Engineering, Electricity, and Magnetism

Electric Motor

link™
CPO Science

Real Investigations in
Science and Engineering

Overview Chart for Investigations–Electric Motor

	Investigation	Key Question	Summary	Learning Goals	Vocabulary
A1	**Magnets** Pages 1–6 50 minutes	What happens when you put two magnets next to each other?	Students observe attractive and repulsive forces between a pair of magnets. They discover that opposite poles attract and like poles repel. Then, they measure the distance over which a magnetic force can occur.	• Predict whether two magnets will attract or repel given their alignment. • Identify properties of magnetic materials and use interactions between magnets to explain attraction and repulsion. • Measure the distance at which magnets attract and repel each other.	magnetic magnetic field magnetic force magnetic pole permanent magnet
A2	**Magnetic Materials** Pages 7–14 50 minutes	What kinds of materials are affected by magnets?	Students experiment with different objects to identify the difference between magnetic and non-magnetic materials. Students then place nonmagnetic materials in between two magnets to determine whether the materials affect the force of the magnet.	• List examples of materials that are and are not affected by magnets. • Measure the distance over which a magnetic field acts on magnetic objects. • Describe the effect of non-magnetic materials on magnetic forces.	magnetic magnetic field magnetic force
A3	**How a Motor Works** Pages 15–22 50 minutes	How does a motor work?	Students learn about the parts of an electric motor and construct a working motor. They learn how permanent magnets and an electromagnet work together to cause a motor to spin. They learn that they can control the direction of spin by changing the orientation of the magnets.	• Construct a working motor. • Use an electromagnet and explain how it reverses its north and south poles. • Determine the direction a motor will spin given the orientation of its magnets.	commutator electric motor electromagnet permanent magnet rotor
A4	**Basic Electric Motor Design** Pages 23–28 100 minutes	How do you design a motor?	Students apply what they have learned about how a motor works to design different motors. They must determine the best placement of magnets to make the motor run for each of the switching disks (also called commutator disks). More than one design works for each disk, so they must decide which design works best.	• Determine the proper placement of permanent magnets to make a motor run with each of the switching disks. • Evaluate motor designs to pair each with a given commutator disk.	commutator electric motor electromagnet permanent magnet rotor
A5	**Measuring Current and Voltage** Pages 29–34 50 minutes	How do you use a digital multimeter to measure current and voltage in the electric motor?	Students use the digital multimeter to measure the current and voltage used by the motor. Students discover how current and voltage change when the motor is running or when it has stopped.	• Use a digital multimeter to measure current. • Use a digital multimeter to measure voltage. • Examine the voltage and current of the electric motor under load and no load conditions.	electric current multimeter voltage

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A6	**Generating Electricity** Pages 35–40 50 minutes	How do we generate electrical energy?	Students learn how moving magnets can be used to create electricity by building and testing an electric generator. They discover that the amount of electricity generated is proportional to the speed at which the magnets alternate back and forth from north to south.	• Assemble an electric generator. • Explain how an electric generator works. • Measure the voltage produced by a generator.	electromagnet electromagnetic induction generator
B1	**Permanent Magnets** Pages 41–48 50–100 minutes	What effects do magnets have?	Students explore how magnets affect each other and discover which materials are attracted to magnets. They will explore quantitatively how far the magnetic force reaches. They also learn about precision in making measurements and calculating averages.	• Describe the properties of a permanent magnet. • Describe and measure the forces that magnets exert on other magnets. • Describe the magnetic field.	magnetic magnetic field magnetic force permanent magnet
B2	**Electromagnets** Pages 49–56 100 minutes	Can electric current create a magnet?	Students explore the properties of electromagnets. Students build a simple electromagnet using wire and a nail. They locate the north and south poles as a function of the direction of current flowing in the electromagnet. Next, students measure the strength of the electromagnet with different amounts of current.	• Build an electromagnet. • Analyze how electric current affects the strength of the magnetic field in an electromagnet. • Compare permanent magnets and electromagnets.	electromagnet right-hand rule
B3	**Earth's Magnetic Field** Pages 57–64 50 minutes	How do we use Earth's magnetic field to tell direction?	Students use a compass to explore the magnetic field of Earth. They observe how the magnetized needle of a compass aligns with the north-south orientation of Earth's magnetic field. Students research the magnetic declination in their area. Students also investigate how materials containing iron can shield out the magnetic field of Earth.	• Properly use a compass and explain how it works. • Describe how magnetic declination affects a compass. • Identify materials that will affect a compass magnetically.	compass magnetic declination
B4	**Designing Electric Motors** Pages 65–72 100 minutes	How does an electric motor work?	Students learn how reversing magnet polarity causes an electric motor to turn. They build an electric motor and measure its speed, and then design and test several different motors using the switching disks (also called commutator disks). The speed of the motor as measured in revolutions per minute (rpm) is introduced as a way to gauge the quality of the motor.	• Build a working electric motor and measure its speed. • Demonstrate how electromagnets and permanent magnets interact to make an electric motor work. • Design different motors and evaluate them for speed.	commutator electric motor electromagnet permanent magnet rotor

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B5	**Current, Voltage, and Power** Pages 73–80 50–100 minutes	How much electricity does a motor use?	Students use a digital multimeter to measure the current and voltage used by the motor when it is spinning and when it is held in place. They construct several different motor designs with varying numbers of permanent magnets and an electromagnet. Then, they calculate and compare the power consumed by the motor for each design.	• Use the digital multimeter to measure current and voltage. • Calculate power when given voltage and current. • Determine the relationship between the number of permanent magnets in a motor and the power used by the motor. • Calculate the difference in power used by a motor when it is spinning as compared to when it is under load.	ampere (A) electric current electrical power volt (V) voltage watt (W)
B6	**Generators** Pages 81–88 50–100 minutes	How does a generator work?	Students learn how moving magnets can be used to create electricity by building and testing an electric generator. Then, by changing the design and speed of the generator, students learn about the principle of electromagnetic induction.	• Assemble an electric generator. • Explain how an electric generator works. • Measure voltage produced by a generator. • Determine the relationship between voltage, number of permanent magnets, and speed.	electromagnetic induction generator
B7	**More Motor Designs** Pages 89–96 50 minutes	Can you create a motor configuration that spins at a specific rate?	Students practice following the engineering cycle by building a motor design to solve a specific engineering problem. They will have to use the scientific concepts of electricity and magnetism to solve specific problems involving electric motors.	• Design an electric motor to meet specific speed criteria. • Build an electric motor and measure its speed. • Test and evaluate a motor to see if it meets the speed criteria.	constraint engineer engineering cycle prototype technology
C1	**Magnetism and Electric Motors** Pages 97–106 100–150 minutes	How much electricity does the motor use?	Students gain familiarity with the electric motor. They first learn how to construct different motor designs with varying numbers of permanent magnets and an electromagnet. Then, they use a digital multimeter to measure the current and voltage used by the motor when it is spinning and when it is held in place.	• Design different electric motors. • Use the digital multimeter to measure current and voltage. • Calculate power when given voltage and current. • Observe the relationship between the number of magnets and electromagnets in a motor and the power used by the motor. • Observe the difference in power used by a motor when it is spinning as compared to when it is held in place.	commutator electric motor electromagnet permanent magnet polarity rotor

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C2	**Optimizing Performance** Pages 107–114 100 minutes	How can the performance of the motor be optimized?	Students will experiment with different alignments of the disk to optimize the motor's performance. They also add a second electromagnet, and compare the motor's speed with one electromagnet to its speed with two.	• Build an electric motor. • Investigate the effect of the switch angle of the disk on the speed of the motor. • Discover how the speed of the motor is affected by the addition of a second electromagnet.	commutator electric motor electromagnet permanent magnet polarity rotor stator frequency rotation speed
C3	**Generators and Faraday's Law** Pages 115–124 50–100 minutes	How does a generator use induction to produce voltage?	Students use a generator to learn how moving magnets can be used to create electricity. By changing the design and speed of the generator, students discover the principle of electromagnetic induction.	• Assemble an electric generator. • Explain how an electric generator works. • Measure the voltage produced by a generator. • Determine the relationship between voltage, number of permanent magnets, orientation of the magnets, and speed. • Use Faraday's law of induction to explain how a generator works.	electromagnetic induction Faraday's law of induction magnetic flux

Next Generation Science Standards Correlation

CPO Science *Link* investigations are designed for successful implementation of the Next Generation Science Standards. The following chart shows the NGSS Performance Expectations and dimensions that align to the investigations in this title.

NGSS Performance Expectations	Electric Motor Investigations
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	A4
MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.	A3, A4, A5, A6
MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	A1, A2
HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	B4, B5, B6, B7, C1, C2, C3
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.	B1, B2, B3

NGSS Science and Engineering Practices	Electric Motor Investigations
Analyzing and Interpreting Data	A4
Asking Questions and Defining Problems	A3, A4, A5, A6
Developing and Using Models	B1, B2, B3
Influence of Science, Engineering, and Technology on Society and the Natural World	B4, B7
Planning and Carrying Out Investigations	A1, A2, B4, B5, B6, B7, C1, C2, C3

NGSS Disciplinary Core Ideas	Electric Motor Investigations
ETS1.C: Optimizing the Design Solution	A4
PS2.B: Types of Interactions	A1, A2, A3, A4, A5, A6, B4, B5, B6, B7, C1, C2, C3
PS3.A: Definitions of Energy	B4, B5, B6, B7, C1, C2, C3
PS3.C: Relationship Between Energy and Forces	B1, B2, B3

NGSS Crosscutting Concepts	Electric Motor Investigations
Cause and Effect	A1, A2, A3, A4, A5, A6, B1, B2, B3, B4, B5, B6, B7, C1, C2, C3

Common Core State Standards Correlation

CCSS-Mathematics		Electric Motor Investigations
MP.2	Reason abstractly and quantitatively.	A2, A4, A5, B1, B2, B3
MP.4	Model with mathematics.	A6, B1, B2, B3
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.	B4, B5, B6, B7, C1, C2, C3
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling.	B4, B5, B6, B7, C1, C2, C3
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	B4, B5, B6, B7, C1, C2, C3

CCSS-English Language Arts & Literacy		Electric Motor Investigations
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.	B1, B2, B3
RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.)	A3, A4, A5, A6
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	A1, A2
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	A1, A2
WHST.9-12.7	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.	B1, B2, B3
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research.	B1, B2, B3
WHST.11-12.7	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.	B4, B5, B6, B7, C1, C2, C3
WHST.11-12.8	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 specific 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.	B1, B2, B3, B4, B5, B6, B7, C1, C2, C3
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research.	B4, B5, B6, B7, C1, C2, C3