Vive La Resistance!

Lesson Plan

Inquiry Lesson Into Resistance and the Factors that Affect It

This lesson looks at conductors and insulators as well as the factors affecting resistance. Along with these focuses students are introduced to graphene and the some of the current research that is being done on this fascinating material. This lesson incorporates technology based learning in large group, small group, and individual settings as well as hands-on activity in which the students must design their own experiment to test their hypothesis. The students are also required to research the current work being done on graphene and form and support an argument based on their research.

Malynda L. Wood
7/25/2014
Vive La Resistance!

Problem

Students in grades 1-8 are often taught that all metals are conductors and all nonmetals are insulators. The physical science curriculum actually reinforces this misconception, and it is covered on the Georgia End of Course Test and Georgia Milestones Assessment System. However, not all nonmetals are insulators and sometimes the best conductors are not metals. This lesson plan will introduce students to the idea that sometimes a nonmetal like carbon can be a good conductor and that speaking in absolutes, such as “always”, “never”, and “all”, in science is usually a bad idea.

Abstract

This lesson looks at conductors and insulators as well as the factors affecting resistance. Along with these focuses students are introduced to graphene and the some of the current research that is being done on this fascinating material. This lesson incorporates technology based learning in large group, small group, and individual settings as well as hands-on activity in which the students must design their own experiment to test their hypothesis. The students are also required to research the current work being done on graphene and form and support an argument based on their research.

Alignment

National Common Core Language Arts Reading and Writing Standards

ELACC11-12RI1: Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

ELACC11-12RI7: Integrate and evaluate multiple sources of information presented indifferent media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

ELACC11-12W1: Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

ELACC11-12W7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
ELACC11-12W8: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

ELACC11-12W9: Draw evidence from literary or informational texts to support analysis, reflection, and research.

Georgia Performance Standards: Science

SCSh4. Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

SCSh6. Students will communicate scientific investigations and information clearly.
   a. Write clear, coherent laboratory reports related to scientific investigations.
   b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
   c. Use data as evidence to support scientific arguments and claims in written or oral presentations.

Georgia Performance Standards: Physics

SP5. Students will evaluate relationships between electrical and magnetic forces.

Georgia Performance Standards: Physical Science

SPS10. Students will investigate the properties of electricity and magnetism.

Objectives

1. The student will compare and contrast the properties of conductors and insulators.
2. The student will experimentally determine the factors that affect the resistance of a conductor.
3. The student will write clear coherent lab report.
4. The student will use reliable resources to assert and support an argument on a scientific topic.

Anticipated Learner Outcomes

After this lesson, students should be able to:
1. Demonstrate an understanding of the concepts of conductivity and insulation.
2. Demonstrate an understanding of the concept of resistance in a material.
3. Demonstrate an understanding of the factors that affect the resistance of an ohmic material.
4. Develop an argument and support it with evidence from research.
5. Demonstrate an understanding of why graphene is such an unusual substance and its potential impact on society.

Assessment/Rubrics

Students will be assessed on their lab reports and their research paper. Each student should complete a lab report for the simulations of Resistance in a Wire and a separate lab report for the Resistance of Graphene. I usually have the students complete the Resistance in a Wire Lab Report on the computer using Word and Excel. Then they complete the lab report for Resistance of Graphene as a hand written lab report. This allows me to assess their ability to use technology, specifically Excel, to show their graphs. The hand written report allows me to assess their knowledge of graphing skills and the parts required in a graph. Please see appendix for lab report rubric.

The research paper rubric that I use can be found at http://www.schoolimprovement.com/common-core-360/blog/common-core-standards-writing-rubric/... This website has rubrics for different grade levels so you can choose the appropriate grade level for your class. I teach this topic to tenth grade physical science students as well as eleventh and twelfth grade physics students. Therefore, this website comes in handy in adjusting the rubrics to the level of my students and allows me to assess them using the same standards their English teachers’ use which provides uniformity of expectations for the students.

Background

Conductors generally have extra valence electrons that are loosely held. Most of these substances are metals which have only one, two, or three electrons in their valence shell. Many metals follow Ohm’s law and are, therefore, considered ohmic materials. Resistance in an ohmic material is affected by length, thickness, temperature, and conductivity of the material in the wire. Insulators do not have loosely held electrons in their valence shell. Most of these substances are nonmetals which have between five and eight valence electrons. Carbon has four electrons in its valence shell. This puts it somewhere between the conductors and the insulators. Most forms of carbon such as graphite and diamond are not conductors. They generally form bonds in which all of their electrons are held tightly in place in the case of diamond or cannot all travel in the same direction due to variations in the direction that the atoms are stacked in the case of graphite. However, graphene is different. Graphene is a single layer of graphite only one atom thick. The carbon atoms in graphene form a flat sheet of hexagonal rings. The sp2 bonds between the carbon atoms leave some electrons unbound, and being a single sheet means they do not get bounced around by other layers interfering. These electrons are free to move about and
allow this form of carbon, an otherwise nonmetallic insulator, to be a conductor that is even better than most metals.

Materials

For this lesson plan, you will need access to computers with internet access and Microsoft Office for your students. Students can work in pairs, but more than two to a computer can be difficult to keep everyone on task. The lesson can be adapted to using one computer with an interactive board if absolutely necessary. Students would need to write down their answers, observations, and data tables to the computer activities if this is the case. The students will also need graph paper. For printable graph paper, check out http://www.printablepaper.net/category/graph.

On the second day, an interactive board or projector will be needed to show the short online video clips. For the hands on activity, you will need multi-meters, aluminum foil, copper wire, paper, rulers, and graphite pencils (6B, 4B, 2B, or HB). These graphite pencils are the graphite pencils used by artists. Normal pencils may or may not work due to the amount of clay and other contaminants in them.

Plan

This plan was designed for a 4x4 block schedule with 90 minute class periods. It is developed to take place over two 90 minute class periods. The first day will require access to a computer lab or enough computers for students to work in pairs. There are lots of good simulations out now even several that are free. The ones in this lesson plan are ones that are free for use though some do require that you sign up for a free account if you want your students’ data saved or to use their class management capabilities. The Concord Consortium has several different projects which are currently free to use and not only will allow you to use the simulations, but manage your class and have their answers to activities sent to you. The PhET Simulations and McCulley’s HTML5 simulations also have other simulations than just the ones used in this lesson plan. Although they do not offer the ability for the students to send their answers directly to you, they also do not require any information from you or your students.

Day 1

Opening:

Bell Ringer Activity

Journal Prompt : What does resistance mean to you? (5 minutes free write)

Discussion: What is resistance? How could resistance apply to physics? How could resistance apply to electricity specifically? (10 minutes)


**Work Period**

**What are conductivity and resistivity and how does temperature affect them?**

Conductivity and Resistivity Online Activity from Concord Consortium and RI-ITEST (10-15 minutes)

The first online activity presents background information and asks students to answer questions about conductivity and resistance. The simulation demonstrates the effect of temperature on resistance. This activity should take students about 10 minutes, although time will need to be adjusted depending on the level of the students. System requirements state that Java 5 or later will work, however, I have had difficulty running the application on Java 6 but Java7 works very well. If you decide to sign up for an account and have your students sign up, they can answer the questions in the space provided in the simulation. Otherwise, students can write their answers on paper or in a Word document to turn in to you as a hard copy or email.

Students should be directed to [http://ri-itest.portal.concord.org/activities/](http://ri-itest.portal.concord.org/activities/) they should select the Electricity Activity and then the Conductivity and Resistivity link. They should read all information and follow all instructions for the simulation before answering the questions at the bottom of the page.

**What other factors affect the resistance of a wire?**

Resistance Simulation Lab (45-50 minutes)

There are actually two good simulations for the effects of length, thickness, and resistivity of the material and both are good for different reasons and with different levels of students. The lab simulation at McCulley’s HTML5 simulations ([http://www.tandftechnology.com/Physics/Programs/Labs/ResistanceOfWireLab/index.html](http://www.tandftechnology.com/Physics/Programs/Labs/ResistanceOfWireLab/index.html)) uses more concrete representations to show what is being measured. Instead of a symbol for length, there is a diagram of a wire and a ruler. The cross-section of the wire is also shown in a diagram so that the students can see exactly what is being measured. Instead of showing just a number for the resistivity of the material the students are given the names of three materials and their specific resistivity. This simulation is good for physical science students or those who need more scaffolding with the concepts. The PhET simulation from the University of Colorado Boulder ([http://phet.colorado.edu/en/simulation/resistance-in-a-wire](http://phet.colorado.edu/en/simulation/resistance-in-a-wire)) uses symbols for each factor and the equation for determining resistance. It does show what happens to the variables when you change one variable by increasing or decreasing the size of the symbol. However, for more concrete thinkers or those who struggle with the abstractness of variables, this may be more difficult for them to gain and link the concept knowledge. However, the PhET simulation does allow for more variation of the resistivity of the
material and would allow for an extension of the data collection for those needing the extra challenge. I can see where I would use both even in a single class to differentiate for various student needs.

Students should be given the instructions for the lab simulation that they are to complete depending on which website you wish them to use. The students should also be given a rubric for writing their lab report. Some students may need to complete the lab report at home if they have access to the technology. I use the same rubric for each lab that my students do so that they become comfortable with the process and what I expect in their report. Please see appendix for the lab report rubric and instructions for each simulation.

**Closing:**

**Ticket Out of the Door Activity:** (10 minutes)

Write and answer the following questions and turn in to the teacher before leaving class.

1. What happens to resistance when temperature increases?
2. What happens to resistance when length increases?
3. What happens to resistance when the thickness increases?
4. What is the difference in resistance between a conductor and an insulator?

**Day 2**

**Opening:**

**Bell Ringer Activity:** (10 minutes)

**Review Questions:** Copy and answer the following in your notebook/journal.

1. Compare and contrast conductors and insulators. What type of material is likely to be a good conductor? What type of material is likely to be a good insulator?
2. What are the four factors that affect resistance? Do you think these factors apply to all conductors?

**Video Clip:** (1 minute)

This one minute video gives just a bit of teaser information about graphene without explaining where it comes from which will hopefully peak students interest.

**Work Period:**

*Resistance Lab* (60 minutes)

Students should write up their own lab report for this activity. They should develop the problem, hypothesis, materials list, procedure, data tables, graphs, analysis, and conclusions.

**Is it a conductor or an insulator? Are you sure?**

In this laboratory inquiry, students are going to predict whether each of three materials is a conductor or an insulator and then check their predictions with the multi-meter. Students should receive a strip of aluminum foil, two pieces of paper that are the same size, and a graphite pencil. Instruct students to use the pencil to shade one piece of the paper completely, but to leave the other blank. The students should then develop a step by step procedure for determining whether or not a material is a conductor or an insulator using the multi-meter.

**Do conductors follow the same rules?**

The students should then develop a procedure to determine if length affects all conductors the same way. Remind students to collect data for at least five length points for both aluminum foil and copper wire. Students should collect resistance data from the multi-meter for each length. Remind them that length is their independent variable, therefore the x-axis, and that resistance is the dependent variable or y-axis. Students should write up their lab report and turn it in at the end of the laboratory activity.

*Video Clip: Sci-Show on Graphene* (5 minutes)


**Closing:**

**Research Topic Introduction:** (14 minutes)

Students should be given a copy of the research paper rubric and the questions their research should answer. I always include a discussion of avoiding plagiarism and choosing reliable sources any time I assign a research paper. I also spend a few minutes going over the rubric with the students. It has been my
experience that no matter how many times they have seen and used the rubric some of them still need a little extra explaining so that they understand what is expected of them. I normally allow at least two to four weeks outside of class depending on the level of students for them to complete this type of research project.

**Research topic question:** Will graphene prove to be the miracle material researchers hope that it is? Based on your research, what do you think will be graphene’s impact on society? Back up your assertions with details from your research. Make sure that you use at least five (5) reliable and documented references, and that your paper is at least five (5) pages long but no greater than eight (8) pages long.

**Summary**

Conductivity is something that often gets taught in terms of generalizations that metals are conductors and nonmetals are insulators. This is not always the case as new research into materials such as graphene is showing us. This lesson not only allows students to investigate the factors affecting the resistance of metal wires which they have learned previously are conductors, but also introduces them to materials they would not normally consider to be conductors and allows them to inquire into whether those materials are also affected by the same factors of resistance. Students also use online simulations to study some factors and then check what they discovered from the computer model against real life materials.
Appendix A

Example Rubrics
# Lab Report: Resistance

Student Name: __________________________________________

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>10 pts</th>
<th>7 pts</th>
<th>5 pts</th>
<th>2 pts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem</strong></td>
<td>The purpose of the lab or the question to be answered during the lab is clearly identified and stated.</td>
<td>The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner.</td>
<td>The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.</td>
<td>The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant.</td>
</tr>
<tr>
<td><strong>Experimental Hypothesis</strong></td>
<td>Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied.</td>
<td>Hypothesized relationship between the variables and the predicted results is reasonable based on general knowledge and observations.</td>
<td>Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic.</td>
<td>No hypothesis has been stated.</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td>All materials and setup used in the experiment are clearly and accurately described.</td>
<td>Almost all materials and the setup used in the experiment are clearly and accurately described.</td>
<td>Most of the materials and the setup used in the experiment are accurately described.</td>
<td>Many materials are described inaccurately OR are not described at all.</td>
</tr>
<tr>
<td><strong>Procedures</strong></td>
<td>Procedures are listed in clear steps. Each step is numbered and is a complete sentence.</td>
<td>Procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.</td>
<td>Procedures are listed but are not in a logical order or are difficult to follow.</td>
<td>Procedures do not accurately list the steps of the experiment.</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.</td>
<td>Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.</td>
<td>Accurate representation of the data in written form, but no graphs or tables are presented.</td>
<td>Data are not shown OR are inaccurate.</td>
</tr>
<tr>
<td>Analysis</td>
<td>The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.</td>
<td>The relationship between the variables is discussed and trends/patterns logically analyzed.</td>
<td>The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.</td>
<td>The relationship between the variables is not discussed.</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Error Analysis</td>
<td>Experimental errors, their possible effects, and ways to reduce errors are discussed.</td>
<td>Experimental errors and their possible effects are discussed.</td>
<td>Experimental errors are mentioned.</td>
<td>There is no discussion of errors.</td>
</tr>
<tr>
<td>Drawings/Diagrams</td>
<td>Clear, accurate diagrams are included and make the experiment easier to understand. Diagrams are labeled neatly and accurately.</td>
<td>Diagrams are included and are labeled neatly and accurately.</td>
<td>Diagrams are included and are labeled.</td>
<td>Needed diagrams are missing OR are missing important labels.</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Conclusion includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment.</td>
<td>Conclusion includes whether the findings supported the hypothesis and what was learned from the experiment.</td>
<td>Conclusion includes what was learned from the experiment.</td>
<td>No conclusion was included in the report OR shows little effort and reflection.</td>
</tr>
<tr>
<td>Safety</td>
<td>Lab is carried out with full attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual.</td>
<td>Lab is generally carried out with attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but one safety procedure needs to be reviewed.</td>
<td>Lab is carried out with some attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but several safety procedures need to be reviewed.</td>
<td>Safety procedures were ignored and/or some aspect of the experiment posed a threat to the safety of the student or others.</td>
</tr>
<tr>
<td>Description</td>
<td>1: Novice</td>
<td>2: Developing</td>
<td>3: Proficient</td>
<td>4: Skilled</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>--------------</td>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Argument</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supports and responds effectively</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Presents written argument</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Indicates who has the burden of proof</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Is convincing</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Rubric Grades 9-10**
<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Argument</th>
<th>Evidence</th>
<th>Organization</th>
<th>Style</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inadequate</td>
<td>Poorly developed arguments, lacks supporting evidence, and flawed organization.</td>
<td>Weak. The argument is not supported by evidence.</td>
<td>Limited. The evidence is not relevant or persuasive.</td>
<td>Poorly organized. The paper lacks a clear structure.</td>
<td>Informal. The writing style is unclear and lacks clarity.</td>
</tr>
<tr>
<td>Developing</td>
<td>Developing arguments, but lacks supporting evidence and organization.</td>
<td>Developing. The argument is not fully supported by evidence.</td>
<td>Developing. The evidence is not fully relevant or persuasive.</td>
<td>Developing. The paper lacks a clear structure.</td>
<td>Developing. The writing style is not fully polished.</td>
</tr>
<tr>
<td>Proficient</td>
<td>Well-developed arguments, supported by relevant and persuasive evidence, and well-organized.</td>
<td>Strong. The argument is fully supported by evidence.</td>
<td>Strong. The evidence is fully relevant and persuasive.</td>
<td>Strong. The paper has a clear and effective structure.</td>
<td>Strong. The writing style is polished and clear.</td>
</tr>
<tr>
<td>Exceptional</td>
<td>Well-developed arguments, supported by strong evidence, and well-organized.</td>
<td>Exceptional. The argument is fully supported by strong evidence.</td>
<td>Exceptional. The evidence is strongly relevant and persuasive.</td>
<td>Exceptional. The paper has a clear and effective structure.</td>
<td>Exceptional. The writing style is professional and clear.</td>
</tr>
</tbody>
</table>
Appendix B

Example Instructions for Simulations
Resistance on a Wire Lab (McCulley’s HTML5)

1. Go to [http://www.tandftechnology.com/Physics/Programs/Labs/ResistanceOfWireLab/index.html](http://www.tandftechnology.com/Physics/Programs/Labs/ResistanceOfWireLab/index.html)

2. Click on Begin to start the lab and spend a few moments reading the instructions and familiarizing yourself with the controls. You can click on the wire at the top to change the length. Clicking the circle will change the thickness, and clicking on the name of the wire type to change the type of wire.

3. Make sure that your wire type is set to Nichrome and then measure the radius of the wire by using the wire cross-section in the bottom left of the program display. You will not be changing either of these factors in part one of this lab.

4. Create a data table in Excel that lists the length of the wire in meters and the resistance of the wire in Ohm's.

5. Collect data for 10 unique lengths and then graph your data in Excel. Make sure that you transfer your graph, with all the things a good graph should contain, into your lab report which should be typed in Word.

6. Keep your wire set as Nichrome and make sure that your wire is at least 2 meters long. Write down the exact length of the wire you will be using and make sure you don't change this parameter through the course of steps 7-8.

7. Create a data table that lists the radius of the wire in mm, the cross-sectional area of the wire in mm squared and the resistance of the wire in Ohm's. You will get the cross-sectional area using the formula for the area of a circle \((A=\pi r^2)\).

8. Make another data table in Excel. Collect data for 10 unique radii and areas and then graph your data (Resistance vs. Area) in Excel. Make sure that you transfer your graph, with all the things a good graph should contain, into your lab report.

9. For this part of the lab you will be switching your wire between copper and aluminum. You will not be changing the thickness of the wire. Make sure you write down the radius of the wire you will be using for this part of the lab.

10. Create a data table in Excel that lists the length of the wire in m and then has two columns for resistance, one for copper and one for aluminum.

11. Randomly generate a certain length of wire and the switch from copper to aluminum and write down both resistances. Don't change your length until you have taken both readings.

12. Collect data for 10 unique lengths and plot two lines on your graph in Excel. Make sure that you transfer your graph, with all the things a good graph should contain, into your lab report.

13. In your analysis, discuss the relationship between the length of a wire and its resistance, the relationship between the cross-sectional area of a wire and its...
resistance, and the significance between the slope of the lines and the conductivity of the wire material you are using.

Resistance in a Wire Simulation (PhET Simulation)

2. Click the run now and read any instructions and familiarize yourself with the controls. There are three sliders. One controls length, the second controls cross sectional area, and the third controls the resistivity of the material.
3. Open Excel and create a data table. Record the cross sectional area and the resistivity of the material. You will not change these for this set of data.
4. Change the length of the wire by using the slider controlling length. Record the length and the resistance for 10 unique lengths.
5. Graph the length versus resistance. Recall how to determine which variable goes on the x-axis and include all the parts needed for a good graph. Include this graph in your lab report.
6. Set the length of the wire and the resistivity. Record these. Change the cross-sectional area using the area slider and record the area and resistance for 10 unique areas in a separate data table.
7. Graph the area versus the resistance. Include this graph in your lab report.
8. Set the length and the area of the wire. Record these. Change the resistivity of the material and record the resistivity and the resistance for 10 unique resistivities in a separate data table.
9. Graph the resistivity versus the resistance. Include this graph in your lab report.
10. In your analysis, discuss the relationship between the length of a wire and its resistance, the relationship between the cross-sectional area of a wire and its resistance, and the relationship between the resistivity and the resistance. If you wanted to change the resistivity of a wire, what about the wire would you have to change?
Appendix C

Websites to Help Students Get Started with their Research
Here are some articles that you can use to scaffold the research paper by pointing them in the right direction. You can use this list as a starting point or allow the students to just use these articles.

http://www.livescience.com/45216-graphene-weak-link-discovered.html
http://www.livescience.com/10808-material-graphene-nobel-prize-start.html
http://www.sciencedaily.com/releases/2014/07/140716095732.htm
http://www.theguardian.com/science/2013/nov/26/graphene-molecule-potential-wonder-material
http://www.cnn.com/2013/10/02/tech/innovation/graphene-quest-for-first-ever-2d-material/
Works Cited


