**Oakland Schools Science Scope**

**Grade 4**

 **Heat, Electricity and Magnetism**

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**About Our Scope Unit/Lesson Template**

This template is designed to serve several teaching and learning principles considered as staples of state of the art science instruction. Here are the key principles in summary:

* It’s critical to **elicit prior knowledge** as a unit or lesson begins
* **Key questions** should drive student explorations and investigations
* **Activity Before Concept** – Student inquiry-based explorations which give personal experience with phenomena and ideas should precede a presentation of science ideas.
* **Evidence is the heart of the scientific enterprise.** Students generate evidence and analyze patterns in data that help to construct scientific explanations around key questions.
* **Concept Before Vocabulary** – attaching science vocabulary to concepts developed by student investigations yields more success than beginning a unit or lesson with a list of science vocabulary.
* **Talk, argument** **and writing** are central to scientific practice and are among the most important activities that develops understanding.
* **Application** of the ideas provides review, extends understanding and reveals relevance of important ideas.
* **Assessment** of knowledge, skill and reasoning should involve students throughout the learning process and be well aligned to the main objectives and activities of the unit.

The Scope Science template is designed to put these principles into practice through the design of the ***SCOPE LEARNING CYCLE FOR SCIENCE***. Each unit has at least one cycle. The components are listed below:

|  |  |
| --- | --- |
| The Key Question for the Unit | Each unit has one, open ended driving question that relates to all the content and skills of the unit. The Key Question is presented at the opening of the unit and revisited at the unit’s conclusion. |
| Engage and Elicit | Each unit begins with an activity designed to elicit and reveal student understanding and skill prior to instruction. Teachers are to probe students for detailed and specific information while maintaining a non-evaluative stance. They also can record and manage student understanding which may change as instruction proceeds.  |
| Explore  | A sequence of activities provides opportunities to explore phenomena and relationships related to the Key Question of the unit. They will develop their ideas about the topic of the unit and the Key Question as they proceed through the Explore and Investigate stage of the learning cycle. Each of the activities may have its own Key Question or central task that will be more focused than the unit question. The heart of these activities will be scientific investigations of various sorts. The results, data and patterns will be the topic of classroom discourse and/or student writing. A key goal of the teacher is to reference the Key Question of the unit, the Engage and Elicit of the students and to build a consensus especially on the results of the investigations. |
| Explain | Each unit has at least one activity in the Explain portion of the unit when students reconcile ideas with the consensus ideas of science. Teachers ensure that students have had ample opportunity to full express their ideas and then to make sure accurate and comprehensible representations of the scientific explanations are presented. A teacher lecture, reading of science text or video would be appropriate ways to convey the consensus ideas of science. Relevant vocabulary, formal definitions and explanations are provided. It’s critical that the activity and supporting assessments develop a consensus around the Key Questions and concepts central to the unit. |
| Elaborate  | Each unit cycle has at least one activity or project where students discover the power of scientific ideas. Knowledge and skill in science are put to use in a variety of types of applications. They can be used to understand other scientific concepts or in societal applications of technology, engineering or problem solving. Some units may have a modest Elaboration stage where students explore the application of ideas by studying a research project over the course of a day or two. Other units may have more robust projects that take a few weeks. |
| Evaluation. | While assessment of student learning occurs throughout the unit as formative assessment, each unit will have a summative assessment. Summative assessments are posted in a separate document. |

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4th Grade Physical Unit 1 Pre Assessment

Read and answer the following questions. \*Remember this is just to “see” what you “already” know and where we need to go from here.

S.IP.04.16

1. A student is conducting an experiment investigating various items that will stick and will not stick to magnets. Which method should be used to present the data?

A. Chart

B. Graph

C. Venn diagram

D. Labeled drawing

 

This is a very simple electric circuit.

2. Explain in as much detail as you can (thinking about both battery and bulb) why you think the bulb lights.

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3. a) How could you change the circuit to make the bulb brighter?

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b) Explain why this would work
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P.PM.04.53

4. Which material is a good conductor of electricity?

A. Copper

B. Plastic

C. Rubber

D. Wood

P.PM.04.53

5. Four objects—paper, plastic, metal, and wood—are removed from a 35˚ refrigerator and placed in a 75˚ room. Which object’s temperature will become 75˚ the quickest?

A. Paper

B. Plastic

C. Metal

D. Wood

6. What is a conductor? Name 3 kinds of materials that will conduct electricity. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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7. If I have a pile of nails, pennies, pencils, and straws, which of the materials would be attracted to the magnet and which ones would be repelled?

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8. P.PM.04.53

A student builds a complete circuit using a battery, a bulb, a buzzer, and wires. She places each object into one of three categories--conductor, energy source, or device. Which one of these materials would be categorized as a conductor?

A. Battery

B. Bulb

C. Buzzer

D. Wire

9. P.EN.04.43

What form of energy changes into the heat energy used by a toaster to brown bread?

A. Light

B. Gravity

C. Electricity

D. Magnetism

10. P.EN.04.43

What form of energy changes into the heat energy used by a toaster to brown bread?

A. Light

B. Gravity

C. Electricity

D. Magnetism

**Grade 4**

**Heat, Electricity and Magnetism**

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This project is similar in content to Activity 3. It is at the teacher’s discretion to use all

or a portion of this activity.

**Unit Introduction**

Energy is a concept which is central to all of science. Matter and energy make up the entire universe. Matter is the substance and energy is the mover of substance. Because energy is an abstract concept (we cannot feel, see or smell most forms of energy), it is difficult to define because it is both a “thing” and a process. Persons, places and things have energy, but normally we only observe it when it is being transferred or transformed. In Learning Cycle #1, students investigate heat energy and its effect when it is transferred or transformed. In Learning Cycle #2, students will explore electricity and electrical circuits as well as the conductive properties of various substances. Students discover the relationship of magnetism and electricity in Learning Cycle #3.

The resources and opportunities to address these topics are of such abundance and quality that the unit has the tremendous potential to be a highly relevant, real world and investigation-rich experience for students. As teachers look for ways to have students use real world data, apply interactive technology to real world questions, and foster meaningful tasks for reading, writing, argumentation and mathematics and framed by the Common Core Curriculum Standards, the issues here provide abundant opportunity. The main limitation is the class time available given other content demands.

*On the Common Core State Standards for English Language Arts and Literacy in Science*

All science teachers will find the Common Core State Standards of ELA a tremendous asset for reaching learning objectives in science education. Reading, writing, argumentation and discourse are central proficiencies necessary for success in science. All teachers should become fluent with the document and are likely to find it validating.

[**http://www.corestandards.org/assets/CCSSI\_ELA%20Standards.pdf**](http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf)

These standards are best reached with science instruction that connects content to real world problems and experiments, complimented with scientific writing, challenging questions, processes for classroom discussion and debate and use of scientific text.

It is recommended that teachers require students to use an interactive science notebook to support learning in this unit. Here are some features and policies to consider:

* Use a bound notebook, like a composition book – you can cut and paste or staple some other materials into it.
* The right facing page is for teacher content, the left is for student reflection
* Leave four pages for a table of contents
* Leave the notebooks in the room
* Quad ruled notebooks are very nice for the graphing activities.

**Learning Cycle 1: Heat Energy**

**Introduction**

As students learn about energy, they explore the concept that adding energy to a substance has an effect on its state, motion, or temperature. They look at how energy can be transformed from form to form (although it cannot be created or destroyed.) Students identify and compare how heat energy can be transformed from chemical energy (burning), mechanical energy (rubbing, friction), or electrical energy (resistance in electrical devices).

**Learning Objectives**

Students will be able to:

* Explain that heat is a form of energy.
* Demonstrate how temperature can be increased in a substance by adding energy.
* Explain that heat energy can be produced when substances burn, are rubbed against each other and when electricity flows through a wire.
* Explain how heat energy is transferred through convection.
* Explore how energy can be transformed from one form to another.
* Explain that the sun is the source of heat and light for the Earth.
* Demonstrate the effects of sunlight on the heating and cooling of Earth materials.
* Demonstrate the effects of insulators and conductors on the transfer of heat energy.

**Key Question: How is heat energy transferred and transformed?**

**Engage and Elicit**

**Activity 1: Energy All Around**

**Purpose**

Students will be introduced to and explore two different forms of energy. Through their explorations, students begin to discover and identify that adding energy to a substance has an effect on its state, motion or temperature.

**Activity Description**

Students will explore heat and electrical energy within five stations. Students create a working definition of energy and begin to understand that energy “makes things happen.” They discover when energy interacts with substances it has an effect on its state, its motion and its temperature.

**Focus Question**

What happens when energy is added to a substance?

**Duration**

One class period

**Materials**

* Beakers 2- capacity of at least 250 mL
* electric fan
* flashlights
* hot plate
* paper circles (1 or 2 per student)
* pinwheel
* plastic rulers
* radio (battery powered)
* radio (electrical)
* radiometers
* shallow pan (2, pie pan)
* thread
* toaster

**Teacher Preparation**

1. Energy is defined as the ability to do work. Work is the product of the force on an object and the distance through which the object is moved. Persons, places and things have energy but energy is usually only observed when it is being transferred or transformed. Energy comes in many forms such as electromagnetic waves from the sun and we feel thermal energy; it is in the food we eat and receive it by digestion. There is also electrical, mechanical, sound, light, kinetic, nuclear, potential and others.
2. Gather materials, set up, and label the Energy Stations. The labels needed are: Heat Energy 1, Heat Energy 2, Electrical Energy and Heat Energy, Electrical Energy 1, and Electrical Energy 2.
3. The equipment needed at each station is listed below.
* Heat Energy Station 1: flashlights, and radiometer(s)
* Heat Energy Station 2: hot plate and beakers for water
* Electrical and Heat Energy Station: toaster, paper snake
* Electrical Energy Station 2: electric fan and pinwheels
* Electrical Energy Station 3: two radios, one powered by an electrical cord and one powered by batteries
1. A radiometer is a device that contains foil “fins” that rotate due to radiation/light energy (technically, the momentum of photons.) The dark side of the fans retreat from the radiation and the light sides advance toward the radiation. Cooling the radiometer will cause it to move in the opposite direction. When exposed to radiant energy, the radiometer becomes a “heat engine” responding to the differences in the temperatures of the light (reflect heat) and dark (absorb heat) paddles. It is available from a variety of science supply sources at low cost.
2. Create a paper snake from a circle of paper. Students may create their own snakes if time permits. A piece of thread will be attached to either the tail or the head of the snake so that it can be held a distance above the toaster while the electrical elements are heating.



**Classroom Procedure**

1. Introduce the unit by telling students you have a lot of energy today. You are ready to do a lot of work. Ask if they are. Then begin the lesson by writing the word “Energy,” on the board and drawing a circle around it. Ask students: “If energy is the ability to do work, what are some other words that relate to this one?” As students list words, write them around the word “Energy” and draw lines from the students’ words to the main concept “Energy.” Add, “We can also say that energy makes things move or changes things. It makes things happen!” Students may generate other words from their first set of words. These, too, can be connected by lines to those words. This process is called concept mapping. **Note:** Concept mapping can help you assess students’ prior knowledge. Because energy is an abstract concept, students often hold misconceptions about it—such as the idea that energy is matter. A sample student map is shown.
2. Pay particular attention to *forms* of energy that students may have suggested for the concept map. Explain to students: “I get my energy from food. The chemicals in food are one form of energy. There are many other *forms* of energy.” Suggest additional forms of energy if students have not identified them on the concept map: light, heat, sound, wind, motion, electrical, mechanical, and chemical. Explain that students will be investigating two forms of energy during their visits to the Forms of Energy Stations in this lesson: heat and electrical. You will discover other forms of energy such as light and mechanical. Some of your ideas on the concept map, though, are not forms of energy. Things like fossil fuels, gasoline, and coal are *sources* of energy.”
3. On the board, make three columns—one labeled “Forms of Energy,” the next labeled “Sources of Energy,” and the third column labeled “Examples.” Have the class help you make lists under each heading.
4. Ask: “Can one form of energy be transformed or changed into another form of energy? If so, what are some examples?” [Wind energy can be transformed into sound energy when we play a wind instrument, such as a flute. Light energy can be transformed into heat energy, as in the case of sunlight.] We will explore more examples in another lesson.
5. Divide the class into groups of four or five students. Have each group take one piece of blank paper and a pencil and go to a different station. Write the questions listed in Step 6 on the board.
6. Say: “You are to use the form of energy at the Form of Energy Station to do something with the materials given. After you do that, write down the answers to these questions:
* What form of energy are we exploring at this Form of Energy Station?
* What happens when we use the things at our station?
* What did our form of energy interact with?
* Where did the energy go?
1. Let groups experiment and examine their materials and how to use them. Walk around the room and help students think through the questions they are to answer. **Note:** Students at the Heat Stations may need guidance: at Heat Station 2 and the Heat and Electricity Station. Students must be careful not to touch the hot plate and the toaster. At the other Stations, students should be able to figure out how to use the materials.
2. After 20 minutes or when you observe groups losing focus, have the groups rotate to one more station and write down the answers to the questions based on their work at the second station.
3. When students have completed their work at the second stations, ask each group to report their discoveries and answers to the questions posed. As students report their answers, record any questions they might have to help guide future lessons. Other students in the class should be given the opportunity to ask questions of the presenting groups. Model this behavior by asking a thoughtful question.

Challenge students to think of other models of energy interacting with matter for each of the stations they visited. For example, instead of using a flashlight and radiometer at the light/heat station, ask them what else they could use to demonstrate light energy being transformed into another form of energy.

1. Discuss what groups have learned. Ask: “Is energy just one kind of thing?” [No, energy has several different forms.] Then ask: “Do we use these forms of energy?” [Wind energy can be used to dry clothes. Light energy helps us see in the dark. Heat energy keeps us warm. Sound energy lets us hear music and the human voice. Electrical energy makes our appliances work.] Then ask: “What does interaction mean?” [Interaction is when energy interacts with matter.] Next ask: “Explain what happened at your Stations when one form of energy interacted with matter.” [Explanations will vary, depending upon the station.] Finally, ask: “What kinds of things can energy do?” [A lot! Among other things, energy can make water boil, turn a pinwheel, and play a radio.]

**Explore**

**Activity 2: Happenin’ Heat**

**Purpose**

Students will explore how heat energy is transferred through convection.

**Activity Description:**

Students will demonstrate that temperature can increase in a substance by adding energy. Students place plastic bags of warm and cool water on top of each other and measure the change in temperature. Next, they measure changes in the temperature of air inside foam cups, each of which has a small container of hot water placed in it. Students also measure changes in the temperature of the water in the foam cups. They graph their results and draw conclusions about heat transfer.

**Focus Question**

How is heat energy transferred by convection?

**Duration**

One class period

**Materials**

* Baby food jars (glass with lids; 1 per group of students)
* Clock or watch
* Colored pencils
* Foam cups (12 oz. or 16 oz. with tight fitting lids; 1 per group)
* Hot water
* Nail and hammer (to create holes in metal lids of baby food jars)
* Re-sealable plastic bags
* Thermometers (2 per group)

**Teacher Preparation**

1. All matter is made up of tiny particles called atoms that are constantly moving. The internal motion of the atoms is called heat energy. The faster the particles move, the more heat energy is produced. Rub your hands together for several seconds. The heat you feel is created by the friction between your hands. You converted mechanical energy (energy of motion) into heat energy. Heat energy causes changes in the temperature and phase (solid, liquid, gas) of any form of matter.



1. Advance Preparation: Each group of students gets two plastic bags. The teacher should have four bags (two to mix and two to position so that they touch one another). Fill one bag in each group half-full of warm water (at least 50 degrees C) and put an equal volume of cold water in the second bag.
2. Each group of students gets two foam cups (12 oz. or 16 oz.) along with two lids (each with a hole punched in it), two thermometers, and a glass baby food jar with a lid. Make two holes in each foam cup lid to accept the thermometers. Make sure the holes are placed in a way that one thermometer goes through one hole and into the jar of water and the other thermometer goes through the other hole and into the cup without touching the jar. The easiest way to make these holes is with a ballpoint pen. Make one hole the size of a thermometer in each of the baby food jar lids with a hammer and nail.

**Classroom Procedure**

1. Begin the lesson by reviewing the forms of energy explored in Lesson 1 (heat and electrical). Ask students to briskly rub their hands together then place their hands on their cheeks. “What do they feel?” [Heat.] “How do we know? Can we measure heat?” [Yes, with a thermometer.] Today we will be exploring how heat can be measured and transferred.
2. Ask two students to come to the front of the classroom. Hand each person a bag of water (one containing hot water and one containing cold water). Ask each of them to describe to the class the water temperature in the bag. Demonstrate how to use a thermometer to measure the temperature of the water in each bag. Record the temperatures on the board. Then ask the class: “Given these descriptions and measurements, what do you predict will happen to the temperature of the water if the water in both bags is mixed together?” [Most students will say that the temperature would be somewhere in-between. They may predict that the temperature will be the mean of the warm and cold temperatures.]
3. Have the two students mix the bags of water. This is best done by having one student hold one bag upright while the second student pours her or his bag of water into it. Ask the two students to again describe the temperature of the water in the bag. Ask the students: “How long did it take to change the water’s temperature?” [It changed right away, as soon as the water in the two bags was mixed.] Measure the temperature and record the new temperature on the board. “Was your prediction correct?”
4. Say: “Now here is a puzzler for you. How could we cause the transfer of heat from one bag to another without mixing the two bags of water?” [Some students may suggest that the bags need to touch each other].
5. Hold two new bags of water in contact with each other. Say: “How is this different than physically mixing the water?” [The bags that hold the water interact but the water in the two bags remains separated.]
6. Have students form groups. Tell them that each group will get two bags of water (one containing warm water and one containing cool water) and a thermometer. They need to measure and record the temperature of the water in each bag. This is best done by standing the bags upright on a table and opening them only enough to slip in the thermometer.
7. After students have made that measurement, ask them to make a prediction about what will happen to the temperature of the water in each of their bags when the bags are touching each other. Let students share and discuss their ideas. Then have students put one of their bags on top of the other.
8. After one minute and again after 20 minutes say: “Check and record the temperature in each of your bags.”
9. After the last measurement, say: “Explain what happened.” [Heat energy was transferred from the warm water in one bag to the cold water in the other.] Ask: “Think about our first experiment, when we mixed the water together in one bag. What is different about the heat transfer in *this* experiment, in which the warm and cool water were not mixed together?” [The heat transfer happens more slowly than if they were mixed.]
10. Have students form groups. Give each student a copy of the Student Page “Cup Capers.” Make sure there are colored pencils available. Have students read the instructions on the Student Page. Answer any questions they may have.
11. Give groups their materials: two foam cups (either 12 oz. or 16 oz.), one lid with two holes poked in it, two thermometers, and one glass baby food jar with metal lid. Give students 35 minutes to do the experiment and record their results. As groups finish, have someone from each group record that group’s results on a class chart on the board.
12. Give students time to inspect the data in the class’ chart. Then discuss the results. Question #1: “In looking at the data you collected, what happened to the air temperature and the water temperature?” [The air temperature increased as the water temperature decreased.] Then ask: “Why did this happen?” [Heat energy moved — was transferred— from the water to the air in the cup.] Continue: “What was the path of the heat energy that was initially present in the hot water?” [The heat energy left the warm water and mixed with the cooler air in the cup.] Then ask: “Were there differences in the rate at which the temperature of the air and the temperature of the water changed in the foam cups?” [Yes. The rate of decrease in water temperature was less than the rate of increase in air temperature.]
13. Challenge students by saying: “Explain this difference.” [Compared to air, water requires about five times more heat energy to increase its temperature by an equal amount. Water also takes longer to cool.] Then ask: “Did the air in the cup become the same temperature as the water in the cup? Why or why not?” [Given enough time, heat energy from the warmer water will continue to “flow” towards the cooler air until both reach the same temperature. Students may not have observed this owing to time limitations.] Finally, ask: “How would you explain the movement of heat energy?” [Heat energy, in and of itself, does not really move. Rather, energy is transferred from one substance to another. Heat energy is transferred (or “moves”) from warmer substances to cooler substances. This phenomenon is known as heat transfer or conduction.]

**Explore**

**Activity 3: Form to Form**

**Purpose**

Students will explore heat energy in depth.

**Activity Description**

Students will review the Heat and Electrical Energy Stations from Activity 1 and explore heat energy more in depth. Students explore stations and make observations of how one form of energy can be transformed to another form of energy.

**Focus Question**

What more can we learn about energy?

**Duration**

One class period

**Materials**

* Balloon
* Beakers (2; with capacity of at least 250 mL)
* Bottle (1; 8 oz. with narrow neck; a small salad dressing bottle works well and glass works best)
* Bottles (empty pop; 4 or 5)
* Bowl, large
* Candle and holder
* File folders
* Flashlights
* Hair dryer
* Hot plate
* Ice cubes (6-10)
* Matches or lighter (teacher use, only)
* Metal cans (2 with one end removed)
* Mirrors
* Paper cups
* Paper snakes (from lesson 1)
* Plastic wrap (4 pieces cut into 6 inch squares)
* Pie pan
* Radiometers
* Rubber bands
* Sand (enough to half-fill 2 metal cans)
* Toaster
* Water

**Teacher Preparation**

1. Advance Preparation: Gather materials and set up the Forms of Energy Stations. Nearly the same materials and stations were used in Lesson 1, but some new materials have been added for this lesson. Label the stations: Light Energy, Chemical Energy, Heat Energy 1, Heat Energy 2, and Electrical Energy. Prepare the stations as follows:
2. Light Energy Station: flashlights, file folder, and radiometers
3. Chemical Energy Station: Candle (if permitted), candle holder, matches. Option 2: Thermometers
4. Heat Energy Station 1: hot plate and beakers of water, large bowl of very hot water, 8 oz. bottle, balloon, cold running water
5. Heat Energy Station 2: metal cans, sand, plastic wrap, rubber bands, toaster, paper snake
6. Electrical Energy Station: plastic cups, ice cubes, hairdryer

**Classroom Procedure**

1. “Let us talk about what we learned at each of the Form of Energy Stations in Lesson 1.” [Give students a chance to review their findings.]
2. Ask: “What else is there to learn about these forms of energy?” [Take time to listen and respond to students’ ideas. Encourage them to comment on one another’s suggestions.]
3. Say: “Well, it sounds like we have some more learning to do. We can start right away. At each of the stations, you will transform one form of energy into a different form of energy. You will be given several materials to do your task. It is your job to figure out how to do this. I am available to help if you and your group get stuck.”
4. Place students in the same groups used in Lesson 1 and then assign each group to a “Form of Energy” station. Give each member of each group the appropriate Student Page for that station. Say: “As a group, answer the questions on the Student Page at your station. Each person must fill out her or his own copy of the page, giving the group’s answer and also writing anything else that person would like to add.”

Answers to questions on Student Pages:

***Light Energy Station*** (At this station, students continue to explore how light as a form of radiant energy causes the radiometer to move. When students block the light with a file folder, they observe that the radiometer stops turning. It is not developmentally appropriate to ask fourth grade students to explain why the radiometer moves as it does; this explanation requires an understanding of the kinetic energy of air molecules.)

Question #1: “The radiometer is an instrument used to measure the intensity of light energy. What do you predict will happen to the radiometer if you place a file folder between the light source and the radiometer?” [The file folder blocks light/radiant energy to the radiometer; this causes the radiometer to stop turning.]

Question #2: “Why?” [Because light energy warms the black panels more than the white panels. The different motions of warm and cold air relative to each other results in energy of motion near the black panels, which cause the radiometer to turn. Blocking the light energy stops the heating that occurs.]

Question #3: “Put the file folder between the light source and the radiometer. Was your prediction correct?” [Answers will vary.]

Question #4: “What happens when you move the flashlight away from the radiometer?” [The amount of light energy from the flashlight decreases as you move it farther from the radiometer. Therefore, the radiometer does not turn as fast as it does when the flashlight is nearby.]

Question #5: “Why doesn’t the radiometer turn when only the classroom lights are turned on?” [There is not enough light energy from the classroom lights to reach the radiometer—the lights are too far away to cause the radiometer to turn.]

Question #6: “In this activity, what form of energy does the light energy become?” [Light/heat energy is transformed into energy of motion.]

Question #7: “What is one good question you have about light/radiant energy?” [Answers will vary.]

***Chemical Energy Station*** (At this stations, students should begin to understand that when fuel burns, it produces heat. Option 1: Students observe a burning candle (the chemical energy in the burning wax and wick are transformed into heat and light energy).

Question #1: “What is happening to the candle?” [It is burning.]

Question #2: “To burn chemical energy from the wax is used as a fuel. What kind of energy is produced when the candle burns? What evidence do you have?” [The chemical energy is changed to heat and light energy. I can see the light of the candle and I can feel the heat that is produced by the burning candle.]

Question #3: “Into what form of energy is the chemical energy transformed?” [The chemical energy is transformed into heat and light energy.]

Question #4: “Can you list other types of fuels that we use to produce heat energy?” [Answers may vary. We burn paper; we burn natural gas or oil to heat our homes, etc.]

Question #5: “What is one good question you have about chemical and heat energy?” [Answers will vary.]

Option 2: Students realize that their skin becomes warmer when they exercise.

Question #1: “What caused the change in the temperature in your skin?” [When I exercise, my body becomes warmer.]

Question #2: “What produced the heat in your body?” [Students may not have the background information to answer this question. Answers may vary. My muscles became warmer; the food I eat is fuel for my body.]

Question #3: “What fuel does your body use?” [Food]

Question #4: “What is one good question you have about chemical energy, fuel and heat energy?” [Answers will vary.]

***Heat Energy Station 1*** (At this station, students should begin to make sense of heat energy. Students boil water on the electric hot plate (changing heat energy into energy of motion) and also partially inflate a balloon by heating the air inside a bottle (also changing heat energy into energy of motion). Question #1: “Cool off the bottle by filling it with cold water once or twice. Pour out the water. Put an un-inflated balloon over the opening of the bottle. Float the bottle in a bowl of very hot water. What happens to the balloon?” [It fills with air.]

Question #2: “Why?” [The heat energy in the water heats the air in the bottle. Hot air expands as its molecules move more. The air uses the space in the balloon and causes it to inflate (to move).] Question #3: “Into what form of energy does the heat energy go?” [Energy of motion.]

Question #4: “The hot plate gives off heat energy. When the water in the beaker boils, into what form of energy is the heat energy transformed?” [Energy of motion.]

Question #5: What form of energy was transformed into heat energy by the electric hotplate? [Electrical energy.]

Question #6: “How could you measure heat energy?” [With a thermometer.] Question #7: “What is one good question you have about heat energy?” [Answers will vary.]

***Heat Energy Station 2*** (At this station students explore how energy of motion can be transformed into heat energy by rubbing hands together, shaking sand, and rapidly bending a paperclip back and forth.) Question #1: “How can you turn energy of motion into heat energy with your hands?” [By rubbing them together.]

Question #2: “How can you transform energy of motion into heat energy with a can of sand?” [By shaking the sand.] (Make sure students put one hand over the opening covered with plastic wrap.) Question #3: “How could you turn energy of motion into heat energy with a paperclip?” [By quickly bending the metal back and forth.]

Question #4: “What is the same about all of these activities?” [All of these activities turn energy of motion into heat energy.]

Question #5: “What happened to the heat energy from any of the activities?” [Some of the heat energy warmed the air around the material, and some of the heat energy warmed students’ hands.]

Students will observe the paper snake/toaster activity from Lesson 1.

Questions #6: “Into what form of energy is the heat energy transformed?” [The heat energy is transformed into the energy of motion when the snake moves in circles.]

Question #7: “What relationship have you discovered between heat energy and energy of motion? What is your evidence?” [Answers will vary. Students should state that energy of motion can be transformed into heat energy and heat energy can be transformed in energy of motion. The evidence is measuring and comparing the temperature of the sand in the can before and after shaking the can, feeling the temperature of hands after rubbing hands together, observing the motion of the paper snake as it is held above the heated toaster.]

Question #8: “What is one good question you have about energy of motion?” [Answers will vary.]

***Electrical Energy Station*** (At this station, students use a device to see the effects of heat. Students compare melting ice cubes when a hairdryer is used. Students understand that electrical energy is transformed into the heat energy produced by the hair dryer.

Question #1: “Can you see heat?” [Not directly, but you can see the effect of heat on other objects.] Question #2: “Can you see how heat affects other objects? Give two examples.” [Yes. Students understand that heat changes, moves or otherwise affects objects. Answers will vary.]

Question #3: “How could you make one ice cube melt fast than the other ice cube?” [Answers will vary. Break it into smaller pieces, hold it in my hand, put it in my mouth.]

Question #4: “What is causing the ice cube to melt faster? What type of energy is produced by the hair dryer? What is your evidence?” [The hair dryer produces heat, causing the ice cube to melt faster. The hair dryer produces heat energy. I can feel the warmth of the hair dryer and see the ice cube melting.]

Question #5: “How is the heat energy produced?” [The motor in the hair dryer makes the heat.] Question #6: What form of energy was transformed into the heat energy that melted the ice cube? What is your evidence?” [Electrical energy is transformed into heat energy. I can see that the hair dryer is plugged into the electrical outlet, this causes the hair dryer motor to run and create the heat energy produced by the hair dryer.]

Question #7: “What is one good question you have about electrical and heat energy?” [Answers will vary.]

1. Let students use the Students Pages to figure out how to use the materials. It is okay if they struggle a bit — that sometimes leads to good learning. Watch for signs of frustration. You will probably need to give some guidance. Allow at least 20 minutes for groups to work at their stations and complete their Student Pages. If you choose, you can extend this over several days and have groups rotate through the stations.
2. Bring the class back together. Have each group explain to the rest of the class what form of energy their station was, what they did at their station, and into what form(s) of energy the original form of energy was transformed. (If you will rotate groups through several stations, delay this discussion to allow all groups the chance to work with the materials.)
3. Discuss students’ findings: Begin by asking: “How did you know that energy changed forms? What was your evidence?” [We could observe energy doing something different.] Then ask: “Did you find any evidence at your Station that energy can be transformed into more than one form? If yes, what is the evidence?” [Responses will vary. This can occur at some stations.] “Now that you have studied energy more, how would you describe energy?” [Energy is the power to change something or do work; something that has several forms and can change among them.] “Can you describe how energy interacted with matter at each of the stations?” [Answers will vary.] And finally, ask: “If I could provide any materials or equipment you asked for, could you think of another way to demonstrate a change in the form of energy at your station? What equipment would you need? Into what form would the energy be changed?” Let groups think about this challenge, develop a response, and then share their idea with the whole class. Affirm students’ work.
4. As an extension, students can develop their own set of “Forms of Energy” stations, devising an example of one form of energy transforming into another form for each station. They can set up the stations for a parent open house or for another class. A poster board or bulletin board display could introduce the visitors to the concept of forms of energy transforming into other forms of energy. Each station would have one or more student hosts, and possibly written directions, to help the participants do and understand what the students have set up.

**Explore**

**Activity 4: Old Sol: Our Friend**

**Purpose**

Students will discover that the sun is the source of heat and light for the Earth.

**Activity Description**

Students will discover that the sun is a source of heat and light. As students conduct investigations, they predict, measure and record temperatures within differently colored construction paper pockets. As an extension, students will build a hot dog cooker to confirm the effect of heat energy from the sun.

**Focus Question**

Where does the Earth get most of its heat and light?

**Duration**

Two to three class sessions

**Materials**

Strip thermometers

Construction paper (red, black, white, blue)

Rulers

Scissors

Glue sticks

Large © Pringles cans (one each or per group)

Black construction paper

Aluminum foil

Hammer

Nail

Wire hanger

Bricks or blocks of wood

Hot dogs

Hot dog buns and condiments

**Teacher Preparation/Information**

1. “Wonders of the Sun” is an excellent teacher and student resource from the National Energy Education Development Project. <http://www.need.org/needpdf/WondersoftheSunStudent.pdf>
2. This lesson was adapted from “Here Comes the Sun” which can be retrieved from: <http://www.uen.org/Lessonplan/preview.cgi?LPid=16281>
3. This activity must be completed on a sunny day.

**Classroom Procedure**

1. Divide the students into groups.
2. Pass out construction paper, scissors, glue, and rulers to make temperature pockets.
3. Instruct students to measure two 6” x 6” squares of each color. Glue three sides together to form a pocket.
4. Review how to read a thermometer with the students. (A “Brain Pop” activity/video is available at <http://www.uen.org/Lessonplan/preview.cgi?LPid=16281> )

(A variety of thermometer resources are available at: <http://www.internet4classrooms.com/grade_level_help/read_both_thermometers_math_second_2nd_grade.htm>)

1. Have students place strip thermometers inside the pockets. Students predict what they think the starting temperature will be for each color of pocket. They will record their predictions on their investigation form.
2. Next, the students place the four pockets outside (or on the window sill) in the sun for the first part of the experiment. Each group may decide on a different location but each group’s four pockets should be placed in the same location. Ask the students to make a second prediction. What do they think the temperature inside the pocket will be after the end of their investigation (3 – 4 hours)?
3. Have students check the pockets periodically; recording the time and temperature of each pocket. A variation may have the students place the pockets in a shaded area and check for temperatures during the following day.
4. Journal the results and compare. Have the students journal the steps of the experiment. Draw pictures. Record observations.
5. Ask the students: What did you notice about the temperatures within each of the pockets? Did the color of the paper make a difference in the amount of heat (temperature) recorded? Did the placement of the pockets make a difference in the temperature? Were the pockets in the sun? The shade? Why do you think there was a difference in the temperature? What is your claim? What evidence have you gathered to support your claim? What reasoning did you use?
6. As an extension, students will create a hot dog cooker. Each student or student group will need one large can (©Pringles) that still has a lid on it.
7. Place a small nail hole in the middle of the lid and also in the bottom of the can.
8. Student will wrap a piece of construction paper around the outside of the can and secure it in place. Students may choose the color of paper to use and justify why they chose a particular color [darker colors will absorb heat more readily]. Have students predict which cooker color will cook the hotdogs the fastest.
9. Straighten a wire hanger.
10. Place the hanger through the holes of the can with about four inches hanging from each end.
11. The cooker is now ready to use the next day.
12. On the following day, remove the hanger and place the hotdog on the straightened hanger. Push the hotdog to the middle of the hanger. Push the hanger through the bottom of the can, place tin foil over the opening, and replace the cover on the can.
13. Outside (or in a sunny window in the classroom) place the two ends of the cooker on bricks/blocks of wood and cook.
14. Test the hotdogs for temperature.
15. Eat and enjoy.

**Explain**

**Activity 5: Sun-Sational!**

**Purpose**

To explore the differences in heating and cooling among various earth materials.

**Activity Description**

Students will explore the differences in the heating and cooling of three different earth materials (dark soil, light sand, and water) when exposed to and removed from sunlight. Students learn that the sun’s energy is transformed to heat energy on Earth.

**Focus Question**

Do the materials we use affect how heat moves?

**Duration**

One class period

**Materials**

* Clock or watch
* Colored pencils or crayons
* Dark soil, room temperature
* Foam cups
* Graph paper
* Light soil, room temperature
* One-cup measures (3)
* Thermometers
* Water, room temperature

**Teacher Information**

1. Heat is the name given to the flow of energy from hotter to cooler objects. Temperature is used to measure the amount of heat energy. A temperature reading is the average amount of energy movement in a substance. The molecules in cold things move very slowly and the temperature is smaller. The molecules in hot things move very quickly, and the temperature rises. Hot substances usually expand when heated. When a hot substance comes in contact with a cold substance, the heat energy will flow from hotter to colder until the objects become the same temperature. [www.uen.org/Lessonplan/preview.cgi?LPid=9762](http://www.uen.org/Lessonplan/preview.cgi?LPid=9762)
2. “Wonders of the Sun” is an excellent teacher and student resource from the National Energy Education Development Project. <http://www.need.org/needpdf/WondersoftheSunStudent.pdf>
3. Advance Preparation: This activity demonstrates how the sun’s energy — in the form of infrared sources of heat energy — warms various Earth materials at different rates. It is important to choose a sunny day and location on the school grounds (or possibly on a windowsill or in a greenhouse). Students sometimes confuse heat and temperature. You should refer to the transfer of heat as “heat energy” and the measurement of heat as “temperature.” Heat can change temperature, but it can also change the structure of a substance without changing temperature.
4. Safety Precautions: Do not use mercury thermometers in your classroom.

**Classroom Procedure**

1. Begin the lesson by reading a book about people who live in the desert. (Suggestion: Ali, Child of the Desert by John London. Your school library may have other appropriate books.) After you finish reading the book, discuss the temperatures in the place where the story was set. Discuss the color of the sand and the color of the clothing worn by the people.
2. Show the class the sand, soil, and water that you have. Say: “These earth materials and the water have been sitting in the classroom for quite some time. What do you think about how warm or cold they are compared to each other?” Emphasize the comparison — which is warmer or colder than which? Have students put predictions on their Student Pages.
3. Let students come forward and put their fingers in each item. Then ask: “Were your predictions correct? Did one item feel coolest? Did one feel warmest?” [Students will probably say that the water felt coolest.]
4. Ask: “How do we measure the effect of heat on this sand, soil, or water?” [We use a thermometer.] Ask a student to place a thermometer in each of your samples. Wait a few minutes for the reading to stabilize. Then ask another student to read aloud the measurements of temperature. All samples should be at about the same temperature — room temperature.
5. Ask: “Were your predictions correct?” At this time, do not offer an explanation as to why the items are all about the same temperature. Instead, listen closely to students’ ideas.
6. Divide the class into groups of three to five students and distribute the equipment to each group.
7. Write on the board: “Which materials will heat up most quickly?” Then say: “We want to find out which material will heat up most quickly. How could you use the things you have available (sand, soil, water, foam cups, measuring cups, a sunny spot, and thermometers) to find this out? Discuss this in your groups. Then have one person write down, step-by-step, how your group would do this.” Allow time for students to complete this work.
8. Say: “Next, your group should make a prediction as to which material will heat up most quickly, and which material will heat up most slowly if you followed the directions you just wrote. Once you have agreed on your predictions, have someone else in your group write them down.”
9. Look at all groups’ plans. Help them work through any problems.
10. Say: “Keeping track of information and observations is one of the most challenging parts of science. To do good work, you need to be organized. So your group’s next task is to create a table in which you can record the temperatures you measure.” Review groups’ blank data tables and help them correct any problems. At a minimum, the tables should have spaces in which to record the type of material being measured, the time, and the temperature of the material.
11. Let students try investigations that are workable. One way to do the investigation is described below, but variations are acceptable, too.
12. Have each group come up and get equal volumes of dark soil, light-colored sand, and water in separate foam cups. (They can use a one-cup measure as a scoop — tell students that each scoop should contain the same volume of material.)
13. Students should place a thermometer into each cup below the surface of the material.
14. Have students wait a few minutes for the readings on the thermometers to stabilize. Record the temperature of each sample in the data table.
15. Have students place the containers in a sunny spot over a time — the longer the time, the more complete the data, assuming the sun continues to shine. Students should record the temperature of each cup at five-minute intervals. Have them leave the cups in their spots until after students have graphed the data and discussed the experiment.
16. After data have been collected, have each student graph their group’s results. All three materials can be shown on the same graph if each is marked using a different color of pencil or crayon. The horizontal axis can be time, and the vertical axis can be temperature.
17. After data has been collected, guide students through an analysis and interpretation of their data. Question #1: “Which material showed the highest temperature gain?” [The dark-colored soil.] Question #2: “Which material showed the least temperature gain?” [Sand.] “Did every group have the same results?” [Probably not.]
18. Next ask: “What does temperature measure?” [The effect of heat energy.] “Why did the soil gain more heat than the sand?” [More light energy is absorbed by darker-colored soil. The light energy is transformed into heat energy, which raises the temperature of the dark soil. **Note:** A substance’s color depends upon what wavelengths/colors of light bounce off of it. Lighter colored objects bounce almost all light back. Darker colors do not bounce much light back up, and therefore convert more of it to heat energy.] Continue: “What form of energy was transformed into what form of energy in this experiment?” [Light energy was transformed into heat energy.] “What kind of matter did the light and heat energy warm up?” [Soil, sand, and water.]
19. Help students draw some larger conclusion by asking: “Who can explain why all three materials did not end up being the same temperature, as they did earlier in our classroom.” [To understand this, students may have to think about rainbows. These materials reflect light differently from each other. When light is reflected, it is not transformed into heat energy. The more light energy was reflected, the less energy was transformed into heat energy. When greater amounts of light energy were absorbed rather than reflected, that light energy was transformed into greater amounts of heat energy. When it is transformed into heat energy, it can raise the temperature of a material.]
20. Challenge students to apply this concept by asking: “How is the temperature of the earth’s surface in different places affected by the earth materials we find in those places?” [Water in the oceans and in the Great Lakes heats up more slowly and cools more slowly; land heats up quickly relative to water. **Note:** There are actually two reasons for this; first, the water reflects light, and second, water has a very high *latent heat.* It can store a lot of energy while changing temperature relatively little. This is a very important reason why life can exist on Earth. ] Then ask: “How does this affect our lives?” [The amount of heat absorbed by the different types of surfaces on the earth is an important factor in creating the weather we experience. People who live on the shores of the Great Lakes and along the oceans enjoy a more moderate climate than people who live farther away from large bodies of water. This is because the Great Lakes and the ocean absorb quite a lot of heat energy, thereby moderating the climate.]
21. To conclude the lesson, remove the cups from the sunlight and have students record the temperature every five minutes. Discuss these results. Ask: “Which material lost heat energy (measured by temperature) most quickly?” [Sand.] “Which material lost heat energy most slowly?” [Water.] “What does this show about the rate of cooling by different earth materials?” [Different earth materials cool at different rates.] “What evidence was used to support your conclusion?”

**Explain**

**Activity 6: Heat Energy**

**Purpose**

Students will understand that heat is a form of energy. Some sources of heat energy include the sun, friction, electricity and burning. Students will understand that heat can be transferred and transformed into different kinds of energy. They will also understand that heat can change objects and make objects move.

**Activity Description**

Students will use prior activities and learn facts about heat energy. Using the “Experts Group” protocol, where student teams develop their own expertise, the teams will present content to one another.

**Focus Question**

How is heat energy defined, measured, and observed?

**Duration**

Two or three class sessions

**Materials**

* Computer with Internet access
* Research materials on heat energy (articles, books, textbook readings)
* Overhead projector, transparencies, and markers (Elmo, Smart Board, etc.)
* Chart paper
* Construction paper
* Magazines
* Scissors
* Bulletin board space in the classroom
* <http://www.physics4kids.com/files/thermo_intro.html>

**Teacher Preparation**

1. Divide the class into four groups.
2. Each group will focus on a different source of heat energy (solar, electricity, friction, burning).
3. Students should use traditional forms of research, such as reference books or class texts, as well as Internet links and the activities conducted in class.

**Classroom Procedure**

1. Groups must work together to research the following information about their source of heat energy.
* What are the characteristics of this type of heat or thermal energy?
* From the activities conducted in class and research, what are some sources of this type of heat energy?
* How is heat measured?
* What kinds of changes can this type of heat energy produce?
* Where can we observe this type of energy being used in our everyday lives?
1. Each member of the expert group must have the necessary information and materials to make a class presentation on their form of heat energy. Encourage students to be creative in their presentations. A gallery walk might be a great technique for presentations.
2. Have a variety of materials for students to use for their presentations, including construction paper, chart paper, markers, overheads, chalkboard, colored chalk, and magazines.
3. Tell students that the key to a successful and interesting presentation is to use visuals, such as labeled diagrams.
4. As students watch the class presentations, have them complete a learning chart with important facts and questions about each type of radiation. Student Learning Charts may look like this:

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of Heat Energy**  | **Characteristics**  | **Example of where it's found or used**  | **My own question**  |
|   |   |   |   |
|   |   |   |   |
|   |   |   |   |
|   |   |   |   |

**Elaborate**

**Activity 7: Heat Energy and Insulation**

**Purpose**

The purpose of this activity is to lay the foundation for understanding conductors and insulators.

**Activity Description**

Students will explore different insulation materials and their effectiveness in reducing the loss of heat energy to the air.

**Focus Question**

How do insulators and conductors affect the transfer of heat energy?

**Duration**

One or two class sessions

**Materials**

* Cloth strips
* Cotton balls
* Foam rubber
* Glue
* Graph paper
* Hot water
* Insulating material (foam, cardboard, cotton)
* Magnifying lenses (10)
* Metal soup cans (10)
* Pens or pencils
* Plastic cup (demonstration only)
* Shoeboxes with lids (10)
* Tape, masking
* Thermometers (20)
* Thermos (demonstration only)
* Ziploc bags, small (6 to 12)

**Teacher Preparation**

MANAGEMENT TIPS:

1. Safety Precautions: If you are concerned about hot water spilling, you may have students tape their cans to the bottom of their shoeboxes and tape the shoeboxes to the desks. They should do this before hot water is poured into the cans. Do not use mercury thermometers in your classroom. If you have mercury thermometers, you must dispose of them with great care. Contact your school district administration, local health department or recycling center.
2. Conduction: In the process of conduction, heat is transferred through a substance or from one substance to another, by the direct contact of molecules. All molecules are constantly in motion. Fast-moving molecules have more heat energy than slow-moving molecules.
3. When fast-moving molecules collide with slow-moving molecules, heat energy is transferred from the faster molecules to the slower molecules, causing the slower molecules to move faster. Now these molecules have enough energy to collide with other slow-moving molecules. This process is repeated over and over. In this way, heat energy is transferred from molecule to molecule throughout a substance. Because all matter is made of molecules, conduction can take place in solids, liquids, and gases. But conduction takes place best in solids, because the molecules of a solid are in direct contact with one another.
4. Some substances conduct heat better and more rapidly than other substances. These substances are good **conductors** of heat. Metals, such as iron and aluminum, are good heat conductors. Sliver is of the best conductors of heat. Copper is another good conductor of heat. That is why the bottom of pots and pans are often made of copper.
5. Substances that do not conduct heat easily are called **insulators**. Glass, wood, plastic, and rubber are examples of good insulators. This is why the handles of pots and pans are made of wood or plastic instead of iron or aluminum.
6. Maton, Anthea, et al. Prentice Hall: Exploring Physical Science. Upper Saddle River, NJ: Prentice Hall 1995.

**Classroom Procedure**

1. Begin the lesson with a demonstration. Set out a cup of coffee or tea in a regular plastic cup (*not* a coffee mug) and pour a cup of coffee into a thermos. Then ask: “Which coffee (or tea) will cool off more quickly? Why?” Ask students to privately write a prediction on their Student Page. Then when everyone has had a chance to make up his/her mind, ask for contributions. Listen to students’ responses, but do not correct them. Encourage students to challenge and build upon each other’s ideas. **Note:** During demonstration leave the lid(s) off the thermos.
2. Fifteen minutes later, take a sip of the coffee in the cup. Say: “Yuck! That coffee is cold!” Then pour some steaming coffee from the thermos. Let students see how hot and enjoyable it is. Using a thermometer to measure the temperature provides relevant data. Ask: “Whose predictions were correct? What happened to the heat energy in my coffee?” [In the plastic cup, the heat energy moved into the air in the room. In the thermos, much of the heat energy remained in the coffee.] “Why is the coffee in the thermos still hot—why did the heat energy not move out of that coffee?” [The coffee in the thermos was surrounded by a good insulator.] “What is an insulator?” [Something that reduces the transfer of heat.]
3. Explain to students: “Today, we are going to learn about insulators—things that reduce the transfer of heat. In earlier lessons, we studied how the sun’s energy and the presence of different kinds of materials on earth can affect temperature. Up to this point, we have talked about heating and cooling as though humans were unable to control it. But, of course, we do control temperature to some degree. We have air conditioners and furnaces. And we have thermoses. Let us explore this idea of insulation together.”
4. Divide the class into groups of four or five students. Give each group a shoebox. Explain: “These are our buildings.”
5. Give each group a metal can. Explain: “These will be the heaters in our buildings.” Also give each group two thermometers.
6. Say: “We are going to explore how we can reduce the amount of heat that is transferred from our building (the shoebox) to the outside world. Heat energy in our building is provided by a hot water heater.”
7. With a pen or pencil, have students poke a small hole in the lid of the shoebox, one near the center of the box, and one in a corner of the box. This is where the thermometers will be inserted.
8. Fill each group’s can about 2/3 full of hot but not boiling water (at least 50o C). (It works best if this is poured from a pitcher or thermos.) Before you pour the water, be sure that the can is centered in the shoebox. Have students place a thermometer through a hole in the roof of the “building” and into the can to monitor temperature. Have them place the other thermometer through the hole located in one corner of the lid.
9. Say: “Each group should write down the air temperature in their ‘building’ and the temperature of the hot water every five minutes for one hour. You need to record these data on your data table.”
10. After an hour, say: “How could we reduce the rate at which heat is transferred out of the ‘building?’” [By insulating the “building.”] “Where is insulation found in a real building?” [Insulation is found in the walls and in the roof.] Say: “What are the walls and roof in our shoebox building?” [Sides of the shoebox and the lid.] “Where would you tape or glue the insulating material?” [Students will have to tape or glue the insulating material to the insides of the shoebox building and to its lid.] Say: “What about insulating the outside of the tin can heater?” [Ideas will vary.]
11. Say: “How will we measure the effectiveness of our insulating material?” [By measuring the rate of heat transfer from the shoebox, and comparing it with the readings that have already been taken—heat transfer from the building when it had no insulation. The method should be the same as was used for the un-insulated “building.”]
12. Ask groups to each choose one type of insulating material to use in another experiment. Make sure that at least one group chooses each type of insulation. Have them tape or glue the insulation to the inside sides and inside tops of their “buildings.”
13. Put fresh hot water in each group’s can. Again, have them take and record temperature readings every five minutes over the course of an hour. (You can create a very large table on the board and have students write directly on it, recording their data there every five minutes.) Students will become curious about comparing different groups’ data. Research shows that simply having students physically record information in a public way engages them more fully in an experiment.
14. Have groups create a graph of their “building’s” temperature with no insulation, and a graph of the “building’s” temperatures with insulation. Temperature, in degrees, can be on the vertical axis of both graphs. Time, in five-minute increments, can be on the horizontal axis. Both graphs, and every group’s graphs, should have the same scale so that they are easily compared.
15. Have groups label and post their graphs on the wall. Give students time to examine other groups’ graphs.
16. Allow students to answer the first questions on their own, and then have a class discussion about results. Question #1: “What effect did insulation have on keeping heat energy in your ‘building?’?” [Insulated buildings retained heat energy better than did uninsulated ones.] Seek an explanation by asking: “Why did this happen?” [The insulation materials provided a barrier to the movement of heat energy.] Question #2: “What insulating materials were most effective?” [Results may vary, depending upon how students applied the insulation. Help students examine the data in order to answer this question.] “You may look at each of the insulating materials with a magnifying glass. Do you notice any differences or similarities?” [Answers will vary.] “What did the most effective forms of insulation have in common?” [They are the ones with the most air pockets. Air pockets trap heat.] Ask students to extend their reasoning by asking: “What does this tell us about air as a conductor of heat?” [Air is a poor conductor of heat energy.] “What will eventually happen to the temperature of the hot water and of the air inside the shoebox?” [Temperatures of both will become the same—the system will reach equilibrium.]
17. As an extension, students can research the R factor. They can contact a home improvement store that sells insulation for homes and ask them what kinds they sell and what the R factors of the various products are. You can try to procure samples of some of these materials. Alternatively, have a builder or salesperson visit your classroom to show samples of insulation and talk about its application in buildings.

**Elaborate**

**Activity 8: Let’s Make a Refrigerator**

**Purpose**

To understand the effects of conductors and insulators on heat transfer.

**Activity Description**

Students will learn about heat transfer as they construct refrigerators to prevent ice from melting.

**Focus Question**

How do insulators and conductors affect the transfer of heat energy?

**Duration**

One class period

**Materials**

Introduction activities:

* 2 quart bottle
* Ice cubes
* Aluminum foil
* Carpet square

Refrigerator Activity:

* Platform scale (for the class)

For each group:

* Small plastic cup
* 2 ice cubes
* 2 paper towels
* 12” waxed paper
* 12” tin foil
* Ziploc© bag
* Optional:
* Cotton balls
* Newspaper
* Fabric scraps

**Teacher Preparation**

POINTS TO EMPHASIZE IN THE SUMMARY DISCUSSION:

1. Conduction: In the process of conduction, heat is transferred through a substance or from one substance to another, by the direct contact of molecules. All molecules are constantly in motion. Fast-moving molecules have more heat energy than slow-moving molecules.
2. When fast-moving molecules collide with slow-moving molecules, heat energy is transferred from the faster molecules to the slower molecules, causing the slower molecules to move faster. Now these molecules have enough energy to collide with other slow-moving molecules. This process is repeated over and over. In this way, heat energy is transferred from molecule to molecule throughout a substance. Because all matter is made of molecules, conduction can take place in solids, liquids, and gases. But conduction takes place best in solids, because the molecules of a solid are in direct contact with one another.
3. Some substances conduct heat better and more rapidly than other substances. These substances are good **conductors** of heat. Metals, such as iron and aluminum, are good heat conductors. Silver is of the best conductors of heat. Copper is another good conductor of heat. That is why the bottom of pots and pans are often made of copper.
4. Substances that do not conduct heat easily are called **insulators**. Glass, wood, plastic, and rubber are examples of good insulators. This is why the handles of pots and pans are made of wood or plastic instead of iron or aluminum.
5. This activity will use the elementary level of the elementary Engineering Design Process developed by Engineering is Elementary. The one provided by EiE is intended for younger learners and has fewer steps and appropriate terminology that children can understand. It is important to remember that like scientists, practicing engineers do not adhere to a rigid process. There are many variations and the process is cyclical. Like the inquiry model, this process can begin at any step and move back and forth between steps. Like scientists, engineers share their ideas with other teams.



1. “Moving through the process might involve asking the following questions or making the following decisions:
2. Ask:

What is the problem?

What have others done?

What are the constraints?

1. Imagine:

What are some solutions?

Brainstorm ideas

Choose the best one

1. Plan:

Draw a diagram

Make lists of materials you will need

1. Create:

Follow your plan and create it

Test it out!

Improve:

1. Talk about what works, what doesn’t, and what could work better.
2. Modify your design to make it better
3. Test it out
4. After you improve your design once, you may want to begin the Engineering Design Process all over again to refine your technology. Or you may want to focus on one step. The Engineering Design Process can be used again and again!

**Classroom Procedure**

1. After reviewing the previous activity on insulators and conductors, invite two students to the front of the class and give each of them an ice cube in a sealable bag. Have the students hold the ice cube and ask, “What is happening?” [The ice is melting. The students’ hands are getting cold. Clarify that the ice did not bring cold to the hand, because there is no such thing as coldness. Actually, cold is the absence of heat. So, the heat from the hands moved to the ice cube, until they finally became the same temperature.] “How does this help to explain how heat is transferred?”

2. Place water with ice cubes in one bowl, warm water (not above 118 degrees F) in one bowl, and room temperature water (or an equal mixture of warm and cold water) in the third bowl. Call on one student to place one hand in the cold water and the hand in the warm water. After at least one minute, ask the student to place both hands in the medium temperature bowl. Ask, “What do you feel?” [The hand that was in warm water should feel cooler and the hand that was in the cold water should feel warmer than the other hand.] “How can we explain this as it relates to heat transfer? What is happening to the molecules in our hands? In the water?”

3. In groups of four or five students, ask students to summarize what they think they know about the transfer of heat energy. [Energy always remains in constant amount. It cannot be created or destroyed but it can be transformed or transferred. Heat energy moves from a warmer object to a colder object such as the heat from one’s hand moves to an ice cube or the heat from the stove moves to one’s hand. This is called heat transfer. It is not expected that fourth grade students will have a full understanding of the three methods of heat transfer. Heat energy is transferred by conduction, convection and radiation. In fourth grade students are becoming familiar with conduction where heat is transferred through a substance or from one substance to another by the direct contact of molecules.]

4. Tell students that today they are going to design a refrigerator. The goal is to keep their ice cube from melting. The materials they will be using are one paper towel, one piece of waxed paper, one piece of tin foil, and one plastic container or cup. (The teacher may allow students to use additional materials, if desired.) After constructing their refrigerators, teams of students will wait 20 minutes before opening their refrigerators and discovering how well their refrigerators worked.

5. This activity will incorporate elements of experimental design and the elementary Engineering Design Process. (Retrieved from <http://www.mos.org/ele/engineering_design.php>) Students will use the attached design sheet to do their planning for their refrigerators. Because of the steps in the design process, allow at least 20 minutes for students to plan and 10 minutes to construct their design. Before the CREATE stage of the process, each group of students will have their plan reviewed by the teacher. The teacher will look for evidence of group work and use of proper materials. Once approved, all groups will begin at the same time.

6. CREATE: Each group will gather materials, weigh and record the weight of each ice cube. Place one ice cube on a paper towel on a desk out of the sun (Do not touch or disturb in any way. This is the control.) Students will use the materials to create a refrigerator as designed in their PLAN.

7. Wait 20 minutes. Students will open their refrigerator and compare the two ice cubes. Is there any visible difference? Students will weigh each ice cube. Record observations.

8. Groups of students will compare results. Which design seemed to work best? Why? Clarify that the refrigerator insulated the ice cube and stopped the transfer of heat.

9. If time, the engineering process will move into the IMPROVE phase. They will modify their design to make it better and test it out!

**Learning Cycle 2: Electricity**

**Learning Objectives**

Students will be able to:

* Demonstrate how electrical energy is transferred and changed through the use of a simple circuit.
* Demonstrate the magnetic effects of a simple circuit.
* Demonstrate that certain objects or materials are good or poor conductors of electricity.

**Key Question: How can electrical energy be transferred and changed in a simple circuit?**

**Engage and Elicit**:

**Activity 1: Electrical Energy**

**Purpose**

To demonstrate how electrical energy can be transferred and changed through the use of a simple circuit.

**Activity Description**

In this lesson, students work in small group to light a bulb using a battery and a wire. Through their explorations, students construct a simple pathway (a circuit) for electricity. Later in the lesson, a small motor is introduced to reinforce the idea that electrical energy can be transferred and changed to do useful work.

**Focus Question**

How can electrical energy be transferred in a simple circuit?

**Duration**

One or two class periods

**Materials**

* Batteries (1 per group; size D)
* Battery holders (1 per group; to fit D cells)
* Bulbs (1 per group; miniature)
* Cardboard cut-out of a battery
* Cardboard cut-out of a bulb
* Flashlight
* Masking tape
* Rope
* Wire (4 per group plus extras; insulated, 10 cm lengths)
* Wire strippers

**Teacher Preparation**

1. Advance Preparation: It is important to organize sets of the bulbs, batteries, battery holders, and wire ahead of time. Strip the ends of the wires with a wire stripper. Put one bulb, one D-cell battery; each group of students will get one of these bags. Retain the insulated wire for use with the introductory activity. Test each of the sets ahead of time to be sure that the battery, bulb, and wire will “work.” (Sad to say, but some batteries lose their “zip” while waiting to be purchased.) Put together a second bag of materials to be tested (coin, nail, paper, pencil, ruler, etc.).
2. Safety Precautions: Do not use rechargeable batteries; their voltage can be unpredictable.
3. Background information: An electric circuit consists of a source of energy, a load or resistance, wires and possibly a switch. The source can be a battery, a thermocouple, a photocell or a generator. The load is the device that uses the electric energy. The load can be a light bulb, an appliance, a machine or a motor. In all cases, the load offers some resistance to the flow of electrons. As a result, electric energy is converted into heat, light or mechanical energy. The switch in an electric circuit opens and closes the circuit. Electrons must have a closed path in which to travel. Electricity cannot flow through an open circuit. Electricity can flow only through a closed circuit.

**Classroom Procedure**

1. Begin the lesson by saying: “Let’s think back to our very first activity in this unit. We explored some different kinds of energy. We have learned about heat energy through our many activities. Today, we are going to discuss electrical energy. Where does our electricity come from? Have you ever wondered what was behind the outlet in your home or here at school? It is rather amazing that by inserting a plug into the wall outlet, you can make your television, computer, refrigerator, vacuum cleaner and all of the other electrical appliances operate. [The teacher may want to have the students draw a picture of what they think is behind the outlet
2. First, let’s create a classroom circuit.” Put the students in groups of 8 or 10. Students will form a circle. (Later you may try to do this activity with the entire class.) One student will hold a battery (or two batteries). A student on the other side of the circle will hold a bulb in a bulb holder. Challenge the students. “How can we get the bulb to light without bringing the battery and bulb closer together?” (A long wire or conductor.) Give each student a 40 – 50 cm length of insulated wire. Ask, “How will we use the wire to light the bulb?” (Students connect the ends of their wires either by holding the ends or by twisting them together. Students on either side of the battery connect the wire to the ends of the battery.) Emphasize that this activity requires teamwork! Help students work together until they are able to light the bulb. “Why did the bulb light?” (There is electrical current flowing through the wire.) “Let’s review how the electricity follows a path.” (Starting from the negative pole of the battery, the path follows the wire until it flows through the bulb (creating light and a small amount of heat) then it flows through the remaining wires back to the bulb.) “This is called a complete circuit! When the wires are undone, the electricity cannot flow. This is called an open circuit.” Give students an opportunity to open and close the circuit.
3. “Work with a partner to make the bulb light. When you think you have done it, draw a picture of your set-up in the Student Pages.” Some groups may construct a simple circuit very quickly, while other groups may take more time. It is important to let most of the class succeed before proceeding. To keep the speedy groups occupied, challenge them to find a second way to light the bulb. **Note:** Do not introduce the term “circuit” at this time. “A path or pathway for electricity to follow” is an appropriate phrase to use until students have had more experience with circuits.
4. After most groups have succeeded in lighting the bulb, ask one group to volunteer to demonstrate its arrangement to the whole class. A cardboard cutout of a battery, a length of rope representing the wire, and a cardboard cutout of a bulb will help students demonstrate their arrangements.
5. After one group has presented, ask: “Did any groups use a different arrangement to light the bulb?” Most likely, there are. If so, have other groups demonstrate their arrangements. If time allows, challenge students to come up with four different arrangements. You or the students can sketch these possibilities on the board. You may also want to create a section for “flops” — sketches of arrangements that did not result in a lighted bulb. If you do this, mention to students that sometimes scientists learn more from what *does not* work than they do from what *does* work. Be careful, however, that you clearly distinguish the two sets of drawings so that it is absolutely clear that one set “works” and the other set does not.
6. Discuss what students have learned. Referring to the collection of sketches on the board, ask: “How are all of the plans that worked the same?” [They all provide a pathway or circuit (circle) for the electricity to follow.] Write the word “circuit” on the board near one of the sketches that shows a clear circle. You can emphasize the point by superimposing a circle on that sketch. “Why does the wire need to touch the bulb on the side, rather than the end?” [Because the filament loops through the bulb and finds its way to the side. (There should be a raised spot at that point. If students look closely at the light bulbs, they can probably see it.) Contact at this point completes the circuit. If students have trouble with this, dismantle a light bulb or provide a drawing that shows the wire looping.] Finally, “You are all very bright students, so I am sure that you can answer this question — How could you make your bulb brighter?” Accept students’ ideas and encourage a discussion. Then distribute some extra batteries and let students try out their ideas. Discuss their results.





**Explore**

**Activity 2: Take the Circuit Challenge**

**Purpose**

To demonstrate and explain how electrical energy is transferred and changed through the use of a simple circuit.

**Activity Description**

In this lesson, student teams construct a closed circuit using a variety of components (e.g. batteries, bulbs, motors, buzzers, and wire). Each team of students “challenges” another team to build their circuit, using only the components provided. Students gain an understanding that electrical energy is transferred and changed through a simple circuit.

**Focus Question**

How can electrical energy be changed in a simple electrical circuit?

**Duration**

One or two class periods

**Materials**

Bags, brown paper (1 per group, numbered 1-6)

Batteries (3 per group, D cell, 1.5 v)

Battery holder ( for D cell)

Bulbs (3 per group, miniature)

Buzzers (2 per group)

Lamp holders (1 per group, for screw base lamps/bulbs)

Masking tape

Motors (small, 2 per group)

Wire (4 or 5 per group insulated, 10 cm length)

Wire strippers

**Teacher Preparation**

1. Advance Preparation: Make up six game kits. Each kit should contain: one to three batteries, two to six wires, and one or more bulbs, buzzers, or motors (for a total of three).
2. Strip the ends of the wires with scissors or wire stripper before putting them in the bag. It is important that each kit is unique from the others and is hidden from students’ view.
3. Put them in a paper bag or a box.
4. Look up the symbols for battery, wire, bulb, and other components on the *Electrical Circuits Introduction* web site.

**Classroom Procedure**

1. Begin this lesson by reviewing with students what they learned about electrical circuits in Lesson 9. Emphasize the idea that to work their plans needed a complete path.
2. On the board, draw and label the symbols for battery, wire, bulb, and other components.
3. Say: “Are you ready to take the Circuit Challenge? Yes!” Share the rules of the game with the class. “There will be (\_\_\_) teams. Each team will get a kit made up of a unique combination of batteries, wires, bulbs, motors, and/or buzzers. No two teams’ kits will be exactly alike. Each of the teams must use its kit to secretly design and construct an original circuit that includes: up to three batteries, up to three components (any combination of bulb, motor, or buzzer), and up to six wires.” Write these limitations on the board so that the students can see them as they work.
4. “After each team constructs a circuit or path using the components in its kit, that team should draw that plan. The symbols for the kit’s components are written on the board.” Take a moment to review these symbols with students. Then continue: “After your team has drawn its circuit, you should dismantle the circuit and put all of the pieces back in the container. You will then hand your team’s kit to another group and challenge them to reconstruct your circuit.”
5. Form groups. Give each group one kit. Have the groups go to different parts of the room or, if possible, send some groups to other locations to work so that there is no spying by students with big ears or wandering eyes. If dispersing the students is not possible, call upon students to be honest and fair during the competition. Remind students that each team will do its best work only if all of its members are paying attention.
6. Give students 15 minutes to design, draw, and dismantle their circuits. Give them a “check-in” signal at 5 minutes, 10 minutes, and 14 minutes. At that time, remind them that they will have to put their components back in the bag in just one minute.
7. Have all teams turn over their kits (but not their drawings) a challenging team. Every team should now have a new kit.
8. Allow 10 minutes for the teams to try to power the component(s) in their new kits. It is possible for a challenging team to successfully power the bulb, motor, or buzzer and still have an arrangement that is slightly different from the “original” design. In this case, that team still “wins.”
9. Have the team that first constructed the circuit for a kit share its drawings with the challenging team. Then ask: “Did the challengers successfully power all the component(s) in the kit? How is the first group’s circuit the same as or different from the challengers’ circuit?” [Responses will vary.]
10. Let the teams that successfully reconstructed a circuit within the time allowed advance to the next round. For this round, “winning” teams can develop a new design. To make it more challenging, pieces left over from the teams that did not “win” can be evenly distributed to the remaining teams.
11. Discuss the outcome of the circuit challenge and review what students learned. To probe students’ thinking, ask “What was the most difficult aspect of the circuit challenge and why?” [Responses will vary. Some students may become frustrated trying to work in a team. This presents a good opportunity to discuss the pros and cons of teamwork and working alone. Remind students that most scientists work in teams, or communicate frequently with their colleagues.] Then ask, “What could your group do to make your circuit even more challenging to copy?” [Responses will vary. Give students some time to think about this question.] “Did any teams use more than one pathway or circuit for the electricity to follow? If so, what did that look like?” [Responses will vary.] Finally, “Did the amount of electrical energy needed have anything to do with the number of components (bulbs, buzzers, motors) that you used?” [Yes. The more components used, the more battery power was needed.]

**Explain**

**Activity 3: Heat and Magnetic Effects**

**Purpose**

To demonstrate and explain how electrical energy is transferred and changed through a simple circuit and the magnetic effects of a simple circuit.

**Activity Description**

In this lesson, students discover the heating and magnetic effect of a simple circuit. They experience how electricity can produce heat energy and magnetism. Through direct observation, students understand that electricity produces heat. Using a compass, they explore the magnetic effects of the circuit. Students further apply their knowledge of electrical effects as they build and investigate electromagnets.

**Focus Question**

How can heat and magnetics effects be observed in a simple circuit?

**Duration**

One or two class periods

**Materials**

For each group of four students:

* 1 battery
* 1 battery holder
* 2 brass brads or paper fasteners
* 1 bulb
* 1 bulb holder
* 1 metric ruler
* 6 paper clips
* 1 piece 2”x2” cardboard
* 3 pieces of insulated wire, 60 cm each, ends stripped
* 1 small inexpensive magnetic compass

**Teacher Preparation**

1. Science language that students should use: battery, complete circuit, incomplete circuit, conductor, insulator.
2. Understanding how an electromagnet works is very basic. By running an electric current through a wire, you can create a magnetic field. A loop of wire that carries an electric current creates a magnetic field through the loop. You can increase the strength of this magnetic field by winding more loops. The more loops, the stronger the magnet. An electromagnet may be constructed with enamel-coated wire wound around a large iron nail and connected to the poles of a battery. When this magnetic field is created it can be used to make motors, to read/write hard drives, to make stereo speakers, etc.
3. It is important to organize sets of the battery, battery holder, bulb, bulb holder, compass, nail and 3 wires ahead of time. Strip the ends of the wires with a wire stripper. Put one bulb, one bulb holder, one D-cell battery, one battery holder, one compass, one nail and three insulated lengths of wire in a zip-loc bag; each group of students will get one of these bags. Test the batteries ahead of time.
4. Prepare a simple switch for each group. Wrap the stripped end of one wire around one of the brass brads. Place the brass brad with wire attached through the end of a paper clip. Wrap the second wire around the second brass brad. Make a hole in the cardboard with a pencil and stick the first fastener with the paper clip through the hole. Mark the place where the end of the paper clip falls on the cardboard. Make another hole and push the second brass brad through it. Turn the cardboard over and open the brads. Put tape over the ends of the brads to hold them securely.





1. **http://web.cvcaroyals.org/~rheckathorn/**

**Classroom Procedure**

Part 1

1. Begin this lesson by reviewing with students what they learned about electrical circuits in Lessons 9 and 10. Emphasize the idea that to work a circuit needs a complete path.
2. On the board, write the words electrical energy, heat energy and magnetism. Explain that they will be investigating examples of each. Ask students to summarize what they have learned about electrical and heat energy. Ask, “What do you think you know about magnetism? Let’s list some important ideas.”
3. Distribute the bags of materials and ask students to demonstrate what they have learned about circuits by building a complete circuit. After checking that each group has constructed a complete circuit, challenge them to add a switch to their circuits. (They will use the third wire when adding the switch.) The teams will draw and label their complete circuits and switches on their Student Pages.
4. To check for understanding, ask the students: “Can you explain how your circuit and switch works?” “Did you try different designs before you were successful?” “Where did you place the switch in your circuit?” “What is the purpose of a switch?” “Can you demonstrate an open circuit? A closed circuit?” “In your circuit, what form of energy is the electrical energy transferred to?” “How do you know?” “What would you feel if you touched the light bulb or wires?” “Is the electrical energy transferred to more than one form of energy?” Question #1: “What form or forms of energy was the electrical energy in your circuit transferred to? What is your evidence?”
5. Discuss how electricity can be used to produce heat. Remind students that they observed a hot plate, toaster, and hair dryer in previous lessons. “Can you think of additional examples when electricity produces heat?” Suggest that students close their circuits and allow the bulb to “burn” for a minute. Touch the bulb. “What do you feel?” “Where does the heat come from?” Students record their ideas.
6. Have the teams join another team. Tell them to create a circuit using two batteries and two bulbs. (If you use one bulb with two batteries, the bulb may ‘blow’.) “Do both bulbs light?” “What do you notice?” Remove the nail from their supplies. Ask students to touch the nail and notice its temperature. Remove the two bulbs from the circuit and connect the wires to each end of the nail. “What do you think will happen?” “Have you created a complete circuit?” “What is your evidence?” Have students predict what will happen. Students use their sense of touch to check the temperature of the nail after connecting the wires for 20 seconds, 30 seconds, and 45 seconds. Leaving the wires attached to the nail longer that one minute will cause the nail to overheat and will drain the batteries. Caution students. Students will record their findings. Question #2: “We discovered that electrical energy can be transferred to light and heat energy in a bulb. Here is a diagram of another way that electrical energy can be transferred into heat energy.” [Students draw a diagram of the battery with wires connected to the nail.] “What is your evidence that electrical energy has been transferred into heat energy?” [The nail feels warmer than it did before connecting it to the battery.] Dismantle the circuits and put materials back into the baggies.

Part 2

1. Review the transfer of electrical energy (heat, sound, light, mechanical) using the previous activities as examples.
2. Explain that electricity can also produce magnetism. “Let’s first look at a magnetic compass.” Have students take the magnetic compass from their supplies and observe how the needle reacts for a few minutes. Instruct students to hold the compass parallel to the floor and to avoid steel or metal objects. “What do you notice about the compass needle?” Explain that this is a magnetic needle. Because the Earth has a magnetic field, the marked end of the magnetic needle points toward the Earth’s magnetic north. “Can you cause the needle to point in a different direction?” Using a long piece of wire, attach one end of the wire to the positive end of a battery. Place the compass on a table and lay the wire across the compass so that it is oriented to north and south. Do not attach the other end of the wire to the battery yet. Predict what will happen when you attach the wire to the negative pole of the battery. “Now attach place the end of the wire on the negative pole of the battery.” “What do you observe?” “What did the compass needle do?” “Why did this happen?” “What is your evidence that an electric current has magnetic effects?” Students draw a diagram and explain how a magnetic compass demonstrates the magnet effects of a simple circuit. Question #3: “Here is a diagram that explains how a compass can show magnetic effects in a simple circuit.”



Google Images

1. “Let us explore some more. Using the 60 cm of insulated wire, wrap it around the nail 20 times. You should have approximately 20 cm of wire at each end of the nail.”



Google Images: thesolutionsite.com

1. Connect one end of the wire to the positive end of the battery and the other end of the wire to the negative end of the battery. Predict what will happen when the nail is moved near the paper clips.
2. Hold the electromagnet near the paper clips. Record what you observe. [The paper clips are attracted to the nail/wire set-up. Students have constructed an electromagnet.] Now have students disconnect one end of the wire. “What happens to the paper clips?” “Who can explain what has happened?” [The paper clips are no longer attracted because the circuit is open.] Reconnect. Record observations. Question #4: “After constructing our electromagnet, we held it near the paper clips. This was evidence that electrical energy can be transferred into [magnetic] energy. When we disconnected the wires, the paper clips [fell off the nail] because [the circuit was opened and the magnetic effects were discontinued].”
3. Ask students to explain how electricity can produce magnetism. Explain that when electricity flows through an insulated wire in a circuit, magnetism is produced. It is small and difficult to notice (we saw it with the compass). “How can we increase the magnetic effects if we wrap the wire around the compass?” (You may want to demonstrate.) “How is this similar to producing heat and light energy?” “How is it different?” “Why do you think it is necessary to wrap the wire around the nail?” “What will happen with fewer wraps? More wraps?” “What will happen if you add more batteries?” Students complete the chart comparing the number of wraps and the number of paper clips. My Conclusion: “Based on evidence, what was the effect of increasing the number of wraps around the nail in the electromagnet?” [The greater number of wraps picked up more paper clips.]
4. Challenge students to produce a stronger magnet with a switch. They can combine teams and supplies. **Caution:** never add more than three batteries. It is a better idea to restrict students to two batteries in the electromagnets. Students record their findings on the chart. My Conclusion: “Based on evidence, what was the effect of two batteries in the electromagnet?” [Two batteries pick up more paper clips than one battery.] Students draw and label a diagram of the electromagnet/switch set-up. They identify the path and the transfer of electrical energy into magnet energy.
5. Summarize the activity by comparing the electromagnet to the compass. (The compass demonstrated the magnetic effects by moving the magnetic needle and the electromagnet demonstrated the magnetic effects by picking up the paper clips.) Summarize and explain that the magnetism is increased by wrapping the wire in a coil which concentrates the magnetism. When an iron core (nail) is placed inside the coil, the magnetic effect is even greater. The electromagnet can attract magnetic materials, like the paper clips. “Will it attract anything else? Let’s find out!”

**Elaborate**

**Activity 4: Conductors and Insulators of Electricity**

**Purpose**

To identify and demonstrate how certain objects are good or poor conductors of heat and electricity.

**Activity Description**

In this lesson, students work in small groups to build a circuit tester. They apply their knowledge of circuits by developing a simple investigation to test a variety of materials to determine if they are conductors or insulators. Students create charts, share ideas, and discuss results.

**Focus Question**

How can we identify good or poor conductors and insulators of heat and electricity?

**Duration**

One or two class periods

**Materials**

* Batteries (1 per group; size D)
* Battery holders (1 per group; to fit D cells)
* Bulbs (1 per group; miniature)
* Wire (4 per group plus extras; insulated, 10 cm lengths)
* Wire (insulated, 1 per student, 40 – 50 cm lengths; ends stripped)
* Sand paper
* 1 bag filled with a variety of materials to be tested (iron nail, pencil, string, plastic ruler, plastic clip, Styrofoam, piece of paper, rubber band, washer, aluminum foil, etc.)

**Teacher Preparation**

1. Science language that students should use: battery, complete circuit, incomplete circuit, conductor, insulator.
2. It is important to organize sets of the bulbs, batteries, battery holders, and wire ahead of time.
3. Strip the ends of the wires with a wire stripper.
4. Put one bulb, one D-cell battery, one battery holder in bags
5. each group of students will receive one of these bags.
6. Retain the insulated wire for use with the introductory activity.
7. Test each of the sets ahead of time to be sure that the battery, bulb, and wire will “work.”
8. Put together a second bag of materials to be tested (coin, nail, paper, pencil, ruler, etc.) for each group.

**Classroom Procedure**

1. Begin the lesson by saying: “We have spent some time learning about circuits. Today, we are going to learn how to use this information to make a circuit tester. Using students prior knowledge have them complete Question #1: “What is a circuit? What is the evidence that a circuit is open or closed?”
2. Challenge the students. “What other materials could we put between the ends of the wires to make the bulb light?” Accept all responses. If students suggest readily available materials, collect the materials to test.
3. Students work in small groups to create a circuit tester. Create a simple circuit with a battery two wires and a bulb. Test it to make sure that it works. Add a third wire to the set up so that one wire is connected to one end of the battery. A second wire is connected to the other end of the battery. The open end of the second wire is attached to the bulb holder. A third wire is attached to the other side of the bulb holder. When the open ends of the wire touch, the bulb should light. Question #2: “Draw a picture of your circuit tester.”
4. Explain that students will use their circuit testers to test items that will complete the circuit. Distribute bags of items to be tested.
5. Using the bag of materials, complete Question #3: “Create a list of items to be tested. Predict which items will light the bulb (closed or complete circuit) and which items will not (open or incomplete circuit).” Using their circuit testers, students work in small groups or with a partner to test all the items on their lists. They record what happened in the “Results” column. “Are there other items you can add to your list?” Discuss the results. Create a classroom chart “Which items caused the bulb to light?” “What items did not cause the bulb to light?” If students have different results, discuss the possible causes for the differences.
6. Working with a partner, then in small groups, students will develop a “rule” about what objects caused the bulb to light and which items did not. After discussing the “rules” explain that the items that caused the bulb to light are called “conductors” and the items that prevented the bulb from lighting are called “insulators.” Create a classroom definition for conductors and insulators and record the definitions under Question #4 in their Student Pages.
7. Have students investigate other materials that would make a good conductors and/or insulators and to keep a list of the items they used, what worked, and what did not in their Student Pages.

**Elaborate**

**Lesson 5: Putting It All Together**

**Purpose**

Students will apply their knowledge of circuits to demonstrate their understanding of open and closed simple circuits.

**Activity Description**

In this lesson students work in small groups to build a circuit board. They apply their knowledge of circuits to build a working game board. Students demonstrate their understanding of the content learned throughout the unit to create a quiz.

**Focus Question**

How can a complete circuit be observed and manipulated?

**Duration**

One to two class sessions

**Materials**

Per student or group

* Aluminum foil (10 strips – 1 cm x 30 cm)
* Batteries (1; size D)
* Battery holders (1, to fit D cells)
* File folders
* Hole punch
* Miniature string lights
* Roll of masking tape
* Sand paper
* Scissors
* Wire (2; insulated, 10 cm lengths)
* Wire strippers

**Teacher Preparation**

1. Advance Preparation: It is important to organize sets of the bulbs, batteries, battery holders, and wire ahead of time. For this activity, the use of small string lights is easier. Holiday lights can be cut apart to create multiple bulb/wire set-ups. Put one bulb with wires and one D-cell battery in a baggie; each student or group of students will get one of these bags. Test each of the sets ahead of time to be sure that the battery, bulb, and wire will “work.”



1. The quiz board works on the premise of an old fashioned switch board. Each question on the quiz board is connected to its answer by a strip of aluminum foil. The aluminum foil is covered by masking tape to prevent short circuits. Create strips by using a large piece of aluminum foil. Place 30 cm strips of masking tape on the foil. Cut around the masking tape/aluminum foil strips to create conductive wires. Create a quiz board to use as a sample to show students.

**Classroom Procedure**

1. Begin the lesson by saying: “We have spent some time learning about heat, energy, electricity, circuits, conductors and insulators. Today, we are going to learn how to use this information to make a quiz board. Show students the sample quiz board. Discuss how the quiz board operates.
2. Challenge the students. “Write ten thoughtful questions about the concepts and ideas we have been exploring and discussing in this unit. You may use your student journal or your Student Pages to help you write the questions. You will also record the answers to your questions.”
3. Distribute copies of a blank question and answer form. Students record their questions and answers on the form. The questions in the left column will not align to the answers on the right column. Students securely fasten the question/answer form to the outside of a file folder. Use a hold punch to make a hole next to each question and answer. The holes on the right side should only go through the front cover. Inside the folder, have the students draw a line from each question to the correct answer. The students use these as a guide for their aluminum strips.
4. Distribute the aluminum foil/masking tape strips, scissors and masking tape. Place each foil strip over each pencil guideline with the foil side facing the folder. The strips should extend over the holes. Tape the strips in place. When finished no foil should be visible – only the masking tape strips.
5. Distribute bulbs, batteries, battery holders, and wires. A long wire is attached to one end of the battery holder. One wire from the light is connected to the other end of the battery holder. Attach another long wire to the wire on the other side of the bulb. Test the circuit to make sure that all connections work. (Hint: It may be helpful to set up the circuit before securing the aluminum strips. The connections can be tested each time a new strip is added.) The bulb/battery set-up may be secured to the front of the file folder.
6. Students test their quiz boards by touching one the wire from the bulb to the foil next to the question and the other wire to the foil next to an answer. When simultaneously touching the foil, the bulb should light.
7. Have students exchange their quiz board with other students to text their work and their knowledge of heat, energy, electricity, circuits, conductors, and insulators.
8. “Why does the quiz board only work when the right question and answer are touched? How is this similar to the wiring in houses?”

**Learning Cycle 3: Magnetism**

**Learning Objectives**

Students will be able to:

* Demonstrate the properties of magnets.
* Demonstrate magnetic fields by observing patterns formed with iron filings using a variety of magnets.
* Demonstrate that magnetic objects are affected by the strength of a magnet.
* Demonstrate that magnetic objects are affected by the distance from a magnet.
* Explain how an electromagnet works.

**Key Question: What effects do magnets and magnetism have on magnetic and nonmagnetic materials?**

**Engage and Elicit**

**Lesson 1: Exploring Magnetism**

**Purpose**

Students will investigate and confirm their understanding of how magnets attract and repel other magnets.

**Activity Description**

In this lesson students work in small groups to complete four activities that serve as an introduction and review of magnetic properties.

**Focus Question**

How do magnets interact with one another?

**Duration**

One class session

**Materials**

* Various types and numbers of magnets (bar, horseshoe, circular, disk, magnetic craft tape)
* String or fishing line and tape
* Tinker toy stand or scientific ring stand and clamp
* Dowels or pencils
* Metal washers (with holes large enough to fit over the pencil or dowel)

**Teacher Preparation**

1. It is important to organize the materials for the classroom demonstration and the four stations in advance.
2. Students should be familiar with the following vocabulary: magnet, magnetism, magnetic field, poles, permanent magnet, temporary magnet
3. Natural magnets are found in some rocks which contain iron. Magnets can also be made of iron, steel, nickel, cobalt, rare earth materials and the alloys of these metals.
4. Every magnet has a magnetic field which interacts with the magnetic fields of objects containing iron or other magnetic materials. Most magnetic materials that students will use are made of some form of iron.
5. Magnets usually have two poles, a north-seeking and a south-seeking pole.
6. The magnetic power of a magnet is strongest near its poles and weakest midway between the poles.
7. When two magnets are placed near one another, they react according to the poles that are near one another. Unlike poles attract and like poles repel.
8. When quantified, the magnetic powers of attraction and repulsion are mathematically equal.
9. Magnets can attract magnetic materials through all nonmagnetic and most magnetic materials.
10. Magnetic fields vary in strength.
11. Two magnets together have a single magnetic field and are considered one magnet.
12. It is possible to magnetize an iron or steel object by stroking it with a magnet.
13. Since magnetic force is greater than that of gravity, magnetism can be used to defy gravity in various ways.
14. An electromagnet can be constructed using a batter, insulated wire and a nail.
15. It is possible to measure magnetic force (attraction and repulsion) in newtons using a spring scale.

  

**Classroom Procedure**

1. Show a simple demonstration of attraction and repulsion using two bar magnets. Place one magnet on the table and then second magnet a distance from the first. Ask students, “What do you think will happen as I move the magnet closer to the first magnet?” Allow students to “turn and talk” to their neighbor and share ideas. Move the magnets closer together. [The magnets will either be attracted or repelled.] Ask the students, “Were you surprised? Why are the magnets behaving the way they did? Can I change how the magnets react?” Record student ideas about what they already think they know about magnets (poles and principles of repulsion/attraction) on chart paper or the board.
2. Although the following activities could be done as class demonstrations, it is recommended that the teacher set up stations so that students have first-hand experience with the magnets.

Station One: (dowel or pencil, several disk magnets, metal washers

* 1. Using a pencil or wooden dowel, insert two disk magnets over the end of the pencil or dowel and see what happens to them. Do they stick together or are they forced apart?
	2. Repeat the experiment by adding several disk magnets to the pencil or dowel. Have the students explain why some attract and some repel each other.
	3. Have the students see if they can make each of the magnets appear to “float above each other.
	4. Students can try variations of the experiment by adding metal washers between the magnet disks. Do the washers change what is happening to the disks?

Station Two: (12-inch string, 2 bar magnets)

* 1. Tie a 12-inch piece of string from the middle of a bar magnet and suspend it from the side of a table with a piece of tape.
	2. Hold the other bar magnet close to the end of the first magnet and see what happens. Are the two magnets attracted to each other or are they repelled? Now turn the magnet in your hand around and try the experiment again.
	3. Record observations.

Station Three: (Tape, 2-12 inch pieces of thread, magnetic craft tape)

* + - * 1. Tape the ends of a 12 inch thread or small string to opposite sides of a small piece of magnetic craft tape.
				2. Tape the loop formed by the thread to a table so that the magnet strip is suspended over the edge.
				3. Do the same with a second piece of magnetic craft tape of equal size. As you hang the magnetic tape, make sure it is as close as possible to the first piece, but not touching.
				4. Spin one of the magnets a few times to wind the thread and then release it.
				5. Using your knowledge of poles, attraction and repulsion, explain the motion of the two magnets.
				6. Record observations.

Station Four: (Ring stand w/ clamp, 10 disk magnets, string or fishing line)

Using a ring stand and clamp (or an improvised stand made from Tinker Toys), suspend one disk magnet from a string or fishing line so that it is a free swinging pendulum. You can hang the magnet in any orientation.

Arrange three piles of two or three disk magnets stacked together in an equilateral triangle, measuring a couple of inches per side, on the ring stand base.

Adjust the length of the pendulum so that the free-swinging magnet will come as close as possible to the magnets on the base without hitting them or the base itself.

Give the pendulum magnet a push and watch what happens.

Have the students record the results in their journals.

Vary the locations and poles of the magnets to develop other patterns. You can arrange the magnets so they all have the same pole up, or you can mix them up. Notice that a tiny change in the location of one of the fixed magnets or in the starting position of the pendulum may cause the pendulum to develop a whole new pattern of swinging.

This experiment shows the force of gravity and the simple pushes and pulls of the magnets as they act together. It is difficult to predict where the pendulum is going to go next, even though you know which magnets are attracting it and which are repelling it.

**Explore**

**Activity 2: Attractive Dilemma**

**Purpose**

Students make predictions and test various items for their magnetic interaction. Students observe that magnetic objects are affected by the strength of the magnet and the distance from the magnet.

**Activity Description**

Students make predictions, test and sort objects into magnetic and nonmagnetic sets. Using their set of magnetic items, students will explore whether a magnet is strong enough to attract objects across the distance from the outside of a glass container to the objects inside the container. Students test the variables of various glass containers and magnets before testing the attraction through water. After they investigate the ability of magnetic fields to pass through an iron nail, they discover that the nail can be turned into a temporary magnet.

**Focus Question**

How do magnets interact with various materials? What effect do distance, medium and magnets have on the ability of objects to interact with magnets?

**Duration**

One class session

**Materials**

For introduction activity:

* Magnets
* Collection of objects
* Plastic bag with a mixture of paper clips and brass (nonmagnetic) fasteners
* Classroom clock with a second hand
* Bag with a mixture of salt and iron filings or bits
* Snack size baggie for the magnets
* Toothpicks

For the teacher:

* Large glass or clear plastic container of water, such as a wide mouth gallon jar or small aquarium
* Several small objects that are attracted by a magnet, such as paper clips, small nails, thumb tacks
* Strong magnet, such as an alnico magnet

For the students (individual or small group)

* Small glass or plastic cup
* Several small objects, such as paper clips, small nails or tacks
* One magnet
* One large iron nail

**Teacher Preparation**

1. Introductory Activity: Students should work in groups of two to five. To attract iron bits from the salt mixture, put a magnet in a plastic bag before running the magnet through the salt/filing mixture. Be sure to allow students plenty of time to brainstorm and problem solve.
2. The teacher should test the magnets with the materials to be certain that the magnets are strong enough to complete the activities.
3. All substances display magnetic properties, but most show them to a very small degree and we consider them nonmagnetic. Very sophisticated equipment is needed to detect magnetic characteristics at these low levels. On the other hand, a few metallic elements such as iron, nickel, cobalt, rare earth materials, plus some of their alloys like steel and strontium ferrite display magnetic properties strongly enough to be considered magnetic or more properly *ferromagnetic.* A common misconception is that some believe that all metals are magnetic but this can be easily corrected by observing a magnet’s effect on copper, aluminum or brass.
4. Magnetic fields pass through media such as water and will attract objects containing iron, cobalt, or nickel in the water provided the magnet is strong enough to attract the objects across the distance from the outside of the glass container to the objects.

**Classroom Procedure**

Introductory activity:

1. Begin the lesson by asking, “What does magnetic mean?” [An object is magnetic when it can be magnetized or attracted by a magnet.] Allow students time to turn and talk to their buddy and discuss, “How can we tell if an object is magnetic?” [By touching an object with a magnet.]
2. This next activity may be a review for the students. In pairs, students will go on a Magnetism Scavenger Hunt in the classroom. First they will complete the scavenger hunt visually. From their seats, students will look around the room and identify and record ten objects that might be attracted to a magnet and ten items that they believe are not attracted to a magnetic. Students will record their predictions. After completing the prediction portion, give each pair of students a magnet. They will test the items to discover if they are correct.
3. Ask, “In your predictions, how did you determine whether an object was magnetic or nonmagnetic? What surprised you? What does this activity tell us about metallic objects?” [Not all metallic objects are magnetic.] Explain that magnets attract metals containing iron, cobalt, and nickel or alloys containing these metals such as steel. Magnets do not attract most other materials. For example, copper, brass and aluminum are not magnetic and would not be attracted to a magnet. Ask, “Can we tell just by looking at a metal whether it is magnetic or nonmagnetic?” [No, not unless you know what the metal is. You would have to test the item with a magnet.]
4. Then ask, how can we sort items into magnetic and nonmagnetic sets? [manually or by using magnets] “Which method would be more efficient? By hand? Or using a magnet? How could we measure efficiency?” Guide students to realize that they could time the two strategies to find out which is more efficient.
5. Students will work in pairs with one student being the sorter and one student being the timer. Distribute bags of paper clips and paper fasteners. Have the students empty their bags on the desk. At the signal, the sorters begin sorting the magnetic and nonmagnetic items. When finished the timers will record the time.
6. Continue sorting for the second and third trials.
7. Distribute magnets. Discuss how the results may differ using magnets.
8. Time the activity the same way; doing three trials.
9. Discuss and record what was learned.
10. Distribute bags of salt and iron filings or bits. Tell students what is in the bag.
11. Repeat the question: “How can we sort items into magnetic and nonmagnetic sets?” Present toothpicks as one strategy; have students try to sort manually.
12. Encourage students to think of other strategies such as dissolving the salt in water and filtering out the iron bits. Consider the pros and cons of each suggestion; including the use of magnets.
13. Pour salt mixture on to a paper plate or large piece of paper. Give each group a magnet which has been placed in a baggie. Use the magnets to pick up the iron bits.
14. Discuss: “Which method of sorting was faster? Why do you think magnets helped sort more efficiently? What were some problems you encountered? How do you think a factory would utilize magnets?” Explain that in industry, magnets are often used to sort magnetic materials from nonmagnetic materials because of the increased efficiency. They are used to sort scrap metal, coins, etc.
15. Record ideas and observations.

Activity Two:

1. Explain to students, “When scientists talk about magnets, they say that magnets have a magnetic field. What do you think we mean by the term, “magnetic field”? [It is the energy force that surrounds a magnet. The force is much stronger at the poles. This will be further explored in future lesson.] Explain, “Today we are going to observe how a magnetic field affects certain objects.” As a demonstration, place several small objects at the bottom of a glass or clear plastic container and fill the container with water.
2. Challenge students to think of a ways to remove the objects from the water without getting wet. Accept and list any responses. Test some of the students’ ideas.
3. Show students a strong magnet such as an alnico magnet and suggest that you try to use the magnet to remove the objects. Ask the students, “Do you think the magnetic field or the area of magnetism around the magnet can travel through the water? I don’t want my hand to get wet!! Will the magnetic field travel through the wall of the container?” “Will all of the objects at the bottom of the container be attracted to magnet? How do we know? How will we find out?” [Do not demonstrate at this time.] Record ideas.
4. Students will work in small groups. Distribute cups or small clear containers to groups of students. Give each group a bag with small items (both magnetic and nonmagnetic) and a magnet. Tell students to place an object in their cup or container. Move their magnet on the outside of the container to see if the object is affected by the magnetic field when the object is on the inside of the container. Ask, “Will the magnetic field pass through the container?” [Yes] “What is your evidence?” [The magnetic objects moved with the magnet.] Record observations and ideas.
5. Add water to each cup until it is about half full. “Will the magnetic field pass through the container and the water?” Allow students the opportunity to predict and test their prediction. They will move their magnet along the outside of the container, attracting the object until it reaches the top of the water. Discuss, “Will the magnetic field pass through the container and the water? What is our evidence?” Record observations and ideas.
6. Demonstrate a nail-magnet system. Hold a long nail with the magnet on the head of the nail. [Using a strong magnet will add to the success of this activity.] Ask the students, “Will the magnetic field pass through the nail?” Allow students to turn and talk.
7. Working in their small groups, provide an opportunity for students to explore constructing their own nail-magnet system by picking up objects from the desk or table. Predict whether the nail magnet system will work in the water. Encourage students to try the system with their own cups of water and different small object. Picking up more than one object will depend on the strength of the magnet. Cleanup work area.
8. Challenge students again with the original question. “How can we remove objects from a container of water without getting wet?” Students should have at least two methods that were successful.
9. Demonstrate placing the magnet on the outside of the demo tank and removing objects by dragging them up the side of the container.
10. Demonstrate placing the large nail in the tank near the objects and then holding the magnet against the head of the nail through the glass. Move the nail close enough to the objects to attract them and pick up the objects in the water. How many objects will the larger system pick up?
11. Allow students time to finish their observations and notes.

**Explore**

**Activity 3: Paper Clip Walk**

**Purpose**

Students demonstrate that magnetic objects are affected by the distance from the magnet.

**Activity Description**

Students use a magnet to make a paper clip “walk” on a paper plate. Students investigate how many paper plates through with the magnetic field will pass.

**Focus Question**

What effect do distance, medium and magnets have on the ability of objects to interact with magnets?

**Duration**

One class session

**Materials**

For the students (individual or small group)

* Paper clip
* Magnet
* Paper plates
* Metric ruler

**Teacher Preparation**

1. Students should work in groups of two to five. The teacher should test the magnets with the materials to be certain that the magnets are strong enough to complete the activities.
2. As students test the strength of the magnet by stacking their paper plates together to see how many paper plates a paper clip is still attracted through, make sure that students understand that the paper plates are not blocking the magnetic field when the magnet will no longer hold the paper clip. The thickness of the paper plates has moved the magnet and paper clip far enough apart that the magnetic attraction is no longer strong enough to hold the paper clip, but it is still passing through the paper.
3. Magnetism will pass through materials that are not magnetic, such as glass, plastic and water (as demonstrated in the previous activity) and also, paper plates. When students are allowed to manipulate magnets and objects, they discover that they can make the objects move without actually touching the objects.

**Classroom Procedure**

1. Ask, “What is magnetic force? What is a magnetic field?” [A magnetic force is the push or pull that a magnet exerts. In other words, it is the force in which a magnet attracts or repels a metal. Magnet field is the area around a magnet that exerts a magnet force. Magnetic fields are strongest at the poles of a magnet.]
2. “Can you feel magnetic force in the air?” [If you move a magnetic object close to a magnet, you can feel the magnetic force or attraction of the magnet.] “Can you feel magnetic force if you place a magnet on each side of your finger? Your hand? Can you feel

a magnetic field pass through your hand?” [Yes, if the magnets are strong enough.]

1. Working in groups, place a metric ruler on the table and position several paper clips on the table next to 0cm on the ruler. Place a magnet on the table next to the 20cm mark. Slowly move the magnet toward the paper clips. Observe what happens as the magnet is slowly moved toward the paper clips. Record the measurement at which the paper clips begin to move. Repeat this activity three times. Challenge students, “What does this demonstrate about the magnetic field of the magnet?”
2. Distribute a paper plate to each student. Instruct students to place a paper clip on the paper plate. Ask students to pick up the paper clip with the magnet.
3. Predict whether the magnetic force or field will pass through the paper plate if they put the magnet under the plate instead of over it. From the previous activity, students learned that a magnetic field can pass through nonmagnetic materials. Allow students to test their prediction. Observe the paper clip as it moves around the plate.
4. As a class, predict how many paper plates can be stacked together before the force of the magnetic field will no longer affect the paper clip.
5. Test the prediction by adding one student’s paper plate at a time. As each student adds his/her plate to the stack, continue testing until the paper clip can no longer be held or moved by the magnet.
6. Challenge students, “What do you observe? Why is the paper clip no longer attracted to the magnet?” [The thickness of the paper plates has moved the paper clip and the magnet far enough apart that the magnetic attraction is no longer strong enough to hold the paper clip, but it is still passing through the paper plates.] Repeat two more times.
7. Measure the thickness of the paper plates. How does the thickness of the paper plates compare to the distance at which the paper clips began to move toward the magnet when we measured them at the beginning of this lesson?

**Explain**

**Activity 4: Magnetic Fields**

**Purpose**

Students demonstrate that magnets have an invisible force field known as a magnetic field.

**Activity Description**

Students learn about the magnetic field of a bar magnet. After completing several activities, students understand that magnets have two poles, similar poles repel, unlike poles attract, magnets have magnetic fields which are strongest at the poles. Using iron filings and compasses, students conclude that magnetic fields can be measured and they have direction.

**Focus Question**

How can we observe and measure the magnetic field of a magnet?

**Duration**

One or two class sessions

**Materials**

For each group of students

* 1 magnetic compass per student
* 2 Alnico bar magnets
* Ring magnets, horseshoe magnets, disc magnets (at least 2 of each, per group)
* 6 sheets of white paper
* Iron filings
* Copper or aluminum wire

Additional materials (for demonstration or per group)

* 1 cow magnet
* 1 small/medium sized bottle (16 – 20 oz. clear plastic or glass)
* Plastic test tube (that fits into the mouth of the bottle and is about 75% as long as the bottle is tall)
* 2 tablespoons iron filings
* 1 roll of scotch tape (duct tape would be fine, too)
* 1 piece paper or tissue paper

**Teacher Preparation**

1. The full lesson can be found at: “Exploring Magnetism” http:// <http://cse.ssl.berkeley.edu/segwayed/lessons/exploring_magnetism/exploring_magnetism/s1.html#ws>
2. Students should work in groups of two to five. The teacher should test the magnets with the materials to be certain that the magnets are strong enough to complete the activities.
3. As students test the strength of the magnet by stacking their paper plates together to see how many paper plates a paper clip is still attracted through, make sure that students understand that the paper plates are not blocking the magnetic field when the magnet will no longer hold the paper clip. The thickness of the paper plates has moved the magnet and paper clip far enough apart that the magnetic attraction is no longer strong enough to hold the paper clip, but it is still passing through the paper.
4. Magnets: Chrome-steel bar magnets quickly lose their magnetic fields when dropped. It is recommended that they not be used for classroom activities. Ceramic bar magnets are usually very strong but brittle and hard to work with. However, there are some ceramic bar magnets that are coated with plastic that will last longer than non-coated magnets. It is recommended that Alnico bar magnets or cow magnets be used.
5. It is recommended that compasses with transparent faces be used. These types of compasses can be used on an overhead or Elmo to demonstrate how to do the magnetic field mapping or together with iron filings.
6. Caution: Compasses can easily change polarity when using them with magnets. By convention in the United States today, the compass arrow is a magnetic north pole, which is attracted to (points to) the magnetic south pole of a bar magnet, often marked with an “S” or with a blue color. This may be confusing but the pointed end of the compass arrow (sometimes painted red) is actually a “north seeking arrow” which points to the geographic North Pole. See Background Material: <http://adventure.howstuffworks.com/outdoor-activities/hiking/compass.htm>
7. Caution: When working with iron filings, students should wear safety goggles.
8. Warning: Do not bring bar magnets near computers, computer monitors, audio tapes, or other such magnetic devices. Strong magnets can destroy materials with magnetic properties.

**Classroom Procedure**

1. Review what students have already explored in previous magnetism activities. Then ask, “Have you ever heard that the Earth is like a giant magnet? Do you know what a magnetic compass is? Do you know how a GPS works?” This lesson will introduce a magnetic compass to identify the magnetic field around a bar magnet. The lesson does not focus on learning about the Earth as a magnet or the magnetic compass. One key goal of this discussion is to draw out any misconceptions that may be in students’ minds about magnetism. It is important that students begin to realize that magnetism does not require a medium to be transmitted. Magnetism is present in space. Review that magnets attract metals than contain iron, nickel or cobalt. Also, remind students that when magnets touch some metals (like the iron nail) they become magnetic themselves.

Activity One:

1. Distribute a bar magnet and a magnetic compass to each student. Discuss what students already know about compasses. Explain how the compass works by having students hold the compass horizontally and the N-S needle is facing up. Next have the students align the line marked “N” (for North) on the glass/plastic top with the arrow inside the compass. Talk about how compasses are used in the wilderness.
2. Let the students experiment with the compass and their bar magnet. What do they notice when the compass is moved closer to the bar magnet? What happens when the compass is moved around the bar magnet? With others in their group, use two bar magnets and several compasses to create different configurations. Have students record their observations.
3. Give each group of four students four to eight more compasses. Ask students to predict what they think will happen when the compasses are arranged around one bar magnet. Record their predictions. Ask students to arrange their compasses around one of the bar magnets. Record their observations. Ask students, “Why do the compass needles respond as they do? What are you observing?” [Magnetic field]
4. Discuss the students’ observations. Ask, “How does a compass work?” After ample discussion, explain that the compass needle is a tiny magnet suspended on a pivot (so that it will turn with minimal friction if a magnetic force is applied to it). The students are observing the magnetic field around the bar magnet. Notice how the compass needles point toward the magnetic south pole and away from the magnetic north pole of the bar magnet. This may be confusing to students as they may have learned that the north end of the arrow points north. The north end of the compass arrow is actually a north seeking arrow. When in the presence of a strong magnet, the north-seeking compass needle will point to the south end of the magnet. (Remember that like poles attract so the north end of the compass needle will be attracted to the south pole of the magnet. Why is the north end of the compass needle attracted to the north magnetic pole of the Earth? This is rather confusing and beyond the understanding of a fourth grade student. The north magnetic pole on Earth actually has a southern polarity. The website <http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/twoends.htm> may also be used if further clarification is warranted. The purpose of this lesson is not to learn about the magnetic Earth but to introduce the magnetic field of a magnetic as detected by a compass.)
5. Hand out several pieces of white paper to each group of students. Tape the paper together and place one bar magnet on top of and in the center of the paper. Explain to students that they will be drawing the magnetic force field around the bar magnet. Have students hypothesize and sketch what they think the force field will look like based on the behavior of the compasses when placed around the magnet. Review the term “force field” or “magnetic field”. To make tracings:
	1. Draw a dot somewhere near the magnet and place the center of a compass over the dot.
	2. Draw a dot at the location of the arrow head (or tail) of the compass needle.
	3. Move the compass center to this new dot, and again draw a dot at the location of the compass needle head (or tail).
	4. Remove the compass from the paper and draw lines connecting the dots with arrows indicating the direction that the compass points.
	5. Continue steps b-d until the line meets the magnet or the edge of the paper.
	6. Pick another spot near the magnet and repeat the process.

Have students continue until they have lines surround the magnet as shown. This is a two-pole or dipole pattern of force field.

If time permits, students could place two magnets side-by-side and do the same magnetic field tracing. Be sure to have them draw their predictions before they determine the actual configuration.

Activity Two: (Warning! Iron filings are messy and stick to magnets. It is important to have paper or sandwich bags between the filings and the magnets.)

1. Give groups of 2-4 students iron filings (two tablespoons in a baggie) and several thin sheets of paper. Have the students place the paper on top of one of their bar magnets, trace the outline of the bar magnet and mark which end is North and which is South. Lightly sprinkle the iron filings uniformly over the paper and then give the paper some gentle taps to make the filings align with the magnetic field.



1. Have students record their observations. Ask students, “What are you observing? Can you explain what is happening?” Record their ideas. “Is the shape of the filings similar to the magnetic field created with your compass tracings?” Include the fact that the filings are acting like tiny magnets in your discussion.
2. Lift up the paper and carefully put the filings back into the baggie.
3. Place two magnets, in some configuration, under the paper. Trace the magnets on the paper. Have students predict what the magnetic field will look like when they sprinkle the filings on the paper. Next, sprinkle some iron filings on the paper over the magnets, tapping gently to get the filings to spread around the magnets and align with the magnetic field. Students will record their observations by making drawings of their results and comparing them to their predictions.
4. Distribute horseshoe, disc and ring magnets to each group of students. Allow students time to explore the polarity of the different magnets. Discuss where the poles of the magnets are located. Can students identify the north and south poles of the ring and bar magnets? How can they identify them using the other magnets? After a few moments to discover and discuss, students will predict the configuration of the magnetic field around each of the magnets. After making their predictions, students will create magnetic fields using paper and iron filings just as they did with the bar magnets. They will record their observations.
5. For the next step, the teacher may do a demonstration for the class, or if there are enough materials, each group could build a 3-Dimensional (3-D) magnetic field visualizer. As the name suggests, you will construct (or purchase) the 3-D magnetic field around a cow magnet.
6. To construct the visualizer: obtain a clear plastic or glass bottle, small/medium sized (20 oz. soda or water bottle). Remove labels.
7. Fill the bottle about one-fifth full of iron filings.
8. Wrap the top of the test tube with masking tape so that the tube fits snugly into the mouth of the bottle, plugging the opening completely. After you put the iron filings in the bottle, jam the tube into the mouth of bottle.
9. Slide the cow or cylindrical magnet into the test tube and put the bottle cap back on. Turn the bottle on its side and rotate it. Watch what happens to the iron filings. [They will form a three-dimensional pattern that traces out the magnetic field of the magnet.]
10. Discuss what the students are observing. Have them pay particular attention to the ends of the magnet. The iron filings stand out like a punk haircut. Shake the magnet out of the tube, and watch the filings collapse. Explain that each atom in a piece of iron is a magnet, with a north pole and a south pole. Most pieces of iron are not magnetic, since the atomic magnets all point in different directions. When you bring a magnet near a piece of iron, the iron-atom magnets line up with the applied magnetic field: The north poles of the iron atoms all point in the same direction. Because the iron atoms line up, the piece of iron becomes a magnet and is attracted to the original magnet. Students should be able to see full loops of force from one pole to the other. The field of a cylindrical magnet comes out of the end of the magnet and then loops around next to the side. The iron filings stick out like a crew cut on the ends of the magnet but lie flat on the sides. Because the iron filings become magnets themselves, their presence slightly changes the shape of the magnetic field. Even so, this exhibit gives an indication of the shape of the magnetic field in three dimensions.



1. Students will draw and record their observations. They complete the questions in their science journals.

**Explain**

**Activity 5: Reading about Electromagnets**

**Purpose**

Students read about the connection between electricity and magnetism.

**Activity Description**

Students read and analyze a piece of text. Using the “Text in the Middle” strategy, students will reveal their understanding and reflect on a selected text.

**Focus Question**

How can we use electrical energy to make a magnet?

**Duration**

One or two class sessions

**Materials**

* “Reading Strategies in Support of Science Proficiency.” Oakland Schools
* “Kidipede: Science for Kids” <http://www.historyforkids.org/scienceforkids/physics/electricity/electromagnet.htm>
* Text in the Middle Template/Worksheet on Electromagnetism

**Teacher Preparation**

1. Text in the Middle is a very flexible template where student thinking can be laid out in two outer columns that surround a short well-selected piece of science text. Comprehension is enhanced when students engage in metacognition, (i.e. thinking about their own thinking). Therefore, those types of prompts are important to use. Such prompts may be difficult at first, but with a collaborative analysis of students work, metacognitive skills will develop.
2. Steps to implementing this strategy include:
* Identify a compelling piece of writing center on important scientific ideas and paste it into a text in the middle template.
* Determine the questions or prompts that will be used in the template.
* Prompt students to closely read the text and respond to the prompts.
* Scan student writing for examples that illuminate student thinking at various level and present them for analysis using a document camera.

**Classroom Procedure**

1. Distribute the “Text in the Middle Template on Electromagnetism.” Encourage students to read the text carefully as they respond to the prompts. If this is the first time that students have used this strategy, it may be more conducive to have them work with a partner.
2. Upon completion, the students may share ideas and thoughts with the class.

**Activity 5: What is an Electromagnet?**

|  |  |  |
| --- | --- | --- |
|  | **Text in the Middle** |  |
| **The most important points in this text are:** | Small iron rocks on the surface of the Earth are also sometimes naturally magnetic, with their electrons naturally happening to spin all the same way. We call these natural magnets lodestones.Until about two hundred years ago, people made magnets by finding a lodestone and rubbing iron on it. The rubbing lined up the electrons of the iron so that all the electrons would pull in the same direction. But today we can use [electricity](http://www.historyforkids.org/scienceforkids/physics/electricity/index.htm) to make magnets. This way you could also make much stronger magnets, and you could turn the magnets on and off.The new way is an electromagnet, or a magnet that works by using [electricity](http://www.historyforkids.org/scienceforkids/physics/electricity/index.htm) to create a magnetic field in a piece of [iron](http://www.historyforkids.org/scienceforkids/chemistry/atoms/iron.htm).When you hook up a [copper wire](http://www.historyforkids.org/scienceforkids/chemistry/atoms/copper.htm) to a battery, [electrons](http://www.historyforkids.org/scienceforkids/chemistry/atoms/electron.htm) begin to flow through the wire, moving from [atom](http://www.historyforkids.org/scienceforkids/chemistry/atoms/index.htm) to atom, from one end of the battery to the other, trying to even out the negative and positive charges at each end of the battery. This makes a circle of electrons just like the circle of electrons inside an iron atom, and, just like the iron atom, that's a magnet.To make the iron atoms strong enough to be a useful magnet, you have to line up a lot of them all going the same way, and it's the same with an electromagnet - you have to make lots of copper wire circles all going the same way. If you wrap these coils around something made of iron, the coils will act like a lodestone and make that iron into a magnet. If you use thousands of coils of wire and a big piece of iron, you can make a very strong magnet that can pick up cars and huge machines.But tiny electromagnets are also very useful, because you can turn them on and off by connecting or disconnecting the batteries. Alternating magnets power stereo speakers, hold fire doors open, and are inside all electric motors, like in a hair dryer or a washing machine.<http://www.historyforkids.org/scienceforkids/physics/electricity/electromagnet.htm>  | **My thoughts about this text:*** Questions I have:
* This reminds me of:
* I don’t understand:
* I want to learn more about:
 |

**Elaborate**

**Activity 6: Electricity and Magnetism (Optional)**

**Purpose**

Students demonstrate the magnetic effects of a simple circuit by creating an electromagnet.

**Activity Description**

Students apply what they have learned about electricity and magnetism as they discover that magnetism and electricity are closely connected. They demonstrate that moving electric charges (an electric current) create a magnetic field in an electromagnet. They also discover that a moving magnetic field creates an electric current in conducting materials, as in a simple motor.

**Focus Question**

How can we use electrical energy to make a magnet?

**Duration**

Two to three class sessions

**Materials**

AIMS Education Foundation. Mostly Magnets: “Making an Electromagnet.” Fresno, CA: Aims Education Foundation. 2008.

“Building Electromagnets and Simple Motors.” <http://www.uen.org/Lessonplan/preview?LPid=28337>

For each group of students

* Steel nail, about 8 cm (3 inches) long
* Insulated wire, 40 cm (16 inches)
* D-cell battery
* Battery holder
* Staples or paper clips
* Small zipper-type plastic bag
* Wire strippers (optional)
* Metric ruler

Optional Simple Electric Motor (per student or group)

* YouTube Video: [*www.instructables.com/id/****Simple****st-****Electric****-****Motor****/*](http://www.instructables.com/id/Simplest-Electric-Motor/)
* D-Cell battery
* 24-gauge enameled wire (30 cm or 12 inches)
* Circular ceramic or alnico disc magnet
* Two large paper clips or safety pins
* Masking tape or plastic tape
* Scissors or sandpaper

**Teacher Preparation**

1. Students should not leave D cells connected to the electromagnets for more than 15-20 seconds at a time since the energy in the D cells will drain very quickly.
2. The ends of each wire need to be stripped of insulation.
3. Each group will need about 100 staples. Squeeze the stapler to deposit them in plastic bags. If groups need more, demonstrate how they can get more. Paper clips can also be used but the results will be different.
4. This lesson has three parts. First students will build an electromagnet and test it. Next they will attempt to make their electromagnet stronger. Finally they will build a simple motor using their electromagnet.
5. One of the key discoveries of all time was the electricity and magnetism are closely connected. Moving electric charges (an electric current) create a magnetic field. Conversely, a moving magnetic field creates an electric current in conducting materials. The discovery of this electromagnetic connection in the 19th century led to the invention of the electromagnet, the electric motor, and the electric generator. While the electric generator is arguably the most important of these inventions in terms of the impact on technology, this activity will explore the much simpler electromagnet and simple motor.
6. Magnetic materials like iron that are not permanent magnets become temporary magnets in the presence of a magnetic field. As long as the magnetic field is present, the materials acts like a magnet. When the magnetic field is removed, the material no longer acts like a magnet.
7. Since an electric current produces a magnetic field, coiling wire around a piece of iron can make an electromagnet. When current flows through this coil, it produces a magnetic field that turns the iron into a magnet. As soon as the current stops, the magnetic field is no longer present.
8. Electromagnets play an important role in technology. Large, powerful electromagnets attached to cranes are used in factories and junkyards to lift and move heavy pieces of steel or iron. Smaller electromagnets are utilized in the electromagnetic switches called solenoids. These switches are used in cars, doorbells, security doors, and many other mechanical devices. (AIMS, ­Mostly Magnets, 2008)

**Classroom Procedure**

Part One

1. Ask the question, “How can I use electrical energy to make a magnet?” Students should recall information from the previous “Text in the Middle” activity. Review how an electrical current creates a magnetic field.
2. Distribute the materials to each group. Tell students that they will follow the instructions on their student page to construct an electromagnet.
3. Inform students that they will decide in their groups how they will record their data so that the results can be shared with the class. Suggest that they may want to make a table for their data. They may also want to perform several trials to verify their data.
4. Students will complete Part One and compare results.
5. Distribute the “Class Graph” and have students determine the scale and record the data.

Part Two

1. Ask students if they think they can make a stronger electromagnet. Accept all ideas.
2. Challenge each group to design and construct an electromagnet that will pick up more staples. Emphasize that they will need to test only one variable at a time, while holding the others constant. For example, they may want to add more batteries or they may want to use a larger nail or they may want to wrap the wire more times. Each variable should be tested separately.
3. Students will record their design and their data on the student page so that they can see and prove that their test resulted in a stronger magnet.

Part Three (Optional)

1. Ask, “What things around your home use an electric motor?” [Electric mixer, telephone, computer, refrigerator, stereo speakers, hair dryer] “What would you say if I told you that today, we are going to build an electric motor?”
2. Show the video: “Simplest Electric Motor” [*www.instructables.com/id/****Simple****st-****Electric****-****Motor****/*](http://www.instructables.com/id/Simplest-Electric-Motor/)
3. Instruct students: Wrap the enameled wire around the battery tightly to make a coil. Use the entire length of wire, making approximately 6-10 wraps around the battery. Leave two inches of wire off each side of the coil. Secure the coil with two wraps of the wire.
4. Scrape or sand all the enamel from both ends of the wire so only copper shows.
5. Bend each paper clip to create and “S” or use the large safety pins. Tape pins or paper clips to each end of the battery. (Be careful because heat is generated.”
6. Place the magnet under the battery. If the battery has a metal coating, eth magnet will adhere to it.
7. Place the wire coil in the loops of the paper clip or thread through the loops in the safety pin.
8. Adjust the paper clips or pins, moving the coil up and down until the coil is affected by the magnetic field. This will be evidence by a wobble in the coil. It will start to move back and forth.
9. Spin the coil slightly and the coil should start spinning by itself. The electric motor should now operate.
10. Trouble shooting is very exciting as well as frustrating because the students will determine what needs to be adjusted. Some problems that students could adjust include scraping all the enamel off the wire, a loose wire coil, or having the paper clips/pins too far from the coil.
11. Discuss the variables that the students could change to make their motors work better. (Change the battery size, change the paper clip size, change the tape, use different magnets, change the number of coils, change the wire, etc.) This lesson can be extended into an inquiry investigation where students elicit a question to be investigated.