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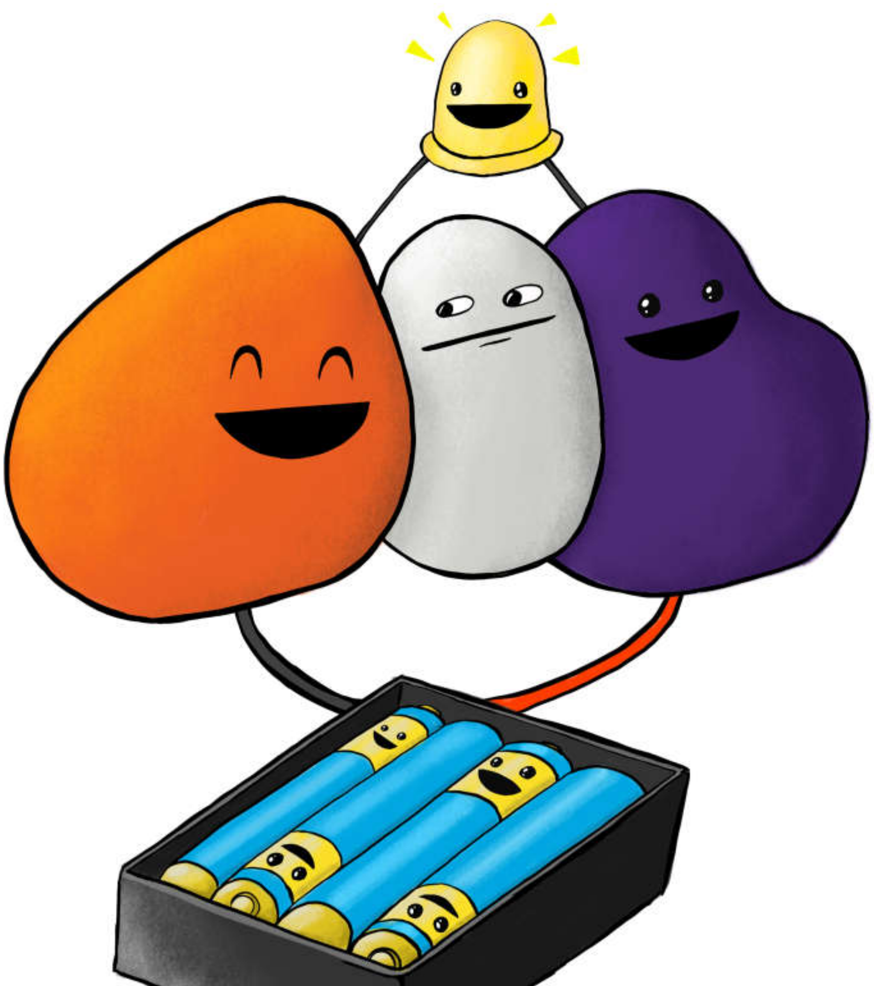
Resistivity Lab



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Comments, Questions, Concerns? Please reach out at: ContactUs@SquishyCircuits.com

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Introduction

What is Resistivity?

Electrical resistivity is how much an object resists electricity to go through it. Every object has a resistivity, which is labeled ρ. Conductors, such as copper have a low resistivity, while insulators, such as glass, have a high resistivity. Resistivity is an important property of any electrical object because it directly relates to the resistance. Resistance is similar to resistivity, but is how hard it is for the electricity to go through a specific object. The resistance depends on the shape and size of whatever material the electricity must pass through.

$$Resistivity\ (\rho) = Resistance(R)\frac{Area\ (A)}{Length\ (\ell)} \quad \therefore \quad R = \rho\frac{\ell}{A}$$

Note: This project is more advanced. We include some background information but if you would like more information about something or are confused, we encourage you to research more about that particular topic or to contact us.

Learning Objectives

1. Students will be able to explain how resistance, voltage, and current are related.
2. Students will explore how resistance is based on physical shape.
3. Students will understand that resistance and resistivity are related, but resistance is a function of the shape of the material and resistivity is a constant property of the material.

Educator Preparation Material

Supplies needed for each student or group of students:

- Conductive Dough
- Battery Holder
- Alligator Clips
- Paper Clips
- 2 Multimeters (1 can be used, but 2 is easiest)
- Ruler

Background Knowledge

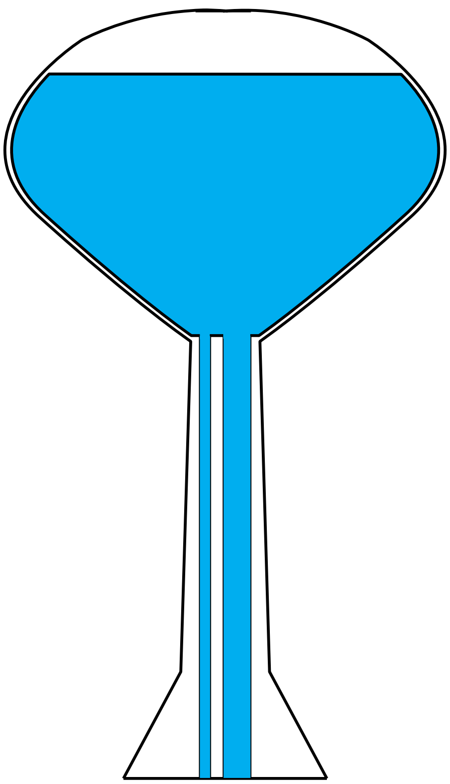
Electricity and Ohms Law

Electricity is the flow of charge called electrons. When describing electrical circuits, three terms are used – voltage, current, and resistance.

Voltage relates to how much potential there is between the positive and negative ends. It is measured in volts.

Current is a measurement of how many electrons are moving through a conductor. It is measured in amps.

Resistance is how difficult it is for the electricity to flow through the conductor. It is measured in ohms.



It can be difficult to visualize these concepts. So, a more tangible example is to think of water instead of electrons. Think of a water tower – it holds water high up in the air, which gives the water a potential. This is like voltage.

Imagine there are two pipes going from the top of the water tower to the ground - one that was big and one that is small. If you had to fill up a bucket with water, would you put the bucket under the big pipe or the small one? You would choose the big pipe because it would fill much faster. This is like the current, similar to the amount of water flowing.

If you'd measure the amount of water going through the pipes, you'd notice that there is less water flowing through the smaller pipe than the big one. It is harder to push water down a smaller pipe than a large one. This is like resistance – the bigger the pipe, the less resistance.

In electricity, these three concepts work the same way but instead of pipes and flowing water, we have conductors carrying electrical current. The three principles are related by **Ohms Law**:

$$Voltage\ (V) = Current\ (I) * Resistance\ (R)$$

Which can also be written as: $I = \frac{V}{R} \quad or \quad R = \frac{V}{I}$

The water analogy still works with Ohms law – basically the higher the water height (higher voltage) and the bigger the pipe (less resistance), the more water flows down the pipe (higher current).

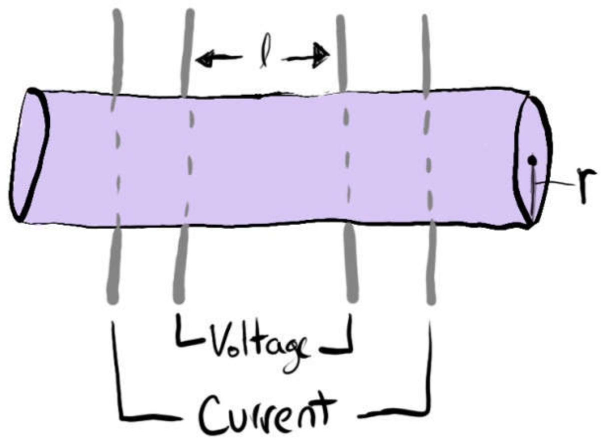
Part 1: Measuring the Resistance

Summary and Background Knowledge

Through Ohm's Law, we know that resistance is equal to the voltage divided by the current. With this knowledge, we can simultaneously measure the current flowing through a sample of conductive dough and the voltage over a distance of dough. Dividing these measurements will give us the resistance of the sample.

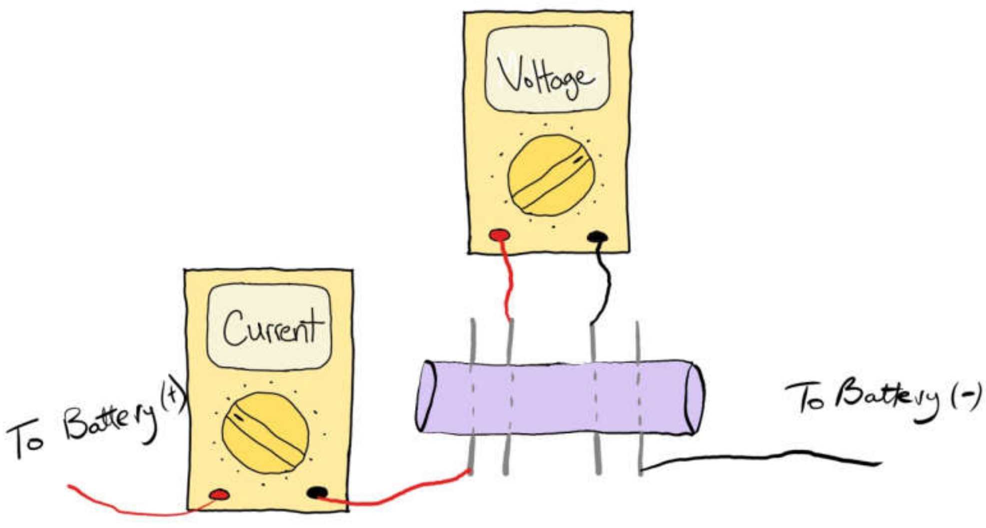
This method of measuring resistance is known as the "Kelvin" or "Four-Wire" resistance measurement. It is important to use this method because it negates any electro-chemical effects happening that will affect the resistance measurement. If your multimeter has a "resistance" setting, try inserting the probes into the dough and you'll see a highly-fluctuating resistance reading!

Procedure:



Roll the conductive dough out into a "snake". Make sure that it has a uniform diameter. Cut the paperclips into four pieces then insert them into the dough as shown.

The outside metal pieces are where the power and current is provided. And the center metal pieces are where the voltage will be measured. Current measurements are constant throughout a circuit and must be taken in series with the circuit, which means you have to make sure the electricity goes through the multimeter. Voltage readings are taken over the circuit. Therefore, hook up the multimeters as shown. If you only have one multimeter, measure the current as shown then hook up the circuit with just wire and measure the voltage across the centermost two metal electrodes.



The resistance of the dough is the voltage divided by the current!

The multimeter readings will change over time due to other effects of the dough. We suggest taking the reading after 1 second of power being applied and to keep that timing the same for each sample. Turn the power off in-between tests.

A test setup measuring the resistance of a dough sample to be 2.858 / .070 = 40.8 Ohms.
In this setup, the leftmost multimeter is measuring current and the rightmost is measuring voltage.

Part 2: Determining the Resistivity

Summary and Background Knowledge:

We can expand our knowledge to determine the resistivity of the dough. Recall, $Resistivity\ (\rho) = Resistance(R)\frac{Area\ (A)}{Length\ (\ell)} \quad \therefore \quad R = \rho\frac{\ell}{A}$

The resistivity of a material should be constant and is a property of the material

Procedure:

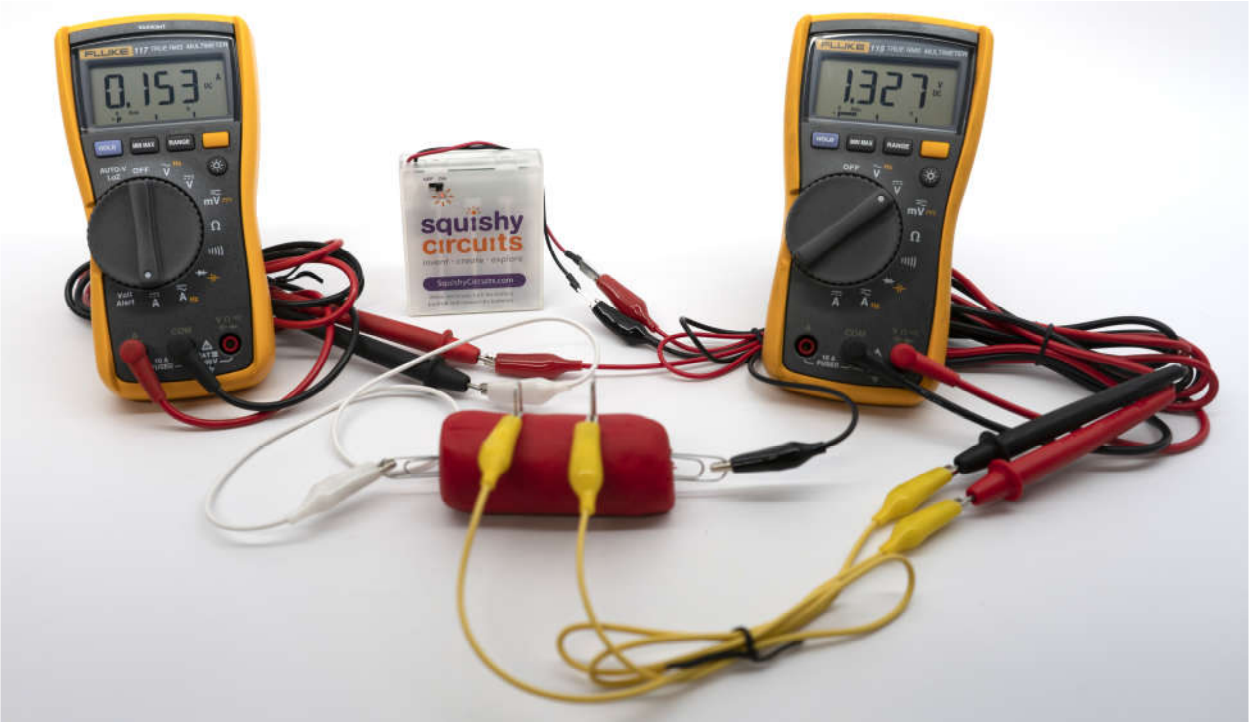
Using the ruler, we can measure the length of the dough sample in between the centermost electrodes and also the diameter of the dough snake. Instruct the students to use a variety of different sized dough cylinders in their data collection.

Trial	Diameter (d)	Length between Center Electrodes (ℓ)	Current (I)	Voltage (V)	Resistance (R=V/I)	Cross Sectional Area ($A=(\pi d^2)/4$)	Resistivity (R*(A/ ℓ))
1							
2							
3							
4							
5							

As predicted, the resistance should change among the samples, based on the dough's shape, but the overall resistivity should remain fairly constant. This is because resistivity is a property of a material and helps to determine the resistance with the geometric shape of the sample!

Note, for better accuracy, extruding the dough through a pipe will provide more accurate results. This will ensure that the dough's width is constant and much more accurate to measure. For a quicker setup, you can simply roll out "snakes" of dough and measure carefully but your final resistivity values may vary.

In this test, the resistance is 3.826/.035 = 109.3 Ohms. The sample has a diameter of 1 inch and a length of 9 inches, resulting in a resistivity of 9.5 ohm-inch.



In this test, the resistance is 1.327/.153 = 8.7 Ohms. The sample has a diameter of 1.25 inches and a length of 1 inch, resulting in a resistivity of 10.6 ohm-inch.

Therefore, it can be seen that the resistance can change drastically among samples based on the shape, but the resistivity of the material remains constant.