Let's Build DC Circuits

OBJECTIVES

- Understand the analogy between water flow and electrical flow
- Learn how to use a breadboard
- Understand circuit schematics
- Make predictions about and build circuits

INFORMATION

1. The Basics of Electricity

A circuit is a set of components connected electrically. These connections provide a pathway for the movement of electric charge. Circuits consist of a voltage source, connecting wires, and other components. As we have discussed, it is often helpful to refer to the analogy between an electrical circuit and water flowing through a pipe system, when learning the basics of electricity (Table 1).

Table 1: Electricity/Water Analogy

Electricity			**Water Analogy**		
Concept	**Explanation**	**Unit**	**Concept**	**Explanation**	**Unit**
Current (I)	net movement of charge	A (charge/s)	Flow rate	volume of water passing a point, per unit time	kg/s
Circuit	*pathway for movement of electric charge*	-	*Water pipe system*	*pathway for movement of water*	-
Voltage (V)	electrical potential difference	V	Pressure difference	water pressure difference due to pipe height and/or pump	Pa (N/m^2)
Voltage source	*battery*	-	*Pressure source*	*pump*	-
Resistance (R)	opposition to current flow	Ω	Relative pipe diameter	resistance (or allowance) of flow due to pipe diameter	friction
Resistor	*component that implements electrical resistance*	-	*Portion of narrow pipe*	*narrow pipe constricts (resists) flow*	-

2. Manipulating Electricity: Circuit Boards

Now that we've reviewed that the goal of an electric circuit is to provide a continuous pathway for the flow of charge, i.e. connections, let's take a look at two types of circuits.

Breadboards provide a convenient way to test circuits. They are comprised of a series of sockets with spring clips inside, to enable electrical contact with any component lead (wire) that is inserted (Figure 1).

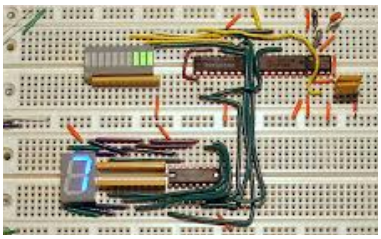


Figure 1: Breadboard with components

The holes of a breadboard are connected internally, such that holes in the terminal strips (rows) have horizontal connections and holes in the bus strips (vertical) have vertical connections (Figures 2, 3). Furthermore, there are two bus strips: ***red*** is the convention for ***power supply***, and ***blue*** for ***ground***.

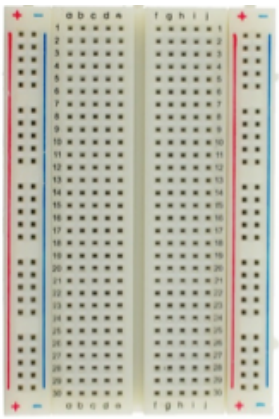


Figure 2: Breadboard

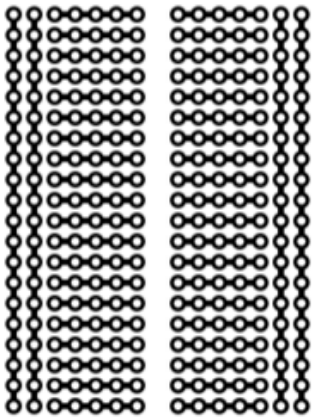
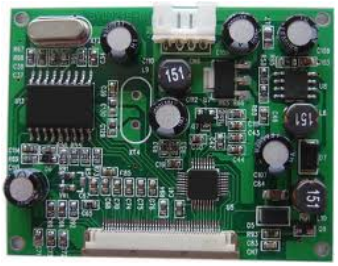


Figure 3: Schematic of internal connections



Printed circuit boards have components, such as resistors and integrated circuits (IE's), soldered to the board (Figure 4). The boards have copper tracks, instead of wires, to link the components into a circuit.

Figure 4: Printed circuit board

3. Basic DC Circuit

The simplest circuit consists of a voltage source connected to a resistor (Figure 5).

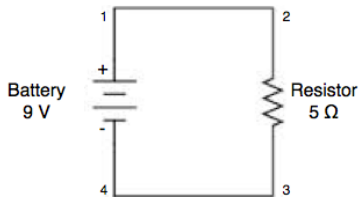


Figure 5: Schematic of simple circuit, with a battery and resistor

An example of this is a battery connected to a lightbulb (resistor) (Figure 6).

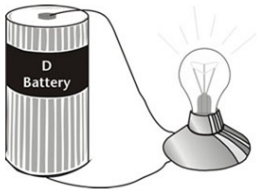


Figure 6: Battery connected to a lightbulb

What would happen if the resistor were replaced with a wire? _____

_____

LAB

1. Breadboard Toolbox

Components (refer to Appendix for a list of common components and their symbols)

- Wire wrapped in insulation
  - Convention: ***Red (+)***, ***Black (-)***
- Alligator clips: an insulated wire, with one clip on each end
- Resistors
- Battery
- Light-emitting diode (LED)

Tools

- Wire cutters
- Digital multimeter, which can be used to test:
  - Connectivity of wires (Y/N = beep/no beep)
  - Voltage between two points in the circuit (V)
  - Resistance of a resistor (Ω)

2. Safety Reminders

- Do not create a short circuit, by connecting both leads of a battery
- Do not touch bare wires
- Always disconnect the battery when manipulating the circuit

3. Exercise 1 - Let's build a simple circuit

Objective: Build a circuit with **one resistor** and test the voltage between various point pairs

Instructions:

1. In the space below, draw and label a schematic of a circuit with one resistor
   a. Draw a battery and label the voltage and terminals
   b. Draw a resistor next to the battery and label its resistance
   c. Draw wires connecting the battery and resistor
   d. Label four test points at the vertices with the 1 at the (+) terminal and move clockwise

Schematic for Exercise 1

How does your schematic compare to Figure 5? _____

_____

2. Build the circuit (as seen in Figure 8)
   a. Using wire cutters, cut two ~ 1" pieces of ***red-insulated wire*** and two ~ 1" pieces of ***black-insulated wire***.
   b. Strip both ends of each piece of wire, with the wire cutters
   c. Place one side of one ***red wire*** into the ***power*** rail of the breadboard
   d. Place one side of one ***black wire*** into the ***ground*** rail, ~10 rows below the power supply wire

      Why do we space these two wires apart? _____

      _____

   e. Prepare a resistor to be added to the breadboard: bend the wire on both sides of the resistor and cut the excess wire, to resemble Figure 7

Figure 7: Resistor

   f. Align the resistor in the terminal strips so that the resistor is parallel to the rails
   g. Connect the resistor to the ***power supply*** and to ***ground***, using the remaining two pieces of wire (one ***red wire***, one ***black wire***)

h. Take one pair of alligator clips and connect one clip to the (+) terminal of the battery and connect the other clip to the power supply wire, in the power rail of the breadboard (Figure 8)

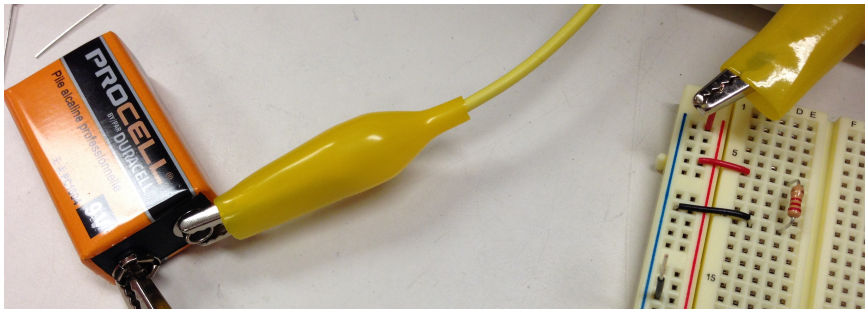


Figure 8: Exercise 1 circuit

** Note your responses to steps 3-6 below, in Table 2. **

3. Predict the circuit's voltage between the point pairs listed in Table 2, starting with the voltage between point 4 and point 1. *Be sure to include units.*

4. ***Avoid*** *direct contact between the (+) and (-) terminals of the battery!* Connect the (-) terminal of the battery to the ground wire in the ground rail of the breadboard, using the other pair of alligator clips. Then, using a multimeter, measure the voltage between each pair of points.

** Disconnect the battery, for safety reasons. **

5. With a ✓or ✗, indicate if there are any discrepancies between your predictions and measurements

6. Account for any differences you observe between your predictions and measurements

Table 2: Voltage in the Circuit (Exercise 1, Steps 3-6)

Voltage [V]	Prediction (P)	Measurement (M)	P=M ?	Explanation (for P ≠ M)
V_{4-1}				
V_{2-1}				
V_{3-2}				
V_{4-3}				

4. Exercise 2 - Let's make an LED light up

Objective: Build a circuit with one resistor and an LED

Instructions:

1. In the space below, draw and label a circuit with one resistor and an LED

Schematic for Exercise 2

2. Why must the resistor be included in *this* circuit? _____

   _____

3. To the circuit you already built, add an LED, with the flat face hooked up to the (+) terminal and the round face to the ground

   What do you *expect* to observe when you connect the battery? _____

   _____

4. Connect the battery. What do you observe? _____

   _____

5. *With the battery disconnected*, flip the LED, then reconnect the battery. What do you observe? _____

   _____

6. What might be causing the discrepancy between your prediction and your observation? _____

   _____

7. In the space below, draw a analogous component to an LED, for the water model.

5. Exercise 3- Let's make a voltage divider

Objective: Build a circuit with two resistors

Instructions:

1. In the space below, draw and label a circuit with two resistors and no LEDs. Again, label the vertices and the wire between the two resistors, with the numbers 1 - 5. Start with 1 in the top left (just above the battery) and travel clockwise to label 2-5. Point 3 should be in the circuit between the two resistors.

Schematic for Exercise 3

2. Predict the circuit's voltage between the point pairs listed in Table 3, starting with the voltage between points 2 and 3. *Be sure to include units.*

Table 3: Voltage in the Circuit (Exercise 3, Step 2)

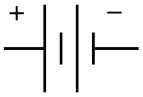
Voltage [V]	Prediction (P)	Measurement (M)	P=M ?	Explanation (for P ≠ M)
$V_{1\text{-}2}$				
$V_{2\text{-}3}$				
$V_{3\text{-}4}$				
$V_{2\text{-}4}$				
$V_{4\text{-}5}$				
$V_{1\text{-}5}$				

3. To the circuit you build in the previous exercise, replace the LED with a resistor.

4. Connect the battery, take your measurements, and record your findings in Table 3 (above). Make not of the differences between your predictions and measurements, also in Table 3.

APPENDIX

Table 4: Common Components of Electric Circuits

Component	Picture	Symbol
Wire		
Resistor		
Battery		
LED