Lab Sim 09: Ohm's Law and DC Circuits

Introduction

Electricity is so common that it goes unremarked in everyday life. So common, in fact, that most people don't know or think about how it works (used to be that if you drove one of those new-fangled horseless carriages, you had to know how an internal combustion engine worked, too…). Household electricity is AC or alternating current. Anything you plug into an outlet is designed to run on this alternating current. But anything that runs on batteries uses DC or direct current. DC circuits are very straightforward and can be understood using Ohm's Law.

Objectives

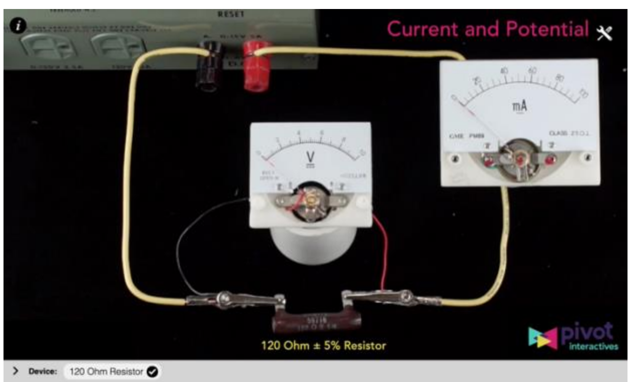
- Observe and measure the relationship between voltage and current in several simple circuits
- Calculate the resistance in a circuit using Ohm's Law ($V = IR$)
- Measure and explain the non-ohmic behavior of an incandescent bulb
- Construct and compare series and parallel circuits
- Model the behavior of Christmas tree (string) lights using series and parallel concepts

Pivot Interactives

This exercise requires the online simulation (Lab 09: Ohm's Law and DC Circuits). You should sign in to your Pivot account and choose the correct Interactive from the PHYS 1420 selection.

Understanding Ohm's Law

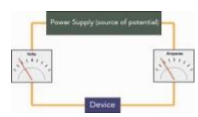
Before we make any measurements, let's make sure we understand the components of the circuit. Examine the video interactive and answer the following questions:

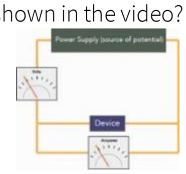


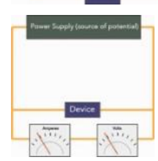
Note that you have to read analog dials! Pay very careful attention to the units, especially for the current. $I = 1\text{A}$ is actually a lot of current; you will be dealing typically with mA, or milliAmps. $1\text{mA} = 0.001\text{A}$, and $100\text{mA} = 0.100\text{A}$. To keep your units consistent, you should always record current in Amps, not milliAmps.

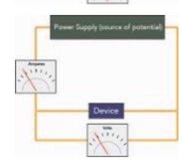
1) (2 points) Select all of the following that correctly describe what a voltmeter and ammeter measure.
   A. A voltmeter measures the potential difference (or voltage) *across* a circuit element.
   B. A voltmeter measures the potential difference (or voltage) *passing through* a circuit element.
   C. An ammeter measures the electric current *passing through* a circuit element.
   D. An ammeter measures the electric current *across* a circuit element.

2) (1 point) Which of the following circuits would yield the same measurements as the circuit shown in the video?

A. 

C. 

B. 

D. 

3) (3 points) If you are trying to establish whether Ohm's Law ($V = IR$) is valid, then:
   A. What variables are you going to measure, and which variable is independent (x–axis) and which is dependent (y–axis)?
   B. What does the slope of your graph mean?
   C. What do you predict for the y–intercept? Why?

Ohmic and Non-Ohmic Devices

4) (5 points) Choose the 120Ω resistor and record current and voltage data. Increase the current in 5mA increments from 5mA to 90mA.

Current I (Amps)	Voltage V (V)
0.005	
0.010	
etc.	

Be sure to record the current values in Amps!

5) (1 point) What are the uncertainties in the current and voltage measurements?
   A. $\partial I = \pm 0.005\text{A}$ and $\partial V = \pm 0.20\text{V}$
   B. $\partial I = \pm 0.0025\text{A}$ and $\partial V = \pm 0.10\text{V}$
   C. $\partial I = \pm 5\text{A}$ and $\partial V = \pm 2\text{V}$
   D. $\partial I = \pm 2.5\text{A}$ and $\partial V = \pm 1\text{V}$

6) (1 point) Does the resistor convincingly exhibit Ohmic ($V = IR$) behavior? What can you point to that answers this question definitively? Hint: Look at your regression!

7) (2 points) According to Ohm's Law, the slope of your graph is the resistance of the device you tested. The

resistor is labeled as $R = 120\Omega$, with a tolerance of $\pm 5\%$. What is the percent error in your value, and is this resistor within tolerance?

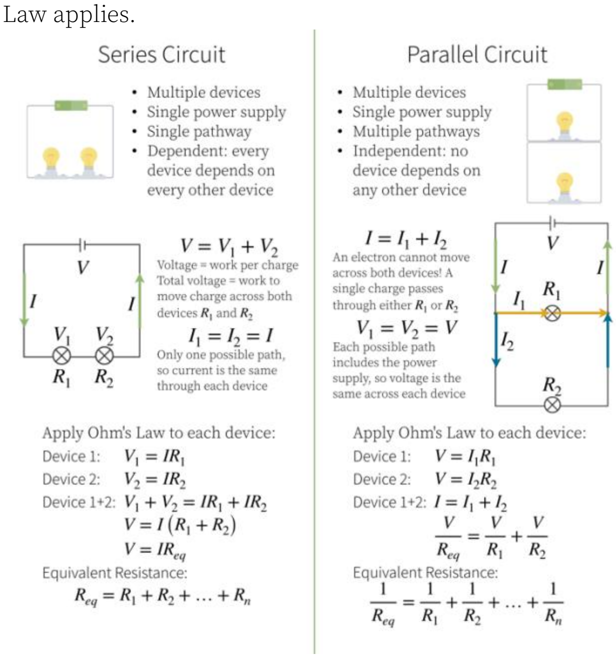
Now let's examine and collect data for the Incandescent Bulb.

CURRENT I (AMPS)	VOLTAGE V (V)
0.02	
0.04	
etc.	

8) (5 points) Pay attention to the scales of your meters! Start with your current set to 20mA, and increase it in 20mA increments until you reach 360mA. As previously, be sure that you record your values in Amps, not milliAmps!
9) (3 points) Overall, does the light bulb obey Ohm's Law? Are there regions where it appears to? Toggle on the regression line. It clearly does *not* fit all the data. De-select points (click on individual points on the graph) until the regression only fits the first five data (0.020A–0.100A). Is this portion linear? Record the slope, labeling it R_1.
   Now, toggle only the second five points (0.120A–0.200A). How about this portion? Convincingly linear? Record the slope (R_2)!
   One more time, this time with the third set of five points (0.220A–0.300A). Record the slope R_3.
10) (2 points) Explain why the bulb does not have a constant resistance. Does the trend in the resistance that you noted above make sense? Hint: Why (literally!) does the filament glow?

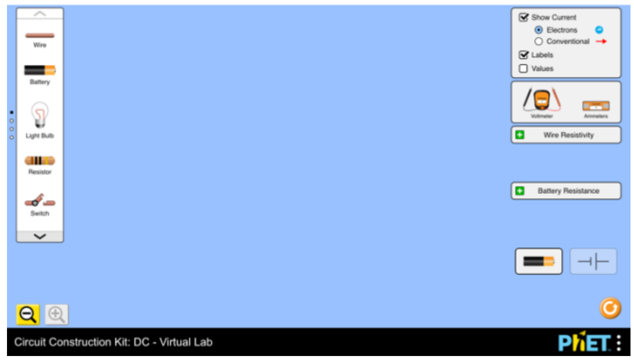
SERIES AND PARALLEL CIRCUITS

What if you need more than one device in your circuit? (Spoiler alert: Most circuits do!) Does Ohm's Law still apply? It does, and so far, it's the only tool we have for analyzing circuits. Let's look at two methods for adding multiple devices to a single circuit and show how Ohm's Law applies.

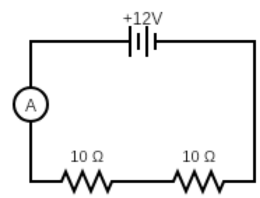


We will use the frame to build and analyze series and parallel circuits. If the frame does not open properly in the Pivot window, click here to open it in a new window.

To construct a circuit, simply drag the element you need from the left toolbar onto the center of the frame. Notice that you can adjust the resistances and battery voltages with a slider at the bottom of the frame. On the right, you have meters, and you can control your view of the circuit. You can also adjust the internal resistance of the battery and the resistivity of the wire.

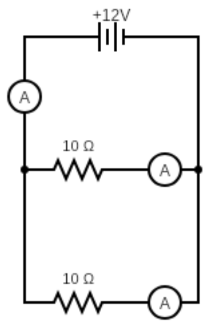


Construct a series circuit with two resistors and a battery. Add an ammeter to your circuit to measure the current. Set the battery voltage to $V = 12V$, and the resistors to $R_1 = R_2 = 10\Omega$.



11) (2 points) What is the total current I? Grab the voltmeter and place the leads on either side of R_1. What is the voltage drop V_1 across this resistor? What is the voltage V_2 across R_2?
12) (1 point) If you replace R_1 and R_2 in your series circuit with new resistors $R_1 = 8\Omega$ and $R_2 = 12\Omega$, but leave the battery at $V = 12V$, what changes?
    A. The equivalent resistance (R_{eq}) increases.
       The total current (I) decreases.
       The voltage across each resistor (V_1 and V_2) remains the same.
    B. The equivalent resistance (R_{eq}) decreases.
       The total current (I) increases.
       The voltage across each resistor (V_1 and V_2) remains the same.
    C. The equivalent resistance (R_{eq}) and total current (I) both increase.
       The voltage across each resistor (V_1 and V_2) decreases.
    D. The equivalent resistance (R_{eq}) remains the same.
       The total current (I) remains the same.
       The voltage across R_1 (V_1) decreases.
       The voltage across R_2 (V_2) increases.
    E. The equivalent resistance (R_{eq}) remains the same.
       The total current (I) remains the same.
       The voltage across R_1 (V_1) increases.
       The voltage across R_2 (V_2) decreases.

Re-arrange your circuit so that you have two bulbs wired in parallel with a single battery. (I would also add an ammeter in series with each resistor.) Set the battery voltage to $V = 12V$, and the resistors to $R_1 = R_2 = 10\Omega$.



13) (2 points) What is the total current I? Grab the voltmeter and place the leads on either side of R_1. What is the voltage drop V_1 across this resistor? What is the voltage V_2 across R_2?

14) (1 point) If you replace R_1 and R_2 in your series circuit with new resistors $R_1 = 8\Omega$ and $R_2 = 12\Omega$, but leave the battery at $V = 12V$, what changes?
   A. The equivalent resistance (R_{eq}) increases.
   The total current (I) decreases.
   The voltage across each resistor (V_1 and V_2) remains the same.
   B. The equivalent resistance (R_{eq}) decreases.
   The total current (I) increases.
   The voltage across each resistor (V_1 and V_2) remains the same.
   C. The equivalent resistance (R_{eq}) and total current (I) both increase.
   The voltage across each resistor (V_1 and V_2) decreases.
   D. The equivalent resistance (R_{eq}) remains the same.
   The total current (I) remains the same.
   The current across R_1 (I_1) decreases.
   The current across R_2 (I) increases.
   E. The equivalent resistance (R_{eq}) remains the same.
   The total current (I) remains the same.
   The current across R_1 (I_1) increases.
   The current across R_2 (I_2) decreases.

15) (1 point) What happens when one device in a series circuit is switched off (maybe a bulb burns out)? Does the same thing happen when one device in a parallel circuit is switched off?
   A. Removing or switching one device off does not affect the other devices in either circuit. If these were light bulbs, one bulb would be out, but the rest would remain lit.
   B. Removing or switching one device off affects the other devices in both circuits. If these were light bulbs, if one bulb goes out, the rest will also go out in either circuit.
   C. In series, removing one device does not affect the other. But in parallel, turning one bulb off would cause the rest to go out as well.
   D. In series, it's all or nothing. If one bulb goes out, they all do. In parallel, you can remove one bulb without affecting the others.

Use the circuit builder to model a string of Christmas tree lights. When you plug the string in, all the bulbs light (and they are equally bright).

But if one bulb burns out, what happens? When one bulb fails, a portion of the string also fails. But the rest of the string remains lit…how does that happen?

16) (3 points) A typical Christmas string light will have at least 50 bulbs. You don't have to model that many bulbs. Your model should:
   - Use at least 9 bulbs
   - Show bulbs of equal brightness
   - Demonstrate that removing one bulb does not cause the entire string to fail

Hint: In the bottom right corner of the frame, you have an option to take a screenshot. Do it! This is the easiest way to display your model. In the response area, you can either click the link icon and send me a link to your image(s) or click the image icon and upload the image(s) directly into the response box (preferred!).

When you have completed this lab exercise in Pivot, please be sure to submit your responses. This lab is due no later than Tuesday, 09 August 2022, at 11:59 PM CDT.