Lab #3b: Controlling external circuits with the Arduino

Purpose:
In this lab you will build a few external circuits and interface these with the Arduino.

What you will need:

1. Arduino board (and USB power cable)
2. Breadboard for building external circuits
3. Circuit components: jumpers, LEDs, resistors, button
4. Digital voltmeter (DVM)

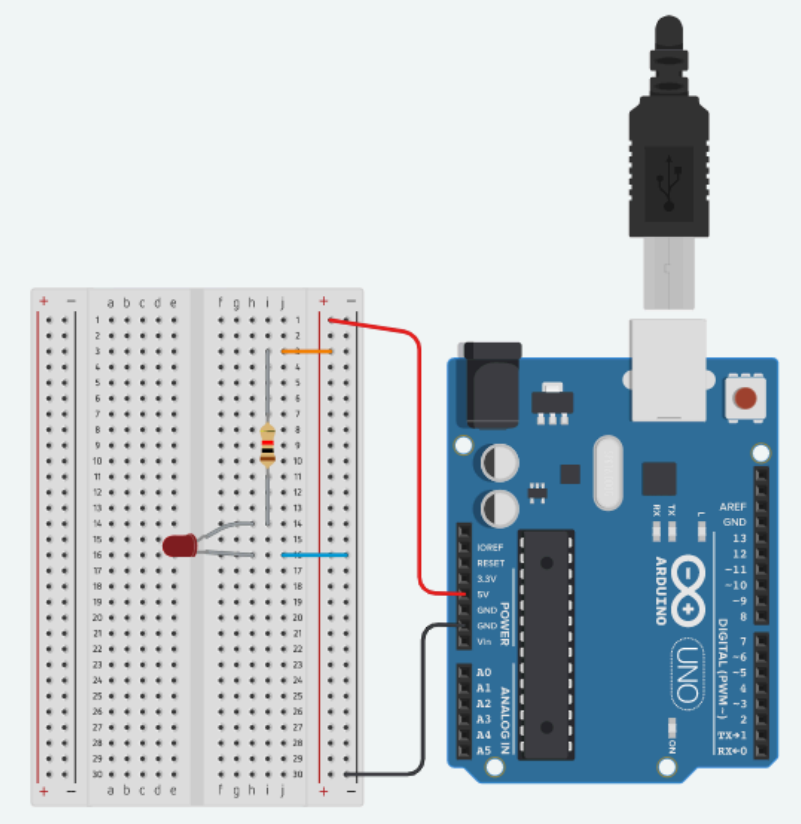
Setup:
If you have not done so already, please install the battery in your DVM. You may need a small screwdriver to open the battery panel.

Online resources:
1. http://engineering.nyu.edu/gk12/amps-cbri/pdf/ArduinoBooks/Arduino%20Programming%20Notebook.pdf
2. https://www.arduino.cc/en/Tutorial/HomePage

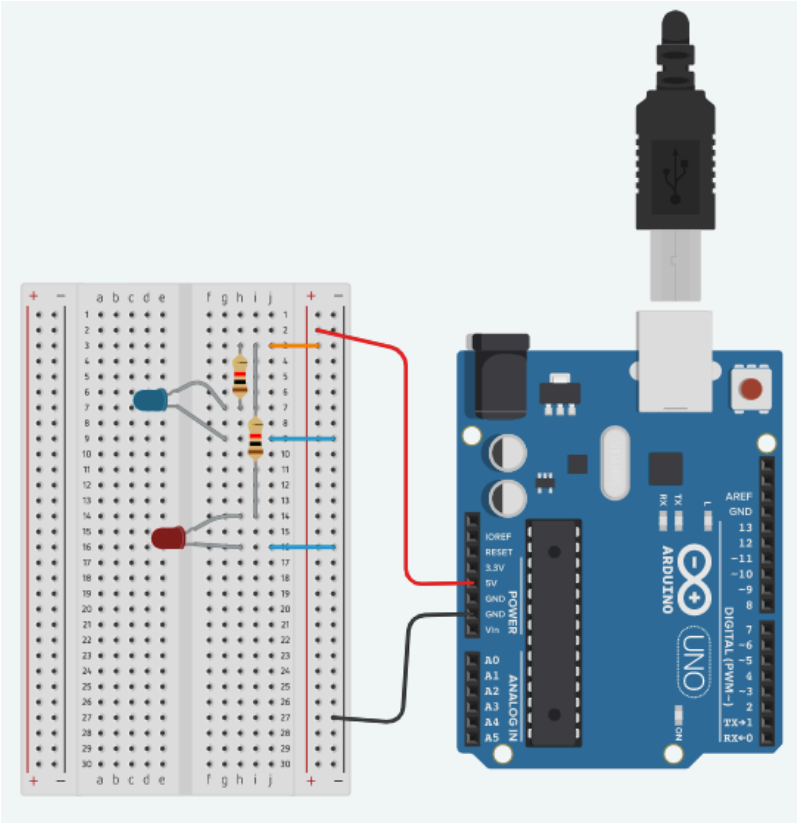
Tasks:

1. Build a simple circuit to turn on a single LED.
    a. **Voltage sources:** We start by bringing over the +5V source from the Arduino to the + power strip on the breadboard. We will connect the GND (meaning 0V, low voltage point) to the - power strip on the breadboard. Each of these strips is referred to as a bus, because they deliver voltage along a path.
    b. **The resistor:** We want to include something like a 220 Ω resistor to limit the amount of current flowing through the circuit. It need not be exactly 220 Ω, but this is a very common value for resistors, so we will use that one. While all of the LEDs will light up without the resistor, and will be much brighter, we run the risk of damaging them by running them too bright. The following link has a good description of how to choose the color code for resistors:
    https://learnabout-electronics.org/Resistors/resistors_06.php
    It is likely that your resistors use the five band color code, though it is possible that it could be the four band style. Ignore the last band (likely a gold band), as that one refers to the tolerance of the measurement (how accurately the resistor was tested for a particular value), and is not important for us at this point.
    c. **The LED**: Pick your favorite color of LED. Notice that the LED has one leg longer than the other. The long leg always goes toward the higher voltage side of the circuit. Bend the long leg out to the side and then back straight so that it is approximately the same length as the shorter leg. This will help when mounting it in the breadboard.
    d. **Make your circuit:** Connect the positive voltage to one of the rows using a short jumper wire. Next place the resistor on the same row as the jumper you placed. Connect the other end of the resistor to another row, maybe 10 units apart or more. Along that same row as the second resistor end, place the long leg (the high voltage side) of the LED, and place the short end on another row. Jumper from the low-voltage side of the LED back to the low voltage bus. Your LED should light up!

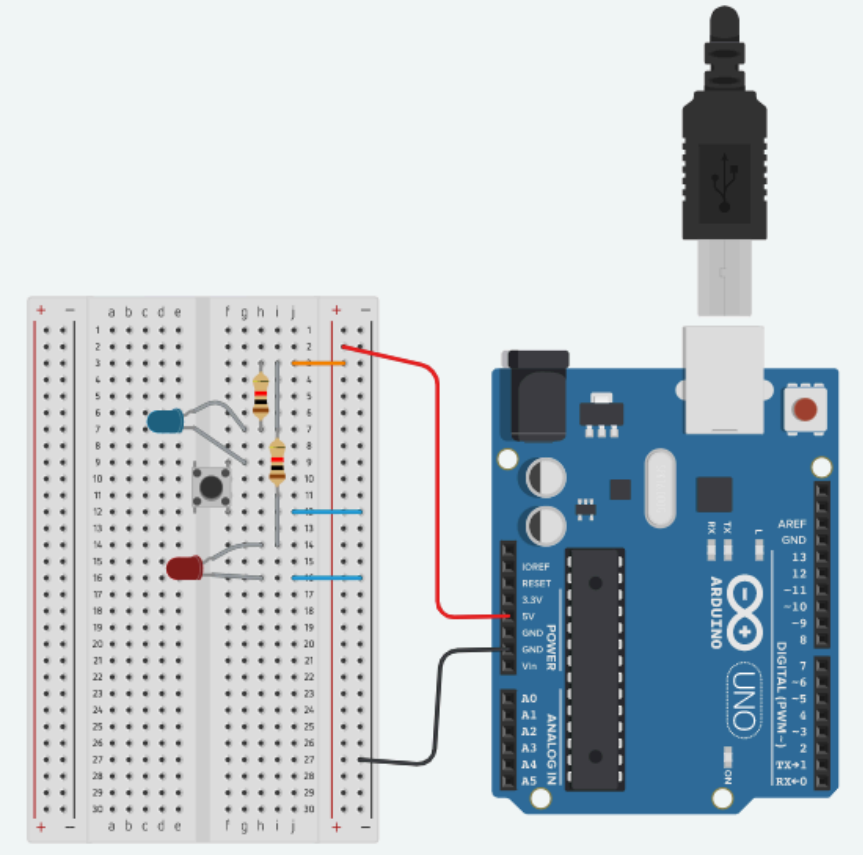
e. **To do:** Using your DVM (on the 20 Volt, DC setting) make the following voltage measurements:
    1. Between 0V (GND) and 5V.
    2. Across the resistor.
    3. Across the LED.
    4. What do you notice about these three values?



2. **Add multiple LEDs to the circuit.** Note that if you connect more LEDs between the resistor and jumper to GND that they may not all light up (if they are different colors). This comes about because LEDs have a complicated voltage-current relationship. In order to get multiple colors of LEDs to light up we need to create separate branches for each, also called wiring in parallel. Do the following:



3. **Add a button.** You can add a button in line with one of your LEDs so that you can control it whether it is on or off.



Note: one side of the button is in line with the low-voltage side of the LED, and the other is in line with the jumper connecting back to GND. If your button doesn't work then you can try rotating it by 90 degrees and trying again. The bumps in the legs of the button should point to the sides (in the orientation shown above).
Instead of powering the LEDs so that they are powered by the 5V source on the board, you will now control each LED by providing power to it from one of the controllable outputs, much like we did for the "Built in" LED in the last part of this lab.

4. **Control the LEDs with a program.** Instead of powering the LEDs so that they are powered by the 5V source on the board, you will now control each LED by providing power to it from one of the controllable outputs, much like we did for the "Built in" LED in the last part of this lab. To do this you will need to do the following things:
    a. We need to split the LEDs so that they have separate voltage sources now, instead of a single ""always on" 5V source. To do this we are going to remove the 5V power from the + bus. Next we need to separate the tops of the LED circuits so that we can provide them with different voltages.
    b. Take a jumper from one of the numbered pins on the other side of the Arduino board and connect that to the "top" of one of your LED circuits (in the pictures above this means the top of the resistor, the high-voltage side). Take a jumper from one of the other pins and run that to the other LED circuit.
    c. Modify your code so that you now setup both of the output pins for output control.
    d. If you want to run the same blink pattern on both then modify the code so that on each loop you write the output to both LEDs at the same time.