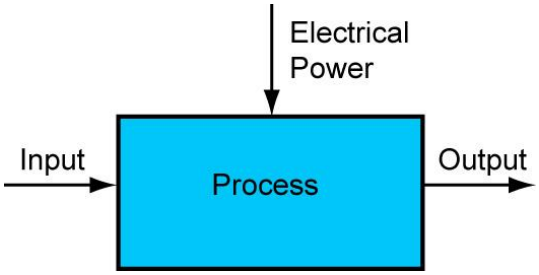
  - Voltage sources and/or loads can be in series or in parallel or a combination of both.

- Sample Circuit:

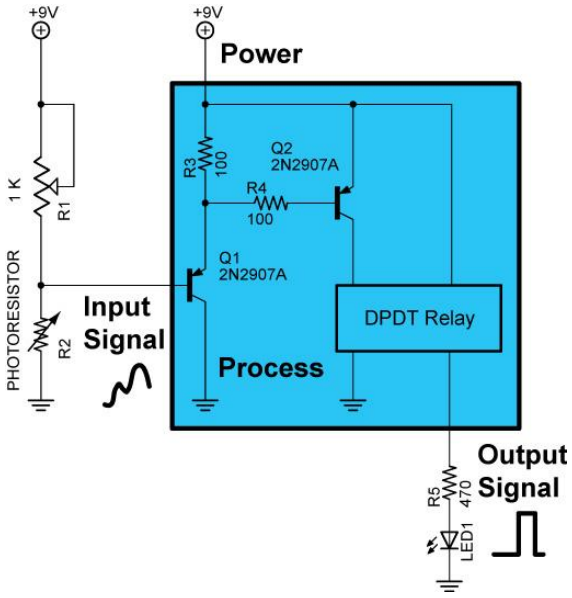


Are These Two Circuits Electrically Equivalent? If Not, Why?

- **Basic Electronics Circuits:**



  - Basically, electronic circuits process input signals to produce output signals that are more useful to us. The process uses electronic components powered by electricity to convert an input signal into a changed output signal. For example in the circuit below, the input signal voltage varies in an analog or continuous manner. The components in the blue box (the process) convert the signal to a digital signal (either on or off) which either turns the Light Emitting Diode (LED) on or off; there is no gradual dimming of the LED.



- **Robot Building for Beginners, Chapter 3, Safety**
  - Safety will be the number one priority for the robotics class. Hazards must be immediately reported to an adult who is attending the session.
  - **Potential Dangers in Robotics:**
    - Burns and fires during soldering and installing heat-shrink tubing.
    - Spark or ignition sources from batteries.
    - Possible bodily harm during drilling, cutting, filing, or milling.
    - Chemical exposure in solder, glues, developers, etchants, and electrical components.
    - Eye injury during drilling, cutting, soldering, stripping, and snipping.
  - Instructions and labels:
    - Read and follow the manufacturer's instructions provided with equipment.
    - Read Material Safety Data Sheets, (MSDS), before using or handling chemicals.
  - Personal protection:
    - Safety glasses:
      - Whenever we are using tools or chemicals in the shop area, safety glasses will be required.
    - Clothing and shoes:
      - Loose clothing is not permitted in the shop area.
      - Long pants are required in the shop area.
      - Shoes and socks must be worn in the shop area.
      - Shoes made of leather or synthetic leather is preferable.
    - Hair:
      - Long hair must be pulled and held back.
    - Ventilation:
      - Use fans to disperse harmful fumes, e.g. soldering.
  - Wash before eating:
    - After soldering, painting, sanding, or handling chemicals or metals, wash hands thoroughly with soap and water.
  - Related web sites:
    - http://www.allaboutcircuits.com/vol_1/chpt_3/1.html
- Perform Simple Circuits Lab 4 – Series/Parallel Fountain

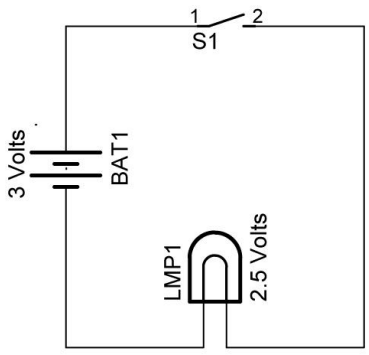
Electronics Technology and Robotics I Week 2
Simple Circuits LAB 1 – Wiring Simple Circuits

- **Purpose:** The purpose of this lab is to acquaint the student with elementary electrical circuit symbols and wiring.

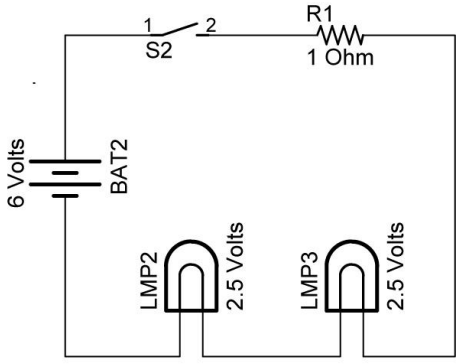
- **Apparatus and Materials:**

  - 1 – 3 Volt Battery Power Supply
  - 1 – 6 Volt Battery Power Supply
  - 1 – 9 Volt Battery Power Supply
  - 2 – 2.5 Volt Lamps
  - 1 – 6 Volt Lamps
  - 1 – 7.5 Volt Lamps
  - 1 – 1 Ohm Resistor (Brown, Black, Gold)
  - 1 – 22 Ohm Resistor (Red, Red, Black)
  - 1 – 68 Ohm Resistor (Blue, Gray, Black)
  - 1 – SPST Knife Switch
  - Alligator Clips

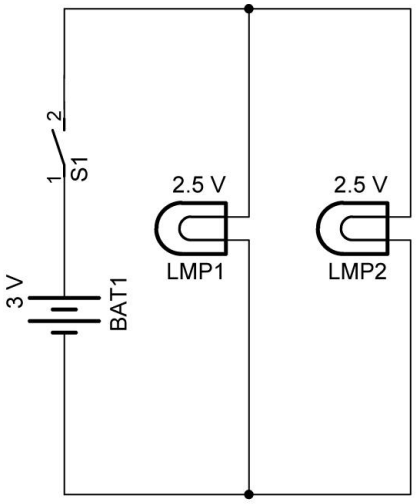
- **Procedure:**
  - Wire the following circuits by connecting alligator clips to the circuit components. Try to position the circuit components to match the component layout in the schematic drawing.
  - Make it a habit to connect a red wire to the positive side and a black wire to the negative side of the battery.
  - Have your instructor check your circuit before closing the switch.



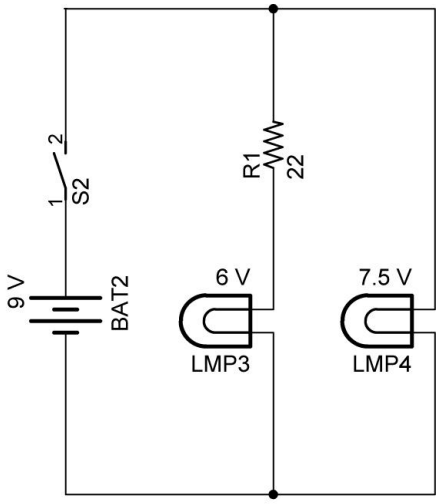
Circuit 1



Circuit 2



Circuit 3



Circuit 4

- **Results:**
  - In Circuit 1, close the switch then disconnect any of the alligator clips and record what happens to the lamp.

  - In Circuit 2, unscrew one of the lamps and record what happens to the other lamp:

  - In Circuit 3, unscrew one of the lamps and record what happens to the other lamp:

  - In Circuit 4, replace the 22 ohm resistor (red, red, black) with a 68 ohm resistor (blue, gray, black) and record the change you observe in the 6 V lamp.

Electronics Technology and Robotics I Week 2
Simple Circuits LAB 2 – Matching Voltage Source to Loads

- **Purpose:** The purpose of this lab is to acquaint the student with several types of electrical loads and the voltage source needed to drive each load.
- **Apparatus and Materials:**
  - 8 – 1.5 Volt AA Batteries
  - 1 – 3 V Battery Holder
  - 1 – 6 V Battery Holder
  - 1 – 12 V Battery Holder
  - 2 – Alligator Clips
  - Loads:
    - 1 – 12 V Fan
    - 1 – 12 V Strobe Light
    - 1 – 12 V Large Gearhead Motor
    - 1 – 12 V LED Cluster
    - 1 – 12 V Piezo Siren
    - 2 – 12 V Small Gearhead Motors
    - 1 – 6 V Gearhead Motor
    - 1 – 3 V Tamiya Motor with Double Gearbox
    - 1 – 3 V Tamiya Motor with Single Gearbox
- **Procedure:**
  - Connect each load to the appropriate voltage source. **If the load is rated at less than 12 volts, have the instructor check your work before you make the last connection.**
  - Check off each load when completed.
- **Results:**

☐  12V Fan	☐  12V Strobe Light	☐  12V Large Gearhead Motor
☐  12V LED Cluster	☐  12V Piezo Siren	☐  12V Small Gearhead. Motors
☐  6V Gearhead Motors	☐  3V Tamiya Motor with Double Gearbox	☐  3V Tamiya Motor with Single Gearbox

Electronics Technology and Robotics I Week 2
Simple Circuits LAB 3 – Conductivity Tester

- **Purpose:** The students apply the principles of a simple electrical circuit to design and build an electrical conductivity tester. The electrical conductivity tester is a simple device that allows students to test different materials to see whether or not they conduct electricity.

- **Apparatus and Materials:**
  - 1 – 3 Volt Battery Power Supply
  - 1 – 2.5 Volt Lamp and Lamp Base
  - Alligator Clips
  - Sample conductors and insulators

- **Procedure:**
  - Using the materials listed, design a electrical conductivity tester circuit such that:
    - The lamp will light when the ends of the two test leads are connected to a conductor, and
    - The lamp will not light when the two test leads are connected to an insulator.
  - Hint: Your tester will look much like Figure 1 in the lesson except one of the wires is cut to make the two test leads.

- **Results:**

Sample	Conductor or Insulator
A	
B	
C	
D	
E	
F	

Electronics Technology and Robotics I Week 2
Simple Circuits LAB 4 – Series/Parallel Fountain

- **Purpose:** The purpose of this lab is to have one group of students design a fountain with nozzles in series and parallel and then have another group of students build the fountain from the design.

- **Apparatus and Materials:**

    - Various PVC Pipe and Fittings
    - PVC Glue
    - 6 – Nozzles

- **Procedure:**
    - Review MSDS for PVC glue.
    - Goggles and latex gloves must be worn when applying PVC glue.
    - Group 1: Design a fountain such that:
        - Use the PVC fittings that are on hand.
        - It is made of 6 nozzles pointing in one direction.
        - The nozzles tips are spaced in a 1' grid.
        - Nozzles are placed in both series and parallel.
        - The final nozzle layout is in a 1' x 2' rectangular grid.
        - The fountain must be 12" tall at the base of the nozzles.
        - The fountain is sourced from a garden hose.
    - Group 1 may only communicate their design to Group 2 by way of drawings and sketches. Group 1 team members may not talk to or give nonverbal signals to Group 2 members.
    - Group 2: Build the fountain based upon Group 1 drawings.
        - Note: The collection of fittings contains more fittings then is needed to complete the project.