

National MagLab

STEM Lesson Plan:

Exploring Electric Motors (Elementary School)



Lesson Objectives: Student will be able to:

- investigate and understand the functioning of electric motors by creating a simple motor using basic materials.
- Identify electric current, magnetic field, and force.

Next Generation Science Standard:

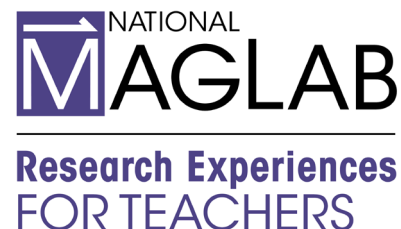
- SC.4.P.8.4: Investigate and describe magnetism, including attraction, repulsion, and magnet interactions.
- SC.912.P.10.16: Explain the relationship between moving charges and magnetic fields, and changing magnetic fields and electric fields.
- SC.912.P.10.17: Explore electromagnetism, explaining electromagnetic waves in terms of oscillating electric and magnetic fields.
- SC.912.P.10.15: Investigate and explain relationships among current, voltage, resistance, and power.

STEM RATIONALE FOR LESSON:

By emphasizing the importance of electric motors, this lesson not only enhances students' understanding of a key technology but also prepares them to engage thoughtfully with the scientific and technological challenges they will face in the future.

- **Fundamental Technology:** Electric motors are foundational to modern technology, powering countless devices and systems that shape our daily lives. From household appliances like fans and refrigerators to industrial machinery and electric vehicles, understanding how electric motors work is essential for grasping the technological landscape we inhabit.
- **Interdisciplinary Connections:** The study of electric motors incorporates principles from various fields, including physics, engineering, and environmental science. This interdisciplinary approach enables students to see the connections between different subjects and encourages critical thinking as they analyze how electric motors function and their implications for technology and society.
- **Sustainability and Environmental Awareness:** As society moves toward more sustainable practices, electric motors play a crucial role in reducing our carbon

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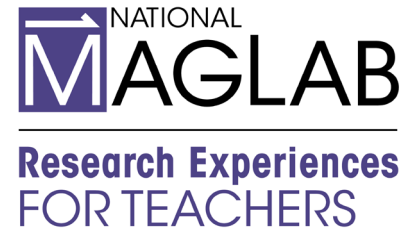
footprint. By discussing electric motors, students can explore their benefits compared to traditional combustion engines, including energy efficiency and reduced emissions. This awareness fosters a sense of responsibility toward environmental stewardship and encourages students to think about the impact of technology on the planet.

- **Career and Technical Education:** Knowledge of electric motors is vital for students considering careers in engineering, technology, robotics, and renewable energy. By understanding the principles behind electric motors, students gain insight into potential career paths and the skills needed to excel in these fields. This lesson can spark interest in pursuing further education and training in STEM (Science, Technology, Engineering, and Mathematics).
- **Innovation and Future Technologies:** Electric motors are at the forefront of innovation, particularly in the context of advancements such as electric vehicles, robotics, and automation. By understanding the importance of electric motors, students can engage with current trends in technology and consider how they might contribute to future innovations. This lesson encourages creativity and problem-solving, essential skills for the challenges of tomorrow.
- **Hands-On Learning Opportunities:** Teaching about electric motors allows for engaging, hands-on learning experiences. Students can conduct experiments, build simple motors, and explore real-world applications, making the learning process dynamic and interactive. This approach enhances student engagement and retention of knowledge.
- **Critical Thinking and Problem Solving:** Understanding electric motors provides students with a platform for developing critical thinking and problem-solving skills. They can analyze motor designs, troubleshoot issues, and understand the implications of motor technology in various contexts. This analytical mindset is invaluable in all areas of life and work.

Culturally Responsive Connection:

Students will gain an awareness of the importance of diversifying the arts to include and embrace the talents and uniqueness of all nationalities and genders. They will come to understand the significant impact that representation in the arts has on youth and others, inspiring individuals to see themselves reflected in creative spaces and encouraging broader participation. Additionally, students will comprehend the need

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for diversity in STEM fields, recognizing and appreciating the valuable knowledge, skills, and perspectives that people from diverse backgrounds contribute to advancing science, technology, engineering, and mathematics.

Time:

- Day: 1-3 Research identify minorities in ballet and create presentations.
- Day: 4 Student Presentations
- Day: 5 STEM Activity
- Each day's activities can take 30-40 minutes.

Materials needed (for each group):

- 3 AAA batteries
- 2 AA batteries
- 1 C battery
- 1 D battery
- 4 pieces #20 Copper magnet wire (8 inches each)
- 8 Paper clips
- 4 Rubber bands
- 4 Disc magnets
- Sandpaper

Previous Knowledge:

1. Begin by introducing the four essential parts of an electric motor, which include:
 - Stator: The stationary part of the motor that generates a magnetic field. It typically consists of coils of wire or permanent magnets.
 - Rotor: The rotating component that is situated within the magnetic field created by the stator. The rotor is connected to the output shaft and is responsible for producing mechanical energy.
 - Commutator: A device that reverses the direction of current flow in the rotor windings. This action is crucial for maintaining the rotor's rotation and preventing it from stopping.

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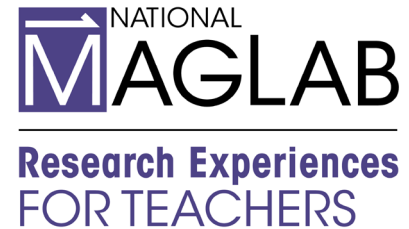


- **Power Source:** The energy supply, usually in the form of electricity, that powers the motor and enables it to operate.
2. After outlining these components, facilitate a discussion on the key distinctions between electric motors and vehicle motors (such as internal combustion engines). Highlight the following points:
 - **Energy Source:** Electric motors rely on electrical energy, while vehicle motors primarily use fuel combustion to generate power.
 - **Efficiency:** Electric motors are generally more efficient than vehicle motors, converting a higher percentage of energy into usable mechanical power.
 - **Environmental Impact:** Electric motors produce no emissions during operation, whereas traditional vehicle motors contribute to air pollution and greenhouse gas emissions.
 - **Maintenance:** Electric motors typically require less maintenance compared to vehicle motors due to fewer moving parts and the absence of complex fuel systems.
 3. Next, emphasize the pivotal role of magnets in the operation of electric motors. Explain that magnets are integral to creating the magnetic fields necessary for the motor's function. Without magnets, the interaction between the stator and rotor would not occur, preventing the conversion of electrical energy into mechanical motion. Discuss how the principles of electromagnetism enable electric motors to operate and provide examples of various applications where electric motors and their magnetic components are utilized, such as in household appliances, industrial machinery, and electric vehicles. This comprehensive overview will help students appreciate the significance of electric motors and the fundamental role magnets play in their operation.

Procedures:

1. **Wind the Magnet Wire:** Begin by carefully winding magnet wire around each battery, ensuring to leave tails of approximately 3-5 cm on each end. This will create a coil that will act as the armature of your motor.
2. **Form the Circular Shape:** Gently remove the winds from the battery and rewrap the tails around the opposite sides of the coil to form a circular shape. Ensure

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that the coil maintains a consistent form as this is crucial for the motor's functionality.

3. **Prepare the Wire Ends:** Using sandpaper, carefully remove the insulation from one tail of the wire and the top half of the opposite tail. This step is essential as it allows for proper electrical conductivity, enabling the flow of current through the coil.
4. **Create the Armature:** Straighten out the tails of the wire to create an armature and place it flat on the table. Ensure that the armature is balanced and ready to be suspended, as this will affect its ability to spin freely.
5. **Construct Supports from Paperclips:** Unfold and bend two paperclips into supports that will hold the armature above the battery and magnet assembly. These supports should be sturdy enough to suspend the armature while allowing it to rotate freely.
6. **Attach Paperclips with Rubber Bands:** Use rubber bands to securely attach one paperclip to each end of the battery, connecting to both the positive (+) and negative (-) terminals. This will help stabilize the setup and ensure that the armature can spin without obstruction.
7. **Position the Magnet:** Place a strong magnet on top of the battery, situated between the paperclip supports. Make sure that the magnet is positioned correctly to ensure attraction, which is critical for the motor's operation.
8. **Install the Armature:** Finally, carefully set the armature into the supports, allowing it to spin freely. Adjust the position if necessary to ensure that the armature has enough clearance to rotate without interference from the magnet or battery.

By following these enhanced steps, students will create a simple yet effective electric motor, gaining hands-on experience with the principles of electromagnetism and mechanical motion.

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Conclusion: Discussion on Armature Function and Continuous Motion in Electric Motors

During the demonstration, engage students in a discussion about the functionality of the armature and its interaction with the supports. Explain that when the bare parts of the armature make contact with the paperclip supports, they complete an electrical circuit. This contact allows current to flow through the wire, creating a magnetic field around the armature. As a result, the armature behaves like an electromagnet, generating a magnetic field that interacts with the fixed magnet above it, which causes the armature to rotate.

Emphasize that this rotation is a critical aspect of continuous motion in electric motors. As the armature turns, the insulated part of the wire comes into contact with the supports, breaking the circuit and stopping the flow of current. This interruption causes the magnetic field to collapse, momentarily halting the armature's movement. However, as the armature rotates further, the bare part re-establishes contact with the supports, allowing current to flow again and creating a magnetic field that re-engages the motion. This cycle of energizing and de-energizing is what sustains the continuous rotation of the armature.

Encourage students to hypothesize about how changing the type of battery could impact the performance of their motor. For example, ask them to consider the following questions:

- **Voltage Variations:** How might using a higher or lower voltage battery affect the speed and strength of the motor's rotation? Would a higher voltage increase the current and result in a more powerful magnetic field?
- **Battery Chemistry:** What differences might arise from using alkaline batteries compared to rechargeable batteries? How could the discharge rate and overall lifespan of the battery impact the motor's operation?
- **Battery Size:** How might the size or capacity of the battery affect the motor's performance? Would a larger battery provide longer run time or more consistent power output?

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By fostering these discussions and hypotheses, students can deepen their understanding of electromagnetism and the practical applications of electric motors. This inquiry-driven approach encourages critical thinking and scientific reasoning, allowing students to explore the underlying principles of electricity and magnetism in a hands-on context.

Differentiation Strategies for Electric Motors Lesson:

1. Whole Group Instruction:

- Utilize a range of visual aids, such as diagrams, images, and videos, to enhance explanations and facilitate comprehension of electric motor concepts.
- Provide clear, concise, and structured verbal instructions to ensure all students understand the lesson's objectives and procedures.
- Foster an interactive classroom environment by encouraging class discussions and peer interactions, allowing students to ask questions, share insights, and collaborate on understanding the material.

2. Small Groups (English Language Learners - ELL):

- Assign each group a language buddy who is proficient in both English and the students' native language, providing a supportive bridge for effective communication and understanding.
- Provide translated written instructions for the experiment to ensure clarity and accessibility for ELL students, allowing them to follow along more easily.
- Incorporate hands-on materials and manipulatives to reinforce concepts through tactile learning, enhancing their understanding of electric motors.
- Encourage students to discuss their findings in both their native language and English, promoting bilingual engagement and helping them build confidence in their language skills.

3. Small Groups (Exceptional Student Education - ESE):

- Offer additional support through a teacher's assistant or a peer tutor within each small group to provide personalized guidance and assistance.
- Adjust the complexity of the experiment based on individual students' needs and abilities, ensuring that all students can participate meaningfully.

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- Allow extra time for completion and comprehension, accommodating individual pacing to support diverse learning speeds and styles.
- Incorporate sensory elements, such as textures, colors, and sounds, to engage students with various learning preferences and enhance their overall experience.

4. Whole Group and Small Groups (General Strategies):

- Incorporate brief check-ins throughout the lesson to assess understanding, clarify concepts, and address any questions or concerns that may arise.
- Promote collaborative learning environments where students can share insights, support one another, and engage in peer teaching, fostering a sense of community.
- Use a variety of instructional modalities—visual, auditory, and kinesthetic—to cater to different learning preferences and enhance engagement across the classroom.
- Provide additional challenges or extensions for students who grasp the concepts quickly, allowing them to explore more complex applications of electric motor technology.

5. Visual Supports (For All Students):

- Display step-by-step instructions on a visual chart or slides for both whole group and small group activities, ensuring that all students can follow along easily.
- Include labeled diagrams that highlight key components of the experiment and illustrate the relationships between those components.
- Utilize color-coded materials or markers to emphasize different steps in the process, helping students visualize and differentiate between the various tasks involved.

6. Multimodal Learning Opportunities (For All Students):

- Integrate engaging videos or animations that demonstrate the principles of electric motors, providing visual context and enhancing understanding of dynamic processes.
- Offer written instructions alongside verbal explanations, catering to diverse learning styles and reinforcing comprehension through multiple formats.

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- Allow students to express their understanding through creative outlets, such as drawing, writing, or building models, accommodating various communication styles and preferences.

7. Assessments:

- Implement varied assessment methods, such as verbal explanations, written reflections, or visual representations (drawings), to gauge understanding and knowledge retention effectively.
- Offer flexible assessment options, allowing students to choose the mode that best showcases their comprehension, fostering a sense of ownership over their learning.

By incorporating these differentiation strategies, the lesson can be effectively tailored to meet the diverse needs of English Language Learners (ELL), Exceptional Student Education (ESE) students, and the general student population. This approach not only enhances accessibility and engagement but also promotes an inclusive learning environment where all students can thrive and succeed.

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Electric Motors Lesson Grading Rubric:

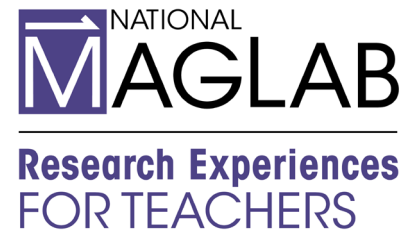
Criteria	Excellent (4)	Proficient (3)	Basic (2)	Limited (1)
Understanding of Electric Motors	Demonstrates a thorough understanding of the electric motor principles, accurately explaining the role of each component and the interaction between magnetism and electricity.	Shows a solid understanding of electric motor concepts, accurately describing most components and their functions.	Displays a basic understanding of electric motor principles but may struggle with clarity or detail.	Exhibits minimal understanding of electric motor concepts, with significant gaps in knowledge.
Experimental Procedure	Successfully follows the experimental procedure, demonstrating precision in winding magnet wire, assembling components, and adjusting variables.	Mostly follows the experimental procedure, with minor deviations. Shows competence in assembling components and adjusting variables.	Follows the experimental procedure but may struggle with precision in winding magnet wire or assembling components. Some confusion with adjusting variables.	Struggles to follow the experimental procedure, resulting in significant errors or omissions. Poor precision in assembly and adjusting variables.
Data Collection and Observation	Records detailed and accurate observations throughout the experiment, noting key moments and changes in the motor's behavior.	Records clear and relevant observations, capturing most key moments and changes in the motor's behavior.	Provides basic observations but may lack detail or miss some important aspects of the motor's behavior.	Fails to adequately record observations, missing key moments and changes in the motor's behavior.
Analysis and Explanation	Provides insightful and thorough explanations of the observed phenomena, connecting the experimental results to the principles of electromagnetism and magnetic fields.	Offers clear explanations of observed phenomena, making connections to electromagnetism and magnetic fields.	Provides basic explanations of observed phenomena but may lack depth or miss some connections to electromagnetism.	Offers limited or unclear explanations of observed phenomena, with little connection to electromagnetism.

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Hypothesis and Variable Exploration	Formulates a detailed and well-supported hypothesis regarding the impact of changing battery types on the experiment's results. Explores variables systematically.	Formulates a reasonable hypothesis regarding the impact of changing battery types. Explores variables in a logical manner.	Formulates a basic hypothesis but may lack detail or clarity. Explores variables inconsistently.	Formulates a limited or unclear hypothesis. Shows minimal exploration of variables.
Communication Skills	Effectively communicates ideas using precise scientific language. Participates actively in discussions, demonstrating a strong grasp of concepts.	Communicates ideas clearly using scientific language. Participates adequately in discussions, showing a solid understanding of concepts.	Communicates ideas using basic scientific language. Participation in discussions may be limited or less clear.	Communication is unclear or limited, struggling to express ideas using scientific language. Participation in discussions is minimal.
Collaboration in Small Groups	Collaborates exceptionally well within the small group, contributing effectively to the experiment and discussions.	Collaborates well within the small group, contributing positively to the experiment and discussions.	Collaborates adequately within the small group, with some positive contributions to the experiment and discussions.	Struggles to collaborate within the small group, with limited or negative contributions to the experiment and discussions.
Adherence to Safety Procedures	Consistently follows safety procedures, demonstrating a strong awareness of potential risks and taking appropriate precautions.	Mostly follows safety procedures, with minor lapses in awareness or precautions.	Follows safety procedures but may exhibit occasional lapses in awareness or precautions.	Demonstrates a lack of awareness of safety procedures, posing potential risks to themselves or others.
Overall Presentation and Organization	Presents work neatly, with a well-organized layout and clear labeling of materials.	Presents work in an organized manner, with adequate layout and labeling of materials.	Presents work with some organization, but layout and labeling may be unclear.	Presents work in a disorganized manner, with unclear layout and labeling.
Creativity and Critical Thinking	Demonstrates creativity in exploring variables and thinking	Shows creativity in exploring variables and some critical thinking about	Displays limited creativity in exploring variables and may struggle	Lacks creativity in exploring variables and demonstrates minimal critical

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critically about the connections between magnetics and electricity.	connections between magnetics and electricity.	with critical thinking about connections between magnetics and electricity.	thinking about connections between magnetics and electricity.
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Appendix:

Additional Resources and References

1. National MagLab - Electric Motors Lesson (<https://nationalmaglab.org/magnet-academy/plan-a-lesson/electric-motors/>)
2. National MagLab – Electromagnets virtual visit (https://youtu.be/YJPGtqujvec?si=9qQiHIRzyC3_f2kA)

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