ENERGY 2

A comprehensive course that teaches the fundamental principles in energy, work and power. Students will unlock the mysteries of alternative energy, thermodynamics, and the earth's resources as they build a homemade weather tracker station, measure energy and power, make a fire water balloon, invent working solar vehicles, learn how to bottle clouds, and construct a real working external combustion engine from soda cans.

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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 the Energy Series

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 can be carried from one place to another by heat flow, or by waves including water waves, light and sound, or by moving objects.
- When fuel is consumed, most of the energy released becomes heat energy.
- Heat flows in solids by conduction (which involves no flow of matter) and in fluids by conduction and also by convection (which involves flow of matter).
- Heat energy is also transferred between objects by radiation; radiation can travel through space.
- The sun is the major source of energy for phenomena on the Earth's surface, powering winds, ocean currents, and the water cycle.
- Solar energy reaches Earth through radiation, mostly in the form of visible light.
- Heat from Earth's interior reaches the surface primarily through convection.
- Convection currents distribute heat in the atmosphere and oceans.
- Differences in pressure, heat, air movement, and humidity result in changes of weather.
- The utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.
- Consider different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and classify them as renewable or nonrenewable.
- Study the natural origin of the materials used to make common 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.

(RS = Radio Shack)

- alligator clip leads (RS#278-1156)
- bi-polar LED (RS #276-012)
- black spray paint
- CDs (3 old ones)
- coin
- copper flashing sheet (½ sq. foot)
- drill with 1/16″ bit
- drinking bird
- electric fan
- electric stove (not gas)
- electrical tape
- electrical wire (3- conductor solid wire)
- fishing line (15lb. test or similar)
- foam block (about 6" long)
- hair dryer
- hole punch
- lamp with an incandescent bulb
- large plastic 2L soda bottle
- lightweight string (about 4 feet long)
- magnifying lens
- multimeter (Radio Shack #22-810)
- nylon bushing (from hardware store)
- old inner tube from a bike wheel
- pack of steel wool
- paper clips
- paper cups
- permanent marker
- pinwheel (can be purchased or made from construction paper)
- plastic straw (longer than the width of the shoe box)
- pliers
- propeller
- push pin
- razor
- salt (1/4 cup)
- sandpaper
- sheet metal shears
- silver or white spray paint
- small candle or alcohol burner
- small shoe box (children's size)
- super glue
- Swiss army knife (with can opener option)
- tape
- three soda cans
- watch or clock
- wire cutters

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 solar energy be concentrated?

Overview: Today you'll use a plain old light bulb to learn more about the special ways that the sun's energy is used and harnessed, and especially the implications that it has on our energy needs.

What to Learn: This experiment will teach you how the sun's rays interact with our planet, and how in turn we use this energy in a number of ways.

Materials

- Lamp with an incandescent bulb
- Magnifying lens

Lab Time

1. The results of this experiment may be easiest to observe if done at night in a dark room. Ask an adult to remove the lampshade from a lamp that uses a single incandescent bulb. An incandescent bulb is the type that gets quite hot when used. Turn on the lamp. Turn off all the other lights in the room.
2. Stand about two feet from the wall that is the greatest distance from the lamp. There should be nothing between you and the lamp bulb. Place the magnifying glass on the wall so that the lens is flat against the wall. Now, slowly move the lens away from the wall and toward the light. Keep the lens parallel to the surface of the wall. As you move the lens outward, watch the wall.
3. Record your observations on the worksheet.

Concentrated Solar Observations:

Describe or draw the image on the wall in the space below:

How bright is this image? How big?

What happens when you move the lens? The bulb? Why is this happening?

The United States Department of Energy's National Renewable Energy Laboratory in Colorado uses solar energy to operate a special furnace. This high-temperature solar furnace uses a lens to concentrate sunlight. A heliostat (a device used to track the motion of the sun across the sky) is used so that the image reflected from a mirror is always directed at the same spot. The lens is used to concentrate sunlight from a mirror to an area about the size of a penny. This concentrated sunlight has the energy of 20,000 suns shining in one spot.

In less than half a second, the temperature can be raised to 1,720° C (3,128° F), which is hot enough to melt sand. This high-temperature solar furnace is being used to harden steel and to make ceramic materials that must be heated to extremely high temperatures.

Concentrated sunlight also has been used to purify polluted ground water. The ultraviolet radiation in sunlight can break down organic pollutants into carbon dioxide, water, and harmless chlorine ions. This procedure has been successfully carried out at the Lawrence Livermore Laboratory in California. In the laboratory, up to 100,000 gallons of contaminated water could be treated in one day.

The curved shape of the magnifying lens we used in this experiment causes light rays to bend and focus on an image. When we look through the lens, we can use it to make writing or some other object appear larger. However, the magnifying lens can also be used to make something smaller. The light from the bulb is bent and focused on the wall when the lens is held far from the lamp and close to the wall. The image is much brighter than the surroundings. This is because all the light falling on the surface of the lens is concentrated into a much smaller area.

When sunlight is concentrated by passing it through a lens, the result can be an intensely bright and hot spot of light. Even a small magnifying glass can increase the intensity of the sun enough to set wood and paper on fire. We are using a light bulb rather than sunlight for this experiment because concentrated sunlight can be very harmful to your eyes. NEVER LOOK AT A CONCENTRATED IMAGE OF THE SUN.

Do you know of any common ways that solar energy can be concentrated for our use? What about heating homes? Even cooling homes in hotter climates? Providing electricity? Did you know that solar energy can even be used to break down pollutants to clean water? Any others?

Exercises Answer the questions below:

1. Name three uses for solar energy:
    a.
    b.
    c.
2. What type of heat energy is transmitted by the sun?
    a. Conduction
    b. Convection
    c. Plasma
    d. Radiation
3. Circle the following phenomena influenced by the sun:
    a. Pressure
    b. Climate
    c. Weather
    d. Wind

Lesson #2: Solar Battery

Overview: This is a favorite experiment of mine, since it really demonstrates the photoelectric effect in a useful way. Here's the deal: electrons can be either free or attached to the atom, and when you hit a metal place with UV light, some of the attached electrons break free and start current flowing in a circuit.

What to Learn: This lesson will help you learn how solar energy reaches the earth in the form of radiation and takes multiple forms, mostly visible light.

Materials

- ½ sq. foot of copper flashing sheet (check the scrap bin at a hardware store)
- Alligator clip leads (RS#278-1156)
- Multimeter (Radio Shack #22-810)
- Electric stove (***not*** gas)
- Large plastic 2L soda bottle
- ¼ cup salt
- Sandpaper & sheet metal shears

Lab Time

1. First, we'll prepare the copper. Use the metal shears to cut the sheet so that it fits on top of the electric burner. Be careful, the edges will be sharp!
2. Wash the sheet very carefully with soap and water on both sides. Once it's dry, use the sandpaper to scrub off any loose particles. Take your time and scrub it all over on both sides.
3. Place the copper on the burner and turn it to the highest setting. Leave it for about a half hour. Watch the copper for the first few minutes. What do you notice?
4. You can prepare your water bottle while the sheet is cooking. Cut the neck off the bottle.
5. After cooking, turn off the burner and allow the copper to cool on the burner for another twenty minutes. It will shrink and you should notice a black layer which may flake off. We want the layer underneath the black layer. Wash the copper to remove any larger black pieces.
6. Cut the sheet in two, and then bend the sheet so that it can fit into the bottle. We want the smoothest side to face outward. Take a fresh, uncooked piece of copper and place it inside. It's important that the two sheets don't touch.
7. Take some salt and pour it in there. Pour water into the bottle, leaving about an inch of air in the top of the bottle. Stir it up with a spoon so that the salt and water form a solution.
8. Turn on your multimeter, and attach the positive side to the uncooked side of copper, and the negative to the cooked side of copper. Set the meter to read amps.
9. Read the meter in both sunlight and shade. What do you notice? Record your data in the worksheet.

Solar Battery Data

Location	Multimeter Reading (Amps)
Full Sunlight	
Shade	
Partial sunlight	

We are using the photoelectric effect for this experiment. This cuprous oxide solar cell ejects electrons when placed in UV light – and sunlight has enough UV light to make this solar cell work. Those free electrons are now free to flow – which is exactly what we're measuring with the volt meter.

Semiconductors are the secret to making solar cells. A semiconductor is a material that is part conductor, part insulator, meaning that electricity can flow freely or not, depending on how you structure it. There are lots of different kinds of semiconductors, including copper and silicon.

In semiconductors, there's a gap (called the bandgap) that's like a giant chasm between the *free* electrons (electrons that have been knocked out of its shell) and *bound* electrons (electrons still attached to the atom). Electrons can be either free or attached, but it costs a certain amount of energy to go either way (kind of like a toll booth).

When sunlight hits the semiconductor material in the solar cell, some of the electrons get enough energy to jump the gap and get knocked out of their shell to become free electrons. The free electrons zip through the material and create a flow of electrons. When the sun goes down, there's no source of energy for electrons to get knocked out of orbit, so they stay put until sunrise.

Reading

Solar energy is the kind of energy most people think of when you mention "alternative energy," and for good reason! Without the sun, none of anything you see around you could be here. Plants have known forever how to take the energy and turn it into usable stuff… so why can't we?

The truth is that we can. While normally it takes factories the size of a city block to make a silicon solar cell, we'll be making a copper solar cell after a quick trip to the hardware store. We're going to modify the copper into a form that will allow it to react with sunlight the same way silicon does. The image shown here is the type of copper we're going to make on the stovetop.

This solar cell is a real battery, and you'll find that even in a dark room you'll be able to measure a tiny amount of current. However, even in bright sunlight, you'd need 80 million of these to light a regular incandescent bulb.

Exercises Answer the questions below:

1. The sunlight causes the electrons to flow from the cuprous oxide because of:
    a. Photosynthesis
    b. The electromagnetic spectrum
    c. The photoelectric effect
    d. The photochemical principle
2. What material do most solar cells use instead of copper?

3. What part of the electromagnetic spectrum is most active in this experiment?
    a. Visible Light
    b. Ultraviolet Light
    c. Gamma Rays
    d. Microwaves
4. When you read amps, you read:
    a. Current
    b. Voltage
    c. Power Draw
    d. Work

Lesson #3: Solar Drinking Bird

Overview: The drinking bird is a classic science toy that dips its head up and down into a glass of water. It's filled with a liquid called methylene chloride, and the head is covered with red felt that gets wet when it drinks. But how does it work? Is it perpetual motion? We'll take a look at what's going on with the bird, why it works, and how we're going to modify it so it can run on its own without using any water at all!

What to Learn: You'll learn more about the sun than about the bird itself, and especially about the sun's influence on the Earth, air, and water.

Materials

- drinking bird
- silver or white spray paint
- black spray paint
- razor
- mug of hot water
- sunlight or incandescent light

Lab Time

1. Take the bird out of its holder, and carefully remove the tail feather, hat, and felt section. Remove any glue with a scraper or hot water, which will allow the glue to loosen and easily peel off. Be careful not to hold the bird by the head, because it is hollow and can break if you grip too tightly!
2. Paint the top (with the peak, from which the hat was removed) either white or silver. Paint the bottom black. Allow it to dry.
3. When the paint is dry, reattach the bird to its stand, and place it in the sun. Adjust the fastening band until the bird is secure, if needed.
4. Liquid is being heated now in the bird, so the bird will begin tipping as water begins moving from the bottom to the top. The bottom of the bird is now black, and black absorbs more energy and heats up the tail of the bird. Since the tail section is warmer, the pressure goes up and the liquid gets pushed up the tube. By covering the head with white (or silver) paint, you are reflecting most of the energy so it remains cool. Remember that white surfaces act like mirrors to IR light (which is what heat energy is).

Observations

1. What is happening to your drinking bird?

2. Does it work better with hot or cold water?

3. Does it work in an enclosed space, such as an inverted aquarium?

4. On a rainy day or dry?

5. In the fridge or on a heating pad?

Reading

The drinking bird in this experiment is an example of a heat engine. The liquid's special properties allow the motion to continue, so long as there is some water provided to the system.

What's so special about the liquid? Methylene chloride is made of carbon, hydrogen, and chlorine atoms. It's barely liquid at room temperature, having a boiling point of 103.5° F, so it evaporates quite easily. It does have a high vapor pressure (6.7 psi), meaning that the molecules on the liquid surface leave (evaporate) and raise the pressure until the amount of molecules evaporating is equal to the amount being shoved back in the liquid (condensed) by its own pressure. (For comparison, the vapor pressure of water is only 0.4 psi.)

The bird needs a temperature difference between the head and tail. Since water needs heat in order to evaporate, the head cools as the water evaporates. This temperature decrease lowers the pressure inside the head, pushing liquid up the inner tube. With more liquid (weight in the head), the bird tips over. The bird wets its own head to start this cycle again.

The trick to making this work is that when the bird is tipped over, the vapor from the bottom moves up the tube to equalize the pressure in both sides, or he'd stay put with his head in the cup. Sadly, this isn't perpetual motion because as soon as you take away the water, the cycle stops. It also stops if you enclose the bird in a jar so water can no longer evaporate after awhile. Do you think this bird can work in a rainstorm? In Antarctica?

Vapor pressure can also change with temperature changes. The vapor pressure goes up when the temperature goes up. Since the wet head is cooler than the tail, the vapor pressure at the top is less than at the bottom, which pushes the liquid up the tube. So it really does matter whether the bird is operating in Arizona or the Amazon. The bird will dip more times per minute in a desert than a rain forest! This is because evaporation will work more quickly in the desert.

Exercises Answer the questions below:

1. Where does most of the energy on earth come from?
    a. Underground
    b. The sun
    c. The oceans
2. What is one way that we use energy from the sun?

3. What is the process by which the liquid is being heated inside the bird?
    a. Precipitation
    b. Pressure
    c. Evaporation
    d. Transpiration

Lesson #4: Can wind be used as a source of energy?

Overview: Construct your own windmill and use it to collect paper clips under its own power. In the process you'll learn important concepts about alternative energy and the growing importance of renewable resources like wind power.

What to Learn: Pay attention to how the sun allows wind to form, and the importance of wind in our future's energy needs and consumption.

Materials

- Pinwheel (can be purchased or made from construction paper)
- Paper clips
- Tape
- Small shoe box (children's size)
- Electric fan
- Lightweight string (about 4 feet long)
- Plastic straw (longer than the width of the shoe box)
- Hole punch

Lab Time

1. Use a hole punch to punch holes in the opposite sides across the width of the cardboard shoe box. Use the narrow sides of the box so the two holes are less than 6 inches (15 centimeters) apart. Make sure the holes are directly opposite each other. Place a plastic straw through the holes. Enlarge the holes if you need to.
2. Use the blades from a pinwheel or cut and fold a square piece of construction paper into the shape of a pinwheel. Attach the blades to one end of the straw.
3. Partially unfold a small paper clip and insert it into the larger end of the straw. Push the straightened end of the paper clip through the center of the pinwheel. Bend this end of the paper clip and tape it to the outside of the pinwheel.
4. Set the fan on a table or countertop. Hold the shoebox so that the pinwheel is free to turn. Have an adult plug in and turn on the fan. Move the windmill box to direct the breeze from the fan toward the blades of the pinwheel. Move the box until you find the best angle of the fan to the pinwheel so that the blades turn freely.
5. Turn off the fan. Tape one end of the string to the side of the straw with no pinwheel just outside the box, and wrap the string around the straw a few times. Tie the other end of the string to a paper clip. Attach five other paper clips to the paper clip tied to the string. Allow the string to hang down so that the paper clips on the end of the string rest on the floor.
6. Now, you will test to see if your windmill can convert wind power to do work and lift the paper clips off the ground. Turn on the fan and hold the box where you did before to make the pinwheel turn. Record all your observations and data in the worksheet.

Wind Energy Observations

1. Does the windmill turn the straw?

2. Does the string wrap around the straw as the straw turns?

3. What happens to the paper clips?

4. How is energy being converted by your windmill?

Reading

One way to store the energy produced by a windmill is to lift a weight. When the weight is allowed to fall, work can be produced. Weights in a grandfather clock are used to store energy and can run a clock for a week or longer. A windmill's energy can be used to pump water to a storage area at a higher elevation. Later, this water can be allowed to fall through a turbine which turns a generator and produces electricity.

Electricity can also be produced directly from wind power. The shaft, or rod to which the windmill blades are attached, can be used to turn a generator. A generator or dynamo is used to convert mechanical energy into electrical energy. Power conversion units can change the direct current that wind generates to an alternating current. The alternating current can be fed directly into utility lines and used in our homes.

The sun is the original source of wind power. Without the sun to heat the earth, there would be no wind. The energy of the sun heats the earth, but all parts of the earth are not at the same temperature. These differences in temperature are responsible for global and local patterns of wind. For example, during the day a constant wind blows from the sea toward the land along coastal regions. Air above the hotter land rises and cooler, heavier air above the ocean moves in to take its place.

The power of the wind can be harnessed to do work. The wind has been used to move sailing ships. The wind has enough power to move ships across oceans and around the world. Windmills have been used for pumping water and turning stones to grind grain. Millions of windmills have been used on the plains of America, Africa, and Australia to pump water from deep wells for livestock and humans.

In this century, windmills or wind engines have been used to generate electricity. More than 15,000 wind engines were installed in California in the 1980s. These wind engines have the capability to produce up to 1.5 billion watts of electricity. In California in 1987, wind was used to produce as much electricity as the city of San Francisco uses in an entire year.

The United States has large reserves of coal, natural gas, and crude oil (which is used to make gasoline). However, the United States uses the energy of millions of barrels of crude oil every day, and it must import about half its crude oil from other countries.

Burning fossil fuels (oil, coal, gasoline, and natural gas) produces carbon dioxide gas. Carbon dioxide is one of the main greenhouse gases that may contribute to global warming. In addition, burning coal and gasoline can produce pollution molecules that contribute to smog and acid rain.

Using renewable energy--such as solar, wind, water, biomass, and geothermal--could help reduce pollution, prevent global warming, and decrease acid rain. Nuclear energy also has these advantages, but it requires storing radioactive wastes generated by nuclear power plants. Currently, renewable energy produces only a small part of the energy needs of the United States. However, as technology improves, renewable energy should become less expensive and more common.

Hydropower (water power) is the least expensive way to produce electricity. The sun causes water to evaporate. The evaporated water falls to the earth as rain or snow and fills lakes. Hydropower uses water stored in lakes behind dams. As water flows through a dam, the falling water turns turbines that run generators to produce electricity.

Currently, geothermal energy (heat inside the earth), biomass (energy from plants), solar energy (light from concentrated sunlight), and wind are being used to generate electricity. For example, in California there are more than 16,000 wind turbines that generate enough power to supply a city the size of San Francisco with electricity.

In addition to producing more energy, we can also help meet our energy needs through conservation. Conservation means using less energy and using it more efficiently.

Exercises Answer the questions below:

1. Name three sources of renewable energy:
    a.
    b.
    c.
2. What does the sun have to do with wind?

3. Name three examples of wind power in historical or current usage:
    a.
    b.
    c.

Lesson #5: Wind Turbine

Overview: We'll take a look at propeller design as we build a working wind turbine.

What to Learn: We use all kinds of resources to meet our energy needs. You'll learn how wind energy is so important, and the principles behind how energy is converted so that we can use it.

Materials

- A digital Multimeter (Radio Shack #22-810)
- Alligator clip leads (RS#278-1156)
- 1.5-3V DC Motor (RS #273-223)
- 9-18VDC Motor (RS #273-256)
- Bi-polar LED (RS #276-012)
- Foam block (about 6" long)
- Scrap piece of wood for mounting
- Propeller from old toy or cheap fan or Radio Shack Solar Kit 277-1201.
- Sharp knife or scissors
- Hair drier
- Hot glue gun

Lab Time

1. Slice the foam block in half lengthwise. Adult supervision is needed! Stack the two pieces and hot glue them together.
2. Mount your blocks on a piece of wood or sturdy paper. Next, attach your motor to the top of the foam. Make sure the shaft is overhanging the edge, because we want to attach a propeller.
3. Attach the propeller to the shaft of the motor, and make sure it is able to spin freely.
4. Mount the solar cell onto your base, and wire the motor into the appropriate places on the solar cell.
5. Go outside and give the cell a test, making sure the propeller spins according to the amount of sunlight.
6. Disconnect the wires and set the solar cell aside. Take your LEDs and spread their metal wires so that you can stick them into the foam block below your propeller.
7. Take alligator clips and attach them to the wires of the motor. Make sure the clips are attached to the wires themselves, not the insulation.
8. We need to figure out if the wires are connected properly. Use a hair dryer on the lowest heat setting, highest power, to spin the propeller. Experiment to find the sweet spot where the propeller will spin well. If your LEDs do not light up, try using the hair dryer on the opposite side, behind the motor. Does it work? If not, then reverse the wires.
9. Disconnect the alligator clips from the LEDs and attach the multimeter to the motor. Click the dial three times to the left to get the right range of voltage. Use the hair dryer again and record your reading from the multimeter on your worksheet. What about if you arrange the dryer to blow from the other side?

Wind Turbine Data Table

Wind Direction or Configuration	Reading (Voltage)
Front of propeller	
Rear of propeller	

Believe it or not, most of the electricity you use comes from moving magnets around coils of wire! Wind turbines spin big coils of wire around very powerful magnets (or very powerful magnets around big coils of wire) by capturing the flow.

Here's how it works: When a propeller is placed in a moving fluid (like the water from your sink or wind from your hair dryer), the propeller turns. If you attach the propeller to a motor shaft, the motor will rotate. It has coils of wire and magnets inside. The faster the shaft turns, the more the magnets create an electrical current.

The electricity to power your computer, your lights, your air conditioning, your radio or whatever comes from spinning magnets or wires!

Reading

Wind power is a recently burgeoning source of renewable energy. Although we've invested in large-scale wind power in North America for the past forty years, recent projects in northern and central Europe have constructed the most massive arrays yet seen. In the North Sea, massive floating turbines generate enough electricity to power thousands of homes. Although legal and environmental challenges restrict how much we can build wind farms (they are quite a hazard to migrating bird populations, and even have effects on livestock and human settlements near them), they will provide an important part of our future energy needs.

Exercises Answer the questions below:

1. True or false: Electricity in a wind turbine is created by magnets in the turbine:
    a. True
    b. False
2. What is one advantage of using wind for electricity?

3. What might be one problem with constructing wind farms to meet all our energy needs?

Lesson #6: Can water be used to store energy?

Overview: Our sun can be used for all kinds of things. In our world that is suffering from an energy crisis, we need to be more proactive to address these needs. Did you know that large bodies of water are used to store heat? Find out how today!

What to Learn: This lab will allow us to see how water interacts with the heat energy of the sun. Remember the key terms we've learned so far: conduction, convection, etc. What type of heat transfer do we observe here?

Materials

- Paper cups
- Measuring cups
- Hot water
- Watch or clock
- Sink
- Refrigerator (with freezer compartment)
- Thermometer

Lab Time

1. Turn on the hot water faucet and wait until the water is hot. Be careful not to burn yourself!
2. Add ¼ cup of hot water to the first paper cup, and 1 cup water to the second paper cup.
3. Place both cups in the freezer compartment of the refrigerator. Be sure to label your cups!
4. Check the water after 30 minutes. Record your data in the worksheet, taking the temperature of each cup and seeing if the water has frozen.
5. Return to the freezer and check the temperature again after 45 minutes. Record your data.
6. Keep checking the cups at fifteen-minute intervals until one has frozen. Record your data in the sheet.

Water Energy Data Table

Time (minutes)	Temperature (Cup 1)	Temperature (Cup 2)	Frozen? (Cup 1)	Frozen? (Cup 2)
0				
30				
45				
60				
75				

1. What conclusions can you draw about the relationship between the water's amount and its ability to store energy? How do you know?

Reading

The sun's rays interact with the earth in a number of different ways, and scientists are getting more creative in their attempts to harness the abundant energy that comes down to influence the surface. Solar ponds are large bodies of water that can store heat during the daytime and release it during the evening to be used by some nearby area. They involve placing a layer of fresh water atop salt water, which remains heavier and sinks to the bottom. The fresh water insulates the bottom layer of water and can retain quite a bit of heat.

In a freshwater pond, as the water on the bottom is heated by sunlight, the hot water becomes lighter and rises to the top of the pond. This convection or movement of hot water to the top tends to carry away excess heat. However, in a saltwater pond, there is no convection so heat is trapped. In Israel a series of saltwater, solar ponds were developed around the Dead Sea. The heat stored in these solar ponds has been used to run turbines and generate electricity.

For another example of water storing large amounts of heat energy, consider the city of San Francisco. It lies at the end of a peninsula, surrounded on three sides by water. If you've ever visited the city during the summer, you'll be surprised by how cold it can get! This is because the water absorbs a large amount of the energy from the sun, leaving the landmass colder than the continental inland. This is why the city of Oakland across the bay can be experiencing completely different weather just a few miles away.

Temperature is a measure of the average hotness of an object. The hotter an object, the higher its temperature. As the temperature is raised, the atoms and molecules in an object move faster. The molecules in hot water move faster than the molecules in cold water. Remember that the heat energy stored in an object depends on both the temperature and the amount of the substance. A smaller amount of water will have less heat energy than a larger amount of water at the same temperature.

Increasing the temperature of a large body of water is one way to store heat energy for later use. A large container filled with salt water, called brine, may be used to absorb heat energy during the day when it is warm. This energy will be held in the saltwater until the night when it is cooler. This stored heat energy can be released at night to warm a house or building. This is one way to store the sun's heat energy until it is needed.

Exercises Answer the questions below:

1. What type of heat transfer is at work in a solar pond?
    a. Kinetic
    b. Conduction
    c. Potential
    d. Convection
    e. Radiation
2. What units do we use to measure energy?
    a. Kilowatts
    b. Joules
    c. Newtons
    d. Kilowatt-hours
3. Draw a diagram of a solar pond in the space below:

Lesson #7: Fire water balloon

Overview: Heat energy can be observed in many ways. This simple experiment allows us to see how heat is transferred.

What to Learn: We're exploring how heat energy can move between objects in a variety of ways.

Materials

- Balloon
- Water
- Matches, candle, and adult help
- Sink

Lab Time

1. Put the balloon under the faucet and fill the balloon with some water.
2. Now blow up the balloon and tie it, leaving the water in the balloon. You should have an inflated balloon with a tablespoon or two of water at the bottom of it.
3. Carefully light the match or candle and hold it under the part of the balloon where there is water.
4. Feel free to hold it there for a couple of seconds. You might want to do this over a sink or outside just in case!
5. Record observations in the worksheet below

Fire-Water Balloon Observations

1. What did the water do to the heat of the match?

2. Why didn't the balloon pop? What does this tell you about heat energy in this system?

So why didn't the balloon pop? The water absorbed the heat! The water actually absorbed the heat coming from the match so that the rubber of the balloon couldn't heat up enough to melt and pop the balloon. Water is very good at absorbing heat without increasing in temperature, which is why it is used in car radiators and nuclear power plants. Whenever someone wants to keep something from getting too hot, they will often use water to absorb the heat.

Think of a dry sponge. Now imagine putting that sponge under a slowly running faucet. The sponge would continue to fill with water until it reached a certain point and then water started to drip from it. You could say that the sponge had a water capacity. It could only hold so much water before it couldn't hold any more and the water started dripping out. Heat capacity is similar. Heat capacity is how much heat an object can absorb before it increases in temperature. This is also referred to as specific heat. **Specific heat** is how much heat energy a mass of a material must absorb before it increases 1°C.

Reading

If you've ever had a shot, you know how cold your arm feels when the nurse swipes it with a pad of alcohol. What happened there? Well, alcohol is a liquid with a fairly low boiling point. In other words, it goes from liquid to gas at a fairly low temperature. The heat from your body is more than enough to make the alcohol evaporate.

As the alcohol went from liquid to gas, it sucked heat out of your body. For things to evaporate, they must suck in heat from their surroundings to change state. As the alcohol evaporated, you felt cold where the alcohol was. This is because the alcohol was sucking the heat energy out of that part of your body (heat was being transferred by conduction) and causing that part of your body to decrease in temperature.

As things condense (go from gas to liquid state) the opposite happens. Things release heat as they change to a liquid state. The water gas that condenses on your mirror actually increases the temperature of that mirror. This is why steam can be quite dangerous. Not only is it hot to begin with, but if it condenses on your skin it releases even more heat which can give you severe burns. Objects absorb heat when they melt and evaporate/boil. Objects release heat when they freeze and condense.

Do you remember when I said that heat and temperature are two different things? Heat is energy – it is thermal energy. It can be transferred from one object to another by conduction, convection, and radiation. We're now going to explore heat capacity and specific heat.

Water is very good at absorbing heat without increasing in temperature, which is why it is used in car radiators and nuclear power plants. Whenever someone wants to keep something from getting too hot, they will often use water to absorb the heat.

Think of a dry sponge. Now imagine putting that sponge under a slowly running faucet. The sponge would continue to fill with water until it reached a certain point and then water started to drip from it. You could say that the sponge had a water capacity. It could only hold so much water before it couldn't hold any more and the water started dripping out. Heat capacity is similar. Heat capacity is how much heat an object can absorb before it increases in temperature. This is also referred to as specific heat. Specific heat is how much heat energy a mass of a material must absorb before it increases 1°C.

Exercises Answer the questions below:

1. What is specific heat?
    a. The specific amount of heat any object can hold
    b. The amount of energy required to raise the temperature of an object by 1 degree Celsius.
    c. The type of heat energy an object emits
    d. The speed of a compound's molecules at room temperature
2. Name two types of heat energy:

3. What type (or types) of heat energy is at work in today's experiment?

4. True or False: Water is poor at absorbing heat energy.
    a. True
    b. False

Lesson #8: Balloon gymnastics

Overview: Heat causes all kinds of things to happen. We'll zoom in on the micro scale of molecules as we explore in today's lesson.

What to Learn: Heat energy influences all kinds of observable phenomena on our planet.

Materials

- water
- plastic bottle
- balloon
- stove top and saucepan or the setup in the video

Lab Time

1. Pour a couple of inches of water into an empty soda bottle and cap with a 7-9″ balloon. You can secure the balloon to the bottle mouth with a strip of tape if you want, but it usually seals tight with just the balloon itself.
2. Fill a saucepan with an inch or two of water, and add your bottle. Heat the saucepan over the stove with adult help, keeping a close eye on it. Turn off the heat when your balloon starts to inflate. Since water has a high heat capacity, the water will heat before the bottle melts. (Don't believe me? Try the Fire-Water Balloon Experiment first to see how water conducts heat away from the bottle!)
3. When you're finished, stick the whole thing in the freezer for an hour. What happened to the balloon?
4. Record all observations in the worksheet

Balloon Gymnastics Observations

1. What happens to the balloon when the balloon is heated? What is happening to its air molecules?

2. What happens to the balloon when you put it in the freezer? What is happening with its molecules now?

Reading

This material may be helpful to interpret today's experiment:

Is it warmer upstairs or downstairs? The upstairs in a house is warmer because the pockets of warm air rise because they are less dense than cool air. The more the molecules move around, the more room they need, and the further they get spaced out. Think of a swimming pool and a piece of aluminum foil. If you place a sheet of foil in the pool, it floats. If you take the foil and crumple it up, it sinks. The more compactly you squish the molecules together, the denser it becomes.

As for why mountains and valleys are opposite, it has to do with the Earth being a big massive ball of warm rock which heats up the lower atmosphere in addition to winds blowing on mountains and changes in pressure as you gain altitude… in a nutshell, it's complicated! What's important to remember is that the Earth system is a lot bigger than our bottle-saucepan experiment, and can't be represented in this way.

Exercises Answer the questions below:

1. Draw a group of molecules at a very cold temperature in the space below. Use circles to represent each molecule.

2. True or False: A molecule that heats up will move faster.
    a. True
    b. False
3. True or False: A material will be less dense at lower temperatures.
    a. True
    b. False

Lesson #9: Ghost coin

Overview: This spooky idea takes almost no time, requires a dime and a bottle, and has the potential for creating quite a stir in your next magic show. The idea is basically this: when you place a coin on a bottle, it starts dancing around. But there's more to this trick than meets the scientist's eye.

What to Learn: Heat energy is carried through different substances and affects the properties of different types of matter

Materials

- Coin
- Freezer
- Plastic bottle (not glass)

Lab Time

1. Remove the cap of an empty plastic water or soda bottle and replace it with a dime.
2. Stick the whole thing upright in the freezer overnight. Make sure your group's bottle is labeled! First thing in the morning, take it out and set it on the table. What happens?
3. Record all observations in the worksheet.

Ghost Coin Observations

Draw a picture of the water molecules inside of the water bottle when this experiment begins.

Now draw a picture of what they look like in the morning. What happened?

Reading

Matter has a tendency to hang out in fairly stable states under normal temperatures. There are three common states of matter; solid, liquid, and gas. There is another state of matter called plasma, but it is not common on Earth. Plasma is a highly energized gas. It is used in fluorescent lights. I'm going to assume you know a bit about solids, liquids and gases so I won't go into much detail about them here (see Unit 3 and 8 for more information).

What I do want to talk about is what happens as temperatures change in a substance. Let's take one of the neatest substances on the Earth, water. Water is quite special since it can be in its solid, liquid and gas state at relatively "normal" temperatures. It's quite special for a variety of other reasons, too, but we'll leave it at that for now.

Pretend we have an ice cube on a frying pan (poor ice cube). Right now the water is in a solid state. It's holding its shape. The molecules in the water are held together by strong, stiff bonds. These bonds hold the water molecules in a tight, very specific pattern called a matrix.

This matrix holds the water molecules in a crystalline pattern and the solid water holds its shape. Now, let's turn on the heat. The heat is transferred from the stove to the frying pan to the ice cube. (We'll talk about heat transfer a bit later.)

As the ice cube absorbs the heat, the molecules begin to vibrate faster (the temperature is increasing). When the molecules vibrate at a certain speed (gain enough thermal energy) they stretch those strong, stiff bonds enough that the bonds become more like rubber bands or springs. When the bonds loosen up, the water loosens up and becomes liquid. There are still bonds between the molecules, but they are a bit loose, allowing the molecules to move and flow around each other.

The act of changing from a solid to a liquid is called melting. The temperature at which a substance changes from a solid to a liquid is called its melting point. For water, that point is 32° F or 0° C. Now we will watch carefully as our ice cube continues to melt (little is more exciting than watching an ice cube melt – golf, maybe). A bit after we see our ice cube go from solid to completely liquid, we notice bubbling. What's going on now? If we were able to see the molecules of water at this point we'd be quite amazed at the fantastic scene before us.

At 212° F or 100° C water goes from a liquid state to a gaseous state. This means that the loosey goosey bonds that connected the molecules before have been stretched as far as they go, can't hold on any longer and "POW!" they snap. Those water molecules no longer have any bonds and are free to roam aimlessly around the room. Gas molecules move at very quick speeds as they bounce, jiggle, crash and zip around any container they are in. The act of changing from a liquid to a gas is called evaporation or boiling, and the temperature at which a substance changes from a liquid to a gas is called its boiling point.

I don't know about you, but I think it's getting a bit hot in here. Let's turn the heat down a bit and see what happens. If our gaseous water molecules get close to something cool, they will combine and turn from gaseous to liquid state. This is what happens to your bathroom mirror during a shower or bath. The gaseous water molecules that are having fun bouncing and jiggling around the bathroom get close to the mirror. The mirror is colder than the air. As the gas molecules get close, they slow down due to loss of temperature. If they slow enough, they form loosey goosey bonds with other gas molecules and change from gas to liquid state.

The act of changing from gas to liquid is called condensation. The temperature at which molecules change from a gas to a liquid is called the condensation point. Clouds are made of hundreds of billions of tiny little droplets of liquid water that have condensed onto particles of some sort of dust. Now let's turn the heat down a bit more and see what happens. As the temperature drops and the molecules continue to slow, the bonds between the molecules can pull them together tighter and tighter. Eventually the molecules will fall into a matrix, a pattern, and stick together quite tightly. This would be the solid state. The act of changing from a liquid to a solid is called freezing, and the temperature at which it changes is called (say it with me now) freezing point.

Think about this for a second – is the freezing point and melting point of an object at the same temperature? Does something go from solid to liquid or from liquid to solid at the same temperature? If you said yes, you're right! The freezing point of water and the melting point of water are both 32° F or 0° C. The temperature is the same. It just depends on whether it is getting hotter or colder as to whether the water is freezing or melting. The boiling and condensation point is also the same point. Now I'm going to mess things up a little bit. Substances can change state at temperatures other than their different freezing or boiling points. Many liquids change from liquid to gas and from gas to liquid relatively easily at room temperatures. And, believe it or not, solids can change to liquids and even gases and vice versa at temperatures other than the usual melting, freezing, or boiling points. So what's the point of the points?

At a substance's boiling, freezing, etc, points, all of the substance must change to the next state. The condition of the bonds cannot remain the same at that temperature. For example, at 100° C water must change from a liquid to a gas. That is the speed limit of liquid water molecules. At 100° C the liquid bonds can no longer hold on and all the molecules convert to gas.

Exercises Answer the questions below:

1. When a gas turns into a liquid, this is called:
    a. Convection
    b. Conduction
    c. Absorption
    d. Condensation
2. When water boils, what happens to the bonds between its molecules?

3. What is the best way to describe how the bonds between water molecules behave when in a liquid state?
    a. Solid bridges
    b. Rubber bands
    c. No bonds
    d. Brittle like chalk
4. The crystalline shape of a solid is referred to as:
    a. a matrix
    b. a vortex
    c. a crystal
    d. a cube

Lesson #10: What's a Joule?

Overview: Energy shows up in all kinds of ways. We'll see how today through a simple lesson.

What to Learn: Energy is the ability to do work. You'll get practice playing with units and learning about how we measure energy and the forms it take.

Materials

- Something that weighs around 100 grams or 4 ounces, about the same as an apple
- A meter or yard stick

Lab Time

1. Grab your 100-gram object, put it on a table.
2. Now lift it off the table straight up until you lift it one meter (one yard).
3. Lift it up and down 20 times.
4. Record your observations in the worksheet.

Joule Observations

1. Describe the energy in your object before you do anything to it. Is there more than one way to say this, in terms of units?
2. When you move the object over one meter, what are you doing?
3. When you do this 20 times, use math to say how many Joules of work you are doing.
4. How many Joules of work do you do if you lift the apple 50 times?

Reading

If we wish to talk about energy further, we need to have a unit of measurement. For energy, a couple of units are the *Joule* and the *calorie*. A Joule is the energy needed to lift one Newton one meter. A Newton is a unit of force. One Newton is about the amount of force it takes to lift 100 grams or 4 ounces or an apple.

It takes about 66 Newtons to lift a 15-pound bowling ball and it would take a 250-pound linebacker about 1000 Newtons to lift himself up the stairs! So, if you lifted an apple one meter (about 3 feet) into the air you would have exerted one Joule of energy to do it.

The calorie is generally used to talk about heat energy, and you may be a bit more familiar with it due to food and exercise. A calorie is the amount of energy it takes to heat one gram of water one degree Celsius. Four Joules are about one calorie.

A 100-gram object takes about one Newton of force to lift. Since it took one Newton of force to lift that object, how much work did we do? Remember work = force x distance so in this case work = 1 Newton x 20 meters or work = 20 Joules.

You may ask, "But didn't we move it 40 meters, 20 meters up and 20 down?" That's true, but work is moving something against a force. When you moved the object down you were moving the object with a force, the force of gravity. Only in lifting it up are you actually moving it against a force and doing work. Four Joules are about 1 calorie, so we did 5 calories of work.

"Wow, I can lift an apple 20 times and burn 5 calories! Helloooo weight loss!" Well… not so fast there Richard Simmons. When we talk about calories in nutrition we are really talking about kilo calories. In other words, every calorie in that potato chip is really 1000 calories in physics. So as far as diet and exercise goes, lifting that apple actually only burned .005 calories of energy … rats.

It is interesting to think of calories as the unit of energy for humans or as the fuel we use. The average human uses about 2000 calories (food calories that is, 2,000,000 actual calories) a day of energy. Running, jumping, sleeping, and eating all use calories/energy. Running 15 minutes uses 225 calories. Playing soccer for 15 minutes uses 140 calories. (Remember those are food calories, multiply by 1000 to get physics calories). This web site has a nice chart for more information: Calories used in exercise.

Everything we eat refuels that energy tank. All food has calories in it and our body takes those calories and converts them to calories/energy for us to use. How did the food get the energy in it? From the sun! The sun's energy gives energy to the plants, and when the animals eat the plants they get the energy from the sun as well.

So, if you eat a carrot or a burger you are getting energy from the sun! Eating broccoli gives you about 50 calories. Eating a hamburger gives you about 450 calories! We use energy to do things and we get energy from food. The problem comes when we eat more energy than we can use. When we do that, our body converts the energy to fat, our body's reserve fuel tank. If you use more energy then you've taken in, then your body converts fat to energy. That's why exercise and diet can help reduce your weight.

Exercises Answer the questions below:

1. If something has a weight of 2 Newtons and is moved half a meter, how many Joules of energy are used? Show your work.

2. What is the source of all this energy we're working with here?

3. It doesn't count as work when you move the apple back down. Why not?

Lesson #11: Measuring Power

Overview: Today you'll measure power and have some handy tools to be able to record and interpret data. We use the same materials as last lesson, but introduce an important concept: that of power**. Power** is work done over time and is measured in watts, which is a Joule per second.

What to Learn: You'll be able to have hands-on experience and understand a working definition of energy, work, and power.

Materials

- Meter or yard stick
- A stopwatch or timer
- Object

Lab Time

1. Grab your 100-gram object and put it on a table.
2. Now lift it off the table straight up until you lift it one meter (one yard).
3. Start the timer and at the same time start lifting the object up and down 20 times.
4. Stop the timer when you're done with the 20 lifts.
5. So, do you have the power of the Dodge Viper? Hmmm, probably not, but let's take a look.
6. First of all, figure out how much work you did. Work = force x distance, so take the force you used and multiply that by the distance you moved it. In this case, you can multiply 1 Newton x 20 meters and get 20 Joules of work.
7. Now figure out how much power you used. Power is work divided by time so take your work (20 Joules) and divide it by how much time it took you to do that work. For example, if you lifted the block 20 times (doing 20 Joules of work) in 5 seconds, you did 20 Joules/5 seconds = 4 Watts of power. To convert Watts to horsepower we multiply by .001 so in this example, you did 4 x .001 = .004 horsepower.
8. Show your calculations in the worksheet below.

Measuring Power Calculations

1. How much work did you do? Show your work. (No pun intended!)

2. How much power did you use? Show your work.

Exercises Answer the questions below:

1. What is work?
    a. Force divided by distance
    b. Force times distance
    c. Energy required for power
    d. Kinetic and potential energy
2. What is power?
    a. Work divided by time
    b. Work multiplied by time
    c. Energy used in an exercise
    d. Calories over time
3. How do we measure work? Name one unit.

4. How do we measure power? Name one unit.

Lesson #12: Steamboats

Overview: This experiment provides a creative way to see how steam can provide power and offer us insight into how power is generated through this common means.

What to Learn: Many natural resources can meet our energy needs. We need to convert the energy stored in water into energy that we can use as electricity or heat.

Materials

- Copper tubing (1/8”-1/4” dia x 12” long)
- Votive candle
- Foam block
- Scissors or razor (with adult help)
- Bathtub

Lab Time

1. Wrap the copper tubing 2-3 times around a thick marker. You want to create a ”coil” with the tubing. Do this slowly so you don’t kink the tubing. End with two 3” parallel tails. (This is easier if you start in the middle of the tubing and work outwards in both directions.)
2. Stick each tail through a block of foam. Bend the wires so they run along the length of the bottom of the boat, slightly pointed upwards. (You can also use a plastic bottle cut in half.)
3. Position a votive candle on the topside of the boat and angle the coil so it sits right where the flame will be.
4. To start your boat, fill the bathtub with water. While your tub fills, hold the tubing in the running water and completely fill the coil with water.
5. Have your adult helper light the candle. In a moment, you should hear the “putt putt” sounds of the boat working!
6. Record all observations in the worksheet below.

Steamboat Observations

1. How is your boat using energy?

2. Take the weight of your boat using a scale. Then measure the distance it travels. How much work is your steam engine doing? Show your calculations below.

Your steamboat uses a votive candle as a heat source to heat the water inside the copper tubing (which is your boiling chamber). When the water is heated to steam, the steam pushes out the tube at the back with a small burst of energy, which pushes the boat forward.

Since your chamber is small, you only get a short ”puff” of energy. After the steam zips out, it creates a low pressure where it once was inside the tube, and this draws in fresh, cool water from the tub. The candle then heats this new water until steam is produced and POP! it goes out the back, which in turn draws in more cool water to be heated … and on it goes. The ”clicking” or “putt putt” noise you hear is the steam shooting out the back. This goes on until you either run out of water or heat.

Troubleshooting: if your boat doesn’t work, it could be a few things:

- The tubing has an air bubble. In this case, suck on one of the ends like a straw to draw in more water. Heating an air bubble will not make the boat move – it needs to be completely filled with water.
- Your coil is not hot enough. You need the water to turn into steam, and in order for this to happen, you have to heat the coil as hot as you can. Move the coil into a better position to get heat from the flame.
- The exhaust pipes are angled down. You want the steam to move up and out of your pipes, not get sucked back in. Adjust the exit tubing tails so they point slightly upwards.

Reading

Solar cells, wind turbines, and hydroelectric power plants (like the Hoover dam) are all examples of alternative energy sources. Although lots of folks still argue about what’s considered “alternative” or not, the general idea is that the sources produce the same energy at less cost, both money-wise and environmentally.

Scientists are now working on substitutes for traditional methods of generating power. For example, they have figured out ways to use alcohol instead of fossil fuels, coal instead of wood, and petroleum instead of whale oil.

Since alternative energy experiments in this area require power plants and machinery the size of a small town, we’re going to focus on a very specialized form of alternative energy called renewable energy.

Renewable energy is the energy created from natural sources, like sunlight, water, wind, and temperature differences (geothermal). We’ll make solar-powered robots, build solar batteries, light up bulbs using a blast from a hair dryer, and capture the energy in light waves on our battery-free radio.

Steam power may seem like an example of traditional energy usage, when in reality it is able to supply a surprising amount of renewable energy as water is heated in a solar collection tower, geothermal plant, or biomass power station.

Exercises Answer the questions below:

1. Name three sources of renewable or alternative energy:
    a.
    b.
    c.

2. Why is it important to look for renewable sources of energy?

3. What is one example of a fossil fuel?

Lesson #13: Stirling Engine

Overview: The Stirling heat engine is very different from the engine in your car. When Robert Stirling invented the first Stirling engine in 1816, he thought it would be much more efficient than a gasoline or diesel engine. However, these heat engines are used only where quiet engines are required, such as in submarines or in generators for sailboats. You're going to make one out of soda cans and old CDs.

What to Learn: A Stirling engine shows us how energy is converted and used to do work for us.

Materials

- three soda cans
- old inner tube from a bike wheel
- super glue and instant dry
- electrical wire (3- conductor solid wire)
- 3 old CDs
- one balloon
- penny
- nylon bushing (from hardware store)
- small candle or alcohol burner
- fishing line (15lb. test or similar)
- pack of steel wool
- drill with 1/16″ bit
- pliers
- scissors
- razor
- wire cutters
- electrical tape
- push pin
- permanent marker
- Swiss army knife (with can opener option)

Lab Time

1. Open each soda can and empty the soda. Remove the top of one soda can with your can opener. This work most easily by moving along the ridge on the can's lid. Be careful not to cut yourself, so use adult supervision.
2. Take the top off the second can in the same way, and then remove the bottom of the second can completely, about ¾ inch above the bottom. Use a sharp razor.
3. Cut the neck off a balloon to serve as the piston, and fit it over the lid of the can open at the top. Use a rubber band to attach it at the top if needed. Now cut a square out of the inner tube that measures ¾ inch on each side. Glue the tube square on the center of the balloon and push down so it stays. To dry it quickly, spray instant dry on it.
4. Take a pushpin and poke a hole in the center of the tube square. Set the can aside.
5. Take a water bottle cap and mark where we will drill holes. Mark one spot on the side of the cap (about halfway up) and at an equal spot opposite. Also make a mark in the center of the cap. *Drill the holes with adult help*, using pliers and a piece of wood to help make precise holes.
6. Attach the bottle cap to the opposite side of the diaphragm on the soda can (on the bottom), so take the balloon off, and flip it upside down, stretching it over the lid again. The point of the pushpin should point up, so thread it through the hole in the middle of the cap. Secure it with glue, and use instant dry. Set this aside.
7. Grab the other can and prepare it for drilling. Make a mark about 1 inch down from the top of the can, and make a similar mark on the exact opposite side of the can. Drill the holes, using a piece of wood to help support the can if needed. *Remember to use adult supervision!*
8. Use the circular template and tape it in place to cut a viewing hole. You want the template secured so that it is not on the same side as the holes. Mark an outline where you will cut, and use a razor to cut it out.

9. Bend the wire in the shape of the crankshaft according to the template. Use pliers to help, cutting the wire to about 8 inches to ensure a precise fit. Bend it with your fingers to match the template. Make two marks according to the template and make marks on the wire. At this point, you will bend the loop in the crankshaft 90 degrees, using two pairs of pliers this time. Make sure the ends of the crankshaft are as flat and straight as possible. Orient and place the wire inside the can with the viewing hole cut out. Check to make sure it can spin freely. Secure the ends with pieces of tape to stop it from sliding out.
10. To make the displacer, take a 16-inch piece of copper wire, straightening it as much as possible. Use pliers to create a small hook of about ½ inch. Use steel wool to roll the wire up. It should be the diameter of the soda can once rolled up. Check that it fits into the bottom of the soda can with enough clearance to fit in and out fairly easily. Use the pliers to work the copper wire to the height of the can.
11. Take your fishing line and cut off a few inches, tying it onto the loop of the wire in the displacer. Secure it with superglue and instant dry if necessary. Thread the fishing line through the diaphragm. Before you do this, take the diaphragm off and put it back on upside down, and pull the pushpin out, threading the fishing line that the pushpin made. Place some oil around the wire so that it slides more easily. Test it to see that there is no drag when you lift the whole displacer.
12. Nudge the displacer into the top of the soda can with the top cut off. Put the diaphragm over the top of the can, making sure the bottle cap is centered. Test again to make sure the displacer falls freely. If it doesn't add more oil.
13. Take about 8 inches of copper wire and stick it through the holes in the sides of the bottle cap. Bend each side of it with pliers. Make sure it can spin freely, so leave a gap on each side of the cap. Use pliers again to bend the sides of the wires in towards the center of the cap, and then again so that it can fit inside the other can. Both sides of the wire should touch the crankshaft in the can above.
14. Press the top can down around the bottom can gently. Don't crush the can; we only want to ease it down a bit further so that it is secure.
15. Secure the crank to the pushrods by orienting the long part towards the bottom of the can. Make a mark about ½ inch higher than the spot where it rests on the crank. Trim the rods at these marks with wire cutters. Allow the connecting rods to stick out the front, mark them about ¼ inch from the end, and make hooks at these spots. Bend the hooks with pliers so that they stay on the crank. Loop the hooks around the crank so that when spun, the push rods allow the displacer to move up and down. Make sure the crank turns freely. If your balloon wants to push the rods up into the crank too far, simply bend the corners in the push rods more sharply to shorten the rods. Be careful that the fishing line doesn't get caught.
16. Tie the fishing line to the middle of the big loop on the crank. Make sure the knot isn't so tight that it restricts the free movement of the crank as it turns. Tape the two strands of fishing line together, and trim the loose ends of the line with scissors.
17. To make the flywheel, grab 3 old CDs or DVDs (anything by Michael Bay will work). Take your piece of nylon bushing, which should be about ½ in diameter and 1 inch long. It should fit through the center of the CD. Attach the CDs to the bushing (make sure it fits nice and snug).
18. Sand the end of the crankshaft so that it glues more easily. Hot glue this side to the nylon bushing, generously gluing through the center of the bushing. Check to see that the flywheel spinning will crank the engine.
19. Position the crank so that the large crank is facing downward. Attach a penny to the top surface of the CD to serve as a counterweight. This will allow the engine to run more smoothly.
20. To make the engine's base, cut the top and bottom off a can as we did before. Place a burner on the inside at the bottom, and then tape it to the can. Make a hole for air with the razor in the side of the can at about the level of the flame. Cut a few more holes in the side. They should be big enough so that you can light the burner.

21. Assemble the engine on top of the burner base. Now we're ready to test this thing, so remember to put on safety goggles! Use a lighter to light the burner, and keep a hand on the top of the can to keep it steady. If you need to give your engine a jump start, spin the flywheel.
22. Record your observations on the worksheet.

Stirling Engine Observations

1. What happens when you start the engine? What is going on?

2. Grab a cold bottle of water and pour a small amount into the top of the bottle cap. What happens? Why does this happen?

This engine was developed because it was quiet and could use almost anything as a heat source. This kind of heat engine squishes and expands air to do mechanical work. There's a heat source (the candle) that adds energy to your system, and the result is your shaft spins (CD).

This engine converts the expansion and compression of gases into something that moves (the piston) and rotates (the crankshaft). Your car engine uses internal combustion to generate the expansion and compression cycles, whereas this heat engine has an external heat source.

Reading

Here's how a Stirling engine is different from the internal-combustion engine inside your car. For example, the gases inside a Stirling engine never leave the engine because it's an external combustion engine. This heat engine does not have exhaust valves as there are no explosions taking place, which is why Stirling engines are quieter. They use heat sources that are outside the engine, which opens up a wide range of possibilities from candles to solar energy to gasoline to the heat from your hand.

There are lots of different styles of Stirling engines. In this project, we'll learn about the Stirling cycle and see how to build a simple heat engine out of soda cans. The main idea behind the Stirling engine is that a certain volume of gas remains inside the engine and gets heated and cooled, causing the crankshaft to turn. The gases never leave the container (remember – no exhaust valves!), so the gas is constantly changing temperature and pressure to do useful work. When the pressure increases, the temperature also increases. And when the temperature of the gases decreases, the pressure also goes down. (How pressure and temperature are linked together is called the "Ideal Gas Law".)

Some Stirling engines have two pistons where one is heated by an external heat source like a candle and the other is cooled by external cooling like ice. Other displacer-type Stirling engines have one piston and a displacer. The displacer controls when the gas is heated and cooled.

This Stirling engine uses the heat from a coffee cup and the cooling from the ambient air.

In order to work, the heat engine needs a temperature difference between the top and bottom of the cylinder. Some Stirling engines are so sensitive that you can simply use the temperature difference between the air around you and the heat from your hand. Our Stirling engine uses temperature difference between the heat from a candle and ice water.

The balloon at the top of the soda can is actually the "power piston" and is sealed to the can. It bulges up as the gas expands. The displacer is the steel wool in the engine which controls the temperature of the air and allows air to move between the heated and cooled sections of the engine.

When the displacer is near the top of the cylinder, most of the gas inside the engine is heated by the heat source and gas expands (the pressure builds inside the engine, forcing the balloon piston up). When the displacer is near the bottom of the cylinder, most of the gas inside the engine cools and contracts. (The pressure decreases and the balloon piston is allowed to contract.)

Since the heat engine only makes power during the first part of the cycle, there's only two ways to increase the power output: You can either increase the temperature of the gas (by using a hotter heat source), or by cooling the gases further by removing more heat (using something colder than ice).

Since the heat source is outside the cylinder, there's a delay for the engine to respond to an increase or decrease in the heat or cooling source. If you use only water to cool your heat engine and suddenly pop an ice cube in the water, you'll notice that it takes five to fifteen seconds to increase speed. The reason is because it takes time for the additional heat (or removal of heat by cooling) to make it through the cylinder walls and into the gas inside the engine. So Stirling engines can't change the power output quickly. This would be a problem when getting on the freeway!

In recent years, scientists have looked to this engine again as a possibility, as gas and oil prices rise, and exhaust and pollutants are a concern for the environment. Since you can use nearly any heat source, it's easy to pick one that has a low-fume output to power this engine. Scientists and engineers are working on a model that uses a

Stirling engine in conjunction with an internal-combustion engine in a hybrid vehicle… maybe we'll see these on the road someday!

Exercises Answer the questions below:

1. What is the primary input of energy for the Stirling engine?

2. As Pressure increases in a gas, what happens to temperature?
   a. It increases
   b. Nothing
   c. It decreases
   d. It increases, then decreases
3. What is the primary output of the Stirling engine?

Lesson #14: Peanut Energy

Overview: Put your safety goggles on for today's lab –we'll be looking at fire again. You'll be measuring how much energy a peanut holds by setting it on fire and measuring an increase in water temperature.

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
- Test tube in wire test tube holders (these look like pliers that are designed to hold a test tube)
- Scale
- Thermometer

Lab Time

1. Today we're working with fire, so follow all special instructions provided about working with fire today.
2. Measure your test tube on the scale when it's empty: ______________________ grams
3. Fill up your test tube with about 10 grams of water and weigh it again: ______________________ grams
4. Measure the initial temperature of the water: __________________________ ^{o}C
5. Put on safety goggles.
6. Using a small pair of pliers, hold the peanut and ask an adult to light the peanut with the lighter until it catches fire.
7. Upon ignition (when the peanut is burning by itself and doesn't need the lighter), hold the peanut under the water close to the bottom of the test tube until the peanut stops burning.
8. Quickly measure the final temperature of the water: __________________________ ^{o}C
9. Record your results on the worksheet.
10. Allow the peanut to cool as you record your observations and complete the data tables.

Let's take an example measurement. Suppose you measured a temperature increase from 20 °C to 100 °C for 10 grams of water, and boiled off 2 grams. We need to break this problem down into two parts - the first part deals with the temperature increase, and the second deals with the water escaping as vapor.

The first basic heat equation is this: $Q = m\ c\ T$

> Q is the heat flow (in calories)
> m is the mass of the water (in grams)
> c is the specific heat of water (which is 1 degree per calorie per gram)
> and T is the temperature change (in degrees)
>
> So our equation becomes: $Q = 10 * 1 * 80 = 800$ calories.

If you measured that we boiled off 2 grams of water, your equation would look like this for heat energy: $Q = L\ m$

> L is the latent heat of vaporization of water (L= 540 calories per gram)
> m is the mass of the water (in grams)
>
> So our equation becomes: $Q = 540 * 2 = 1080$ calories.

The total energy needed is the sum of these two:

> Q = 800 calories + 1080 calories = **1880 calories.**

Reading

Did you know that eating a single peanut will power your brain for 30 minutes? The energy in a peanut also produces a large amount of energy when burned in a flame, which can be used to boil water and measure energy.

Peanuts are part of the bean family, and actually grow underground (not from trees like almonds or walnuts). In addition to your lunchtime sandwich, peanuts are also used in woman's cosmetics, certain plastics, paint dyes, and also when making nitroglycerin.

What makes up a peanut? Inside you'll find a lot of fats (most of them unsaturated) and antioxidants (as much as found in berries). And more than half of all the peanuts Americans eat are produced in Alabama. We're going to learn how to release the energy inside a peanut and how to measure it.

There's chemical energy stored inside a peanut, which gets transformed into heat energy when you ignite it. This heat flows to raise the water temperature, which you can measure with a thermometer. You should find that your peanut contains 1500-2100 calories of energy! Now don't panic - this isn't the same as the number of calories you're allowed to eat in a day. The average person aims to eat around 2,000 Calories (with a capital "C"). 1 Calorie = 1,000 calories. So each peanut contains 1.5-2.1 Calories of energy (the kind you eat in a day). Do you see the difference?

So did all the energy from the peanut go straight to the water, or did it leak somewhere else, too? The heat actually warmed up the nearby air, too, but we weren't able to measure that. If you were a food scientist, you'd use a nifty little device known as a *bomb calorimeter* to measure calorie content. It's basically a well-insulated, well-sealed device that catches nearly ***all*** the energy and flows it to the water, so you get a much more accurate temperature reading. (Using a bomb calorimeter, you'd get 6.1-6.8 Calories of energy from one peanut!)

Peanut Energy Data and Observations

Trial #	Mass of Water (grams)	Temperature Increase (^oC)	Heat Energy 1 (calories)
Sample	*10 grams*	*80 ^oC*	*= (10 grams) x (1 degree per cal per gram) x 80 (^oC) = 800 calories*

Trial #	Mass of Water Boiled Off (grams)	Heat Energy 2 (calories)
Sample	*2 grams*	*=542calories per gram x 2 grams = 1080 calories*

Trial #	Heat Energy 1 (calories)	Heat Energy 2 (calories)	Total Energy Produced (calories)
Sample	*800 cal*	*1080 cal*	*1880 Calories*

Part 2 Evaluation

Student Worksheet

Overview: Today you're going to take two different tests: the quiz and the lab practical. You're going to take the written quiz first, and the lab practical at the end of this lab. The lab practical isn't a paper test – it's where you get to show your teacher that you know how to do something.

Lab Test & Homework

1. Your teacher will call you up so you can share how much you understand about Energy and how it works. Since science is so much more than just reading a book or circling the right answer, this is an important part of the test to find out what you really understand.
2. While you are waiting for your turn to show your teacher how much of this stuff you already know, you get to get started on your homework assignment. The assignment is due next week, and half the credit is for creativity and the other half is for content, so really let your imagination fly as you work through it. Choose one:
   a. Write a short story or skit about energy, power, or work from the perspective of the object (like a ball or pendulum or roller coaster). You'll read this aloud to your class.
   b. Make a poster that teaches the main concepts of kinetic and potential energy. When you're finished, you'll use it to teach to a class in the younger grades and demonstrate each of the principles that you've learned.
   c. Write and perform a poem or song about work, power, and/or energy. This will be performed for your class.

Part 2 Quiz

Name____

1. What type of heat energy is transmitted by the sun?
    a. Conduction
    b. Convection
    c. Plasma
    d. Radiation
2. Circle the following phenomena influenced by the sun:
    a. Pressure
    b. Climate
    c. Weather
    d. Wind
3. When you read amps, you read:
    a. Current
    b. Voltage
    c. Power Draw
    d. Work
4. Name three sources of renewable energy:
    a.
    b.
    c.
5. What units do we use to measure energy?
    a. Kilowatts
    b. Joules
    c. Newtons
    d. Kilowatt-hours
6. True or False: Water is poor at absorbing heat energy.
    a. True
    b. False
7. True or False: A molecule that heats up will move faster.
    a. True
    b. False
8. True or False: A material will be less dense at lower temperatures.
    a. True
    b. False
9. If something has a weight of 2 Newtons and is moved half a meter, how many Joules of energy are used? Show your work.

10. What is work?
    a. Force divided by distance
    b. Force times distance
    c. Energy required for power
    d. Kinetic and potential energy
11. What is power?
    a. Work divided by time
    b. Work multiplied by time
    c. Energy used in an exercise
    d. Calories over time
12. Why is it important to look for renewable sources of energy?

Part 2 Lab Practical

Student Worksheet

This is your chance to show how much you have picked up on important key concepts, and if there are any holes. You also will be working on a homework assignment as you do this test individually with a teacher.

Materials:

- Something that weighs 100 grams (like an apple)
- A meter stick
- A calculator
- Scale

Lab Practical:

You will demonstrate that you know how energy is measured and how work is done using the materials.

1. In your own words describe what work is.

2. Measure the weight of the object in grams. Record your measurement here:

3. Move the object one meter 5 times. How much work did you do? Record your data here:

Answers to Exercises

Lesson 1: Can solar energy be concentrated?

1. Name three uses for solar energy: (electricity, air conditioning/climate control, water treatment, solar furnace, oven
2. What type of heat energy is transmitted by the sun? (radiation)
3. Circle all the following phenomena influenced by the sun: (wind, climate, weather)

Lesson 2: Solar Battery

1. The sunlight causes the electrons to flow from the cuprous oxide because of the: (photoelectric effect)
2. What material do most solar cells use instead of copper? (silicon)
3. What part of the electromagnetic spectrum is most active in this experiment? (UV light)
4. When you read amps, you read: (current)

Lesson 3: Solar Drinking Bird

1. Where does most of the energy on earth come from? (the sun)
2. What is one way that we use energy from the sun? (plants, solar power)
3. What is the process by which the liquid is being heated inside the bird? (evaporation)

Lesson 4: Can wind be used as a source of energy?

1. Name three sources of renewable energy: (solar, hydropower, biomass, wind, geothermal)
2. What does the sun have to do with wind? (creates areas of higher and lower pressure air by heating them, which makes the air move as wind)
3. Name three examples of wind power in historical or current usage: (windmills, sailing, electricity)

Lesson 5: Wind Turbine

1. True or false: Electricity in a wind turbine is created by magnets in the turbine: (true)
2. What is one advantage of using wind for electricity? (no pollution, less reliance on fossil fuels)
3. What might be one problem with constructing wind farms to meet all our energy needs? (might kill birds)

Lesson 6: Can water be used to store energy?

1. What type of heat transfer is at work in a solar pond? (convection)
2. What units do we use to measure energy? (Joules)

3. Draw a diagram of a solar pond in the space below: (should show salt water on bottom, layer of fresh water, and heat stored in the upper layer by the sun's rays from above)

Lesson 7: Fire Water Balloon

1. What is specific heat? (the amount of heat energy that material must absorb to increase in temperature 1 degree C)
2. Name two types of heat energy (conduction, convection, and radiation)
3. What type (or types) of heat energy is at work in today's experiment? (radiation and convection)
4. True or False: Water is poor at absorbing heat energy. (false)

Lesson 8: Balloon Gymnastics

1. Draw a group of molecules at a very cold temperature in the space below. Use circles to represent each molecule. (should be grouped very tightly)
2. True or False: A molecule that heats up will move faster (true)
3. True or False: A material will be less dense at lower temperatures (false)

Lesson 9: Ghost Coin

1. When a gas turns into a liquid, this is called: (condensation)
2. When water boils, what happens to the bonds between its molecules? (They snap or break.)
3. What is the best way to describe how the bonds between water molecules behave when in a liquid state? (rubber bands or elastic)
4. The crystalline shape of a solid is referred to as: (a matrix)

Lesson 10: What's a Joule?

1. If something has a weight of 2 Newtons and is moved half a meter, how many Joules of energy are expended? (1 Joule)
2. What is the source of all this energy we're working with here? (the sun)
3. It doesn't count as work when you move the apple back down. Why not? (The force of gravity does the work, not your arm.)

Lesson 11: Measuring Power

1. What is work? (force times distance)
2. What is power? (work over time)
3. How do we measure work? Name one unit. (Joule, calorie)
4. How do we measure power? Name one unit. (Watt, horsepower)

Lesson 12: Steamboats

1. Name three sources of renewable or alternative energy: (wind, solar, water, geothermal, wave, tide, biomass)
2. Why is it important to look for renewable sources of energy? (Because other sources like fossil fuels are finite and will run out.)
3. What is one example of a fossil fuel? (coal, oil, natural gas)

Lesson 13: Stirling Engine

1. What is the primary input of energy for the Stirling engine? (the candle)
2. As Pressure increases in a gas, what happens to temperature? (It increases.)
3. What is the primary output of the Stirling engine? (the moving piston)

Vocabulary for the Unit

Alternative energy is energy obtained from non-fossil fuel sources. This is also known as renewable energy.

Conduction is heat energy transferred directly between substances.

Convection is heat energy exchanged through intermediary molecules.

Energy is the ability to do work.

Joule is the standard unit used to measure energy, defined as one Newton of force moved over 1 meter.

Kinetic energy is the energy of motion that an object has when it is pushed, flies, or falls.

Potential energy is the energy that an object has in relation to the system in which it exists.

Power is work done over a period of time.

Specific heat is how much heat energy a mass of a material must absorb before it increases 1°C.

Radiation is energy transmitted through the electromagnetic spectrum, on our planet from the sun.