LAB 6. KIRCHOFF'S RULES

6.1. Problem

- How can Kirchoff's rules predict voltages and currents in complex circuits?
- What is the easiest way to measure voltages and currents in a circuit?

6.2. Equipment

digital multimeter with ohmmeter and voltmeter functions; five different resistors; wires (at least five); breadboard; alligator clips; one battery and one plug-in DC power supply

6.3. Background

In previous exercises you learned how to build circuits from schematic diagrams and to measure resistance, current, and voltage in simple circuits. This week you will practice and strengthen these skills while investigating circuits whose behavior can only be predicted by using Kirchoff's rules.

Kirchoff's rules are two conservation equations in terms of specific circuit characteristics. The loop rule or voltage rule is a consequence of conservation of energy. It states that the voltages across each component in a loop sum to zero.

$$0 = \Sigma V_i$$

The junction rule or current rule is a consequence of conservation of charge, specifically, that no point is a source or sink of electric charges. It states that the current originating at any point in a circuit is zero: any current coming out of a point is balanced by current coming into the same point.

$$0 = \Sigma I_i$$

Since one of these equations is in terms of voltages and the other in terms of current, it is necessary to be able to relate the two. For this, we use the familiar voltage-current relation for resistors

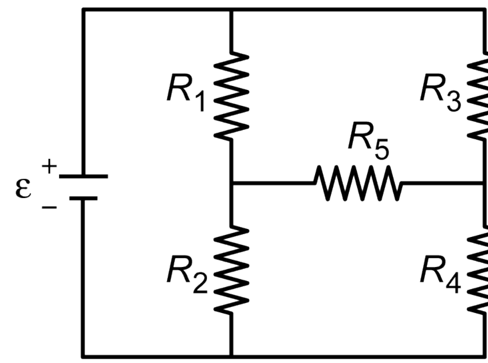
$$V = IR$$

where V is the potential drop across the resistor, I is the current through the resistor, and R is the resistance of the resistor. In both SI and common American usage, potential is measured in volts (V), current in amperes (A), and resistance in ohms (Ω).

6.4. Circuits

1. Bridge

The bridge circuit has the schematic structure below.



1. Select five resistors with different resistances.
2. Using the multimeter in ohmmeter mode, individually measure the resistance of each resistor. Be sure to use the lowest setting that will give a reading in range. Record the resistance values.
3. Construct the circuit shown above. You may use any of your resistors in any position. Record the resistor values for each position in the table below.
4. Decide on your convention for the direction of current through each resistor. For your own reference, draw them as arrows by each resistor in the diagram.
5. Using the multimeter in voltmeter mode, measure the voltage across the potential source (ε) and across each resistor. The sign of the voltage depends on which voltmeter probe you place on which side of a resistor. Use the convention that the (–) probe goes on the first (up-current) side encountered when moving in the direction of the arrow, and the (+) probe on the second (down-current) side. Record the values below, making note of the signs.

	ε = ____________________	
R_1 = ____________________	V_1 = ____________________	I_1 = ____________________
R_2 = ____________________	V_2 = ____________________	I_2 = ____________________
R_3 = ____________________	V_3 = ____________________	I_3 = ____________________
R_4 = ____________________	V_4 = ____________________	I_4 = ____________________
R_5 = ____________________	V_5 = ____________________	I_5 = ____________________

6. Use $I = V/R$ to calculate the current I through each resistor. Enter in the table above.

2. Second Bridge

Switch any two of the resistors in the circuit above. Record the resistances, measure the voltages, and calculate the currents as before.

ε = ____________________

R_1 = ____________________ V_1 = ____________________ I_1 = ____________________

R_2 = ____________________ V_2 = ____________________ I_2 = ____________________

R_3 = ____________________ V_3 = ____________________ I_3 = ____________________

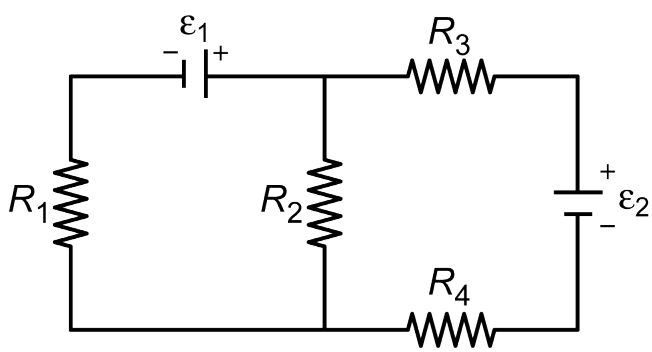
R_4 = ____________________ V_4 = ____________________ I_4 = ____________________

R_5 = ____________________ V_5 = ____________________ I_5 = ____________________

3. Two sources

This circuit uses only four resistors, but it makes up for it by having two voltage sources.

1. Using four of your resistors and two voltage sources, build the circuit below. You may put any resistor in any position.



2. Decide on your convention for current directions through each resistor. For your own reference, draw them as arrows by each resistor in the diagram.
3. Record all resistances, measure all voltages, and calculate all currents as before.

ε_1 = ____________________

ε_2 = ____________________

R_1 = ____________________ V_1 = ____________________ I_1 = ____________________

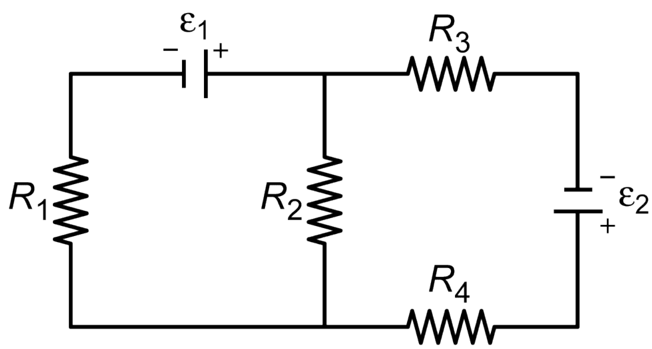
R_2 = ____________________ V_2 = ____________________ I_2 = ____________________

R_3 = ____________________ V_3 = ____________________ I_3 = ____________________

R_4 = ____________________ V_4 = ____________________ I_4 = ____________________

4. Flip a source

This is exactly the same circuit as before, but you will reverse the polarity of the second voltage source.



1. Keep the same circuit as before, but reverse the polarity of the second voltage source.
2. Draw all current arrows exactly the same as for the previous circuit.
3. Record all resistances, measure all voltages, and calculate all currents. (The sign of ε_2 will reverse from circuit 3.)

ε_1 = ____________________

ε_2 = ____________________

R_1 = ____________________	V_1 = ____________________	I_1 = ____________________
R_2 = ____________________	V_2 = ____________________	I_2 = ____________________
R_3 = ____________________	V_3 = ____________________	I_3 = ____________________
R_4 = ____________________	V_4 = ____________________	I_4 = ____________________

6.5. Lab Report

Make a spreadsheet to model each of the circuits you investigated. Set the spreadsheet up as shown in class: make a list of measured source voltages and resistor resistances, and incorporate these by reference into a coefficient matrix and constant column vector to express the simultaneous equations from Kirchoff's rules. Invert the matrix to solve the simultaneous equations and thus find the unknown currents, and calculate the voltages from the currents.

This only needs to be done for two circuits rather than four, because the first two and the last two circuits are the same design, differing only in specifics (resistances or source voltages) which you can easily change in the spreadsheet.

Upload your spreadsheet to Canvas, or share the link to Canvas.

For each circuit, make a table showing and comparing voltages and currents for each resistor determined experimentally and predicted by your spreadsheet. Put this into a word processor or pdf file and upload it to Canvas. Turn in this paper.