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Properties of Matter

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NGSS LESSON PLAN 1 (POETS) HS-PS2 INVESTIGATION

Grade: 11-12	**Topic: Properties of Matter**	**Lesson # 1 (90 minutes)**

Brief Lesson Description:
Students will investigate the relationship(s) between thermal and electrical properties of matter. First, students will use a multimeter and temperature probe to investigate the relationship between electrical resistance and temperature of an electrical resistor composed of metals. They will then graph collected data to analyze the relationship and draw a conclusion as to their relationship. They will then perform the same investigation on a thermal resistor made of a semiconducting substance and analyze that collected data. Finally, using Claim-Evidence-Reasoning (CER) structure, students will use their experimental evidence to state the similarities and differences between the electro-thermal properties of metals and semiconductors.

Before proceeding with this lesson, the teacher should familiarize him / herself with Vernier Logger Pro®:

***Vernier Logger Pro®* Overview:** https://www.vernier.com/products/software/lp/

Performance Expectation(s)/Standards:
Students who demonstrate understanding can:

HS-PS2-6. **Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.** * [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [*Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.*]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including oral, graphical, textual and mathematical).	PS2.B: Types of Interactions • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	Structure and Function • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Specific Learning Outcomes/Including Evidence Statements:

Observable features of the student performance by the end of the course:		
1	Communication style and format	
	a	Students use at least two different formats (including oral, graphical, textual and mathematical) to communicate scientific and technical information, including fully describing* the structure, properties, and design of the chosen material(s). Students cite the origin of the information as appropriate.
2	Connecting the DCIs and the CCCs	
	a	Students identify and communicate the evidence for why molecular level structure is important in the functioning of designed materials, including:
		i. How the structure and properties of matter and the types of interactions of matter at the atomic scale determine the function of the chosen designed material(s); and
		ii. How the material's properties make it suitable for use in its designed function.

b	Students explicitly identify the molecular structure of the chosen designed material(s) (using a representation appropriate to the specific type of communication — e.g., geometric shapes for drugs and receptors, ball and stick models for long-chained molecules).
c	Students describe* the intended function of the chosen designed material(s).
d	Students describe* the relationship between the material's function and its macroscopic properties (e.g., material strength, conductivity, reactivity, state of matter, durability) and each of the following:
	i. Molecular level structure of the material;
	ii. Intermolecular forces and polarity of molecules; and
	iii. The ability of electrons to move relatively freely in metals.
e	Students describe* the effects that attractive and repulsive electrical forces between molecules have on the arrangement (structure) of the chosen designed material(s) of molecules (e.g., solids, liquids, gases, network solid, polymers).
f	Students describe* that, for all materials, electrostatic forces on the atomic and molecular scale results in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.

Prior Student Knowledge:

HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Use a model to predict the relationships between systems or between components of a system.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Brainstorm with students about the concept of thermal energy. Ask the class if they think there if there is any relationship between electrical energy and thermal energy. Many will say no. Some will say yes without a clear rationale.

Ask the students if they have ever tried to use a smartphone that was too hot.

Have students brainstorm over why this happens. Get an old computer from the school technology department and show the students how much of the computer's composition is devoted to cooling.

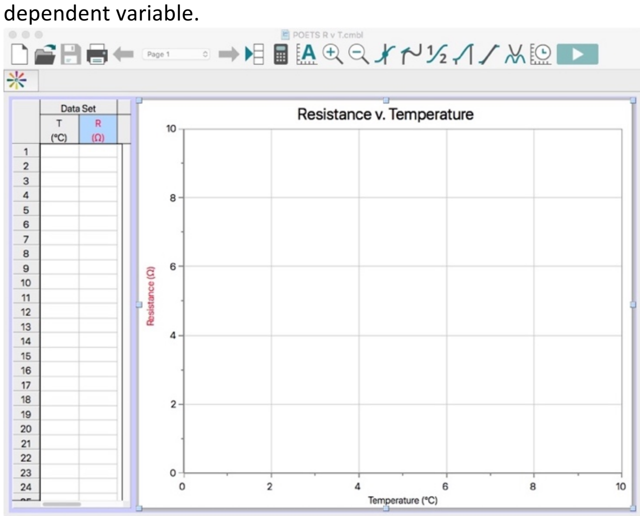
In this activity, students will compare the electrothermal properties of metals and semiconductors. They will test the electrical resistance of a standard resistor versus its temperature, and they will then test the resistance versus temperature of a thermal resistor.

It is important to describe the composition of each component: a resistor is composed of metallic elements, and a thermal resistor is composed of semiconducting elements.

Composition of Resistors: https://learn.sparkfun.com/tutorials/resistors
Composition of Thermal Resistors: https://www.electronics-tutorials.ws/io/thermistors.html

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:
Part I: Resistance v Temperature for a Standard Electrical Resistor

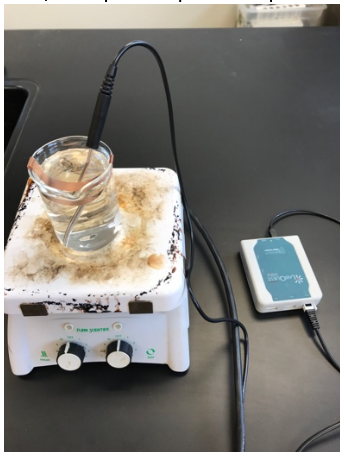
1. First, set up a computer data collection program (Vernier Logger Pro, Microsoft Excel, etc.) to collect temperature and electrical resistance data as indicated. Temperature should be set to be the independent variable, and resistance should be set as the dependent variable.



2. Next, set up a multimeter to collect resistance.

3. Next, place an electrical resistor in a 100 mL beaker of water. The resistor needs to be submerged in the water, but the ends need to be accessible to the multimeter. Students need to be told that the resistor is composed of metallic elements.

4. Next, set up a temperature probe or thermometer to collect temperature data.



5. Begin heating at a medium-high setting.
6. Collect temperature and resistance every 30 seconds until the water begins to boil. Be sure to stir the water regularly to maintain a uniform temperature in the beaker.
7. Produce a graph of the data.

Part II: Resistance v Temperature for a Semiconductor

8. Open a second window of the data collection software. Set the data collection parameters as in Part 1.
9. Using a new 100 mL beaker of water, place a thermal resistor in the water as indicated.

10. Set up the temperature probe to collect temperature data.
11. Begin heating at a medium-high setting.
12. Set the multimeter to the kΩ range as indicated.

13. Collect temperature and resistance every 30 seconds until the water begins to boil. Be sure to stir the water regularly to maintain a uniform temperature in the beaker.
14. Produce a graph of the data.

Materials:

- Computer graphing program (Vernier Logger Pro, Microsoft Excel, etc.)
- 1 - Multimeter capable of measuring electrical resistance
- 1 – Temperature probe or thermometer
- 1 - Thermal resistor
- 1 - Standard electrical resistor (any resitance)
- 1 - 100 mL glass beaker
- 1 – Hot plate

EXPLAIN: Concepts Explained and Vocabulary Defined:

For Students after the activity:

1. **What trends do you see in your data?**
2. **Share your data with other groups.**
3. **As a class, do you see the same trends?**

Students will write a Claim-Evidence-Rationale (CER) passage explaining their findings. Students should have found that for the standard resistor, resistance did not change with a change in temperature, resulting in a linear graph with zero slope. For the thermal resistor, on the other hand, they should have noticed a linear relationship with either a negative or positive slope. Students should ***claim*** that semiconductors' resistance is temperature dependent while metals' resistance is not temperature dependent. Students should refer back to their experimental data as ***evidence***, and then they should analyze the data to ***rationalize*** their claim.

Vocabulary:
Resistance: opposition to electrical flow
Temperature: Average kinetic energy of the particles of a substance

ELABORATE: Applications and Extensions:

The dependence of electrical resistance on temperature is material specific. Metals' resistance is not thermally dependent, but semiconductors' resistance is thermally dependent, and students' analysis should show a linear relationship between the two properties.

Since a semiconductor's thermal dependence on resistance is linear, ask students how this relationship could be used. The equation of the resistance v temperature graph can be used as a conversion factor between resistance and temperature, allowing thermal resistors to be used as electrical temperature sensors.

Semiconductors can also be used to build switches that control devices to operate within specific temperature ranges.

Refer back to the engaging question about the smartphone not working in high temperatures. ***Challenge the students to explain this phenomenon using a CER format***. The students should recognize that the semiconducting materials in the phone's circuitry are designed to operate only within a certain temperature range, and when that range is exceeded, the device fails.

EVALUATE:

Formative Monitoring (Questioning / Discussion):

1. What is happening to the electrical resistance of the metal resistor as temperature increases?
2. What is happening to the electrical resistance of the thermal resistor (semiconductor) as temperature increases?
3. What trends do you notice in resistance v temperature of each material?
4. How do the trends of each material differ?
5. What can the data analysis show us?

Summative Assessment (Project Extension):

1. What claim can you make of the electrothermal properties of metals versus those of semiconductors?
2. What evidence do you have to support your claim?
3. How does your evidence rationalize your claim?
4. How can your data analysis explain temperature driven device failure?

Materials Required for This Lesson/Activity			
Quantity	**Description**	**Potential Supplier (item #)**	**Estimated Price**
1 per district	Vernier Logger Pro	Vernier Science and Technology	$250 site license
1 per district	Vernier Logger Lite (limited, but free, alternative to Logger Pro)	Vernier Science and Technology	Free