Physics 1E03: Lab 2

OHM'S LAW & KIRCHHOFF'S LAWS

Lab Objectives

- Understand how resistance, voltage, and current are related
- Explore the difference between adding resistors in series and parallel
- Use Ohm's Law to predict the current in several different circuits
- Simplify circuit analysis by finding the equivalent resistance and solving for it experimentally
- Build and explore how voltage dividers work
- Apply Kirchhoff's voltage and junction laws experimentally and theoretically to a circuit

Theory: Resistors in Parallel and Series

- A useful quantity to study in circuits is the *equivalent resistance*
  - This is the value that a single resistor would have which could replace the entire network of resistors in the circuit
- When resistors are placed end-to-end, they are said to be in *series*

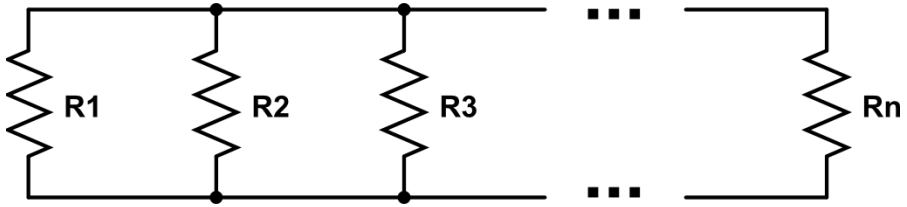
- The equivalent resistance of resistors in series is given by

$$R_{eq} = \sum_{i=1}^{n} R_i = R_1 + R_2 + R_3 + \cdots + R_n.$$

Theory: Resistors in Parallel and Series

- Alternately, we could also have resistors in *parallel*

- Occurs when the terminal of resistors are connected to the same two nodes

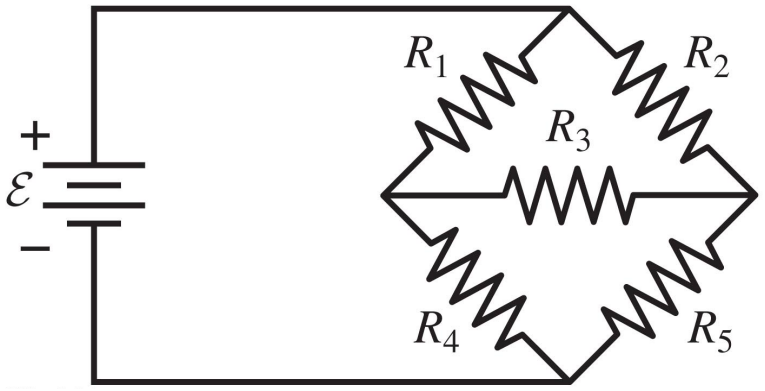


- The equivalent resistance of resistors in parallel is given by

$$\frac{1}{R_{eq}} = \sum_{i=1}^{n} \frac{1}{R_i} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}.$$

Theory: Kirchhoff's Laws

- Not all circuits can be categorized as "series" or "parallel"
- How can we calculate the voltages and currents of circuits like this?
- Kirchhoff created two rules to help solve any circuit diagram

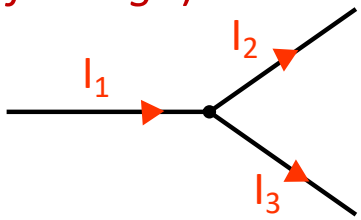


Example of a circuit whose resistors are neither in series or parallel

Theory: Kirchhoff's Laws

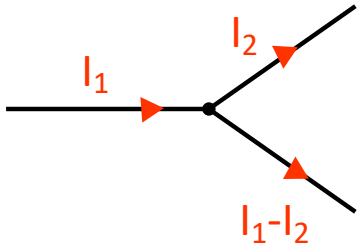
1. The Junction (Node) Rule: $\sum_{junction} I = 0$

Total current in = total current out at any junction in a circuit (*arises from conservation of charge*)



$I_1 = I_2 + I_3$

Or alternatively:



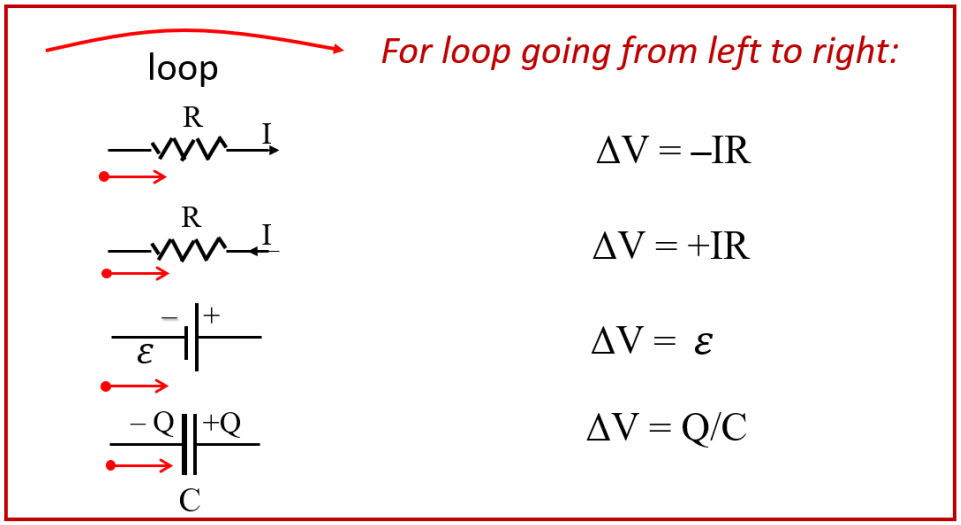
$I_1 = I_2 + (I_1 - I_2)$

Note: Direction of current is chosen arbitrarily. If it turns out to be negative after analyzing the circuit, it means actual current is in the opposite direction

Theory: Kirchhoff's Laws

2. The Loop Rule: $\sum_{closed\ loop} \Delta V = 0$

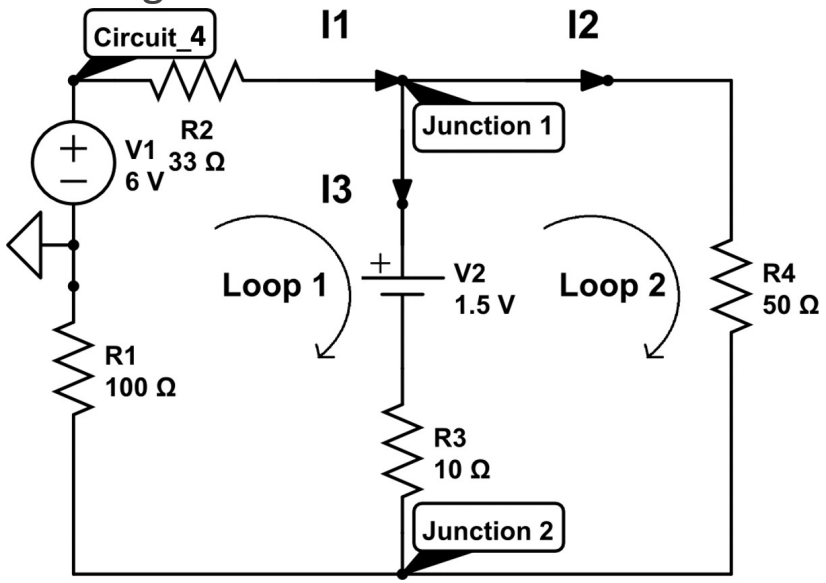
Sums of potential difference around any closed loop is zero *(arises from energy conservation)*. As charge (q) moves through a circuit its potential energy (qV) will change, but must return to original value after one full loop, $\sum_{loop} q\Delta V = 0$



Note: If the loop goes from right to left instead, then all the signs for the potential difference would switch

Theory: Kirchhoff's Laws

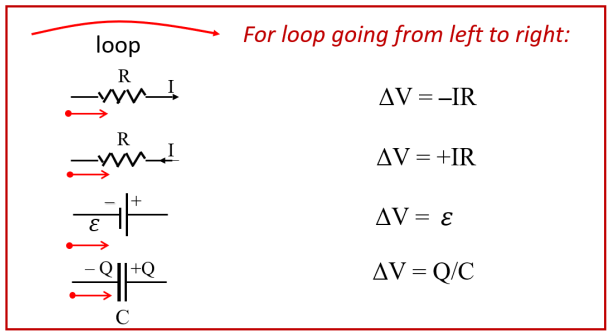
- Using these rules, let's write the equations for the following circuit:



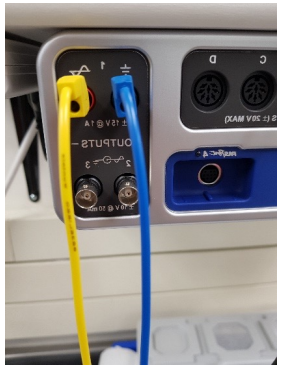
Recall:

Junction rule: $\sum_{junction} I = 0$

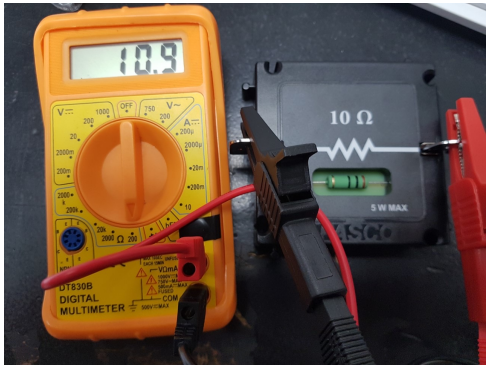
Loop rule: $\sum_{closed\ loop} \Delta V = 0$



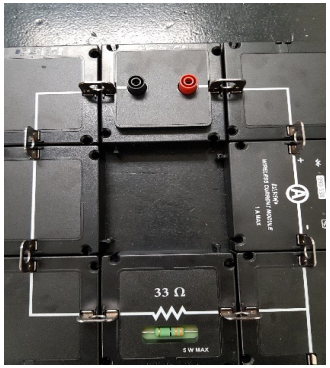
Equipment



PASCO Capstone Software



Digital Multimeter



Circuit Building Blocks

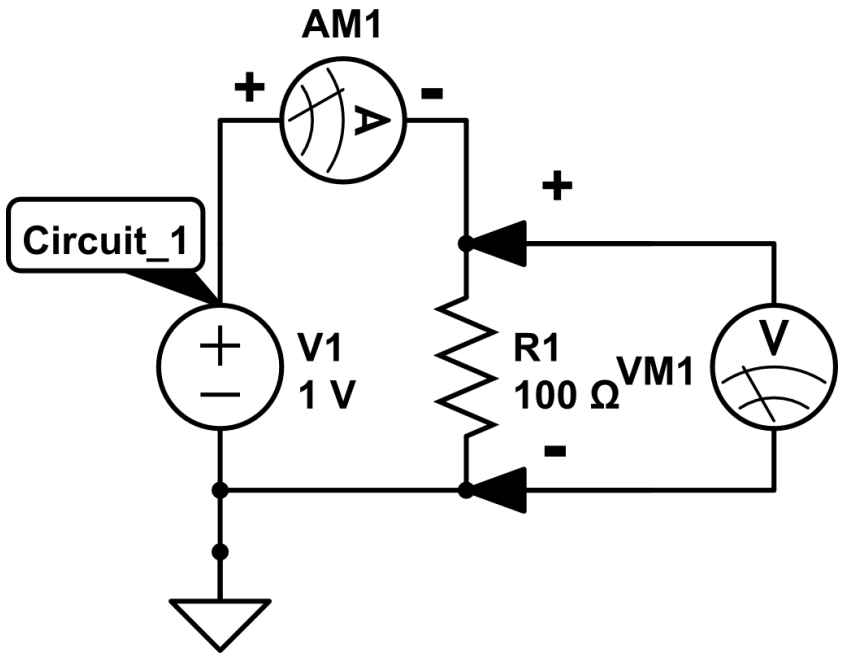
Digital Voltmeter & Ammeter

Part 1: Measuring Electric Quantities

- Goal is to measure the voltage and current passing through the resistor R1

- Start by building Circuit_1 using the building blocks and set up the power supply through the PASCO software

- Measure the current/voltage using the ammeter/voltmeter and compare with theoretical predictions
  - Notice where the + and – ends are connected for each electrical device



Part 1: Measuring Electric Quantities

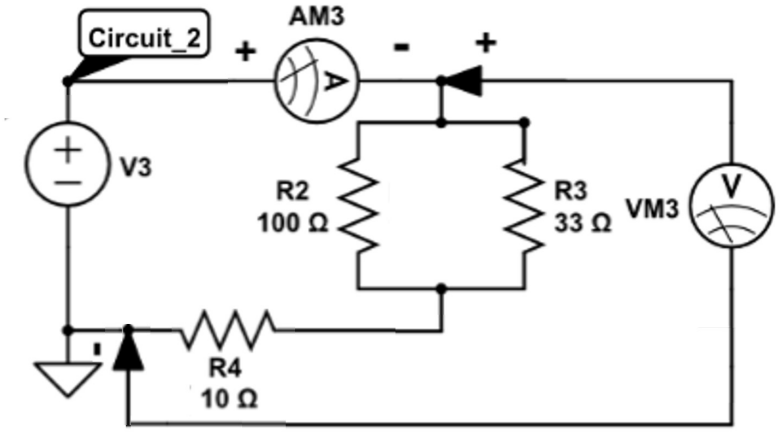
IMPORTANT
DO NOT keep the power supply on at all times. Make sure it is kept on only when you are taking measurement.

Part 2: Circuit Analysis

- Goal is to examine how resistors in series behave

- After building Circuit_2, use PASCO to record the voltage and current of the circuit
  - Make sure to have the TA's check your work before continuing

- Use the recorded data to construct a voltage vs current graph
  - Remember to include things like a title, labeled axes, line of best fit, etc.

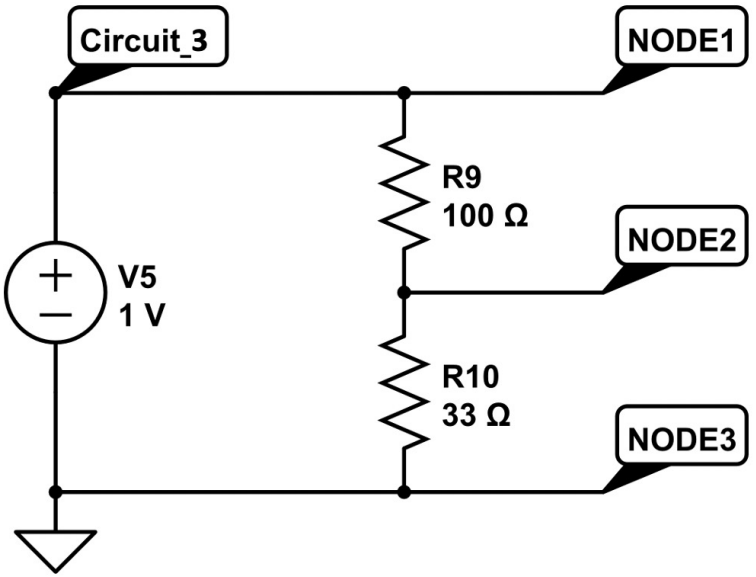


Part 3: Voltage Dividers

- Here you will learn how voltage dividers work

- Before constructing Circuit_3, work out the theoretical values for the voltages between nodes 1 and 2, then again for between nodes 2 and 3
  - Your pre-lab questions should help you in doing this!

- Construct Circuit_3 then measure/record these values in your report
  - How do they compare to your theoretical values?

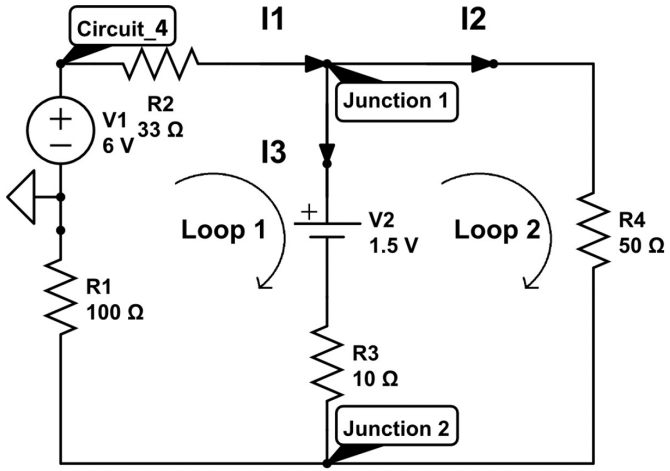


Part 4: Kirchhoff's Rules- Two Loop Circuit

- Here we want to apply Kirchhoff's laws to a two-loop circuit

- Before building the circuit, use the digital multimeter to measure the resistance of each resistor you will be using
  - Record these values (including uncertainty) on your report

- Construct Circuit_4, making sure the battery polarity and power supply are properly orientated/set up
  - Have a TA examine your set up before taking measurements

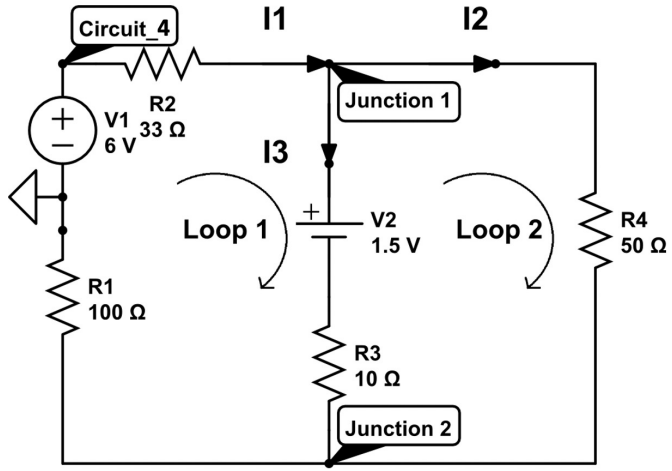


Part 4: Kirchhoff's Rules- Two Loop Circuit

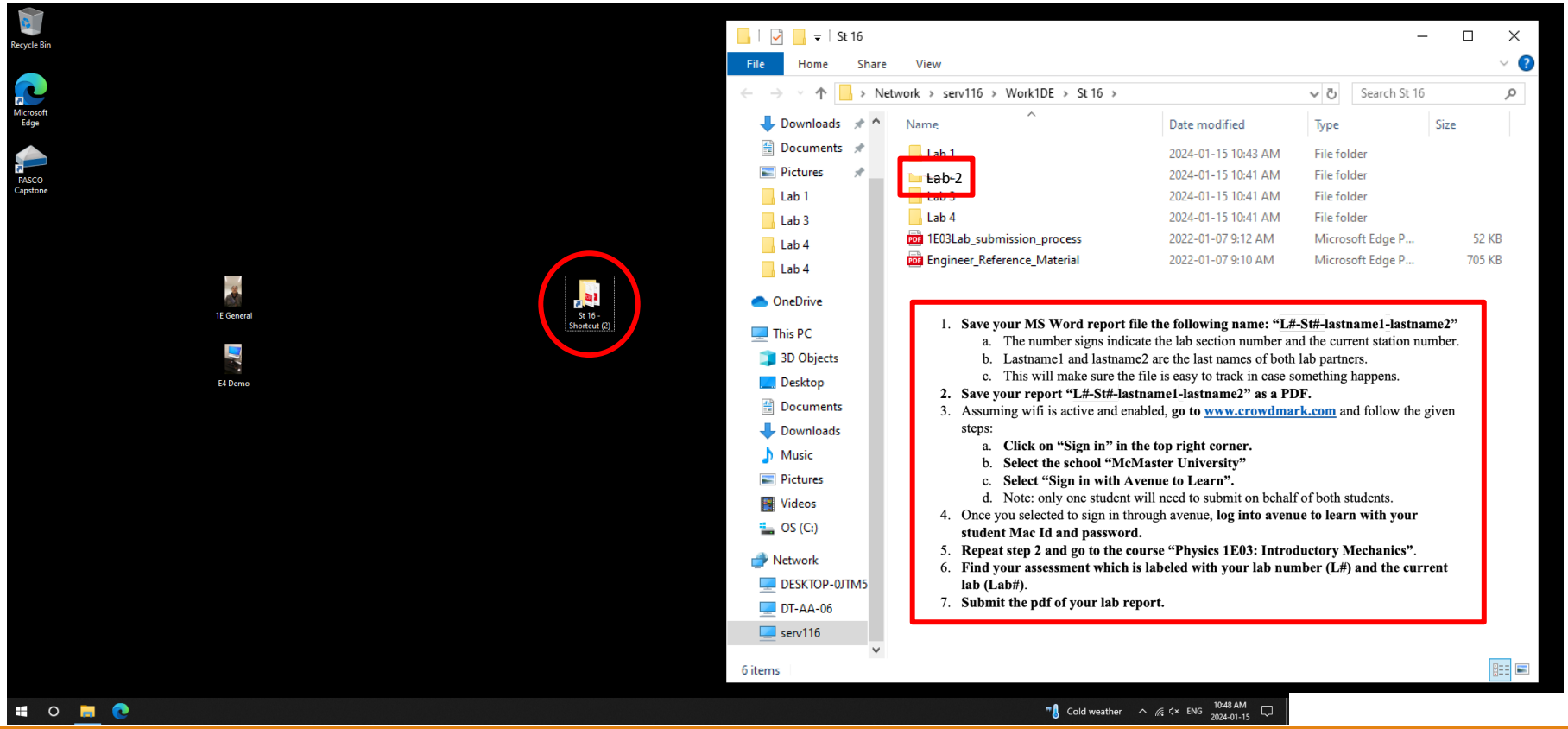
- Using the voltmeter, measure the voltage across each electrical component
  - Record these values into your report

- Using the ammeter, measure currents I1, I2, and I3 at both junctions 1 and 2
  - At the end, you should have 6 total measurements

- Compare your results with theoretical values obtained from solving the junction/loop laws you derived earlier



Saving and submitting the report



Good Luck!