4.3 - Electricity Unit, Packet 3

First & Last Name: ______________________________ Period/Hour:______

NOTE: Packets are due after completing Part 5. Check each page to be sure all blanks are completed.

Score
- ☐ Above & Beyond
- ☐ Meets Expectations
- ☐ Near Expectations
- ☐ Incomplete – *fix the following pages:*

Driving Question: How do voltage and resistance determine current?

Anchoring Phenomenon: You walk into a room and flip a switch. The lights turn on. We do this so often we hardly ever stop to think about how and why this occurs. How does flipping a switch enable electrical charge to move? And where did this electricity come from? We'll explore this further in this packet.

Deeper Questions
1. How do charges move through a conductor?
2. How are electrical energy and electrical power calculated?
3. What is electrical potential?

Schedule

Part 1: Introduction
- Initial Ideas & Data Dive
- Discussion & Developing Explanations

Part 2: Core Ideas
- Core Ideas & Revisions of Part 1 Explanations

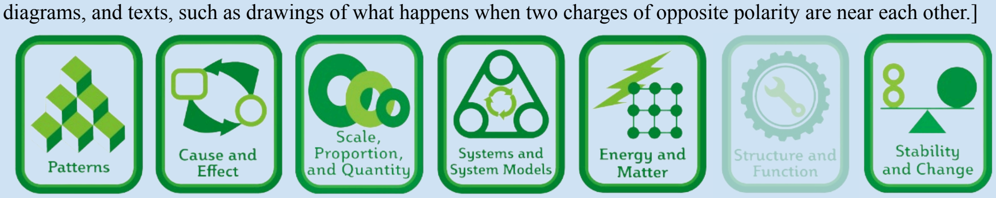
Part 3: Investigation
- Part 3A: Ohm's Law
- Part 3B: Play-Doh Resistivity

Part 4: Review & Assessment
- Ranking Your Readiness & Practice Problems
- Formative Assessment & Mastery Check

Part 5: Life Connections
- Life Connections

Image Source

NGSS Standards (*PEs & CCCs are summarized below. SEPs are noted throughout the packet*). HS-PS2-4 - Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. 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. HS-PS3-5 - Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.]



Semester Schedule

1. Electricity
- 4.1: Where do charges come from?
- 4.2: How much force exists between charged particles?
- 4.3: How do voltage and resistance determine current?
- 4.4: How do different circuits change voltage & resistance?
- 4.5: Unit Assessment

2. Thermal Energy
- 5.1: What is the difference between temperature & heat?
- 5.2: What determines how quickly temperature changes?
- 5.3: How can thermal energy be used for work?
- 5.4: Unit Assessment

3. Waves, Light, Sound
- 6.1: How do harmonic motion & linear motion differ?
- 6.2: What determines the properties of waves?
- 6.3: What is sound, and what determines its properties?
- 6.4: What is light, and what determines its properties?
- 6.5: How is light changed by reflection & refraction?
- 6.6: Unit Assessment

4. Solar Cooker Project
How can we design a tool to use light & heat for work?

These materials were partly developed with assistance from artificial intelligence.

Resource Links: Class Website; Core Ideas; Quizlet; PhET Circuit simulation;

Part 1: Introduction (4.3.1)

Overview: In this activity, you will begin by discussing ideas about electricity and how simple circuits work. You will then watch a short video about simple circuits and Ohm's Law.

Initial Ideas - *Record your ideas separately (e.g., on a white board or scratch paper).*
SEP: Engaging in Argument from Evidence

Electricity is the result of the movement of electrons through a conductor. In a simple circuit a switch completes a loop that allows electrons to flow. Three students wonder how the switch on a battery-powered flashlight enables the light to turn on. **Do you agree or disagree with each student's claim**? *Image Source*

- Evel: "The switch allows electrons to 'fill up' the wires and flow back into the battery."
  Agree/Disagree
- Betty: "The battery acts like a water pump - it pushes the electrons through the wire."
  Agree/Disagree
- Harry: "Ben Franklin argued that positive particles create electricity - I think that the negative electrons are pushing or pulling positive protons through the wire."
  Agree/Disagree

Work in your small groups to discuss your ideas. How are your ideas similar or different? Decide as a group whether each statement is correct (and why). Be prepared to present your ideas.

Data Dive - *Use the accompanying videos to refine your understanding of the claims above and develop an initial explanatory model.* *SEP: Engaging in Argument from Evidence*

Video 1 – How ELECTRICITY works - working principle
Summary: Provide a 2-3 sentence summary of how electricity works.

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Video 2 - What is CURRENT– electric current explained, electricity basics
Summary: In 2-3 sentences, summarize what current is.

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Video 3 - Voltage Explained - What is Voltage? Basic electricity potential difference

Summary: Provide a 2-3 sentence summary of what creates voltage.

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Video 4 - Ohms Law Explained - The basics circuit theory

Summary: Provide a 2-3 sentence summary of Ohm's Law and how it applies to circuits.

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Discussion - *Record your ideas in the spaces below. SEP: Asking Questions & Defining Problems*

As a class, discuss your ideas about these statements. What are the ideas that most agreed on? Where did your ideas differ as a class? Record your ideas in the spaces below.

We generally agree that…	***We disagreed or were unsure if…***

Initial Explanations - *Record your ideas in the spaces below. SEP: Constructing Explanations & Designing Solutions*

Video 5: Electric Potential Energy **What causes electrical current (movement of charge through wires)?** *Watch before answering!*

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Part 2: Core Ideas (4.3.2)

Overview: In this activity, you will begin with a short presentation to provide you with information that will help you improve and revise your initial ideas. Your instructor will decide on how to implement this portion. You will then work in small teams to address the questions listed below.

Driving Questions - *Record your ideas separately (e.g., on a white board or scratch paper).*
SEP: Developing & Using Models

1. What is a circuit? What determines if a wire will function as a circuit?
2. What is voltage? What is electromotive force? How are these terms similar but different?
3. What is an electric current? How is it measured?
4. What is the difference between amperes and coulombs? How are they similar & different?
5. A battery has a positive and negative terminal. How does this relate to current direction?
6. What is resistance? How is it measured?
7. Use Ohm's law to explain how changes to voltage & resistance affect current.
8. Summarize four ways in which resistance in a conductor can be changed.
9. Why do batteries seem to weaken over time? What is happening within the battery?
10. How is electric current analogous to pumping water? How does it relate to potential energy?
11. How can Ohm's law be used to explain how a lightbulb's filament produces light?
12. Lightbulbs are sold by their wattage. How do watts relate to voltage and current?
13. How do turbines generate electricity? How is this similar to electrical motor function?
14. What is the difference between AC & DC? Why is AC more widely used for electricity?

Revising Explanations - *Record your ideas in the spaces below. SEP: Construction Explanations & Designing Solutions*

What causes electrical current (movement of charge through wires)? Based on this new information, how would you now respond to this question?

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Throughout this packet, you will be updating this explanation as you gain more information and more experience. When you complete this packet, compare your initial explanation to your final version. You should see clear improvement with each revision.

Part 3A Investigation: Ohm's Law (4.3.3a)

Pre-Investigation Questions - *Prepare verbal responses as a group for these questions. Raise your hand when you're ready to present your explanations. Your instructor will provide feedback and decide if you can proceed to the investigation. SEP: Developing & Using Models*

1. What is a circuit? What determines if a wire will function as a circuit?
2. How is voltage different from current? How is each measured and calculated?
3. What is resistance? How is it measured?
4. Use Ohm's law to explain how changes to voltage & resistance affect current.

This activity was completed ________________________________ (*instructor signature*)

Overview: You will explore the properties of a simple electrical circuit are determined by Ohm's law.
Note: the simulation incorrectly shows faster-moving current with higher values. In reality, electron movement in conventional current is slow, around 0.01 cm/s. Higher current means more electrons are moving, not that they move faster.

Getting Ready: Navigate to the PhET Circuit Construction simulation.

Trial 1 Directions - *Carefully read the directions below* ***before*** *beginning. SEP: Planning & Carrying Out an Investigation*

1. Predict how current will change as resistance is changed: ________________________________

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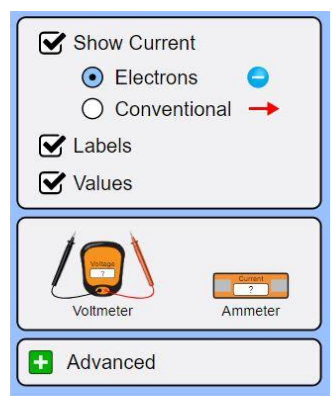
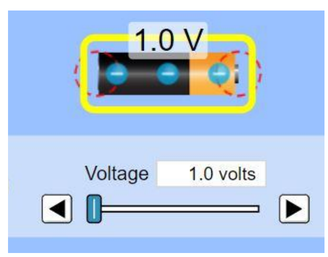
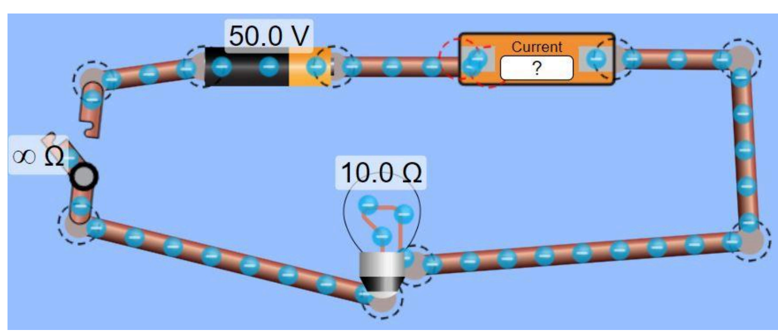
2. You will be using light bulbs, a battery, wires, and resistors to assemble a circuit as shown in this schematic diagram. Set the display to these values ⇒



3. Select and drag the battery from the left display onto the board.
4. With the battery selected, it should be outlined in yellow and it will display a voltage slide selector on the bottom of the screen. The default is 9V. Slide or type in 50 V.



5. Create a circuit by dragging a lightbulb, a switch, wires, and an ammeter onto the board. Arrange them similar to this example. Use the ammeter from the menu tabs on the right, connecting it in series with the circuit as in this diagram. Ignore negative values; they indicate the current direction.
6. Click the switch to close it and observe the displayed current values.



7. With the lightbulb at 10 Ω in the circuit with a 50V battery, record the current measurement in Results.
8. Repeat this by increasing the value of the light bulb's resistance. Click on the lightbulb to highlight it and slide the bar or type in the next value of resistance. Record your data in Results.

Trial 1 Results - *Record your data and show your work below. SEP: Analyzing & Interpreting Data*

Resistor Value (Ω)	10	20	30	40	50
Total Current (A)					

Summarize how current changes as resistance changes: ____

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Trial 2 Directions - *Carefully read the directions below <u>before</u> beginning. SEP: Planning & Carrying Out an Investigation*

1. Predict how current will change as voltage is changed: ________________________________

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2. Repeat the previous steps using a 100 Ω resistor. Change the voltage across the resistor to determine the electrical current through the resistor. Also note the relative bulb brightness at each voltage.
3. The switch should be open and the battery should be set to 1 V.
4. Close the switch, and record the current in the circuit in table 2.
5. Step up the voltage of the battery to the next voltage setting; repeat the above step. Increase each step.

Trial 2 Results - *Record your data and show your work below. SEP: Analyzing & Interpreting Data*

Voltage (Ω)	1				120
Total Current (A)					
Bulb Brightness					

Summarize how current changes as voltage changes: ____

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Post-Investigation Questions - *SEP: Evidence Based Arguments*

1. What happened to the current in the circuit as the resistance in the circuit increased? Was the change linear? Explain your answer.

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2. What happened to the current in the circuit as the voltage in the circuit increased? Was the change linear? Explain your answer.

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3. What relationship do you see between the current and volts used by the bulbs in the circuit to the brightness? Explain your answer.

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Part 3B Investigation: Play-Doh Resistivity Lab (4.3.3b)

Purpose: Investigate Play-Doh's conductivity to confirm how thickness (cross-sectional area) and the length of the conductor impact electrical resistance. **Materials:** small can of Play-Doh; multimeter; ruler; paperclips

Trial 1 Directions - *Carefully read the directions below before beginning.*
SEP: Planning & Carrying Out an Investigation

1. Roll out a uniform thickness of the whole can of Play-Doh. Form it into a 10 cm long cylinder, ensuring it's well-mixed to remove air bubbles and cracks. Record the cylinder's thickness.
2. Insert a paperclip on each end. Set the multimeter to Ohms and attach probes. Record resistance.
3. Mark 3 cm from one end. Cut the Play-Doh here, keeping the larger portion. Return the smaller piece to the container.
4. Roll the remaining Play-Doh for a smaller thickness but the same 10 cm length. Record the resistance using the steps above.
5. Repeat until the table is filled or no Play-Doh remains.

Trial 1 Results - *Record your data and show your work below.* *SEP: Analyzing & Interpreting Data*

Trial	1	2	3	4	5	6	7
Thickness (cm)							
Resistance (Ω)							

What is happening to the resistance of the Play-Doh cylinders as the cross-sectional area gets smaller?

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Trial 2 Directions - *Carefully read the directions below before beginning.*
SEP: Planning & Carrying Out an Investigation

1. Roll out a Play-Doh "wire" with a uniform thickness (about 2.5 cm, or 1 inch). Record the wire's length using a ruler.
2. Set the multimeter to Ohms, starting at 200 **Ω**. Measure the resistance by placing the probes on the wire ends. Adjust the Ohms setting if needed.
3. Cut the Play-Doh "wire" 5 cm from one end. Return the cut portion to the Play-Doh container.
4. Repeat these steps for the remaining wire until the data table is complete or the wire is finished.
5. Turn off the multimeter when done and calculate the resistance for each Play-Doh wire.

Trial 1 Results - *Record your data and show your work below.* *SEP: Analyzing & Interpreting Data*

Trial	1	2	3	4	5	6	7
Length (cm)							
Resistance (Ω)							

What is the relationship between the length of the conductor to the conductor's resistance?

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Why is it not a good idea to use really long extension cords or use multiple extension cords connected into each other when using electrical devices such as power tools?

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Why is it recommended to use a thicker gauge extension cord when using a cord longer than 50ft?

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Part 4A: Review & Assessment (4.3.4a)

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Step 1: Rank each Driving Question in Part 2 based on your comprehension (you can rank them as *1,2,3* or *green/yellow/red*, or any other method). Then work in teams to review anything that is still unclear.

Step 2: Identify any remaining areas of confusion or concern. Then review these topics with your instructor.

Step 3: Complete the Formative Assessment (*last page of the packet*). Your instructor will determine if you will work individually, in pairs, or in small groups. Then compare and evaluate your responses as a class.

Step 4: Individually complete a Mastery Check. If your performance indicates that additional support is needed, your instructor will determine how to help you move forward.

Part 4B: Calculations Practice (4.3.4b)

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Current = voltage/resistance   Voltage = current x resistance   Resistance = voltage/current   Power = Voltage x Current

Current = Amps (A)
Voltage = Volts (V)
Resistance = Ohms (Ω)

1. If your skin has a resistance of 100,000 ohms, and you touch a 9-volt battery, what current will flow through you?

2. What current will flow through you(resistance 100,000ohms) if you touch 120-volt house potential?

3. Soaked in seawater, your resistance is lowered to 100 ohms. Now how much current will flow through you if you touch a 9-volt battery?

4. Soaked in seawater, what current will flow through you if you touch the 120-volt house potential?

5. How much resistance is in a toaster that draws 5 amps of current when plugged into a 110-volt wall socket?

6. How much resistance is in a light bulb that draws 0.3 amps of current when attached to a 1.5-volt "D" battery?

7. What would be the resistance if you tried to run the 5 amp toaster off the 1.5V "D" battery?

8. What voltage is needed to run an electric iron drawing 5.5 amps of current through a circuit with a resistance of 20 ohms?

9. What voltage is needed to run a light bulb drawing 0.5 amps of current through a circuit with a resistance of 3 ohms?

10. What voltage is needed to run an immersion heater drawing 3.0 amps of current through a circuit with a resistance of 3 ohms?

11. If the Voltmeter reading is 12V, and the Ammeter reading is 3A, what is the resistance?

12. What is the value of the resistor if a current of 2A flows when 8V is applied?

13. How much current will flow through a 10 Ohm resistor when 30V is applied?

14. What voltage is required to cause a current of 0.5A to flow through a 10 Ohm resistor?

15. What are the units for power, resistance, current, and voltage?

16. How many volts does a wire have with a current of 5 amps and a resistance of 20 ohm's?

17. What is the current in wire that gives off 500 watts and has a voltage of 100 volts?

18. What is the resistance of if the voltage is 250 volts and the current is 2 amps?

19. How many watts of power are produced when a wire has a current of 10 amps and a voltage of 250 volts?

Part 5: Life Connections – Electric Car Efficiency (4.3.5)

Directions: For this activity, you will consider three claims about the cost of charging a Tesla electric vehicle as compared to an efficient non-hybrid vehicle like a Toyota Prius. Is "cost" directly related to a car's efficiency?

Overview: An average car drives 13,500 miles per year. A Tesla uses on average 295 Wh/mile in a warm climate - up to 132 MPGe. The recharge efficiency of a new Tesla is 90% and includes any parasite losses. The cost per kWh is $0.13/kWh. The Prius averages 50 mpg. The average cost of gas in the US is $3 per gallon. There is also an equivalent of 36.65 kWh in one gallon of gas.

Are electric vehicles more efficient than regular cars? Read each claim below carefully.
Nina: *"Electric vehicles are way more efficient than regular cars or hybrids because they only cost a few cents to drive per mile."*
Avery: *"Electric vehicles use electric motors that are close to 90% efficient compared to other cars that use gas and are around 30% efficient."*
Daryll: *"Electric vehicles have motors that are more efficient but the energy they get has to be transmitted over large distances and is mostly generated by burning fossil fuels, which is what a regular car burns."*

Who do you agree with and why? It's ok to pick more than one person. Explain your thinking.

I most agree with the following:______________________________because ______________________________

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Tesla cost:
13,500 miles x 295 Wh/mile = 3982500 Wh X 1kW/1000W = 3982.5 kWh x 1/0.90 = 4425 kWh x $0.13/kWh = $575.25 per year or $47.94 per month for the consumer. This reflects the energy required to run the electric vehicle. However, considering energy losses in transmission (17%), the actual efficiency is 83%. Coal-fired power plants, supplying most of our electricity, are 33% efficient, while gas-fueled turbine power plants reach 42%. Converting energy to an equivalent gas cost:
4425 kWh per year x 1/0.83 x 1/0.42 = 12,693.6 kWh needed per year / 36.65 kWh/gallon of gas = 346.3 gallons of gas per year or **$86.59 per month equivalent gas used to power an electric car.**

Prius Cost:
13,500 miles x 1/50 mpg = 270 gallons x $3/gallon = $810 per year or **$67.5 per month for the consumer.**
A car that averages at least 40 mpg:
13,500 miles x 1/40 mpg = 337.5gallons x $3/gallon = $1012.50 per year or **$84.38 per month for the consumer.**

1. **After looking at this data, what is more efficient, an electric car or internal combustion vehicle?**

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Electricity Packet 4.3 Formative Assessment (4.3.4)

Name: ____ Hour____ Date:__________ Score:________

Directions: A 3x5 notecard with *handwritten* notes can be used to guide your answers. Your instructor may allow you to work in assigned groups. If so, have a different person write each response while others assist.

1. **What is electrical current and where does it come from?** In your response, include and underline the following terms: *electrons, energy source, voltage*

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2. Three students shared their ideas about a battery. **Do you agree or disagree with each student's claim**?
   a. Mike: "Magnetic fields within the battery cause electrons to spin, generating the electromotive force that results in electric currents in the wire." Agree/ Disagree
   b. Lucia: "Wires connect opposite ends of a battery, each with a different electrical charge. This allows electrons to move through the wire." Agree / Disagree
   c. Oscar: "Electrical currents result from the friction that occurs as resistance increases within the wire, generating electrical energy." Agree / Disagree

   Which claim seems most accurate? __________________ **Why**? ________________________________

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3. **Summarize Ohm's Law - how do voltage and resistance determine current? Include the correct units of measurement for each aspect.**

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4. **Summarize four ways in which resistance in a conductor can be changed.**

5. **Lightbulbs are sold by their wattage. How do watts relate to voltage and current?**

6. **A) How is electricity generated by a power plant? B) What is the difference between AC and DC, and why is one used more often to transmit electricity to homes and businesses?**

