

Resistances in parallel and in series.

Introduction

In this lab you will investigate simple DC (direct or constant current) circuits made with a DC power supply and resistors. You will be able to measure voltage, current, and resistance for different components in your circuits.

Equipment

Protoboard with voltage supply Resistors Wires Multimeter and analog ammeter, alligator clip probes

Have lots of spare fuses on hand for the ammeter!!!!

Theory

To understand the relationship between current (I), voltage (V), and resistance (R) in a circuit, we can use a few simple relationships:

Ohm's Law $V = I R$

Resistance is a measure of how difficult it is for current to flow through a circuit element (a wire, a resistor, etc.) "Ohmic" devices have a linear relationship between voltage and current.

Kirchhoff's Rules

The sum of currents going into any node in a circuit must equal the sum of currents leaving the node.

The sum of voltage changes around any loop in a circuit is zero

"Kirchhoff's Rules" arise from the principles of conservation of charge and conservation of energy. The first rule simply says that since current is moving charge the number of Coulombs per second (Amperes) going into any junction of a circuit must be the same as the total current leaving that junction. For the node shown in the top frame of Figure 1 this can be written as

$$I_A = I_B + I_C$$

The second rule says that the change in potential energy per unit charge (that is the change in voltage) must be zero when you make a complete loop around any path in a circuit. The bottom frame of Figure 1 shows a circuit with two loops. Using the currents defined in the top frame, the changes in voltage around the loops can be written

$$5 V + V_{R1} = 5 V - I_B R_1 = 0 \quad \text{(loop 1)}$$

$$V_{R1} + V_{R2} = +I_B R_1 - I_C R_2 = 0 \quad \text{(loop 2)}$$

Here we also use Ohm's Law which says that the voltage across a resistor should decrease by $V=IR$ in the direction of the current. Notice that we follow both loops in a single direction. For loop 2, we go around the loop in the direction opposite to I_B but in the same direction as I_C , and so the voltage increases by $I_B R_1$ but decreases by $I_C R_2$. The three equations determined from Kirchhoff's Rules provide enough information to allow us to solve the three currents I_A , I_B and I_C .

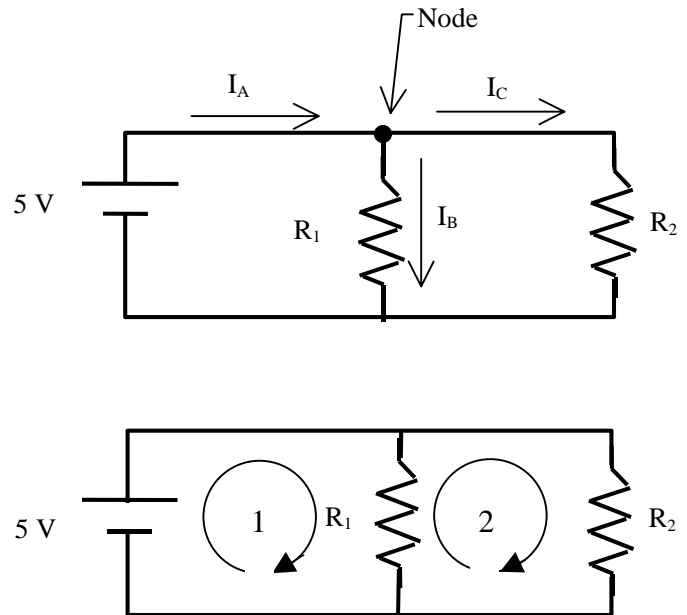


Figure 1: The current going into a node must equal the current leaving a node (Top). The voltage change going around any closed loop must be zero (bottom).

Effective Resistance for Resistors in Parallel and in Series:

Resistors in series have *the same current going through them*. Resistance increases since the current must pass through all the resistors. The effective resistance of several resistors in series is given by

$$R_{\text{effective}} = R_1 + R_2 + R_3 + \dots \quad (\text{in series})$$

Resistors in parallel have *the same voltage across each of them*. The circuit in Figure 1 shows two resistors in parallel. Because the current can split up among the different paths, the effective resistance decreases. The effective resistance of several resistors in parallel is given by:

$$\frac{1}{R_{\text{effective}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \quad (\text{in parallel})$$

Measuring Voltage, Current and Resistance:

Voltage: When using a voltmeter to measure voltage, the probes are attached across to points in the circuit and the meter measures the voltage difference ΔV between those two points. The ideal voltmeter has a very high resistance so that it draws very little current from the circuit.

Current: An ammeter is used to measure current in units of Amperes (or Amps). The ammeter must be inserted *in* the circuit so that the meter measures the current passing through it. The ideal ammeter has low resistance so that it doesn't affect the voltage in the circuit.

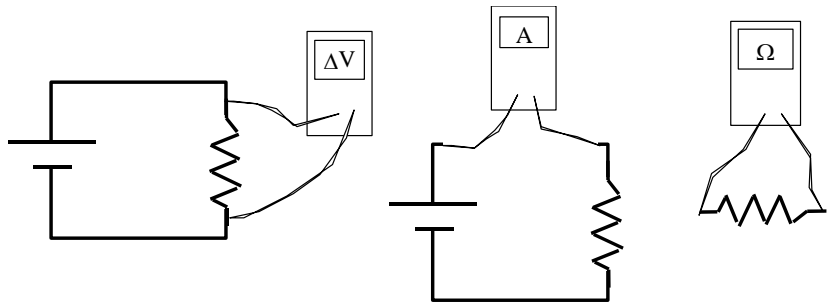


Figure 2: A voltmeter measures the voltage difference across two points in the circuit. An ammeter must be inserted into the circuit in order to measure current. When an ohmmeter is used to measure resistance, the circuit element must be disconnected from the rest of the circuit.

CAUTION: *It is possible to damage the ammeter by passing too much current through it. Make sure it is properly connected (in series with a resistor as shown in Figure 2). If too much current goes through the ammeter it will blow a fuse!*

Resistance: An Ohmmeter is used to measure resistance in units of Ohms (Ω). A circuit element must be removed from the circuit in order to measure its resistance, otherwise you are not measuring the resistance of that element but rather the effective resistance of everything it is connected to.

Understanding Resistor Codes:

Resistors are often color coded with their values. There are usually four bands of color. The first two bands represent two digits and the third band represents additional powers of ten. The fourth band is either silver or gold, indicating the value is good to 10% or to 5%. The numbers represented are:

Color	Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
Value	0	1	2	3	4	5	6	7	8	9

A resistor with bands of Brown, Blue, Red and Gold would signify the three digits 162 and have a value of $16 \times 10^2 = 1600$ Ohms. Practice using your Ohmmeter to until you understand color code on several resistors.

Procedure

Series Circuit:

Choose three resistors with different values. For a 5 Volts power supply, in the hundreds of Ohms will result in currents of 10 to 100 mA. Choose three resistors of different values between 100 and 999 Ohms.

Use your Ohmmeter to measure the three resistances and record them in a data table.

Construct the series circuit shown.

Measure the voltages across each resistor. The current should flow from the positive terminal of the power supply to the negative and the voltages should drop across each resistor in the direction of the current. If you are going around the loop in a clockwise direction, make sure your voltmeter has its negative terminal the “same” side of each resistor. (For example across R_1 point (A) should be the negative terminal, across R_2 it should be point (B), across R_3 point (C) should be the negative terminal and across the battery point (D) should be negative. Record these values as V_{AB} , V_{BC} , etc.

Now you will use your multimeter as an ammeter to measure current. ***The meter must be inserted into the circuit to measure the current. BE SURE NOT TO BLOW THE FUSE ON YOUR METER BY USING IT INCORRECTLY*** -- do not use it the same way as you would a voltmeter. To measure the current at point (A), for example, you would unplug the wire from the resistor and connect one side of the ammeter to the end of the wire. The other lead of the ammeter then is connected to the end of the resistor where the wire used to be-- the current you wish to measure goes through the ammeter but is still limited by also having to go through the resistor. Refer again to Figure 2.

Measure the currents at points A, B, C and D. **BE SURE TO CHANGE THE SCALE ON YOUR AMMETER TO MATCH YOUR MEASUREMENT.** If your measurement is too small for your multimeter you may need to use an analog ammeter. Record as I_A , I_B , etc.

Use Ohm’s Law to predict the voltage drop through each resistor and compare to the measured values. The circuit should obey Ohm’s Law to within about 10 percent. ($V_B = I R_{\text{effective}}$). If this is not the case the circuit may not be constructed properly, your meter may be inaccurate or you may not be using it properly. Stop and seek help if this is the case.

Calculate the effective resistance for all three resistors (see above) and compare to value determined from Ohm’s Law: $V_{\text{Batt}} = I_{\text{Batt}} R_{\text{effective}}$.

Apply Kirchhoff’s Voltage Rule by writing an equation for the voltages around the single loop in this circuit. Write it first with symbols, then use your numbers to check this rule.

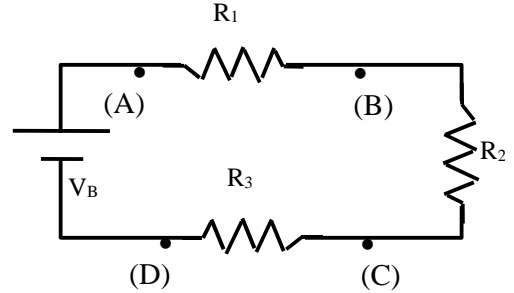


Figure 3: Series Circuit

Parallel Circuit

Choose two resistors which have similar, but not identical, values. Measure the values with an Ohmmeter and record them.

Construct the parallel circuit shown.

Measure the voltages across the power supply and the resistors.

Insert your ammeter within the circuit at points A, B, C and D and record the currents.

Do the resistors each obey Ohm’s Law?

Calculate the effective resistance of the two resistors in

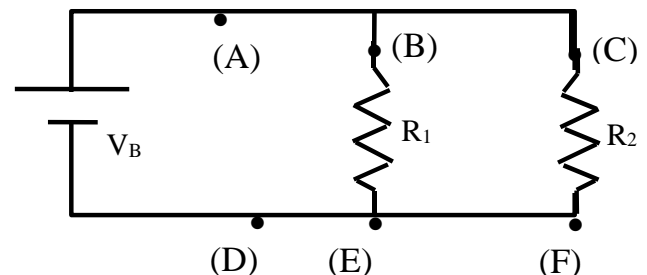


Figure 4: Parallel Circuit

parallel and determine whether the voltage across the battery is equal to the current from the battery times the effective resistance.

There are two loops in this circuit. Going around each loop clockwise, write Kirchhoff's voltage loop equations, first with symbols, then your numbers.

There are two nodes in this circuit. Draw pictures of the nodes and show the currents coming in and out. (Label them I_A , I_B , I_C or I_D) Write the equations for Kirchhoff's Rules as it applies to these nodes, first with symbols, then with your numbers.

For your report:

Your report should include a title page with summary, sketches and data tables, equations. The final summary should address how well Ohm's Law or Kirchhoff's rules hold and compare experimental values to theoretical predictions. (Comparisons should include typical percentage error). Discuss possible sources of discrepancy.

Deriving the effective resistances: (optional)

For the series circuit, use Kirchhoff's equation for the voltages then for each voltage substitute the equation $V_B = I R_{\text{effective}}$ to re-derive the expression for the effective resistance of resistors in series.

For the parallel circuit, use Kirchhoff's current equation for the top node on this circuit and then for each current substitute the relationships $I = V / R$ to re-derive the expression for the effective resistance of parallel resistors.

Series Circuit: Sketch the circuit and label resistors and points along the circuit where measurements were made. Record data below and label each number to correspond to your sketch (For example $V_{AB} = 1.56V$ or $I_B = .046$ Amps.)

Record Data Here, then transcribe below for your calculations:

Battery:	$V_{batt} =$	$R_1 =$	$R_2 =$	$R_3 =$
Voltages Measured:	$V_{AB} =$	$V_{BC} =$	$V_{CD} =$	
Currents Measured:	$I_A =$	$I_B =$	$I_C =$	$I_D =$

Data (insert symbol and value from above) and calculations:

	Resistor	Current for this Resistor	Voltage from Ohm's Law	Measured Voltage	% Difference
Resistors:	$R_1 =$	$I_A =$			
	$R_2 =$				
	$R_3 =$				

Effective Resistance	$R_{eff} =$ V_{batt}/I_{Batt}	
Theoretical Value	R_{eff}	
% Difference		

Kirchhoff's Rules for voltages around the series circuit (write out using symbols, then show the calculations using your numbers):

Parallel Circuit: Sketch the circuit and label resistors and points along the circuit where measurements were made. Record data below and label each number to correspond to your sketch (For example $V_{AB} = 1.56V$ or $I_B = .046$ Amps.)

Record Data Here, then transcribe below for calculations:

Battery:	V_{Batt}	$R_1 =$	$R_2 =$
Voltages Measured:	$V_{BE} =$	$V_{CF} =$	
Currents Measured:	$I_A =$	$I_B =$	$I_C =$ $I_D =$

Data (insert symbol and value from above) and calculations:

	Resistor	Current for this Resistor	Voltage from Ohm's Law	Measured Voltage	% Difference
Resistors:	$R_1 =$	$I_B =$			
	$R_2 =$				

Effective Resistance	$R_{eff} =$ V_{batt}/I_{Batt}	
Theoretical Value	R_{eff}	
% Difference		

Write the following using symbols, then show the calculations using your numbers.

Kirchhoff's Rules for Voltages around the two loops:

Loop 1:

Loop 2:

Kirchhoff's Rules for Currents going into and out of a node: