

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

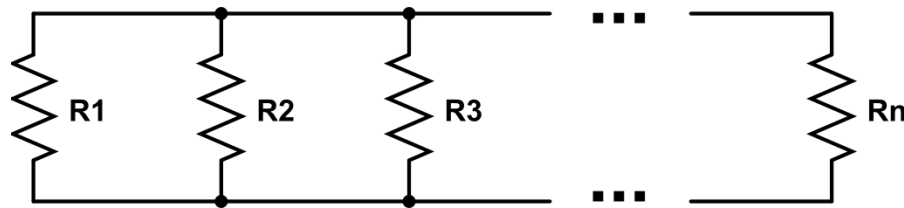


- The equivalent resistance of resistors in series is given by

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

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

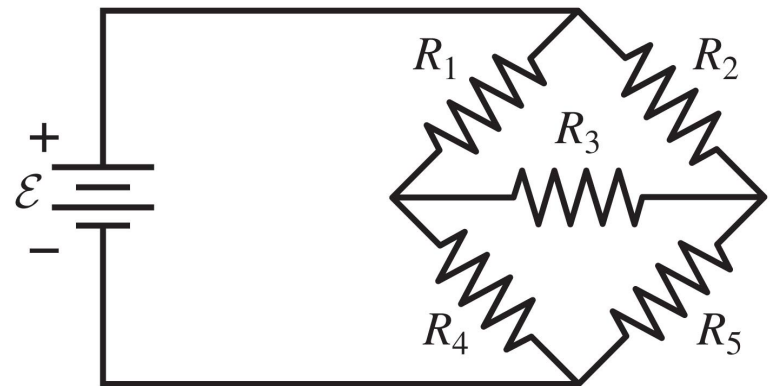


- The equivalent resistance of resistors in parallel is given by

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

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

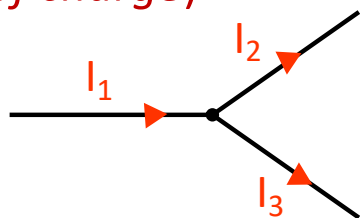


Example of a circuit whose resistors are neither in series or parallel

Theory: Kirchhoff's Laws

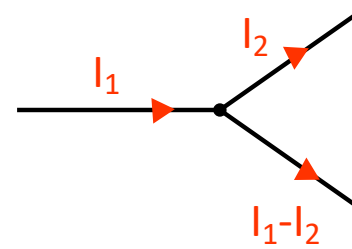
1. The Junction (Node) Rule: $\sum_{\text{junction}} I = 0$

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:



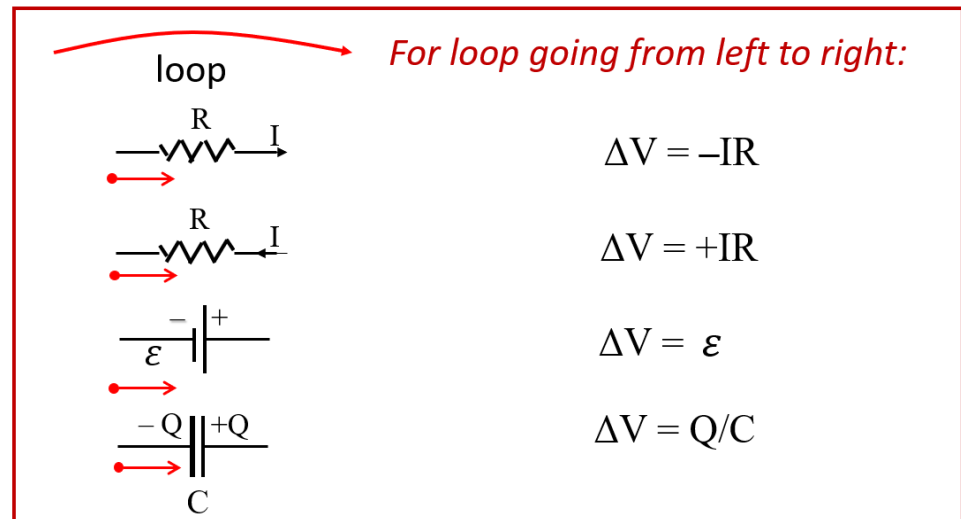
$$I_1 = I_2 + (I_1 - I_2)$$

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

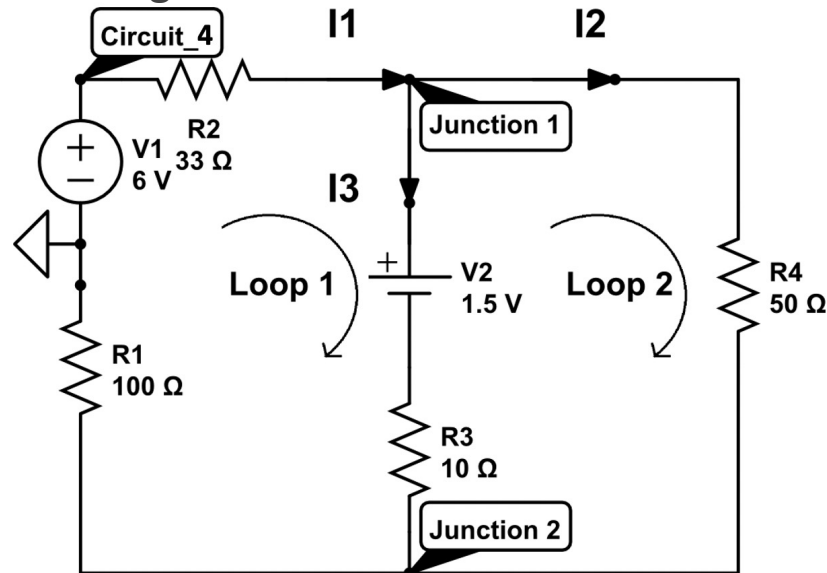
Sums of potential difference around any closed loop is zero (*arises from energy conservation*). As charge (q) moves through a circuit its potential energy (qV) will change, but must return to original value after one full loop, $\sum_{\text{loop}} q\Delta V = 0$



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

Theory: Kirchhoff's Laws

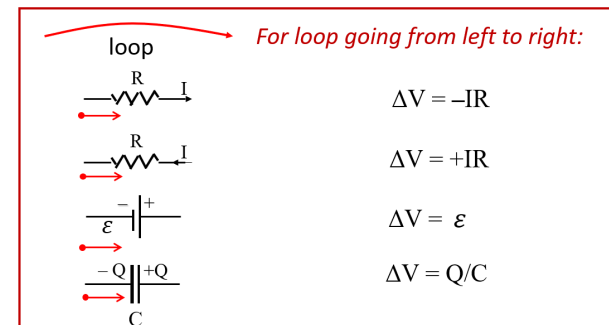
- Using these rules, let's write the equations for the following circuit:



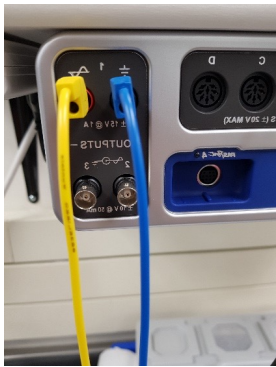
Recall:

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

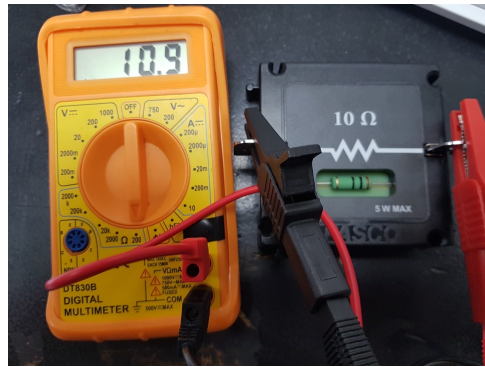
Loop rule:
$$\sum_{\text{closed loop}} \Delta V = 0$$



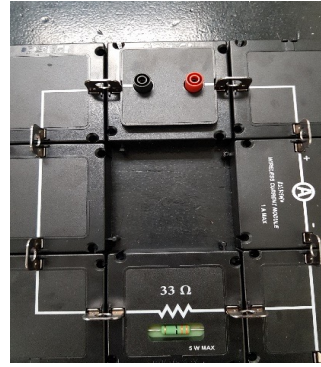
Equipment



PASCO Capstone
Software



Digital Multimeter



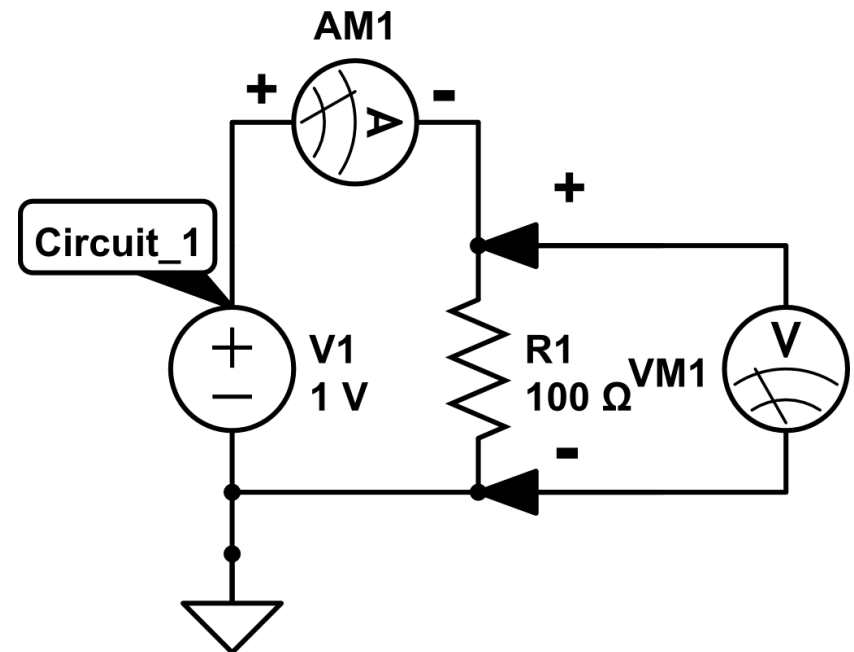
Circuit Building
Blocks



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



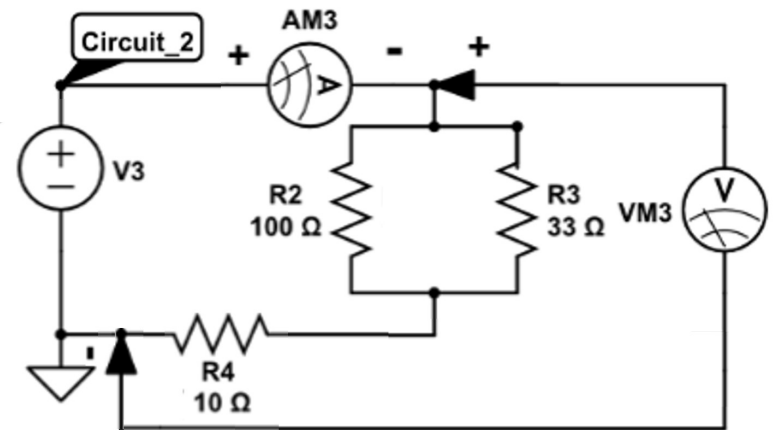
Part 1: Measuring Electric Quantities

****IMPORTANT****

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

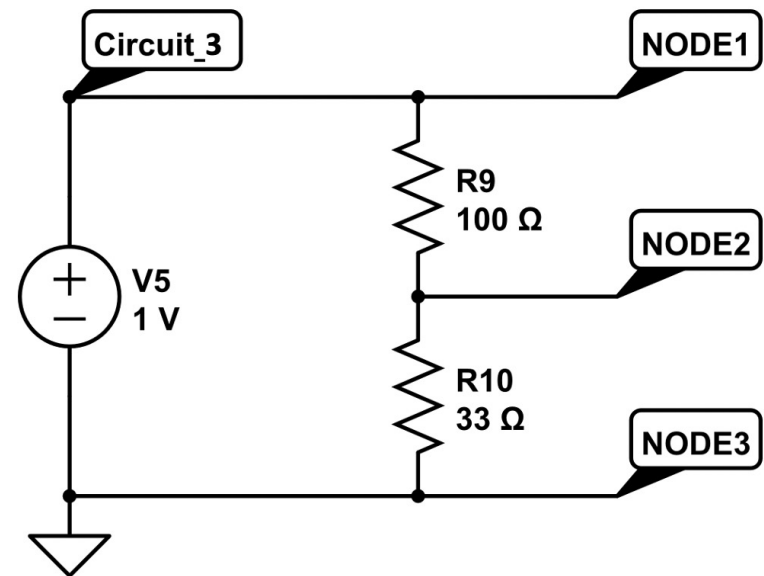
Part 2: Circuit Analysis

- 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.



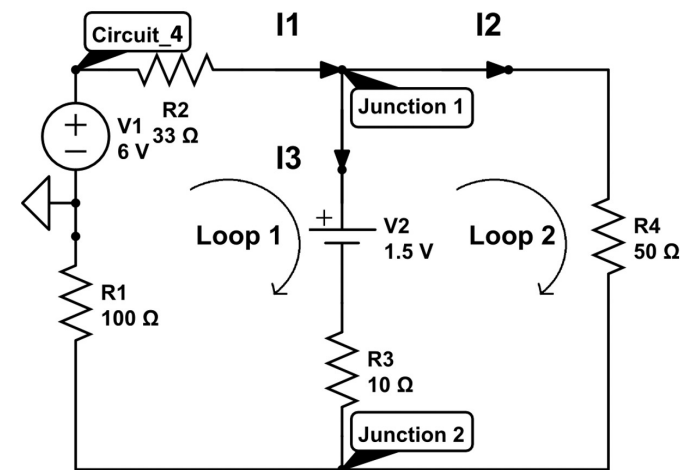
Part 3: Voltage Dividers

- 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?



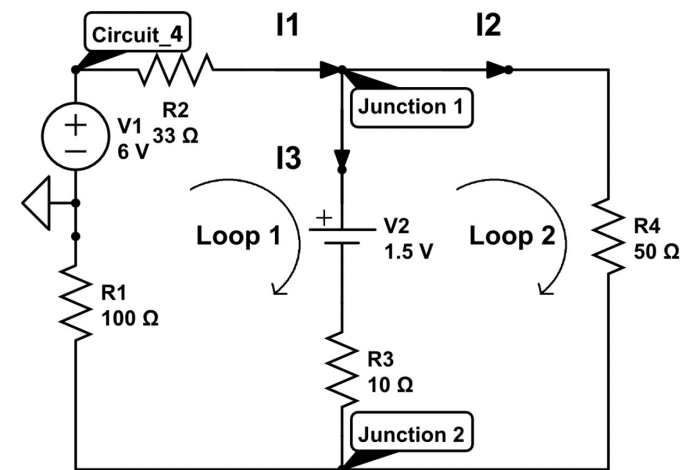
Part 4: Kirchhoff's Rules- Two Loop Circuit

- 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 I_1 , I_2 , and I_3 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

The screenshot shows a Windows desktop with icons for Recycle Bin, Microsoft Edge, PASCO Capstone, 1E General, and E4 Demo. A red circle highlights a shortcut icon labeled 'St 16 - Shortcut (2)'. To the right, a File Explorer window is open, showing the path 'Network > serv116 > Work1DE > St 16'. The 'Lab-2' folder is highlighted with a red box. Below the folder list, a red box contains the following instructions:

1. Save your MS Word report file the following name: "**L#-St#-lastname1-lastname2**"
 - a. The number signs indicate the lab section number and the current station number.
 - b. Lastname1 and lastname2 are the last names of both lab partners.
 - c. This will make sure the file is easy to track in case something happens.
2. Save your report "**L#-St#-lastname1-lastname2**" as a PDF.
3. Assuming wifi is active and enabled, go to www.crowdmark.com and follow the given steps:
 - a. Click on "Sign in" in the top right corner.
 - b. Select the school "McMaster University"
 - c. Select "Sign in with Avenue to Learn".
 - d. Note: only one student will need to submit on behalf of both students.
4. Once you selected to sign in through avenue, log into avenue to learn with your student Mac Id and password.
5. Repeat step 2 and go to the course "Physics 1E03: Introductory Mechanics".
6. Find your assessment which is labeled with your lab number (L#) and the current lab (Lab#).
7. Submit the pdf of your lab report.

Good Luck!