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Goals of this second circuit lab packet:

1 – to learn to use voltmeters an ammeters, the basic devices for analyzing a circuit.
2 – to learn to use two devices which make circuit building *far* more simple: a digital multimeter and a breadboard

Lab A: Using an Ammeter and Voltmeter

Goal:
Find the resistance of a mystery resistor using an ammeter and a voltmeter.

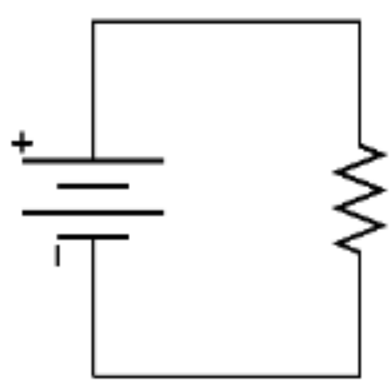
Ammeter A device that measures the current in a circuit. It is *always* connected in SERIES to the device through which it is measuring current.
Voltmeter A device that measures the voltage in a circuit. It is *always* connected in PARALLEL to the device through which it is measuring voltage.

An ammeter is always connected in ____________________.

A voltmeter is always connected in _____________________.

For the first lab, I want everyone to use *analog* devices, for the experience of using them and seeing how they work. In the future, we will also learn to use a digital multimeter.

1. Find a resistor to use in your circuit. You can chose a light bulb, but it is better to use a traditional resistor.
Connect a resistor to a battery as such:



What resistor did you pick?

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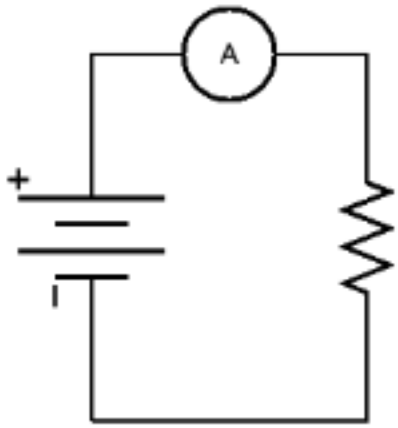
2. To measure current, connect an analog ammeter in series with the resistor:



What number do you record for the current?

Issues to consider in connected an analog ammeter:
- I have a large collection of analog ammeters on different scale, from Amps all the way down to microamps.
If you pick to sensitive an ammeter, it will max out immediately.
If you pick to strong an ammeter, the needle will not move.
You need to select the appropriate ammeter, in which the needle moves somewhere to the middle of the device.

- You may pick an ammeter that uses a unit other than Amps, such as milliamps. If so, you need to *convert* your result into Amps, because that is the SI unit.

- You may notice that the ammeter arrow seems to go the opposite way, but doesn't record any useful number. If this happens, you are recording negative current and can easily fix this by flipping the ammeter around.

- If the current is very very small, try adding another battery to increase it.

3. Come up with a test to answer the following question. Does it matter which side of the resistor the ammeter is on? Give the answer, and explain or draw diagrams to show how you answered it:

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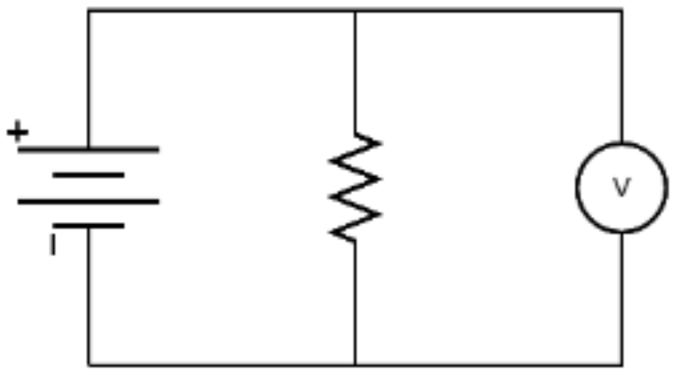
4. To measure voltage, connect a voltmeter in parallel to your resistor.



What voltage did you record?

Issues in using an analog voltmeter:

- Again, you need to select a voltmeter of an appropriate scale

- Again, you need to convert to the correct SI unit, which is volts.

- Some of my voltmeters are designed for Alternating Current (which switches directions). These have a tilde (~) on them. They will not work for this lab.

6. Now that you have voltage and current, use Ohm's Law (V = IR) to find the resistance of your mystery resistor in Ohms.

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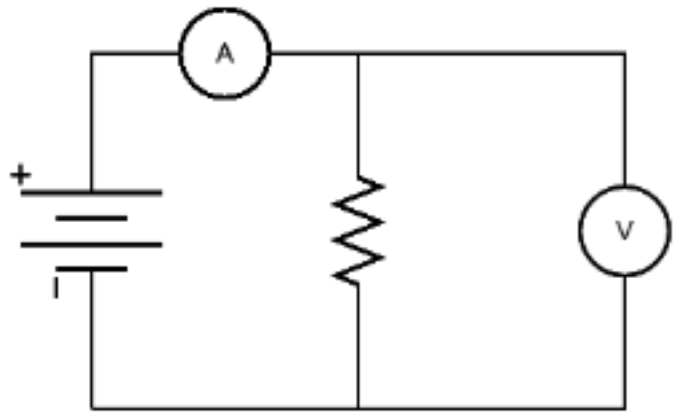
7 and 8. Repeat this measurement for two different resistors.
To speed up your measurements, you can connect both the ammeter and voltmeter simultaneously, like this:



Space to find resistor 2

Space to find resistor 3

9. How accurate do you feel these measurements are? What sources of error may this experiment contain?

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Lab B: Confirming the Series and Parallel Circuit Rules

1. Solve some of the series and parallel circuit problems from the packet entitled Circuit Math 1. I tis important you know very well the rules for current and voltage in a parallel and series circuit!

In a series circuit, the ____________________ is the SAME for all resistors.

In a series circuit, the ____________________ adds up for all resistors.

In a parallel circuit, the __________________ is the SAME for all resistors.

In a parallel circuit, the __________________ adds up for all resistors.

2. Using the red, yellow, and green mystery resistors from before, build a parallel circuit with 3 resistors.
Not all of the resistors need to be the have resistance.
Draw it here:

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3. Figure out a way to measure the *current* on each branch of the parallel circuit, and the total. You will need to place the ammeter in a certain location for *each* of these measurements.
For *each* of the measurements, draw a circuit diagram showing how you placed the ammeter, and record the current that you recorded *in amps*.

Measure current on the FIRST branch	Measure current on the SECOND branch
Measure current on the THIRD branch	Measure current of the *total circuit*.

Did you confirm the *rule* for current on a parallel circuit?

	Resistor 1	Resistor 2	Resistor 3	Total
Current (Amps)				

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4. Repeat the previous procedure to confirm the *voltage* rule for a parallel circuit. You will need to place a voltmeter in a specific location for each measurement.
For each of the measurements, draw a circuit diagram showing how you placed the voltmeter and record your measurement in *volts*.

Measure voltage on the FIRST branch	Measure voltage on the SECOND branch
Measure voltage on the THIRD branch	Measure voltage of the *total circuit*.

Did you confirm the *rule* for voltage on a parallel circuit?

	Resistor 1	Resistor 2	Resistor 3	Total
Voltage (Volts)				

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5. Now, rearrange your three resistors into a *series* circuit.
Measure the *voltage* of each resistor on the series circuit. To do so, you will need to place the voltmeter in three different locations. To measure the voltage of the *total circuit*, place the voltmeter parallel to the battery or batteries.

Measure voltage of the FIRST resistor	Measure voltage of the SECOND resistor
Measure voltage of the THIRD resistor	Measure voltage of the *total circuit*.

Did you confirm the *rule* for voltage on a parallel circuit?

	Resistor 1	Resistor 2	Resistor 3	Total
Voltage (Volts)				

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6. Using an ammeter, measure the current in four different locations on a series circuit.

Ammeter before the first resistor	Ammeter between the first and second resistors.
Ammeter between the second and third resistors.	Ammeter after the third resistor.

Did you find, according to the rule, that the current was constant for all points on the series circuit?

7. While doing the 4 sections of this lab, did you have any new intuitions about *why* these rules are true?

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Lab C: Using a Digital Multimeter

Goal:
Repeat labs **A.** and **B.** using, instead of analog voltmeters and ammeters, a digital multmeter.
[You can do enough until you feel you have a full grip on how the multimeter works]

You can record all measurements below:

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Lab D: Using a breadboard
A breadboard is a device that allows you to make a very complex circuit, very quickly, in a very small space.

The circuit boards we have been using are great for learning the basics, but to take our game to the next level we need a more professional device.

A **breadboard** is a device wherein you plug in small circuit components. The holes within the breadboard are connected to each other. It is frequently used to make prototypes before creating real circuit boards or soldering.

The **jumper wires** are small pinged wires that connect to the breadboard.

Alligator cables are the one's that open and close like an alligator.

GOAL:
Discover how the breadboard is wired.

Materials:
- Battery and holder
- Light bulb (and holder)
- 3 Alligator clips
- 2 jump wires
- 1 breadboard

1. Using a batteyr holder, three alligator clips, and two jumper wires, and a light bulb create a device so that whenever two jumper wires connect, the light bulb turns on .

Explain or draw how you set this up:

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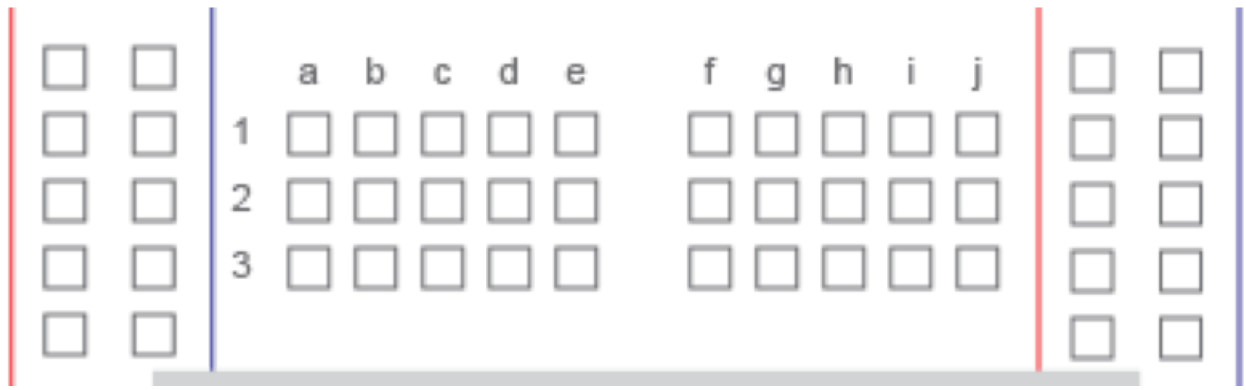
2. Using your device, poke the jumper wires into various spots on the breadboard.
Figure out: When does the bulb light?
When does it not light?

The spots on the breadboard are *connected* underneath using a wire. By examining it with your jumper cable poking device, figure out how the holes of the breadboard are connected. Draw it on this diagram:



3.
New materials:
- 2 small lamps that can be attached to the breadboard.
- more jumper cables.

Attach the lamps to the breadboard.
Using the breadboard, create a **series circuit** and a **parallel circuit**, each with a battery at two lamps.

PROVE you have created the correct type of circuit by testing the following:
For a series, if you remove one lamp, the other should turn off.
For a parallel, if you remove one lamp, the other should stay on.
The parallel circuit should have *brighter* lamps.

Explain how draw how to put two light bulbs in series	Explain or draw how to put two light bulbs in parallel:

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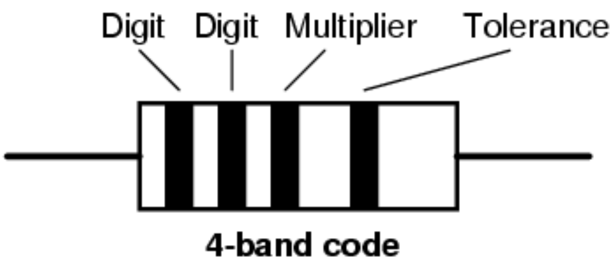
Lab E: Color Band Resistors

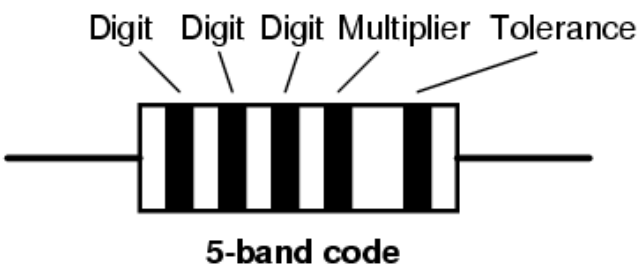
When using a breadboard, arguably the most important device you will use is a resistor.

Unlike before, there are no more mystery resistors. You can find the resistance of any resistor by reading the bands on the side of the resistor.

(Images from https://www.allaboutcircuits.com/textbook/reference/chpt-2/resistor-color-codes/)

A 4 band resistor:





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Select a resistor from Mr. Kuncik's collection.
Write the colors of the 4 or 5 bands.

Digit 1	Digit 2	Digit 3 (if it is there)	Multiplier	Tolerance

Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20

To get the total resistance, first put the digits together to make a 2 or 3 digit number.
Then, multiply by the multiplier.
Don't worry about tolerance today.

What resistance did you get? Explain how you got it.

Using the breadboard and the digital multimeter, repeat lab A (measuring the resistance of a resistor). Record your measurements and calculations below. Did you get the *same* resistance that is recorded on the color bands?

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Lab F Breadboard and Digital Multimeter:

Goal:
Repeat the ‘confirming series and parallel circuit rules’ lab using a breadboard and a digital multimeter.

Use the space below for any measurements and ideas: