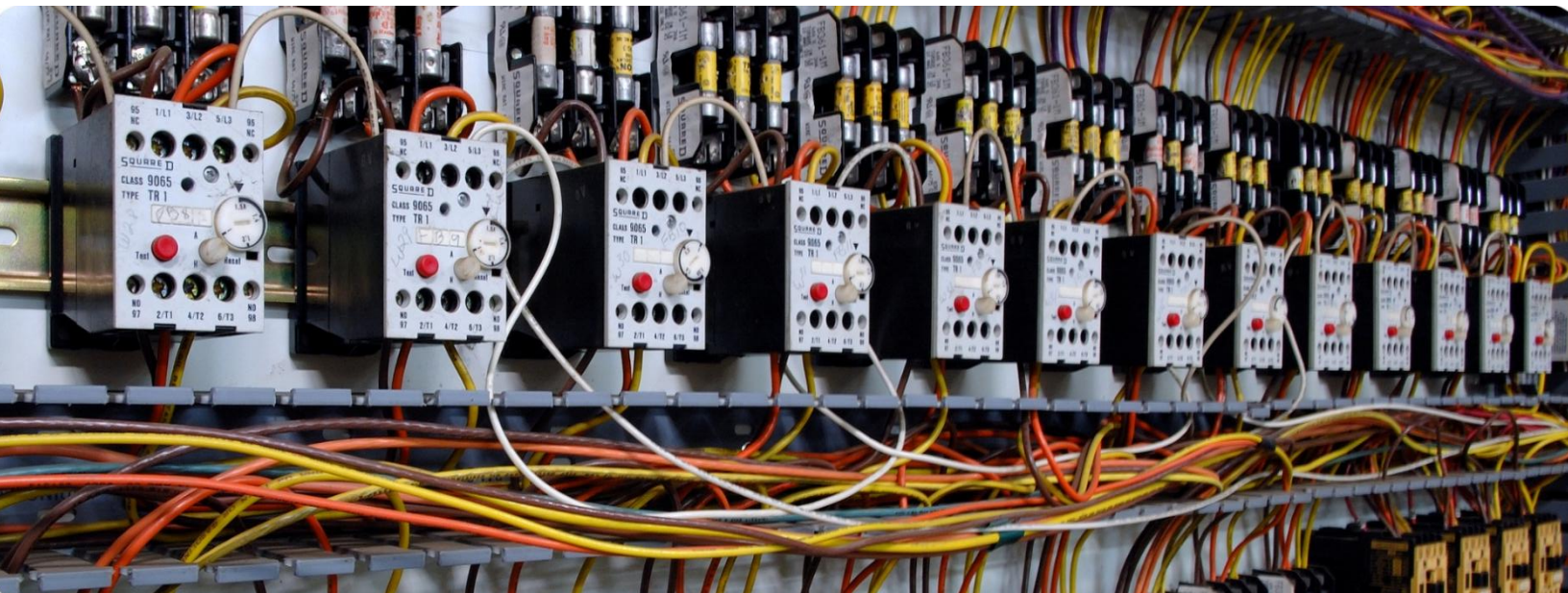


Participant Resource Guide

Electrical Foundations

May 2026



Course Outline

- Module 1: Introduction to Electricity
- Module 2: Basic Electrical Principles
- Module 3: AC and DC Electricity
- Module 4: Circuit Components & Architecture

Module 5: Magnetism and Electromagnetism

- Module 6: Electrical Tools
- Module 7: Safety and PPE



U.S. Department of Transportation
Federal Transit Administration

Course: Electrical Foundations

Version Date: May 2026

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Module 5 – Magnetism and Electromagnetism

Objectives

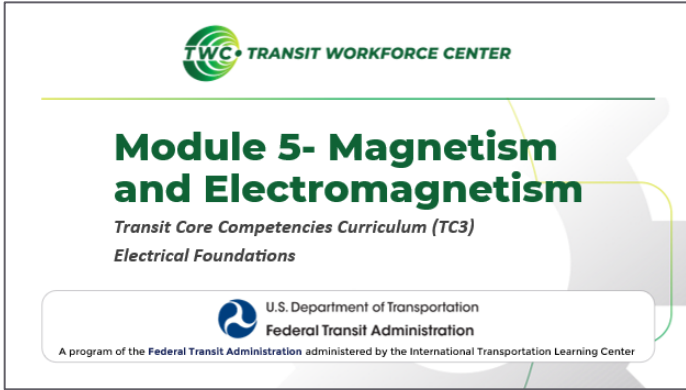
- Explain basic magnetism, including magnetic fields, poles, and magnetic materials.
- Explain how electromagnetism works and describe how electricity and magnetism are related.
- Describe how an electromagnet works and what affects its strength.
- Explain how electromagnetism is used in transit systems such as relays, motors, and generators.
- Explain Faraday's Law of induction and how changing magnetic fields are used to generate electricity in real-world systems.

Key Terms

- Electric Field
- Electromagnetism
- Electromagnets
- Faraday's Law of Induction
- Magnetic Field
- Magnetic Flux
- Magnetic Poles
- Magnetism
- Permanent Magnets

Participant Resource Guide

Magnetism and Electromagnetism



The cover slide features the TWC logo at the top left, followed by the text 'TRANSIT WORKFORCE CENTER'. Below this is the main title 'Module 5- Magnetism and Electromagnetism' in a large, bold, green font. Underneath the title is the subtitle 'Transit Core Competencies Curriculum (TC3) Electrical Foundations'. At the bottom, there is a logo for the U.S. Department of Transportation Federal Transit Administration and a line of text: 'A program of the Federal Transit Administration administered by the International Transportation Learning Center'.


Objectives

- Explain basic magnetism, including magnetic fields, poles, and magnetic materials.
- Explain how electromagnetism works and describe how electricity and magnetism are related.
- Describe how an electromagnet works and what affects its strength.
- Explain how electromagnetism is used in transit systems such as relays, motors, and generators.
- Explain Faraday’s Law of induction and how changing magnetic fields are used to generate electricity in real-world systems.

4

Agenda

- Welcome and Warm Up
- 5.1 Magnetism
- 5.2 Electromagnetism
- 5.3 How Magnetism Creates Electricity
- Quiz and Wrap Up




5

Warm Up

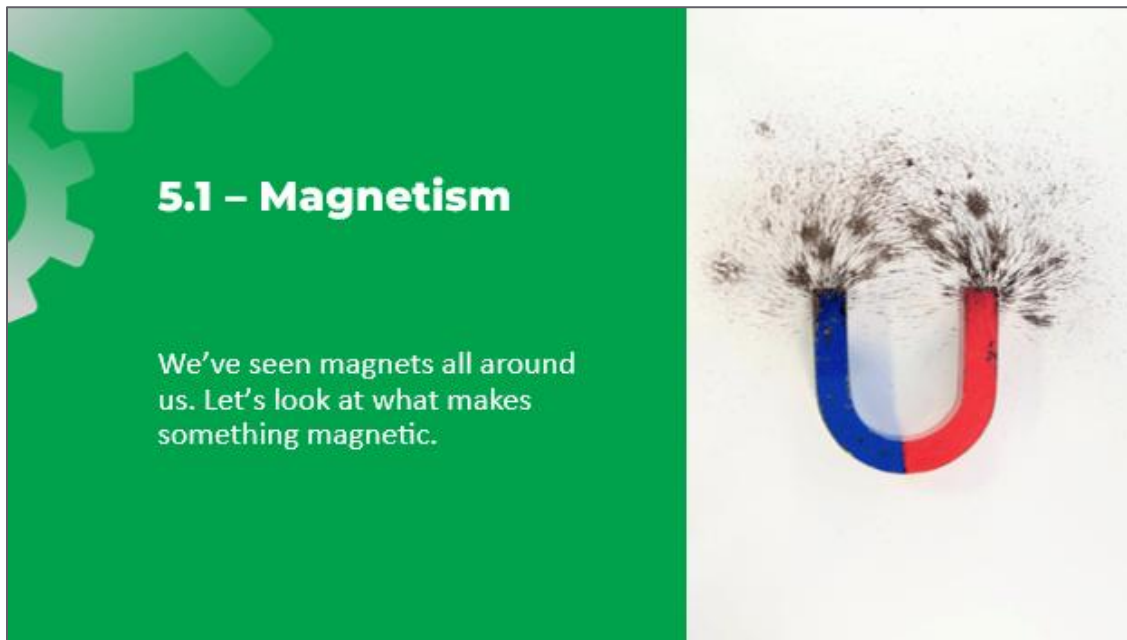
Have you ever used something that worked without touching it?

- What do you think is happening?
- What kind of force might be involved?



Notes:

- Before we get into today's topic, I want you to think about something familiar.
- Have you ever used something that worked without actually touching it?
- Things like automatic doors, wireless chargers, or tapping a card to unlock a door – Nothing is physically pushing or pulling, but something is clearly causing an action
 - What do you think is happening behind the scenes?
 - What kind of force do you think might be involved here?



Notes:

- We've seen magnets all around us.
- Let's look at what makes something magnetic.

Magnetism

- A **force** that makes some materials pull together or push apart
- When **electrons** move, they create a magnetic field, that can pull or push on other materials
- Ex: Motors turn, Relays activate, Sensors detect movement, etc.



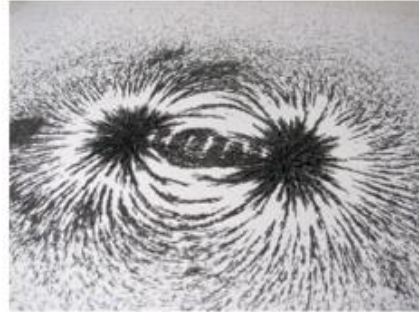
Notes:

- **Magnetism** is one of the fundamental forces of nature — like gravity — it's what causes certain materials to attract or repel each other.
- It all starts with the *motion* of electric charges. Think back to the lessons on electricity.
 - What part of an atom moves to create an electric charge?
- When electrons move, they create an electric charge. They also create a **magnetic field** that can pull or push on other materials.
- We see magnetism in natural magnets, like iron and lodestone, but it also shows up around electric currents, which means it plays a big role in electrical systems too.
- Magnets and electricity are connected, when electric charges move, they create magnetic force. Which is why we see magnetism in motors, relays, and coils.

Magnetic Fields

What is a Magnetic Field?

- Invisible area around a magnet where magnetic force can pull or push on objects
- Show the direction and strength of magnetic force



How Can We See It?

- Using iron powder, we can see the pattern of field lines that flow from the north to south pole of a magnet

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Notes:

- A **magnetic field** is an invisible area of influence around a magnet or current-carrying wire. It applies a magnetic force on materials that are sensitive to magnetism—like iron or steel.
- Field lines are not real objects — they just show the *direction* and *strength* of the magnetic force.
- You can visualize magnetic fields using field lines. These lines show the direction the magnetic force flows—from the north pole to the south pole of a magnet.
- You might not see the field, but you can observe its effects—like when iron filings line up around a bar magnet. That’s the magnetic field in action.
- Notice how the metal filings in this image surround the magnet. That’s the magnetic field.

Instructor Demo: Polarity


All magnets have two poles: North and South

Watch and Observe:

- What happens when magnets with the **same** polarity meet? What happens when **opposite** polarities meet?

What did you observe about polarity?

- Like poles **repel (push)** while opposite poles **attract (pull)**
- Polarity explains why magnets push or pull



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Notes:

- Watch and Observe the magnets, then answer the following questions:
 - What happens when magnets with the **same** polarity meet?
 - What happens when **opposite** polarities meet?
- **What did you observe about polarity?**
 - Like poles repel (push) while opposite poles attract (pull)
 - Polarity explains why magnets push or pull

Magnetic Field Strength and Distance

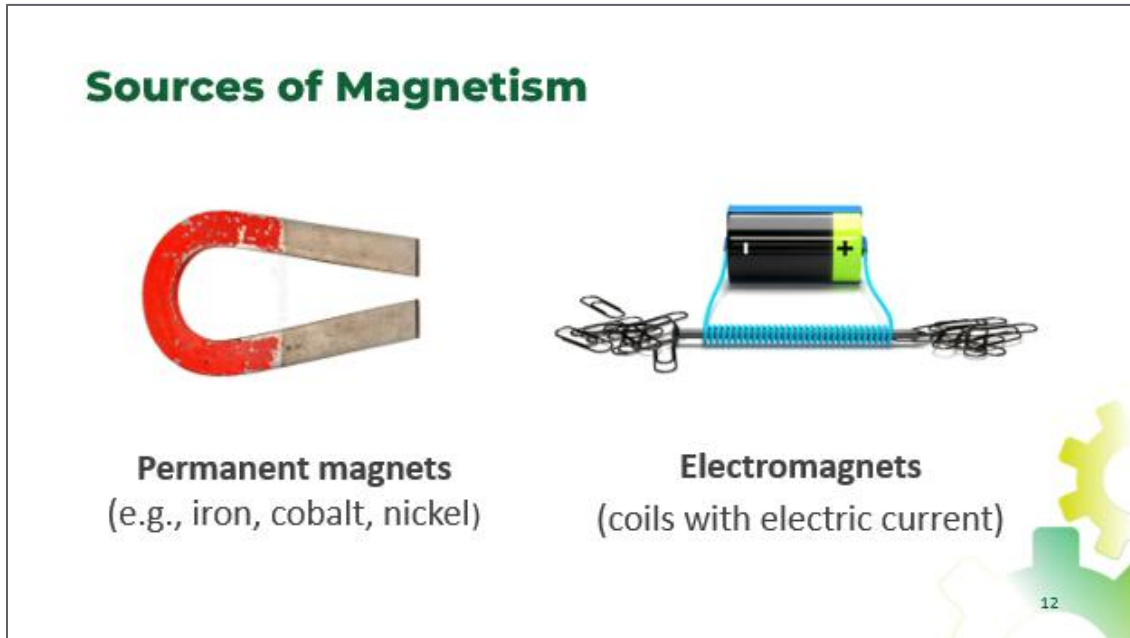
Make a prediction: Based on the polarity demonstration, where do you think the magnetic field is strongest?

- Magnetic field strength gets **weaker** as you move farther from the source.
- Field strength is **strongest** close to the poles of the magnet.



Notes:

- While our demonstration is fresh in your mind, let's make a prediction:
 - Based on the polarity demonstration, where do you think the magnetic field is strongest?
- Magnetic field strength **decreases with distance**—the farther you move from the magnet, the **weaker the magnetic force** becomes.
- The field is **strongest near the poles**, where the magnetic lines are most concentrated. That's why the attraction or repulsion is easiest to feel at those points.



Notes:

- Magnetism can come from a few different sources, and each one behaves a little differently:
 - **Permanent magnets**, like those made from **iron, cobalt, or nickel**, create a **constant magnetic field**—they don't need electricity to work.
 - **Electromagnets** are created when **electric current flows through a wire coil**—the magnetism only exists while the current is flowing, which makes them useful in things like motors, relays, and magnetic locks.
- Understanding these different sources helps explain how magnetism is used in everyday technology.

Magnetic Materials

Some materials are pulled strongly by magnets, others aren't.

- **Strong:** iron, steel, nickel, cobalt. Stick tightly to magnets and are used in motors and tools
- **Weak:** aluminum, stainless steel. May move slightly toward a magnet but not much
- **Non-magnetic:** copper, gold, plastic. Do not react to magnets at all.

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Notes:

- Not all materials react to magnets the same way—some are strongly attracted, some are barely affected, and others are actually pushed away.
- There are three main categories of magnetic materials:
 - **Strongly magnetic materials**, like iron, nickel, and cobalt, are strongly attracted to magnets. These are the materials used to make permanent magnets.
 - **Weakly magnetic materials**, such as aluminum and platinum, are weakly attracted to magnetic fields—but the effect is so slight, you usually don't notice it without special equipment.
 - **Non-magnetic materials**, like copper and gold, are actually slightly repelled by magnetic fields.
- Understanding these differences is key when choosing materials for electrical tools, shielding, or magnetic components in circuits.

Activity: Visualizing Magnetic Fields



Objective: Show the invisible magnetic field around a magnet using iron filings or powder.

Materials:

- White paper
- Sheet protector
- Iron filings or fine iron powder
- Tape
- 2 Bar magnets

The screenshot shows a digital activity page with the following content:

- Activity**
- Visualizing Magnetic Fields**
- Objective:** Show the invisible magnetic field around a magnet using iron filings or powder.
- Materials:**
 - White paper
 - Sheet protector
 - Iron filings or fine iron powder
 - Tape
 - 2 Bar magnets
- Instructions:**
 - Put the sheet of paper inside the sheet protector.
 - Put 2 1/2 teaspoons of iron filings or iron powder inside the sheet protector. Tap to keep the iron filings on one side of the sheet of paper.
 - Place the upper side of the sheet protector closed to keep things safe.
 - Use the sheet protector on a flat surface and lightly tap or shake it to distribute the iron filings.
 - Place a bar magnet in the center of the paper. Lightly tap or shake the flat gently to help the filings settle into the magnetic field lines. Observe the results and draw the magnetic field lines on the sheet of paper.
 - Next, place the second bar magnet near the first on the south pole and north pole regions. Observe the results and draw the magnetic field lines on the sheet of paper.
 - Finally, place the second bar magnet near the first on the south pole and south pole and north pole and north pole. Observe the results and draw the magnetic field lines on the sheet of paper.
- Draw the magnetic field lines for each magnet orientation. Your final drawing shows where the magnetic field is strongest and weakest.**

Notes:

- Use this activity to show the invisible magnetic field around a magnet by using iron filings or powder.
- Video Overview: https://www.youtube.com/watch?v=QzMaDS_nvcw



Activity

Visualizing Magnetic Fields

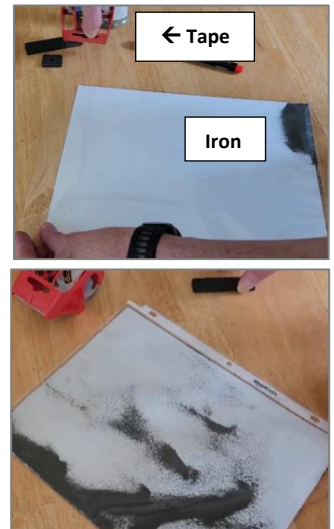
Objective: Show the invisible magnetic field around a magnet using iron filings or powder.

Materials:

- White paper
- Sheet protector
- Iron filings or fine iron powder
- Tape
- 2 Bar magnets

Instructions:

1. Put the sheet of **paper** inside the **sheet protector**.
2. Put 1-2 teaspoons of **iron filings** or iron powder inside the sheet protector. Try to keep the iron filings on one side of the sheet of paper.
3. **Tape** the open side of the sheet protector closed to keep things tidy.
4. Lay the sheet protector on a flat surface and lightly tap or shake it to distribute the iron filings.
5. Place **one bar magnet** in the center of the paper. Lightly tap or shake the tray lightly to help the filings settle into the magnetic field lines. Observe the results and draw the magnetic field lines on the chart in #8.
6. Next, place the **second bar magnet** near the first so the south pole and north pole pull together. Observe the results and draw the magnetic field lines on the chart in #8.
7. Finally, place the second bar magnet near the first so the south pole and south pole are near each other and push apart. Observe the results and draw the magnetic field lines on the chart in #8.
- 8.



Draw the magnetic field lines for each magnet orientation. Your lines should show where the magnetic field is strongest and weakest.

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Source: This activity was created by Donna Falk - Virtual Science Teachers - Virginia General Assembly for COVA STEM


Applications

Everyday Uses:

- Magnetic resonance imaging (MRI)
- Electric motors and generators
- Magnetic levitation trains and sensors
- Compasses for navigation
- Magnetic strips in credit cards

On the Job:

- What applications do you see where you work?



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Notes:

- Magnetism isn't just something you learn about in theory—it's all around us in everyday life and technology.
 - **In medicine**, MRI machines use strong magnetic fields to create detailed images of the body.
 - **Electric motors and generators** rely on electromagnetism to convert energy between electrical and mechanical forms.
 - **Maglev trains** float above tracks using magnetic repulsion—eliminating friction and enabling high-speed travel.
 - **Compasses** use the Earth's magnetic field for navigation—still critical in outdoor settings and aviation.
 - And the **magnetic strips on credit cards** store data using tiny magnetic fields, making digital transactions possible.
 - **Cell phones** use small but powerful magnets in components like speakers, microphones, vibration motors, wireless charging systems, and camera stabilization mechanisms.
- These are just a few examples of how magnetism powers the systems we depend on every day. What applications do you see where you work?

Knowledge Check



What does a magnetic force do?

(A.) It produces electricity on its own

B.) It creates a force that pulls or pushes certain materials

C.) It causes movement within a device

D.) It only works when heated

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Knowledge Check



Which statement correctly describes how magnetic poles behave?

A.) Magnetic force is strongest in the middle of the magnet

B.) A magnet can have more than one north pole

C.) North and North poles attract each other

D.) Opposite poles attract, and like poles repel

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Summary and What's Next

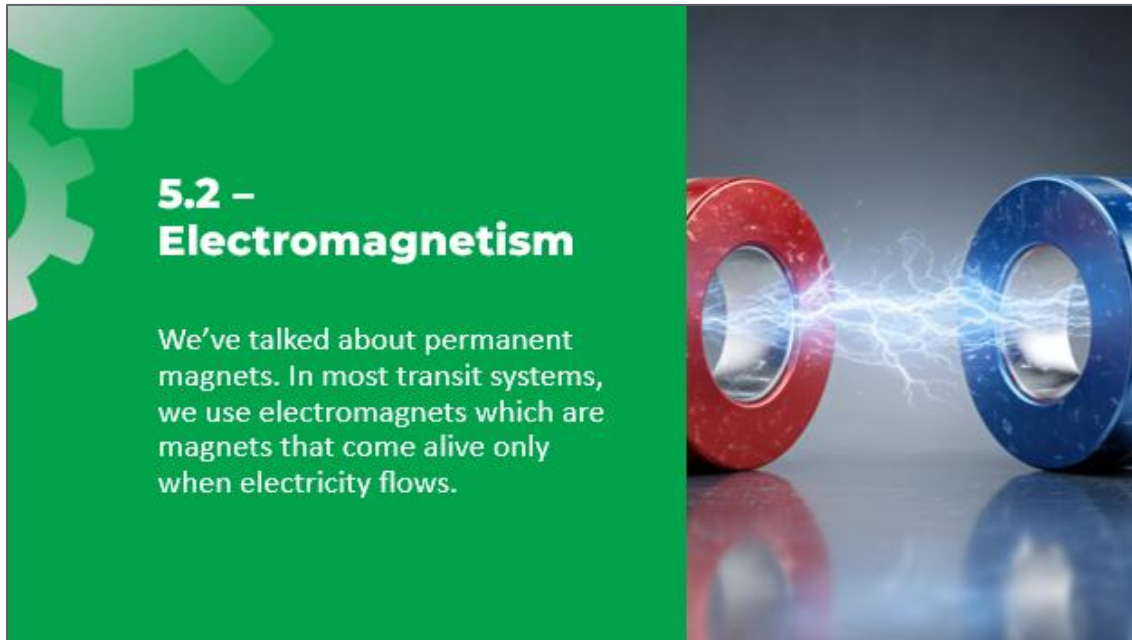
- ✓ **Magnetism:** A force that pushes or pulls certain materials.
- ✓ **Magnetic Field:** Invisible forces around a magnet, strongest at the poles
- ✓ **Poles:** Every magnet has North/South; opposites attract, likes repel
- ✓ **Sources:** Permanent magnets and electromagnets
- ✓ **Applications:** Motors, generators, locks, sensors, credit cards

Now that we understand magnetism, we'll explore how adding electricity creates electromagnetism.

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Notes:

- Understanding magnetism sets the stage for learning how electric currents and magnetic fields interact, leading to electromagnetism.

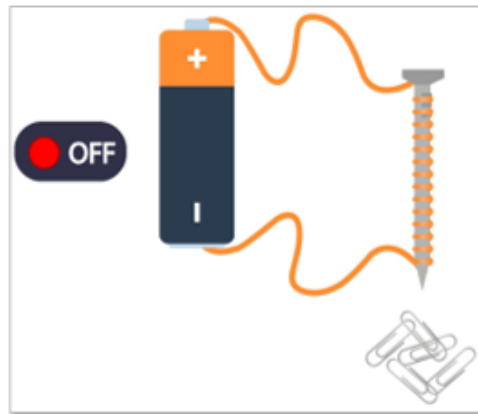


Notes:

- You've learned about permanent magnets.
- In most transit systems, we use electromagnets which are magnets that come alive only when electricity flows.

Introduction to Electromagnetism

- Happens when electricity and magnetism work together to affect charged particles
- When electricity moves through a wire, it creates a magnetic field around it.
- Used where electric current makes things move (motors, relays, etc.)



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Notes:

- **Electromagnetism** is one of the fundamental forces of nature, it happens when **electricity** and **magnetism** work together to affect charged particles.
- When electricity moves through a wire, it creates a magnetic field in circles around the wire – kind of like the ripples in a pond.
- When that field is used to move something, like turning a motor shaft or closing a switch, that's electromagnetism in action.
- Electromagnetism a core part of how modern electrical systems work.

Electromagnetism in Action



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Notes:

- Let's take a closer look at this process.
 - As you watch the video, jot down two interesting facts or one question you have about this process.
1. What interesting facts did you hear in the video?
 2. What questions do you have so far?

Video Link - <https://vimeo.com/1161149792/5404c11636>

Activity: Build an Electromagnet



Objective: Create an electromagnet and analyze impact of adding more copper loops and a fresh battery.

Materials (per group):

- 1 large iron nail (about 3 inches long)
- 2 feet of insulated copper wire (22–24 gauge)
- 1 D-cell battery
- Small paper clips or metal tacks
- Electrical tape (optional)

The screenshot shows a worksheet titled "Build an Electromagnet" with the following content:

Objective: Create an electromagnet and analyze impact of adding more copper loops and a fresh battery.

Materials (per group):

- 1 large iron nail (about 3 inches long)
- 2 feet of insulated copper wire (22–24 gauge)
- 1 D-cell battery
- Small paper clips or metal tacks
- Electrical tape (optional)

Instructions:

1. Wrap the wire tightly around the nail, leaving about 3 inches of wire free on each end. See the graphic on page 22.
2. Connect each free end of the wire to a battery terminal (one to the positive terminal and one to the negative terminal). Hold them in place or secure them with tape.
3. Test your electromagnet by touching the nail to paper clips or tacks.
4. Experiment with the number of loops:
 - a. Remove some wire (10) and test the electromagnet again.
 - b. Add more coils and test again.
 - c. Compare your results.

Follow-up questions:

Use the space below to write your answers to the following questions:

1. What happens when you add more loops?
2. (Optional) What happens when you use a fresh battery?

Notes and Learning Space

© 2026 Transit Workforce Center – Pg. 19

Notes:

- Your objective for this activity is to create an electromagnet
 - You will also analyze the impact of adding more copper loops and a fresh battery.



Activity

Build an Electromagnet

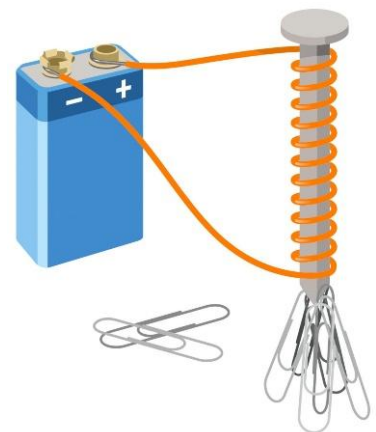
Objective: Create an electromagnet and analyze impact of adding more copper loops and a fresh battery.

Materials (per group):

- 1 large iron nail (about 3 inches long)
- 2 feet of insulated copper wire (22–24 gauge)
- 1 D-cell battery
- Small paper clips or metal tacks
- Electrical tape (optional)

Instructions:

1. **Wrap the wire** tightly around the nail, leaving about 3 inches of wire free on each end. Use the graphic as a guide.
2. **Connect** each free end of the wire to a battery terminal (one to the positive terminal and one to the negative terminal). Hold them in place or secure them with tape.
3. **Test** your electromagnet by touching the nail to paper clips or tacks.
4. **Experiment** with the number of loops:
 - Remove some wire coils and test the electromagnet again.
 - Add more coils and test again.
 - Compare your results.

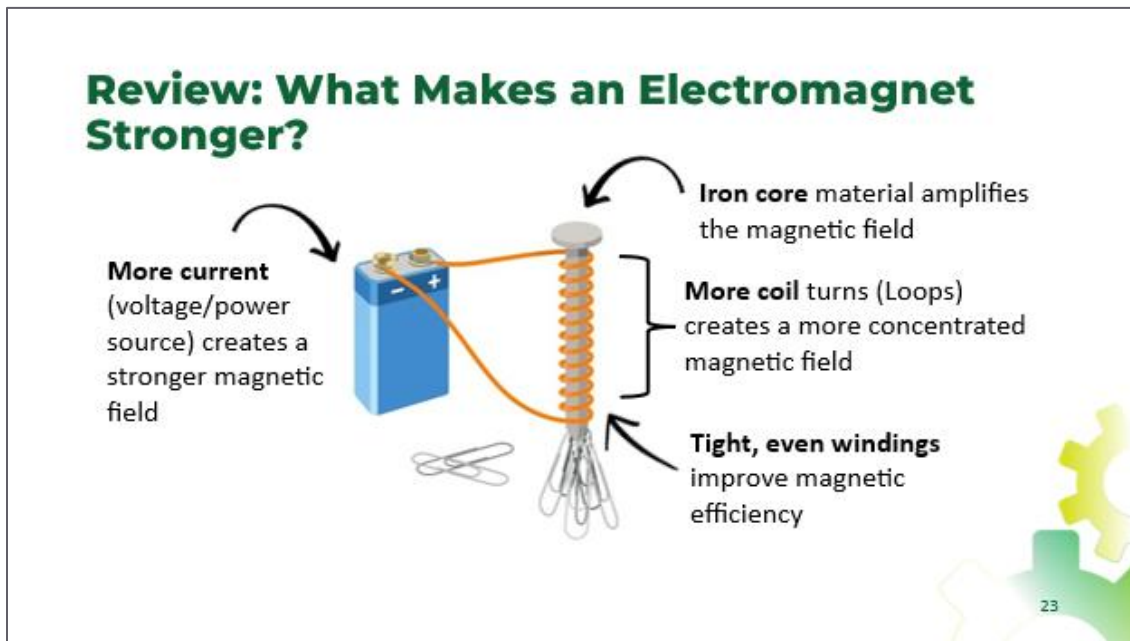


Follow up questions:

Use the space below to write your answers to the following questions:

1. What happens when you add more loops?
2. (Optional) What happens when you use a fresh battery?

Notes and Planning Space:



Notes:

- Let's review some key takeaways from our electromagnet activity.
- Several key factors determine how strong an electromagnet will be. If you increase any of these correctly, the magnetic field becomes stronger.
 1. First, current - the more electric current flowing through the coil, the stronger the magnetic field it produces. If voltage drops, magnetic strength drops.
 2. Second, the core material. Using iron inside the coil boosts the magnetic field because the iron itself becomes magnetized.
 3. Third, the number of coil turns. More loops mean the magnetic field becomes more concentrated and powerful.
 4. Fourth, the quality of the winding. Tightly wrapped, evenly spaced coils work more efficiently. Loose or damaged windings reduce magnetic strength.
- In real equipment like relays or solenoids, this matters. Low voltage equals a weak coil. A damaged or loose winding means poor magnetism. And weak magnetism can prevent the device from operating properly.
- So, remember: more power, more loops, and better core material equal a stronger electromagnet.

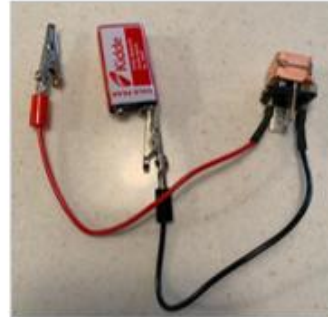
Demo: Electromagnets and Relays



Goal: Demonstrate how an electromagnet activates a relay.

Demonstration Steps

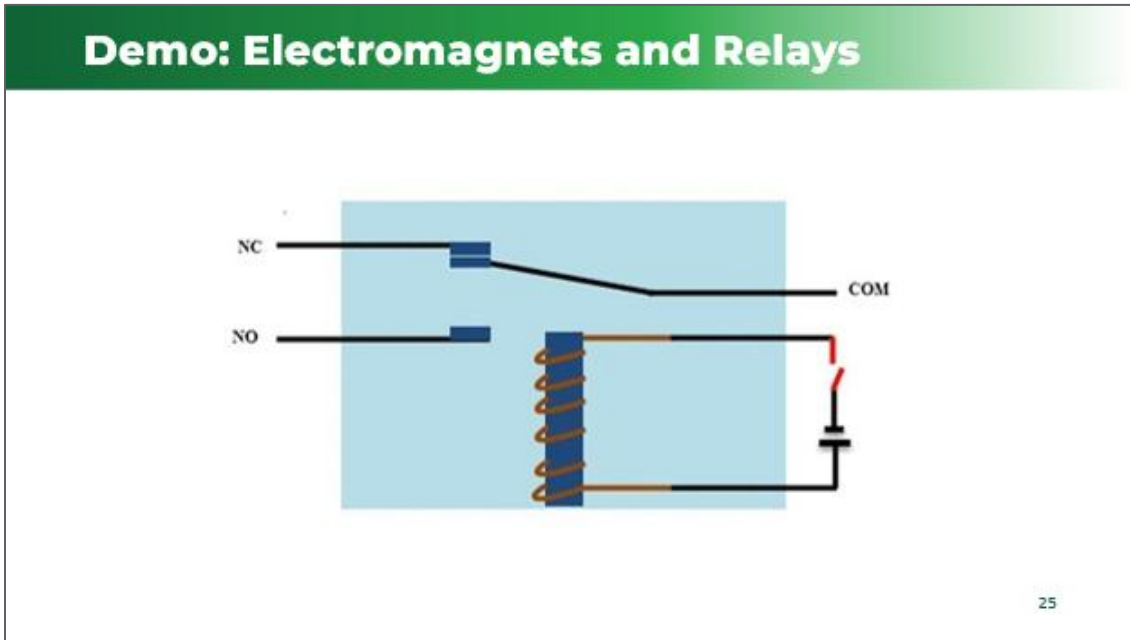
1. Connect wires to relay terminals 85 and 86.
2. Connect one wire to the battery.
3. Tap the second wire to the other battery terminal to make and break the circuit.
4. Observe the relay armature:
 - Energized → Armature pulls down
 - De-energized → Armature springs back



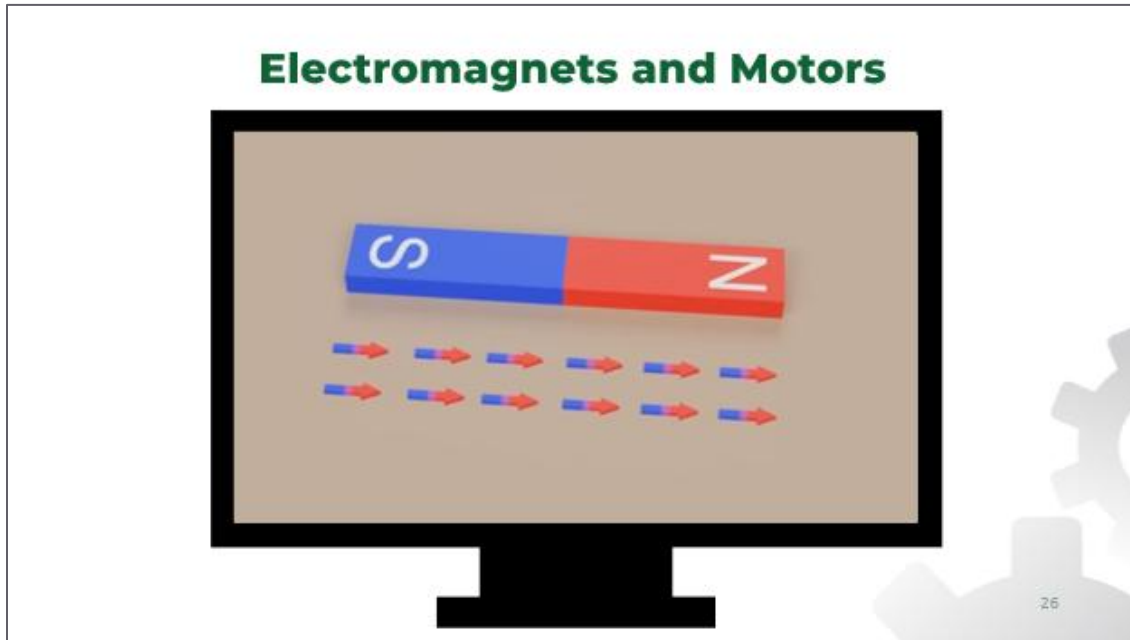
24

Notes:

- Let's build off of our activity by seeing how electromagnetism activates a **relay** — this is not just theory; this is how real equipment works.
 - First, let's connect the two wires to terminals 85 and 86 on the relay. These are the coil terminals.
 - Now let's connect one wire to the battery. When we tap the second wire to the other battery terminal, we complete the circuit and allow current to flow.
- Watch the armature closely. When current flows, the coil becomes an electromagnet and pulls the armature down.
- When we disconnect the wire, the magnetic field collapses immediately. The armature springs back to its original position. That movement is what makes or breaks the electrical contact inside the relay.
- What we're seeing: Current creates a magnetic field. The magnetic field creates motion. No current means no magnetism.
 - This is exactly why low voltage, or a weak coil can cause a relay to chatter, fail to pull in, or drop out unexpectedly.



**OPTIONAL DEMO*



Notes:

- This video will show us how electromagnets are used in motors. It starts with an overview of a simple circuit.
- Do you remember the three essential pieces of a simple circuit?
- Next, watch the video. Pay attention -- you'll be building your own motors in our next activity!

Activity: Build a Simple Motor



Directions: Create a simple motor that shows how electricity and magnetism interact. When you are finished building your motor, answer the following questions on pg. 2.

Materials:

- 1 C-cell battery
- Insulated copper wire
- 2 paper clips
- Sandpaper
- 2 small neodymium magnets
- Pencil or marker for wrapping wire
- Electrical tape



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Notes:

- Your objective for this activity is to create a simple motor to demonstrate electricity and how it interacts with magnetism.
- When you have finished building your simple motor, go ahead and answer the following questions on page 2 of your handout.



Activity

Build a Simple Motor

Directions: Follow the directions below to create a simple motor that shows how electricity and magnetism interact. When you are finished building your motor, answer the following questions on the next page.

Materials:

- 1 C-cell battery
- Insulated copper wire (magnet wire)
- 2 paper clips
- Sandpaper
- 2 small neodymium magnets
- Pencil or marker for wrapping wire
- Electrical tape

Steps:

1. **Make the Coil** - Wrap the wire around a pencil or marker about 10 times leaving a few inches free on each end. Carefully slide the coil off the pencil so it stays coiled.
2. **Prepare the Axles** – Straighten the loose wire ends so they stick out evenly on both sides of the coil. You can wrap the ends around the coil to help it keep its shape.
3. **Strip the Insulation** - Use sandpaper to remove *all* the insulation from one end of the wire and *only the top half* from the other end. This allows current to flow part of the time giving the coil its push.
4. **Build the Supports** - Bend paper clips into small stands and tape them to each end of the battery (one on the positive, one on the negative side). Use the photo for guidance.
5. **Add the Magnet** - Stack the magnets on top of the battery between the supports.
6. **Assemble the Motor** - Place the coil between the supports so its ends rest in the paper clip loops. The coil should balance and spin freely.
7. **Test It** - Give the coil a small spin. If connections are good, it will keep spinning on its own. You can also try changing the direction of the current.



Follow up questions:

Use the space below to write your answers to the following questions:

3. Using the concepts we have discussed in the module, what role(s) did each of the materials used to build the motor play?
4. Why does the motor continually rotate instead of making one rotation and stopping?
5. If you tried it, how did changing the direction of the current alter the motion of the motor?

Notes and Planning Space:

Applications of Electromagnetism

General

- Electric motors
- Relays
- Magnetic locks
- Speakers and microphones



Transportation

- Electric vehicle motors
- Magnetic levitation trains
- Regenerative braking systems



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Notes:

- Electromagnetism powers a huge range of everyday technologies—it's behind the motion, control, and sound in many electrical systems.
 - Some general examples include:
 - Electric motors, which convert electrical energy into mechanical movement.
 - Relays, which use magnetic fields to control electrical circuits.
 - Magnetic locks, often used in security systems.
 - Speakers and microphones, where electromagnets create or detect sound vibrations.
 - In the transportation industry, electromagnetism plays a big role in:
 - Electric vehicle motors
 - Magnetic levitation (maglev) trains, which glide without touching the track.
 - Regenerative braking systems, which turn motion back into electricity.
 - From powering motion to enabling communication and control, electromagnetism is at the heart of modern technology.
-
-
-
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Knowledge Check



What creates a magnetic field in an electromagnet?

A. The type of metal used on the coil

B. Heat from the wire

C. Electric current flowing through a coiled wire

D. The color of the wire insulation

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Knowledge Check



Which action will make the electromagnet stronger?

A. Increasing the electric current

B. Reducing the number of wire loops

C. Using a wooden core

D. Spreading the loops farther apart

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Knowledge Check



Which of the following is a real-world use of electromagnetism?

A. Solar panels

B. Magnetic locks

C. Diesel engines

D. Incandescent light bulbs

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Summary and What's Next

- ✓ **Electromagnetism:** Electricity flowing through a wire creates a magnetic field around the wire or coil.
- ✓ **Electromagnets:** Coiling wire around a core and adding current creates a controllable magnet.
- ✓ **Magnet Strength:** More current, more coil turns, an iron core, and tighter coils make the magnet stronger.
- ✓ **Applications:** Motors, relays, magnetic locks, speakers, EV motors, maglev trains, regenerative braking.

Now that we understand electromagnetism, next we'll explore how these principles create electricity.

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Notes:

- Understanding electromagnetism sets the stage for creating electricity.

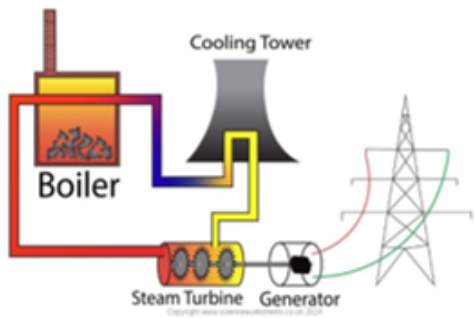


Notes:

- We've seen how electricity can create magnetism, but it also works the other way around.
- And moving a magnet can create electricity. Let's see how that happens.

Magnetism and Electricity

- At a power plant, energy moves through a system: *Boiler* → *Steam Turbine* → *Generator* → *Power Lines*
- The steam spins the turbine, and the turbine spins the generator.
- Inside the generator, a **spinning magnet changes the magnetic field** around coils of wire.
- That change creates **voltage** and produces **electricity**.



The diagram illustrates the energy conversion process in a power plant. It shows a closed loop of pipes connecting a boiler, a steam turbine, a generator, and a cooling tower. The boiler heats water to produce steam, which flows to the steam turbine. The turbine is mechanically connected to the generator. The generator produces electricity, which is transmitted through power lines. The cooling tower is used to condense the steam back into water, which is then pumped back to the boiler. The number 34 is visible in the bottom right corner of the diagram area.

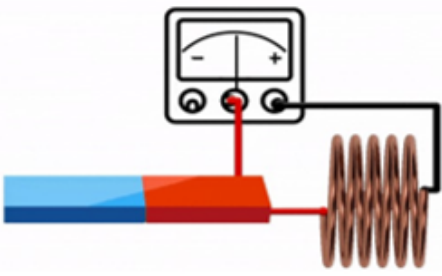
Notes:

- Think for a moment about a powerplant used to generate electricity. How does that happen?
 - a) On the left, the boiler heats water and produces steam.
 - b) That steam flows to the turbine and causes it to spin.
 - c) The turbine shaft is connected directly to the generator.
 - d) Inside the generator, a **magnet** spins inside coils of wire. As it spins, the **magnetic field** around the wires **changes**. That changing magnetic field induces **voltage**. And that voltage becomes the **electricity** that travels out through the power lines.

Faraday's Law of Induction

A changing magnetic field can induce an electric current in a conductor.

- A magnet moves near a coil of wire
- The magnetic field through the coil changes
- Causes electrons to move in the wire
- Electron movement creates electric current



The diagram illustrates Faraday's Law of Induction. It shows a bar magnet with a blue north pole and a red south pole moving to the right, as indicated by a blue arrow. The magnet is positioned near a coil of wire. The coil is connected to a galvanometer, which has a scale with a zero in the middle and minus and plus signs on either side. The galvanometer's needle is deflected to the right, indicating an induced current. The number 35 is visible in the bottom right corner of the diagram area.

Notes:

- The power plant scenario is a real-world example of Faraday's Law.
 - In 1831, Michael Faraday made a breakthrough discovery: A changing magnetic field can induce an electric current in a conductor. This became known as **Faraday's Law of Electromagnetic Induction**, and it's the principle behind how we generate most of the world's electricity today.
 - Whenever a magnetic field changes near a wire—either by moving the magnet, moving the wire, or changing the field strength—it causes **electrons to start moving**, creating an electric current.
 - Without this discovery, we wouldn't have **generators, motors, transformers, or power grids**.
 - Every time a generator or alternator turns, it's using Faraday's discovery.
 - This is the same effect your buses and trains rely on to charge systems while running.
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Faraday's Law of Induction

- The faster the magnet moves, the more current is produced.
- Faster change = more voltage
- Generators and motors move quickly because more movement means more electricity

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Notes:

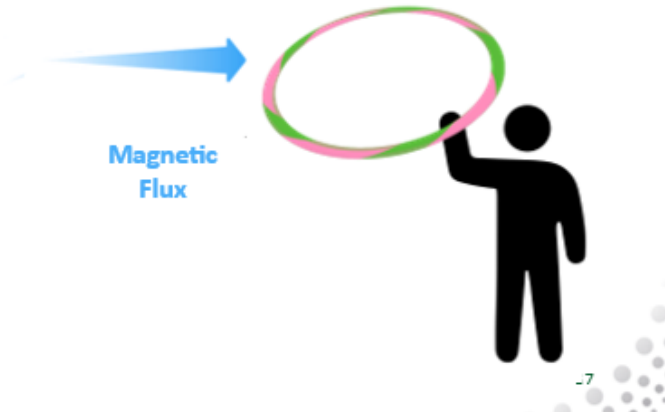
- Faraday's Law says that the voltage induced in a circuit is proportional to how fast the magnetic flux changes through it.
 - In other words: **Faster change = more voltage.**
- If the magnetic field around a coil changes quickly by moving a magnet faster or changing the field strength sharply, you get a higher voltage.
- This is why generators spin so rapidly: more movement means more electricity.
- Faraday's Law is one of the cornerstones of electrical generation, helping explain everything from small motors to massive power plants.

 **Analogy: Magnetic Flux**

Magnetic Flux is the amount of magnetic field passing through an area.

Straight hoop = more flux

Tilted hoop = less flux



The diagram illustrates the concept of magnetic flux using a hula hoop analogy. A blue arrow labeled "Magnetic Flux" points from the left towards a hula hoop held by a black silhouette of a person. The hoop is tilted, showing its circular face at an angle. The hoop is colored with a gradient from green to pink. The text on the left explains that a straight hoop (perpendicular to the flux) captures more flux, while a tilted hoop captures less. A small "-7" is visible in the bottom right corner of the diagram area.

Notes:

- Magnetic flux is a way of describing how much magnetic field passes through a loop of wire.
- **Think of it like this:** Imagine holding a hula hoop in the wind.
- The wind represents the magnetic field. The amount of wind passing through the hoop represents magnetic flux.
 - If the wind is weak, only a little passes through. If the wind is strong, more passes through.
- If you turn the hoop sideways, less wind passes through.
 - If the wind suddenly gusts or changes direction, the amount passing through the hoop changes.

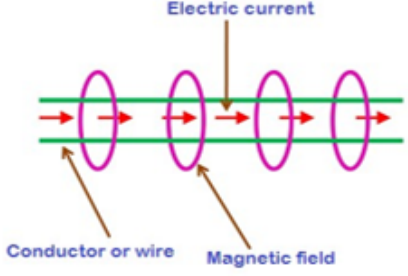
Magnetic Flux

Perpendicular vs. Parallel

- Perpendicular magnetic field = maximum flux
- Parallel magnetic field = zero flux

Constant vs. Changing

- Constant = No electron movement, no current
- Changing = Electron movement, current flows, electricity created



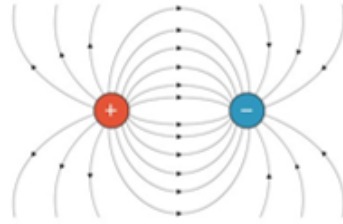
The diagram illustrates a conductor (a green horizontal line) with an electric current flowing to the right, indicated by red arrows. Purple ovals represent magnetic field lines that are perpendicular to the conductor. Labels include 'Electric current' pointing to the red arrows, 'Conductor or wire' pointing to the green line, and 'Magnetic field' pointing to the purple ovals. The number '38' is visible in the bottom right corner of the diagram area.

Notes:

- You can think of magnetic flux like counting how many magnetic field lines pass through a surface.
- There are several things that can influence magnetic flux.
- *Perpendicular vs. Parallel:*
 - If the magnetic field is **perfectly perpendicular** to the surface ($\theta = 0^\circ$), you get the **maximum flux**. If the field is **parallel** to the surface ($\theta = 90^\circ$), the flux drops to **zero**.
- *Changing vs. Constant*
 - Whether the magnetic flux is changing or constant is critical to producing electricity.
 - If the magnetic flux stays **constant**, nothing happens—there's no electric field, and **no current** is created.
 - But if the magnetic flux **changes**—whether by moving a coil, changing the field strength, or tilting the surface—an electric field is generated.
- That electric field **pushes charges**, and **current** starts flowing through the wire.

Magnetic Fields

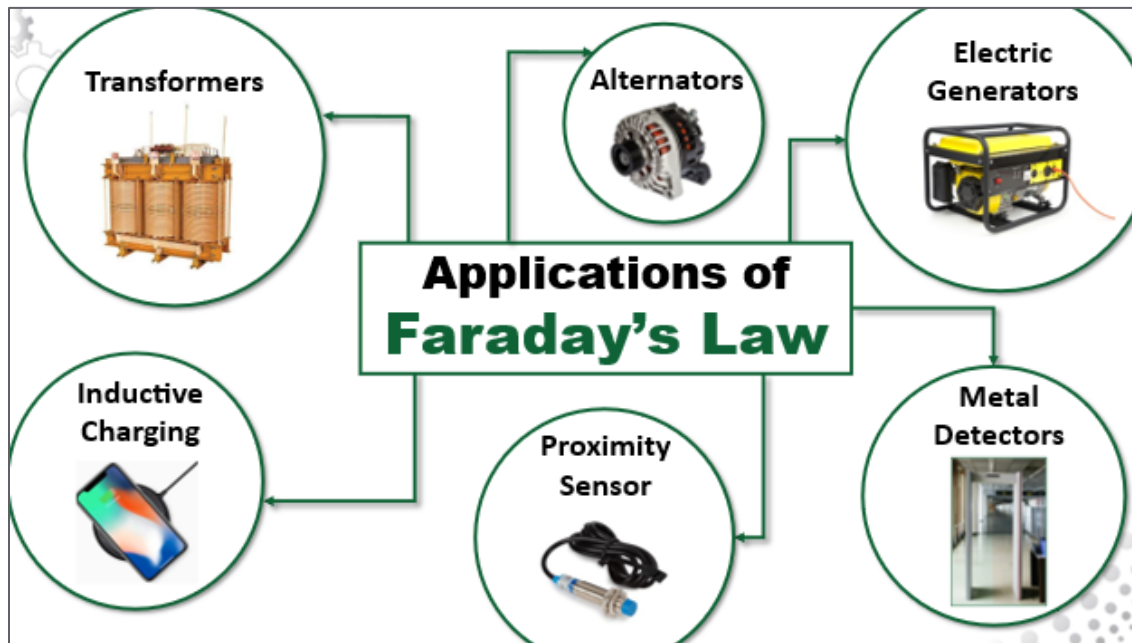
- Changing **magnetic fields** create **electric fields** which moves electrons.
- An **electric field** is the space around a charged object where other charges feel a force.
- Electric fields are invisible but can be represented by arrows.
- Direction: **Away** from **positive** charges, **toward negative** charges.



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Notes:

- To understand electromagnetic induction, we need to understand electric fields, because electric fields are what actually move charges.
 - An **electric field** is the space around a charged object where other charges experience a force. Even though we can't see it, the field is what pushes or pulls charges through space.
 - Electric fields are a fundamental force, similar to gravity.
 - Gravity acts on mass, while electric fields act on electric charge.
 - We represent electric fields with arrows to show direction. The arrows point **away** from **positive** charges and **toward negative** charges, helping us visualize how the force would act on another charge placed nearby.
 - The stronger the charge, the stronger the electric field—just like a larger planet creates a stronger gravitational pull. This idea becomes especially important when we talk about electromagnetic induction.
 - **Faraday** showed that a changing magnetic field creates an electric field, and that electric field is what drives current. So, as we move forward, remember this:
 - Magnetic fields don't directly "push electrons."
 - They create electric fields—and electric fields are what cause charges to move.
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Notes:

- Faraday's Law explains how a changing magnetic field can create electricity. What makes this powerful is how widely it's used in real systems.
 - a) **Transformers** rely on changing magnetic fields to increase or decrease voltage so electricity can be transmitted efficiently and used safely.
 - b) **Alternators** and **electric generators** convert mechanical motion into electrical energy. As components rotate within a magnetic field, voltage is induced and current is produced.
 - c) **Inductive charging** uses changing magnetic fields to transfer energy without direct contact, like wireless phone chargers.
 - d) **Proximity sensors** detect metal objects by sensing changes in a magnetic field, which induces a measurable signal.
 - e) **Metal detectors** also use electromagnetic induction. When metal disrupts the magnetic field, a current is induced and detected.
- All of these applications come back to the same principle: a changing magnetic field creates an electric field, and that electric field drives current.

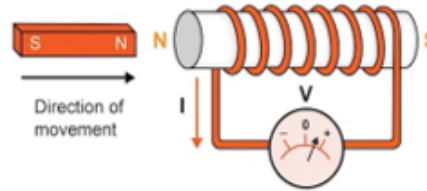
Demo: Faraday's Law



Goal: Show that moving a magnet near a coil creates electricity, and that faster movement produces a bigger effect.

Steps:

1. Connect coil ends to the LED or multimeter.
2. Move the magnet slowly through the coil.
3. Observe a small flicker/needle jump
4. Move the magnet faster. Compare the difference.
5. Try different magnet orientations or multiple passes.



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Notes:

- Once you have seen the demo, review and answer the following questions:
 1. Why does the meter only jump when the magnet is moving?
 2. How does speed affect the voltage?
 3. Where do we use this principle in transit systems?

Knowledge Check



What key action causes electricity to flow in a coil of wire?

A. Keeping a magnet still beside the coil

B. Moving a magnet near the coil

C. Heating the coil

D. Adding more wire to the coil

Knowledge Check



According to Faraday's Law, what increases the amount of current or voltage produced?

A. Using a stronger battery

B. Reversing the coil direction

C. Moving the magnet faster

D. Adding more insulation

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Knowledge Check



Why does moving a magnet past a coil make electricity?

A. The coil stores energy like a battery

B. The movement creates an electric field that pushes electrons

C. The magnet rubs electrons off the wire

D. The wire becomes permanently magnetized

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Summary and On the Job

Key Ideas:

- Magnets have poles — like poles repel, opposite poles attract
- Magnetic fields act across space, even without contact
- Moving electric charges create magnetic fields
- Changing magnetic fields create electric current (Faraday's Law)

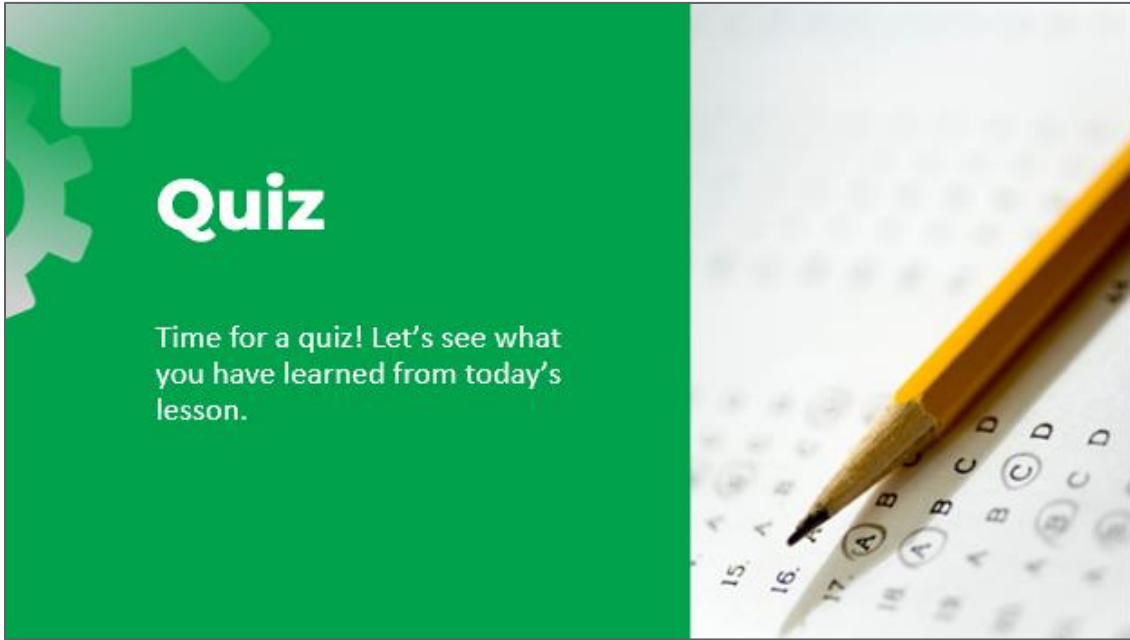
On the Job:

- Relays, contactors, and solenoids rely on electromagnets
- Motors and generators rely on magnetic fields
- Understanding magnetism helps you troubleshoot and stay safe

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Notes:

- Let's step back and look at the big picture of what we covered in this module.
 - First, **magnets have poles**. Like poles repel, and opposite poles attract. That push and pull is the foundation of everything we discussed.
 - **Magnetic fields** act across space. They don't require physical contact to create force.
 - When electric charges move, they create magnetic fields. And when **magnetic fields** change, they can create electric current. That's the principle behind **Faraday's Law**.
 - This isn't just theory. On the job, **electromagnets move relays** and contactors. Motors turn electrical energy into motion. **Generators** and **alternators** produce electricity using magnetic fields.
 - When you understand how magnetism and electromagnetism work, you're better prepared to **diagnose** issues, **repair** systems correctly, and **work safely** around energized equipment.
- Everything in this module connects back to one idea: electricity and magnetism are not separate — they work together in nearly every electrical system you touch.



Revisiting the Objectives

- Explain basic magnetism, including magnetic fields, poles, and magnetic materials.
- Explain how electromagnetism works and describe how electricity and magnetism are related.
- Describe how an electromagnet works and what affects its strength.
- Explain how electromagnetism is used in transit systems such as relays, motors, and generators.
- Explain Faraday's Law of induction and how changing magnetic fields are used to generate electricity in real-world systems.

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Notes:

- If you were explaining today's objectives to someone else, how would you summarize what they mean and why they matter?
- Which of today's objectives do you feel most confident about? Which were most challenging? Explain your reasoning.
- Can you give an example of how you could apply one of today's objectives in a real-world situation?
