

Laboratory - Kirchoff's Laws

Purpose

To verify Kirchoff's laws in each of two electrical circuits.


Some Fundamentals of Electronics

Simple electronic circuits can be constructed from emfs (often called voltage sources) and passive components, which include resistors, capacitors, and inductors.

EMF's

Emf stands for electromotive force.

Direct current (DC) emf's (or voltage sources), are indicated in schematics by the

symbol: 

Emf's provide a source of power that pushes charge carriers through the circuit. The flow of these charge carriers is referred to as current, I.

Resistors

In circuit schematics, resistors are identified by the symbol:



Resistors restrict the flow of electricity. Larger resistances cause less current to flow through a branch of a circuit.

When resistors are connected in series, as shown below, resistances of each resistor can be added, such that total resistance, R_{Tot} , is given by:

$$R_{Tot} = R_1 + R_2 + \dots$$

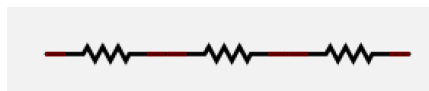


Fig. Resistors in series.

The resistance of resistors connected in parallel, meanwhile, combine in accordance with the relation:

$$1/R_{Tot} = 1/R_1 + 1/R_2 + \dots$$

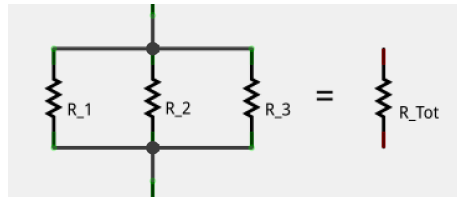



Fig. Resistors in parallel.

Ohm's Law describes the very important relationship between resistance, voltage (V), and current (I) according to:

$$V=IR \quad (\text{Ohm's Law})$$

That is, for a given voltage source applied across a resistor, increasing R must cause current, I, to decrease. Furthermore, the “voltage drop” across the resistor, R, is IR.

Capacitors

Capacitors are identified by the symbol: 

The symbol is representative of two parallel plates, a common type of capacitor.

In direct current (DC) circuits, capacitors represent an “open circuit,” or a *break* in a circuit branch. When a DC voltage is applied to the capacitor, there is a brief flow of charged particles as the capacitor becomes charged (positively on one side and negatively on the other), but once charged, no DC current can flow through the circuit.

In the case of alternating current (AC) circuits, a voltage or current source causes electrons to flow briefly in one direction and then reverses to flow in the other direction. In this scenario, a capacitor charges briefly while the applied voltage pushes current in one direction, and then discharges when the voltage reverses (causing the current to flow in the opposite direction). As the AC voltage alternates, the capacitor continually charges and discharges. As such, despite preventing DC current to flow, the presence of a capacitor in an AC circuit permits the flow of alternating current (as the initials AC implies), essentially acting as a “closed circuit” or an uninterrupted section of wire.

Inductors

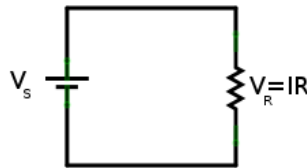
Inductors are identified by the symbol: 

Inductors are essentially coils of wire. Inductors provide very little resistance to DC current, but exhibit very high resistance to AC currents. No inductors are used in this lab.

Theory

Kirchoff's first law:

The algebraic sum of the emf's and "voltage drops" around any closed loop is zero.



For example, in the circuit shown above, the sum of the emf V_s and the voltage drop created by resistor R must equate to zero, such that,

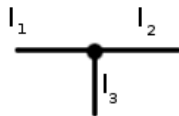
$$V_s + V_R = 0$$

or,

$$V_s = -V_R$$

Kirchoff's second law:

The algebraic sum of currents into any junction is zero.



Accordingly, for the junction shown above, $I_1 + I_2 + I_3 = 0$.

That is, the current flowing into the circuit must be equal to the current flowing out. So, for example, if I_1 and I_2 both flowing into the junction, then I_3 must flow out of the junction with a magnitude of $I_1 + I_2$, such that in this case $I_3 = -(I_1 + I_2)$.

Notes on Electrical Circuits

All resistors used in this lab should have a tolerance of $\pm 5\%$. (See appendix A for resistor colour code system.)

The contacts S1 and S2 are contained in a single box and are operated by a single toggle switch which is “normally open,” as shown in both diagrams, in order to protect the sources from prolonged current drain.

Whenever you wish to make any measurement (voltage or current) you must first close both contacts by means of the toggle switch. Since the switch is spring-loaded it will need to be held in the closed position until the measurement has been completed.

To measure voltage across any circuit element, the voltmeter should be connected *in parallel* with that circuit element.

To measure current through any circuit element, the ammeter should be connected *in series* with that circuit's element.

Procedure

Part 1

Assemble the circuit shown in Figure 1.

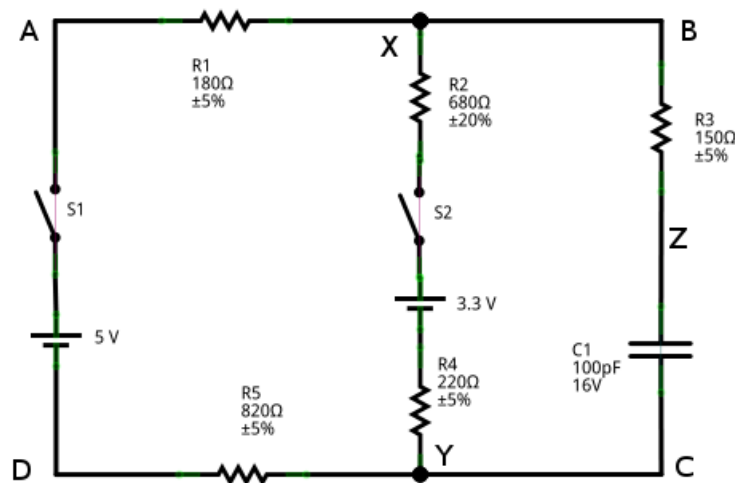


Figure 1.

Set the multimeter to a suitably low DC voltage scale. Verify Kirchoff's first law for the outermost loop by traversing it clockwise with the multimeter and measuring the voltage drop across each circuit element encountered. (Draw the circuit diagram and on it record the polarity of the voltages, the magnitude of each voltage, and then calculate the algebraic sum.)

Also verify Kirchoff's first law for the other two possible loops.

Set the multimeter to a suitably low DC current scale (start with a “higher,” or less-sensitive, scale in order to protect the meter, and adjust if necessary). Verify Kirchoff’s second law at junction X by measuring the current in each of the three “branches” at the junction: the first branch containing the 5 V source, the second containing the 2.5 V source, and the third containing the 150 ohm resistor (record the direction as well as the magnitude of each current on the circuit diagram and then calculate the algebraic sum).

Part 2

Assemble the circuit shown in Figure 2.

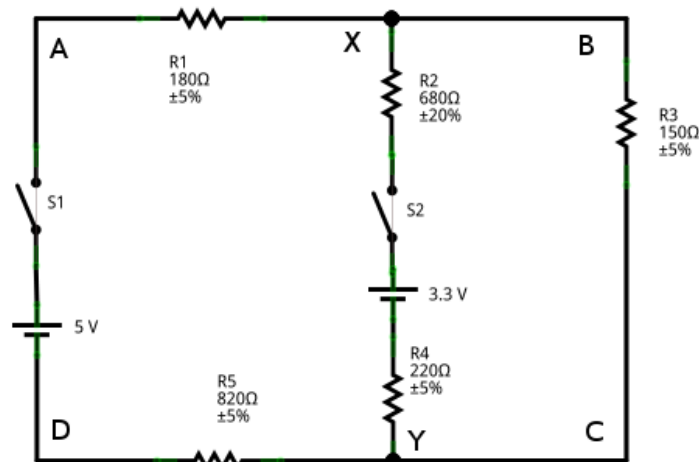


Figure 2.

Repeat all the procedural steps of Part 1.

Questions

For Circuit 1:

Assuming that both laws hold, calculate the current in each of the three branches and compare with experimental values.

Does Kirchoff’s first law hold?
Does Kirchoff’s second law hold?

For Circuit 2:

Assuming that both laws hold, calculate the current in each of the three branches and compare with experimental values.

Does Kirchoff’s first law hold?
Does Kirchoff’s second law hold?

Appendix A: Resistor Colour Codes

Resistors can be identified by a standardized colour coding system, using coloured bands to indicate the magnitude of resistance and the associated uncertainty in the resistance.

Black =	0
Brown =	1
Red =	2
Orange =	3
Yellow =	4
Green =	5
Blue =	6
Violet =	7
Grey =	8
White =	9

Gold = 5%
Silver = 10%

4-Band Code

When reading a 4-banded resistor, the first two colours represent the first digit and decimal of the magnitude, i.e. 2.2. The third colour represents the power of the decimal multiplier, i.e. 10^x , where x is 1 for a brown band. The fourth band represents the uncertainty in the magnitude of the resistor.

Therefore, a resistor banded Red Red Brown Gold would have a magnitude of 2.2×10^1 ohms, or 220 ohms, with a tolerance of 5%.

5-Band Code

Five-band coded resistors provide greater precision than four-band resistors. You may encounter them, but in most cases in undergraduate physics the extra precision provided by the five-band resistor will be unnecessary.

A resistor banded Red Orange Violet Orange Gold would have a magnitude of 2.37×10^3 ohms, or 2.37 kohms, with a tolerance of 5%.