ENERGY 1

A comprehensive course that teaches the fundamental principles in work, energy, and power. Students will build several different kinds of batteries, learn how solar, wind, and water can be used to generate electricity, construct simple machines, race bobsleds, zoom roller coasters, build hydraulic-pneumatic machines and so much more.

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This curriculum is aligned with the National State Standards and STEM for Science.

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Introduction

Greetings, and welcome to the study of Energy. This unit was created by a mechanical engineer, university instructor, airplane pilot, astronomer, robot-builder and real rocket scientist… me! I have the happy opportunity to teach you everything I know about energy over the next set of lessons. I promise to give you my best stuff so you can take it and run with it… or fly!

To get the most out of these labs, there are really only a couple of things to keep in mind. Since we are all here to have fun and learn something new, this shouldn't be too hard.

One of the best things you can do as the student is to cultivate their curiosity about things. *Why did that move? How did that spin? What's really going on here?*

This unit on Energy is chock full of demonstrations and experiments for two big reasons. First, they're fun. But more importantly, the reason we do experiments in science is to hone your observational skills. Science experiments really speak for themselves much better than I can ever put into words or show you on a video. And I'm going to hit you with a lot of these science demonstrations and experiments to help you develop your observing techniques.

Scientists not only learn to observe what's going on in the experiment, but they also learn how to observe what their experiment is telling them, which is found by looking at your data. It's not enough to invent some new kind of experiment if you don't know how it will perform when the conditions change a bit, like on Mars. We're going to learn how to predict what we think will happen, design experiments that will test this idea, and look over the results we got to figure out where to go from there. Science is a process, it's a way of thinking, and we're going to get plenty of practice at it.

Good luck with this Energy unit!

For the Parent/Teacher:
Educational Goals for Energy 1

Energy is the mover and shaker of the universe. Heat from the sun, sounds from your radio, riding a bike and watching a movie are all expressions of different forms of energy. As you sit there reading this, there is energy flowing all around you in the form of light waves, sound waves, radio waves, heat and more. You are constantly being bombarded by energy. Energy is everywhere, all the time.

We're going to focus on different forms of energy such as kinetic and potential energy, how simple machines (pulleys, levers, and pendulums) make energy into usable forms, and investigate several methods of finding, converting, storing and using alternative energy.

Here are the scientific concepts:

- Energy comes from the sun to the Earth in the form of light.
- Sources of stored energy take many forms, such as food, fuel, and batteries.
- Machines and living things convert stored energy to motion and heat.
- Energy can be carried from one place to another by waves, such as water waves and sound, by electric current, and by moving objects.

By the end of the labs in this unit, students will be able to:

- Design and build experiments that demonstrate that sources of stored energy take many forms, such as food, fuel, and batteries.
- Know how to demonstrate how solar energy reaches Earth through radiation, mostly in the form of visible light.
- Understand how to determine that energy can be carried from one place to another by waves, such as water waves and sound, by electric current, and by moving objects.
- Differentiate observation from inference (interpretation) and know scientists' explanations come partly from what they observe and partly from how they interpret their observations.
- Measure and estimate the weight, length and volume of objects.
- Formulate and justify predictions based on cause-and-effect relationships.
- Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
- Construct and interpret graphs from measurements.
- Follow a set of written instructions for a scientific investigation.

Master Materials List for All Labs

This is a brief list of the materials that you will need to do *all* of the activities, experiments and projects in this unit. The set of materials listed below is just for one lab group. If you have a class of 10 lab groups, you'll need to get 10 sets of the materials listed below. Most materials are reusable.

- AA-size battery
- alligator clip leads (RS#278-1156)
- aluminum foil
- aluminum soda can
- balloon
- black paint or spray paint (flat)
- bleach
- can with a lid
- digital multimeter
- earphones
- electrodes
- foam block (about 6" long)
- glass container
- graphite from inside a pencil (use a mechanical pencil refill)
- hot glue gun with glue sticks
- index cards
- long cardboard tube
- marbles
- masking tape
- milk jug lids or film can tops (4)
- nail (galvanized)
- newspaper
- paint brush
- paper
- paper clip
- pennies minted before 1982 (or a short section of copper pipe)
- pennies, quarters, or washers
- penny
- pipe foam insulation (3/4-inch)
- plastic cups (3)
- plate
- popsicle stick
- propeller
- pulley
- radio or music player
- razor or scissors
- real silverware (not stainless)
- rubber band
- salt
- set of magnets (at least 6)
- solar cell
- Solar Project Kit (Radio Shack #277-1201) or other solar cell with motor (usually sold in hobby stores)
- spoon
- stopwatch
- straws
- string
- string or yarn
- tape
- tea bags (2)
- thermometer
- tomato juice
- toy cars
- vinegar (distilled white)
- washer or a weight
- water or violin rosin
- wood screws (brass)
- wooden skewers

Lab Safety

Goggles: These should be worn when working with chemicals, heat, fire, or projectiles. These protect your eyes from chemical splatter, explosions, and tiny fast-moving objects aimed at the eyes. If you wear glasses, you can find goggles that fit over them. Don't substitute eyeglasses for goggles, because of the lack of side protection. Eyeglasses don't provide this important side eye protection.

Clean up Messes: Your lab area should be neat, organized, and spotless before you start, during your experiment, and when you leave. Scientists waste more time hunting for lost papers, pieces of an experiment, and trying to reposition sensitive equipment… all of which could have easily been avoided had they been taught organizational skills from the start.

Dispose of Poisons: If a poisonous substance was used, created, or produced during your experiment, you must follow the proper handling procedures for disposal. You'll find details for this in the experiments as needed.

Special Notes on Batteries: Do not use alkaline batteries with your experiments. Find the super-cheap kind of batteries (usually labeled "Heavy Duty" or "Super Heavy Duty") because these types of batteries have a carbon-zinc core, which does not contain the acid that alkaline batteries have. This means when you wire up circuits incorrectly (which you should expect to do because you are learning), the circuits will not overheat or leak. If you use alkaline batteries (like Energizer and Duracell) and your students short a circuit, their wires and components will get super-hot and leak acid, which is very dangerous.

No Eating or Drinking in the Lab: All foods and drinks are banned from your classroom during science experimentation. When you eat or drink, you run the very real risk of ingesting part of your experiment. For electricity and magnetism labs, always wash your hands after the lab is over to rinse off the lead from the electrical components.

No Horse Play: When you goof around, accidents happen, which means chemicals spill, circuits short, and all kinds of hazards can occur that you weren't expecting. Never throw anything to another person and be careful where you put your hands – it could be in the middle of a sensitive experiment, especially with magnetism and electricity. You don't want to run the risk of getting shocked or electrified when it's not part of your experiment.

Fire: If you think there's a fire in the room (even if you're not sure), let your teacher know right away. If they are not around (they always should be), smother the fire with a fire blanket or use a fire extinguisher and send someone to find an adult. Stop, drop, and roll!

Questions: If you're not sure about something stop and ask, no matter what it's about. If you don't know how to properly handle a chemical, do part of an experiment, ask! If you're not comfortable doing part of the experiment, then don't do it.

Lesson #1: Can a Battery be Used to Store Energy?

Overview: We start our unit on energy with some of the most common sources of energy in our lives: batteries! We'll learn the basics of what makes them special.

What to Learn: Ask yourself how the energy is moved in this battery. What causes the electricity to flow?

Materials

- Earphone or headset for a portable radio
- Small piece of aluminum foil
- Tomato juice
- New, shiny penny
- Two wires with alligator clips on each end of the wires
- Plate
- AA-size battery
- Spoon

Lab Time

1. Examine the metal shaft of the part of the earphone or headset that is inserted into a portable radio. You will notice that just below the tip of the shaft there is a plastic spacer. Clip on one of the wires below this spacer. Then clip on the other wire above this spacer.
2. To test that the wires are properly connected to the earphone or headset, take the unconnected ends of the two wires and touch them to an AA-size battery. One wire should touch the positive end of the battery, while the other is touching the negative end of the battery. Place the earphone or headset to your ear. If your connections are made correctly, you should hear a crackling sound in the earphone or headset. If you do not hear a crackling sound, check your connections carefully.
3. Place a small piece of aluminum foil, about five inches (13 centimeters) square, on a small plate. Using a spoon, make a puddle of tomato juice on the aluminum foil. The puddle of tomato juice should be slightly larger than a penny. Next, place a new, shiny penny face down in the puddle of tomato juice.
4. Using the alligator clip, attach one of the wires connected to the earphone to one of the edges of the aluminum foil. Take the end of the other wire and touch the alligator clip to the penny. Move the alligator clip over the penny.
5. Record your observations on the worksheet below.

Battery Observations

1. Do you hear a crackling sound when you touch the alligator clips to the penny in the puddle of tomato juice? What do you hear when you move the alligator clip over the penny?

2. What do you hear when you stop touching the penny with the alligator clip?

Reading

In this experiment you made a simple battery with a penny, aluminum foil, and tomato juice. You completed a circuit with your battery by touching one of the wires attached to the earphone or headset to the penny, while touching the other wire to the aluminum foil. When you completed the circuit, a flow of electrons was produced by your battery. The crackling sound you heard was caused by the earphone or headset converting electrical energy from your battery into sound energy.

In your battery, the aluminum in the aluminum foil loses electrons. The other part of the reaction is more complex. Either the acid in the tomato juice or copper ions (that form when the copper metal in the penny reacts with the acid in the tomato juice) gain the electrons lost by the aluminum.

The main types of batteries are known as primary and secondary batteries. Dry cell batteries, like the ones used in flashlights and portable radios, are primary batteries. Another important primary battery is the mercury battery. Mercury batteries are typically small and flat. They are used to power cameras, watches, hearing aids, and calculators.

An advantage of primary batteries is that they are generally inexpensive. One disadvantage is that they cannot be recharged. When the chemical substances in the primary batteries are used up, the battery is dead.

Lead storage batteries and nickel-cadmium (NiCad) batteries are examples of secondary batteries. Car batteries are lead storage batteries. Flashlight batteries that are rechargeable are NiCad batteries. Secondary batteries are more expensive than primary batteries. However, unlike primary batteries, lead storage batteries and NiCad batteries can be recharged repeatedly.

Exercises Answer the questions below:

1. Fill in the blank: A battery produces __________________ energy from _______________________ energy.
2. Another name for a battery is:
    a. Solar array
    b. Voltaic cell
    c. Nuclear reactor
    d. Fusion cell
3. As one chemical loses electrons, what happens to the other chemical?
    a. It loses electrons
    b. It gains electrons
    c. Nothing
    d. It decomposes
4. When will a battery run out?
    a. When its batteries run out
    b. When its chemicals are used up
    c. When all the electrons are gone
    d. When the bunny stops drumming

Lesson #2: Salty Battery

Overview: Did you know that you can make electricity using a few common materials and even sea salt? We'll find out how, and why chemicals have so much to teach us when it comes to energy.

What to Learn: How is the electricity being generated? Where does this current come from?

Materials

- water
- salt
- vinegar (distilled white)
- bleach IMPORTANT: WEAR GOGGLES!
- glass container (like a cleaned out jam jar)
- electrodes
- real silverware (not stainless)
- shiny nail (galvanized)
- large paper clip
- dull nail (iron)
- wood screws (brass)
- copper pennies minted before 1982 (or a short section of copper pipe)
- graphite from inside a pencil (use a mechanical pencil refill)
- 2 alligator wires
- digital multimeter

Lab Time

1. Make sure to use safety goggles for this experiment. Do not handle any harmful chemicals without adult supervision.
2. Fill a cup with water, adding a teaspoon of salt, a teaspoon of distilled white vinegar, and a few drops of bleach. **NOTE: BE very careful with bleach! Cap it and store as soon as you've added it to the cup.**
3. Find two of the following materials: copper*, aluminum*, brass, iron, silver, zinc, graphite (* indicates the ones that are easiest to start with – use a copper penny and a piece of aluminum foil). Attach an alligator clip lead to each one and dunk into your cup. Make sure these two metals DO NOT TOUCH in the solution.
4. You've just made a battery! Test it with your digital volt meter and make a note of the voltage reading. Connect the multimeter in series to read the current (remove a clip from the metal and clip it to one test probe, and attach the other test probe to the metal. Make sure you're reading AMPS, not VOLTS when you note the reading for current. Current is measured in amps).
5. Test out different combinations of materials and note which gives the highest voltage reading for you. Is it enough to light an LED? Buzzer? Motor? What if you made two of these and connected them in series? Three? Four?

Salt Battery Data Table

Material	Voltage Reading

Reading

Electrochemistry studies chemical reactions that generate a voltage and vice versa (when a voltage drives a chemical reaction) are called "oxidation and reduction reactions," or redox for short. When electrons are transferred between molecules, it's a redox process.

Fruit batteries use electrolytes (solution containing free ions, like salt water or lemon juice) to generate a voltage. Think of electrolytes as a material that dissolves in water to make a solution that conducts electricity. Fruit batteries also need electrodes made of conductive material, like metal. Metals are conductors not because electricity passes through them, but because they contain electrons that can move. Think of the metal wire like a hose full of water. The water can move through the hose. An insulator would be like a hose full of cement – no charge can move through it.

You need two different metals in this experiment that are close, but not touching inside the solution. If the two metals are the same, the chemical reaction doesn't start and no ions flow and no voltage is generated – nothing happens.

We can learn a lot about energy from chemistry and the ways that they interact with each other. A basic way that batteries operate can be explained by electrochemistry: the study of these electrical properties of chemical elements and compounds.

The basic idea of electrochemistry is that charged atoms (ions) can be electrically directed from one place to the other. If we have a glass of water and dump in a handful of salt, the NaCl (salt) molecule dissociates into the ions Na+ and Cl-.

When we plunk in one positive electrode and one negative electrode and crank up the power, we find that opposites attract: Na+ zooms over to the negative electrode and Cl- zips over to the positive. The ions are attracted (directed) to the opposite electrode and there is current in the solution.

Exercises Answer the questions below:

1. Which measurement refers to the flow of electrical current?
   a. Volts
   b. Ions
   c. Amps
   d. Watts
2. What is another name for a battery?
   a. Chemitrode
   b. Voltaic cell
   c. Nuclear reactor
   d. Fusion cell
3. Which direction are ions going to flow if a current becomes available?
   a. Towards the same-charged electrode
   b. Towards the opposite-charged electrode
   c. Towards no electrode, they float out into space

Lesson #3: Do Plants Store Energy?

Overview: Put your safety goggles on for today's lab, because we're working with fire! You'll be measuring how much energy a peanut holds by setting it aflame.

What to Learn: All our energy needs on earth come from somewhere. We cannot make our own food, but plants can. We are all connected to the plants and soils that they grow in because they provide our very basic needs, as well as some of our more modern needs.

Materials

- Goggles
- 2 shelled peanuts
- Small pair of pliers
- Match or lighter
- Sink
- Timer

Lab Time

1. Today we're working with fire, so follow all special instructions about working with flames today.
2. Close the drain with a sink stopper, and fill the sink with around an inch of water.
3. Put on safety goggles. Using a small pair of pliers, hold the peanut over the sink and ask your adult helper to light the peanut with the lighter until it catches fire. Have your data recorder ready with the timer.
4. Upon ignition (when the peanut is burning by itself and doesn't need the lighter), start the timer and run it until the peanut stops burning. Record the time on the worksheet. The adult remains present for the entire duration that the peanut is one fire.
5. Drop the peanut into the sink once finished to ensure all flames are out. Allow it to cool as you record additional observations in the worksheet and complete the exercises.

Do Plants Store Energy? Data and Observations

Peanut	Time burned (write in seconds):
1 2	

Observations:

Does the peanut burn with a clean flame or a sooty flame?

What color is the flame? What color does the peanut turn when it burns?

Did the size of the peanut change after it had burned for several minutes?

Reading

A peanut is not a nut, but actually a seed. In addition to containing protein, a peanut is rich in fats and carbohydrates. Fats and carbohydrates are the major sources of energy for plants and animals.

The energy contained in the peanut actually came from the sun. Green plants absorb solar energy and use it in photosynthesis. During photosynthesis, carbon dioxide and water are combined to make glucose. Glucose is a simple sugar that is a type of carbohydrate. Oxygen gas is also made during photosynthesis.

The glucose made during photosynthesis is used by plants to make other important chemical substances needed for living and growing. Some of the chemical substances made from glucose include fats, carbohydrates (such as various sugars, starch, and cellulose), and proteins.

Photosynthesis is the way in which green plants make their food, and ultimately all the food available on earth. All animals and non-green plants (such as fungi and bacteria) depend on the stored energy of green plants to live. Photosynthesis is the most important way animals obtain energy from the sun.

Oil squeezed from nuts and seeds is a potential source of fuel. In some parts of the world, oil squeezed from seeds--particularly sunflower seeds--is burned as a motor fuel in some farm equipment. In the United States and elsewhere, some people have modified diesel cars and trucks to run on vegetable oils.

Fuels from vegetable oils are particularly attractive because, unlike fossil fuels, these fuels are renewable. They come from plants that can be grown in a reasonable amount of time. Fossil fuels are nonrenewable fuels because they are formed over a long period of time.

Exercises Answer the questions below:

1. What is the process called where plants get food from the sun?
    a. Osteoporosis
    b. Photosynthesis
    c. Chlorophyll
    d. Metamorphosis
2. Where does all life on the planet get its food?

3. List two ways that we could use the energy in a peanut:
    a.

    b.

Lesson #4: Can Electricity be Made from Sunlight?

Overview: We'll get some hands-on experience with a real solar cell to answer the question of today's lab.

What to Learn: This lab will help you learn how and where most of our energy comes from - the sun!

Materials

- Silicon solar cell
- Two wires with alligator clips on each end of the wires
- Earphone or headset for a portable radio
- AA-size battery

Lab Time

1. Examine the metal shaft on the part of the earphone or headset that is inserted into a portable radio. You will notice that just above the tip of the shaft there is a plastic spacer. Clip on one of the wires below this spacer. Then clip on the other wire above this spacer.
2. To test that the wires are properly connected to the earphone or headset, take the unconnected ends of the two wires and touch them to an AA-size battery. One wire should touch the positive end of the battery, while the other should touch the negative end of the battery. Place the earphone or headset to your ear. If your connections are made correctly, you should hear a crackling sound in the earphone or headset. If you do not hear a crackling sound, check your connections carefully.
3. Take the earphone or headset, with wires attached, and the solar cell outside into the sunshine. Ask a friend to join you. Your friend can help you hold the solar cell.
4. Place the earphone or headset to your ear. Ask your friend to hold one of the flat sides of the solar cell facing the sun. The two flat sides of the solar cell are different. In this experiment, you will determine which flat side must face the sun for the cell to generate electricity.
5. While your friend holds one of the flat sides of the solar cell facing· the sun, you hold one of the alligator clips on the side of the cell facing the sun. At the same time, touch the other alligator clip to the opposite side of the cell. As you hold the alligator clips to the cell, avoid blocking the sunlight striking the solar cell.
6. Ask your friend to turn the solar cell over so that the side that was not facing the sun before now does. Touch a clip to the two sides of the solar cell.
7. After determining which side of the solar cell needs to face the sun to make a crackling sound in your earphone or headset, ask your friend to hold that side toward the sun. Touch the two alligator clips to each side of the solar cell. Move the alligator clip touching the bottom of the solar cell around the bottom side to keep making the crackling sound in your earphone or headset. Next, block the sunlight striking the solar cell.
8. Record your observations on the worksheet below.

Sun Energy Observations

1. Describe the difference between the two sides of the solar cell. Which side must be facing the sun to cause crackling in the earphone or headset when you touch the clips to the solar cell? What happens to the crackling sound when you block the sunlight from striking the solar cell?

2. When you examine your silicon solar cell, you will notice that the two flat sides of the cell are different. One side should have a silvery color, while the other side should appear dark. You should determine in this experiment that one side of the solar cell needs to face the sun for you to hear a strong crackling sound in the earphone or headset. The crackling sound is electricity, generated by the solar cell, passing through the earphone or headset. Can you hear it?

Reading

The solar cell you are using for this experiment is made from the element silicon. Silicon solar cells consist of two thin wafers of treated silicon that are sandwiched together. The treated silicon is made by first melting extremely pure silicon in a special furnace. Tiny amounts of other elements are added which produce either a small positive or negative electrical charge.

Usually, boron is added to produce a positive charge and phosphorus is added to produce a negative charge. The addition of these other elements to pure silicon to produce an electrical charge is called doping.

After being doped, the molten silicon is allowed to cool. As it cools, the doped silicon grows into a large crystal from which very thin wafers are cut. A wafer cut from a large crystal of silicon doped with boron is called the positive or P-layer because it has a positive charge. A wafer cut from a large crystal of silicon doped with phosphorous is called the negative or N-layer.

To make a solar cell, a positive wafer (called the P-layer) and a negative wafer (called the N-layer) are sandwiched together. This causes the P-layer to develop a slight positive charge, and the N-layer to develop a slight negative charge. The solar cell is connected to a circuit by wires leading from the P-layer and the N-layer. When light falls on the surface of the cell, electrons are made to move from one layer to the other. Thus, a current of electricity flows through the circuit.

The first solar cells provided electrical power for space satellites and vehicles. Satellites and space vehicles are still big users of solar cells. Solar cells are now being used to provide electrical power for calculators and similar devices, weather stations in remote areas, oil-drilling platforms, and remote communication relay stations.

The best silicon cells convert only a small portion of the sunlight striking the cells into electricity. The efficiency of solar cells is about 15 percent. This means that 15 percent of the sunlight that strikes the cell is converted into electrical energy. The sunlight that is not converted into electricity either reflects off the surface of the cell or is converted into heat energy.

Exercises Answer the questions below:

1. If two electrodes become activated by a current, which way will the ions flow?
    a. To the electrode of the same charge
    b. To the electrode of the opposite charge
    c. None of the above
2. What type of energy source is the solar panel most closely related to?
    a. Biofuel
    b. Chemical battery
    c. Nuclear reactor
    d. Plant energy
3. The solar cell's efficiency is not very good. How much of its energy is converted into electricity?
    a. 50 %
    b. 80%
    c. 30%
    d. Less than all of these
4. Name one common use for solar cells:

Lesson #5: Solar Boat

Overview: Does it matter at what angle a solar panel receives incoming sunlight? If so, does it matter enough to make a difference? We'll find out today in this clever experiment.

What to Learn: Sunlight is very important for all life on earth. Without it, we would not be able to survive. Thankfully we can use its energy in all kinds of ways, like we will today!

Materials

- Solar Project Kit (Radio Shack #277-1201) or other solar cell with motor (usually sold in hobby stores)
- Foam block (about 6" long)
- Alligator clip leads (RS#278-1156)
- Propeller (if your kit doesn't come with one) – you can rip one off an old small personal fan or old toy

Lab Time

1. Attach the wires of the solar cell to the motor (one to each motor terminal).
2. Attach the propeller to your motor. If the shaft won't fit, drill out the center hole. If the hole is too large, use a tiny dab of hot glue on the shaft tip to secure the propeller into place.
3. Stand out in the sun. How do you need to hold your solar cell to make the propeller spin the fastest?
4. Position the motor on a block of foam so that the propeller hangs off the edge and is free to rotate. Hot glue the motor into place, being careful not to get any hot glue near any vents in your motor.
5. Hot glue your solar cell to the foam block. You might want to check the final position in sunlight before attaching it.

Solar Boat Observation

Draw a picture of the angle at which your solar boat performs the best. Why do you think this is?

Reading

Does it really matter what angle the solar cell makes with the incoming sunlight? If so, does it matter much? When the sun moves across the sky, solar cells on a house receive different amounts of sunlight. You're going to find out exactly how much this varies by building your own solar boat.

Many solar companies advise people on how to position their solar panels depending on where in the world they live. Of course you would want to think about this if you live in a place where the sun is blocked for part of the year. Surprisingly, some of the world's fastest growing solar power markets are in cold, northern climates like Canada and Russia!

Exercises Answer the questions below:

1. What kind of electricity comes from a battery and photovoltaic cell?
    a. Nuclear
    b. Voltaic
    c. Electrochemical
    d. Ionized
2. Electricity is another name for the free flow of:
    a. Protons
    b. Quarks
    c. Electrodes
    d. Electrons
3. True or false: Ions are attracted to the same charge.
    a. True
    b. False
4. Do solar panels work in cloudy climates?
    a. Yes
    b. No

Lesson #6: Solar Car

Overview: We're making our very own solar-powered cars as you discover important concepts about the sun's energy and how to capture it.

What to Learn This lesson reinforces the ideas from previous experiments: how sunlight provides energy for our use in a variety of ways.

Materials

- Solar Project Kit (Radio Shack #277-1201) or other solar cell with motor (usually sold in hobby stores)
- Foam block (about 6" long)
- Alligator clip leads (RS#278-1156)
- 2 straws (optional)
- 2 wooden skewers (optional)
- 4 milk jug lids or film can tops
- Set of gears, one of which fits onto your motor shaft (most solar motor kits come with a set), or rip a set out of an old toy
- Razor or scissors
- Stopwatch

Lab Time

1. Measure four inches from the end of your piece of balsa wood and cut in a straight line with the scissors or razor. Take the remaining piece and measure it so that you divide it in half lengthwise. Cut it with the razor. *Note: Adult supervision is needed for this step!*
2. Use the hot glue gun to join the two pieces, one on top of another.
3. Next, cut the straw into three pieces, each measuring as follows: 1 x 1 and 5/8", 1 x 1 and 7/8", and one extra leftover piece.
4. Now to attach the wheels to the body of the car. Take the second largest gear (it should be about the same size as the wheel), setting aside the other gears. Press the metal rod axle into the wheel, then thread the small washer in the car kit into the axle. Place the straw over the axle, and then attach the washer and wheel to the other side to complete the wheel and axle assembly. Check to make sure the axle spins freely by holding onto the straw. Attach the wheel to the base of the balsa wood with hot glue.
5. Start assembling the remaining wheels in the same manner, but after you add the shorter of the straws and washer, add the gear before closing the axle with the final wheel. Check to make sure that both the wheel and the gear spin freely when you hold the straw. Attach this axle to the body of the car with hot glue.
6. Attach the smallest of the gears to the shaft of the motor, and then align the motor so that the small gear meshes with the gear on the wheel and axle. Hot glue the motor in place when you've found the sweet spot.
7. Attach the solar cell to the body of the car with a small dab of hot glue. Take care to make sure the wires are facing away from the gears so that we don't have the wires flying all over the place.
8. Attach the wires by twisting them together according to their color.
9. Go outside on a nice sunny day and mark out a set distance for your cars to travel. Use a stopwatch to record how quickly they travel the distance. Compare these results to different weather patterns. Do you notice anything? Record all your data on the worksheet.

Solar Car Data Table

Date	Weather	Time

Total distance traveled:

Reading

Electrons orbit the nucleus of an atom in specific layers called shells, and which shell they are in depends on the amount of energy they have. When sunlight hits a solar cell, it knocks an electron free of its shell. Once an electron is knocked out of its shell, it's called a *free electron.* The free electrons start flowing through the silicon to create electricity. The solar cells are structured is such a way as to keep the electricity flowing only in one direction. The electron flow created is DC (direct current).

The solar cells you can buy from stores require huge amounts of energy in creating the solar cell, which is the primary downside. You need high temperatures, big vacuum pumps, and lots of people to make a set of solar cells. However, if we focus just on the physics of the solar cell, then we can easily create our own solar battery and other solar cell projects using household items. While these cells won't look as spiffy as the ones from the store, they still produce electricity from sunlight.

Solar energy (power) refers to collecting this energy and storing it for another use, like driving a car. The sun blasts 174 x 1015 watts (which is 174,000,000,000,000,000 watts) of energy through radiation to the earth, but only 70% of that amount actually makes it to the surface. And since the surface of the earth is mostly water, both in ocean and cloud form, only a small fraction of the total amount makes it to land.

A solar cell converts sunlight straight into electricity. Most satellites are powered by large solar panel arrays in space, as sunlight is cheap and readily available out there. While solar cells seem "new" and modern today, the first ones were created in the 1880s, but were a mere 1% efficient. (Today, they get as high as 35%.) A solar cell's efficiency is a measure of how much sunlight the cell converts into electrical energy.

Solar cells are usually made of silicon. Sunlight is made of packets of energy called photons. When photons hit the silicon, one of three things can happen: the photons can pass straight through the silicon if they have a low enough energy; they can get reflected off the surface; or (and this is the fun part) they get absorbed and the electrons in the silicon get knocked out of their shell. Once they get knocked out, they start flowing. Once this happens, voila! We have electricity!

Exercises Answer the questions below:

1. Most solar cells are made of what material?
    a. Hydrogen
    b. Aluminum
    c. Silicon
    d. Titanium
2. Name one benefit of solar cells and one drawback of using them for electricity.
    a. Benefit:
    b. Drawback:
3. Electrical current begins flowing when:
    a. Sunlight hits an atom
    b. Electrons are knocked out of orbiting atoms
    c. Protons get charged
    d. An atom's nucleus splits

Lesson #7: Can the Sun be used to heat water?

Overview: Although you won't need any lab coats, we are getting serious with our scientific skills here. We're going to explore the sun's energy potential in our experiment today.

What to Learn: You'll explore how the sun affects what we see as energy every day.

Materials

- Paint brush
- Thermometer (outdoor type)
- Newspaper
- Aluminum foil
- Water
- Large plastic glass
- Empty aluminum 12-ounce (355 milliliter) soft drink can
- Black paint or spray paint (flat, not shiny)

Lab Time

1. Go outside and spread a sheet of newspaper on the ground. Place an empty aluminum soft drink can on the newspaper. Have an adult help you paint the outside of the aluminum can. You can use a brush and can of paint or spray paint. Be sure to use paint that is suitable for a metal surface. The paint should give you a flat (not shiny) surface. Be sure not to get the paint on anything but the can and newspaper. After painting, set the can where the paint can dry overnight.
2. You will need to do the rest of this experiment on a warm, sunny day. Partially fill a large plastic glass with cool tap water. Check the temperature of the water with a thermometer. Pour the water from the plastic glass into the painted black can, completely filling the can. Pour out any extra water remaining in the plastic glass. Cover the can's opening with a small piece of aluminum foil about the size of a quarter.
3. Set the black can outside in a sunny spot. Pick a place where the sun will shine on the can all day. (You do not want the can to be in the shade.)
4. After the can of water has been in the sunshine for about four hours, pour the water into the large, plastic glass. Check the temperature of the water with the thermometer. Feel the outside of the can.
5. Record your observations on the worksheet below, and continue to discuss what's going on in this experiment.

Heating Water Data Table

Time	Temperature
Beginning of experiment	
After 2 hours	
After 4 hours	

Total difference in temperature: (+/-)

Reading

When the sun is overhead, about 1,000 watts of solar power strike 1 square meter (10.8 square feet) of the earth's surface. Using solar cells, this solar energy can be converted to electricity. However, because sunlight cannot be converted completely to electricity, it takes at least a square meter of area to gather enough sunlight to run a 100-watt light bulb.

Solar energy is still more expensive than other methods of generating electricity. However, the cost of solar electricity has greatly decreased since the first solar cells were developed in 1954.

It has been proposed that panels of solar cells on satellites in orbit above the earth could convert solar energy to electricity twenty-four hours a day. These huge solar power satellites could convert electrical energy to microwaves and then beam these microwaves to Earth. At the earth's surface, tremendous fields covered with antennas could convert the microwave energy back to electricity.

It would take thousands of astronauts many years to build such a complicated system. However, there are many practical uses of solar energy in use today. These uses include heating water, heating and cooling buildings, producing electricity from solar cells, and using rain and snow from the water cycle to power electrical generators at dams.

In this experiment, you should find a significant increase in the temperature of the water that was left in the black can during the day. The tap water initially may be about 21°C (70°F), but after the water has been heated inside the can, the temperature should rise to more than 38°C (100°F). The exact temperature you achieve in your miniature, solar water heater (black can) will depend on your location and the time of year. However, you should find that the water temperature will go much higher than the temperature of the outside air.

The energy of sunlight powers our biosphere (air, water, land, and life on the earth's surface). About 50 percent of the solar energy striking the earth is converted to heat that warms our planet and drives the winds. About 30 percent of the solar energy is reflected directly back into space. The water cycle (evaporation of water followed by rain or snow) is powered by about 20 percent of the solar energy.

Some of the sunlight that reaches the earth is used by plants in photosynthesis. Plants containing chlorophyll use photosynthesis to change sunlight to energy. Since these green plants form the base of the food chain, all plants and animals depend on solar energy for their survival.

The electromagnetic radiation from the sun includes ultraviolet, visible, and infrared radiation. Ultraviolet radiation is the type of sunlight that causes tanning of skin. Visible radiation is the type of sunlight we see with our eyes. Infrared radiation is the type of sunlight that we feel as heat when the sun is shining on our skin. All these forms of solar radiation have energy associated with them.

When solar energy from the sun's electromagnetic radiation strikes a black surface, solar energy is converted to heat energy and the surface is warmed. Other colors will absorb solar energy, but lightly colored surfaces tend to reflect the light, while darker colors absorb the solar energy. You may have noticed this difference if you ever walked barefoot on a dark road on a hot summer day.

Direct solar energy is not hot enough for cooking. The higher temperatures required for cooking or for changing water to steam require concentrating the energy of sunlight with mirrors or lenses. However, directly absorbed solar energy is hot enough for heating homes and producing hot water with little or no energy costs.

When we turn on a hot water faucet at a sink, water is taken from a hot water tank. In industrialized countries, we usually heat water using electricity or natural gas and store the hot water in this insulated tank. However, around the world, there are millions of solar heaters used for heating water.

Solar water heaters use a black metal plate covered with insulated glass. These solar heaters are usually placed on rooftops to receive the maximum amount of sunlight. Water flows through tubes beneath the black metal plates. Solar energy heats the black metal plates and the water passing in tubes underneath the plates. The heated water is piped to a storage tank, where it is kept until needed. If the location of the solar heater is not consistently sunny, then an auxiliary heater--using electricity or natural gas--is sometimes used to heat the water.

Exercises Answer the questions below:

1. The solar energy that hits the earth is responsible for what proportion of the energy on our planet?
    a. Nearly all of it
    b. About 50%
    c. 25%
    d. None of these
2. Name one way that the physical earth uses the earth's energy:

3. True or false: Solar power is generally less expensive than other forms of power.
    a. True
    b. False

Lesson #8: Marshmallow roaster

Overview: Do you like marshmallows cooked over a campfire? I sure do. What if you don't have a campfire? We'll solve that problem by building our own food roaster that you can use to roast hot dogs, marshmallows, or anything you want. And it's battery-free since this device is powered by the sun.

What to Learn: Again, you'll see how the sun can directly meet our energy needs!

Materials

- 7×10" page magnifier (Fresnel lens)
- Cardboard box, about a 10" cube
- Aluminum foil
- Hot glue, razor, scissors, tape
- Wooden skewers (BBQ-style)
- Chocolate, marshmallows, & graham cracker
- Thermometer

Lab Time

1. Take a razor and cut out a hole from the cardboard box slightly smaller than the Fresnel lens. Make sure the lens will fit.
2. Find the side of the lens that has grooves and place that side facing outwards. Secure the lens with hot glue. Use adult help if needed.
3. Cover each side of the inside of the box with aluminum foil. The lens will collect incoming light, but we don't want the box itself to catch on fire! This is what the foil is for. Don't worry about making the foil perfectly arranged. It just needs to cover every exposed part of the box.
4. Close the flaps of your box and seal it shut.
5. Cut a small window (maybe twice the size of the marshmallow) in the side of the box. Use your skewer to poke a hole through one door and out of the other. This is where the marshmallow goes.
6. Put a marshmallow in place on the skewer, and place your oven in the sun to get cooking! Record your observations and data on the worksheet. Use a thermometer to get your temperature readings in degrees Celsius.

Marshmallow Roaster Data Table

Time	Is it cooked?	Temperature (C)
2 hours		
3 hours		
3.5 hours		
4 hours		
4.5 hours		
5 hours		
5.5 hours		
6 hours		

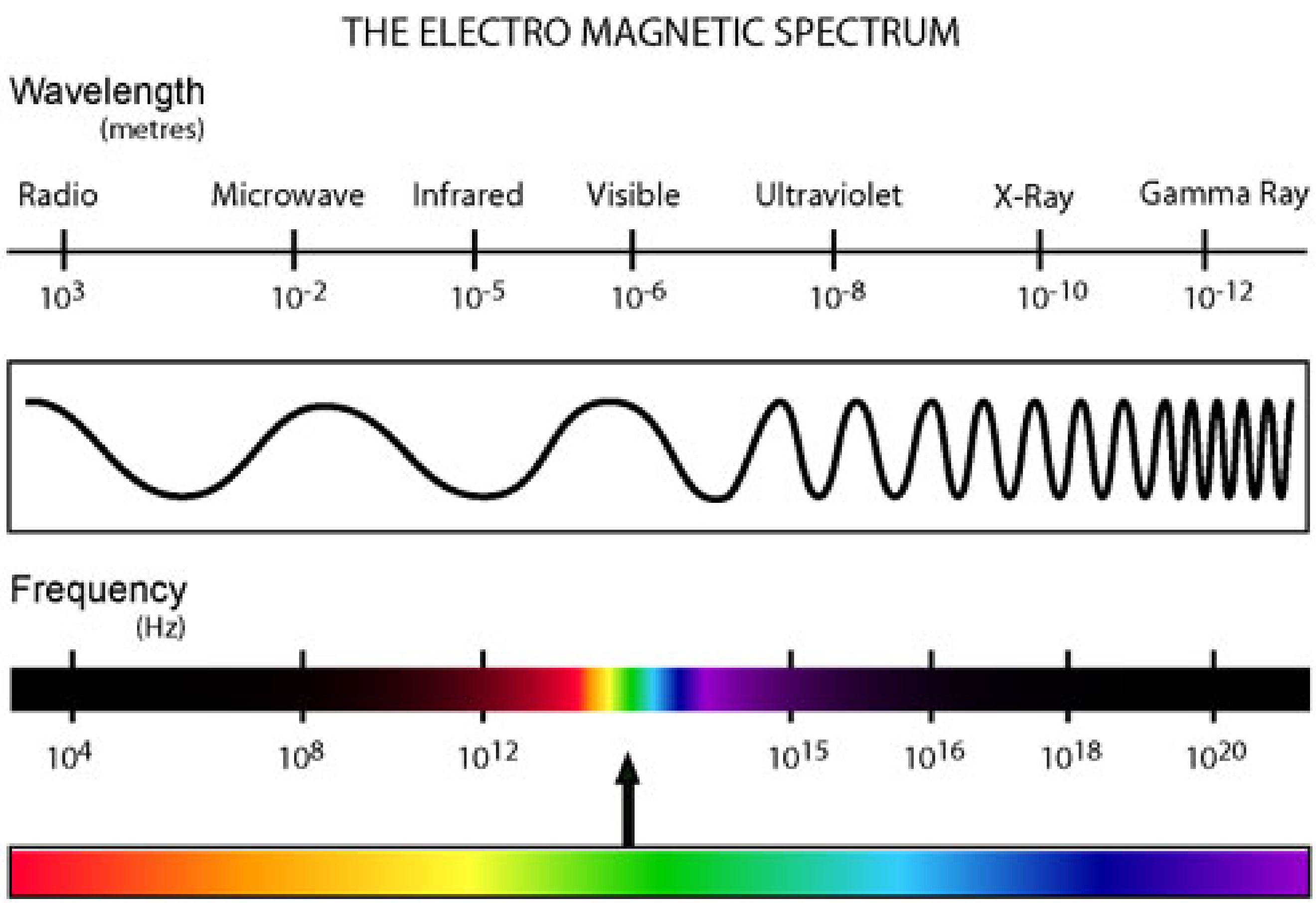
Reading

The Fresnel lens is a lot like a magnifying glass. A Fresnel lens (first used in the 1800s to focus the beam in a lighthouse) has lots of ridges you can feel with your fingers. It's basically a series of magnifying lenses stacked together in rings (like in a tree trunk) to magnify an image.

The best thing about Fresnel lenses is that they are lightweight, so they can be very large, which is why you'll find them in lighthouses. Fresnel lenses curve to keep the focus at the same point, no matter close your light source is.

The Fresnel lens in this project is focusing the incoming sunlight much more powerfully than a regular handheld magnifier. But focusing the light is only part of the story with your roaster. The other part is how your food cooks as the light hits it. If your food is light-colored, it's going to cook slower than darker (or charred) food. Notice how the burnt spots on your food heat up more quickly!

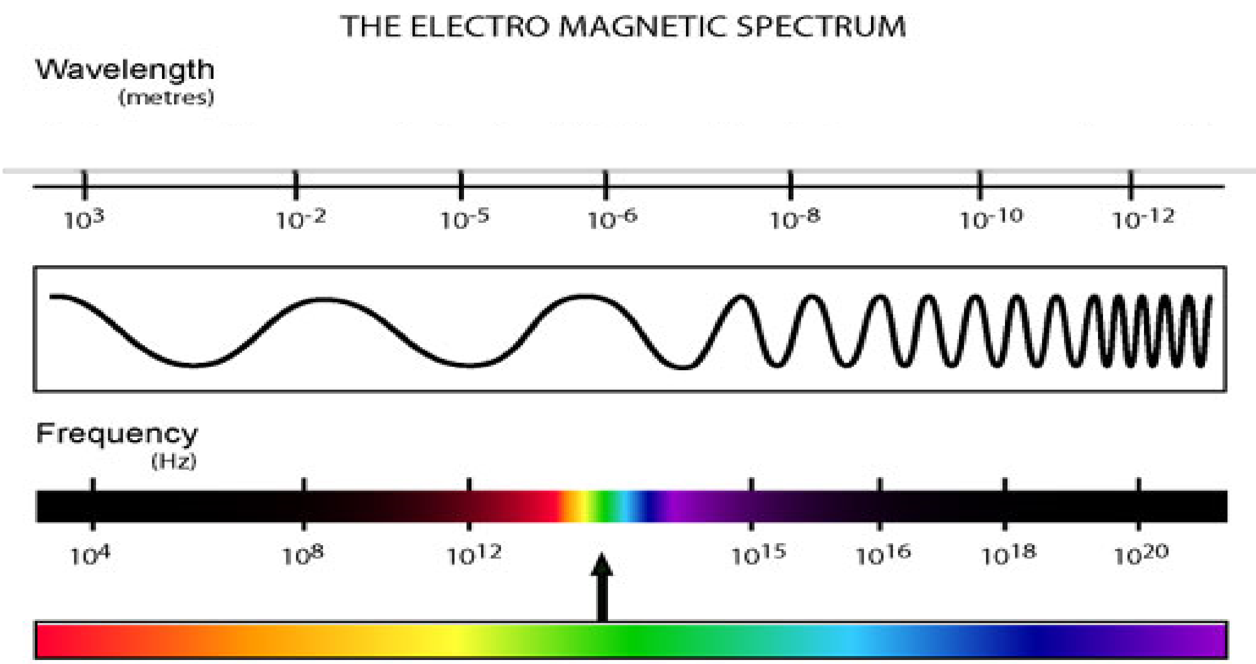
This lesson focuses on the different parts of the **electromagnetic spectrum**. You can use the diagram below to illustrate each of the important divisions we make. Do you notice how energetic light is, and how different the uses are for each type? Infra-red is the one most directly responsible for cooking our food, while the visible spectrum is what we see in the sky all around us.



Use a helpful mnemonic device to help you remember the spectrum and its parts: RMIVUXG, such as "Red Monkeys In Violet Underwear X-ray Good"… even though it's not proper English, it might do the trick to help remember the different parts of the spectrum.

Exercises Answer the questions below:

1. Label the parts of the electromagnetic spectrum below:



Lesson #9: Can the sun be used for cooking?

Overview: The first large-scale application of solar power generation involves the basic principle of what we'll be using to heat our food. This type of energy collection, called solar thermal power, uses the heat energy from the sun to concentrate and convert sunlight into electricity. Usually this involves heating water into steam that turns a turbine. You may have seen these types of power plants as they involve collection towers with an array of mirrors arranged in a circle around the tower. The largest solar power plants in the world are solar thermal arrays, notably the Agua Caliente plant in the Mojave Desert, which generates up to 350 megawatts of power, enough to power thousands of homes.

What to Learn: This will help you understand how the sun's energy is converted to meet our needs.

Materials

- Three clear, clean plastic cups
- Two small tea bags
- Aluminum foil
- Watch or clock
- Measuring cup
- Water
- Two spoons
- White sheet of paper
- Plastic pan (4 inches deep and 12 inches across is a convenient size but other sizes can be used)

Lab Time

1. Use two sheets of aluminum foil and place them crosswise to completely cover the bottom and sides of a plastic pan. Try to arrange the aluminum foil so that it is smooth and curved like a bowl. The aluminum foil will help to reflect the solar energy and concentrate the light and heat toward the center of the pan. Place this aluminum-covered pan outside in a warm, sunny spot where the sunlight will shine directly on it.
2. Add one cup of water to each of two plastic cups. The water you add to the cups should be neither hot nor cold, but about room temperature. Place one cup of water in the middle of the pan. Turn the empty plastic cup upside down and place it on top of this cup. Leave this "solar cooker" undisturbed for one hour. The other cup of water should remain inside.
3. After one hour, gently place one tea bag in each of the water-filled cups. Wait ten minutes and then lift the tea bag out of each cup. Using a spoon, stir each cup of tea. Place both cups of tea on a white piece of paper and look down on the two cups to compare their darkness. Put your finger in each cup of tea to compare their temperatures.

Solar Cooking Data Table

	Cup 1	Cup 2
Temperature at start		
Temperature after 1 hour		

Cooking involves heating food to bring about chemical changes. Sometimes foods are heated simply because the food tastes better warm than cold. In making tea, we sometimes heat water to help dissolve instant tea or help dissolve sugar if the tea is sweetened.

Normally the water used to make tea is heated on a range top or in a microwave oven. Using a range or microwave oven requires buying energy in the form of electricity or natural gas. Using a solar cooker does not require any energy costs because it uses a freely available renewable energy source: the sun.

A curved mirror in a bowl-like shape can focus reflected sunlight at a spot for cooking. A mirror about 1.5 meters (5 feet) across can generate a temperature of 177°C (350°F) and boil a liter of water in about fifteen minutes. In sunny areas of the world, solar cookers can be used instead of burning firewood for cooking.

Another way reflected and focused sunlight is used is to generate electricity. In southern California in 1982, a solar-thermal plant was built that can generate ten million watts of electrical power. This plant consists of 1,818 mirrored heliostats. A heliostat is a device that moves to track the sun across the sky and to reflect the sunlight at the same point. Each heliostat has twelve mirrors, and all the heliostats reflect sunlight to the same spot. The reflected light is directed at the top of a 90-meter (295-foot) tall tower. The concentrated sunlight is used to boil water and heat the steam up to 560° C (1,040 ° F). The steam turns a turbine that powers a generator to produce electricity.

One obvious disadvantage of solar-thermal plants is that they only operate when the sun is shining. The heat energy can be stored for a time by heating up a liquid or melting salt. Or the energy can be used to break water into hydrogen and oxygen. The hydrogen can then be stored and burned later to produce water and release energy.

Exercises Answer the questions below:

1. What type of solar energy are we seeing in this experiment?
    a. Solar fusion
    b. Solar voltaic
    c. Solar thermal
    d. Radiation potential
2. Name two ways that the earth's systems depend on the sun:
    a.

    b.

3. What is one advantage of solar thermal energy? What is one disadvantage?
    a. Advantage:
    b. Disadvantage:

Lesson #10: Solar cookies

Overview: By now you know how the sun's energy can be converted to meet our energy needs. But can it be used to directly provide us with energy? Today we'll find out how and make some treats along the way.

What to Learn: Ask how the sun can be used to provide energy directly, without being converted into electricity or other forms of energy first. Also, you'll be able to name different parts of the electromagnetic spectrum.

Materials

- Two large sheets of poster board (black is best)
- Aluminum foil
- Plastic wrap
- Black construction paper
- Cardboard box
- Pizza box (clean!)
- Tape & scissors
- Reusable plastic baggies
- Cookie dough (your favorite)
- Thermometer (preferably with a needle point reader)

Lab Time

Note: There's a real food safety concern here, as the cookie dough stays in the "danger thermal zone" for more than four hours. Do not eat the cookies until they register 165 on an instant-read thermometer, or omit the eggs in your recipe.

1. Measure an inch from each of three sides of the pizza box. Use the scissors/razor to cut a door out of the pizza box. Bend the door open if necessary. Cover the inside of the door with aluminum foil.
2. The heat needs to get trapped inside the box. Take your plastic wrap and tape it over the opening between the door and the inside of the pizza box. It doesn't matter which side you tape it on.
3. To help the heat stay inside the box, line the inside with aluminum foil. You can also add an insulation layer with some cotton balls, shredded paper, or fine shavings. On top, place your foil. On top of this, put down the black construction paper. Use tape to secure it all in place.
4. Check to make sure the box still closes. Take your cookie dough and place it in balls onto the surface of the paper.
5. Record your observations and data on the table below. Measure the temperature with a thermometer as well.
6. Enjoy your cookies! Be sure to share!

Solar Cookie Data Table

Time	Is it cooked?	Temperature (C)
3 hours		
4 hours		
4.5 hours		
5 hours		
5.5 hours		
6 hours		
6.5 hours		
7 hours		

The solar cookie oven uses the light from the sun, specifically the UV and IR parts of the spectrum, to bake the dough into some delicious treats. The UV rays are energetic and are responsible for damaging our skin if we don't shield it. The atmosphere of our earth does a lot to dissipate this energy so we aren't subject to some of the more harmful parts of the energy that the sun emits. In fact, the sun can eject enormous, energetic bursts of radiation far into space in the form of solar flares. We experience these flares as scrambles in our satellite signals, as well as see their effects visually in the atmosphere as aurorae.

The solar cookie oven operates on the basic principle that the electromagnetic radiation can be concentrated to be directly useful for our energy needs. Instead of converting the energy into electricity to power an oven, for example, the sun's rays are now directly heating the surfaces that the cookies rest on. A few ingredients are necessary for this oven to operate properly, which is what this experiment explores.

Sunlight at the Earth's surface is mostly in the visible and near-infrared (IR) part of the spectrum, with a small part in the near-ultraviolet (UV). The UV light has more energy than the IR, although it's the IR that you feel as heat.

We're going to use both to bake cookies in our homemade solar oven. There are two different designs – one uses a pizza box and the other is more like a light funnel. Which one works best for you?

Your solar cooker does a few different things. First, it concentrates the sunlight into a smaller space using aluminum foil. This makes the energy from the sun more potent. If you used mirrors, it would work even better!

You're also converting light into heat by using the black construction paper. If you've ever gotten into car with dark seats, you know that those seats can get *HOT* on summer days! The black color absorbs most of the sunlight and transforms it into heat (which boosts the efficiency of your solar oven).

By strapping on a plastic sheet over the top of the pizza-box cooker, you're preventing the heat from escaping and cooling the oven off. Keeping the cover clear allows sunlight to enter and the heat to stay in. (Remember the black stuff converted your light into heat?) If you live in an area that's cold or windy, you'll find this part essential to cooking with your oven!

Exercises Answer the questions below:

1. Name the type of heat energy that the sun provides:
    a. Convection
    b. Conduction
    c. Radiation
    d. Invection
2. What are some ways that the sun's energy can be directly harnessed?

3. Name three of the different parts of the electromagnetic spectrum:
    a.
    b.
    c.

Lesson #11: Buzzing hornets

Overview: Energy isn't just found in the sunlight or power plants that provide us with electricity, but in the molecules that vibrate as sound waves.

What to Learn: This lesson will show us how different materials transfer energy.

Materials

- 2 index cards
- Popsicle stick (larger, like a tongue-depressor size)
- Rubber band
- Scissors
- String or yarn
- Hot glue gun

Lab Time

1. Cut two of the corners off the popsicle stick. Use hot glue to attach the index card to the stick quickly along the uncut side. If the index card is longer than your popsicle stick, trim it with the scissors.
2. Cut the second index card in half along its width (hamburger style). Now fold each piece of the index card in half a total of three times, so that you are left with a small, folded rectangle.
3. Use hot glue to sandwich the folded paper over one of the sides of the popsicle stick.
4. Take the remaining folded index card half and tie the string around it, making one tie on its opposite side. Your result should look something like a string-tied package, but looser. Attach the card to the other side of the popsicle stick, sandwiching it with hot glue.
5. Allow the glue to dry. Take the large rubber band and wrap it around the index card so that it covers both sides and both index card sandwiches.
6. Test your hornet by whipping it around your head quickly until it makes a sound.
7. Try spinning your hornet at different speeds: slow, medium, and fast. Note the sound difference. Record your observations and data on the worksheet below.

Buzzing Hornets Data

Speed of spin	Sound
Slow	
Medium	
Fast	

Here is the principle at work behind the buzzing hornet: When you sling the hornet around, wind zips over the rubber band and causes it to vibrate like a guitar string, and the sound is focused (slightly) by the card. The card really helps keep the contraption at the correct angle to the wind so it continues to make the sound.

Troubleshooting: Most kids forget to put on the rubber band, as they get so excited about finishing this project that they grab the string and start slinging it around, and then they wonder why it's so quiet. Make sure they have a large rubber band (about 3.5" x ¼ "– or larger) or you won't get a sound.

Reading

Sound is everywhere. It can travel through solids, liquids, and gases, but it does so at different speeds. It can rustle through trees at 770 mph (miles per hour), echo through the ocean at 3,270 mph, and resonate through solid rock at 8,600 mph.

Sound is made by things vibrating back and forth, whether it's a guitar string, drum head, or clarinet. The back and forth motion of an object (like the drum head) creates a sound wave in the air that looks a lot like a ripple in a pond after you throw a rock in. It radiates outward, vibrating its neighboring air molecules until they are moving around, too. This chain reaction keeps happening until it reaches your ears, where your "sound detectors" pick up the vibration and works with your brain to turn it into sound.

This is one example of energy being transferred through matter. Just as electricity and sunlight also transfer energy (as ions and radiation, respectively) so too does sound. Although sound does it more indirectly, because the sound waves communicate the rippling or vibration of the molecules in space! Instead of electrons flowing or photons blasting at you, you're on the other end of a slinky from whatever made the sound! *Tip: Use a slinky to show compression waves as a demonstration. This is the type of wave that forms when you snap one side and allow the bunched coils to travel to the other side.*

Exercises Answer the questions below:

1. Which of the following best describes how sound gets to us?
    a. Chemical electricity
    b. Solar radiation
    c. Heat conduction
    d. Vibrating molecules

2. Name two ways energy is transferred:
    a.

    b.

3. True or false: A loud noise represents molecules that vibrate violently.
    a. True
    b. False

Lesson #12: Harmonica

Overview: Move over Mozart! We'll create our own musical instruments today and explore more about the world of sound.

What to Learn: Ask yourself how this experiment is similar to the Buzzing Hornets lesson we did last week. How is it different?

Materials

- two tongue depressor popsicle sticks
- three rubber bands, one at least 1/4″ wide
- paper
- tape

Lab Time

1. Rip the paper in half. Stack the popsicle sticks on top of each other, and wrap the paper around them. Secure the whole thing with tape. Make sure you can slide the paper off easily. We'll call this a cuff.
2. Create another cuff with the other paper and popsicle sticks.
3. Take a fat rubber band and put it on a popsicle stick lengthwise.
4. Slide a cuff onto each end, leaving a bit of room at the end.
5. Lay the second popsicle stick on top, and wrap the second rubber band around and around to secure the ends and ensure they stay in place. Do this at both ends.
6. Play the harmonica by putting the thing up to your lips. Kids have to touch your lips to make this effective. To change the pitch, slide the cuffs closer together or farther apart. Is there a difference in sound?
7. Note how the pitch changes when you change the cuffs along the length of the harmonica. Record your data in the worksheet.

Harmonica Data Table

Position	**Pitch: Higher/Lower?**
Middle 1/4th	N/A
Close to the ends of the stick	
Close to the middle of the stick	

Here's what is going on in this experiment:

The rubber band vibrates as you blow across it and you get a great sound. You can change the pitch by sliding the cuffs (this does take practice).

Troubleshooting: This project is really a variation on the Buzzing Hornets, but instead of using wind to vibrate the string, you use your breath. The rubber band still vibrates, and you can change the vibration (pitch) by moving the cuffs closer together or further apart. If the cuffs don't slide easily, just loosen the rubber bands on the ends. You can also make additional harmonicas with different sizes of rubber bands, or even stack three harmonicas on top of each other to get unusual sounds.

If you can't get a sound, you may have clamped down too hard on the ends. Release some of the pressure by untwisting the rubber bands on the ends and try again. Also – this one doesn't work well if you spit too much – wet surfaces keep the rubber band from vibrating.

Musical instruments harness the energy of the vibrating molecules in their materials to great effect. They are usually classified into the method by which sound is created or transmitted. Many instruments, including guitars, banjos, mandolins, and even pianos use strings that vibrate at a pitch determined by its length or width. Materials like nylon, steel, or bone explain why a classical guitar sounds different from a dobro, popular in bluegrass music.

The harmonica is a simple reed-type instrument, where the musician's breath forces the molecules in a reed-like material to vibrate, creating a sweet, high pitch. Other famous examples include the flute, oboe, and bassoon.

Your voice is a vibration, and you can feel it when you place a hand on your throat when you speak. As long as there are molecules around, sound will be traveling though them by smacking into each other.

That's why if you put an alarm clock inside a glass jar and remove the air, there's no sound from the clock. There's nothing to transfer the vibrational energy to – nothing to smack into to transfer the sound. It's like trying to grab hold of fog – you can't, because there's nothing to hold on to.

Exercises Answer the questions below:

1. A battery creates electricity out of chemical energy, while sound is transmitted through:
   a. Heat movement
   b. Rotating atoms
   c. Molecule movement
   d. Solar radiation
2. Your harmonica is most like which of the following instruments:
   a. Guitar
   b. Piano
   c. Clarinet
   d. Timpani
3. Explain how this experiment is similar to the Buzzing Hornets. How is it different?
   a. Similar

   b. Different