

Ohm's Law

Activity Overview

In this activity, students will explore the relationship between current and potential difference for several resistors which obey Ohm's Law. They will experimentally measure the resistance of the resistors. Students will then examine the relationship between current and potential difference using a light bulb to observe a non-ohmic material.

Materials

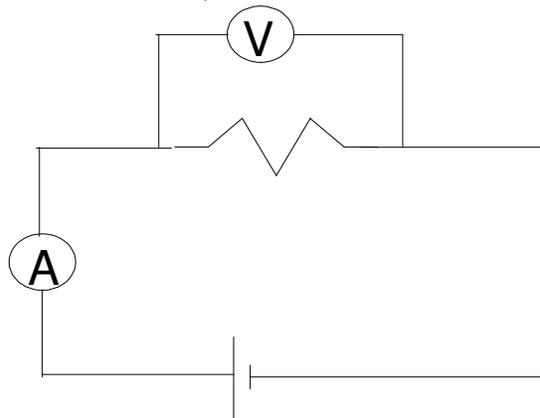
- TI-Nspire™ or TI-Nspire™ CAS
- Variable DC power supply (0 - ~12 V)
- Two digital multimeters
- Several resistors ranging from ~100 Ω to ~1000 Ω
- Light bulb in a socket with terminals exposed
- connecting wires

Notes

- Many multimeters have two current settings: a 200 mA setting which is protected by a fuse and a 10 A setting. Students must be careful not to exceed 200 mA when using the more sensitive setting. For resistors $\geq 100 \Omega$, this will not be a problem as long as the potential difference across the resistor is less than ~12 V. Students will need to carefully monitor the current when using the light bulb. Students need to know the maximum voltage rating of the light bulb. A standard bulb rated for 120 V AC works fine for this data collection (students may be a little disappointed that it barely glows). Smaller bulbs designed for use with circuit kits often have a maximum voltage rating less than 12 V. Students must be careful not to exceed the voltage rating to avoid burning out the filament.
- If the resistors are color-coded, students will need to decode them. The first two colored stripes give the first two digits of the resistance. The third stripe gives the number of zeros after the first two digits. The color code is: black = 0, brown = 1, red = 2, orange = 3, yellow = 4, green = 5, blue = 6, violet = 7, gray = 8, white = 9. The fourth stripe indicates the tolerance; a gold stripe indicates $\pm 5\%$.
- Students must be instructed how to correctly set up the meters. One meter should be set as a voltmeter, and the other meter should be set as an ammeter. The ammeter must be connected in series with the resistor, and the voltmeter must be connected in parallel across the resistor.
- In this activity students will create their own .tns file on the TI-Nspire™. The data will be recorded on a Lists & Spreadsheet page and then graphed for analysis. Either Data & Statistics or Graphs & Geometry may be used for the graphing the data. The instructions will guide students to use Graphs and Geometry so that data for multiple resistors can be placed on the same set of axes.

Set-Up

- Two multimeters will be needed to collect the data. One should be configured as a voltmeter, and the other should be configured as an ammeter. The ammeter may be configured in the 200 mA setting if available. This allows for precise current measurements up to 200 mA.
- Choose a resistor and record its resistance, if given, or its color code.
- Construct a simple circuit with the power supply, resistor, ammeter, and voltmeter according to the diagram below. Connect the ammeter as part of the main loop between the power supply and the resistor, and connect the voltmeter across the resistor.



Data Collection Part 1

- Before beginning data collection, open a Lists & Spreadsheet page on the TI-Nspire™. Label the first column “v1” and the second column “i1”. Enter 0 as the first entry in both columns. The first column will be used to record the potential difference across the resistor in volts. The second column will be used to record the current through the resistor in amps. If your multimeter measures current in milliamperes, be sure to convert the measurement to amps before recording it.
- Turn on the power supply and adjust it so that the potential difference across the resistor is ~ 1 V or less. Record the potential difference and the current.
- Record 6 – 8 data points using voltage values covering the range from 0 – 12 V.
- Turn off the power supply. Replace the first resistor with a different one. Label the next two columns in the spreadsheet “v2” and “i2”. Collect data for this resistor using the same range of voltage values. Collect data for a total of three or four resistors.

Data Analysis Part 1

Normally, when constructing a graph for data analysis, the independent variable is placed on the x-axis and the dependent variable is placed on the y-axis. In this activity, however, it will be more convenient for the analysis to place the independent variable, potential difference, on the y-axis and the dependent variable, current, on the x-axis.

- Open a Graphs & Geometry page on the TI-Nspire™.
- To create a scatter plot press Menu → 3: Graph Type → 4: Scatter Plot. Set the x variable as i1 and the y variable as v1 for scatter plot 1. Use s2, s3, ... for the other data sets. Once the scatter plots have been set, press Ctrl-G to hide the entry line.
- To scale the graph, press Menu → 4: Window → 9: Zoom – Data. All of the data sets should be plotted on the graph.

Describe the apparent shapes of the graphs. What kind of relationship do these graphs imply between potential difference and current?

Ohm's Law states that for many materials, the current through the material is directly proportional to the potential difference across the material over a wide range of potential differences.

Based on the graphs, do these resistors appear to obey Ohm's Law?

If the resistors obey Ohm's Law, a line through the origin should fit the data.

- Press Menu → 6: Points & Lines → 4: Line. Move the cursor to the origin and click the button on the NavPad when it indicates it is at the intersection point. Move the cursor up and right until the line best fits the first data set. Press the button on the NavPad again to set the second point. Click on the origin again and construct the best fit line for the second data set. Continue until there is a best fit line for each data set.
- To measure the slope of each line press Menu → 7: Measurement → 3: Slope. Click once on each line to measure the slope and then click once in a clear part of the screen to print the value.

Compare the slopes to the resistance values obtained from the resistor color codes. Do they agree within the tolerance of the resistors?

Based on the above results, write an equation which relates potential difference, current, and resistance.

Data Collection Part 2 (light bulb)

- Open a new Lists & Spreadsheet page on the TI-Nspire™. Label one column “vbulb” and the second column “ibulb”.
- Construct the same circuit as before except use a light bulb in place of the resistor. Start with as small of a potential difference as the power supply will allow and collect several data points as the voltage is increased by increments. Be careful not to exceed the maximum current for the ammeter; do not burn out the bulb. Depending on the voltage for which the bulb was designed, it may or may not glow brightly with the voltage values used.
- Record the data on the Lists & Spreadsheet page. Be sure the current is recorded in amps, not milliamps.

Data Analysis Part 2 (light bulb)

- Open a Data & Statistics page on the TI-Nspire™. Click on the x-axis label and choose “ibulb”. Click on the y-axis label and choose “vbulb”. The data should appear.
- If the graph needs to be re-scaled, press Menu → 5: Window/Zoom → 2: Zoom – Data.

Based on the graph, does the light bulb appear to obey Ohm's Law? (Is the graph a direct proportion?) If not, give a general qualitative description of the relationship between potential difference and current based on this graph.

The resistance of an object is a ratio of the potential difference across it to the current through it ($R = V / I$). For materials which obey Ohm's law (ohmic), this ratio is constant. The ratio changes for non-ohmic materials.

- Return to the Lists & Spreadsheet page with the light bulb data. Label the third column “r”
- In the gray cell just below the column label enter the formula “=vbulb/ibulb”. This calculates the resistance of the light bulb for each value of potential difference.

What happens to the resistance of the light bulb and the potential difference across it increases?

By what factor did the resistance of the light bulb change for the voltage range applied?

Why do you think the resistance of the light bulb is changing like this? How is the light bulb filament different from the resistors used in Part 1?