kemtec™
excite. encourage. inspire.

Let's Build Electromagnets

15-201, 15-205

AquaPhoenix Scientific is committed to developing science materials that challenge students. Kemtec kits are designed to promote:

- Alignment to Next Generation Standards
- Enhancement of teacher instruction through exceptional materials
- Engaged hands on learning
- Learning through inquiry
- Mastery of core science concepts
- Focus on STEM curriculum and career exploration
- Problem solving
- Cooperative teamwork
- Real world application
- Safety
- Assessment and accommodations for all students

A rubric is recommended for assessment purposes. We suggest that both teacher and student assessment is used. Providing a rubric prior to lessons allows students to better understand the expectations of the assignment.

Let’s Build Electromagnets
Kemtec 15-205/15-201

Contents

Materials Included and Needed

Materials Included in Class Kit 15-205

The materials in this kit are sufficient for 24 students working in 6 groups of 4 students.

Instructor’s Manual	Dowel rod 1/2" x 3" (6)
Reproducible Student Data Sheets	Alligator clip leads, pair (3)
6 V lantern battery (3)	Wire strippers/cutters (2)
Magnet wire, spool, 30 Gauge (3)	Masking tape
Box of steel paper clips, box 100 (2)	Steel washers, pk100 (2)
Steel nail, 3" (6)	Sandpaper
Steel bolts (6)	Weigh Dish, Large (3)
Iron Filings	

Materials Included in Single Kit 15-201

Instructor’s Manual	Dowel rod 1/2" x 3"
Reproducible Student Data Sheets	Alligator clip leads, pair
6 V lantern battery	Wire strippers/cutters
Magnet wire, 30 Gauge	Masking tape
Box of steel paper clips, box 100	Steel washers, pk100
Steel nail, 3"	Sandpaper
Steel bolt	Weigh Dish, Large
Iron Filings	

Note: The materials supplied are for use only with the exercises described in this manual.
Kemtec disclaims responsibility for any other uses of these materials.

Materials Required But Not Included:

Impact Goggles	Rulers

Impact goggles must be worn by all students during the activities in this kit to protect the eyes.

Standards, Grade Level, Objectives

National Standard for Grade Levels 4-6

Correlation to Specific Standards:

- Understanding Science through Engineering Practices
- Engineering Design: Grade 3-5 (Define a problem, Research and Consider Multiple Solutions, Generate and Test Solutions, Optimize Solutions through Revisions.)
- Grade 3-5: PS2.A Forces and motion & PS2.B Types of interactions
- Grade 3-5: PS3.A Definitions of energy & PS3.B Conservation of energy and energy transfer
- Grade 3-5: PS3.C Relationship between energy and forces
- 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.

Learning Objectives:

Students will

- Build a simple electromagnet and quantitate its strength.
- Build and compare the strengths of electromagnets made of different materials.
- Vary the design of the electromagnet to optimize its strength.
- Analyze the qualities of the electromagnets built in the class.
- Design and build the strongest electromagnet possible using the components provided in this kit.
- Design, evaluate, and revise their projects to optimize their solution.
- Realize the importance of electromagnets in our everyday lives.

The Ultimate Goal: This series of experiments has been designed to prepare students for learning additional skills in the engineering process.

Engineering Design

- Systematic problem solving
- Students should explicitly learn how to engage in engineering design practices to solve problems"

Iterative Cycle

- Enable opportunity for applying science knowledge
- Focus on failures as opportunity for improvement and redesign
- Opportunity for creativity and innovation

Instructor’s Quick Reference Timeline & Pre-Lab Information

Instructor's pre-lab preparation:

- Prior to the experiments, the teacher should present the concepts in the background section of this manual.
- Student research projects including reports to the class are recommended to make students aware of how extensively electromagnets are used in current technology.
- Pre-lab set up – 5 minutes to set out materials provided in this kit. You will want to keep the 6 V batteries, alligator clip leads, and wire cutters in a common area so that these items may be shared.

Student's pre-lab preparation:

- Students should be familiar with the concepts in the background material section of this manual prior to doing the experiments. They should also become familiar with the key terms.

Time Requirements:

- Two lectures to cover background material should precede the laboratory experiments.
- Four thirty minute class periods are required for the experiments; this unit is divided into four different experiments which take approximately one thirty minute class period each.

LESSON PLANS

GRADE LEVELS:	
Grade 4-6	
UNIT NAME:	
Let’s Build Electromagnets	
LESSON PLAN TITLE: The Main Essential Question	DAY WITHIN UNIT: 1-7
• How can students “explicitly learn how to engage in engineering design practices to solve problems”?	
NATIONAL STANDARD(S) ADDRESSED	
• Understanding Science through Engineering Practices • Engineering Design: Grade 3-5 (Define a problem, Research and Consider Multiple Solutions, Generate and Test Solutions, Optimize Solutions through Revisions.) • Grade 3-5: PS2.A Forces and motion & PS2.B Types of interactions • Grade 3-5: PS3.A Definitions of energy & PS3.B Conservation of energy and energy transfer • Grade 3-5: PS3.C Relationship between energy and forces • 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.	

CONTENT MASTERY OBJECTIVES:

This series of experiments has been designed to prepare students for learning additional skills in the engineering process.

Students will

- Build a simple electromagnet and quantitate its strength.
- Build and compare the strengths of electromagnets made of different materials.
- Vary the design of the electromagnet to optimize its strength.
- Analyze the qualities of the electromagnets built in the class.
- Design and build the strongest electromagnet possible using the components provided in this kit.
- Design, evaluate, and revise their projects to optimize their solution.
- Realize the importance of electromagnets in our everyday lives.

LANGUAGE OBJECTIVE(S):

Students will learn to use the terminology associated with electricity and electromagnets, and practice using the terminology as they engage in discussions with their classmates during the lessons provided.

VOCABULARY

Tier 1: Basic Words	Tier 2: Appear Frequently	Tier 3: Multiple Meanings	Tier 4: Science Specific
Design		Current	Permanent magnet
Build		Field	Temporary magnet
			Electric current
			Electromagnet
			Magnetic field
			Magnetic core
			Electric motor

MATERIALS NEEDED (FOR EACH GROUP OF STUDENTS)

Reproduce student pages from the instructor's manual, including the Experimental Procedures, Student Data Table, Build the Strongest Electromagnet Design Sheet, and Student Worksheet.

6 V lantern battery*	Dowel rod, ½" x 3"	Magnet wire spool, 30 gauge
Alligator clip leads*	Paper clips, box/100*	Wire strippers/cutters*
Masking tape*	Steel nail, 3"	Steel bolt
Steel washers pk/100*	Sand paper	Weigh dish
Impact goggles	Ruler	

See experimental protocols for kit components required for individual experiments. All required materials, except goggles and rulers are provided in the kit.

INSTRUCTIONAL TECHNOLOGY AND ONLINE RESOURCES

How Electromagnets Work: http://science.howstuffworks.com/electromagnet.htm

The Earth's Magnetic Field: csep10.phys.utk.edu/astr161/lect/earth/magnetic.html

http://adventure.howstuffworks.com/outdoor-activities/hiking/compass1.htm

Engineering Design Process: http://www.teachengineering.org/engrdesignprocess.php

NGSS - The Next Generation Science Standards: www.nextgenscience.org/next-generation-science-standards

Create or find a word cloud or word splash online using electromagnets vocabulary, then have students link several words from the cloud into sentences. www.wordle.net, www.wordclouds.com

LESSON ACTIVITIES WITH DAILY ESSENTIAL QUESTIONS

Day 1: The Essential Question: What is the importance of electromagnets in everyday life?

- Apply an activating strategy such as a word splash or an anticipation guide about electromagnets.
- Lecture 1, cover background materials preceding the laboratory experiments. Introduce the topic and teach Temporary and Permanent Magnets and What is an Electromagnet?
- Assign “Electromagnets in the World Around Us Research Project”: Bring in a list of five interesting items that contain electromagnets to share with the class.
- Share with students that there will be a team competition at the end of the unit to compare engineered electromagnet designs.

Day 2: The Essential Question: How Does the Earth’s Magnetic Field Relate to Studying Electromagnets?

- Lecture 2, cover background materials preceding the laboratory experiments. Teach concept of Magnetic Field. Demo the magnetic field using iron filings, if possible. Discuss the Earth’s Magnetic Field.
- Allow students to share their list of electromagnets by writing on the board if possible. Make a count of items the class found.
- Review vocabulary for the unit.

Day 3: The Essential Question: How can we build an electromagnet to solve a problem and quantitate its strength?

- Introduce the Engineering Design Process
- Systematic problem solving
- Enable opportunity for applying science knowledge
- Focus on failures as opportunity for improvement and redesign
- Opportunity for creativity and innovation

Day 4: The Essential Question: How does changing the materials used to build an electromagnet affect its function?

- Experiment 1: Electromagnet Core Materials
- Experiment 2: Electromagnet Core Thickness

Day 5: The Essential Question: How does changing the design of an electromagnet change its function?

- Experiment 3: Electromagnet Coil Count

Day 6: The Essential Question: How can we discover the properties of the strongest electromagnet by experimentation?

- Experiment 4: Build the Strongest Electromagnet

Day 7: The Essential Question: What would you change to improve your team's electromagnet?

- Electromagnet Design Competition – Which Engineering Team's Electromagnet Design picks up the most magnets?

ACCOMODATIONS

Have the students draw a picture of the magnetic field. Identify the direction of the current in the magnetic field by drawing arrows in the proper direction on the picture.

TEAM BUILDING

The teacher will encourage students to assist one another with reading and interpreting the building instructions as part of the team building activities. The teacher will encourage the students to teach one another and to engage in discussions and brainstorming activities throughout the unit.

HOMEWORK:

EXTENDING LEARNING BEYOND THE CLASSROOM

Online research resources are also assigned as homework or for computer lab class time for enriching class discussions.

Students should be encouraged to discuss the concepts they are learning outside of class.

"Electromagnets in the World Around Us" may be assigned as a research topic.

ADDITIONAL STUDENT READING:

EXTENDING LEARNING BEYOND THE CLASSROOM

Amazing Magnets. Hutchinson. 2009. Newmark Learning. ISBN:9781607193036 16 pages

Investigating Electromagnetism. Cregan. 2007. Shell Education. ISBN:9781433391040 34 pages

Electromagnetism, and How it Works (Scientific American) Tomecek. 2007. Chelsea House Publications. ISBN:9780791090527 72 pages

Electricity and Magnetism Science Fair Projects Gardner. 2010. ISBN:9780766034181 160 pages

How Stuff Works. Brain. 2010. Chartwell Books ISBN:9780785824329

Background Information

The Earth's Magnetic Field

Have you ever heard of the North Pole and the South Pole? These are actually magnetic poles of the Earth we live on. Did you know that the Earth is one great big giant magnet with an iron core? Have you ever used a compass? A compass has a small magnet inside of it, which is able to detect the magnetic field of the Earth.

Permanent and Temporary Magnets

Magnets are materials that produce a force field which attracts or repels materials which contain iron. Magnets do not have this same effect on other materials such as paper, rubber, and plastic, which do not contain iron. A magnetic field is not something that is visible to the eye, but the attraction and repelling of magnets within the field is readily visible. Permanent magnets are made of materials that always have a magnetic field. Temporary magnets are made of materials that only magnetize in the presence of an external magnetic field. Once the magnetic field ceases to exist, temporary magnets no longer exhibit magnetic properties such as attracting iron containing compounds or expressing polarity and attracting or repelling other magnets.

Most of the time when you are thinking of a magnet, you are thinking of permanent magnets; those materials that remain magnetic even when not in the presence of a magnetic field or an electrical current. These magnets are made of ferromagnetic materials, such as alnico and ferrite, which are processed to align their internal structures so that they are very difficult to demagnetize. Temporary magnets are made of materials such as annealed iron, which do not hold magnetism well. While there are magnetic materials such as lodestones, which occur in nature, most magnets are man-made.

What is an electromagnet?

An electromagnet is a temporary magnet which exists when a current or electricity goes through a wire coil, causing a magnetic field. Unlike permanent magnets, electromagnets only have magnetic properties when electricity is passing through them. Thus, they are truly temporary magnets. Electric current produces magnetism as it causes electrons to move. Electrons are surrounded by forces creating an electric field. A coil of wire near a magnetic field does not create electricity unless the magnetic field is changing. If the magnetic field changes due to movement of a magnet or spinning of the wire, an electric current is produced in the wire due to the magnetic field caused by the flow of electrons. So, an electric current can produce a magnet and a magnet can produce an electric current.

It is fairly simple to build a basic electromagnet. You just wrap some insulated copper wire around an iron core. Then, you create an electric current by attaching a battery to the ends of the wire coils around the core. When the current flows through the wire, the magnetic field magnetizes the inner core, enabling a temporary magnet to form. When the current is disconnected, the magnetic field ceases to exist and the iron core loses its magnetic properties.

You will use electricity from a battery to make an electromagnet. The battery will be the source of electric current to provide the magnetic field requirement. While magnets are polar; having north and south ends, you will not have to be concerned about which end of your electromagnet you attach to the positive terminal of the battery and which end of your electromagnet you attach to the negative terminal of the battery, because which ends you connect just changes the direction of the magnetic field or the polarity of the electromagnet. If you place a compass at the end of the electromagnet after it has been hooked up to the battery, you can determine the electromagnet's north and south poles. If you change the battery connection, you can detect a reversal of the poles of the electromagnet with the compass.

You will investigate several properties of electromagnets to see how they affect the strength. Adjusting the components you use to make your electromagnet; the thickness and type of the wire you use in your coil, the size and material the core is made of, and the amount of current going through the coils will all affect the strength of your electromagnet. Once you have examined some of these properties in these lab investigations, you should have a good understanding of how electromagnets work and what properties affect their strength.

Magnetic Field

The flow of electric current through a wire induces a magnetic field. Although the magnetic field is not visible, the effects of the field can be visualized using iron filings. The magnetic field may also be experienced by testing the surrounding area for magnetic attraction and repulsion. In this way, the magnetic fields around a wire with an electric current flowing through it have been diagramed. The fields appear like a series of waves coming off of the wire. If you have access to iron filings, you may demonstrate the same effect of a magnetic field by placing a permanent magnet on a sheet of paper and sprinkling the filings around the magnet. The tiny iron filings line up along the magnetic field. See figure 1. The same effect is seen in a wire that has a current flowing through it. The magnetic field lines can be diagrammed in a similar way.

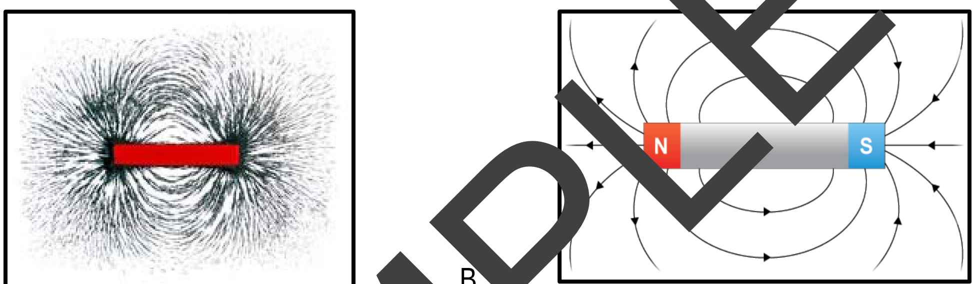
A.  B.

Figure 1. A. To visualize a magnetic field, sprinkle iron filings around a permanent magnet. B. A diagramatic representation of the magentic field surrounding a magnet. Notice that the magnetic field lines arise from the north-pole (N) and end at the south-pole (S) and that the greatest concentration of the magnetic field is at the poles. http://www.bbc.co.uk/bitesize/ks3/science/images/magnetic_field.jpg

Remember that the magnetic field is not just two dimensional as it appears on the paper; it is actually three dimensional and surrounds the magnet or wire. When an electric current flows in a wire toward you, the magnetic field created by the current flows in a counter-clockwise direction around the wire. You may remember this by using Right-Hand Rule #2 of physics. Point your right thumb in the direction of the current flow in a wire, and your fingers will curl in the direction of the magnetic field as you form a fist. This is actually a good visual, as the magnetic field is three dimensional like your fingers. Now, if you reverse the direction in which the current flows, say by attaching the wire to the opposite poles of the battery, you will change the direction of the magnetic field so that it flows in a clockwise direction. Because of this directionality of the induced magnetic field, when you are making the coils in your electromagnets, you must wrap the wire around your magnetic core only in one direction. If you wrap wire on your electromagnet core partly in one direction, and partly in the opposite direction, the magnetic fields from the two sections will effectively cancel each other out and your electromagnet will not work.

Electromagnets in the World Around Us

What common items in our lives utilize electromagnets? Did you know that doorbells, microwave ovens, electric motors, televisions, and even toasters utilize electromagnets to work? Electromagnets are a big part of our everyday lives. Electromagnets are also elemental components of transformers, junk yard electromagnets, speakers, and all kinds of other electronic and medical equipment. Your teacher may assign a research project for you to investigate technological advances in our society that utilize electromagnets and share what you learn with the rest of your class.

The Engineering Design Process

The Engineering Design Process is a stepwise process of development and evaluation which engineers use to analyze problems they are working on. It is something like the Scientific Method which scientists use in their experimental process. Both the Engineering Design Process and the Scientific Method help guide the logical process of evaluating problems and developing solutions.

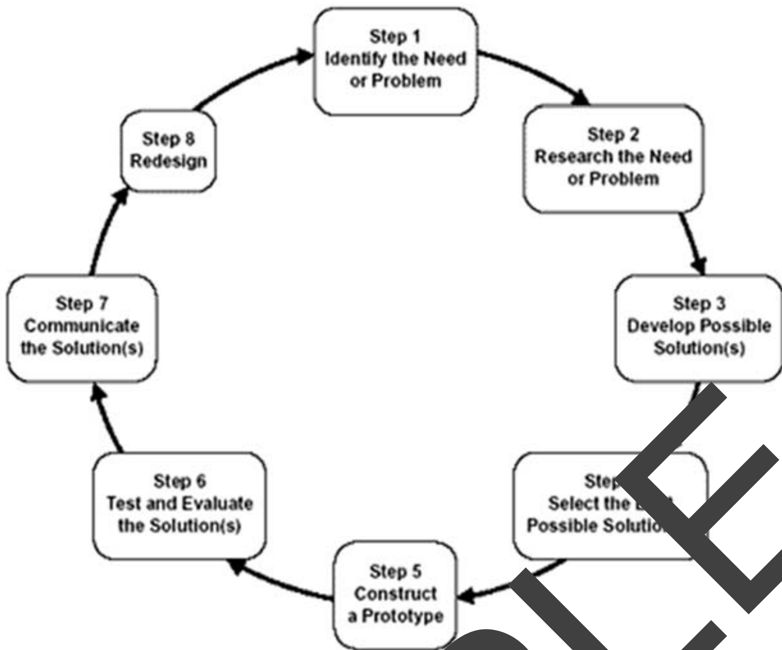
Most students can identify the standardized steps of the scientific method used by a scientist to divide an experiment into simplified parts for analyzing a question or problem for which they are seeking an answer. Although the terminology used may differ from one school to another, the process used by a scientist includes specific parts: a hypothesis, materials, methods, results, discussion, and conclusion. Like this method helps scientists design experiments in a very organized manner, the Engineering Design Process is an established method engineers use to approach problems in an organized manner. These established processes also help scientists and engineers to interpret or repeat work done by others.

While different engineers may use slightly different processes and terminology, the organization of the thought process used by engineers is well established. The Engineering Design Process is sometimes simplified into a five step process described as Ask, Imagine, Plan, Create, Improve. It can be expanded to an eight step process described as Define Problem, Research Problem, Brainstorm Solutions, Build Model or Prototype, Test Your Solution, Share Your Results, and Modify and Re-Design. Basically, the steps of the process follow this general scenario:

- Define the problem to be solved and the standards to be used to determine optimal performance.
- Research the problem, limitations, and what others have already done.
- Brainstorm possible solutions with other engineers.
- Select the best possible solution for the problem as a team.
- Design the model or prototype solution.
- Test the planned solution.
- Publish or communicate the results of the test.
- Re-evaluate your results and improve the prototype based on the test data and communication feedback.
- Test the improved prototype and continue the evaluation and improvement process until the standard performance has been achieved.

Since the Engineering Design Process is purposefully repetitive, the process is often diagrammed as a continuous cycle (Figure 1).

Figure 1
Steps of the Engineering Design Process



http://www.doe.mass.edu/frameworks/scitech/2001/standards/strand4.html

The design process can be used to improve upon the technology of the entire project at once, or to focus on and evaluate only a single component of a project at one time. The design process can be used over and over again within a project. Solutions may be improved upon continually using this same method.

Engineers tend to work on projects with others in a group. They save a significant amount of time by discussing ideas together and coming up with well thought out processes prior to dividing projects into areas of expertise. They may work on entire projects together, or divide projects up into parts and work as individuals or in smaller teams. After a solution is tested, they regroup to re-evaluate processes for improvements. As you work though the Build an Electromagnet Experiments, you will be encouraged to research and discuss the processes you engage in with other students, and work like engineers in your thought processes. You will be encouraged to discuss what you feel are the best solutions for making improvements to your original projects. Sharing ideas is an important part of being in an engineering team.

Key Words

permanent magnet – magnetic material that remains magnetic even when it is no longer in a magnetic field or being induced by an electrical current.

temporary magnet – a piece of iron containing material that acts as a magnet only when in the presence of an induced magnetic field caused by a permanent magnet or an electric current.

electric current – the flow or movement of electric charge, generally through a wire or a circuit.

electromagnet - a temporary magnet produced in a magnetic field generated by an electric current.

magnetic field – the lines of force surrounding a permanent magnet or a charged particle

magnetic core – a piece of iron containing material used inside of an electromagnet to increase the magnetic strength of the coil.

electric motor – a device that uses electrical energy to produce movement, or mechanical energy.

Reference Materials

http://www.infoplease.com/dk/encyclopedia/electromagnetism.html

http://www.howstuffworks.com/electromagnet.htm

http://electronics.howstuffworks.com/motor4.htm

http://www.bbc.co.uk/bitesize/ks3/science/energy_electricity_forces/magnets_electric_effects/revision/1/

Topics for Further Discussion

- Heat will be generated in the electromagnets, especially the steel nail used in Experiment 2. Talk about the loss of energy as heat and how this loss may be reduced.
- Discuss the difference between coil count and the amount of wire in the comparison being made in Experiment 2. The core thickness affects the amount of wire in the electromagnet. For this reason, one might choose to compare the same amount of wire in the coils vs. the same number of coils.
- Discuss the difference in the core in terms of diameter, length, and iron content and how each aspect would affect the strength of an electromagnet.

Experimental Procedures
Experiment 1: Electromagnet Core Materials

Essential Question: How does changing the materials used to build an electromagnet affect its function?

Figure 2. Core materials.

Your group will need:

Steel bolt	Dowel rod 1/2" x 3"
6 V lantern battery (share)	Alligator clip leads (for battery)
Magnet wire	Wire cutters (share)
Steel washers	Masking tape
Steel paper clips	Student data sheet (reproduced)
Sandpaper	Impact goggles
Ruler	Weigh Dish, Large (share)

Impact goggles must be worn by all students protect the eyes.

Procedure:

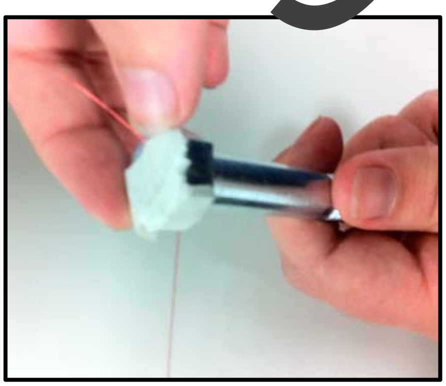
Your group will build two electromagnets with different core materials; one with an iron-containing core, one with a wooden core. You will compare the strength of the two electromagnets by noting how many washers or paperclips the electromagnets can hold.

Step 1. Assign one student to hold the steel bolt and one student to hold the wooden dowel rod for your group. You will use these items for the centers or cores of your electromagnets.

Step 2. Assign one student to manage the spool of magnet wire. This student may hold the center of the spool on their fingers or place a pencil through the hole in the center of the spool and hold both ends of the pencil, so that the wire may roll off of the spool easily when other students are winding wire onto the electromagnet cores (the steel bolt and the wooden dowel.)

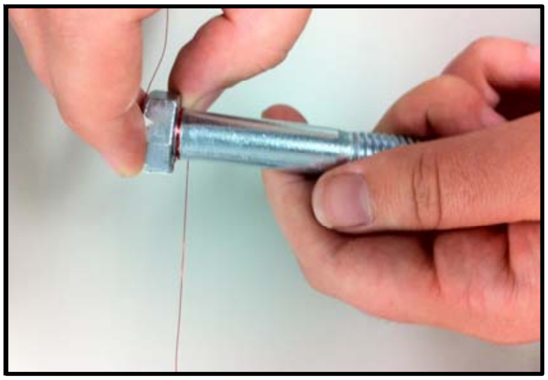
Step 3. Assign one student to manage several pieces of masking tape. This student should be ready at all times with small pieces of tape to hold the wire down whenever necessary.

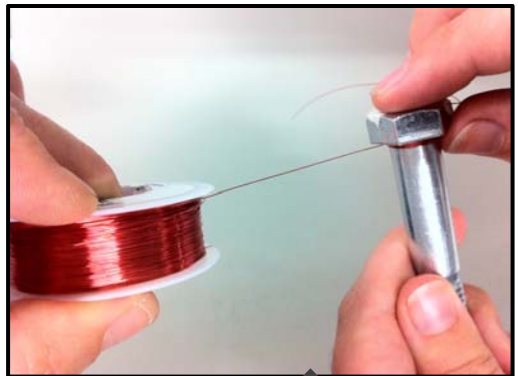
Step 4. Measure 15 centimeters of magnet wire and make a small bend in the wire to mark it. This will be your lead wire for connecting your electromagnet coil to the battery later.



Step 5. Attach the small bend in the wire to the top end of the steel bolt, directly under the head using a small piece of tape, leaving the 15 centimeter lead loose as a tail.

Step 6. Begin turning the bolt so that the magnet wire winds directly from the wire spool to the bolt. When you wrap the wire around the bolt, you must wrap the wire only in one direction.



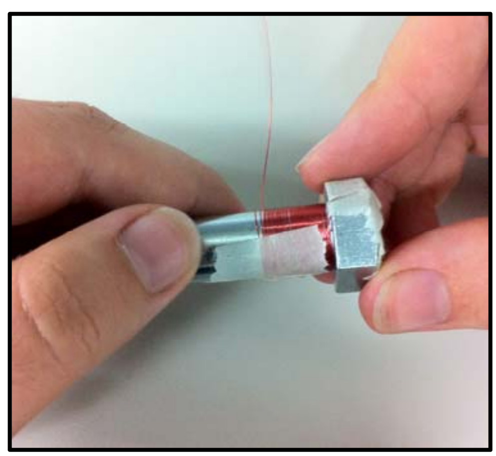


Note: You must only wrap the wire in one direction because the magnetic field depends on the direction of the electrical current creating it. If you change directions, you will effectively cancel out the magnetic field.

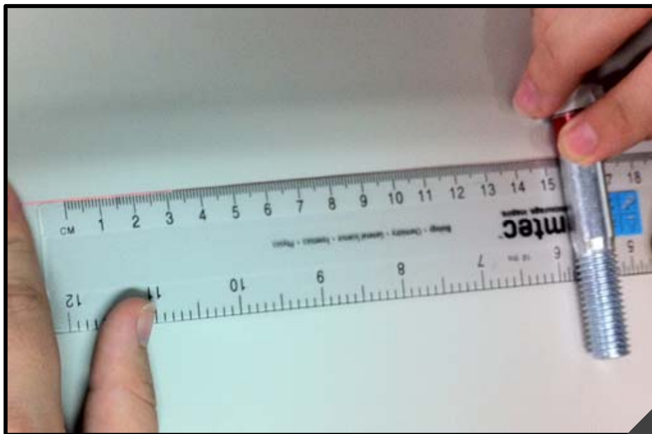
Step 7. Turn the bolt slowly and have one student continuously push the wraps of wire together to keep them as neat as possible. The wire should not overlap or loosen from the bolt. Keep the wire flat and tight.

Step 8. The small piece of tape holding the wire to the bolt may help your group to keep track of how many turns of wire are on your magnetic core. Count one wrap every time the tape reappears. Everyone should help keep the count. Stop winding when you have 40 wraps of wire on the bolt.

Step 9. Have the student managing the masking tape apply a piece of tape to the last wrap of wire to hold it in place.



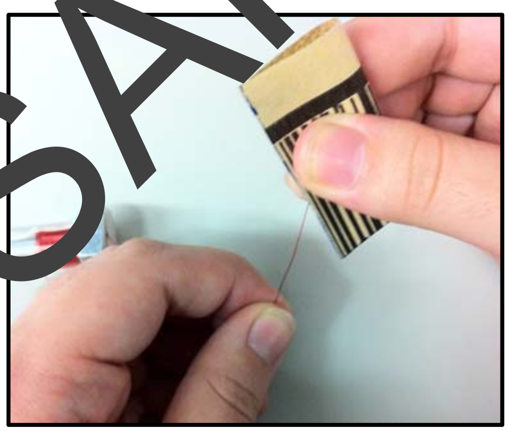
Step 10. Measure an additional 15 centimeters of wire from the last wind and mark the location with a small bend in the wire. You will leave this tail for your second lead for joining to the electromagnet to the battery.



Step 11. Send one student from your group to locate a pair of wire cutters from the shared materials area. Using the wire cutters, cut the magnet wire at the location where you marked it with the small bend, leaving a 15 centimeter tail as a lead wire. Have a student return the wire cutters to the shared materials area for other groups to use.

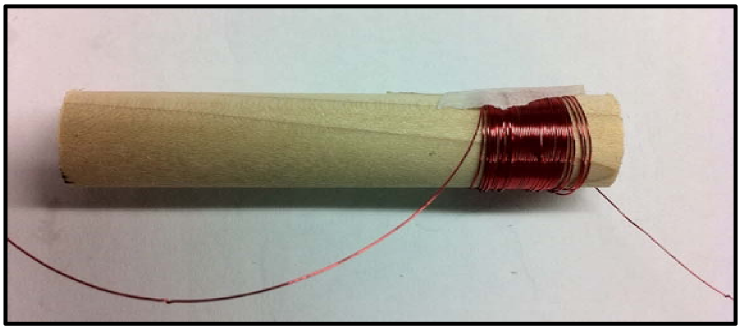
Step 12. You will need to expose about two centimeters of the copper wire on the ends of the leads so that you can make an electrical connection between the electromagnet and the battery.

Step 13. Locate your small piece of sandpaper. You will use the sandpaper to gently scrape the insulation off of the lead ends. Fold the sandpaper, rough sides together, and draw the last two centimeters of each magnet wire lead through the folded sandpaper as you gently press the folded sandpaper closed against the wire. You will have to turn the wire and repeat this process a couple of times to remove the coating from all the way around the wire. The wire should lose its outer colored coating and look shiny. Do not rub too hard or too long, or you will break the wire.



Step 14. Your electromagnet is now ready for testing. Place it on your workspace and proceed with building your electromagnet with the wooden core.

Step 15. Repeat step 4 through 13 using the wooden dowel in place of the steel bolt to make your electromagnet with a wooden core.

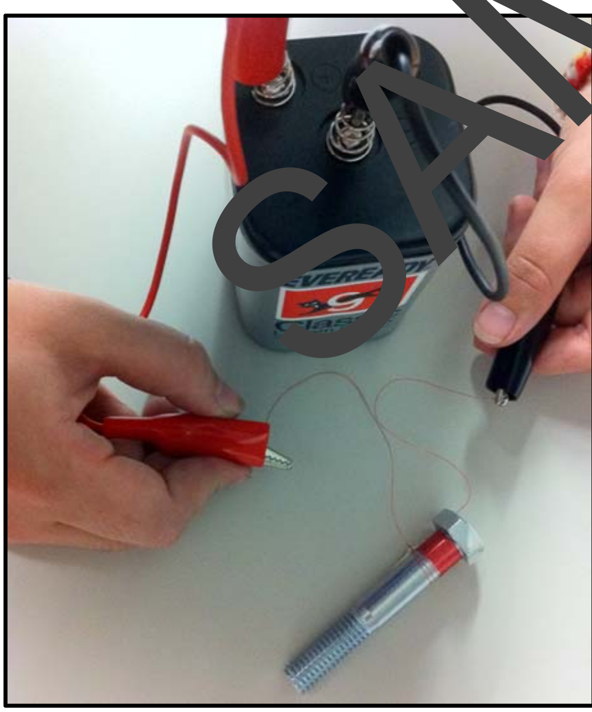


Step 16. When your second electromagnet is ready, you will attach a battery to the wire leads of your electromagnets. An electric current will flow through the wire, exposing the steel core and the wooden core to a magnetic field.

Step 17. Locate the alligator clip leads and the 6 V battery. You will be sharing this set-up with one other group, so you may have to wait for a turn to use the battery.

Step 18. Pour the small washers into the large plastic weigh boat.

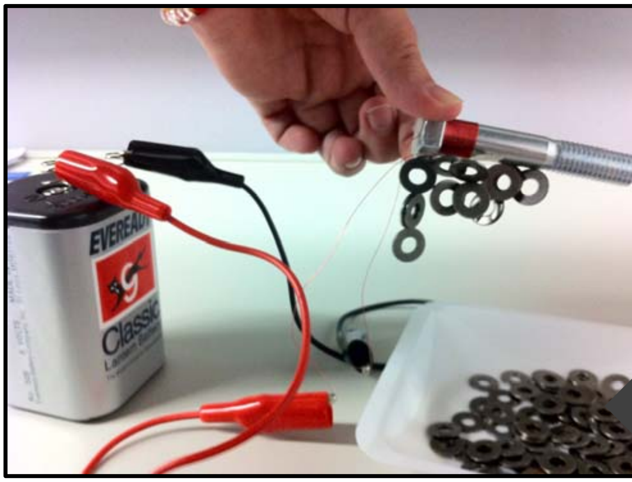
Step 19. Before connecting your electromagnets to the battery, place the electromagnets, one at a time, into the weigh boat of washers. Note how many washers each electromagnet lifts. Record the number of washers that attach to each electromagnet in your student data sheet in the appropriate space. This will serve as your control prior to applying a current to the electromagnet.



Step 20. Now you will connect a battery to your electromagnet with the bolt core to apply current to the coil. Attach one clip end of the negative (black) alligator clip lead to the negative pole (coil) on the top of the 6 V battery (marked -) and the other end of the black clip lead to one of the stripped wire ends of the electromagnet.

Step 21. Attach one clip end of the positive (red) alligator clip lead to the positive pole (coil) on the top of the 6 V battery (marked +) and the other end of the red clip lead to the other stripped wire end on the electromagnet.

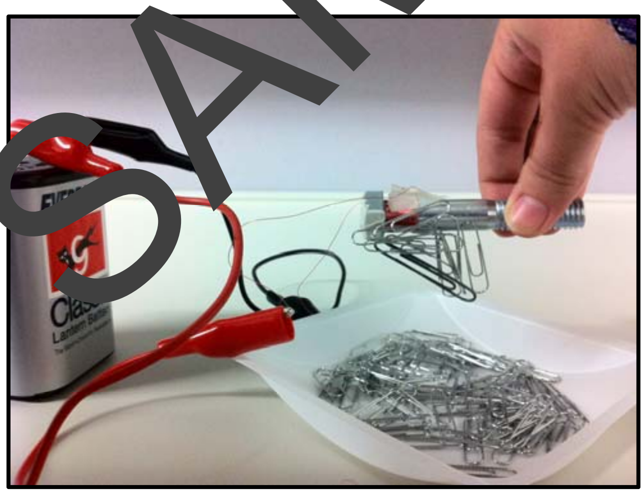
Step 22. Place the electromagnet in the weigh boat of washers. Count the number of washers the electromagnet lifts now that the electric current is running through the coil. Record the number of washers that attach to the electromagnet in the appropriate space in your student data sheet.



Step 23. Disconnect the clip leads from the electromagnet. Note what happens to the washers. When the battery is no longer connected, the magnetic field is gone. Return the washers to the large weigh dish.

Step 24. Repeat steps 20 through 23 for the wooden electromagnet.

Step 25. Repeat the electromagnetic testing process in steps 20-23 using paper clips in the weigh boat in place of the washers. Record the number of paperclips you can pick up with the bolt core electromagnet, and then the wooden core electromagnet. Write the data in your student worksheet. This information will be compared to results of other lab experiments.



Step 26. Save the electromagnet with the steel bolt core to be used in Experiment 2 and Experiment 3.

Experiment 2: Electromagnet Core Thickness

Essential Question: How does changing the materials used to build an electromagnet affect its function?

You will need:

6 V lantern battery	Wire strippers/cutters
Magnet wire, 30 Gauge	Masking tape
Steel paper clips	Steel washers
Steel nail	Alligator clip leads, pair
Steel bolt electromagnet, 30 coil	Weigh Dish, Large
Sandpaper	Student Data Sheet
Ruler	Impact goggles

Impact goggles must be worn by all students protect the eyes.

Procedure:

Your group will build another electromagnet with a small core thickness to compare to your electromagnet with the steel bolt core. You will compare the strength of the two electromagnets by noting how many washers or paperclips each electromagnet can hold.

Step 1. Find your steel nail to use as a core for your new electromagnet.

Step 2. Assign one student to manage the spool of magnet wire. This student may hold the center of the spool on their fingers or place a pencil through the hole in the center of the spool and hold both ends of the pencil, so that the wire may roll off of the spool easily when other students are winding wire onto the electromagnet cores (the steel bolt and the steel nail.)

Step 3. Assign one student to manage several pieces of masking tape. This student should be ready at all times with small pieces of tape to hold the wire down whenever necessary.

Step 4. Measure 15 centimeters of magnet wire and make a small bend in the wire to mark it. This will be your lead wire for connecting your electromagnet coil to the battery later.

Step 5. Attach the small bend in the wire to the top end of the steel nail, directly under the head using a small piece of tape, leaving the 15 centimeter lead loose as a tail.

Step 6. Begin turning the nail so that the magnet wire winds directly from the wire spool to the bolt. When you wrap the wire around the nail, you must wrap the wire only in one direction.

Step 7. The small piece of tape holding the wire to the nail will help your group to keep track of how many turns of wire are on your magnetic core. Count one wrap every time the tape reappears. Everyone should help keep the count.

Step 8. Turn the nail slowly while one student continuously pushes the wire together to keep the wraps as close as possible. The wire should not overlap or loosen from the nail. Keep the wire neat and tight.

Step 9. Stop winding when you have 40 wraps of wire on the nail. Have the student managing the masking tape apply a piece of tape to the last wrap of wire to hold it in place.

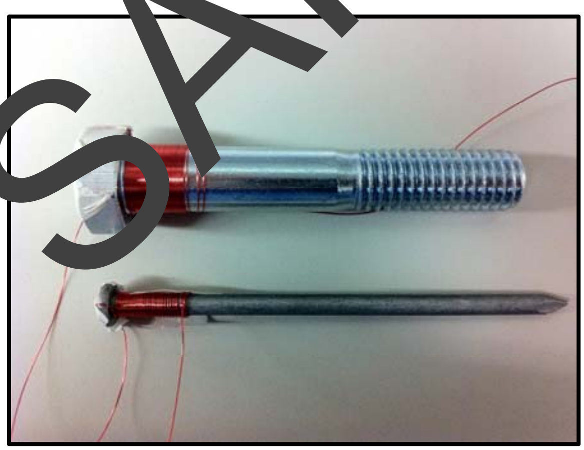
Step 10. Measure an additional 15 centimeters of wire from the last wind and mark the location with a small bend in the wire. You will leave this tail for your second lead to join the electromagnet to the battery.

Step 11. Send one student from your group to locate a pair of wire cutters from the shared materials area. Using the wire cutters, cut the magnet wire at the location where you marked it with the small bend, leaving a 15 centimeter lead. Have a student return the wire cutters to the shared materials area for other groups to use.

Step 12. You will need to expose about two centimeters of the copper wire on the ends of the leads so that you can make an electrical connection between the electromagnet and the battery.

Step 13. Locate your small piece of sandpaper. You will use the sandpaper to gently scrape the insulation off of the lead ends. Fold the sandpaper, rough sides together, and draw the last two centimeters of each magnet wire lead through the folded sandpaper as you gently press the folded sandpaper closed against the wire. You will have to turn the wire and repeat this process a couple of times to remove the coating from all the way around the wire. The wire should lose its outer colored coating and look shiny. Do not rub too hard or too long, or you will break the wire.

Step 14. Your electromagnet is now ready for testing. Place it on your workspace along with your electromagnet which you made in the last experiment with the steel bolt core.



Step 15. Next you will attach a battery to the wire leads of each of your electromagnets. An electric current will flow through the wire, exposing the steel cores to a magnetic field.

Step 16. Locate the alligator clip leads and the 6 V battery. You will be sharing this set-up with one other group, so you may have to wait for a turn to use the battery.

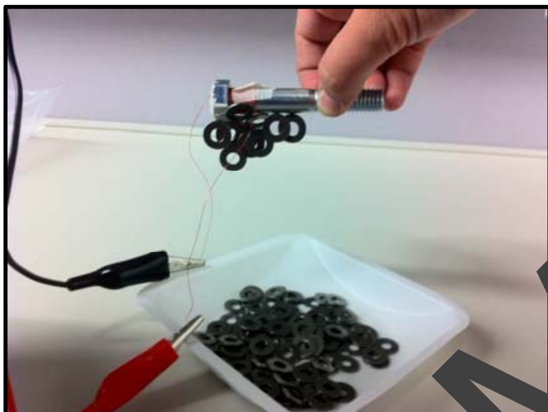
Step 17. Pour the small washers into the large plastic weigh boat.

Step 18. Place each electromagnet in the weigh boat of washers. Note how many washers each electromagnet lifts. Record the number of washers that attach to each electromagnet in your student data sheet in the appropriate space.

Step 19. Attach one clip end of the negative (black) alligator clip lead to the negative pole (coil) on the top of the 6 V battery (marked -) and the other end of the black clip lead to one of the stripped ends of wire one of your electromagnets.

Step 20. Attach one clip end of the positive (red) alligator clip lead to the positive pole (coil) on the top of the 6 V battery (marked +) and the other end of the red clip lead to the other stripped end of wire on the electromagnet you are testing.

Step 21. Place the electromagnet in the weigh boat of washers. Count the number of washers the electromagnet lifts now that the electric current is running through the coil. Record the number of washers that attach to the electromagnet in the appropriate space in your student data sheet.



Step 22. Disconnect the clip leads from the electromagnet. Note what happens to the washers. When the battery is no longer connected, the magnetic field is gone. Return the washers to the large weigh dish.

Step 23. Repeat steps 19 through 22 for the other electromagnet.

Step 24. Repeat the electromagnet testing process steps in 19-22 using paper clips in the weigh boat in place of the washers. Record the number of paperclips you can pick up with each electromagnet, and write the data in your student worksheet. This information may be compared to results of other lab experiments.

Experiment 3: Electromagnet Coil Count

Essential Question: How does changing the design of an electromagnet change its function?

You will need:

6 V lantern battery	Wire strippers/cutters
Magnet wire, 30 Gauge	Masking tape
Steel paper clips	Steel washers
Steel bolt	Alligator clip leads, pair
Sandpaper	Weigh Dish, Large
Student Data Sheet	Impact Goggles
Ruler	

Impact goggles must be worn by all students protect the eyes.

Procedure:

Your group will build a new electromagnet with a steel bolt core. Each group in your class will build an electromagnet with a different number of coils on it; 20, 60, 80, 100, 120, or 140 coils. (Note that you will already have data for 40 coils.) Your teacher will assign the number of coils to your group. (If you are doing a single kit, you may want to select just a few different numbers of coils to save time.) Write the number of coils you are assigned into the procedure below in the blank space in Step 9. You will compare the strength of your group's electromagnet to the strength of electromagnets from other groups by noting how many washers or paperclips each electromagnet can hold. You will use the data from your 40 coil electromagnet from Experiment 1.

Step 1. Remove the wire from your steel bolt electromagnet which you made and used in the previous experiments. You will use the steel bolt to make your new electromagnet.

Step 2. Assign one student to manage the spool of magnet wire, so that the wire may roll off of the spool easily when another student is winding wire onto the steel bolt electromagnet core.

Step 3. Assign one student to manage several pieces of masking tape. This student should be ready at all times with small pieces of tape to hold the wire down whenever necessary. If you are making a lot of coils, temporarily taping the wire down may allow you to take a break.

Step 4. Measure 15 centimeters of magnet wire and make a small bend in the wire to mark it. This will be your lead wire for connecting your electromagnet coil to the battery later.

Step 5. Attach the small bend in the wire to the top end of the steel bolt, directly under the bolt head using a small piece of tape, leaving the 15 centimeter lead loose as a tail.

Step 6. Begin turning the bolt so that the magnet wire winds directly from the wire spool to the bolt. When you wrap the wire around the bolt, you must wrap the wire only in one direction. This is critical now, because you are adding a lot more coils and you may need to wrap some coils on top of one another. Be sure to only wrap the wire only in one direction. Keep the coils very neat. Wrap to the end of the bolt, and if you still have more coils to add, wrap back to the top of the bolt, being sure to add the coils in the same direction.

Step 7. The small piece of tape holding the wire to the nail will help your group to keep track of how many turns of wire are on your magnetic core. Count one wrap every time the tape reappears. Everyone should help keep the count.

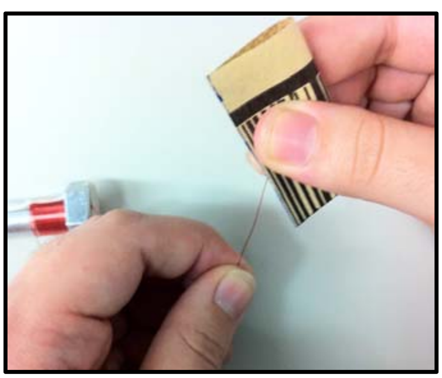
Step 8. Turn the bolt slowly and have one student continuously guide the wraps of wire together to keep them as neat as possible. The wire should not overlap or loosen from the nail. Keep the wire neat and tight. If you come to the end of the smooth part of your bolt, you will need to start overlapping coils on top of the first row of coils. Do not change the direction you are winding the wire, just start winding back toward the head of the bolt.

Step 9. Stop winding when you have _______ (your assigned number) coils of wire on the bolt. Have the student managing the masking tape apply a piece of tape to the last wrap of wire to hold it firmly in place. Do not worry about how many pieces of wire the tape covers. The tape will not affect the function of your electromagnet.

Step 10. Measure an additional 15 centimeters of wire from the last wind and mark the location with a small bend in the wire. You will leave this tail for your second lead for joining to the electromagnet to the battery.

Step 11. Send one student from your group to locate a pair of wire cutters from the shared materials area. Using the wire cutters, cut the magnet wire at the location where you marked it with the small bend, leaving a 15 centimeter lead. You should now have a 15 cm lead or tail of wire at each end of the coils. Have a student return the wire cutters to the shared materials area for other groups to use.

Step 12. You will need to expose about two centimeters of the copper wire on the ends of the leads so that you can make an electrical connection between the electromagnet and the battery.



Step 13. Locate your small piece of sandpaper. You will use the sandpaper to gently scrape the insulation off of the lead ends. Fold the sandpaper, rough sides together, and draw the last two centimeters of each magnet wire lead through the folded sandpaper as you gently press the folded sandpaper closed against the wire. You will have to turn the wire and repeat this process a couple of times to remove the coating from all the way around the wire. The wire should lose its outer colored coating and look shiny. Do not rub too hard or too long, or you will break the wire.

Step 14. Your electromagnet is now ready for testing. When all of the groups are ready, each group will proceed to test their electromagnet in front of the rest of the class.

Step 15. Start with the electromagnet from the group with the lowest number of coils (20). Proceed successively through the 60, 80, 100, 120, and 140 coil electromagnets, as follows, until you have a number of washers and a number of paperclips which each electromagnet can hold and have entered the data into your student worksheet.

Step 16. Locate the set of alligator clip leads and the 6 V battery you will be using.

Step 17. Pour the small washers into the large plastic weigh boat.

Step 18. Attach the clip end of the negative (black) alligator clip lead to the negative pole (coil) on the top of the 6 V battery (marked -) and the other end of the black clip lead to one of the stripped ends of wire of your electromagnet.

Step 19. Attach the clip end of the positive (red) alligator clip lead to the positive pole (coil) on the top of the 6 V battery (marked +) and the other end of the red clip lead to the other stripped end of wire on the electromagnet you are testing.

Step 20. Place the electromagnet in the weigh boat of washers. Count the number of washers the electromagnet lifts. Record the number of washers that attach to the electromagnet in the appropriate space in your student data sheet. Return the washers to the plastic weigh boat.

Step 21. Repeat the electromagnetic testing process using paper clips in the weigh boat in place of the washers.

Step 22. Repeat the testing process until each group has tested their electromagnet using steps 18 through 21. All students should record the number of washers and the number of paperclips for each electromagnet in their data sheet.

Step 25. Use the washer data to graph your results on the graph paper provided. Plot the number of coils on the x-axis and the number of washers on the y-axis.

Experiment 4:   Build the Strongest Electromagnet

Essential Question: How can we discover the properties of the strongest electromagnet by experimentation?

You will need:

Dowel rod 1/2" x 3"	Alligator clip leads, pair
6 V lantern battery	Wire strippers/cutters
Magnet wire, 30 Gauge	Masking tape
Box of steel paper clips, box 100	Steel washers, pk100
Steel nail, 3"	Weigh Dish, Large
Steel bolt	Student Data Sheet
Sandpaper	Impact goggles
Ruler	

Impact goggles must be worn by all students protect the eyes.

Procedure:

Using any of your group's kit items, design and build the strongest electromagnet you can. You will determine how strong your electromagnet is by how many washers your group's electromagnet is able to hold. Using your student data sheet, record what your group uses for their design including all materials, so that others may repeat your experiments and get similar results. Record the number of washers your electromagnet holds in each of your test runs. Keep records of all design changes you make and how they affected the strength of your electromagnet.

At the end of the experiment, each group will compete to demonstrate how many washers their electromagnet can hold. Then you will discuss what properties of the strongest electromagnet enabled it to win the competition.

Extension Activity Suggestions

- You may try experimenting with different core materials. The materials you choose should be able to become magnetized, which implies that it should contain iron (or nickel or cobalt). To determine if the material you choose will make a good electromagnet core, you can test it by seeing if it is attracted to a permanent magnet. Materials that do not contain iron do not make effective electromagnet cores.
- Another way to improve the strength of your electromagnet is to increase the diameter of the inner iron-containing core. Does the length of the core also matter?
- As you have learned, the more coils there are on your magnet, the stronger the magnetic field it exerts. More current flowing through the coil will create a stronger electromagnet. Be very careful, though, as more current generates more heat! As you increase the current passing through the wire, the heat generated increases exponentially. It is good practice to increase the diameter of the magnet wire if you want to increase the current going through the wire coils. To increase the current, you would increase the voltage going into your electromagnet. You may do this by increasing the voltage of the battery. A good way to demonstrate this is to use D-Cell batteries connected in a series. Each D-Cell contributes 1.5 volts, so five D-cell batteries in a series would contribute 7.5 volts, which is more than the 6 V battery in your kit supplies.

Let's Build Electromagnets
Student Data Table

Name____________________

Experiment 1: Electromagnet Core Material

	Number of Washers		Number of Paperclips	
Core Material	Before Current	With Current	Before Current	With Current
Steel Core Electromagnet				
Wooden Core Electromagnet				

Experiment 2: Electromagnet Core Thickness

	Number of Washers		Number of Paperclips	
Core Thickness	Before Current	With Current	Before Current	With Current
Steel Bolt Core				
Steel Nail Core				

Experiment 3: Electromagnet Coil Count

Coil Count	Number of Washers	Number of Paperclips
20 Coils		
40 Coils		
60 Coils		
80 Coils		
100 Coils		
120 Coils		
140 Coils		

Plot the washer data on graph paper. Give your graph a title.

Let’s Build Electromagnets
Student Data Question Sheet Name______________________

Do you reach a point where the strength of your electromagnet does not increase? Explain your answer.

____

____

____

____

How does the electromagnet strength relate to the number of coils?

____

____

Which weight do you think is a better test of electromagnet strength, the washers or the paper clips? Why?

____

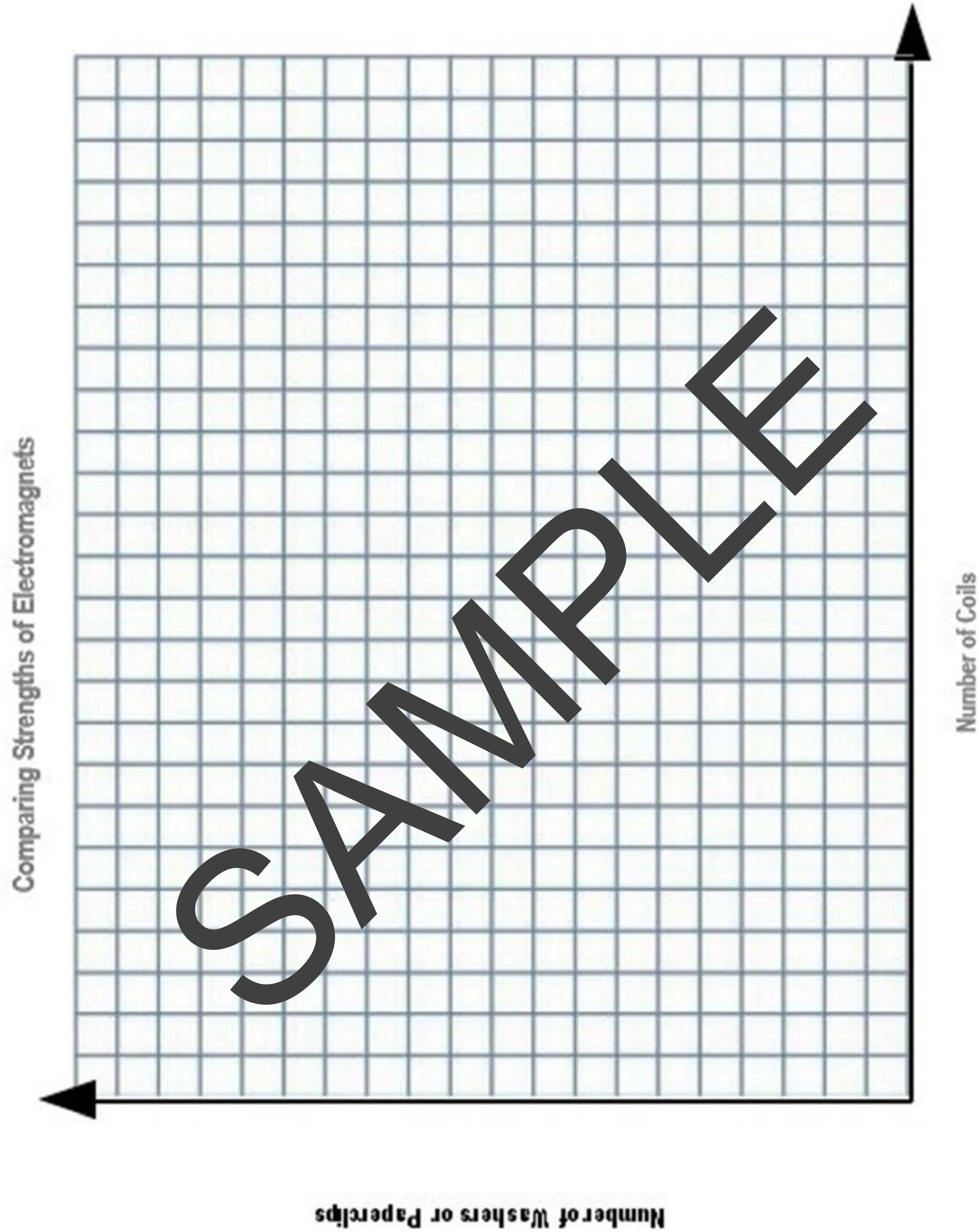
____

____

____

Parts of an Electromagnet

Graph Paper


Comparing Strengths of Electromagnets
Number of Coils
Number of Washers or Paperclips
SAMPLE

Build the Strongest Electromagnet Design Sheet
(Experiment 4)

Name ___________________________

Group ___________________________

Draw and label your initial design in the box below.

List and describe the materials you used to build your electromagnet.

1.	2.
3.	4.
5.	6.

Test One – Number of washers held:_________________________

Write your notes here. (Include thoughts, results, and ideas for possible changes.)

Name ________________________

Changes made to improve design:

Test two – Number of washers held:____________________________

Write your notes here. (Include thoughts, results, and ideas for possible additional changes.)

Additional changes made to improve design:

Number of washers held in final competition:______________________

Let’s Build Electromagnets
Student Worksheet   Name________________________

1. When the battery is no longer connected to the electromagnet, the steel bolt core will lose its magnetism. Why does this happen? How does this affect how many washers can be lifted using the electromagnet?

2. How does disconnecting the electromagnet with the wooden dowel core affect how many washers can be lifted?

3. Why are the results different with the wooden core than with the steel bolt core?

4. What features would you change on your group’s electromagnet to make it stronger if you could use additional items that were not offered for you to use?

5. How could you test a material ahead of time to make sure it is going to make a good electromagnet core prior to building an electromagnet?

Let's Build Electromagnets Answer Key
Student Data Table – Sample Data

Experiment 1: Electromagnet Core Material

	Number of Washers		Number of Paperclips	
Core Material	Before Current	With Current	Before Current	With Current
Steel Core Electromagnet	0	13	0	21
Wooden Core Electromagnet	0	0	0	1

Experiment 2: Electromagnet Core Thickness

	Number of Washers		Number of Paperclips	
Core Thickness	Before Current	With Current	Before Current	With Current
Steel Bolt Core	0	13	0	21
Steel Nail Core	0	6	0	7

Experiment 3: Electromagnet Coil Count

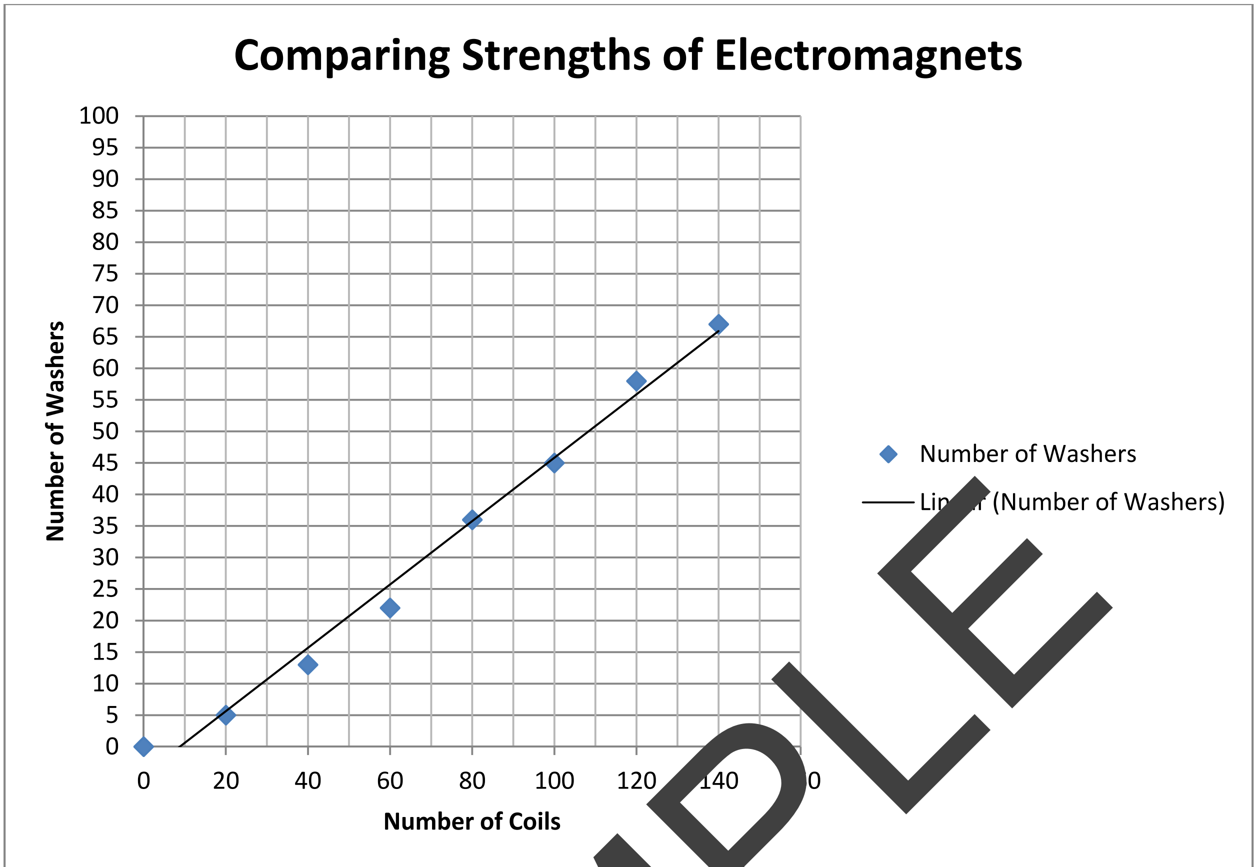
Coil Count (X)	Number of Washers (Y)	Number of Paperclips
No Coils	0	0
20 Coils	[illegible]	6
40 Coils	13	21
60 Coils	[illegible]	25
80 Coils	36	33
100 Coils	45	40
120 Coils	58	60
140 Coils	67	68

Plot the washer data on graph paper. Give your graph a title.

Do you reach a point where the strength of the electromagnet does not increase? No

Is the increase in strength dependent on the increase in the number of coils?
Yes. (The increase in strength is proportional to the increase in the number of coils. This is evident by the linear increase in the graph.)

Which weight do you think is a better test of electromagnet strength, the washers or the paper clips? Why?
Answers will vary, but the washers are more independent and do not hook together like the paperclips do. For this reason, they may give a more reliable measure of electromagnet strength. Students might argue that the paperclips being lighter might give a more refined method of analyzing differences in strength.



Comparing Strengths of Electromagnets
Number of Washers
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
Number of Coils
Number of Washers
Linear (Number of Washers)

Let’s Build Electromagnets
Student Worksheet Answer Key

1. When the battery is no longer connected to the electromagnet, the steel bolt core will lose its magnetism. Why does this happen? How does this affect how many washers can be lifted using the electromagnet?

   When the battery is disconnected, **there is no electric current** to cause electron movement through the wire coil. Without a magnetic field created, the electromagnet loses its temporary magnetic properties, so the washers are not attracted to the iron core. **No washers can be lifted** with the disconnected electromagnet. The circuit must be complete so there is current to create the magnetic field.

2. How does disconnecting the electromagnet with the wooden dowel core affect how many washers can be lifted?

   Disconnecting the electromagnet with the wooden dowel core **does not have much affect** because the wooden core does not magnetize to strengthen the electromagnet. Only the coil is involved in magnetizing the electromagnet, so the strength is minimal.

3. Why are the results different with the wooden core than with the steel bolt core?

   Wood does not have any iron in it, so it does not magnetize. The magnetic core in the electromagnet made with the bolt allows amplification of the electromagnetic field **because a steel bolt contains iron.**

4. What features would you change on your group’s electromagnet to make it stronger if you could use additional items that were not offered for you to use?

   Answers will vary, but may include a core material that has more iron in it, a core that can become a stronger magnet, thicker magnet wire, more wire coils, a larger core diameter, more current in the battery supply, more current from another source.

5. How could you test a material ahead of time to make sure it is going to make a good electromagnet core prior to building an electromagnet?

   See if the material is attracted to a permanent magnet. If it is, it will make a good core material.

Anticipation Guide

Building Electromagnets

Name ______________________________________

This is what I already Know about Electromagnets	This is what I want to find out about Electromagnets	This is what I learned about Electromagnets

Science Process Skills Assessment

Student ______________________________ Date ______________________

Activity ____

Criteria	Poor	Fair	Good	Outstanding
The student followed safety rules.				
The student used measurement skills correctly.				
The student used materials appropriately.				
The student is able to work well with others in a team to enhance the project.				
The student was able to collect and record data.				
The student used skills of observation and recorded observations in lab sheet.				
The student was able to analyze what was observed.				
The student used inference and prediction skills.				
The student was creative in making improvements to the project.				

Science Process Skills Self-Check

Name ____________________________ Date _____________________

Activity ____

Criteria	Poor	Fair	Good	Outstanding
I followed safety rules very carefully.				
I understand measurement and measure correctly.				
I used the building materials appropriately.				
I worked with my team to do better work than I could have done alone.				
I am able to collect and record data.				
I make careful observations and record my observations in the lab sheet.				
I understand how to analyze what I observe.				
I used prediction skills to help me decide how to do my project.				
I was creative in making improvements to the project.				

I think the way I could improve my work most is to: __________________________________

____

Accommodations for Students

Auditory Processing:

- use clear, concise directions
- have students paraphrase directions
- use both written and oral directions
- record directions or pertinent information so that it can be heard again
- cue students as to questions or discussions to follow
- place yourself close to students when giving directions

Below grade reading ability:

- record materials
- have students make flashcards of vocabulary words
- highlight key words or concepts
- allow students to read aloud if they desire
- break reading into small segments
- rewrite specific information to student level

Short and long-term memory difficulties:

- have printed materials to go along with visual materials
- color code written materials as well as related supplies
- use numbering and check lists
- keep extra copies of materials available
- have in class folders or notebooks in which students may store materials
- be consistent with routines

Writing difficulties:

- have students dictate to you or to a classmate
- provide printed copy with spaces to fill in
- ask for short paragraphs with four to seven sentences or short answers
- have students type out answers
- have students record their answers or responses

Resource: McCarnet and Wunderlich, The Pre-Referral Intervention Manual, Hawthorn Ed., [illegible]

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