GOING FOR A SPIN: Making a Model Steam Turbine

PLANNING OVERVIEW

SUBJECT AREAS:
Physical Science, Math, Language Arts

TIMING:
Preparation: 30-60 minutes
Activity: 1-2 45-minute class periods

Note: "Going for a Spin" and "Getting Current" are best done in conjunction with one another.

Summary

Students explore how various energy sources can be used to cause a turbine to rotate.

Objectives

Students will:

- Recognize how the force of wind, falling water, and expanding steam can be used to do work.
- Create a model of a turbine and cause it to spin using the forces of wind, falling water, and expanding steam.
- Create a steam device that simulates some of the conditions of a steam-driven power plant.
- Use the scientific method to write up their work, including hypothesizing and drawing conclusions.
- Assess the ability of the turbine model to actually generate electricity.
- Use diagrams and narratives to describe how their apparatus worked and why.
- Compare their models to an actual power plant.

Materials

Per student group:

2 aluminum pie pans

Metal funnel, 4 inches (10 cm) in diameter

Scissors

Compass (for drawing circles)

Ruler

Pencils

Several plastic straws (the long soda type is best, but regular sized straws can be used)

Push pins

Small, thin washer (optional)

Small cooking pot, no bigger than 5 or 6 inches (13–15 cm) in diameter

Student Handout, "Going for a Spin," pages 36–39

Copy of Chapter 2 Discussion, "Energy and Electricity"

Student Handout, "Scientific Method Form," page 185

For all groups to share at a "central station":

Hot plate(s) or other heat source(s)

Oven mitts

Source(s) of falling water, such as a faucet and sink, or a large jug or bottle of water and a bucket or tub

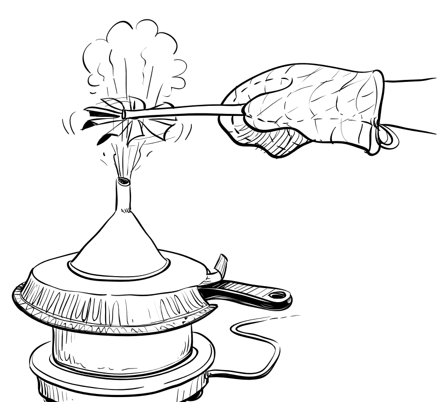
Towels for clean-up

Teaching Notes

Please review with your students all safety rules for working with heat and steam, particularly if you must use an open flame. Remind students to take care when cutting the aluminum pie plates.

This activity is intended for use in conjunction with the activity, "Getting Current." Each represents the two main functions of many typical power plants. However, each activity is designed to stand alone, if necessary.

The turbine model in this activity is not powerful enough to generate electricity, but it will successfully show students how different energy sources cause a turbine to spin. In "Getting Current" students will demonstrate how electricity is produced using electromagnetism. Though the two activities cannot be "connected" to produce electricity using the turbine model, students should be able to make a mental link between the two devices.



If you wish to do a more complicated project that shows a student-made turbine causing a generator to produce electricity, see the Tennessee Valley Authority materials listed in the Teacher Resources section of the Appendix.

Important Note: There are many different scientific method formats. The one suggested here is very basic and you may prefer to use your own format. If your students are not familiar with the steps of the scientific method, then you may wish to explain the method further.

Warm-up

Ask students if they have tried to wade across a rushing river or into ocean waves. Perhaps some have stood near a large waterfall. Ask students to describe these experiences. Have students connect the force of moving water with the idea of using it to do work.

Next ask students about the power of steam. It may be more difficult for kids to picture how steam can be forceful enough to make something move. Have students relate their experiences with steam (steamy showers, tea kettle, geyser, or natural steam vent). Students may think of steam as a wispy vapor that is not very powerful.

Review Chapter 2, especially the idea that we can produce and harness steam in a particular way that makes it very forceful — enough to spin a turbine that can be used to do work.

Tell students that in this activity they will be exploring how we use wind, water, and steam to turn turbines. Remind students that in the generation of electricity, the sole purpose of making a turbine rotate is to spin a generator.

The Activity

1. Gather the necessary materials and set up your classroom to accommodate the activity. Refer to the Student Activity page for the specific procedure. Develop a plan for use of a "central station," if needed.

2. Use the Chapter 2 Discussion information to discuss turbines and the various ways we can cause them to turn (wind, water, and steam).

3. Explain to students that power plant turbines are highly engineered devices that are designed to make the best use of the force of wind, water, or steam. In this activity, students make very simple turbines that will spin when blown on ("wind"), placed under falling water or held up to the homemade steam device.

   Remind students that most power plants today use steam to spin their turbines, and review how steam-driven power plants work. Emphasize that in order for the steam at a power plant to hit the turbine with enough force, it must be confined, creating high-pressure steam, and then released through a small opening, bursting out and expanding at great velocity.

4. Distribute copies of the Student Activity page for "Going for a Spin" and review the procedure. Organize student groups and give out all needed materials. Explain, if needed, that some materials are shared and that groups will be taking turns using the heat source at the "central station."

5. Once students have had a chance to look over the directions for constructing the turbine model and the steam device, and have a general idea of what they both look like, go over the instructions for using the Scientific Method Form on page 185.

6. Once finished with all three tests of the model turbine, tell students to write up the activity. Have students stay in their groups for discussion and support, but ask each individual to write up his or her own description. Consult Student pages 36–39 for exact directions.

Wrap-up

Gather the entire class together and have groups share their experiences with their turbines and the three different energy sources. Discuss ways they adapted the turbine model to make it work best. Talk about whether the angle of the blades or the distance from the resource needed to be adjusted for different energy sources and why.

Have students share their predictions regarding whether the turbine model could actually produce electricity. Ask if they changed their predictions after working with the model. Discuss why they thought the turbine in this activity is being called a "model."

Relate the use of their "wind" and water to turn their turbine models to the use of actual wind and water resources for the production of electricity. Explain that in this unit they will be learning about the many interesting ways we can use different energy resources to produce electricity without having to burn fuels. Remind students that there are also ways to produce electricity without using a turbine at all, such as with solar (photovoltaic) cells or hydrogen fuel cells, but that in this activity we are concentrating on turbines — the most common method in use today.

Ask students to explain why the steam device worked the way it did. (In the steam device, the steam is confined in a small space and so is constrained from expanding in all directions. This creates high-pressure steam that forces its way out through the small opening of the funnel. When it bursts out of the small opening of the funnel, it rises and expands with great force.)

Ask groups how far from the opening they held their turbines to get the most spin. Guide the discussion to the idea that the expanding steam hits the blades of the turbine, causing them to turn. There is a certain point above the opening where the most expansion occurs, thus causing the most spin.

Next, review the various ways we can produce steam to turn a turbine. Direct the discussion beyond burning fossil fuels (the most common way). Points to include are the use of fuels such as biomass (students may first think of wood, but explain that there are many other types of biomass), of steam that comes directly from the earth (geothermal), and of the sun's heat to boil water (as in the process of solar thermal).

If any students have completed the extra credit, have them share their descriptions. To carry this further, you might facilitate the building and testing of any of these student designs, or suggest it as extra credit homework, or as a science fair project.

Assessment

Students will have had the opportunity to:

- Create and test a model of a turbine as well as a steam-producing device.
- Draw conclusions regarding the use of wind, water, and steam as energy sources.
- Use the scientific method, including hypothesizing and drawing conclusions.
- Relate turbine models being driven by various energy sources to an actual power plant.
- (Optional) Suggest a "home-made" turbine design that would be useful for generating a small amount of electricity.

Permission was granted by the Tennessee Valley Authority to adapt portions of their junior high curriculum unit, "The Energy Sourcebook," for use in this activity.

FOR THE STUDENT

GOING FOR A SPIN: Making a Model Steam Turbine

In this activity you will demonstrate how different energy sources can be used to spin a turbine. Remember that the sole purpose of spinning a turbine at a power plant is to rotate an electrical generator. The turbine in this activity is not strong enough to operate an electrical generator; however, you can still experience how the force of wind, water, and steam are used to make a turbine spin.

You will also be constructing a device that produces steam in a manner similar to that used at a steam-driven power plant. You will recall from the Chapter 2 Discussion that the actual steam production technology at a power plant is extremely sophisticated and produces steam at very high pressures. However, this activity works well enough to get the point across.

Be sure to review all the safety instructions found in the Student Preface before you begin this activity.

Materials

Per student group:

2 aluminum pie pans

Metal funnel, 4 inches (10 cm) in diameter

Scissors

Compass (for drawing circles)

Ruler

Pencils

Several plastic straws (the long soda type is best, but regular sized straws can be used)

Push pins

Small, thin washer (optional)

Small cooking pot, no bigger than 5 or 6 inches (13–15 cm) in diameter

Copy of Student Activity, "Going for a Spin"

Copy of Chapter 2 Discussion, Energy and Electricity

Copy of "Scientific Method Form," page 185

For all groups to share at a "central station":

Hot plate(s) or other heat source(s)

Oven mitts

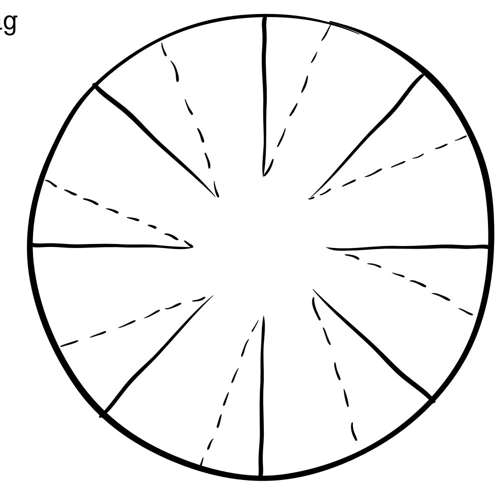
Source(s) of falling water, such as a faucet and sink, or a large jug or bottle of water and a bucket or tub

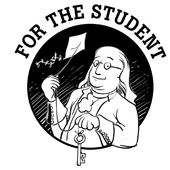
Towels for clean-up

Procedure

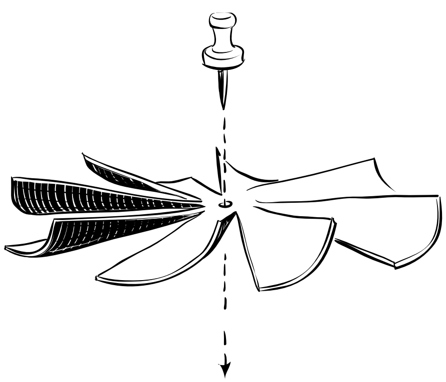
THE TURBINE

1. Using your compass, measure and draw a 3.5 inch (approximately 8 cm) diameter circle with a pencil on one of the aluminum pie plates. Divide the circle into halves, then fourths, then eighths (marking the divisions by drawing your pencil down the straight edge of the ruler). As shown in the diagram, cut the circle into 8 blades by cutting along the 8 divisions on the solid lines, to within ¾ inch (2 cm) of the center. Make sure not to cut all the way to the center.



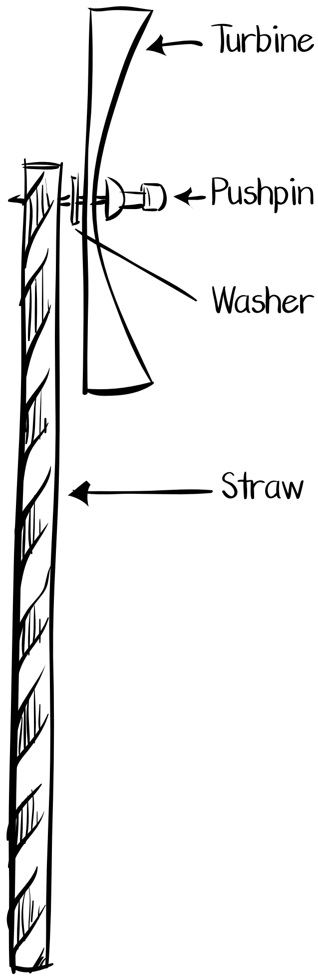


2. Taking each blade, bend one side gently up (along the dashed lines) so that all blades are curved up the same direction. (Pick a direction, such as clockwise, and stick to it all the way around). Don't overwork the blades at this point. You may need to make adjustments to the bend of the blades when you start using your turbine.



3. Using a push pin, attach the turbine to a straw at one end (illustration at right). Leave space (or insert washer, if needed) between the straw and the turbine, so it spins freely.

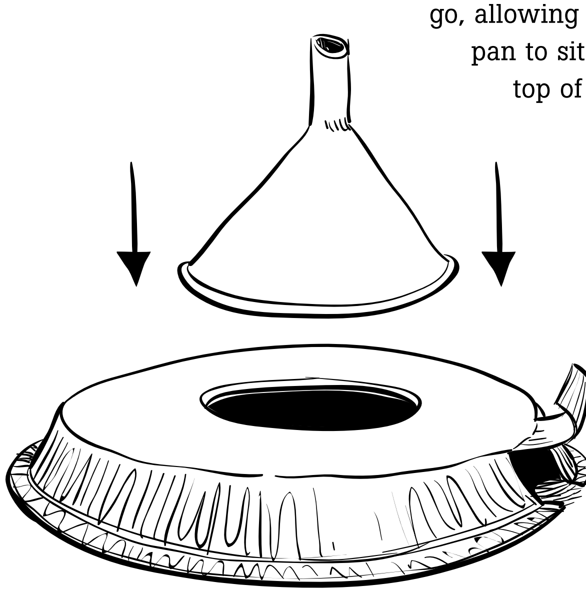
4. Next, construct your steam device (illustration at right), so that you will be ready when it's your turn to use the heat source(s) at the "central station."



THE STEAM DEVICE

1. Trace the circumference of the funnel onto the center of one of the aluminum pie pans. Using scissors, poke a hole in the center of the pan. Cut from the center out toward the edge of the traced circle, but stop about ¼ inch (almost 1 cm) from the circle itself. The line you traced is where the funnel will sit on the pie pan. The hole you are cutting must be smaller than this, so cut the circle about 1/4 inch (almost 1 cm) inside from the traced circle. This way your funnel will sit on the pie pan without falling through and will cover the gap so that steam won't escape.

2. If necessary, cut a place on the edge of the pie pan where the cooking pot handle will go, allowing the pie pan to sit level on top of the pot.



THE SCIENTIFIC METHOD FORM

Before testing your turbine model and steam device, complete Steps 1 through 3 that follow. Remember that each student should do his or her own write-up, though you are doing the experiment in a group.

1. You will be using the Scientific Method Form provided with this activity unless your teacher tells you to use a different experiment write-up form.

2. For the Research section, unless your teacher indicates otherwise, you may summarize what you have learned from reading and discussing Chapter 2 about power plant turbines. Be sure to credit this book as the source of information.

3. For the Hypothesis, you should address the following:

   a. Predict how well your turbine model will perform using the three "resources": water, "wind" (your breath), and steam. For example, will the shape of the blades and/or their angle in relationship to the force of the resource affect the turbine's performance? When using steam, will it matter how far you hold the turbine from the opening that releases the steam? Will there be an optimal amount of "wind" to get the best spin? Does it matter how far the water falls or at what angle you hold the turbine blades in the stream of water?

   b. Predict whether you think this particular turbine model would actually be able to produce a small amount of electricity if it were connected to a small generator.

4. As you work on constructing and testing your devices using the directions in "Testing the Turbine (see page 39)," fill out the Procedure and Data sections of the form.

   Since the directions are lengthy, be sure to summarize them for the Procedure.

   For the Data sections, draw pictures showing your turbine using the three different resources (wind, water, steam). Make notes about how the turbine performed using different variations, such as varying heights of water, varying "wind" speeds and distances from your mouth when blowing, different angles of holding the blades, and alterations to the shape of the blades.

   For the steam test, be sure to include the height at which your turbine spun the fastest.

5. For the Conclusion portion of the form:

   a. Compare the actual performance of the turbine to your predictions (hypothesis) regarding how the turbine worked with each resource. Make any other comments on what you learned while doing the tests, based on your notes from the Data section. Comment on why the authors have been referring to the turbine as a "model."

   b. Reassess your thinking in your original prediction as to whether the turbine could actually generate electricity.

TESTING THE TURBINE

1. Test your turbine by blowing on it, to simulate the energy of wind. Gently make adjustments to the turbine blades to get the most spin. Try varying the distance from your mouth or the force of your breath.

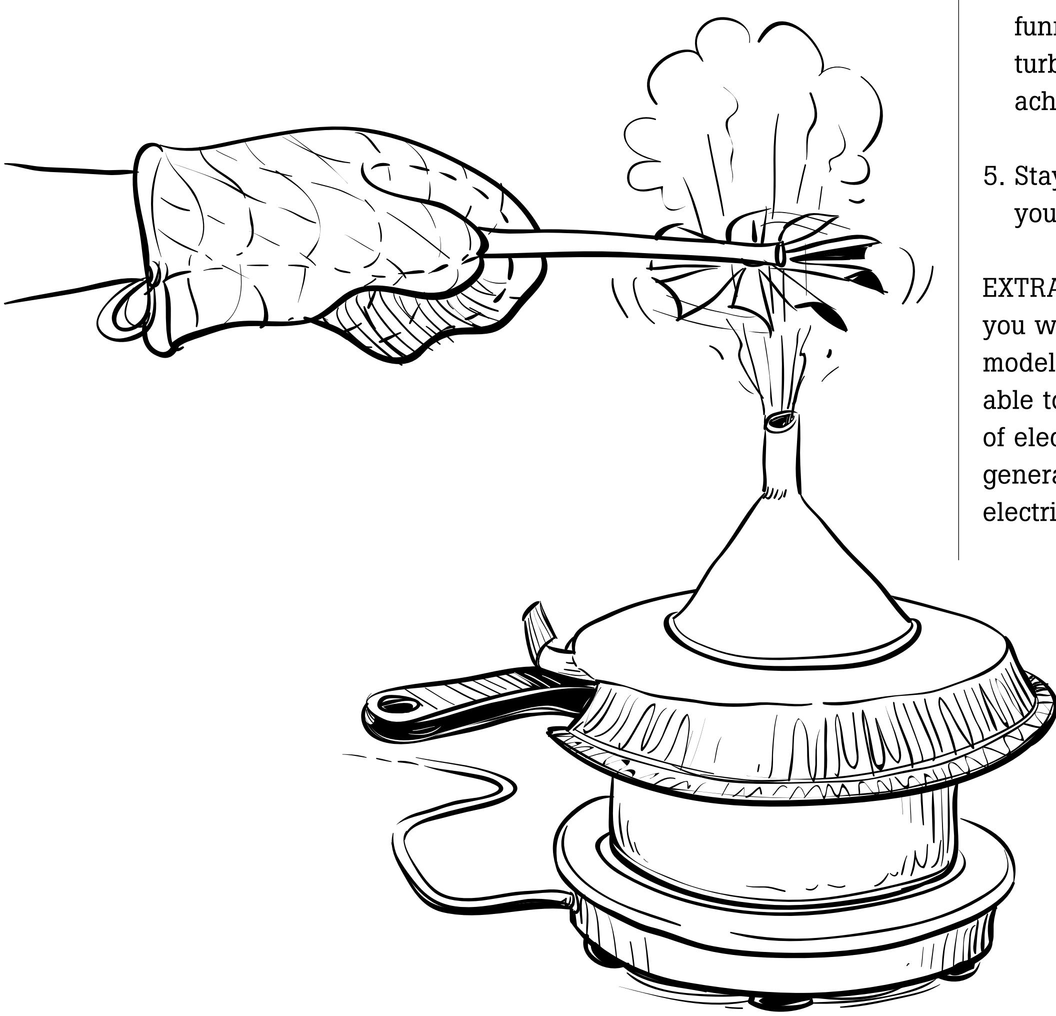
2. Test your turbine with a stream of falling water, making any needed adjustments for optimum spin. See how fast you can get the turbine to spin. Try varying amounts of falling water and varying heights from which the water falls before it hits the turbine.

3. Test your turbine using steam. Using the heat source, fill the cooking pot ¼ full of water and bring to a boil. Wearing oven mitts, place your steam device on top of the pan. Make sure that the funnel fully covers the opening in the middle of the pie plate. Steam should be issuing only from the funnel opening.

4. Wearing an oven mitt, hold your turbine "face" down over (but not directly on) the funnel opening. Remove the turbine and gently adjust its blades, if needed, to ensure optimum spin. Hold the turbine over the funnel opening again and raise and lower it slowly to see at which height it will spin fastest. Using the ruler, make an estimated measurement of the height from the funnel opening at which your turbine's top speed was achieved.

5. Stay in your groups to finish your experiment write-ups.

EXTRA CREDIT: Describe how you would design a turbine model that would actually be able to generate a small amount of electricity using a very small generator. If it worked, what electrical apparatus could it run?



FOR THE TEACHER

GETTING CURRENT: Generating Electricity Using a Magnet

PLANNING OVERVIEW

SUBJECT AREAS:
Physical Science, Math, Language Arts

TIMING:
Preparation: 30 minutes
Activity: 1-2 45-minute class periods

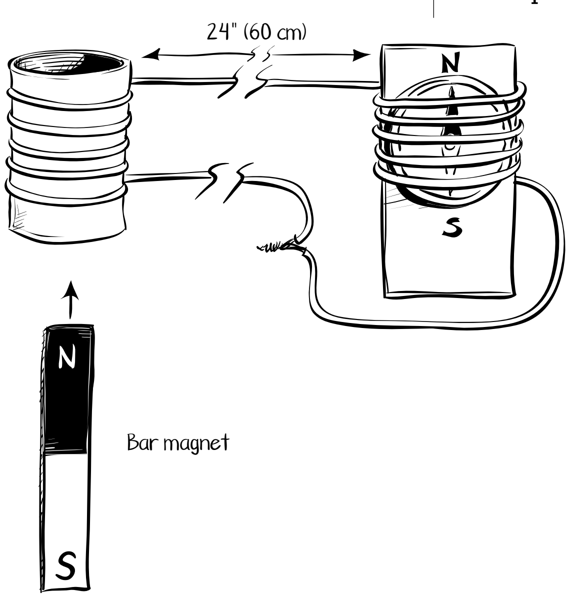
Summary

Students investigate how generators produce electricity by using electromagnetism.

Objectives

Students will:

- Hypothesize what will happen and why when a bar magnet is passed in various ways through coils of wire.
- Construct and use a model that demonstrates the actions of an electricity generator.
- Prepare a brief summary of the activity, including a description of the set-up and what occurred when it was tested.
- Draw a conclusion comparing their hypotheses to what was observed in the activity.
- Compare their models to an actual electricity generator.
- Propose explanations relating magnetism and electricity.
- Recognize that the main reason for making an electrical turbine spin is to turn a generator.
- Compare both models to an actual power plant turbine and generator (if "Going for a Spin" was also done).



Model generator

Materials for Warm-up

(Optional)

Iron filings

Stiff paper

Strong bar magnet

Materials for Student Activity

Per student group:

Student handout: "Getting Current"

Copy of Chapter 2 Discussion, Energy and Electricity

A directional compass

A strong bar magnet with north and south poles

13 feet (4 m) insulated copper wire

Cardboard toilet paper tube

Transparent tape (optional)

At least one for the entire class:

Wire stripper/cutter

Teaching Notes

Ensure that students understand that the activity setup is just a demonstration of the idea that moving a conductive wire in a magnetic field can create an electrical current. The setup in this activity does not look like a power plant generator, but both use coiled wire and strong magnets. The model works using the same principle.

Remind students to keep magnets away from computer disks, audio or video tapes, etc.

Since this activity is a simple demonstration, the full scientific method outline is not called for here. Rather, certain key elements of the method are used, including hypothesizing, describing the activity, gathering data, and drawing conclusions.

If students have trouble with their models, have them try making more coils. If this doesn't produce an electric current (move the compass dial), you may need stronger magnets.

Items in the materials list can be found at hardware, electronics, or school supply stores. You can also order them from a science supplier such as Sargent-Welch, Edmund Scientific, or Nasco Science. If you can't find iron filings, show the magnetic field illustration (also in the student handout) to your students. Discuss it using information in the Warm-up section, or have students view a video or CD-ROM that discusses magnetic fields.

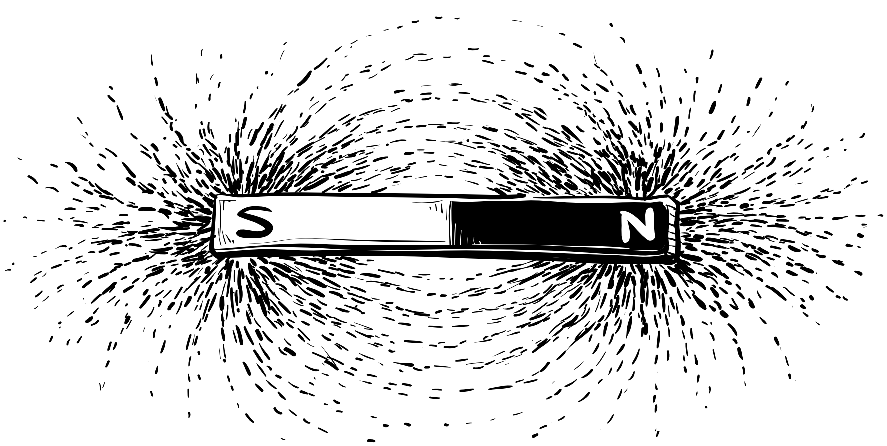
Warm-up (Optional)

If you were able to find some iron filings, try this with your students: Place a stiff piece of paper over a bar magnet that is resting on a flat surface. Sprinkle some iron filings on the piece of paper. Ask students to observe what happens. The interesting pattern that results is due to the magnetic field surrounding the magnet.

Explain that any magnetic field is actually invisible to us. The iron filings are lining up in reaction to the magnetic field, and show the lines of magnetic force — the "attraction" that occurs between the two opposite poles (north and south) of the magnet. The lines of force in a magnetic field travel from north to south — much the same way electric current flows from negative to positive (opposite charges attract).

In this activity, the magnetic field of the bar magnet interacts with electrons in a wire to create an electrical current.

Note: Students may ask what causes magnetism in the first place. Tell students that until recently, the cause of magnetism was not well understood. In fact, not long ago, the *Encyclopedia Britannica* stated: "Few subjects in science are more difficult to understand than magnetism." Recently scientists have begun to unlock magnetism's mysteries, but the answers are very complex, having to do with "spin" of electrons on their own axis as they buzz around the nucleus of an atom.

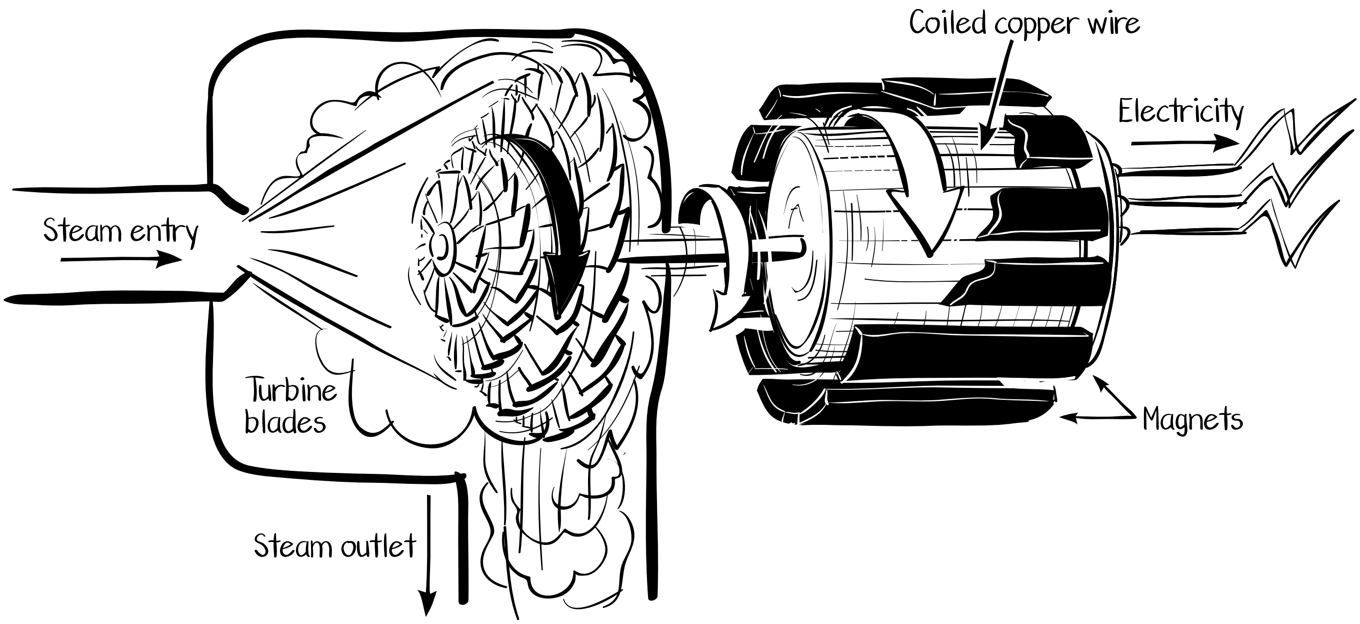


Iron filings showing magnetic fields

The Activity

1. Gather the necessary materials and set up your classroom to accommodate the activity. Refer to the Student Activity page for the specific procedure.

2. Use the Chapter 2 Discussion to talk about how a power plant generator works. Using the graphic of the typical steam-driven power plant on page 29, discuss how the power plant turbine provides the spinning force that turns the generator. While this diagram does not show the inner workings of the generator, it does illustrate the interconnection of the turbine and the generator.



Inside a turbine generator

3. Next direct the students' attention to illustration, "Inside a turbine generator" (also in the student handout). Explain that in generators the rapid spinning of wire coils between the two poles of strong magnets produces an electrical current.

4. Point out that in most power plant turbines the wire coils are moving and the magnets are stationary. However, it can work the other way around. We can move a magnet in and out of wire coils (as demonstrated in this activity) and still generate an electric current.

5. Review with the class the outline they must prepare to write-up the activity. The specific directions for doing so are found in the Student Handout for this activity. Tell students that they will be working in groups to do the activity, but each will do his or her own write-up.

6. Organize students into groups. Pass out materials and copies of the Student Activity pages.

7. Have students look over the activity directions, then reflect on what they've learned so far about generators and electromagnetism. Then ask them to fill in the Hypothesis portion of their outline (see page 45). Explain that they need to predict what they think will happen when they do the activity and why.

8. Have students create and test their own model generators. Allow time for them to also do their activity write-ups. Remind them that the background information they need to help explain how their experiment works was included in your discussion of this activity, and is also found both in the Chapter 2 Discussion, as well as in their student handout, "Getting Current."

9. Have the class get together after groups have tested their model generators and have done their write-ups. Ask students to use what they've learned from studying Chapter 2 and their experiences with both activities to write a brief narrative, on separate paper, comparing both the turbine model and the generator model to an actual power plant turbine and generator. If you did do "Going for a Spin," then have students explain how their generator model compares to an actual power plant generator.

Wrap-up

Call the class together to discuss their findings. Ask students to explain why they think generators work the way they do.

Ensure that students are able to make the connection between electricity and magnetism and have a general understanding of electromagnetism.

Next conduct a discussion connecting this activity (and that of "Going for a Spin" if you have done it as well) to an actual power plant that uses turbines and generators.

Referring back to the Warm-up, remind students that magnets create a magnetic field around them. This field causes electrons to move in the conductive wires that are spun inside the magnetic field. If these wires are connected in a complete pathway, or circuit, an electric current will then course through the wires.

Explain that the compass in their activity set-up serves as a "galvanometer," a device that indicates electric current. The very small current produced by the passing of the magnet through the coils of wire causes the compass needle (which is magnetized) to turn aside, or deflect. This is a property of electromagnetism.

Extension

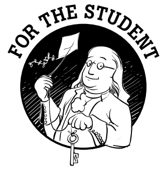
As a follow-up, students may also wish to look up power plant generators in reference books or on the Internet to learn more about how they work. Other interesting topics to pursue are the electromagnetic force and the history of the compass (this one may appeal to both history and science buffs alike).

Assessment

Students will have had the opportunity to:

- Create and test a model generator.
- Prepare a write-up of the activity, including using hypothesis, description, and conclusion.
- Develop an activity write-up that includes diagrams and labels and tells why the activity worked the way it did based on what they have learned about electricity and magnetism.
- Produce a brief narrative description comparing an actual power plant generator to their turbine models from the first activity and their generator models from the second activity.

Permission was granted by the Tennessee Valley Authority to adapt portions of their junior high curriculum unit, "The Energy Sourcebook" for use in this activity.



GETTING CURRENT: Generating Electricity Using a Magnet

Generators use magnets and wire coils to produce electricity. The electricity is produced by the rapid rotation of wire coils between the two poles of strong magnets (or the spinning of magnets surrounded by wire coils). Turbines — driven by a force such as pressurized steam, moving water, or forceful wind — provide the spinning power.

Magnets are surrounded by a magnetic field that can cause electrons to move in wires turning inside this field. If these wires are conductive (allowing electrons to flow easily), and if they are connected in a complete pathway (called a circuit), an electric current will then run through those wires.

While most generators operate by rapidly turning wire coils inside the two poles of a magnet, it also works the other way around — we can move a magnet in and out of wire coils to generate an electric current. In this activity, you will demonstrate this concept using a compass (which has a magnetized pointer that acts as a current detector) to show that electricity has been produced.

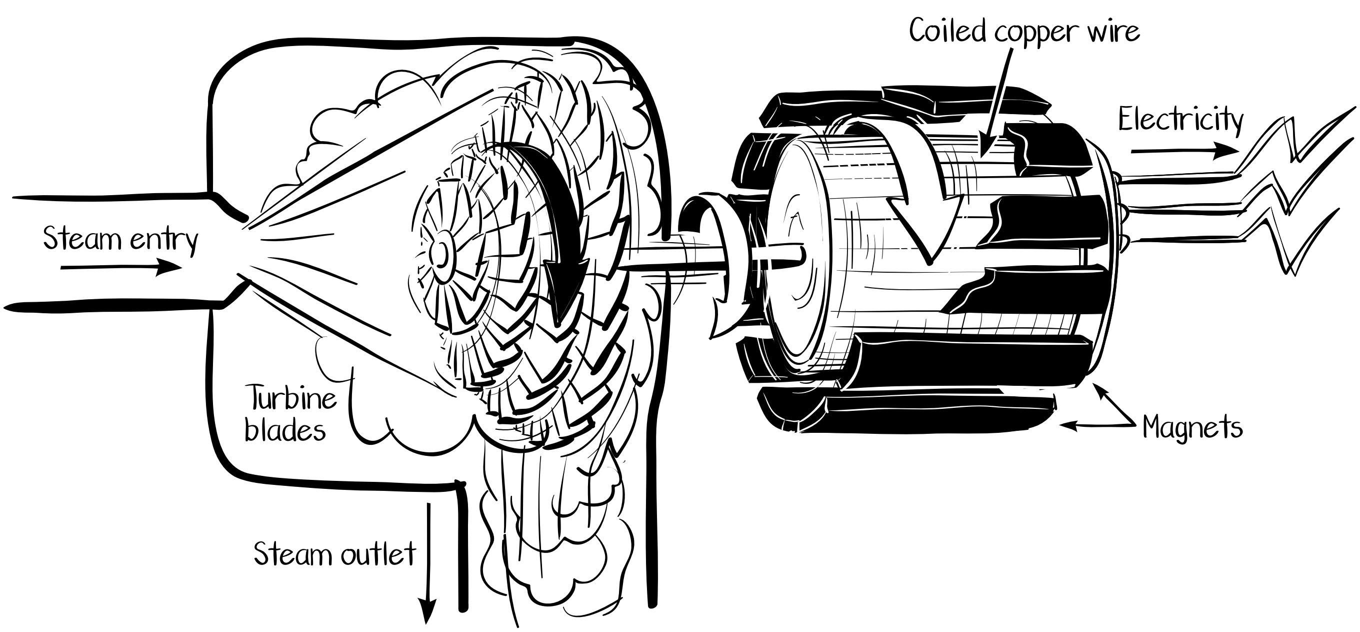
Materials

Per student group:

- A compass
- A strong bar magnet with north and south poles
- 13 feet (4 m) insulated copper wire
- Cardboard toilet paper tube
- Transparent tape (optional)

At least one for the entire class:

- Wire stripper/cutter



Inside a turbine generator

Prepare Write-up Outline

Make an outline, leaving room to write in each section, using the format below. Be sure to title your paper and include name, group name or number, and date.

1. Hypothesis. Predict what will happen.

2. Activity Description/Data. Describe the set-up and what happened when you tried all the variations suggested.

3. Conclusion. Revisit your hypothesis. Tell whether or not it was correct, and why.

Next, review what you have learned so far about generators and electromagnetism, and study the directions for the activity. Based on this information, pose a hypothesis predicting how you think the generator model will work and why.

When everyone in your group has completed his or her hypothesis, move on to the Procedure.

Procedure

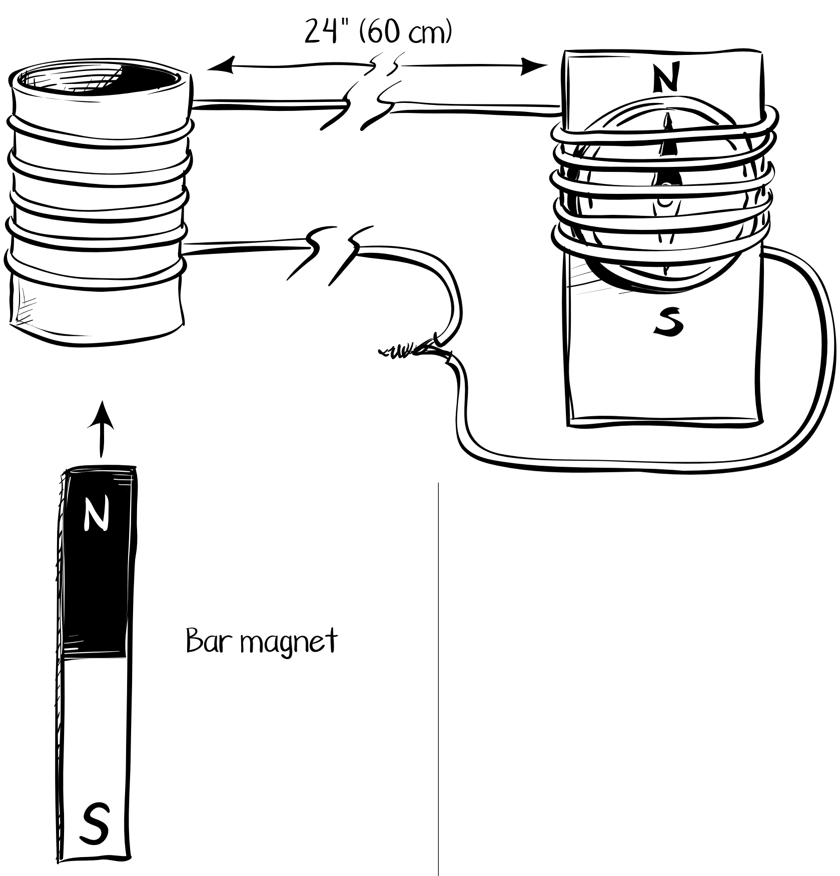
1. Remove about ¾ inch (2 cm) of insulation from each end of the wire.

2. Wrap one end of the wire around the compass five times as shown. Be sure to position the compass so that the needle is directly underneath the wire wrapped around it. CAUTION: Ends of wire are sharp.

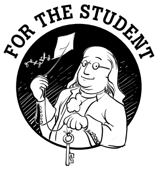
3. Extend the other end of the wire out about 24 inches (about 60 cm) from the compass and then wind the remaining length around the cardboard tube five times. The bar magnet will pass through these coils.

4. Run the remainder of the wire back to the compass. Twist the two exposed ends of the wire together. If desired, secure the wire to the compass with transparent tape.

5. Have one group member pass the magnet back and forth through the coils. If nothing happens disconnect one side of the wire and add more coils to the tube, then reconnect. Keep the compass at least 20 inches (50 cm) from the magnet so that the magnet itself does not cause the needle of the compass to be deflected.



Model generator



6. Other group members should watch the compass closely to observe and record what happens.

7. Change the direction of the magnet by inserting it from the opposite end of the tube. Observe and record what happens. Next turn the magnet around (inserting the other pole first). Observe and record what happens.

8. Stay in your groups to finish writing up your activity. Group members should share insights and give each other support, but each person should write his or her own.

   Include your three observations based on the three different ways you tested the model. Using the Chapter 2 Discussion, your classroom instruction, and the information on this worksheet, explain why the compass reacted the way it did in your conclusion.

9. Be prepared to discuss your findings with the class.

UNLOCKING SOME OF MAGNETISM'S MYSTERIES

Although we can't see magnetism, we've all seen its effects. We know that magnets have a force that can attract certain materials (or another magnet). The force of a magnet can also cause another magnet to move away. We use magnetic forces everyday, from refrigerator magnets holding up memos to magnetic poles in common devices such as motors and telephones.

Most of us are also familiar with the terms north pole and south pole. This is something you usually can find marked on a bar magnet. (The labels north and south pole are arbitrary names given by scientists who first studied magnetism.) All magnets have north and south poles — no matter what shape they are. Magnets have the most force at the poles. However, magnetic lines of force actually extend all around the magnet, creating a magnetic field.

Scientists are still exploring what causes these lines of magnetic force. They do know that most atoms actually act like microscopic magnets, each with its own tiny north and south pole. When atoms are all jumbled up — as they are in most materials — we don't notice the atoms' magnetic force. But, in certain materials (mostly some metals), the atoms all line up, creating a collective north pole at one end and a south pole at the other. This results in magnetism at each pole strong enough to attract a material such as iron.