SUPERCHARGED SCIENCE

Unit 12: Alternative Energy

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Appropriate for Grades:
K-12 (see notes on each project)
Duration: 5-40 hours, depending on how many activities you do!

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. In this unit, we're going to explore ways to get power from the sun, wind, magnetism, and molecules by studying solar batteries, wind turbines, crystal radios, fuel cells, and more.

NOTE: Make sure you complete Unit 8 (Chemistry), Unit 9 (Light), Unit 10 (Electricity), and Unit 11 (Magnetism) before starting here. This unit builds on principles from those previous units.

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Materials for Experiments

This Unit is a bit different from the rest. While we usually try to keep the materials simple for you, some of these materials are *not* your everyday items. The experiments for Lesson 1 (Basic Alternative Energy) are mostly everyday items, however Lesson 2 experiments (Advanced Alternative Energy) require specialized equipment, so you'll want to pick which experiments you want to do before buying the materials.

NOTE: This material list is for the entire Experiment section online.

Lesson 1 Experiments:

Bags (zipper-close and plastic)
balloon
batteries, AA-size
bottle, plastic two-liter
bowl, plastic
clay, modeling
corn syrup
measuring cups and spoons
cups (paper, plastic, and Styrofoam)
earphone or headset
Epsom salt
Small electric fan
Flowerpot with saucer (unglazed ceramic)
Aluminum foil
funnel
grass clippings, freshly cut
hole punch
ice chest or cooler or freezer
glass jars or water glass
lamp with incandescent bulb
Lysol spray
magnifying lens
match or lighter
mitt, insulated
newspaper
oven
black paint with paintbrush or black spray paint
paper clips
white copy paper
peanut (shelled)
penny
aluminum pie pan
pinwheel
plate
pliers
shoebox
silicon solar cell
sink
aluminum
soft drink can
spoons
straw
string
tape
tea bags
thermometer
tomato juice
watch or clock
water
wires with alligator clips

Lesson 2 Experiments:

We've broken the materials down in this list by project, so you'll find overlap between the different projects. Most projects take a bit of time to do – they're not like the quick 5-minute activities you have seen so far.

We'll be re-using items from Units 10 and 11 here, like motors, lights, battery packs, wires, and electrical components. If you already have these parts, simply scratch them off this list (below).

Solar Battery

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

Solar Oven

- 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)

Marshmallow Roaster

- 7x10" page magnifier (Fresnel lens)
- Cardboard box, about a 10" cube
- Aluminum foil
- Hot glue, razor, scissors, tape
- Wooden skewers (BBQ-style)
- Chocolate, marshmallows, & graham crackers

BristleBot

- Old toothbrush
- Tiny vibrator motor from Radio Shack or Solorbotics (you can also rip one out of an old cell phone) or use a disk motor
- Small watch battery

Solar Vehicles

- Multi-meter
- Solar Project Kit (Radio Shack #22-1201) or other solar cell with motor (usually sold in hobby stores) with gear set
- Foam block (about 6" long)
- 2 straws (optional)
- 2 wooden skewers (optional)
- 4 milk jug lids or film can tops

Wind Turbine

- A digital Multi-meter
- 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)
- Propeller from old toy or cheap fan

Fruit Batteries

- Apple, lemon, grapefruit, lime, potato, or other fruit/vegetable
- Digital multi-meter
- Alligator wires (RS #278-1156)
- Zinc plate, galvanized nail
- Copper plate (1/2" x 2") or shiny copper penny (you can scrub a tarnished penny with ketchup to shine it up)

Steamboats

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

For Grades 9-12:

Stirling Engine

- Three diet shake tin cans (Slim Fast, Adkins, etc.)
- Three soft drink aluminum cans (one of which is a taller 12 oz beer can if available)
- JB Weld Epoxy
- Red High-Temp RTV Silicon Gasket Maker
- 2" or longer straight pin (e.g. yarn darner)
- 3/4" to 1/2" PVC elbow (outer diameters are 1-1/4" and 1" respectively)
- Small balloon
- Flat washer and nut
- Metal coat hanger
- Old CD
- Wire nut to connect coat hanger to CD (optional)
- Wooden base and wood screws (optional)
- Tools: tin snips or stainless steel scissors, pliers, can opener, hammer

Crystal Radio

- Toilet paper tube
- Magnet wire (Radio Shack part #278-1345)
- Germanium diode (1N34A) (Radio Shack part #276-1123)
- Alligator clip test leads (Radio Shack part #278-1157)
- 100' stranded insulated wire (for the antenna)
- Scrap of cardboard
- Brass fasteners (3-4)
- Telephone handset or get a crystal earphone from C. Crane (part #EKI) – they also carry the germanium diode if Radio Shack doesn't have it.

Fuel Cells

Fuel Cell Car Kit (Item# KT-FUELCCK from www.hometrainingtools.com). This kit is a bit expensive, but if you want to build a car that runs entirely from sunlight and water, this is the one you want to get. The company that makes this particular model also sells the conversion kits for (real!) cars. Great starter kit for kids interested in fuel cell technology - after kids get the hang of how it works, they can up the power and perhaps use it on a go-cart?

Beam Robots

- Tiny eccentric motor from Radio Shack or Solorbotics (you can also rip one out of an old cell phone)
- Vibrating disk motor from Radio Shack or Solarbotics (you can also rip one out of an old cell phone)
- Two 2.2k-Ohm resistors from Radio Shack or Solarbotics
- Six 4700 µf electrolysitc capacitors
- Two PNP 3906 transistors from Radio Shack or Solarbotics (get a few extras, as these are the first things to burn out)
- Twp NPN 3904 transistors from Radio Shack or Solarbotics (get a few extras, as these are the first things to burn out)
- Two voltage triggers from Solarbotics (get the 1380-G or J or N)
- Two 37x33mm solar cells from Solarbotics (we won't be using the circuit on the back - just the solar cell)
- Paper clips (a few of each: small and large)
- Hot glue gun, soldering iron with solder, electrical tape
- Pliers, wire cutters, diagonal cutters (if you have them)

Optional Beam Robots: After you've built the BEAM robots above, you can move onto more advanced designs. Here's the parts you'll need for them:

- Solar Roller
- Trimet
- Miniball

Key Vocabulary

BEAM robots use solar cells to store energy from the sun into capacitors (think electricity storage tanks) until the tanks are full (which is when the robot starts to move). Instead of having complicated brains, they rely on nervous-system type of sensors to interact with their world.

The source of power in an AM **crystal radio** comes directly from the radio waves themselves.

Molecules can also be split chemically, or by getting hit by a fast-moving particle. It takes energy to split a water molecule, called **electrolysis**.

Energy is the ability to do work. Energy can be transferred, in other words it can be changed from one form to another and from one object to another.

When you combine oxygen and hydrogen atoms together, it makes water and a puff of energy. That's what a **fuel cell** does.

A propeller placed in a moving fluid will turn a motor shaft (which has coils of wire and magnets inside). The faster the shaft turns, the more the magnets create an electrical current. This is how a **generator** works.

Power measures how quickly work can be done. Mathematically, power is work divided by time. Power can be measured in horsepower or Watts.

Renewable energy is the energy created from natural sources, like sunlight, water, wind, and temperature differences (geothermal).

A **solar cell** converts sunlight straight into electricity. Solar cells are usually made of silicon. Light (photons) hit a solar cell and get absorbed, knocking electrons out of their shell, which start flowing through the silicon to create DC current.

Work is moving something against a force over a distance. Mathematically, work = force x distance. Work can be measured in Joules or calories.

Unit Description

Earth, our home in space, has supported life for a long time. But with a growing human population, people are having a greater effect on the environment than ever before. Together we must learn about the problems facing our environment and work to protect the earth.

There are many ways we can work together to protect the earth. We can ask adults to use more fuel-efficient cars (cars that get more miles per gallon of gasoline). We can ride bikes or walk instead of getting rides in cars. We can recycle aluminum, paper, plastic, and glass, and we can plant trees. We can save energy by turning off lights when they are not in use. We can save energy by not keeping rooms and buildings too hot in the winter or too cold in the summer. Another way we can help the earth is to learn more about the environment.

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.

This unit is designed to help you better understand our environment by doing experiments with air, water, land, energy, and life. It’s your guide to doing, observing, and thinking about your environment.

By understanding our environment, we can learn to protect the earth and to use our natural resources wisely for generations to come.

Objectives

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 be making 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.

We're also going to study the energy locked in substances by learning how to split the water molecule and extracting the energy using fuel cells and electrochemistry. We'll also have a peek at the power from steam and how apples can power your clocks.

How many of these things do you remember from our previous lessons?

- Energy is the ability to do work.
- Work is moving something against a force over a distance.
- Power measures how quickly work can be done.

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 learn how to tap into the potential that's all around you.

Highlights:

- A solar cell converts sunlight straight into electricity.
- Solar cells are usually made of silicon.
- Light (photons) hit a solar cell and get absorbed, knocking electrons out of their shell, which start flowing through the silicon to create DC current.
- A propeller placed in a moving fluid will turn a motor shaft (which has coils of wire and magnets inside). The faster the shaft turns, the more the magnets create an electrical current.
- The source of power in an AM (crystal) radio comes directly from the radio waves themselves.
- Molecules can also be split chemically, or by getting hit

by a fast-moving particle. It takes energy to split a water molecule (electrolysis).

- When you combine oxygen and hydrogen atoms together, it makes water and a puff of energy. (That's what a fuel cell does.)
- BEAM robots use solar cells to store energy from the sun into capacitors (think electricity storage tanks) until the tanks are full (which is when the robot starts to move). Instead of having complicated brains, they rely on nervous-system type of sensors to interact with their world.

Textbook Reading

Lesson 1: Basics of Alternative Energy

Earth, our home in space, has supported life for a long time. But with a growing human population, people are having a greater effect on the environment than ever before. Together we must learn about the problems facing our environment and work to protect the earth.

There are many ways we can work together to protect the earth. We can ask adults to use more fuel-efficient cars (cars that get more miles per gallon of gasoline). We can ride bikes or walk instead of getting rides in cars. We can recycle aluminum, paper, plastic, and glass, and we can plant trees. We can save energy by turning off lights when they are not in use. We can save energy by not keeping rooms and buildings too hot in the winter or too cold in the summer. Another way we can help the earth is to learn more about the environment.

This lesson is designed to help you better understand our environment by doing experiments with air, water, land, energy, and life. It's your guide to doing, observing, and thinking about your environment.

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Atoms and Molecules

Understanding something about atoms and molecules will help you understand our environment.

Everything in the world around us is made of atoms and molecules. We talked about this in Units 3 and 8 extensively, but here's a quick review:

Atoms are the basic building blocks of all things. There are about 100 different kinds of atoms. Molecules are combinations of tightly bound atoms. For example, a water molecule is a combination of two hydrogen atoms and one oxygen atom.

Molecules that are made of only a few atoms are very small. Just one drop of water contains about two million quadrillion (2,000,000,000,000,000,000,000) water molecules.

Polymers are large molecules that may contain millions of atoms. Important natural polymers include natural rubber, starch, and DNA. Some important artificial polymers are nylon, which is used in making fabrics; polyethylene, which is used in making plastic bags and plastic bottles; and polystyrene, which is used in making styrofoam cups and insulation.

Atoms are made of smaller particles called electrons, protons, and neutrons. The nucleus is the center of the atom and contains protons and neutrons. Protons are positively charged, and neutrons have no charge. Electrons are negatively charged and surround the nucleus and give the atom its size.

Atoms and molecules that are charged are called ions. Ions have either a positive charge or a negative charge. Positive ions have more protons than electrons. Negative ions have more electrons than protons.

Sodium chloride, which is the chemical name for table salt, is made of positive sodium ions and negative chlorine ions.

Atoms, ions, and molecules can combine in chemical reactions to make new substances. Chemical reactions can change one substance into another or break one substance down into smaller parts of molecules, atoms, or ions.

A Note about Science and Experiments

One way to learn more about the environment and science is to do experiments. Science experiments provide a way of asking questions and finding answers. The results that come from experiments and observations increase our knowledge and improve our understanding of the world around us.

Science will never have all the answers because there are always new questions to ask. However, science is the most important way we gather new knowledge about our world.

Not every experiment you do will work the way you expect every time. Something may be different in the experiment when you do it. Repeat the experiment if it gives an unexpected result and think about what may be different.

Not all of the experiments in this book give immediate results. Some experiments in this book will take time to see observable results. Some of the experiments may take a shorter time than that suggested in the experiment. Some experiments may take a longer time than suggested.

Science is not merely a collection of facts, but a way of thinking. You can play a key role in maintaining and encouraging someone's interest in science and the surrounding world by sharing what you know with them in a way that really makes them want to know more.

Energy, Temperature and Heat

Without the sun, there would be no life on Earth. The sun warms the earth, generates wind, and carries water into the air to produce rain and snow. The energy of the sun provides sunlight for all the plant life on our planet, and through plants provides energy for all animals.

The sun is like a giant furnace in which hydrogen nuclei (atoms without electrons) are constantly smashed together to form helium nuclei. This process is called nuclear fusion. In this process, 3.6 billion kilograms (8 billion pounds) of matter are converted to pure energy every second. The temperature in the sun exceeds 15 million degrees.

Nuclear fusion is one kind of energy. Other forms of energy include: mechanical energy, heat, electrical energy, chemical energy, and light. Mechanical energy is the energy of organized motion, such as a turning wheel. Heat is the energy of random motion, such as a cup of hot water. Electrical energy is the energy of moving charged particles or electrons, such as a current in a wire. Chemical energy is the energy stored in bonds that hold atoms together. Light is any form of electromagnetic waves, such as X rays, microwaves, radio waves, ultraviolet light, or visible light.

Energy can be converted from one from to another. For example, the nuclear energy of the sun is converted to light, which goes through space to the earth. Solar collectors of mirrors can be used to focus some of that light to heat water to steam. This steam can be used to turn a turbine, which can power a generator to produce electricity.

Most of our energy needs are met by burning fossil fuels such as coal, oil, gasoline, and natural gas. The chemical energy stored in these substances is released by burning these fuels. When fossil fuels burn, they combine with oxygen in the air and produce heat and light.

Fossil fuels are not renewable. When they are used up, they are gone forever. However, renewable energy sources such as wind, sun, geothermal, biomass and water power are renewable. They can be used over and over to generate the energy to run our society.

Tremendous amounts of renewable energy are available. For example, the solar energy that falls on just the road surfaces in the United States is equal to the entire energy needs of the country. Although there are sufficient amounts of renewable energy, we must improve our methods of collecting, concentrating, and converting renewable energy into useful forms.

Sources and Savings of Energy

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 I 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 sixteen thousand (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.

Cooling and Heating

Cooling and heating are opposite processes. Cooling is the removal of heat energy from an object or space and heating is the addition of heat energy to an object or space. We use these opposite processes a great deal in our daily lives. For example, in the kitchen we use the cooling provided by a refrigerator to keep food cold. We also use the heat from a stove to cook food.

Nearly 75 percent of the energy used by the average family household in the United States goes for cooling and heating purposes. Air conditioning and refrigeration are the major cooling requirements of a home, while water and space heating are the most important heating requirements.

Solar Energy

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.

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.

Energy From Biomass

Fossil fuels, which include petroleum, natural gas, and coal, supply nearly 90 percent of the energy needs of the United States and other industrialized nations. Because of their high demand, these nonrenewable energy resources are rapidly being consumed. Some estimates suggest there is only a SOD-year supply of oil and natural gas remaining on Earth. Coal supplies are expected to last about a thousand years.

We must find other sources of energy to meet the increasing fuel demands of modern society. Important alternate sources of energy include: solar, wind, biomass, hydroelectric, geothermal, nuclear, and tidal energy.

One of the benefits of using alternate sources of energy is that many of them are "clean." This means that they do not cause pollution. Also, many alternative energy sources are renewable energy sources. They are replaced naturally-such as plant life-or are readily available - such as the sun and wind. In addition, the use of renewable forms of energy will allow us to stretch out our current supply of fossil fuels so they will last longer.

Plants are the most important biomass energy source. Plant material can be burned directly-as with wood-or it can be converted into a fuel by other means. We'll learn how water can be heated by composting grass, how a peanut burns, and how corn syrup can be made into ethyl alcohol in our experiments for this section.

Lesson 2: Advanced Alternative Energy

Solar Energy

This 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?

There are three different ways to conduct heat energy: conduction, convention, and radiation. When I sit on a cold bench, I *conduct* heat to the bench through touch. Wind chill factor is a form of *convective* heat transfer, and requires a fluid (the wind, in this case) to move the energy (heat) around. *Radiant* heat explains how the sun can warm the earth through the vacuum of space. The sun doesn't need to touch (conductive) the earth or even share in the same fluid atmosphere to transfer the energy (convective) – it warms us up through radiation, or light.

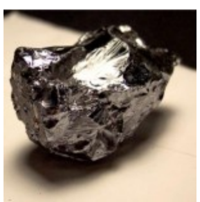
Solar energy (power) refers to collecting this energy and storing it for another use, like driving a car. The sun blasts 174 x 10^{15} watts (which is 174,000,000,000,000,000 watts) of energy through radiation to the earth, but only 70% of that amount actually makes it to the surface. And since the surface 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.

The big leap in technology came in the 1950s when semiconductors were experimented with at Bell Labs.

Today, engineers design space satellites armed with solar panel arrays which continually rotate to track the position of the sun. Solar panels on homes, however, are stationary and reply on the earth's rotation to guide their path.



How does a solar cell work?

Solar cells are usually made of silicon. Sunlight is made of packets of energy called photons (covered in Unit 9). 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 knocked out of orbit, 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 current (more on this in Unit 10).

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.

But how does the silicon *do* that?

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 and 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 knocked out of its shell) and bound electrons (electrons attached to an atom). Electrons can be either free or attached, but it costs a certain amount of energy to go either way (like a toll both).

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 low 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.

Wind and Water Power

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), the propeller turns. If you attach the propeller to a motor shaft, the motor will rotate, which 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! (Refer to Unit 11 for more detail about how moving magnets create electricity.)

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 vehicles.

Battery-Free Radios?

A crystal radio is among the simplest of radio receivers - there's no battery or power source, and nearly no moving parts. The source of power comes directly from the radio waves themselves.

The crystal radio turns the radio signal directly into a signal that the human ear can detect. Your crystal radio detects in the AM band that have been traveling from stations (transmitters) thousands of miles away.

After working with the electromagnetic spectrum in Unit 9 where we played with frequency and wavelengths of light, you'll find that you've got all the basics for picking up AM radio stations using simple equipment from Radio Shack.

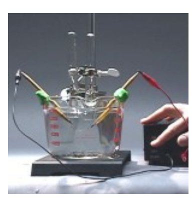
The radio is made up of a tuning coil (magnet wire wrapped around a toilet paper tube), a detector (germanium diode) and crystal earphones, and an antenna wire.

One of the biggest challenges with detecting low-power radio waves is that there is no amplifier on the radio to boost the signal strength. You'll soon figure out that you need to find the quietest spot in your house away from any transmitters (and loud noises) that might interfere with the reception when you build one of these.
One of things you'll have is to figure out the best antenna length to produce the clearest, strongest radio signal in your crystal radio.

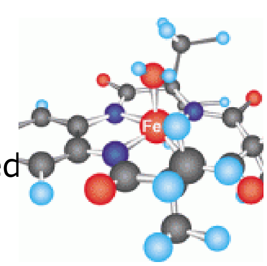
Energy from Molecular Bonds

We're going to use electricity to split the water molecule (H_2O) into hydrogen and oxygen atoms. Molecules can also be split chemically, or by getting hit by a fast-moving particle. When you recombine the hydrogen and oxygen, energy is produced – enough to power a small car.

If you guessed that this has to do with electricity and chemistry, you're right! But you might wonder how they work together. Back in 1800, William Nicholson and Johann Ritter were the first ones to split water into hydrogen and oxygen using electrolysis. (Soon afterward, Ritter went on to figure out electroplating.) They added energy in the form of an electric current into a cup of water and captured the bubbles forming into two separate cups, one for hydrogen and other for oxygen.



It takes energy to split a water molecule. (On the flip side, when you combine oxygen and hydrogen together, it makes water and a puff of energy. That's what a fuel cell does.)



Back to splitting the water molecule – as the electricity zips through your wires, the water molecule breaks apart into smaller pieces: hydrogen ions (positively charged hydrogen) and oxygen ions (negatively charged oxygen). Remember that a battery has a plus and a minus charge to it, and that positive and negative attract each other.

So, the positive hydrogen ions zip over to the negative terminal and form tiny bubbles right on the wire. Same thing happens on the positive battery wire. After a bit of time, the ions form a larger gas bubble.

If you stick a cup over each wire, you can capture the bubbles and when you're ready, ignite each to verify which is which. We covered the basics of electrolysis in Unit 8, and now we're going to show you how to store the energy and use it power a small car in our experiments together.

Energy from Food

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 splits into 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 (charged atoms Na (sodium) and Cl (chlorine) in this case) are attracted to the opposite electrode and there is current in the solution.

Electrochemistry studies chemical reactions that generate a voltage and vice versa (when a voltage drives a chemical reaction), called oxidation and reduction (redox) reactions. 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 (covered in Unit 10). 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.

One of the biggest challenges with fruit batteries is reading an average voltage. Due to the nature of the experiment, the voltage can vary as much as +/- 30%. Does it really matter which fruit we use to power a LED? If so, does it matter *much*? That's what we're going to discover!

BEAM Robots

This is one of the coolest applications of renewable energy to come about in recent years. BEAM stands for Biology, Electronics, Aesthetics, and Mechanics. It basically refers to a class of robots that instead of having complicated brains, rely on nervous-system type of sensors to interact with their world.

Some BEAM robots skitter, dance, flash, jump, roll, or walk, and most are solar powered. The result is a fast responding robot made of old cell phone parts that can fit inside your hand. We'll be making a few different types so you can get a good handle on this type of programming-free, battery-free robotics.

Activities, Experiments, Projects

Note: This section is an abbreviated overview of the experiments online.

Experiment: *Can Solar Energy Be Concentrated?*

Materials

- Lamp with a single incandescent bulb
- Magnifying lens

Procedure

The results of this experiment may be easiest to observe if done at night in a dark room.

Ask an adult to remove the lamp shade 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.

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.

Observations

Does an image of the lamp appear on the wall? How bright is this image? How big is this image?

Discussion

You should see an upside down image of the light bulb appear as you move the magnifying lens away from the wall. The image should be much brighter than the area around it and much smaller than the size of the real bulb. The image may be only about the size of your fingernail or smaller.

The curved shape of the magnifying lens 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 not 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.

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.

Other Things to Try

Trace the exact size and shape of the magnifying lens on a piece of paper. Cut out this piece of paper and tape in on the wall. Focus the image of the lamp on this piece of paper and copy the bulb image on the paper. Compare the size of the bulb image to the size of the piece of paper. How much bigger is the lens than the focused image of the bulb? Use this ratio of sizes to estimate the increase in the brightness of the image.

Can you explain why the image of the bulb is upside down when it is projected on the wall? See if you can find information about optics in a book or encyclopedia that could help you explain this reversal of the image.

Repeat this experiment using two magnifying lenses. Observe the effect of moving the positions of the two lenses relative to each other and the wall.

Experiment: *Can a Salt Be Used for Heating and Cooling?*

Materials

- Epsom salt
- Aluminum pie pan
- Water
- Oven
- Two small, zipper-close,
- Insulated mitt
- plastic bags
- Sink
- Measuring cups

Procedure

Ask an adult to turn on the oven and to set the temperature of the oven to 450° F (232°C). Pour one-half cup of Epsom salt into an aluminum pie pan and gently shake it to evenly spread the Epsom salt over the bottom of the pan. Place the pie pan in the oven. Heat the Epsom salt in the hot oven for thirty minutes.

Ask an adult to remove the pan of Epsom salt from the hot oven using an insulated mitt. Place the pan on the stovetop and allow it to cool for ten minutes. Make sure the oven is turned off.

Add one-quarter cup of the Epsom salt that was not heated in the oven to a small plastic zipper-close bag. Next add one-quarter cup of room temperature water to the bag, seal, and shake the bag. Feel the temperature of the outside of the bag.

Next add one-quarter cup of the cooled Epsom salt that was heated in the oven to the second zipper-close bag. Add one-quarter cup of room temperature water to the bag and seal the bag. Give the bag a couple of shakes and then feel the outside of the bag.

When you are finished with this experiment, pour the contents of both bags down a sink drain. Then flush the bags and the sink with water. Also rinse out the aluminum pie pan with water. DO NOT DRINK ANY OF THE LIQUID AND DO NOT EAT ANY OF THE EPSOM SALT. EPSOM SALT CAN MAKE YOU SICK IF YOU EAT IT.

Observations

Do you notice any difference in the appearance of the Epsom salt after it is heated in the oven? Does the bag containing the water and the Epsom salt that was not heated feel warm or cool after shaking? Does the bag containing the water and the Epsom salt that was heated feel warm or cool after shaking?

Discussion

Epsom salt is a hydrate of the salt called magnesium sulfate. A hydrate is a chemical substance containing water combined with another chemical substance (usually a salt). The water molecules in a hydrate are called waters of hydration. They can usually be removed from the hydrate by heating. The process of removing water from a hydrate is called dehydration.

In this experiment, when you heated the Epsom salt in the oven, you removed most of the water molecules (waters of hydration) in the salt.

A salt is made of positive and negative ions. Ions are charged atoms or groups of atoms. In Epsom salt, magnesium i n r positive and sulfate ions are negative. The waters of hydration surround these ions in Epsom salt.

You should find that the bag containing water and the dehydrated Epsom salt feels warm. The bag containing water and the hydrated Epsom salt feels cool. When dehydrated Epsom salt is mixed with water, heat is given off. When hydrated Epsom salt is mixed with water, heat is absorbed. When something gives off heat it feels warm, while something that absorbs heat feels cool.

Energy is required to remove individual ions from a salt crystal. However, energy is given off when the individual ions that break away from the crystal become surrounded by water molecules that are dissolving the salt. If more energy is required to remove individual ions from a salt crystal than is given off when the ions become surrounded by water, then the salt solution becomes cold. If more energy is given off when the ions become surrounded by water than is needed to remove individual ions from a salt crystal, then the salt solution becomes warm.

When hydrated Epsom salt dissolves in water, more energy is required to remove the magnesium and sulfate ions (and the waters of hydration) from the crystals than is given off when the magnesium and sulfate ions become surrounded by the dissolving water molecules.

This is why the bag containing the unheated Epsom salt became cold when you added water.

On the other hand, when dehydrated Epsom salt dissolves in water, more energy is given off by the ions becoming surrounded by water molecules than is needed to break the magnesium and sulfate ions from the crystals. This is why the bag containing the dehydrated Epsom salt became warm when you added water.

Most instant hot packs and cold packs that are available in drugstores work on the principle just discussed. When the cold or hot pack is needed, the bag is squeezed to cause the water and salt to mix. Depending on the salt used in the pack, energy is either absorbed (cold pack) or given off (hot pack). Ammonium nitrate is the most commonly used salt in cold packs. And calcium chloride is the most commonly used salt in hot packs.

Other Things to Try

Repeat this experiment using a thermometer to measure the temperature change when the Epsom salt is dissolved in water. Use the thermometer to measure the temperature change when dehydrated magnesium sulfate is dissolved in water.

Repeat this experiment using table salt. Do you observe a temperature change when the table salt dissolves in water?

Exercises for Basic Alternative Energy

1. Does it matter the time of day when using a solar cell?
2. What does temperature measure?
3. How can we store energy in water for later use?
4. What are common problems with windmills?
5. What are three different kinds of batteries, and what is their limitation?
6. What is the difference between dehydration and hydration, and why is this important?
7. Name two ways a house can save money on energy bills during the summer.
8. How can we get fuel from a peanut?

Exercises for Advanced Alternative Energy

1. What are three different sources of alternative energy?
2. What's the difference between *alternative* and *renewable* energy?
3. What is power a measure of?
4. What is energy?
5. How does a solar cell work?
6. Where does the power from a crystal radio come from?
7. How does a wind turbine create electricity?
8. Is a motor and generator the same thing?
9. Does the water molecule give energy when you split it apart?
10. Would you get more energy from splitting an atom or a proton?
11. How can a car be powered by only sunlight and water?

Answers to Basic Energy Exercises

1. Does it matter the time of day when using a solar cell? *Yes, the sun's angle to the solar cell will change the power generated.*
2. What does temperature measure? *The average speed of the molecules in a substance.*
3. How can we store energy in water for later use? *A large container of salt water can absorb heat energy during the day and release it during the evening because in a salt water pond, the warmer water is trapped below the surface of the water under an insulating layer and does not escape through convention.*
4. What are common problems with windmills? *No-wind conditions and storms.*
5. What are three different kinds of batteries, and what is their limitation? *Dry cells (found in flashlights and portable radios), mercury batteries (inside cameras and watches), and lead storage batteries (car batteries). Most batteries are non-reversible and cannot be recharged, making them single-use.*
6. What is the difference between dehydration and hydration, and why is this important? *Dehydrated means to remove the water from a substance. Hydrated magnesium sulfate requires heat when combined with water to break the ions, and will become cold (endothermic). Dehydrated magnesium sulfate generates heat when combined with water and becomes warm (exothermic).*
7. Name two ways a house can save money on energy bills during the summer. *With proper insulation to keep the cool air indoors and decrease the heat transfer through walls, windows, and doors; surround the house with shady trees to decrease the air conditioner's work load by keeping the house out of direct sunlight.*
8. How can we get fuel from a peanut? *A peanut is not a nut, but a seed which has proteins, fat, and carbohydrates. The oil (fat and carbs) from the peanut can be ignited and the energy is released in the form of heat and light.*

Answers to Advanced Alternative Energy Exercises

1. Solar cells, wind turbine, hydro (water) power plants, fuel cells.
2. Renewable energy is the energy created from natural sources, like sunlight, water, wind, and temperature differences (geothermal).
3. Power measures how quickly work can be done.
4. Energy is the ability to do work. Work is moving something against a force over a distance.
5. A solar cell converts sunlight straight into electricity by using a special material that allows electrons to be knocked out of their shells when hit by a photon. The free electrons are directed into flow of DV current.
6. The source of power comes directly from the radio waves themselves.
7. Wind turbines spin big coils of wire around very powerful magnets when their propellers (which is attached to the motor shaft) rotate.
8. Yes, they are the same object, but it's how you use them that makes them different. A motor uses electricity (applied to the terminals) to rotate the shaft, and a generator rotates the shaft to create electricity at the terminals. If you spin the shaft of a motor with your fingers, you can measure a voltage at the terminals.
9. No. A water molecule requires energy to split it apart (endothermic reaction). When the opposite occurs - hydrogen and oxygen combine, the reaction is exothermic (gives off energy).
10. *Much* more energy is released from splitting a proton than an atom. The forces that hold together a proton are much greater than the furthers that bind an atom.
11. When you combine oxygen and hydrogen together, it makes water and a puff of energy. That’s what a fuel cell does. Most fuel cells are reversible, meaning that you can fill their tank with water and leave them out (with their solar panel pointed toward the sun), and the solar cell will split apart the water molecule and store the gases in separate tanks. When you're ready to drive your car, the fuel cell switches so it now combines the gases to create electricity to turn the motor (which turn the wheels of the car).

