Microelectronics and Energy Transfer

Companion Lesson to X-STEM All Access Episode "Leveling up with Microelectronics"

Grade Band: Middle School-High School	**Topic:** Microelectronics and Energy Transfer

Brief Lesson Description: Students will explore energy transfer in circuits using hands-on and simulation activities.

Performance Expectation(s):

HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

MS-PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Specific Learning Outcomes:
Students will be able to

-capture interest by exploring the role of microelectronics in everyday devices.
-investigate how microelectronic components manage and store energy through hands-on activities.
-explain energy relationships in microelectronic systems and utilize computational modeling.
-apply their understanding of energy management in microelectronics to real-world problems.
-assess their understanding of energy transfer, potential energy, and computational modeling in microelectronics.

Narrative / Background Information

For the microelectronics 5E lesson plan, students need foundational knowledge in basic circuit concepts, including understanding components like resistors, capacitors, and power sources. They should be familiar with the principles of energy transfer, including the roles of potential and kinetic energy, as well as Ohm's Law to relate voltage, current, and resistance. An understanding of how energy is stored (in capacitors) and dissipated (in resistors) is important, as well as how microelectronics function in everyday devices such as smartphones or computers. Familiarity with basic computational tools, like spreadsheets or circuit simulation software, will also help students model energy relationships in circuits during the lesson.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Developing and Using Models Develop a model to describe unobservable mechanisms. (MS-PS3-2) **Using Mathematics and Computational Thinking** Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)	**PS3.A: Definitions of Energy** A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2) Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. There is a single quantity called energy due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-1) **PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) Energy cannot be created or destroyed, but it can be transported from one place to	**Systems and System Models** Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems. (MS-PS3-2) Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-1) **Connections to Nature of Science** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

	another and transferred between systems. (HS-PS3-1) Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) The availability of energy limits what can occur in any system. (HS-PS3-1) **PS3.C: Relationship Between Energy and Forces** When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)	

Possible Preconceptions/Misconceptions:

1. **Electricity is "used up" in a circuit**: Many students believe that electricity is consumed as it flows through a circuit, rather than understanding that energy is transferred or transformed (e.g., into light or heat), while the current itself remains constant in a closed circuit.
2. **Capacitors and batteries are the same**: Students often confuse capacitors with batteries, thinking both store energy in the same way. In reality, capacitors store energy temporarily and discharge quickly, while batteries provide a steady, long-term energy supply.
3. **Resistors stop the flow of current**: Some students may think that resistors block or completely stop current, rather than recognizing that resistors reduce the amount of current by converting electrical energy into heat.
4. **Higher voltage means more energy**: Students may equate voltage directly with energy, not realizing that voltage is the potential difference and energy transfer also depends on the current and resistance in the circuit (Ohm's Law).
5. **Energy is only transferred to visible components (like LEDs)**: Many students believe that energy is only used by obvious components (like LEDs) and fail to recognize that all components, including resistors and wires, contribute to energy transfer and dissipation in a circuit.

LESSON PLAN – 5-E Model

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

Start the lesson by showing the X-STEM Episode "Leveling Up with Microelectronics" featuring Dr. Korine Duval. After watching the video, discuss the following prompts as a class:

How do electronic components use energy?
Why are smaller electronic devices more efficient in energy consumption?

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:
Introduction to Energy in Circuits (5-10 minutes):

1. Start by reviewing the basics of circuits: how they allow energy to flow, how components like resistors and capacitors work, and the difference between potential and kinetic energy in a system

   Ask guiding questions:
   "What do you think happens to energy as it moves through a circuit?"
   "How might different components (e.g., capacitors, resistors) affect energy transfer?"

   Explain that students will explore these concepts by building circuits and using simulations to visualize energy transfer.

2. **Hands-On Circuit Building (20-25 minutes):**
   Group Formation: Divide students into small groups of 2-3, ensuring that each group has access to a breadboard, components, and a multimeter.

Activity Instructions:

Step 1: Build a basic series circuit using an LED, resistor, and battery.

Step 2: Use a multimeter to measure the voltage across different components (battery, resistor, LED) and record the data.

Step 3: Next, add a capacitor to the circuit and measure the voltage again after some time. Ask students to observe how the capacitor affects the behavior of the LED and the voltage across the circuit.

Discussion during Activity:
Encourage students to think about what happens to energy as it moves through the circuit. Ask them to hypothesize what the capacitor is doing with the energy (i.e., storing potential energy).

Ask questions like:
"What do you notice about the voltage readings before and after adding the capacitor?"
"How is the energy stored and transferred in this circuit?"

Troubleshooting Tips:
If students struggle with the setup, guide them to check connections on the breadboard or troubleshoot using the multimeter to find loose or incorrect wiring.

Encourage students to experiment with different resistances or capacitors to observe changes in energy behavior.

3. **Simulating Energy Transfer (20-25 minutes):**

Step 1: Once students have completed their physical circuits, transition to using a simulation tool (such as PhET Circuit Construction Kit or Tinkercad).

Step 2: In the simulation, students will build virtual circuits similar to their physical ones. They can visualize how energy (depicted as energy units or arrows) flows through the circuit in real time.

Guided Exploration:
Ask students to modify the circuit in the simulation by changing component values (resistance, capacitance) and adding new components (e.g., additional LEDs or resistors).

Students should observe and record how these changes affect the energy flow, voltage, and overall behavior of the circuit. Instruct them to track where energy is being stored (in capacitors) and how it moves (through resistors and LEDs).

Discussion Questions:
"What do you notice about energy flow when you change the resistor's value?"
"How does adding a capacitor affect the system's energy?"
"What do you think happens to the stored energy when the circuit is turned off or interrupted?"

4. **Discussion and Modeling (10-15 minutes):**

Bring the class together to discuss findings from both the physical circuits and simulations. Encourage students to share:

Observations about how energy is stored and transferred.
Differences between their physical circuits and the simulations.
Insights on how components like resistors and capacitors influence the energy in a circuit.

Develop a Model:
Ask students to draw a simple energy model of their circuit in their lab notebooks or on a handout. The model should include:
Energy input (from the battery).
Energy storage (capacitor).
Energy transfer (resistor and LED).

Students should label where potential and kinetic energy are found in the system and how the arrangement of components affects energy transfer.

EXPLAIN:

Start direct instruction by asking students to reflect on the following prompts:
How do microelectronic components manage energy?
How can we calculate energy flow in an electronic system?

Next, use the Lecture Slides "Energy Relationships and Computational Modeling in Microelectronics" to formalize student learning about the topic. Students should take notes in their notebooks during the lesson.

After the lecture, return to the original prompts and ask how their thinking has changed.

ELABORATE: Applications and Extensions:

1. **Introduction to Energy Efficiency in Microelectronics:**

   Begin by explaining the importance of energy efficiency in modern technology, such as mobile phones, laptops, and other battery-powered devices. Discuss why it's important to minimize energy loss in microelectronics, touching on environmental and practical aspects (e.g., longer battery life, reduced heat output).

   Use examples of cutting-edge technologies, such as energy-efficient microchips or low-power sensors, to demonstrate the application of these concepts.

2. **Task Assignment: Redesigning a Circuit for Energy Efficiency**

   Split students into small groups, and give each group a basic circuit design that they have already explored in the Explore phase. The circuit should have components like resistors, capacitors, and LEDs.Explain that their goal is to modify this circuit to make it more energy-efficient. They should consider:
   -Reducing power consumption by adjusting resistance and capacitance.
   -Minimizing energy loss (as heat or inefficiency in the circuit).
   -Optimizing the arrangement of components to store or transfer energy more efficiently.

3. **Design Process:**

   Brainstorming (10-15 minutes): Each group should discuss how they could redesign the circuit. Encourage them to think creatively but within the constraints of the physical components and the basic laws of energy (conservation of energy, potential vs. kinetic energy).

   Prototyping/Building the Circuit (20-30 minutes): Groups should modify their circuits, trying different configurations of resistors and capacitors to optimize energy flow and efficiency. They should measure and record voltage, current, and power consumption at different points in the circuit using multimeters.

4. **Calculating Energy Efficiency:**

   For High School Students: Instruct students to use their collected data to create a computational model. This could be done using a spreadsheet or programming language like Python. They should calculate:
   -Energy input (using voltage and current readings: P=VIP = VIP=VI).
   -Energy loss (e.g., how much is dissipated as heat via resistors).
   -Efficiency of their circuit (by comparing input energy to useful output energy).
   Students should use the formulas and data to predict how changes in the circuit (e.g., increasing resistance) will impact energy use.

   For Middle School Students: Students will create a conceptual model using diagrams to show how energy moves through their redesigned circuit. They should focus on:
   -Where energy is stored (e.g., in capacitors as potential energy).
   -How rearranging components impacts energy storage and transfer.
   -A comparison of the efficiency of their modified circuit to the original.

   They should label key points where energy is used or lost and explain how the arrangement of components affects this process.

5. **Real-World Applications Discussion and Reflection:**

   Ask students to relate their redesigned circuits to real-world applications. For example, in smartphones, how are circuits

designed to extend battery life? What trade-offs exist between performance and energy efficiency in microelectronics?

Highlight current trends in microelectronics, such as the development of low-power chips for wearable tech or energy-harvesting devices that capture small amounts of energy from the environment to power tiny electronics.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Throughout the lesson, formative assessment questions are found in ***bold italics*** and can be used to check student understanding throughout the lesson.

Summative Assessment (Quiz / Project / Report):
Each group presents their circuit design, explaining:
-How they modified the circuit to improve energy efficiency.
-The data they collected and the calculations they made (for high school).
-The energy model they developed, highlighting potential energy storage and transfer (for middle school).
-The real-world implications of their circuit redesign and what they learned about energy efficiency.

Use the Presentation Rubric to assess student presentations

Elaborate Further / Reflect: Enrichment:
Objective:
Students will apply their understanding of energy transfer and efficiency by analyzing real-world microelectronic devices to identify design choices that improve energy efficiency.

Research a Device:
Have students work in small groups to select a common electronic device (e.g., smartphones, laptops, or LED light bulbs). Each group should research how energy is managed in the device, focusing on components like microprocessors, capacitors, or power-saving features.

Identify Energy Efficiency Feature:
Students will identify and explain at least two design choices that improve energy efficiency in their chosen device. For example, they might focus on power-saving modes, energy-efficient components, or how heat is managed in the device.

CAREER CONNECTIONS

The global microelectronics market is anticipated to grow rapidly over the forecast timeline due to technological breakthroughs and the surging demand for electronic equipment. Ranging from Integrated Circuit Design Engineers to Semiconductor Engineers, there are many promising careers for students to pursue in the field of microelectronics.

To help students learn about this variety of careers, have them visit https://usasciencefestival.org/resources/ to access the Student Career Resources.

Select the Microelectronics Industry from the menu.

Have students browse the careers within your chosen cluster. Select one career that they would like to learn more about. They should then gather the following information using the student graphic organizer or in a class notebook:

- Job description and typical responsibilities
- Education and training required
- Skills and qualities needed
- Average Salary
- Work environment and schedule
- Professional Organizations, Educational Programs, and Internship & ApprenticeOpportunities

Choose a Choice Board Activity and use the information gathered to complete the chosen activity.

Career Interview Write a set of 5-7 questions you would ask someone in this career. Include the responses based on your research.	**Pros and Cons Chart** Make a T-chart listing at least five pros and five cons of the career based on your findings.	**Career Poster** Design a poster or infographic showcasing key details about the career (e.g., job tasks, salary, skills, and job outlook).

Provide students an opportunity to share their findings with peers or with you.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency Addressed: Self-Awareness and Self-Management

In the X-STEM Episode, Dr. Duval talks about loneliness in her field and ways that she sought connection with others. This SEL lesson will help your students to consider how this affects their own lives.

Start by asking, **"Has anyone ever felt lonely, even when surrounded by others?"**
Allow a few students to share their thoughts. Emphasize that loneliness is a common experience, but it's important to know how to manage it.

Clarify Loneliness: Explain that loneliness is a feeling of disconnection or isolation, not just being physically alone. Even people with many friends can feel lonely.

Have students take out their journals or notebooks. Ask them to reflect silently for 3 minutes on the following questions:
-When have I felt lonely?
-What do I think caused that feeling?
-What did I do to feel better, or what could I have done?

Share that loneliness is a signal that we need social connection, just like hunger tells us we need food. Feeling lonely doesn't mean there's something wrong with us—it's a human experience. Loneliness can be managed by taking specific actions to build connections or shift perspectives.

Write key points on the board:
- Recognize: Acknowledge the feeling without judgment.
- Reach Out: Talk to someone you trust, even if it's just for a quick chat.
- Take Care of Yourself: Engage in activities that make you feel good—exercise, hobbies, or volunteering.
- Challenge Negative Thoughts: Sometimes loneliness comes with negative self-talk. It's important to challenge those thoughts and remind yourself that you are worthy of connection.

Peer Conversation: Have students turn to a partner and discuss one action they can take the next time they feel lonely. Encourage positive, actionable ideas.
Wrap-up: Bring the class back together and ask a few volunteers to share what they discussed. End by reminding students that seeking help or reaching out when lonely is a strength, not a weakness.

INTERDISCIPLINARY CONNECTIONS/IDEAS

Art: Link the lesson to art by having students create visual representations of energy flow within microelectronic circuits. Using mixed media, they can illustrate how energy moves and is transformed in devices like smartphones or tablets. This could include diagrams or 3D models showcasing components such as capacitors, resistors, and power sources.

History: Use the Unit "Past, Present and Future of Microelectronics" from Scale K-12 for students to learn about the history and evolution of the microelectronics industry, the supply chain, and career connections.

Mathematics: Use the Unit "Let the Chips Fall" from Scale K-12 for students to calculate material use and make recommendations based on data.

Materials Required for This Lesson/Activity	
Quantity	**Description**
1 per group	Bread Boards and Electronics Components (Resistors, capacitors, LEDS, transistors, Jumper Wires, Battery)
1 per group	Multimeter for measuring voltage and Current
1 per group	Computer with access to circuit simulation software (such as PhET Circuit Construction Kit or Tinkercad).
1 per group (High School)	Computer with access to spreadsheet or programming environment
1 per group (Middle School)	Graph Paper for modeling

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