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Focus on what matters.

Transforming Energy

UNIT 8

Lab Manual

Front Cover:

The front cover shows wind turbines that are part of a wind farm. Wind turbines transform energy from one form to another to do work.

Unit 8: Transforming Energy

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<u>Section 1</u>: Magnetic Forces

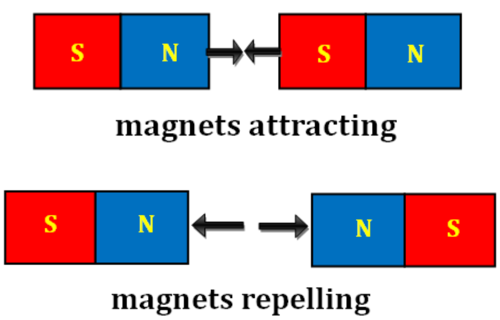
Navigating by Earth's Magnetic Field

Dolphins navigate using Earth's magnetic field.

Dorothee Kremers is a scientist. She and a team of scientists were curious if bottle-nosed dolphins are able to sense magnets. **Magnets** are objects that produce a magnetic field. A **magnetic field** is the invisible area around a magnet that attracts or repels other magnets and magnetic materials such as iron.

Earth – A Giant Magnet

The reason scientists care about animals' ability to sense magnetic fields is that Earth itself is a giant magnet. It has a magnetic field that is created in Earth's liquid iron core and extends far into space. Scientists believe animals such as dolphins, sea turtles, bats, spiny lobsters, and many insects navigate from place to place using Earth's magnetic field.

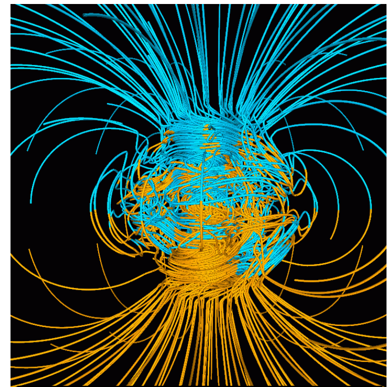


how magnets interact

Understanding how Earth's magnetic field could help animals navigate begins with the basic rules of magnetism. Magnets exert a force on other magnets or magnetic materials. A force is a push or pull that acts on an object, changing its speed, direction, or shape. Magnets either repel or attract other magnets or magnetic materials. To **repel** means to push away. To **attract** means to pull toward.

All magnets, including Earth itself, have a north pole and a south pole. (Earth's magnetic north pole is actually near the South Pole, while its magnetic south pole is near the North Pole.) The north pole of one magnet always attracts the south pole of another. However, two north poles will always repel each other. Two south poles will also repel each other.

Magnetic Fields



Earth's magnetic field

One hypothesis about how animals navigate using Earth's magnetic field is that they have tiny magnetic particles in their cells that react with Earth's magnetic field, somehow signaling the nervous system in a way that guides the animals as they travel around the planet.

However, scientists cannot say for sure how animals use Earth's magnetic field. The scientists who studied dolphins focused on one part of this question: Can dolphins sense magnets?

Dolphins Sense Magnets

Dorothee and her team set up an experiment with six dolphins. They set up two different kinds of barrels. One kind of barrel was made of a magnetic material. The other kind of barrel had an identical shape and density, but it was demagnetized. The scientists then videoed how the dolphins interacted with the different barrels. Their experiment showed that the dolphins swam toward the magnetized block much faster than they swam toward the demagnetized block.

The scientists still don't know exactly how animals can sense magnetic fields. But they believe that animals in the ocean may benefit from having a magnetic sense that detects Earth's magnetic field. This is because the ocean is vast, with few landmarks that animals can use to mark their path. "Inside the ocean, the magnetic field would be a very good cue to navigate," Dorothee said in a 2014 interview with *Live Science*.

The experiment didn't tell scientists that dolphins could sense Earth's magnetic field. This is because the magnets used by the scientists had a much stronger magnetic field than Earth's own magnetic field. More research needs to be done to explore whether dolphins can sense Earth's weaker magnetic field, and if this is how dolphins navigate.

How People Use Magnets

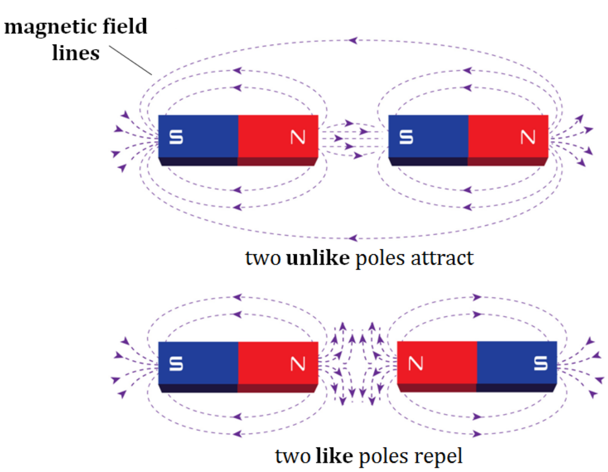
A compass's magnetic north pole points toward Earth's internal magnetic south pole (near the geographic North Pole).

People can also use Earth's magnetic field to navigate with the help of a compass. A compass is an instrument that aligns with Earth's magnetic poles. The red tip of the compass needle is a magnetic north pole. Because north poles are attracted to south poles, the red tip always points toward Earth's internal magnetic south pole (near the geographic North Pole).

Why Magnets Are Useful

In addition to compasses, there are many other ways that magnets are used in everyday life. Vacuum cleaners and music speakers use magnets to do work. Strong magnets on cranes can be used to pick up and move objects made of iron, such as junkyard cars.

One of the reasons that magnets are so useful is that they can attract or repel other magnets or magnetic materials without touching them. Whenever a magnet or a magnetic material is within another magnet's magnetic field, the field exerts a force that either attracts or repels the magnet or magnetic material.



Imagine you have two magnets. When they are within each other's magnetic fields, they form a system because they interact with one another by exerting a force on each other. For example, if you orient the magnets so that their like poles face one another, they will repel each other.

When two magnets interact, they form a system.

Relationship Between Forces and Energy

Now imagine that you push those repelling magnets toward each other. You have to use mechanical energy to move them together. Mechanical energy is the energy of a substance or system due to its motion. As you push the repelling magnets together, you apply a force to the system that transfers the energy from your hands into the system. In other words, your pushing force provides an input of mechanical energy into the system.

That input of mechanical energy is stored in the system as potential energy. You can see evidence of this potential energy when you let go of the two repelling magnets. They will move apart from one another. The potential energy stored in the system has been changed back into mechanical energy.

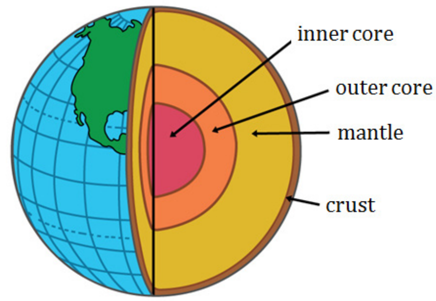
If you change the distance between the interacting magnets, you change how much energy is transferred into the system. For example, the closer you push two repelling magnets together, the more energy you need to use. This means more energy is transferred into and stored within the system. This will cause the magnets to move farther apart when you release them.

Conservation of Energy

In a perfect system, the total amount of energy is always conserved as it changes from one form to another. In other words, however much potential energy the system of interacting magnets has, that same amount of energy will change into mechanical energy as the magnets are released and move away from one another. However, in the real world, some of that energy is transferred out of the system. When energy is transferred, it moves into or out of an object or system. For example, if the magnets are on the ground, friction will transfer some of the energy out of the system. Friction is a force that slows motion whenever two objects rub against each other by turning mechanical energy into heat.

Earth's Magnetic Field

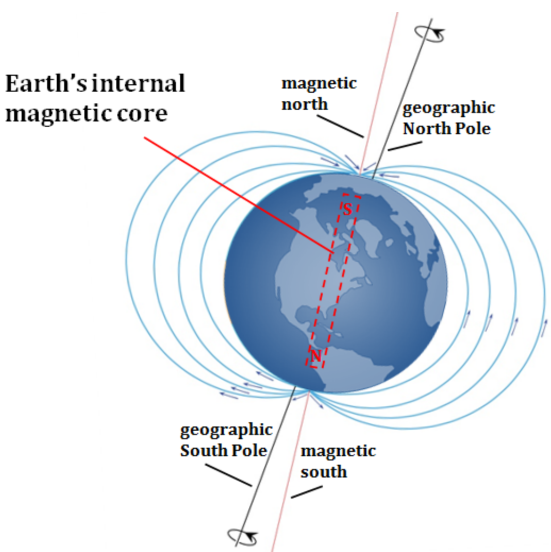
Earth is a magnet because of its internal structure. Earth has four layers: an inner core, an outer core, a mantle, and a crust. Earth's outer core is magnetic because it is made up of liquid iron and nickel metal. Earth's magnetic field extends far out into space. It protects the planet from solar winds released by the sun. It isn't very strong. It is weaker than a typical fridge magnet.



Earth's internal layers

Because Earth is a magnet, it has a magnetic north pole and a magnetic south pole. However, these poles are opposite the geographic North and South Poles, which are the northernmost and southernmost fixed points on Earth.

Earth's magnetic north, which is near the geographic North Pole, is actually a magnetic south pole. This is why the north pole of a compass is attracted to it. Earth's magnetic south, which is near the geographic South Pole, is actually a magnetic north pole.



Earth's geographic and magnetic poles

Further complicating matters is the fact that the magnetic poles move every year. The reason this happens goes back to the materials that make up Earth's interior. Earth's liquid outer core is in constant motion as the liquid iron and nickel swirl around. As it moves, Earth's magnetic field changes.

Common Core Connection – ELA

Reading Informational Text – Key Ideas and Details

Read the following article, and then answer the questions below.

Many experiments on animal behavior have determined that organisms as diverse as bacteria and hamsters can detect the intensity of the Earth's magnetic field.

The most visible interaction between animals and the magnetic field comes every year as animals migrate from cold to warm climates and back again. To navigation-challenged humans, animal migration can seem almost magical. How do animals like salmon, leatherback turtles, butterflies, and hummingbirds manage to migrate thousands of miles? It turns out that it's not magic at all: it's an invisible ecological interaction.

An inner compass is very important to migrating animals, particularly on days when it's overcast. This makes it hard to navigate using the sun or the stars. In a 2014 study of monarch butterflies, researchers from the University of Massachusetts Medical School discovered that migrating monarchs orient themselves to the south – even in the absence of cues from the sun. This means that even when it's overcast, butterflies can continue moving southward to their winter home.

When humans use a compass, it's visible in our hands. If animals have a compass, where is it? For a long time, studies of animal behavior showed animals aligning themselves with the earth's magnetic field. No one knew exactly how they managed to figure it out. However, research has discovered that many species contain small quantities of magnetite. This is the same material used in the ancient lodestones that humans used to guide their journeys.

Animal navigation has long fascinated humans. We enjoy watching the geese migrate overhead as fall approaches, but for a long time, no one knew how they managed to find their way. While it's not completely clear how all animals navigate using the Earth's magnetic field, recent investigations of animal anatomy have drawn us closer to the answer to this perplexing question.[1]

<u>Questions</u>:

1. What is the central idea of this text?
2. What ideas support this central idea?
3. How does the author develop this central idea from paragraph to paragraph?

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[1] Adapted from a decodedscience.org article by Tricia Edgar

Name: ______________________________ Date: __________

Magnetic Fields Investigation

Focus question: How does increasing the number of magnets in a system affect how far the system's magnetic field extends beyond the magnets?

Use what you know about magnets and magnetic fields to write a hypothesis for the focus question in the space below.

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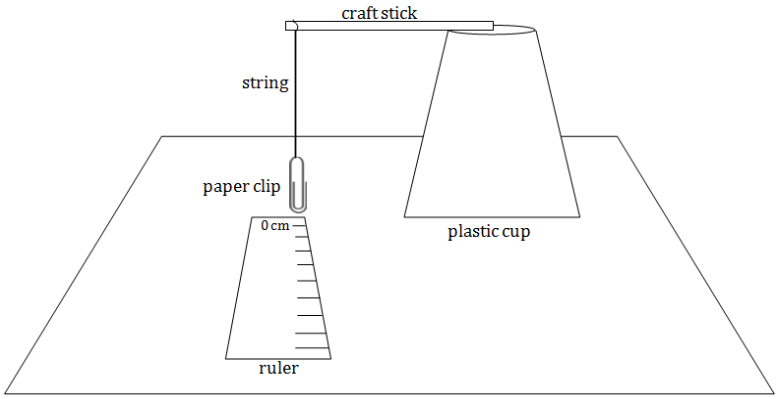
Materials

- 15 centimeters of string
- 5 ring magnets
- 1 craft stick
- 1 plastic cup
- 1 small paper clip
- 1 ruler
- 1 roll of invisible tape
- 1 pair of scissors

Model Set-Up

1. Turn the plastic cup upside down and tape it to a flat, level surface.
2. Tape a craft stick to the bottom of the upturned cup so it the majority of the craft stick hangs off the edge of the cup. Place a ruler on the desk/table so the 0 centimeter end is just under the craft stick taped to the cup.
3. Tie the string to one end of the small paper clip. Tape the free end of the string to the end of the craft stick hanging off the cup so the paper clip hangs just above the 0 centimeter mark on the ruler (see the diagram on the next page).



Test Procedure

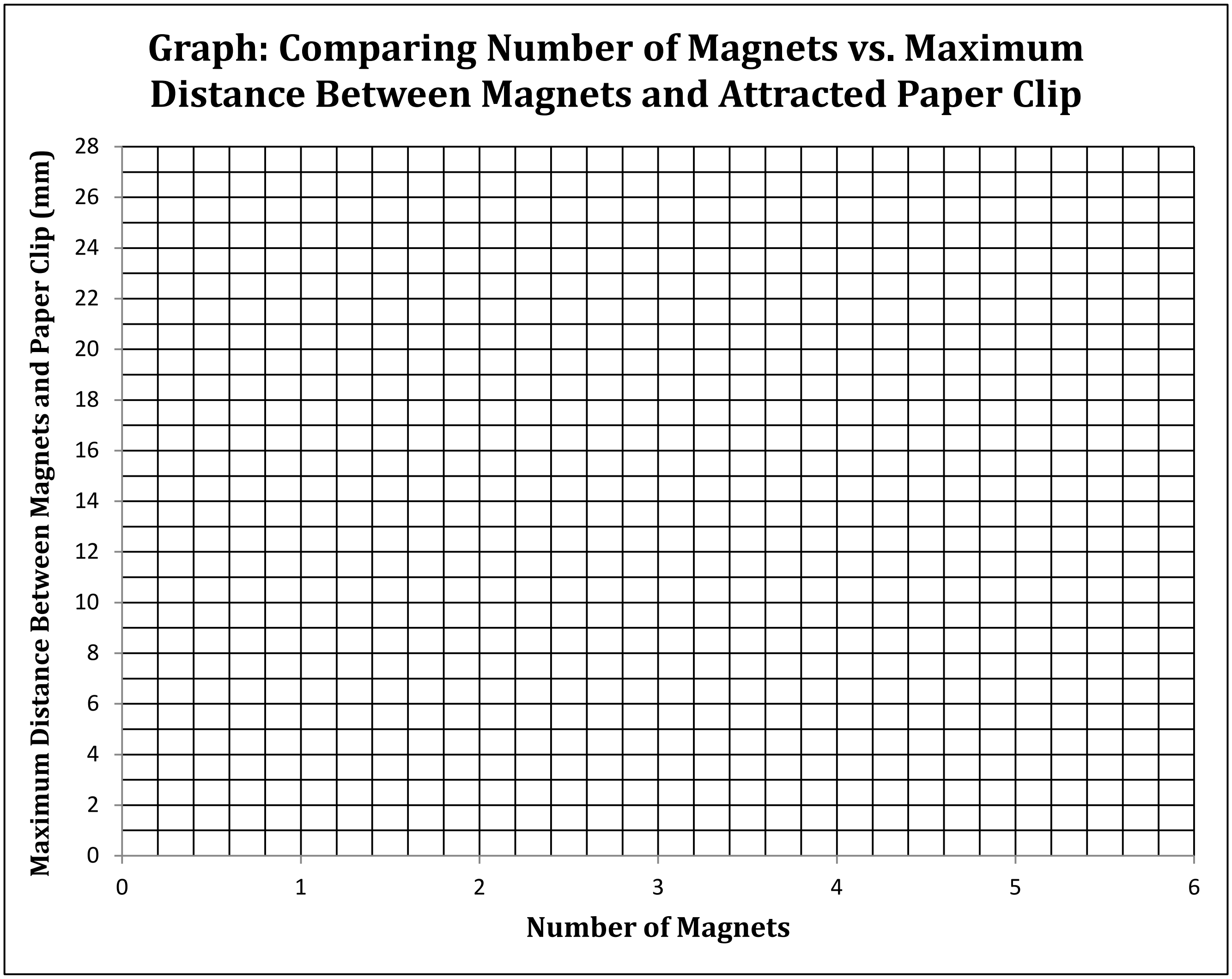
1. Bring one ring magnet near the paper clip so the paper clip attaches to it.
2. Hold the magnet with the attached paper clip upright against the desk/table surface. Slowly move the magnet away from the cup until the paper clip just starts to separate from the magnet. Place the 0 centimeter end of the ruler at this point.
3. Move the magnet away from the cup along the edge of the ruler until the force of the magnetic field acting on the paper clip weakens and the paper clip falls back toward the cup.
4. Record the maximum distance between the magnet and the paper clip before the paper clip falls back toward the cup. Record this measurement in Table 1.
5. Repeat Steps 1-4 for four more tests, using one additional magnet in each test

Data

Table 1: Comparing How Number of Magnets Affects Maximum Distance Between Magnets and Attracted Paper Clip

Tests	Number of Magnets	Maximum Distance Between Magnet and Attracted Paper Clip (mm)
1	1	
2	2	
3	3	
4	4	
5	5	

Graph your data from Table 1 in the blank line graph below.



Analysis and Conclusion

Explain how the data you collected in the investigation does or does not support your hypothesis about how the number of magnets in a system affects how far the system's magnetic field extends beyond the magnets. Use specific evidence from the investigation to support your argument.

Name: ____ Date: ____________

Repelling Magnets Investigation

Focus question: How does changing the distance between repelling magnets in a system affect the amount of potential energy stored in the system?

Use what you know about magnetic forces and energy to write a hypothesis for the focus question in the space below.

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Investigation summary: Your team will use two sets of repelling ring magnets placed on a vertical dowel to see how far one set of magnets will move up the dowel when they are placed different distances from the second set of magnets at the base of the dowel and then released.

Materials

- 5 ring magnets
- 1 dowel
- 1 ruler
- goggles (per student)

Magnet System Set-Up

1. Bring together three ring magnets and place them on a flat, level surface. Put the dowel into the hole of the magnets and hold it vertically.
2. Slide a set of two, free-moving magnets onto the dowel so they are repelled by the fixed magnets at the base of the dowel.

Test Procedure

1. Slide the free-moving magnets 2 centimeters from the fixed magnets on the dowel. Release the magnets and measure how high the base of the magnet set travels up the dowel.
2. Repeat Step 1 for two more trials.
3. Repeat Steps 1-2 for two more tests, first with the free-moving magnets 1 centimeter from the fixed magnets and then 0 centimeters away from the fixed magnets (in contact with the fixed magnets).

Table 1: Distance Repelled Magnets Travel Up a Dowel When Placed at Different Starting Positions from Fixed Magnets		
	Test 1: Base of Free-Moving Magnet Set Starting Position: 2 centimeters from Fixed Magnets	
	Maximum Distance Traveled (cm)	Total Distance Traveled (max. distance – starting position)
Trial 1		
Trial 2		
Trial 3		
	Average Distance Traveled	
	Test 2: Base of Free-Moving Magnet Set Starting Position: 1 centimeter from Fixed Magnets	
	Maximum Distance Traveled (cm)	Total Distance Traveled (max. distance – starting position)
Trial 1		
Trial 2		
Trial 3		
	Average Distance Traveled	
	Test 3: Base of Free-Moving Magnet Set Starting Position: 0 centimeters from Fixed Magnets	
	Maximum Distance Traveled (cm)	Total Distance Traveled (max. distance – starting position)
Trial 1		
Trial 2		
Trial 3		
	Average Distance Traveled	

Analysis and Conclusion

1. Describe any patterns you noticed in the data you collected in Table 1.

2. Explain how the data you collected in the investigation do or do not support your hypothesis about how changing the distance between repelling magnets in a system affects the amount of potential energy stored in the system.

Section 1 Review

Multiple Choice	Critical Thinking
MC1. Which of the following statements is <u>true</u> about Earth's magnetic core? A. It has a north pole and a south pole. B. It produces a magnetic field. C. Earth's magnetic core is stronger than other magnets on Earth. D. both A and B **MC2**. Which of the following statements <u>best</u> explains how magnets interact with other magnets and magnetic materials? A. A magnetic field is the physical outer part of a magnet that covers the magnetic poles. B. Magnets produce attractive or repelling forces that act on other magnets and magnetic materials whenever they come into contact with them. C. Magnets produce attractive or repelling forces that act on other magnets and magnetic materials without coming into contact with them. D. none of the above	**CT1**. How can one magnet exert a force on another magnet without coming into contact with each other? **CT2**. Ayanna has a magnet. How could Ayanna test different materials to determine whether they are magnetic? **CT3.** Why would you have to apply a force to two repelling magnets to push them together? **CT4.** How are forces related to energy transfer? Use evidence (such as an example) to support your answer.

<u>Section 2</u>: Magnets and Electricity

Trains that Float on Air

The world's fastest train is in Shanghai, a city in China. This train is called the Shanghai Maglev. It reaches speeds of 431 kilometers per hour (268 miles per hour). It can travel 30 kilometers (18.6 miles) in seven minutes and 20 seconds.

The Shanghai Maglev leaves the airport.

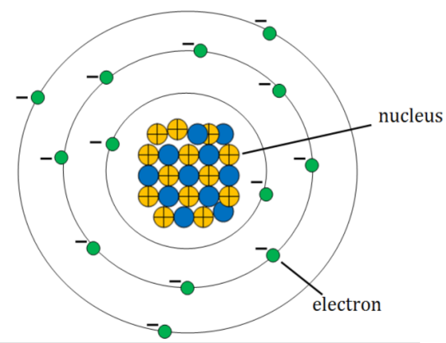
The Shanghai Maglev is able to reach such speeds because it uses giant magnets to float over the tracks. (Maglev is short for magnetic levitation.) Floating above the tracks offers the trains a significant advantage. There is very little friction to slow the trains down. Engineers in the United States are discussing using maglev trains to connect the East and West Coasts.

Maglev trains work because they use a kind of magnet called an electromagnet. **Electromagnets** are tightly wound coils of wire that produce a magnetic field when electricity passes through the wire. They are useful in various technologies because the magnet can be turned off and on. This is different from **permanent magnets**, which stay magnetized without electricity.

Electromagnets Use Electricity

Electromagnets become magnetized when electricity moves through the wire. **Electricity** is the flow of electrons through a conductor. Electricity is all around us. It is found in our bodies as electrical impulses and in the sky during storms as lightning. It also powers much of our modern world, turning on lights and powering motors, cell phones, and many other technologies.

Electricity happens because of the structure of matter. Remember that all matter is made of tiny particles called atoms. Atoms are made up of even smaller particles, including protons, neutrons, and electrons. Protons and neutrons are found in the nucleus, and electrons orbit the nucleus at different distances called shells. Protons have a positive charge (+), and electrons have a negative charge (-).



This is a model of an atom.

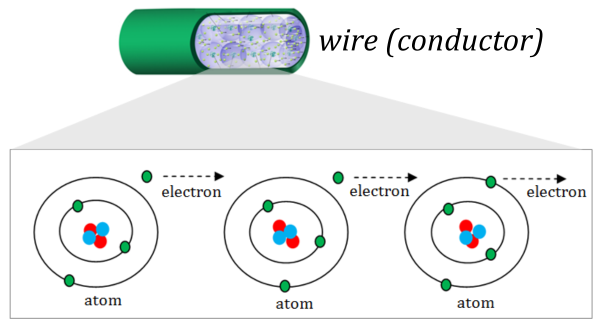
Interactions of Charged Particles

Charged particles change the space around them. They produce an **electric field** that can exert a force on other charged particles within the field. Similar to magnets, charged particles either attract or repel one another. Particles that have an opposite charge attract one another within their electric field, while particles with the same charge repel one another within their electric field.

Electrons are kept in orbit in their shells because the positive charges of the protons in the nucleus attract the negatively charged electrons. The strength of the field weakens with distance. Because of this, electrons in shells closest to the nucleus are tightly bound. Electrons in the outermost shell are much more loosely bound. When a force is applied, electrons in the outer shells can be pushed from one atom to another. Once that first electron has been pushed away from its atom, it moves to another atom. This movement of electrons causes electrons to all move in the same direction as one another. It is the movement of these electrons that creates electricity.

Moving Electrons

Electrons can move more easily through some materials than others. **Electric conductors** are materials that allow electrons to pass through them easily. Metals such as copper and aluminum are electric conductors because they have electrons that are loosely held, and therefore can easily be pushed from their shells by an outside force.



This diagram shows electricity moving through a conductor. The green outer covering of the wire is an insulator.

Electric insulators are materials that do not allow electrons to pass through easily because electrons do not easily separate from their atoms. Rubber and plastic are both good electric insulators. This is why electrical cords are covered in rubber or plastic. The electricity cannot travel through the rubber or plastic and is forced to follow the path on the aluminum or copper wires.

Some materials are semiconductors, which means they can sometimes act as a conductor, depending on what other molecules are around.

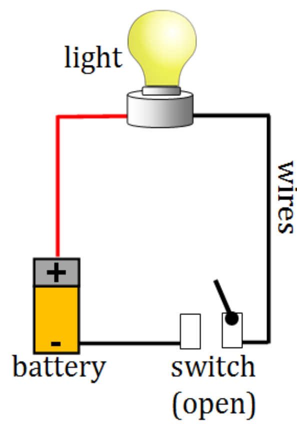
Electromagnets are Part of a Circuit

Because electromagnets are made with electricity, they can be demagnetized when the electricity is turned off. This is possible because electromagnets form a circuit. A **circuit** is the circular path that electrons travel in a negative to positive direction.

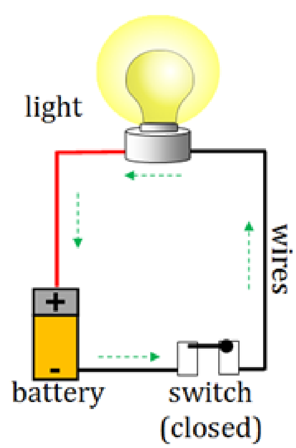
All circuits have the same basic parts. All circuits have an energy source such as a battery. The battery has stored chemical energy that converts to electrical energy, which is the energy of electrically charged particles. The battery's energy provides the input of force that pushes the electrons in the conductive material through the circuit.

All batteries have a positive side (+) and a negative side (-). Electrons travel from the negative end of the battery through the circuit to the positive end because the negatively charged electrons are attracted to the positive side of the battery. A battery's voltage affects how much it can push and pull electrons through a circuit. **Voltage** is a measure of the difference in electric charge between two points. A high voltage pushes and pulls electrons with more force than a low voltage. Voltage is measured in volts (v).

Circuits also have wires. Wires are the paths that electrons travel in the circuit. Energy moves from the battery through the conductors inside the wires. The wires in a circuit are attached to an object that can convert electrical energy to do work. Work is any change in position, speed, or state of matter due to force. All circuits must include something that can do work. Without this part, the electricity will cause danger by overheating the circuit. This is called a "short circuit."



For example, a light bulb is an object that does work. When electrons reach the light bulb in a circuit, they transfer electrical energy. The light bulb changes the electrical energy into outputs of light energy and heat. In a perfect system, the same amount of energy that was transferred through the circuit would be available to light up the bulb because of the conservation of energy. However, in the real world, some of the energy transfers out of the system due to resistance, which is the force opposing the current. The electrons then continue on their path. They return to the opposite side of the battery.



Finally, most circuits have switches. The switch opens and closes the circuit. Electrons flow when a circuit is closed. This is "on." A closed circuit will cause the light bulb to light up. Electrons cannot flow when a circuit is open. This is "off." No work can be done in an open circuit.

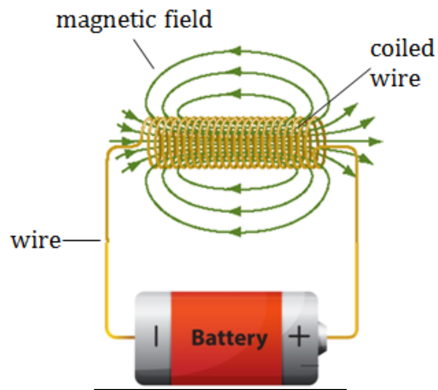
Electromagnets in Circuits

The way a circuit is put together affects the amount of electric current that can do work. **Current** is a measure of the rate that electric charge passes through a point in an electric circuit over time. The amount of work that can be done increases as current increases. For example, a fast current will cause a light bulb to be brighter than a slow current. This is because more electrons reach the bulb in the same amount of time. Current is measured in amps (A).

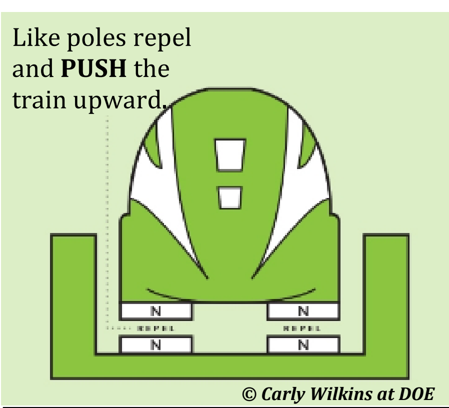
Currents Produce Magnetic Fields

Electric current produces a magnetic field. As electrons in a conductor move in the same direction as one another, their movement produces a magnetic field around the wire conductor.

The magnetic field around a straight wire is not very strong. However, if the wire is wrapped in a coil, the fields produced in each turn of the coil add up to create a stronger magnetic field. This is the idea behind an electromagnet: a tightly coiled wire produces a magnetic field when electricity passes through the wire. The electromagnet becomes magnetized when the circuit is closed. It becomes demagnetized when the circuit is open.



a simple electromagnet



how a maglev train floats

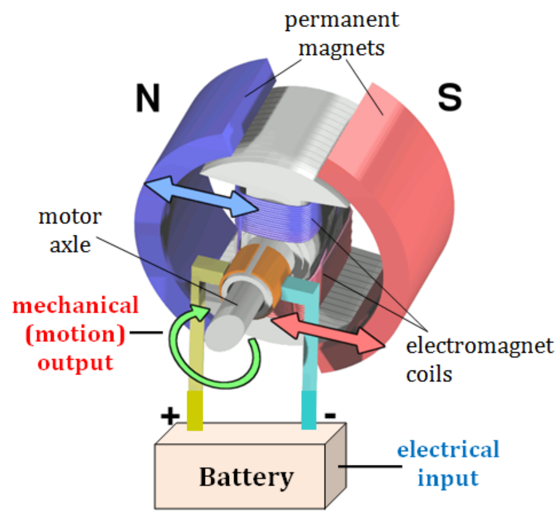
Maglev trains are designed with electromagnets on the bottom that produce a powerful magnetic field. The track, called a guideway, has loops of conductive material such as aluminum. As the train passes over the loops, magnetic repulsion between the electromagnets on the train and the magnetic loops keeps the train a certain distance from the guideway.

Electromagnets and Motors

Electromagnets are not just found at the bottom of high-speed trains. They are an important part of electric motors, which are found in a wide range of household items, including electric screwdrivers, washing machines, automatic can openers, fans, electric toothbrushes, and many toys that move.

A **motor** is a machine that transfers an input of electrical energy into an output of mechanical energy.

An electromagnetic motor has two parts: an outside permanent magnet and an inside electromagnet. The electromagnet becomes magnetized when it is connected to an electric current.



an electric motor

If the electromagnet is positioned so that its north pole is near the north pole of the permanent magnet, the two magnets will repel each other, and be attracted to each other's south pole. These attracting and repelling forces cause the electromagnet to rotate, generating mechanical energy. If a gear is attached to the spinning electromagnet, the gear can be made to do work.

Changing Speed of Motor

There are different ways to change the speed that a motor spins. The more coils an electromagnet has, the stronger its magnetic field will be. Because the electric current is so connected to the magnetic field, this stronger magnetic field causes the current to flow even faster. A faster current means that the electrons are moving faster. That faster movement creates a stronger magnetic field, which then causes the current to move even faster.

Name: ____ Date: ________________

Electromagnetic Forces Investigation

Introduction: What factors affect how quickly an electric motor spins? Use your electric motor and the steps below to investigate the question.

A. How does the <u>number of magnets</u> interacting with the motor coil affect how fast the motor spins? Write a prediction for the question in the space below.

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Test your motor:

1. Connect your motor to the 9-volt battery.
2. Bring one ring magnet near the motor coil so the coil spins. If needed, give the coil a little spin to get it moving. Observe how quickly the motor coil starts spinning on its own and how fast it spins.
3. Repeat Step 2 for two more tests, first with 2 ring magnets and then 3 ring magnets.

Analyze the results

1. What did you observe about the speed of the motor coil when you tested the system with different numbers of magnets?

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2. Explain how your observations support or do not support your prediction. Use evidence from the investigation to support your argument.

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B. How does the <u>orientation of the magnets</u> interacting with the motor coil affect how fast the motor spins? Write a prediction for the question in the space below.

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Test your motor:

1. Connect your motor to the 9-volt battery.
2. Bring the end of a three-magnet set near the motor coil. If needed, give the coil a little spin to get it moving. Observe how quickly the motor coil starts spinning on its own and how fast it spins.
3. Repeat Step 2, this time turning the magnet set so the sides of the magnets are near the motor coil.

Analyze the results

1. What did you observe about the speed of the motor coil when you tested the system with the magnets in a different orientation?

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2. Explain how your observations support or do not support your prediction. Use evidence from the investigation to support your argument.

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C. How does the <u>distance between the magnet and the coil</u> affect how fast the motor spins? Write a prediction for the question in the space below.

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Test your motor:

1. Connect your motor to the 9-volt battery.
2. Bring the end of a three-magnet set near the motor coil. If needed, give the coil a little spin to get it moving. Observe how quickly the motor coil starts spinning on its own and how fast it spins.
3. Observe how the speed of the coil is affected as you slowly move the magnet set away from the coil, and then slowly move it back toward the coil.

Analyze the results

1. What did you observe about the speed of the motor coil when the magnets interacted with the coil from different distances?

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2. Explain how your observations support or do not support your prediction. Use evidence from the investigation to support your argument.

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D. How does <u>increasing the voltage flowing through the motor</u> affect how fast the motor spins? Write a prediction for the question in the space below.

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Test your motor:

1. Connect your motor to one AA battery (1.5 volts) by touching the black and red alligator clip wire ends to the positive and negative ends of the battery.
2. Bring the end of a three-magnet set near the motor coil. If needed, give the coil a little spin to get it moving. Observe how quickly the motor coil starts spinning on its own, how consistently it spins, and how fast it spins.
3. Repeat Steps 1-2 with a 9-volt battery.

Analyze the results

1. What did you observe about the speed of the motor coil when batteries with different voltages were used to power the motor?

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2. Explain how your observations support or do not support your prediction. Use evidence from the investigation to support your argument.

Section 2 Review

Multiple Choice	Critical Thinking
MC3. Which of the following would <u>increase</u> the strength of an electromagnet? A. adding a larger permanent magnet B. more coils in the conductive wire C. a battery with a lower voltage D. all of the above **MC4**. Which of the following would <u>decrease</u> the strength of an electromagnet? A. adding a larger permanent magnet B. more coils in the conductive wire C. a battery with a lower voltage D. all of the above	**CT5**. How are electric charges similar to magnets? How are they different? **CT6.** How do electromagnets combine electricity and magnetism? **CT7**. Given what you know about the relationship between electric currents and magnetic fields, what would you expect to happen to the magnetic field of an electromagnet when the electric current is increased? **CT8.** What would happen to an electric motor if it didn't have a permanent magnet?

Section 3: Engineering Wind Turbines

Mimicking Animals

Engineers have studied how hummingbirds hover.

Many engineers have studied the wings of hummingbirds because of their amazing flight abilities. They are the only birds that can fly both forward and backwards. They can also hover in mid-air, fly sideways, and even upside-down.

For example, engineers in North Africa are developing wind turbines that mimic the hummingbird's wings as it hovers. A **wind turbine** is a device that converts mechanical energy from the wind into electrical power. **Wind** is moving air molecules. Wind turbines can be as tall as a 20-story building and have blades that are 60 meters (200 feet) long.

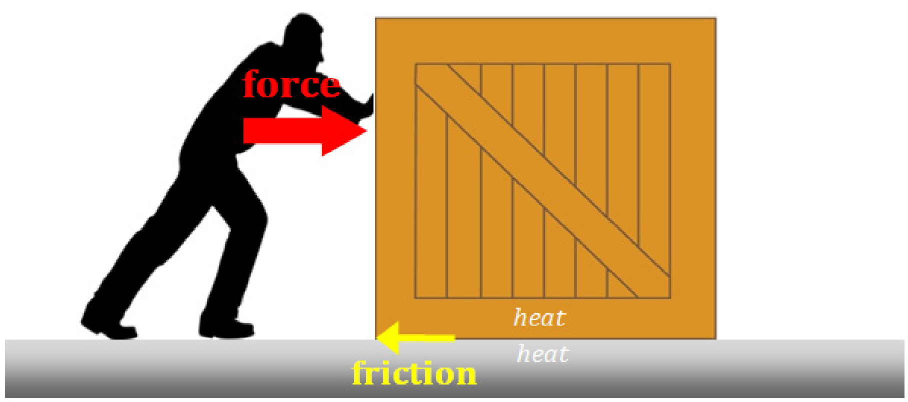
These wind turbines capture energy from the wind.

Other engineers have looked to other animals for inspiration about the shape of their wind turbines. Humpback whales and schools of fish have also inspired different designs, from the shape of the blades to their placement on the tower and the relationship of each turbine relative to the other turbines.

The Search for Efficiency

The main reason that engineers are searching for new ways to design wind turbines is to improve their efficiency. In any energy system where energy is being converted from one form to another, not all of the energy is converted to a form that can do work. Some is usually transformed into non-usable forms of energy.

A simple example of this is moving a box across the floor. You, the box, and the floor form an energy system. As you push the box, you are providing an input of force that transfers mechanical energy to the box. This mechanical energy is what causes the box to move.

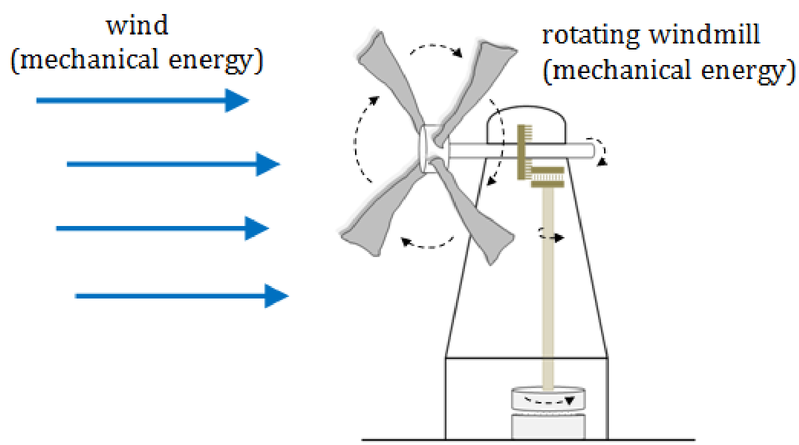


However, as the box moves across the floor, the force of friction transfers energy out of the system by turning some of the mechanical energy into heat. The more friction there is, the less efficient your energy system is because less mechanical energy is available to do the work of moving the box.

Engineers are always looking for ways to design technologies that transform energy as efficiently as possible. They want to generate more work while using less energy. This is true for wind turbines, which capture the kinetic energy of the wind.

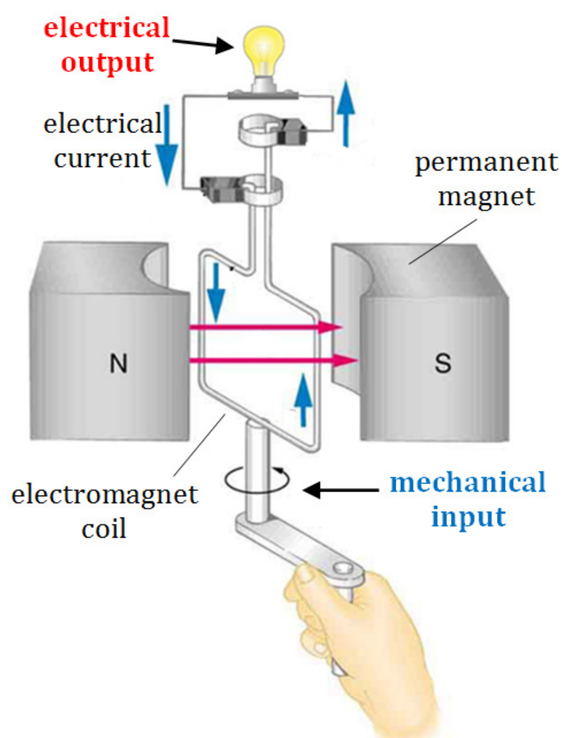
How a Wind Turbine Works

As the wind blows, it pushes on a wind turbine's blades. This pushing force transfers the mechanical energy in the wind to the blades, causing the blades to turn.



The blades are connected to a drive shaft, which is a long bar of steel that can rotate. As the wind moves the blades, the blades rotate the drive shaft. The drive shaft is connected to a generator. A **generator** is a machine that converts an input of mechanical energy into an output of electrical energy.

The generator uses the same principles of electromagnetic force as an electric motor, but it works in reverse. A generator uses an input of mechanical energy, such as from the wind, to move a magnet near a wire conductor, which creates a flow of electrons, generating electricity.



a simple hand-powered generator

Types of Wind Turbines

Engineers experiment with different blade shapes and sizes. There are two basic designs: vertical-axis wind turbines and horizontal-axis wind turbines.

Horizontal-axis turbines are much more common because they are generally more efficient at converting the wind's mechanical energy into electricity. They look like massive airplane propellers on a pole.

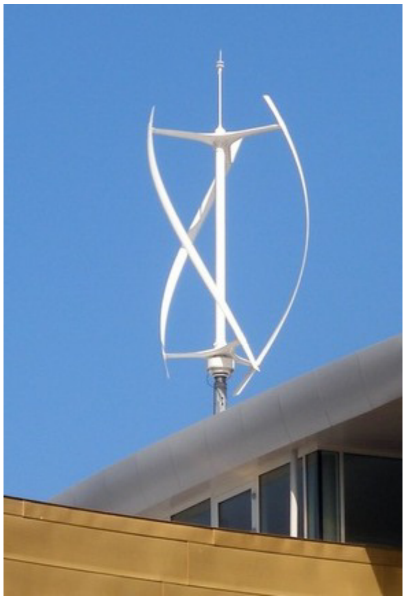
However, horizontal-axis wind turbines work most efficiently when the wind flows at a right angle to the blades. This means that the main rotating shaft and electrical generator must point into the wind. They are also very tall, with long blades. This makes them best suited for open spaces, such as fields, that have a lot of wind.

a horizontal-axis wind turbine

The other kind of turbine is called a vertical-axis wind turbine, and it often looks like a massive egg beater. In this kind of wind turbine, the main drive shaft is perpendicular to the ground. The main components are located at the base, making any service and repair much easier. One advantage of the vertical-axis wind turbine is that it does not need to be pointed into the wind. It will function similarly regardless of wind direction. This makes it a better option for many urban areas where tall buildings make wind flow more unpredictable. However, this design is less efficient than horizontal-axis wind turbines because the blades rotate more slowly.

a vertical-axis wind turbine

Examples of Vertical-Axis Wind Turbines



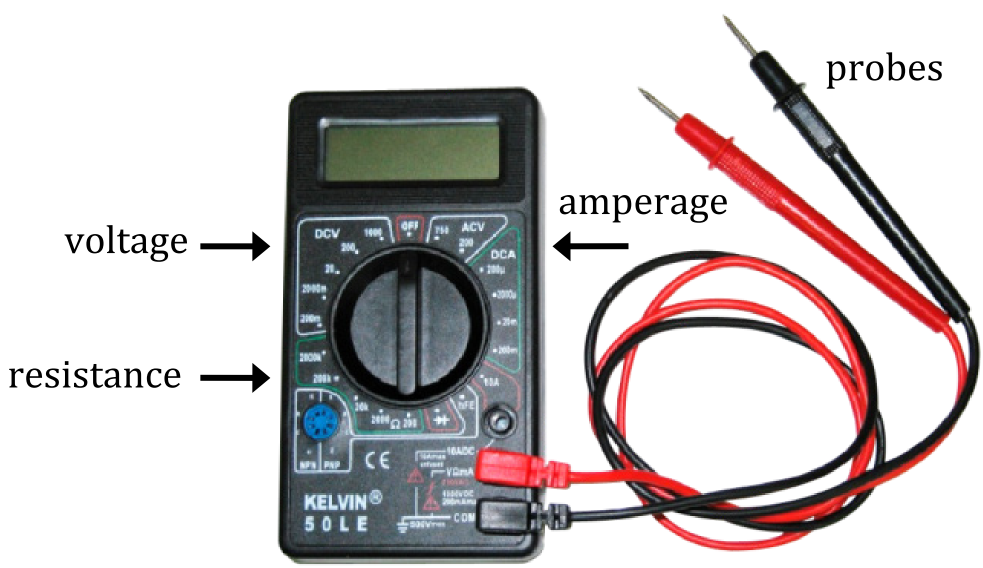



How to Use a Multimeter

- The multimeter will allow you to measure the amount of voltage produced by your wind turbine. It can also be used to measure amperage and resistance, but only voltage will be measured in your circuits.
- The dial on the multimeter turns the instrument on and is used to select what you want to measure.
- **<u>DO NOT</u>** use this instrument to test wall outlets or other electrical devices.
- To extend the life of the battery, the switch should be in the “OFF” position when the instrument is not in use and the dial should be turned slowly.

<u>Symbols</u>

- A multimeter dial is divided by the type of measurement being taken. The options are:
  - DCV = Direct Current **(Voltage)**
  - DCA = Direct Current **(Amperage)**
  - ACV = Alternating Current **(Voltage)**
  - Ω = **(Resistance)**



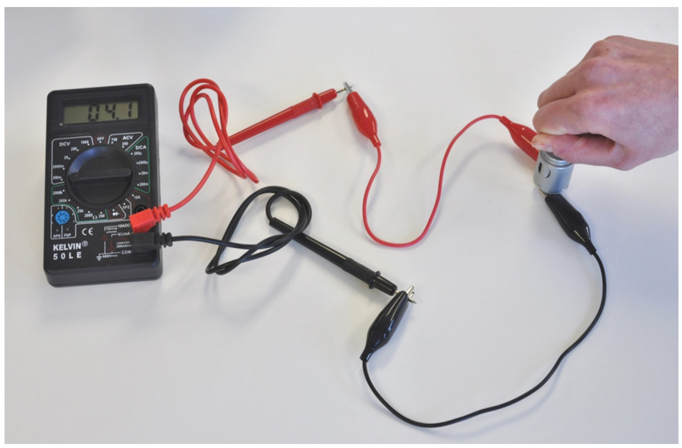
Units

- Values on the multimeter represent the available range of measurements from 1 millivolt or less to 1,000 volts.
- The range of settings determines the maximum quantity that can be measured. For example: DCV 200m measures up to 200 millivolts; DCV 2,000m measures up to 2,000 millivolts, etc. The lesson will tell you which value to select on the multimeter. Changing the value setting on the multimeter changes the sensitivity of the measurement.
- The units for voltage follow the same standards as other metric system measurements (k = kilo, m = milli, μ = micro).

Measuring Voltage of a Motor

1. Plug in the multimeter test leads. The **red lead** (positive) goes into the VΩmA port and the **black lead** (negative) goes into the COM port.
2. Slowly turn the dial to DCV on the multimeter and select the voltage range required.
3. Place or attach the metal probes of the test leads to the corresponding electrodes of the device you are testing.

NOTE: If you get a negative reading from the multimeter, the electrical polarities (positive and negative sides of the multimeter) are reversed. Swap the position of the black and red probes contacting the electrodes on your device to correct.



The photo shows a multimeter measuring the voltage output of a motor as a person spins the axle. The motor is functioning as a generator in this context.

Section 3 Review

Multiple Choice	Critical Thinking
MC5. An electric motor transforms most of its energy into useful mechanical energy and wastes only a small amount as heat. What property of the electric motor is being described? A. efficiency B. power C. transformation D. strength	**CT9**. How does the force of blowing wind change the energy of a wind turbine? **CT10**. Why do wind turbines use generators? **CT11.** How do generators apply the principles of magnetism to function?

Science Words to Know

attract – to pull toward

circuit – the circular path that electrons travel in a negative to positive direction

current – a measure of the rate that an electric charge passes through a point in an electric circuit over time; measured in amps

electric conductor – a material that electrons can easily pass through

electric field – the area around a charged particle that attracts or repels other charged particles

electric insulator – a material that electrons do not pass through easily

electricity – the flow of electrons through a conductor

electromagnet – a tightly wound coil of wire that produces a magnetic field when electricity passes through the wire

generator – a machine that converts an input of mechanical energy into an output of electrical energy

magnet – an object that produces a magnetic field

magnetic field – the invisible area around a magnet that attracts or repels other magnets and magnetic materials such as iron

motor – a machine that converts an input of electrical energy into an output of mechanical energy

permanent magnet – an object that stays magnetized without electricity

repel – to push away

wind – moving air molecules

wind turbine – a device that converts mechanical energy from the wind into electrical power

voltage – a measure of the difference in electric charge between two points

Back Cover:

The back cover shows dolphins swimming in the ocean. Dolphins use Earth's magnetic field to navigate.

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