Resistance from Voltage

Directions and Suggestions for Teacher

Purpose:

This lab is designed to have students come to understand the connection between the radius of a wire and the resistance of the wire. At the same time, it will hopefully give them a tangible experience with the definition of an Ohm (the voltage required to produce a current of one amp).

Virtual Part:

(https://thephysicsaviary.com/Physics/Programs/Labs/ResistanceFromVoltageLab/)

This lab can easily be paired with a live lab that mimics the virtual lab. It is important to give the students a hands-on experience as frequently as possible.

Measuring Radius:

In the top left corner of the program will be a cross-section of the wire they are testing. The grid provided is marked out in 0.1 mm increments. Students should make the best estimate of the wire's radius and then convert that estimate into meters.

Calculating Area:

Students should use the formula for a circle to get the cross-sectional area of their wire in m^2 for each trial. We will be using area as our independent variable instead of radius.

Measuring Voltage:

Students will use the sliders on the power supply to adjust the voltage until exactly 1.0 A of current is going through the wire. This voltage will be numerically equivalent to the resistance of the wire in Ohms. If a higher voltage is required to create 1.0 A of current, there is a switch on the power supply that can give students access to higher voltages.

Working Through the Lab:

Students will be changing the gauge or thickness of the wire for each of the trials. Clicking on the cross-section of the wire will give the students access to a new thickness. I would suggest students do at least 5 different thicknesses with 10 thicknesses being an ideal number to use to get a good graph.

The program will randomize the length of the wire and the resistivity of the material the wire is constructed from, so all students will get different results. Students should not refresh the website while working or it will generate new values and thus make all the old data irrelevant. Below is a sample of what potential data might look like.

Data:

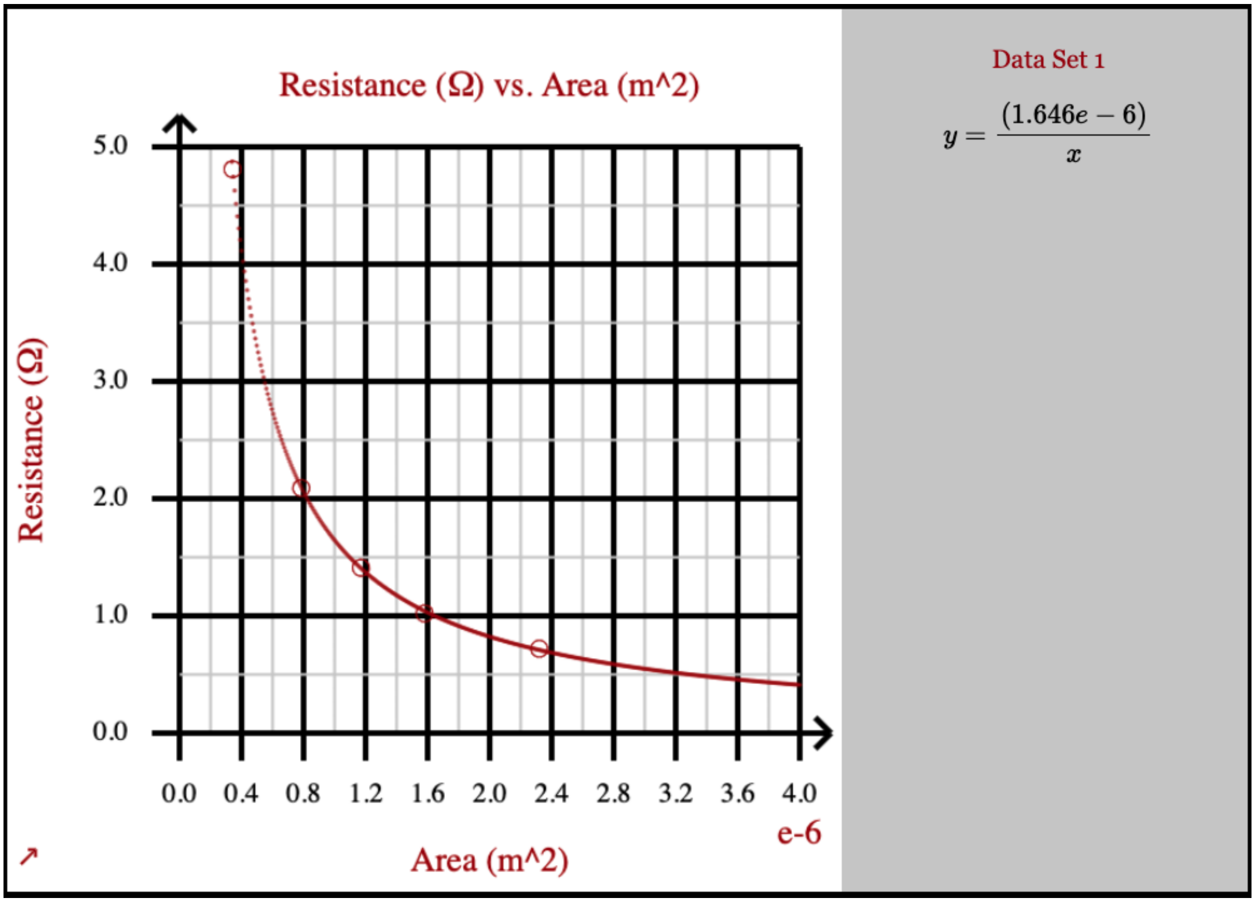
Radius (m)	Area (m^2)	Resistance (Ω)
8.6e-4	2.32e-6	0.72
7.1e-4	1.58e-6	1.02
6.1e-4	1.17e-6	1.41
5.0e-4	7.85e-7	2.09
3.3e-4	3.42e-7	4.81

Graphing Data:

(https://www.thephysicsaviary.com/Physics/Programs/Tools/Graphing/)

Once students have finished collecting data, they should graph it and find a relationship between the variables. The cross-sectional area in m^2 is the independent variable and should be placed on the x-axis and the resistance of the wire (Ω) should be on the y-axis. This graph should come out to be an inverse graph.

I prefer always having the students transfer their graph onto their lab sheet by hand.



Equation:

For this graph students get an inverse relationship between the variables. This indicates to them that a larger cross-sectional area will cause the wire's resistance to decrease. Doubling the area will cause the resistance of the wire to be cut in half. Doubling the radius of the wire will cause a four fold increase in area and thus the resistance will be cut to a quarter of its original value.

The equation for an inverse relationship is given below.

$$y = A/x$$

We want to continue to emphasize to them the idea that each of these letters has real physical significance. Looking at the axes, they should see that the y is the resistance of the wire in Ohms and the x is the cross-sectional area in m^2. So the equation becomes:

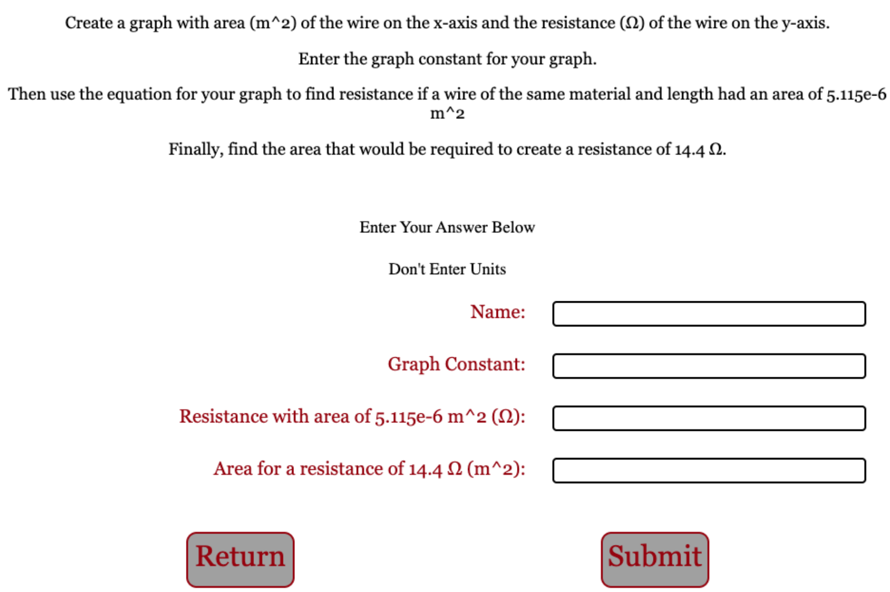
$$R = (\text{graph constant})/\text{Area}$$

We then want students to think about the significance of the graph constant. We can prompt them by asking what other things about the wire might have changed that would have led to a change in the resistance of the wire other than the cross-sectional area. Hopefully a few of the students will realize that the length of the wire would also make a difference in terms of the voltage needed to make an amp flow through the wire. Then there might be a few students who will also realize that the material that the wire was made of would make a difference too.

Checking their work:

Once the students have reached the point where they have graphed and created an equation, they will then be able to check their work. They should simply hit “Finished” on the program to be brought to a form they can fill out to see if they did everything correctly. Remind students that they all will be getting different answers and that they shouldn’t worry if their answers differ from those of their classmates.

Make sure to stress that they should have graphed the area in meters squared. They will be entering their value from their graph as the graph constant. They will then use their equation to make a prediction on how much resistance this wire would have for an area which they didn’t collect data on. Finally, they will be asked to calculate which area would be needed to create a certain resistance.


Create a graph with area (m^2) of the wire on the x-axis and the resistance (Ω) of the wire on the y-axis.

Enter the graph constant for your graph.

Then use the equation for your graph to find resistance if a wire of the same material and length had an area of 5.115e-6 m^2

Finally, find the area that would be required to create a resistance of 14.4 Ω.

Enter Your Answer Below

Don't Enter Units

Name:

Graph Constant:

Resistance with area of 5.115e-6 m^2 (Ω):

Area for a resistance of 14.4 Ω (m^2):

Return

Submit

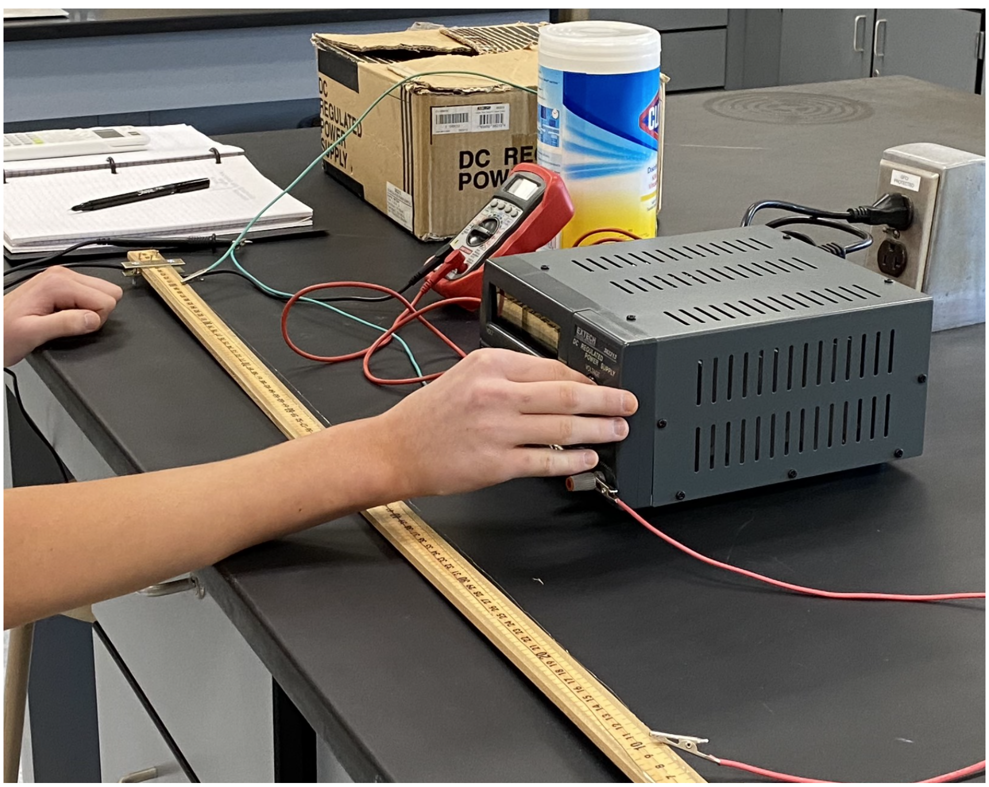
I would normally offer a small amount of extra credit added to the lab grade if they get all their answers correct. I would have them show me their completion certificate so I could record that they earned the extra credit. If a student doesn’t get everything correct, you can have them redo the lab by refreshing their page if time permits.

Live Part:

I would have the students complete a live part that is similar to, but slightly different than, what they did in the virtual part. Since I only had one variable voltage supply, I would have groups of two continually cycle through the live part as other students worked on the virtual part. I would use a nichrome wire with a relatively small diameter and I would have them only create a current of 100 mA and then we would multiply by 10 to get the Ohms.

The main difference with the live part is that I would have each lab group do a different length of wire rather than a different radius of wire. Doing different lengths made the time required to collect data significantly more manageable. Doing different lengths also made set up much easier. Students would simply more alligator clips along the wire to adjust the length. Students would put their data on the board and by the end of the class we would have a complete set of data that students could graph.

The set up I used in this lab is shown in the picture below.



Conclusion:

I personally like to have students write out a conclusion by hand after they are done with the entire lab (live part and virtual part). Some things you can have students include in the conclusion.

1. **Restatement of the purpose.**
    a. This is a great way to open the conclusion
    b. It helps to reinforce the reason we were doing the lab.
2. **Brief Summary of the steps**
    a. I don't want too much here but I do want students to transition from the purpose to the results with a sentence or two summary of the steps.
    b. This part of the conclusion should paint with a very broad brush what type of data we were collecting and what remained constant when collecting data.
3. **Results**
    a. I want students to clearly state what type of relationship existed between the two variables we were examining.
    b. I want them to clearly explain what this means in simple to understand terms.
    c. Basically, they will be making sense of the equation they have discovered in the lab.
4. **Error**
    a. They should talk about their percentage of error from the lab (you can have them do this for the live part or the virtual part or both).
    b. They should brainstorm at least one possible source of that error and how it can be minimized if they redid the lab.
5. **Limitations to the model**
    a. Whenever possible I want them to think about when the mathematical model for the lab would break down and no longer apply.
    b. For instance, with this lab, the equation they create would break down if the temperature of the wire changed significantly for one of their trials. Electricity in a wire could cause a significant change in temperature of the wire so this is something to be aware of when using the model that we create.

Going Further

If you have the time, you could challenge the students with the following types of things.

1. How would your graph change if we collected data on a wire made with a different material. Have the students sketch lines on their graph that would be representative of materials with a higher resistivity and a lower resistivity.

2. Have the students collect the data but with a different amount of current in the wire as the standard. If you collected the voltage required to produce a current of 1 A, maybe try the voltage required to produce a current of 10 mA and then multiply by 100 to get the resistance of the wire. Higher currents will heat the wire and will give slightly different resistances for the wire.

3. Have the students measure the diameter of the wire using a micrometer and then have them figure out the resistivity of the wire based on the data collected by the class.

This lab was created by Frank McCulley for thephysicsaviary.com.