Electric and Magnetic Mischief

Grade Level or Special Area: 8th Grade Science
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Length of Unit: Six Lessons and a Culminating Activity (12 45-minute class periods)

I. ABSTRACT

This unit expands on the student understanding of electricity and magnetism. The unit includes a review of basic concepts of electricity. It also includes Earth's magnetism, the connection between electricity and magnetism, and applications of electricity and magnetism. Hands-on activities enhance the learning in the unit "Electric and Magnetic Mischief".

II. OVERVIEW

A. Concept Objectives
   1. Students will develop an awareness of the interactions and processes of Earth's magnetism.
   2. Students will understand the connection between electricity and magnetism.
   3. Students will understand applications of electricity and magnetism.

B. Content from the *Core Knowledge Sequence* (not all the content from this section is covered in this unit)
   1. Science: Electricity and Magnetism: Electricity (pp.199-200)
      a. Basic terms and concepts (review from grade 4)
         i. Electricity is the flow of electrons in a conductor
         ii. Opposite charges attract, like charges repel
         iii. Conductors and insulators
      b. Electricity as the flow of electrons
         i. Electrons carry negative charge, protons carry positive charge
         ii. Conductors: materials like metals that easily give up electrons
         iii. Insulators: materials, like glass that do not easily give up electrons
      c. Flowing electricity
         i. Electric potential is measured in volts
         ii. Electric flow or current is measured in amperes: 1 ampere = flow of 1 coulomb of charge per second (1 coulomb = the charge of 6.25 billion billion electrons)
         iii. The total power of an electric flow over time is measured in watts
         iv. The unit of electrical resistance is the ohm. Ohm's law: watts = amps x volts and the corollaries: amps = watts/volts; volts = watts/amps
   2. Magnetism and Electricity
      a. Earth's Magnetism
         i. Earth's magnetism is believed to be caused by movements of charged atoms in the molten interior of the planet
         ii. Navigation by magnetic compass is made possible because earth is a magnet with north and south magnetic poles
      b. Connection between electricity and magnetism
         i. Example: move a magnet back and forth in front of wire connected to a meter, and electricity flows in the wire. The reverse: electric current flowing through a wire exerts magnetic attraction

ii. Spinning electrons in an atom create a magnetic field around the atom
iii. Unlike magnetic poles attract, like magnetic poles repel
iv. Practical applications of the connection between electricity and magnetism, for example:
a) An electric generator creates alternating current by turning a magnet and a coil of wire in relation to each other; an electric motor works on the reverse principle.
b) A step-up transformer sends alternating current through a smaller coil with just a few turns next to a larger coil with many turns. This induces a higher voltage in the larger coil. A step-down transformer does the reverse, sending current through the larger coil. A step-down transformer does the reverse, sending current through the larger coil and creating a lower voltage in the smaller one

C. Skill Objectives
1. Students can identify various conductors and insulators.
2. Students recognize that like charges repel and opposite charges attract.
3. Students can solve the Ohm's Law equation.
4. Students will locate the Magnetic North Pole using a magnetic compass.
5. Students will recognize that the Earth is magnetic because charged particles are in the Earth's core.
6. Students will construct a magnetic compass and use it to locate north and south poles.
7. Students can explain how electricity and magnetism are related.
8. Students recognize applications of electricity and magnetism.
9. Students can analyze how an electric motor operates.

III. BACKGROUND KNOWLEDGE

A. For Teachers
1. Ardley, Neil. *Experiments with Magnets and Electricity*
2. Wainwright, Camille. *Science Explorer Electricity and Magnetism*
3. Whalley, Margaret. *Experiments with Magnets and Electricity*

B. For Students
1. Magnetism (Kindergarten and 2nd Grade) p. 20, p. 60
2. Electricity (1st grade and 4th Grade) p. 38, p. 104

IV. RESOURCES

A. Wainwright, Camille. *Science Explorer Electricity and Magnetism*
B. Catherall, Ed. *Stuck on Magnets*
C. Van Rose, Susanna. *Eyewitness Books-Earth*
D. Ardley, Neil. *Experiments with Magnets and Electricity*

V. LESSONS

Lesson One: A Review of Basic Terms and Concepts of Electricity (one 45 minute class period)

A. *Daily Objectives*
1. Concept Objective(s)
a. Students will understand the connection between electricity and magnetism.

2. Lesson Content
    a. Basic terms and concepts (review from grade 4)
        i. Electricity is the flow of electrons in a conductor
        ii. Opposite charges attract, like charges repel
        iii. Conductors and insulators
    b. Electricity as the flow of electrons
        i. Electrons carry negative charge, protons carry positive charge
        ii. Conductors: materials like metals that easily give up electrons
        iii. Insulators: materials, like glass that do not easily give up electrons
    c. Flowing electricity
        i. Electric potential is measured in volts
        ii. Electric flow or current is measured in amperes: 1 ampere = flow of 1 coulomb of charge per second (1 coulomb = the charge of 6.25 billion billion electrons)
        iii. The total power of an electric flow over time is measured in watts
        iv. The unit of electrical resistance is the ohm. Ohm's law: watts = amps x volts and the corollaries: amps = watts/volts; volts = watts/amps
3. Skill Objective(s)
    a. Students can identify various conductors and insulators.
    b. Students recognize that like charges repel and opposite charges attract.
    c. Students can solve the Ohm's Law equation.

B. *Materials*
1. Various conductors, such as copper, iron and aluminum (at least five)
2. Various insulators, such as glass, wood and plastic (a least five)
3. Appendix A: Electricity Review Worksheet (one for each student)
4. Appendix B: Electricity Review Worksheet Answer Key (one for the teacher only)

C. *Key Vocabulary*
1. Electricity – electric charges that flow through a wire or similar material
2. Conductors – materials through which electrons move freely
3. Insulators – materials through which charges of an electric current are not able to move freely
4. Attract – to pull to or toward oneself or itself (electron-proton interaction)
5. Repel – to force away or apart (electron-electron, proton–proton interactions)
6. Ohm's Law – ohms (resistance) = volts (voltage) / amps (current)
7. R=V/I or I = V/R or V= IR

D. *Procedures/Activities*
1. Ask students if they remember what electricity is. If students are not able to give a definition, tell them that electricity is the flow of electrons.
2. Ask students what type of charge electrons carry and what type of charge protons carry. If they are unable to answer, remind them that a proton carries a positive charge and an electron carries a negative charge.
3. Remind students that opposite charges attract and that "like" charges repel. Ask them to name two charges that repel (electron-electron or proton –proton) and to name two charges that attract (electron to proton).
4. Ask students to define conductor and insulator. If they are not specific enough, give the definitions. Show students various materials that are conductors and insulators. As you present each material, have students write down if each

material is a conductor and insulator. After all materials have been presented, ask for volunteers to share their answers. Tell students to check their answers to see if they identified the material correctly as an insulator or conductor. Ask students if they can name any other insulators or conductors that were not identified in the activity.

5. Ask students if they remember the formula for Ohm's Law. Write the formula on the board for all students to see. Remind students on the method to solve Ohm's law equation. Read the following example and do the problem together as a class on the board.
   A light bulb is connected to a 12 V battery. If the current of the light bulb is 0.4 amps, what is the resistance of the light bulb?
   For Ohm's law you know the current is 0.4 amps and the voltage is 12 V.
   Use R= V/I, R= 12V/ 0.4A, R= 30 ohms
6. Give students an Electricity Review Worksheet (Appendix A). Allow students to use remaining time to complete the worksheet. Any section of the worksheet that is not completed is homework.

E. Assessment/Evaluation

1. Evaluate student understanding of insulators, conductors, repulsion, attraction and Ohm's Law by scoring the Electricity Review Worksheet (Appendix A). Use Appendix B to grade.

Lesson Two: Earth's Interior and Magnetism (two 45 minute class periods)

A. *Daily Objectives*

1. Concept Objective(s)
   a. Students will develop an awareness of the interactions and process of Earth's magnetism.
2. Lesson Content
   a. Earth's magnetism is believed to be caused by movements of charged atoms in the molten interior of the planet
3. Skill Objective(s)
   a. Students will locate the Magnetic North Pole using a magnetic compass.
   b. Students will recognize that the Earth is magnetic because charged particles are in the Earth's core.

B. *Materials*

1. Magnetic compass (one for each student)
2. Ruler (one for each student)
3. White construction paper (one for each student)
4. Glue
5. Colored pencils, crayons or markers
6. Appendix C: Compass Diagram (one for each student and one for the teacher)
7. Appendix D: Example of Earth Paragraph (one for the teacher only)

C. *Key Vocabulary*

1. Magnetism – the force of attraction or repulsion of magnetic materials
2. Molten – melted especially by intense heat
3. Magnetic poles – the ends of a magnetic object, where the magnetic force is strongest
4. Van Allen Belts – two doughnut-shaped regions that contain electrons and protons traveling at very high speeds
5. Magnetosphere – the region of Earth's magnetic field confined by solar wind
6. Navigation – method of determining position, course and distance traveled

7. Magnetic Compass – a device that has a magnetized needle that can spin freely, a compass needle always points north

D. *Procedures/Activities*

1. Ask students to take out a piece of paper and a writing utensil. Ask students to copy down all of the notes you are going to write on the board.
2. Tell students that the Earth is a magnet with north and south poles. Tell them scientists believe that the Earth acts as a magnet because there is circulation of molten material inside the Earth's core. Write this information on the board. Ask students if they know of any materials the Earth's core might be made of that allows it to be magnetic. After allowing several students to guess the materials Earth's core is made of, tell them that scientists believe it is made of flowing nickel-iron. Write this information on the board.
3. Tell students that J. A. Van Allen discovered two doughnut-shaped regions that contained electrons and protons traveling at high speeds. These charged particles and the particles in the magnetosphere contribute to the Earth's magnetic field. Write this information on the board. Also write down the definition of magnetosphere. Be sure to lecture and write at a pace so that the students are able to take notes.
4. Tell students that it is Earth's magnetism that allows Earth to be navigated by the use of a magnetic compass. Ask students if they know what navigation means. If students are not able to give a specific definition, tell them the definition. Write this on the board. Tell students that the compass has been used for navigation. Write this on the board. Ask students if they are familiar with a compass. Tell them the definition of a compass and write it on the board. Show a compass to the class and show the students how it is pointing to the north.
5. Tell students that Sir William Gilbert was an English physician who became interested in compasses in the 1500's. He confirmed that the compass point always points in the same direction, no matter where you are. Write this on the board. Tell students Gilbert believed that this was because Earth acted as a giant magnet. He was correct. The compass always points to the Magnetic North Pole. The Magnetic North Pole is in Canada. Write this on the board and also write the definition of magnetic poles.
6. Tell students that they are going to do an activity that allows them to discover the Magnetic North Pole. They are also going to identify landmarks during this activity.
7. Tell students they are going to receive a photocopy of a Compass Diagram (Appendix C), a compass, and a white piece of construction paper, and a ruler. Show students a photocopy of the compass diagram pointing out all of the labeled directions.
8. Tell the students they will cut the diagram out and glue it into the middle of the construction paper. Tell them they will place the magnetic compass in the center of their diagram and will allow the magnetic compass to point to the Magnetic North Pole.
9. Tell them they are going to rotate their papers until the north of the compass points north on the compass diagram. You can demonstrate these steps using a pre-cut diagram.
10. Tell them that when everyone has reached this step, the whole class will go to the location you have chosen for this activity to locate landmarks.
11. Tell the students that the landmarks can be anything they observe, such as trees or buildings. They will locate landmarks, using their ruler as a pointer to aid in locating the correct direction of each landmark. Tell students they will draw as

many landmarks as time allows. They will complete the assignment by neatly coloring and labeling their landmarks.

12. After procedures have been discussed, give a photocopy of the Compass Diagram (Appendix C), a piece of construction paper, ruler and a compass to each student. Observe that students are correctly following the procedures on the Compass Diagram handout (Appendix C) and provide assistance where needed. When students have completed setting up the first part of the activity (Step #5), move all students to the location you have chosen for this activity. Have students locate positions of landmarks, using their ruler as a pointer guide. Allow students to locate and draw as many landmarks as possible during the time remaining. Remind students to neatly color and label landmarks. Students should also write a paragraph on their understanding of why we are able to navigate Earth. They should include definitions of any key terms in the paragraph. Any portion of the assignment that is not finished during the class period, the students should complete as homework.

E. *Assessment/Evaluation*

1. Evaluate student understanding by scoring the paragraph with definitions and key terms on navigating Earth (Appendix D: Example of Earth Paragraph) and observing their illustrations with directions of landmarks.

Lesson Three: Navigation of Earth through Magnetism (two 45 minute class periods)

A. *Daily Objectives*

1. Concept Objective(s)
   a. Students will develop an awareness of the interactions and process of Earth's magnetism.
2. Lesson Content
   a. Navigation by magnetic compass is made possible because Earth is a magnet with north and south magnetic poles
3. Skill Objective(s)
   a. Students will construct a magnetic compass and use it to locate north and south poles.

B. *Materials*

1. ½ inch masking tape
2. Magnetic compass (one for each bowl of water available to students)
3. Bowl of water (at least five for the students to share)
4. Piece of cork or styrofoam cut into a flat arrow shape (one for each student)
5. Steel paper clip (one for each student)
6. Bar magnet with marked poles (one for each student)
7. Steel needle (one for each student)
8. Appendix E: Magnetic Compass Lab Report (one for each student)
9. Appendix F: Magnetic Compass Lab Report Answer Key (one for teacher)

C. *Key Vocabulary*

None

D. *Procedures/Activities*

1. Review information from previous lessons with the class. Use these questions as a guide for the class review:
   a. Why is the Earth magnetic?
   b. What are the materials in the Earth core?
   c. What is flowing in the Earth's core at high speeds?
   d. What contributes to the Earth's magnetic field?
   e. What is navigation?

f. What device can we use for navigation?
g. Does a compass always point is the same direction?
h. Who confirmed that a magnetic compass always points in the same direction?

2. Tell students they are going to construct a homemade magnet and a compass. Tell the students they are each going to receive a handout (Appendix E: Magnetic Compass Lab Report) with the procedures to follow. Tell them they should follow the steps carefully. Explain to the students that they are going to stroke a paper clip about 20 times using the south pole of the magnet. Tell them to be sure to stroke toward the end of the paper clip. This will make the paper clip a magnet. Tell them to place the cork or styrofoam piece flat on to the table and tape the paper clip onto the top of it. Then they will float the cork on the water in one of the bowls provided. Tell them when the cork stops moving, they will use the magnetic compass to verify that the point of the paper clip points north. They will then stroke the eye of the needle with the north pole of the bar magnet. This makes the needle into a magnet. Then they will bring the eye of the needle near the point of the paper clip. They will stroke the point of the needle with the magnet's north pole. To complete the activity portion of the lab they will bring the eye of the needle near the point of the paper clip again.
3. They should be sure to recognize that when they bring the eye of the needle towards the paper clip point, the "unlike" poles attract to each other. They should also recognize that when they bring the point of the needle towards the paper clip, the "like" poles repel. Tell the students that this happens because the point of the needle becomes a south pole, then the eye changes and becomes a north pole.
4. During the activity, walk around the class to aid any students that may need assistance. Be sure to observe that the students are safely using all of the materials and are following laboratory safety rules. Students should complete the Magnetic Compass Lab Report (Appendix E).

E. *Assessment/Evaluation*

1. Evaluate student understanding of compasses by scoring the Magnetic Compass Lab Report (Appendix E).

Lesson Four: Characteristics and Properties of Electricity and Magnetism (two 45 minute class periods)

A. *Daily Objectives*

1. Concept Objective(s)
   a. Students will understand the connection between electricity and magnetism.
2. Lesson Content
   a. Example: move a magnet back and forth in front of wire connected to a meter, and electricity flows in the wire. The reverse: electric current flowing through a wire exerts magnetic attraction
   b. Spinning electrons in an atom create a magnetic field around the atom
   c. Unlike magnetic poles attract, like magnetic poles repel
3. Skill Objective(s)
   a. Students can explain how electricity and magnetism are related.

B. *Materials*

1. Wire with ends stripped of insulation, 20 cm long (two for each group)
2. Small light bulb and holder (one for each group)
3. Magnetic compasses (three for each group)

4. D cell battery, 1.5 V (one for each group)
5. Electrical tape
6. Appendix G: Electricity and Magnetism Relationship Lab Report
7. Appendix H: Electricity and Magnetism Relationship Lab Report Answer Key

C. *Key Vocabulary*

1. Electric charge – a property of electrons and protons, electrons carry a negative charge and protons carry a positive charge
2. Electric Current – the flow of electric charge through a material

D. *Procedures/Activities*

1. Tell the students to take out the piece of paper and writing utensil to write down the notes you are going to write on the board.
2. Ask the students what types of magnetic poles attract. They should answer "unlike" poles attract. Ask them what types of magnetic poles repel. They should answer "like" poles repel.
3. Tell the students that in 1820, a Danish scientist Hans Christian Oersted noticed that when electricity ran through a wire, the needles on his compasses lined up around the wire. This observation led to the discovery that electricity and magnetism are related. Write that electricity and magnetism are related on the board.
4. Ask students what charge an electron has. They should answer negative. Ask students what charge a proton has. They should answer positive. Tell students that electrons and protons have a property called electric charge. Write this on the board. Tell students that when electric charges flow through a wire they create an electric current. Write this on the board. Tell students that an electric current creates a magnetic field and the direction of the current determines the direction of the magnetic field. Write this on the board.
5. Tell the students that Andre-Marie Ampere thought that magnetism was the result of circulating atoms. Tell the students that Ampere thought that atoms could become magnets because of the motion of the electrons and he was correct. Tell the students that magnetism is caused by the movement of charges and write it on the board. Also tell the students that spinning electrons around an atom create a magnetic field around that atom. Write this on the board
6. Tell the students the activity they are going to do connects electricity and magnetism concepts. Tell them that each group is going to have two wires with the insulation stripped off the ends, three compasses, a D cell battery, a light bulb and a light bulb holder. Divide students into small groups (three-four students). Give each student the handout Electricity and Magnetism Relationship Lab Report (Appendix G). Read over the procedure with the class. Disperse equipment to each group. Tell the students to carefully follow the procedures on the lab report. Tell the students that they should be able to answer the activity questions: (1) What happened to the compasses during the activity? and (2) What can you infer about the connection between electricity and magnetism?

E. *Assessment/Evaluation*

1. Evaluate student understanding of the relation between electricity and magnetism by scoring the Electricity and Magnetism Relationship Lab Report (Appendix G). Specifically, the activity questions: (1) What happened to the compasses during the activity? and (2) What can you infer about the connection between electricity and magnetism?

Lesson Five: Magnetism to Electricity and Electricity to Magnetism (two 45 minute class periods)

A. *Daily Objectives*
   1. Concept Objective(s)
      a. Students will understand the connection between electricity and magnetism.
   2. Lesson Content
      a. Example: move a magnet back and forth in front of wire connected to a meter, and electricity flows in the wire. The reverse: electric current flowing through a wire exerts magnetic attraction
      b. Spinning electrons in an atom create a magnetic field around the atom
      c. Unlike magnetic poles attract, like magnetic poles repel
   3. Skill Objective(s)
      a. Students will recognize the factors that affect electromagnets.

B. *Materials*
   1. D cell battery (one for each group)
   2. Iron nails (five for each group)
   3. Small piece of aluminum (one for each group)
   4. Penny (one for each group)
   5. Nickel (one for each group)
   6. Dime (one for each group)
   7. Conductive wire (2 m for each group)
   8. Paper clips (15-20 for each group)
   9. Piece of wood (one for each group)
   10. Piece of steel (one for each group)
   11. Appendix I: Electromagnet Lab Report (one for each student)
   12. Appendix J: Electromagnet Lab Report Answer Key (one for the teacher)

C. *Key Vocabulary*
   1. Electric Current – the flow of electric charge through a material
   2. Electromagnet – a strong magnet that can be turned on and off

D. *Procedures/Activities*
   1. Review information from previous lessons with the class. Use these questions as guide for the class review:
      a. Why is the Earth magnetic?
      b. What are the materials in the Earth core?
      c. What is flowing in the Earth's core at high speeds?
      d. What contributes to the Earth's magnetic field?
      e. What is navigation?
      f. What device can we use for navigation?
      g. Does a compass always point is the same direction?
      h. Who confirmed that a magnetic compass always points in the same direction?
      i. What types of magnetic poles attract?
      j. What type of magnetic pole repel?
      k. What charge does an electron have?
      l. What charge does a proton have?
      m. How was it discovered that electricity and magnetism are related?
   2. Tell the students that they are now going to do an activity that uses both electricity and magnetism. They are going to construct an electromagnet. Tell them an electromagnet is a magnet that can be turned on and off. This is a quality that makes it useful as a tool. Tell the students that an electromagnet is

also useful because it can create a stronger magnetic field than a regular magnet can alone. Tell them after they build the electromagnet they will use different objects to test for attraction between the nails of the electromagnet and the objects (aluminum, penny, nickel, dime, wood, steel and paper clips).

3. Divide the class into groups of approximately three-four students. Hand each student a copy of the Electromagnet Lab Report (Appendix I). Read over the procedures with the students. Demonstrate any procedures that you feel will help the students understand the procedure. Either hand out all of the equipment or allow students to obtain the equipment at set-up stations. Tell them to carefully read and follow the instructions.
4. During the lab it is important to monitor student behavior and walk around to help any groups that may need assistance. Students should complete the Electromagnet Lab Report (Appendix I) and be sure to answer all of the questions

E. *Assessment/Evaluation*

1. Evaluate student understanding of what factors affect electromagnets by scoring the Electromagnet Lab Report (Appendix I).

Lesson Six: Applications of Electricity and Magnetism (two 45 minute class periods)

A. *Daily Objectives*

1. Concept Objective(s)
   a. Students will understand applications of electricity and magnetism.
2. Lesson Content
   a. Practical applications of the connection between electricity and magnetism, for example:
      i. An electric generator creates alternating current by turning a magnet and a coil of wire in relation to each other; an electric motor works on the reverse principle.
      ii. A step-up transformer sends alternating current through a smaller coil with just a few turns next to a larger coil with many turns. This induces a higher voltage in the larger coil. A step-down transformer does the reverse, sending current through the larger coil. A step-down transformer does the reverse, sending current through the larger coil and creating a lower voltage in the smaller one
3. Skill Objective(s)
   a. Students recognize applications of electricity and magnetism.
   b. Students can analyze how an electric motor operates.

B. *Materials*

1. D cell battery (one for each group)
2. Large paper clips (two for each group)
3. Permanent circular magnet (one for each group)
4. Small balls of clay (three for each group)
5. Empty film canister (one for each group)
6. Pliers
7. Sandpaper (at least one piece for each group)
8. Insulated wires, approximately 15 cm each (two for each group)
9. Enamel coated wire, 22-24 gauge, (one meter for each group)
10. Appendix K: Electric Motor Lab Report (one for each student)
11. Appendix L: Electric Motor Lab Report Answer Key (one for the teacher)

C. *Key Vocabulary*

1. Electric generator – a device that uses motion and converts it into electric current
2. Alternating current – current consisting of charges that move back and forth in a circuit
3. Step-up transformer – a transformer that increases voltage
4. Step-down transformer – a transformer that decreases voltage
5. Voltage – the difference in electrical potential between two places
6. Electrical potential – potential energy per unit of electric charge
7. Transformer – a device that increases or decreases voltage
8. Electric motor – a device that use electric current to produce motion

D. *Procedures/Activities*

1. Tell students that there are a lot of applications that use both electricity and magnetism. Ask students if they can think of any items that use both electricity and magnetism. They may name various items, such as, telephones, door bells, and computers
2. Tell students to take out a piece a paper and copy the notes you are going to write on the board.
3. Tell them you are going to list some items that use both electricity and magnetism to function. List the following devices on the board: Transformers, Galvanometers, Electric Generators and Electric Motors. Read out loud and write the following information on the board:
   a. Transformer - a device that consists of two separate coils of wire wrapped around an iron core. It increases or decreases voltage.
   b. Step-up transformer - a device that sends alternating current through a smaller coil with just a few turns next to a larger coil with many turns, this increases voltage in the larger coil.
   c. Step-down transformer - a device that sends current through a larger coil and decreases voltage in the smaller coil.
   d. Galvanometer - device that consists of several loops of wire suspended between the poles of a magnet. It uses an electromagnet to detect small amounts of current.
   e. Electric generator - device that creates alternating current by turning a magnet and a coil of wire in relation to each other. It uses motion and converts it into electric current.
   f. Electric motor -device that use electric current and uses it to produce motion
4. Tell students that they are going to construct an operating electric motor. They will use the procedures on Electric Motor Lab Report (Appendix K). Hand each student the handout and read through the procedure together as a class. Demonstrate any parts of the procedure that you feel will help the student's understanding of the procedures. Either handout all of the equipment or allow students to obtain the equipment at set-up stations. Tell them to carefully read and follow the instructions.
5. During the lab it is important to monitor student behavior and walk around to help any groups that may need assistance. Students should complete the Electric Motor Lab Report (Appendix K) and be sure to answer all of the questions.

E. *Assessment/Evaluation*

1. Evaluate student understanding of applications of electricity and magnetism and understanding of electric motor operation by scoring Electric Motor Lab Report (Appendix K).

VI. CULMINATING ACTIVITY (three 45 minute class periods)

A. Electricity and Magnetism Test (Appendix M)

B. Electricity and Magnetism Activity #1 - Each student will take information from the unit and input it into a booklet. Booklet should include important information and neatly colored, relevant illustrations that explain the information they have provided. These booklets will be shared with other students, such as fourth graders, who have studied both electricity and magnetism.

C. Electricity and Magnetism Activity #2 - In small groups (three-four students), the students will pick one of the hands-on activities from the previous lessons, modify it, and demonstrate it to another class, such as fourth graders, who have studied both electricity and magnetism.

VII. HANDOUTS/WORKSHEETS

A. Appendix A: Electricity Review Worksheet
B. Appendix B: Electricity Review Worksheet Answer Key
C. Appendix C: Compass Diagram
D. Appendix D: Example of Earth Paragraph
E. Appendix E: Magnetic Compass Lab Report
F. Appendix F: Magnetic Compass Lab Report Answer Key
G. Appendix G: Electricity and Magnetism Relationship Lab Report
H. Appendix H: Electricity and Magnetism Relationship Lab Report Answer Key
I. Appendix I: Electromagnet Lab Report
J. Appendix J: Electromagnet Lab Report Answer Key
K. Appendix K: Electric Motor Lab Report
L. Appendix L: Electric Motor Lab Report Answer Key
M. Appendix M: Electricity and Magnetism Test
N. Appendix N: Electricity and Magnetism Test Answer Key

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Appendix A

Electricity Review Worksheet

Name_____ Date_____

1. List the material as a Conductor or Insulator:

a.) Glass_____ f.) Silver_____
b.) Wood_____ g.) Aluminum_____
c.) Copper_____ h.) Sand_____
d.) Iron_____ i.) Plastic_____
e.) Foam_____ j.) Rubber_____

2. Define the following words:
   a.) Electricity:_____
   b.) Conductor:_____
   c.) Insulator: _____
   d.) Attract:_____
   e.) Repel:_____
   f.) Ohm's Law:_____

3. Fill in the missing word:
   a.) "Like" charges _____.
   b.) "Unlike" charges _____.
   c.) In Ohm's Law the "I" represents _____.
   d.) In Ohm's Law the "V" represents _____.
   e.) In Ohm's Law the "R" represents _____.

4. Solve the following problems using Ohm's Law (Do NOT Forget Units)

a.) The voltage of a light bulb is 1.5 V and the current is 0.3 amps. What is the resistance?

b.) A curling iron operates at a current of 0.5 amps. If the resistance is 30 ohms, what is the voltage?

c.) If a light bulb filament has a voltage of 1.5 V and resistance of 15 ohms, what is the current?

d.) A waffle iron has a voltage of 3 V and a current of 0.1 amps, what is the resistance?

e.) A clock has a current 0.2 amps and a resistance of 30 ohms, what is the voltage?

Appendix B

Electricity Review Worksheet Answer Key

1. a.) Insulator
b.) Insulator
c.) Conductor
d.) Conductor
e.) Insulator
f.) Conductor
g.) Conductor
h.) Insulator
i.) Insulator
j,) Insulator

2. a.) Electricity - electric charges that flow through a wire or similar material
b.) Conductors - materials through which electrons move freely
c.) Insulators - materials through which charges of an electric current are not able to move freely
d.) Attract - to pull to or toward oneself or itself (electron-proton interaction)
e.) Repel - to force away or apart (electron-electron, proton–proton interactions)
f.) Ohm's Law: ohms (resistance) = volts (voltage) / amps (current)
R=V/I or I = V/R or V= IR

3. a.) repel
b.) attract
c.) current
d.) voltage
e.) resistance

4a.) 5 ohms
b.) 1.5 V
c.) 0.1 amps
d.) 30 ohms
e.) 6 V

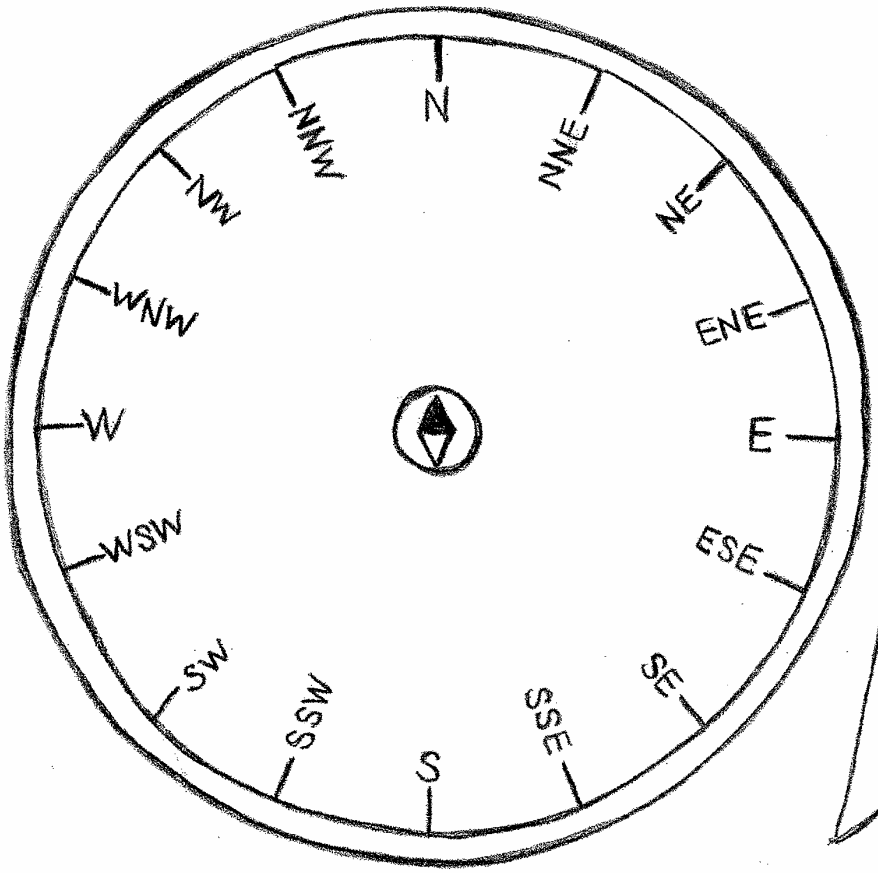
Appendix C

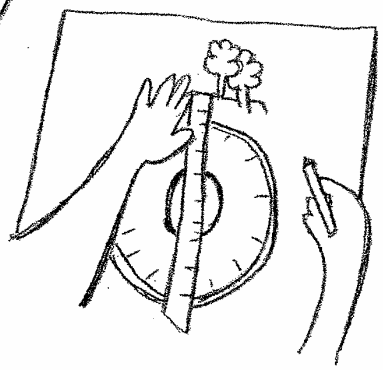
Compass Diagram

Adapted from *Stuck on Magnets* (p. 14)

Procedure:

(1) Cut out a copy of the Compass Diagram.
(2) Glue it to the center of a piece of construction paper.
(3) Place the compass in the center of the diagram.
(4) Allow the magnet to point to the Magnetic North Pole.
(5) Move the paper until the North point points north.
(6) Place the ruler at the center of the compass diagram.
(7) Point the ruler to the first landmark.
(8) Record the direction of the landmark by drawing a straight line from the point on the compass diagram.
(9) Draw a symbol to represent the landmark at the end of the line.
(10) Continue drawing other landmarks and recording their directions the same way.
(11) Neatly color and label each landmark.





Appendix D

Example of Earth Paragraph

Earth is a giant magnet. It is believed that Earth is magnetic because there is circulation of molten material inside the Earth's core. The molten material is believed to be nickel-iron. Van Allen Belts contain electrons and protons traveling at high speeds. These particles and the particles in the magnetosphere contribute to the Earth's magnetic field. The magnetosphere is the region of Earth's magnetic field confined by solar wind. The Earth's magnetism allows it to be navigated by the use of a magnetic compass. Navigation is the method of determining position, course and distance traveled.

Appendix E

Magnetic Compass Lab Report

Name_____ Date_____

Procedure:

(1) Stroke a paper clip about 20 times using the south pole of the magnet. Be sure to stroke toward the end of the paper clip. This will make the paper clip a magnet.
(2) Cut a piece of cork or Styrofoam into the shape of an arrow.
(3) Place it flat on the table.
(4) Tape the paper clip onto the top of it.
(5) Float the cork on the water in one of the bowls provided.
(6) When the cork stops moving, use the magnetic compass to verify that the point of the paper clip points north.
(7) Stroke the eye of the needle with the north pole of the bar magnet. This makes the needle into a magnet.
(8) Bring the eye of the needle near the point of the paper clip. Write down observations.
(9) Then stroke the point of the needle with the magnet's north pole.
(10) Bring the eye of the needle near the point of the paper clip again. Write down observations.

Observations:

Activity Questions:

(1) What do you think happened to the needle in step #7?

(2) What do you think happened to the needle in step #9?

(3) What did you learn from this activity?

Appendix F

Magnetic Compass Lab Report Answer Key

Observations:
Answers may vary.
Possible observations: They should be sure to recognize that when they bring the eye of the needle towards the paper clip point, the unlike poles attract to each other. When they bring the point of the needle towards the paper clip, the poles repel.

Activity Questions:

(1) The eye of the needle becomes a south pole.

(2) The point of the needle seems to become a south pole, then the eye changes and becomes a north pole.

(3) Answers may vary.

Appendix G

Electricity and Magnetism Relationship Lab Report

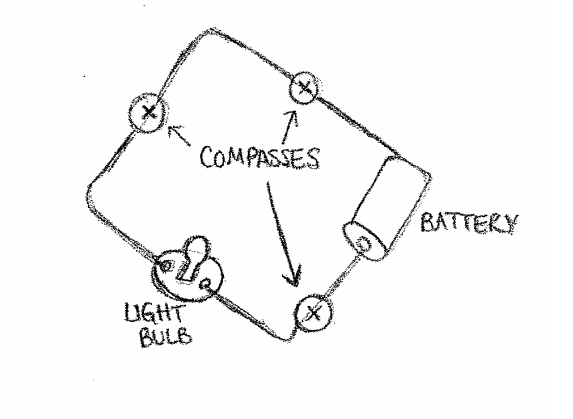
Adapted from *Science Explorer Electricity and Magnetism* (p. 30)

Name_____ Date_____

Procedure:

(1) Each group should collect two wires with the insulation stripped off the ends, three compasses, a D cell battery, a light bulb and a light bulb holder.
(2) Connect one end of each wire to the light bulb holder.
(3) Connect the open end of one of the wires to the battery using electrical tape.
(4) Spread out the three compasses along (underneath) the wire.
(5) Observe the direction(s) that the compasses are pointing. Write down observations.
(6) Center the wires over the compasses, making sure the compass needles are free to turn.
(7) Touch the free end of the remaining wire to the battery.
(8) Observe the compasses as current flows through the wire. Write down observations.
(9) Move the wire away from the battery, then touch it to the battery again.
(10) Observe the compasses again. Write down observations.

Figure 1: Diagram of Equipment Set-Up



Observations:

Activity Questions:

(1) What happened to the compasses?

(2) Using your observations and what you know about electricity and magnetism, write a paragraph about the connection between electricity and magnetism.

Appendix H

Electricity and Magnetism Relationship Lab Report Answer Key

Observations:
Answers may vary.
Possible observations: When the wire is touched to the battery, a circuit is created and the compass needles will move. When the wire is removed from the battery, the compasses point north.

Activity Questions:

(1) When no current is flowing, the compass needles all point to the magnetic north. The compasses move when electricity in the wire creates a magnetic field. The compass needles align themselves with the magnetic field.

(2) Answers may vary.
Electricity and magnetism are related. Electrons and protons have a property called electric charge. When electric charges flow through a wire, they create an electric current. An electric current creates a magnetic field. A magnetic field is created by the movement of charges. The direction of the current (the moving charges) then determines the direction of the magnetic field. Also, on the reverse, moving a magnet back and forth in front of a wire connected to a meter, causes electricity to flow through the wire.

Appendix I, page 1

Electromagnet Lab Report

Adapted from *Integrated Science Laboratory Manual* (pp. 313-316)

Name_____ Date_____

Procedure:

(1) Hold the five nails in a bunch. Touch the aluminum foil to the nails to test for magnetic attraction between the nail and the aluminum foil. Repeat using the penny, nickel, dime, wood and steel. Record results.
(2) Find out how many paper clips are attracted to the nails. Record results.
(3) Hold five nails together and neatly wrap about 25 cm of wire around the nails in single layer. Do NOT overlap the coils. Be sure to leave about 50 cm of wire at one end and about 125 cm of wire at the other end.
(4) Attach the shorter end of the wire to one terminal of the battery.
(5) Touch the 125 cm end of the wire to the open battery terminal.
(6) Test each material for attraction to the nails while the electromagnet is on. Record results.
(7) Give the electromagnet power again and see how many paper clips the nails can hold. Record results.
(8) Use the 125 cm end of the wire to wrap another 25 cm of wire in a single layer around the nails.
(9) Repeat steps 5, 6, and 7.
(10) Wind a second layer of wire over the first winding, using the 100 cm end of the wire. You should have about 50 cm of unwound wire left.
(11) Repeat steps 5, 6, and 7. Remember to record results.

Note: Do not operate the electromagnet for more than a few seconds at a time. It will rapidly use up the battery power.

Observations:

Test	Object	Attraction (Yes/ No)
Five nails alone	Aluminum	_____
	Penny	_____
Number of paper clips =	Nickel	_____
	Dime	_____
	Wood	_____
	Steel	_____
Five nails, 25 cm of wire	Aluminum	_____
	Penny	_____
Number of paper clips =	Nickel	_____
	Dime	_____
	Wood	_____
	Steel	_____
Five nails, 50 cm of wire	Aluminum	_____
	Penny	_____
Number of paper clips =	Nickel	_____
	Dime	_____
	Wood	_____
	Steel	_____
Five nails, two layers of wire	Aluminum	_____
	Penny	_____
Number of paper clips =	Nickel	_____
	Dime	_____
	Wood	_____
	Steel	_____

Appendix I, page 2

Activity Questions:

(1) How is an electromagnet different from a regular magnet? _____

(2) Which materials did the electromagnet attract? Which materials did the electromagnet not attract?

(3) Why are some objects attracted to the electromagnet? Why were the other objects not attracted?

(4) List the common property of the materials that were attracted to the electromagnet. _____

(5) Explain how you might construct an electromagnet that could hold more paper clips? _____

(6) Think about what components go into an electromagnet and what enhances the magnetic field. How can you increase or decrease the strength of an electromagnet without making any changes to the arrangement of the wire or nails? Write a procedure you would follow to answer this question.

Appendix J

Electromagnet Lab Report Answer Key

Sample Data
Observations:

Test	Object	Attraction (Yes/ No)
Five nails alone	Aluminum	No
	Penny	No
Number of paper clips = 0	Nickel	No
	Dime	No
	Wood	No
	Steel	No
Five nails, 25 cm of wire	Aluminum	No
	Penny	No
Number of paper clips = 2	Nickel	No
	Dime	No
	Wood	No
	Steel	Yes
Five nails, 50 cm of wire	Aluminum	No
	Penny	No
Number of paper clips = 5	Nickel	A little
	Dime	No
	Wood	No
	Steel	Yes
Five nails, two layers of wire	Aluminum	No
	Penny	No
Number of paper clips = 10	Nickel	A little
	Dime	No
	Wood	No
	Steel	Yes

Activity Questions:

(1) An electromagnet uses an electric current and can create a stronger magnetic field. It can also be turned on and off.

(2) Steel or iron objects and paper clips were strongly attracted. Nickel was weakly attracted. The aluminum foil, penny, dime and wood were not attracted.

(3) Materials that were attracted have electrons that align with the magnetic field of the magnet. The other objects that were not attracted do not have electrons that align with the magnetic field.

(4) The materials are all iron or iron alloys.

(5) Answers may vary. A possibility may include increasing the number of layers of wire.

(6) Answers may vary. Be sure that students write a complete procedure that is easy to follow. Possibilities may include: Increasing the strength of the electromagnet by increasing the electric current, using a battery that has a higher voltage, or adding a wire that connects to two or more batteries in a circuit.

Appendix K

Electric Motor Lab Report

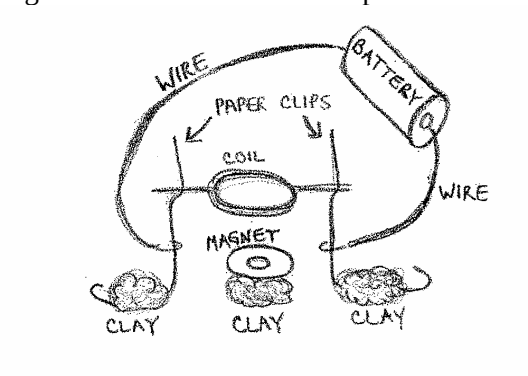
Adapted from *Science Explorer Electricity and Magnetism* (pp. 82-83)

Name_____ Date_____

Procedure:

(1) Wrap about 1 meter of enamel-coated wire around the film canister. Leave about 5 cm free at each end.
(2) Remove the film canister and wrap the two free ends about four times around the coil to keep it from unwinding.
(3) Use the sandpaper to scrape off all of the enamel from about 3 cm of one end of the coil of wire.
(4) Sand off about half (the bottom half) of the enamel from about 3 cm of the other end of the enamel coated wire.
(5) Bend two paper clips and hold them down with clay as shown in figure 1.
(6) Place the free ends of the wire on the paper clips. Balance the coil of wire and adjust the paper clips and wire so that the coil can rotate freely.
(7) Use clay to hold the permanent magnet in place directly below the coil of wire.
(8) Remove the insulation from the ends of the two wires.
(9) Attach the wires to the battery and the paper clips. See figure 1.
(10) Give the coil a gentle push to start it turning. If it does not spin, check the following:
    (a) Are the paper clips in good contact with the battery?
    (b) Will the coil spin in the opposite direction?
    (c) Will the coil work on another group's apparatus?
(11) Make modifications, if needed.

Figure 1: Electric Motor Set-up



Observations: _____
_____
_____
_____

Activity Questions:

(1) How is the flow of current through the coil related to how you sanded the ends of the enamel-coated wire?

(2) A magnetic field is created when the motor is connected to the battery. Explain why.

(3) Why does the coil rotate?

(4) The motor you made is capable of producing motion, but not able to do much useful work. What are some ways you could modify your motor to make it capable of doing useful work?

Appendix L

Electric Motor Lab Report Answer Key

Observations:
Observations may vary. Possibilities could include how the electric motor rotated. It could also include any modifications or adjustments that had to be made to the electric motor to allow it to operate.

Activity Questions:

(1) Current flows when both of un-insulated ends of the wire are in contact with the paper clips. Current does not flow when the unsanded half of the wire is in contact with the paper clip.

(2) When a circuit is complete it allows current to flow through the motor. A flowing current then produces a magnetic field.

(3) When the coil becomes a magnet, it is either pushed or pulled by the force of the permanent circular magnet.

(4) Answers may vary. Possible answers may include: (a) Adding attachments that would allow the machine to perform tasks, such as lifting a light object. (b) Using more cells (c) Making the motor larger or sturdier.

Appendix M, page 1

Electricity and Magnetism Test

Name_____ Date_____

Modified True/False: Indicate whether the sentence or statement is true or false. If false, change the identified word or phrase to make the sentence or statement true.

____ 1. Copper is a good <u>conductor</u> of electric current. _____

____ 2. Increasing the number of loops in an electromagnet will cause the strength of its magnetic field to <u>decrease</u>. _____

____ 3. A <u>motor</u> uses motion to produce an electric current. _____

____ 4. A <u>transformer</u> is a device that increases or decreases voltage. _____

Multiple Choice:

____ 5. Magnetic poles that are alike
   a. attract each other.
   b. repel each other.
   c. do not react to each other.
   d. always point toward the south.

____ 6. Where is the magnetic north pole?
   a. at the geographic north pole
   b. at the geographic south pole
   c. along the coast of Antarctica
   d. in northern Canada

____ 7. A magnetic field is produced by moving electrons, which carry an electric
   a. proton.
   b. charge.
   c. circuit.
   d. resistance.

____ 8. An electric current produces a(an)
   a. magnetic domain.
   b. magnetic field.
   c. electrical resistance.
   d. permanent magnet.

____ 9. Materials that allow the charges of an electric current to move freely through them are called
   a. insulators.
   b. conductors.
   c. resistors.
   d. magnets.

____ 10. An example of an insulator is
   a. rubber.
   b. copper.
   c. silver.
   d. iron.

Electricity and Magnetism Test continued on next page

____ 11. An example of a conductor is
   a. wood.
   b. glass.
   c. plastic.
   d. aluminum.

____ 12. As in the case of unlike magnetic poles, unlike electric charges
   a. attract each other.
   b. repel each other.
   c. exist in pairs.
   d. do not interact.

____ 13. According to Ohm's law, what is the resistance of a light if the voltage is 9.0 volts and the current is 0.30 amps?
   a. 0.033 ohms.
   b. 2.7 ohms.
   c. 30 ohms.
   d. 8.7 ohms.

____ 14. According to Ohm's law, resistance is equal to voltage divided by
   a. time.
   b. conduction.
   c. current.
   d. potential.

____ 15. The charge on a proton is
   a. negative, and the charge on an electron is positive.
   b. positive, and the charge on an electron is negative.
   c. the same as the charge on an electron.
   d. can change according to the situation.

____ 16. A device that increases or decreases voltage is called a(n)
   a. alternator.
   b. transformer.
   c. generator.
   d. turbine.

____ 17. A device used to measure small currents is a(n)
   a. electric motor.
   b. commutator.
   c. armature.
   d. galvanometer.

____ 18. The symbol for current is
   a. C.
   b. I.
   c. P.
   d. V.

Completion

19. When placed near each other, unlike magnetic poles _____ each other.

20. An atom can act as a tiny magnet due to the spinning and orbiting motion of negatively charged particles called _____.

Electricity and Magnetism Test continued on next page

21. Earth's magnetism is thought to be due to the circulation of molten iron and nickel within Earth's _____.
22. Protons and electrons have a property called electric _____.
23. A(n) _____ is a material in which charges are not able to move freely.
24. The flow of charge through a material is called electric _____.
25. Like electric charges _____ each other.
26. For a current of 3 amps and a voltage of 9 volts, the resistance is _____.
27. A step-up transformer is a device that increases _____.
28. _____ is the flow of electrons in a conductor.
29. The Earth's _____ allows it to be navigated by the use of a compass.
30. Spinning _____ around an atom create a magnetic field around the atom.

Short Answer

31. Suppose that a bar magnet is suspended a few millimeters above another bar magnet. If the north pole of the bottom magnet is on the left, where is the north pole of the top magnet? Explain.

32. How does a conductor differ from an insulator? Give an example of each.

33. What is the resistance of a lamp operating at 115 volts and using 0.25 amp of current? What relationship did you use to find the answer?

Appendix N

Electricity and Magnetism Test Answer Key

MODIFIED TRUE/FALSE

1. T
2. F, increase
3. F, generator
4. T

MULTIPLE CHOICE

5. B
6. D
7. B
8. B
9. B
10. A
11. D
12. A
13. C
14. C
15. B
16. B
17. D
18. B

COMPLETION

19. attract
20. electrons
21. core
22. charge
23. insulator
24. current
25. repel
26. 3 ohms
27. voltage
28. electricity
29. magnetism
30. electrons

ESSAY

31. The north pole of the top magnet is also on the left. Because the top magnet is hovering over the bottom magnet, the magnets must be repelling each other. Magnets repel each other when like magnetic poles are brought close together.
32. Electric current moves freely through conductors, but not through insulators. The reason is that some of the electrons in a conductor are only loosely bound to their atoms. These electrons are able to move throughout the conductor, forming an electric current. In an insulator, the electrons are bound tightly to their atoms and do not flow easily. Examples of conductors include copper, silver, and iron. Examples of insulators include rubber, glass, and wood.
33. Use Ohm's Law: Resistance = voltage/ current = 115V/ 0.25A = 460 ohms