North Carolina State University

Mechanical Engineering

2014 Instructors
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Engineering Building 3, Rm 2220

Contents

A. INTRODUCTION

SUNDAY: 3:30-5:30 PM – SAS Hall 2203, Meet and greet

ENERGY ENGINEERING SUMMER CAMP					
TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	Friday
9:00 AM	WELCOME	REVIEW	REVIEW	REVIEW	REVIEW
9:30 AM	ENERGY DISC. I	INNOVATION CNTR	ENERGY MANAGE	SOLAR HOUSE	PRESENT
10:00 AM	MAE LABS	INNOVATION CNTR	ENERGY MANAGE	SOLAR HOUSE	PRESENT
10:30 AM	MAE LABS	INNOVATION CNTR	ENERGY MANAGE	SOLAR HOUSE	PRESENT
11:00 AM	LIBRARY	BATTERY FLASHLIGHT	WIND POWER	SOLAR HOUSE	PRESENT
11:30 AM	SOLAR OVEN	BATTERY FLASHLIGHT	WIND POWER	FUEL CELL CAR	
12:00 PM	*LUNCH*	*LUNCH*	*LUNCH*	*LUNCH*	
1:00 PM	SOLAR OVEN	BATTERY FLASHLIGHT	WIND POWER	FUEL CELL CAR	
1:30 PM	SOLAR OVEN	BATTERY FLASHLIGHT	WIND POWER	FUEL CELL CAR	
2:00 PM	SOLAR OVEN	THERMO-ELECTRIC	WIND POWER	FUEL CELL CAR	
2:30 PM	SOLAR OVEN	THERMO-ELECTRIC	WIND POWER	ANALYSIS & PRESENT	
3:00 PM	SOLAR OVEN	THERMO-ELECTRIC	ANALYSIS & PRESENT	ANALYSIS & PRESENT	
3:30 PM	WRAP UP	THERMO-ELECTRIC	ANALYSIS & PRESENT	ANALYSIS & PRESENT	

A.1. Safety Guidelines

During the course of the week you will be working with stuff that is dangerous if proper precautions are not taken. Developing good safety practices is essential for any engineer and will help provide an environment to learn and have fun. At the beginning of each activity, the relevant safety precautions will be discussed. When completing each activity, it is important that all items are neatly returned and stowed. Each activity will have a supply checklist, please **CHECK OUT** and **CHECK IN** all items on the lists.

- If you are unsure if something is hot, or is electrically active, ***do not touch it***.
- If a fire is ignited tell a councilor and immediate leave the location. You should be aware of all fire exits for your room.
- Light can be deceiving and cause permanent eye damage that takes days before the full extent of damage is realized. ***Do not look directly at bright light without proper eye protection.***
- ***We will be using sharp objects***. Please use caution when handling all materials and supplies. If you are cut, please stop what you are doing and let a councilor know so that it can be properly assessed and treated.

A.2. Background on Energy & Energy Conversion Technologies

Largely adapted from Reference 1 & 2

A.2.1. Energy is all around us

We use energy every day. It surrounds us in different forms, such as light, heat, and electricity. Our bodies use the energy stored in molecules of substances like carbohydrates and protein to move, breathe, grow, and think. We also use energy to do work and to play. Humans have invented thousands of machines and appliances that use energy to make our work easier, to heat our homes, and to get ourselves from place to place. Some of these machines use electricity, while others, like automobiles, use the energy stored (potential energy) in substances such as gasoline.

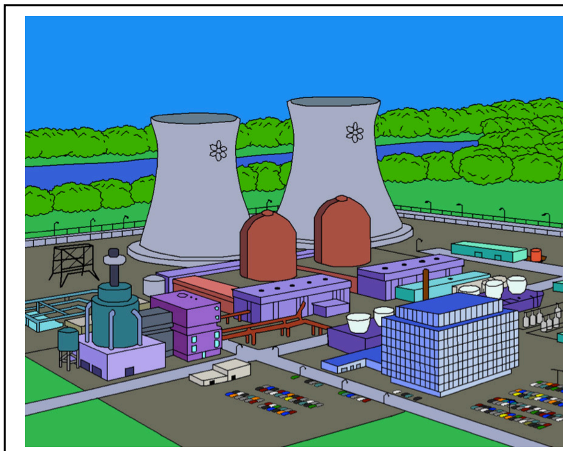


Figure 1. Nuclear power plant from the Simpsons – Uses thermal energy from nuclear fission to generate steam that then spins a turbine to generate electric power.

The two most common forms of energy we use are heat and electricity. Heat is the energy of moving particles in any substance. Generally, the faster the particles move, the warmer the substance is. Electricity is the energy of electrons moving along a conductor like a copper electrical wire. Most of the machines around us use either heat or electricity to do their work. A good example is an electric clothes dryer. The dryer uses an electric motor to turn the drum that tumbles the clothes inside. The same motor also turns a fan that blows air through the clothes as they tumble. Lastly, a heating element creates large amounts of heat, which is used to dry the clothes more quickly.

Energy cannot be created or destroyed (first law of thermodynamics), but the ability to convert energy from one form to another is critical to modern society. For example, energy from coal can be converted to electricity that can then be transmitted to your house where the electrical energy can be converted to work energy to power a fan in your computer.

Table 1: Introduction to forms and uses of energy

Form of energy	What is it?	How is it generated?	Where or how is it used
Heat	Conduction and convection: energy of moving particles (atoms and molecules) Thermal radiation (electromagnetic wave)	- Burning fuels such as oil, natural gas, gasoline - Solar radiation - Nuclear energy - Electrical current	- heating air and water in buildings, industry - Manufacturing and processing materials - Transportation
Light	Electromagnetic waves Photons	- Sun - Incandescent light - LEDs - Burning fuels as wood	- Illuminating spaces - Laser processes - Communication, fiber optics
Electricity	Energy of electrons moving through a conductor	- By photovoltaic panels - From batteries - Dynamo generators	- Turning motors - Generating heat - Running electronics
Radio waves	Electromagnetic energy	- Radio transmitters	- Microwave ovens - Radar navigation
Mechanical	Force and distance to move and object	- Falling water - Motors	- Cars, trains… - Generating electricity - Home appliances
Sound	Vibrations passing through a medium	- Vibrating surfaces - Speakers	- Communication - Instruments

A.2.2. Non-renewable Energy

Much of our energy supply comes from coal, oil, natural gas, or radioactive elements. They are considered non-renewable because once they are removed from the ground and used, they are not immediately replaced. In fact, the world's natural gas, crude oil and coal deposits took millions of years to form. Uranium, which is used for nuclear energy, has limited supply as well. Humans will have arguably used up most of these deposits in less than 200 years. Once they are gone, non-renewable energy supplies cannot be replaced within human time scales. These energy sources are often used to heat water to form steam. The steam is then used to turn a turbine connected in series to an electrical generator composed of copper windings and magnets.

A.2.3. Renewable Energy

Renewable energy on the other hand quickly replaces itself and is usually available in a never-ending supply. Renewable energy comes from the natural flow of sunlight, wind, or water around the Earth. As long as sunlight, water and wind continue to flow and trees and other plants continue to grow, we have access to a ready of supply of energy.

Solar Energy

For billions of years, the sun has poured out huge amounts of energy in several forms, including light, heat, radio waves, and even X-rays. The Earth, in orbit around the sun, intercepts a very small part of the sun's immense output. On Earth, direct sunlight is available from sunrise until sunset. Solar collectors and modules are designed to capture some of the sun's energy and convert it to useable heat or electricity. Solar energy is becoming increasingly popular for remote power needs such as telecommunication towers, agricultural applications (irrigation and pasture management), in tropical countries that are not connected to an electrical grid, for heating swimming pools, and many other applications around the world.

Wind Energy

Wind energy is really just another form of solar energy. Sunlight falling on oceans and continents causes air to warm and rise, which in turn generates surface winds. The wind has been used by humans for thousands of years, first to carry ships across oceans and, later, to pump water and grind grain. More recently, wind has been harnessed as a clean, safe source of electricity. The power produced from wind turbines in locations with consistent levels of moderate wind can now compete with the costs of fossil fuel sources of power.

Figure 2. Solar energy and wind power are two promising solar energy technologies.

Biomass Energy

The term "biomass" refers to any form of plant or animal tissue. In the energy industry, biomass refers to wood, straw, biological waste products such as manure, and other natural materials that contain stored energy. The energy stored in biomass can be released by burning the material directly, or by feeding it to microorganisms that use it to make biogas, a form of natural gas. Energy from biomass is still used around the world, for everything from cooking and heating to generating electricity. While this form is renewable, it can have a great contribution to pollution then first suspected due to the formation of compounds such as sulfur oxides that contribute to acid rain.

Hydroelectric Energy

Humans have used waterpower to supply energy for almost as long as we've used wind. Archaeologists have discovered descriptions of waterwheels used for grinding grain that date back to more than 3,000 years ago. Today, the energy of falling water is used mainly to drive electrical generators at hydroelectric dams. As long as snow and rainfall can fill the streams and rivers, moving water can be a renewable source of energy.

Canada generated 61% of its electricity supply from hydroelectricity in 1999, mostly from facilities with large dams. In the US Hydroelectric accounted for just over 6% of power produced. Hydroelectric generation does not produce significant greenhouse gas emissions, but does have other major environmental impacts. The reservoirs often destroy vast areas of highly productive forest and wildlife habitat. The dams also damage freshwater ecosystems by blocking the movement of fish and other organisms.

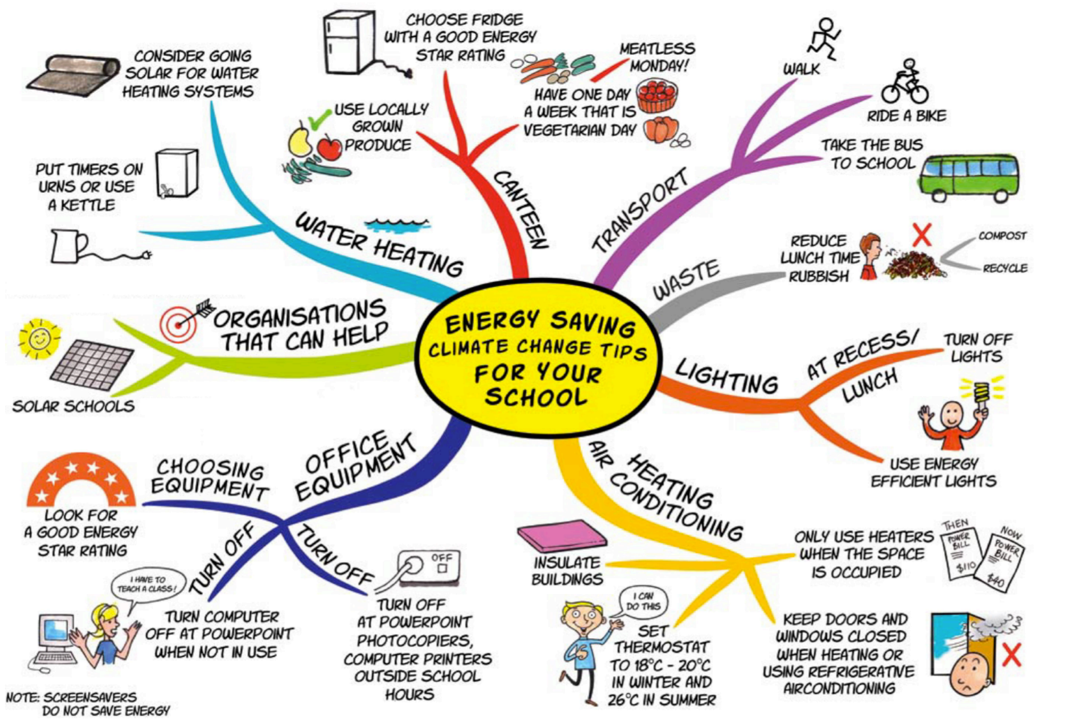


Figure 3. Examples of ways to conserve energy

A.2.4. Energy Efficiency and Conservation

Conserving energy and using energy efficient power consuming devices is often the simplest and most effective way to save energy. Even though energy conservation reduces energy services, it can result in increased financial capital, environmental quality, national security, and personal financial security. Therefore, it is critical that in addition to developing clean and renewable power generation, conserving energy and using energy efficiently will significantly impact the global energy demand. The sustainable energy hierarchy illustrated in **Figure 4** visualizes its importance.

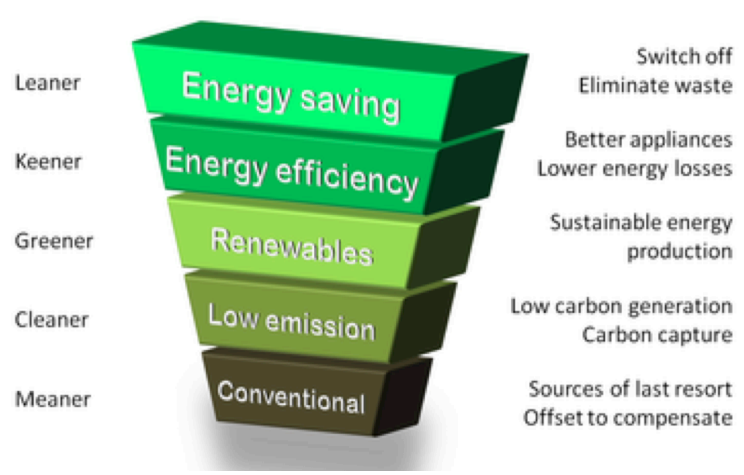


Figure 4. Sustainable Energy Hierarchy

A.2.5. Why is energy conservation and renewable energy important today?

***Energy Price Stability*:** In the last several years, we have seen large fluctuations in the cost of natural gas, oil, and electricity due to global economics and political events in some parts of the world. Renewable energy is not subject to sharp price changes because it comes from sources such as sunshine, flowing water, wind, and biological waste, all of which are free. This gives people greater certainty about the cost of energy, which is good for society and the economy. By comparison, fossil fuels are limited in their supply, and their price will increase as they become scarcer. Renewable energy supplies will never run out. While the supplies of coal, oil, and natural gas are limited, sunshine, wind, biomass, and water power are considered almost limitless resources.

Figure 5. Once gas or oil is taken from the earth and used, it cannot be replaced.

***Global climate and air quality*:** Air pollution is a major problem in many cities in the US and around the world, largely caused by burning of fossil fuels, including fuels used for transportation. The great advantage of using renewable energy in place of fossil fuels is that renewable energy adds very few pollutants to the environment. Renewable energy is considered "clean" and "green." When fossil fuels are burned, they release carbon dioxide. This gas acts like an invisible blanket, trapping more of the sun's energy in the atmosphere, causing the Earth to warm up little by little. Carbon dioxide is building up in the atmosphere as more and more fossil fuels are used in homes, factories, and automobiles. If this continues, most scientists think our planet is likely to become significantly warmer, which could cause many serious problems around the world. These problems could include melting of arctic ice, increased forest fires, rising sea levels, loss of animal habitat, damage to coral reefs, the spreading of tropical diseases, expanding deserts, and more frequent and severe storms.

Protecting Landscapes and Watersheds: Some energy projects, particularly big coal mines, hydro dams, and oil and gas activities, can have a large impact on lands and watersheds. Damage or loss of natural lands and watersheds is likely to affect humans and animals. For example, wilderness areas could be lost for when energy resources are extracted. Hydro dams can flood large areas, while the facilities associated with oil and gas and oil sands development can affect forests and disrupt animal movements and migrations. On the other hand, solar energy can provide a continuous supply of energy, which is integrated directly into buildings so that it has very little impact on land use. Run-of-river hydro plants can be designed to allow for free flow of existing streams.

B. ENERGY FACT SHEETS

From Reference 3

Biomass

Description of biomass:
Any organic material that can be used for its energy content – wood, garbage, yard waste, crop waste, animal waste, even human waste.

Renewable or nonrenewable:
Renewable

Description of photosynthesis:
The process by which radiant energy from the sun is converted to glucose, or sugar. This glucose stores chemical energy within the plant.

Ways we turn biomass into energy we can use:
Burning to produce heat, fermentation into alcohol fuel (ethanol), bacterial decay into methane, conversion to gas or liquid fuels by addition of heat or chemicals.

Who uses biomass and for what purposes:
Industry burns waste wood to make products, homes burn wood for heat, waste-to-energy plants burn organic waste products to produce electricity, ethanol is used as a transportation fuel.

Effect of using biomass on the environment:
Burning biomass can produce air pollution and does produce carbon dioxide, a greenhouse gas. It can also produce odors. Burning biomass is cleaner than burning fossil fuels.

Important facts about biomass:
Biomass gets its energy from the sun through the process of photosynthesis.

Using biomass reduces the amount of organic material placed in landfills.

Fast-growing crops can be grown for their energy content.

Using biomass does not contribute to the greenhouse effect, since the amount of carbon dioxide produced equals the amount taken in during growth.

Coal

Description of coal:
Coal is a black, solid hydrocarbon (fossil fuel) formed from the remains of ancient plants in swamps millions of years ago.

Renewable or nonrenewable:
Nonrenewable

Where coal is located and how we recover it:
Coal is located underground in many areas of the country. Shallow seams are surface mined. Coal buried deep is reached through underground mine shafts.

Ways we turn coal into energy we can use:
Most coal is burned to produce heat.

Who uses coal and for what purposes:
Power plants burn most of the coal to produce electricity. Industries also burn coal to make products, especially steel and iron.

Effect of using coal on the environment:
Burning coal can pollute the air and cause acid rain. Burning coal also produces carbon dioxide, a greenhouse gas.

Important facts about coal:
Coal produces nearly half of the electricity in the U.S.

The U.S. has the largest reserves of coal in the world.

Coal is found in Appalachian states and some western states.

Wyoming, West Virginia, Kentucky, Pennsylvania, and Montana are the top coal-producing states.

Coal is transported mainly by train and barge. Transporting coal is a huge expense.

Geothermal Energy

Description of geothermal energy:
Geothermal energy is heat produced in the earth's core by the slow decay of naturally-occurring radioactive particles.

Renewable or nonrenewable:
Renewable

Where geothermal resources are located and how we recover them:
Low temperature resources are almost everywhere a few feet underground. High temperature resources are found mostly at the edges of tectonic plates, especially around the Ring of Fire in the Pacific.

Ways we turn geothermal energy into energy we can use:
We can drill wells to reach high temperature resources or lay pipes filled with fluid underground. Some geothermal resources come out of the ground naturally, and we can pipe it to where it's needed.

Who uses geothermal energy and for what purposes:
Power plants use geothermal steam to produce electricity. Homes and businesses use the hot water and steam for heat.

Effect of using geothermal energy on the environment:
There is very little environmental effect.

Important facts about geothermal energy:
Earth is made of layers – an inner core of iron, an outer core of magma (melted rock), a mantle of magma and rock, and a crust. The crust is not a solid piece, but giant plates of land that move. Along the edges of the plates, geothermal resources tend to come to the surface.

Hydropower

Description of hydropower:
Hydropower is the force of moving water caused by gravity.

Renewable or nonrenewable:
Renewable

Description of the water cycle:
The sun shines onto the Earth, evaporating the water in oceans, rivers, and lakes. The water vapor rises into the atmosphere and forms clouds. The water vapor condenses and falls to Earth as precipitation.

Ways we turn hydropower into energy we can use:
We can harness the energy in flowing water by damming rivers and using waterfalls.

Who uses hydropower and for what purposes:
Electric utilities use hydropower dams to turn the energy in flowing water into electricity.

Effect of using hydropower on the environment:
Dams can flood land and disrupt animal and fish habitats. Hydropower doesn't pollute the air, but it can churn up sediments in the water.

Important facts about hydropower:
Hydropower dams are the cheapest and cleanest way to produce electricity.

There are few places in the U.S. where new dams can be built.

Some existing dams could have turbines installed to produce electricity.

Natural Gas

Description of natural gas:
Natural gas is a colorless, odorless gas formed millions of years ago from tiny plants and animals. It is a fossil fuel.

Renewable or nonrenewable:
Nonrenewable, although methane produced from landfill gas is classified as renewable.

Where natural gas is located and how we recover it:
Natural gas is located in underground rock formations in sedimentary basins. We drill wells to reach it and pipe it from the ground.

Ways we turn natural gas into energy we can use:
Usually we burn natural gas to produce heat.

Who uses natural gas and for what purposes:
Industry burns natural gas to manufacture products. Homes and businesses burn natural gas to heat buildings and water, and for cooking. Power plants burn natural gas to produce electricity.

Effect of using natural gas on the environment:
Natural gas is a cleaner burning fossil fuel, but it produces some air pollution and carbon dioxide, a greenhouse gas.

Important facts about natural gas:
Mercaptan, an odorant that smells like rotten eggs, is added to natural gas so leaks can be detected.

Natural gas is shipped by millions of miles of underground pipelines.

Natural gas can be used as a transportation fuel if it is put under pressure and engines are modified.

Petroleum

Description of petroleum:
Petroleum is a liquid hydrocarbon, a fossil fuel formed millions of years ago from the remains of tiny sea plants and animals. It can be thin and clear like water or thick and black like tar.

Renewable or nonrenewable:
Nonrenewable

Where petroleum is located and how we recover it:
Petroleum is located underground in rocks in sedimentary basins. Much is under water. We drill wells to find it, then must pump it from the ground.

Ways we turn petroleum into energy we can use:
Petroleum is refined into many different fuels that are burned to produce heat. When gasoline is burned in vehicles, it causes small explosions that push pistons to produce motion.

Who uses petroleum and for what purposes:
Most petroleum products are used by the transportation sector to move people and goods. Industry burns petroleum to manufacture products and also uses petroleum as a feedstock to produce many products.

Effect of using petroleum on the environment:
Burning petroleum can cause air pollution and produce carbon dioxide, a greenhouse gas. Drilling for and transporting petroleum can cause damage to the land and water if there are leaks or spills.

Important facts about petroleum:
We use more petroleum than any other energy source.

The U.S. does not produce enough petroleum to meet our needs.

We import about half of the petroleum we use from foreign countries.

The Middle East has huge reserves of petroleum.

Petroleum is moved over land mostly by pipeline, and over water by tanker.

Propane

Description of propane:
Propane is a colorless, odorless fossil fuel found with petroleum and natural gas. It was formed millions of years ago from the remains of tiny plants and animals.

Renewable or nonrenewable:
Nonrenewable

Where propane is located and how we recover it:
Propane is found with petroleum and natural gas deposits and is separated from both fuels during refining and processing.

Ways we turn propane into energy we can use:
We put propane in tanks under pressure to turn it into a liquid so that it is more easily moved from place to place, then we burn it to produce heat.

Who uses propane and for what purposes:
Industry uses propane to make products; farmers use propane for heat in rural areas; homes use propane for outdoor grills; businesses use propane to fuel indoor machinery and as a fleet fuel.

Effect of using propane on the environment:
Propane is a cleaner burning fossil fuel, but burning it does produce some air pollutants and carbon dioxide, a greenhouse gas.

Important facts about propane:
Propane is an LPG – liquefied petroleum gas.

Propane is easily turned into a liquid under pressure. It takes up 270 times less space as a liquid.

Propane is stored in underground caverns and moved by pipelines and trucks.

Propane is called a portable fuel because it is easily transported as a liquid.

Solar Energy

Description of solar energy:
Solar energy is radiant energy from the sun that travels to Earth in electromagnetic waves or rays.

Renewable or nonrenewable:
Renewable

How solar energy is produced and how we recover it:
Solar energy is produced in the sun's core when atoms of hydrogen combine under pressure to produce helium, in a process called fusion. During fusion, radiant energy is emitted.

Ways we turn solar into energy we can use:
We can capture solar energy with solar collectors that turn the radiant energy into heat, or with photovoltaic cells that turn radiant energy into electricity. We also use the visible light of solar energy to see.

Who uses solar and for what purposes:
We all use the visible light from the sun to see during the day. Many homes and buildings use solar collectors to heat interior spaces and water, and PV cells to produce electricity.

Effect of using solar on the environment:
Solar energy is very clean energy, producing no air or water pollution.

Important facts about solar:
Solar energy is not available all of the time and is spread out so that it is difficult to harness. Today, it is expensive to use solar energy to produce electricity, but new technologies will make solar energy a major energy source in the future.

Uranium

Description of uranium:
Uranium is a common metallic element found in rocks all over the world.

Renewable or nonrenewable:
Nonrenewable

Where uranium is located and how we recover it:
Uranium is located underground in rock formations. Mines are dug to recover it. The U.S. has plenty of uranium, but imports most used in nuclear power plants because it is cheaper to do so.

Ways we turn uranium into energy we can use:
Uranium is processed and turned into uranium fuel pellets for nuclear power plants. Uranium atoms are split in the process of fission to produce heat.

Who uses uranium and for what purposes:
Nuclear power plants use uranium to produce electricity.

Effect of using uranium (nuclear energy) on the environment:
Uranium fission produces radioactive waste that is dangerous for thousands of years and must be stored carefully. Leaks of radioactive materials pose a danger.

Important facts about uranium (nuclear energy):
Nuclear power plants produce little pollution except for radioactive waste, which must be stored in special repositories. There is no permanent repository in the United States at this time and most waste is stored on site at nuclear power plants. A permanent repository is mandated by Congress, but a final location has not been chosen.

Wind

Description of wind energy:
Wind is the circulation of air caused by the uneven heating of Earth's surface.

Renewable or nonrenewable:
Renewable

Where wind energy is located and how we recover it:
Wind is produced when the sun shines on the Earth, heating the land more than the water. The warmer air over land rises and cooler air moves in to take its place, producing convection currents.

Ways we turn wind into energy we can use:
We use wind turbines that have blades which turn in the wind that turn a turbine to produce electricity.

Who uses wind and for what purposes:
Usually, independent power producers (not big utilities) build wind farms to produce electricity.

Effect of using wind on the environment:
Wind turbines are very clean, producing no air or water pollution. They take up a lot of land, but most of the land can be used for other things, such as farming and grazing cattle, at the same time.

Important facts about wind:
Wind turbines do not produce a lot of electricity, and do not produce it all of the time.

Wind turbines cannot be used in many areas. There must be stable, continuous wind resources.

There are large wind resources on the ocean. The first offshore wind farm in the United States was approved in 2011 and will be built off the coast of Cape Cod, MA.

Forms of Energy

Fill in the blanks with the words at the bottom of the page. Some words may be used more than once.

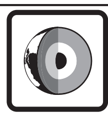
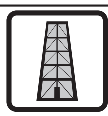
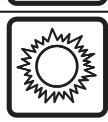
1. Stored energy and the energy of position are ______________________________ energy.
2. Compressed springs and stretched rubber bands are ______________________________ energy.
3. The vibration and movement of the atoms and molecules within substances is called heat or ______________________________ energy.
4. The scientific rule that states that energy cannot be created or destroyed is called the Law of ______________________________.
5. The movement of energy through substances in longitudinal waves is ______________________________.
6. The energy of position – such as a rock on a hill – is ______________________________ energy.
7. The movement of objects and substances from place to place is ______________________________.
8. Electromagnetic energy traveling in transverse waves is ______________________________ energy.
9. Energy stored in the bonds of atoms and molecules is ______________________________ energy.
10. The movement of atoms, molecules, waves, and electrons is ______________________________ energy.
11. The movement of electrons is ______________________________ energy.
12. The amount of useful energy you get from a system is its ______________________________.
13. The energy in petroleum and coal is stored as ______________________________ energy.
14. X-rays are an example of ______________________________ energy.
15. Fission and fusion are examples of ______________________________ energy.
16. A hydropower reservoir is an example of ______________________________ energy.
17. Wind is an example of the energy of ______________________________.

Word Bank

- chemical
- Conservation of Energy
- electrical
- energy efficiency
- gravitational
- kinetic
- motion
- nuclear
- potential
- radiant
- sound
- stored mechanical
- thermal

How We Use Our Energy Sources

In the boxes, describe the main uses of each energy source. Put a * beside the most important use. Some sources may be used in only one or two ways.

	TRANSPORTATION	MAKE PRODUCTS	HEATING/COOLING	LIGHTING	MAKE ELECTRICITY
					
					
					
					
					
					
					
					
					
					

C. ACTIVITIES

1. Home Energy Management Game
   Concepts: Energy conservation, energy management

2. Solar Oven
   Concepts: Solar energy and thermal energy

3. Mini wind turbine
   Concepts: Wind and hydropower

4. Spare Change Flashlight
   Concepts: Battery energy storage, light

5. Thermoelectric Freezer
   Concepts: Energy conversion, refrigeration

6. Fuel Cell Car
   Concepts: Fuel cells, chemical energy conversion, transportation

1. Energy Management

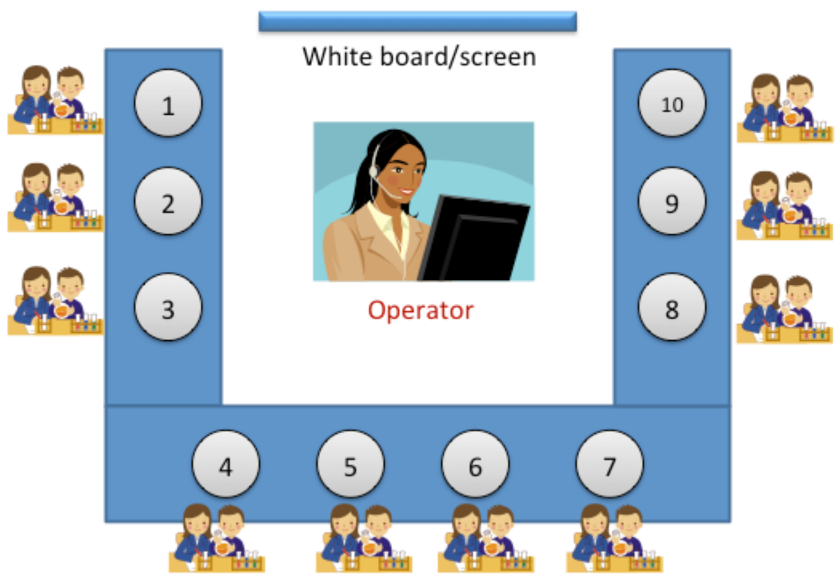
1.1. Introduction

In this activity, you will be playing the Home Energy Management Game. The objective of the game is to allow you to understand the basic energy consumption patterns in average households and assess their techniques to lower the energy bills if real-time pricing is implemented. The game will mimic real household energy consumptions. Seven appliances are chosen to represent major electric loads inside a typical single family house. Each household will be run by a group of two students. There will be 1 grid operator and 1 operator assistant who will determine the electricity prices based on load levels. Each household will be given $600 play money at the beginning of the game. The group with the most money left on the table at the end of the game wins!

The goals of the game are:

1. Teach you how to calculate the energy consumption and cost
2. Allow you to think about how to reduce electricity consumption and lower electricity bills
3. Illustrate to you the benefits of scheduling loads by using smart grid technologies.

Game illustration:



1.2. Basic procedure

Students will be divided into groups of two people. There will be approximately 10 groups representing 10 households. There will be 7 key appliances in each household. The energy price will be determined by grid operators. $600 (Play money) will be provided to keep track of the money spent by each household.

2.0. Solar Oven

2.1. Background

(Adapted from: greenlearning.ca) Most people know that the sun is a great source of energy; however, when most people think of the solar energy, they think of electricity and solar panels. In this experiment you will see another side of "solar power," that is, solar thermal power. You are familiar with the idea that the sun heats the Earth, with the help of the greenhouse effect, so you know that the sun radiates a lot of heat energy. Solar thermal energy has been experimented with since the 1800's, and since 1892, millions of people have reaped the benefits of this thermal energy in the form of solar heated water. In more recent years, scientists have perfected the use and collection of solar thermal energy to produce electricity, heat homes, and purify water. **Figure 7** shows a solar thermal collector that is used to heat a fluid, such as oil or steam, in order to power a heat engine and produce electricity.

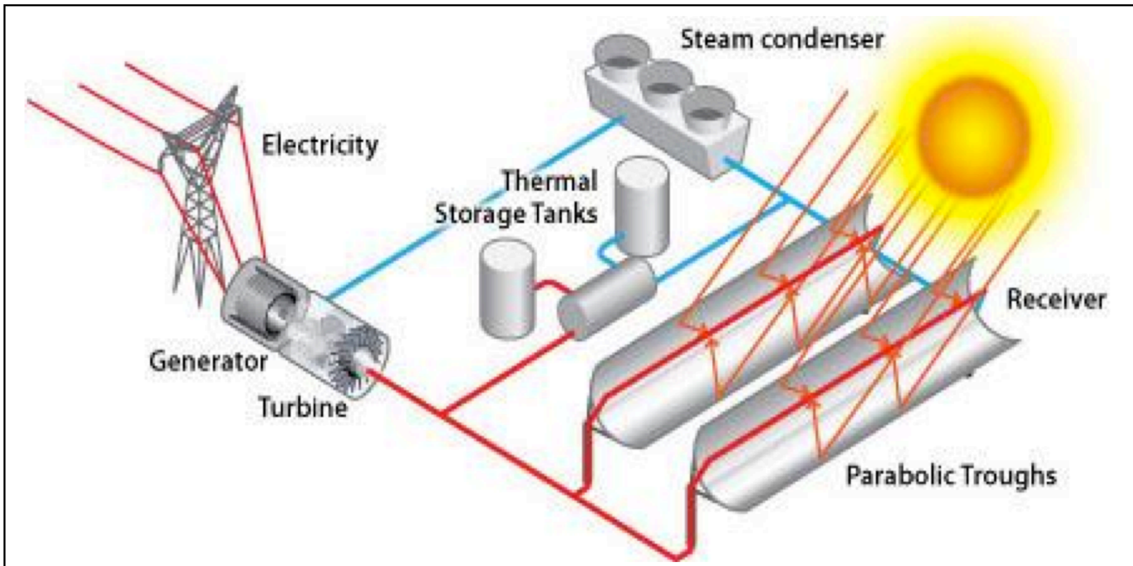


Figure. Solar thermal power plant

One of the more interesting uses of solar thermal energy is solar cooking. Near the end of the 19th century, a British Soldier in India received the first patent for a solar cooker design. Although there is a long history behind solar ovens, many of the designs we see today came about in the 1950's when the United Nations funded research for solar cooker designs in order to alleviate some reliance on plant life for fuel. The conclusion of the numerous studies was that with a properly constructed solar cooker, food could be cooked thoroughly and nutritiously. In order to test the sun's thermal power, you will be constructing a solar cooker, performing several tests, collecting data and analyzing the design.

2.2. Solar Oven Activity Guide

Adapted from reference 4

Who: Group of 4 students
What: Build a solar oven and bake cookies. The purpose of this activity is to learn concepts of solar energy and heat transfer.
Where: Classroom and outdoors
Time: 4 hours

Supplies:

Item (Consumables)	Quantity	Check out	Check in	Notes
Large cardboard box	1		NA	
Small cardboard box	1		NA	
Transparent oven bag	1		NA	
Sunglasses	4		NA	
Cookie dough	6 cubes		NA	
Shredded paper	small box		NA	
Aluminum foil roll	1			
Aluminum foil bake tin	1			
Multimeter thermocouple	1			
Duct tape roll	1			
White glue bottle	1			
Plastic cup	1			
Utility knife	1			
Yard stick	1			
Oven mitts	4			
Cupcake wrappers	6			

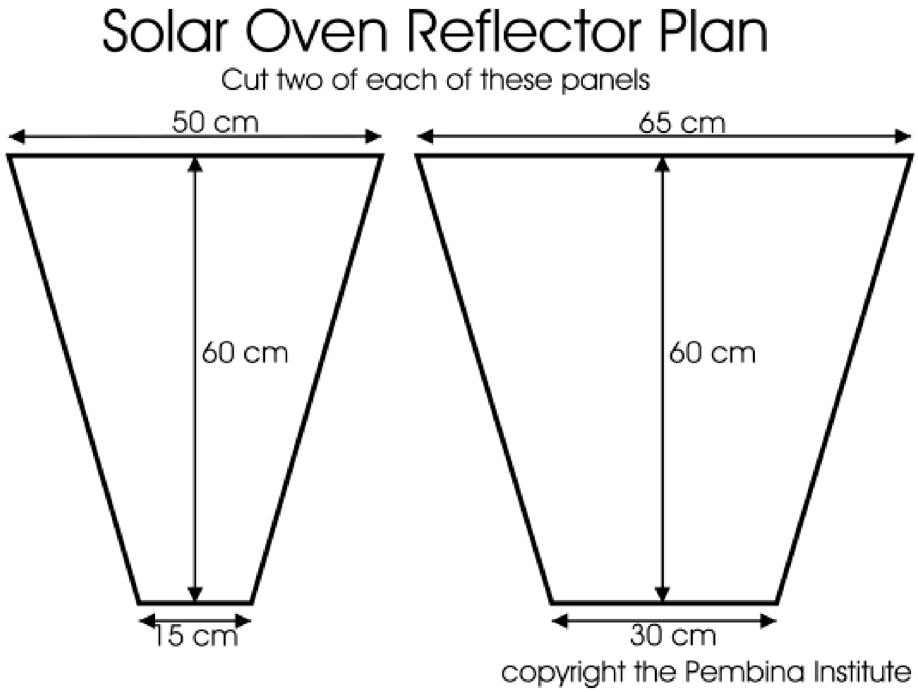
Objectives:

- Learn basic principles of solar thermal heating and heat transfer.
- Measure the temperature at various points in time and calculate heat transfer rates.
- Explore the effects of shade on temperature and rate of heat transfer.
- Construct heating curves and predict effects of certain design alterations.

SAFETY NOTES:

- **Eye Hazard** - Use sunglasses when working with shiny materials in sunlight.
- **Burn Hazard** - The solar oven design you are using is capable of reaching temperatures of 400 degrees Fahrenheit! Use extreme caution and oven mitts or gloves to prevent burns when handling the contents of the oven.
- **Cut Hazard** – Use utility knife carefully and as directed by activity leader

Procedure:



A. Prepare the Reflective Panels

1. Using a meter stick and pen, draw the outlines of the reflector segments on your cardboard. Use the measurements on the blueprint template.

2. Using the utility knife, carefully cut out the 4 cardboard segments. Use a ruler or straight-edge to help guide your cuts. **CAUTION: Utility knives can be dangerous.** Extend the blade only as far as necessary to cut through the cardboard. Use some scrap cardboard or wood under the material you are cutting to avoid damaging the tabletop.

3. Remove the top from the white glue bottle and pour approximately 100 ml (~ 1/4 cup) into the plastic container. Add 4 tablespoons of water to the glue and stir thoroughly. This will make the glue thinner and easier to spread evenly.

4. Carefully unroll enough aluminum to completely cover one section. Keep the foil as smooth and flat as possible. Wrinkles and creases in the foil will reduce the efficiency of the reflector. If the cardboard is wider than the foil, use two pieces of foil and plan to join them near the middle.

5. Apply a thin layer of white glue over the entire surface of the cardboard. Be sure to spread the glue right to the edge of the cardboard. Use the flat edge of a piece of scrap cardboard as a squeegee to spread the glue out evenly.

6. Before the glue dries, place the foil on the cardboard shiny side up, and smooth it down over the entire surface. Try to press out any wrinkles, bubbles, or creases in the foil. If your foil gets badly wrinkled during the gluing process, tear it off and try again with fresh glue.

7. Using the utility knife, trim the foil so that it is flush with the edge of the cardboard all around. Set the panel aside to dry.

8. Repeat steps 4 through 7 for the remaining sections.

B. Join the Panels

1. Cut 8 pieces of duct tape 60 cm long and set them aside (stick them to the edge of the table for easy retrieval).

2. Arrange the segments as shown in the photo below, foil side down, wide sections alternating with narrow ones. The narrow end of each should point toward you.

3. Carefully position the first two panels, keeping a 2 mm space between them. Position one of your 60- cm strips of duct tape over the joint between the panels. Press it onto the joint, being sure it sticks securely to both panels over its full length.

4. Join the third and fourth panels as in step 3 above.

5. Carefully flip the joined panels over on the table. This may require two people. Reinforce the joint between each panel using another

strip of duct tape.

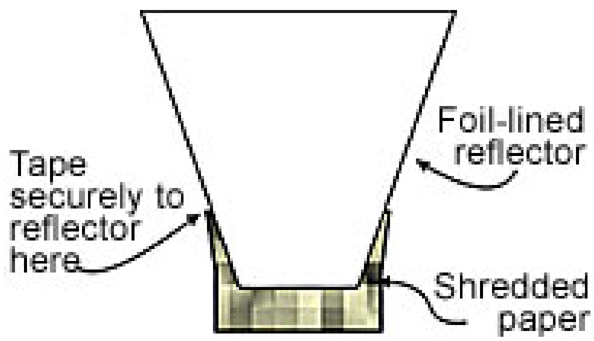
6. Stand your reflector up (foil side in), bringing the edges of the outer two panels together. Have your partner hold the reflector in position while you add the last piece of duct tape.

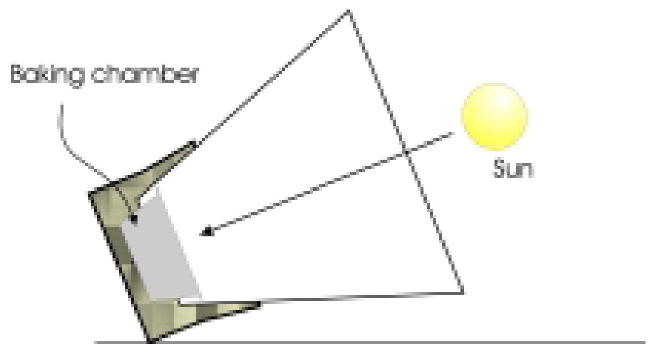
7. Finish the last joint inside the reflector by applying the remaining piece of duct tape.

C. Add the Insulated Box

1. Using duct tape, fasten the cardboard box securely to the bottom of the reflector by its flaps. Be sure the box is centered. Add a few strips of duct tape to the corners to make the assembly more rigid.

2. Stuff shredded paper into the gaps between the box and the reflector. Leave a little of the paper on the bottom of the box, as shown in the illustration.





E. Test the Solar Oven

The solar oven is now ready to be tested. If it is a sunny day, you can warm up your oven in preparation for its first cooking job.

1. Place cookie dough squares into muffin tin and then into the tin baking pan.

2. Place the baking tin into the transparent plastic oven bag, making sure to slip in the thermocouple thermometer as well. Arrange the bag so that the plastic forms a smooth, unwrinkled window over the baking chamber.

3. Press the baking chamber tightly into the bottom of the reflector.

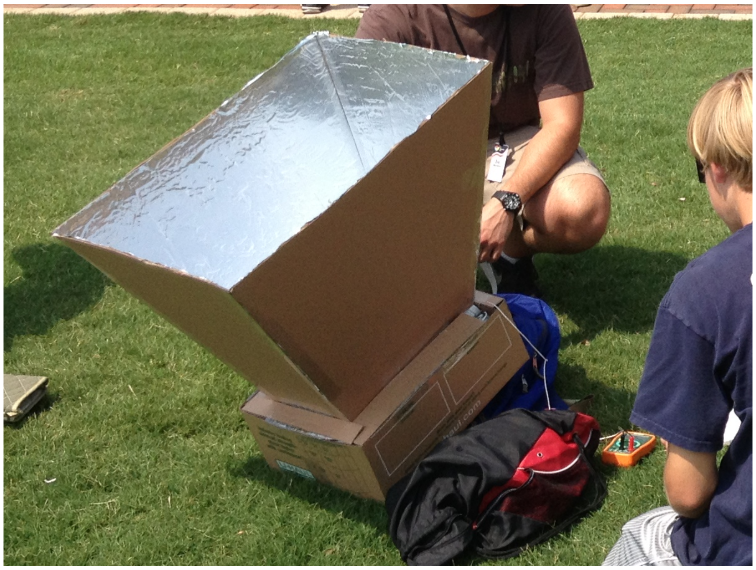
4. Outside, and with your sunglasses on, arrange your cooker so that the cooking chamber is fully illuminated by the sun. The diagram below shows you how to orient the reflector to get the most heat from the sun. You will need to prop the reflector up on some books, bricks, or other objects to keep it at the right angle.

5. If the day is sunny, clear, and warm, the temperature inside the cooker should begin to reach 100 degrees C or more within minutes. Allow the cooker to reach its maximum temperature and record this. If your cooker reaches 100 degrees C, you can use it for heating foods. If it gets to temperatures of 175 degrees or higher, it will begin to bake your cookies.

F. Measurements

Record temperatures in oven and determine heat transfer into and out of oven.

1. The oven will heat up very quickly over the first few minutes; make sure to record the temperatures at the intervals shown in the table on the next page. You will also need to record the temperature of the surroundings.



2. The other test that you will perform will explore the effect of shade on the oven. You may choose to do this at any time while you are baking your cookies. Use something (your workbook will suffice), to cover about 25% of the opening of the oven; record the temperature of the oven, not the surroundings, at 15 second intervals for one minute. Remove the shade and allow some time to pass for the oven to heat back up again. Repeat this process again, this time shading about 75% of the oven.

The cookies should take about 40 minutes to bake after the oven has heated up. In total the experiment should take about an hour (the cookies may not turn brown). Remove the cooking pan **with oven mitts**.

Start calculating the heat transfer rates when you have collected all the necessary data. Plot the rate of heat transfer and temperature of the oven as a function of time on the provided graphs.

Solar oven data:

Time (min)	Temperature (°F)		Heat Transfer Rate (W)
	Oven	*Surroundings*	
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
12			
14			
16			
18			
20			
25			
30			
35			
40			
45			

% Shade	Time (sec)	Temperature (°F)
25	0	
	15	
	30	
	45	
	60	
75	0	
	15	
	30	
	45	
	60	

Heat Transfer Rate:

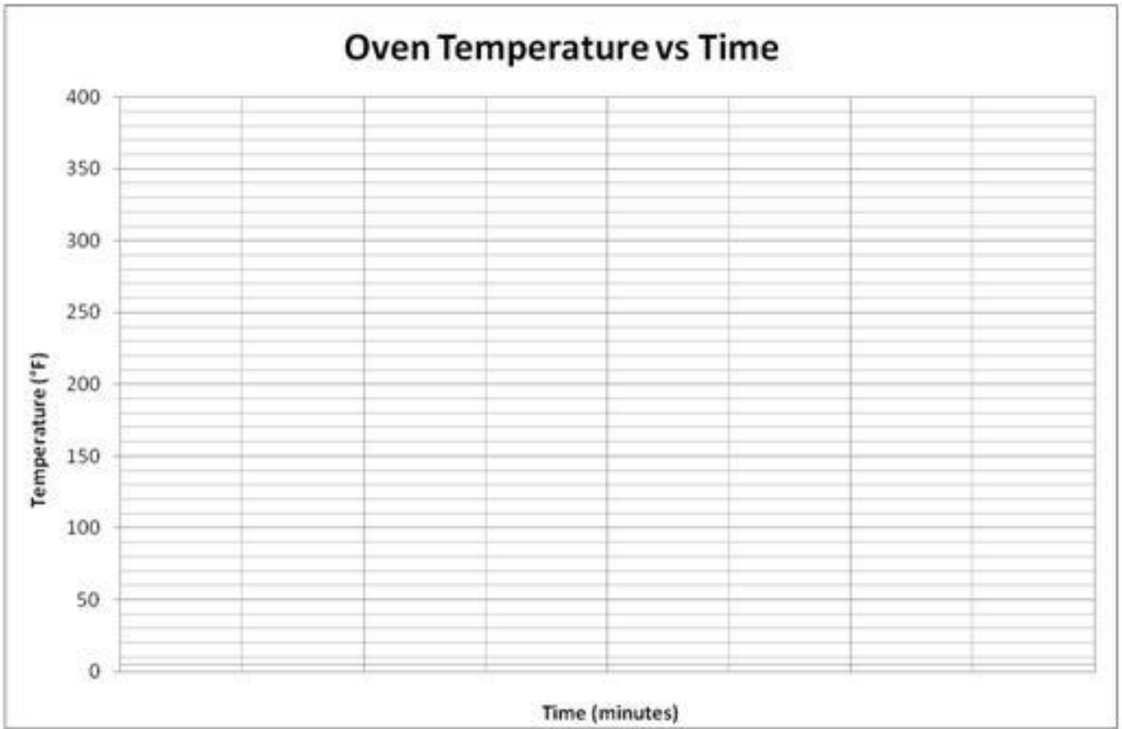
$$q = kA\frac{\Delta T}{L}$$

k=.2 (.15 to 0.24 W m−1 K−1) (PET) (thermal conductivity)

A = heat transfer area

ΔT = temperature difference across medium

L = material thickness



Notes and Observations:

3.0. Mini Wind Turbine

3.1. Wind power introduction

Although most people don't think about it, wind power is essentially another form of solar power. Sunlight that reaches the Earth heats surface air, causing a temperature difference, which in turn causes the less dense heated air to rise and the cooler surrounding air rushes in to fill the void creating a surface wind. One of the earliest uses of wind energy was the sail. Sails were, and are still today, used to power various modes of transportation, like sailboats. Wind energy was also converted into mechanical energy in order to pump water and spin grinding wheels. In the Netherlands windmills were used extensively to pump seawater out of low-lying areas in order to dry the land out and produce useful farmland. Windmills were, and are still used today, on many farms to pump water from wells to water troughs for livestock.

The most recent adaptation of windmills and wind energy is the conversion of mechanical energy into electrical energy through the use of wind turbines. The key to success in this process is the electrical generator. The blades of the wind turbine are connected to a rotating shaft, which goes through a gearbox and into a generator, which converts the work of the shaft into useful electrical energy.

The one of the simplest types of generators is a permanent magnet alternator, also known as a magneto. It works on the exact opposite principle as an electromagnet. An electromagnet uses a rotating coil of wire with a current running through it to induce a magnetic field in the iron bar that is placed in the middle of the coil, where as, a magneto uses a magnetic field in the vicinity of a coil to induce a current in the coil. Magneto's are generally used to produce brief high voltage burst to power spark plugs in lawn equipment, and other small engine powered devices. A magneto, for use in spark plug applications, usually consists of several permanent magnets, two coils of wire, one with about 200 turns of thick wire and the other with about 20,000 turns of very fine wire, wrapped together and a flywheel. Magneto's in this application also require an electronic control unit, a capacitor and a breaker.

Figure 9. Wind mills

In order to test the wind's power you will be building a simple wind turbine, which will supply electrical energy via a permanent magnet alternator. In this simplified version of an alternator, you will use strong magnets passing over four coils of fine wire to produces an alternating current.

3.2. Wind Turbine Activity

Adapted from reference 5

Who: Group of 4 students
What: Build a small wind turbine with generator and test power out in wind tunnel. The purpose of this activity is to learn concepts of wind energy, mechanical work, electric generators and AC power.
Where: Classroom and Wind tunnel
Time: 4 hours

Supplies:

Item	Quantity	Check-out	Check-in	Notes
Scissors	1			
Electrical tape	1			
Ruler	1			
White glue bottle	1			
10 cm Nail	1			
Utility knife	1			
Rare earth magnets	4			
Cardboard sheet (22x30 cm)	1		NA	
Permanent marker	1			
Magnetic compass	1			
Small cardboard box	1		NA	
Plastic spoons	10		NA	
Large cork	1		NA	
Wooden dowel 6mm x 20 cm	1		NA	
24 gage - copper wire	100 m			

Shared items	Quantity	Check-out	Check-in	Notes
Hot glue gun	1			
Wire cutter	1			

Objectives:

- Learn the basic principles of the conversion of mechanical energy to electrical energy.
- Measure the resistance of coils
- Explore the effects of blade design, wind speed, and rpm's of turbine on voltage and current production.
- Power an LED with the apparatus.

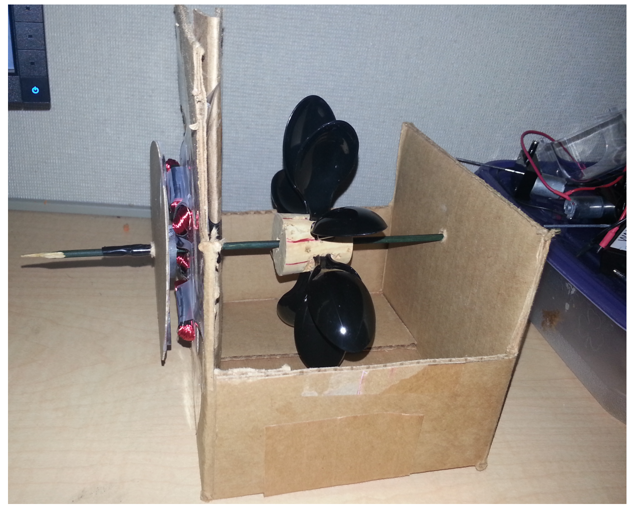
Safety:

- **Strong Magnets** – keep away from all personal electronics.
- **Cut Hazard** – careful use of utility knife
- **Burn Hazard** – Use of hot glue gun must be under activity leader supervision

Procedure:

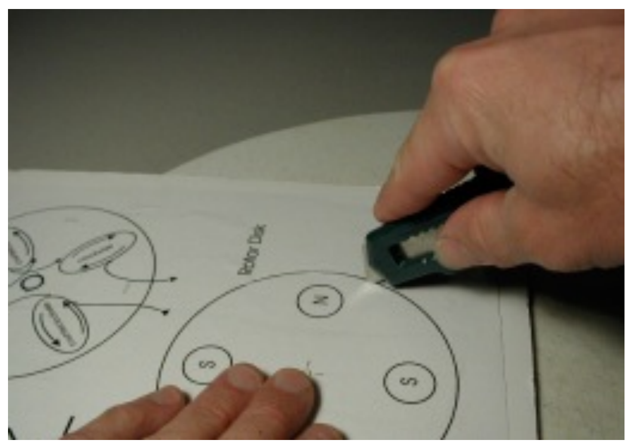
Example of final turbine pictured on right

A. Prepare the Disks



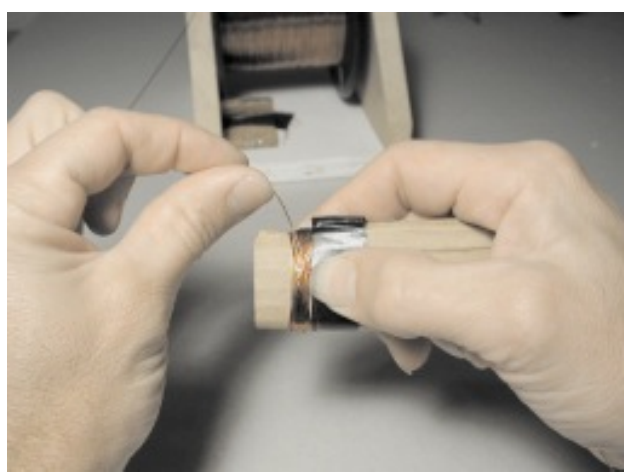
1. Glue the template sheet (at end of instructions & given as a handout) to the corrugated cardboard sheet making sure to spread the glue evenly over the entire back surface of the template.

2. Once the glue has dried, use the utility knife to cut the rotor and stator disks from the cardboard sheet. **CAUTION: Utility knives can be dangerous.** Carefully trim the edges. Use some scrap cardboard or wood under the material you are cutting to avoid damaging the tabletop.



3. Use a nail to punch a small hole through the rotor disk at its exact center, shown on the template. Using the utility knife, make a larger (approx. 1 cm) hole at the center of the stator disk.

B. The Stator



1. Cut a 3 x 16 cm piece of cardboard, fold it in half and secure it with a piece of electrical tape.

2. Cut 8 short (approx. 4 cm) strips of electrical tape and put them aside.

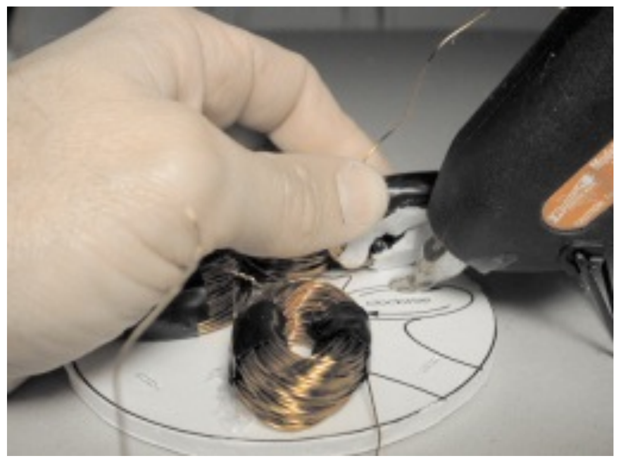
3. Leaving a lead of about 10 cm, start winding the magnetic coil onto the jig to create the first coil. Wrap the wire as neatly and tightly as possible. Use 200 wraps or turns.

4. Carefully slip the coil off the jig and secure it using two pieces of the previously set aside electrical tape.

5. Create 3 more coils by repeating steps 1-4, leaving about 3 cm of wire between the individual coils. Leave 10 cm of wire after the last coil has been wrapped.

6. Lay the coils loosely on the disk in the positions shown on the template. Arrange the coils so their windings alternate between clockwise and counterclockwise (twist it if necessary). If done correctly, an electron should travel in the direction indicated by the arrows on the template, starting with the counterclockwise coil on the left hand side.

7. Using a small patch of emery cloth or sand paper, remove the enamel insulation from two free ends of wire, exposing about 1 cm of bare wire (make sure this wire is completely bare).



8. Check your connections: Set your multi-meter for measuring electrical resistance (ohms). If your connections are good, there should be little resistance to the movement of electrons, and the meter should read about 10 ohms or less. To check this, touch or connect the multi-meter probes to the two free ends of the wire. If the coils are not properly connected, the reading will be either a very large number or infinity.

9. Once you are confident the coils have been constructed and positioned properly, glue them to the stator disk. Lift each coil up a little and apply a large blob of glue to the template where the coil should rest. Let the glue solidify before gluing the next coil.

C. The Rotor

1. Using a magnetic compass, determine the polarity of each of the 4 magnets and mark the south pole of two magnets and the north pole of the remaining two using a felt pen.

2. Warm up your hot glue gun, and prepare to attach the magnets to the rotor disk. **CAUTION: Hot glue guns can cause burns. Be sure glue guns are warmed up only when needed, and are unplugged immediately after. Hot glue can stick to skin and**

clothing. The magnets must be arranged so that their polarity alternates (i.e. N-S-N-S). Their position and polarity are indicated on the template.

3. Squeeze a small (1 cm) blob of hot glue on the spot where the first magnet will go. Quickly press a magnet with its washer onto the blob. Allow the glue to solidify before moving onto the next magnet.

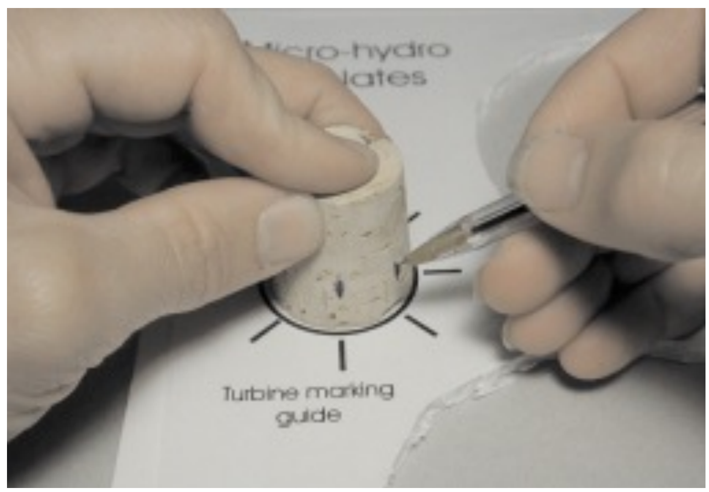
4. Repeat this for the remaining magnets, making sure to alternate north and south poles as you go.

D. The Shaft

1. Using a pencil sharpener, put a point on each end of the wooden dowel (it is not necessary to make a sharp point – blunt will do).

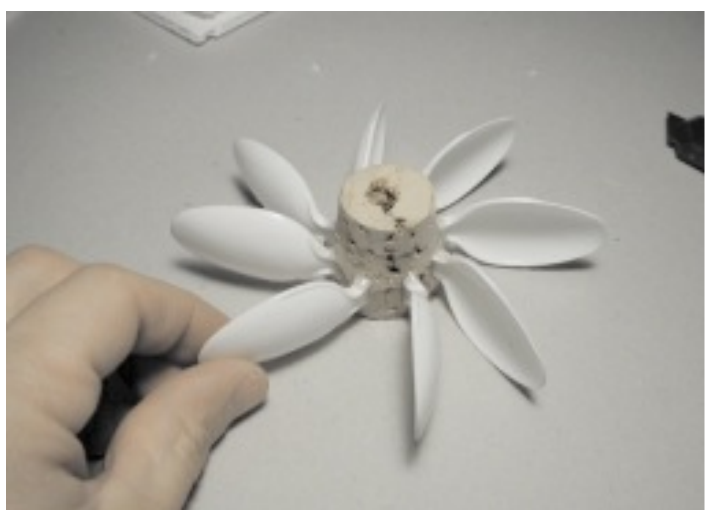
E. The Turbine

1. Center the wide end of the cork on the marking guide on the template page, and mark the cork with a pen or pencil, as shown below.



2. Place the cork wide-end down on a cutting board. Use the utility knife to cut shallow slits into the cork where the spoons will be inserted. **USE CAUTION!**

3. Using the wire cutters, cut the spoon handles off of the 8 plastic spoons leaving a 1 cm stem on the bowl of the spoon. (Should have been already done)



4. Be sure the glue gun is warmed up and that you have a glue stick or two handy.

5. Insert the first spoon into the cork, using the turbine template as a guide. Push the stem of the spoon into the cork to a depth of about 1 cm.

6. Repeat step 6 with the remaining 7 spoons. Adjust the angle and depth of the spoons so they are evenly spaced and all project from the cork at the same angle.

7. When you are satisfied with your turbine, add some hot glue to each spoon to secure it on the cork.

F. The Housing

1. Assemble the bottom of the cardboard box and tape it shut.

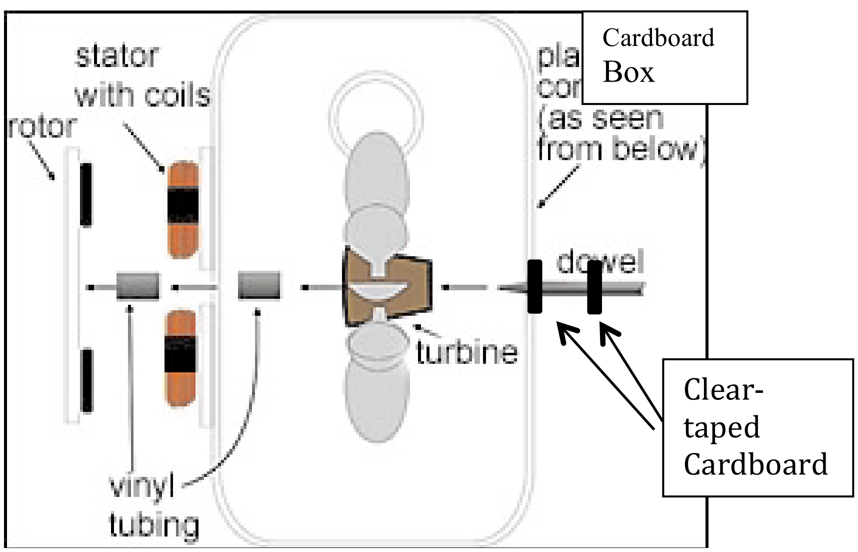
2. Using a ruler, find the center of one of the sides as accurately as you can. Mark this point with the permanent marker. Repeat this process for the other side.

3. At the mark on each side of the container, cut a 1/4" (6 mm) hole through the cardboard.

4. Lay the stator with its attached coils on the side of the container so that its center hole is over the hole in the box. Tape the stator to the cardboard box using clear tape.

5. Using the utility knife, make 4 small slits on the side of the cardboard box, corresponding with those on the stator disk.

6. Using the brass paper fasteners, securely mount the stator disk to the side of the cardboard box. Bend the tabs flat on the inside of the cardboard box.



7. Using scissors, cut the front and back of the cardboard box above the centerline hole on the sides of the box (a cm or two of excess won't hurt too much).

G. Final Assembly

1. From scrap cardboard, cut out two 2 cm diameter disks and tape over one side of each cut-out with clear tape. Carefully using a utility knife, cut out a ¼" (6 mm) hole in the center of each disk using a utility knife.

2. Insert the dowel through the side of the box, one of the taped cardboard disks (with the taped side facing the cardboard box, the turbine, the other side of the box, stator and rotor as shown on the previous page.

3. Wrap electrical tape around the dowel so that when the rotor is placed on it, it will rotate close to but not touch the stator.

4. Adjust the rotor on the electrical tape and rotate it until the rotor is able to rotate without wobbling. Glue it in that position to ensure stability.

5. Adjust the position of the rotor so that the magnets are able to rotate closely to the coils of magnetic wire without touching them, and then glue the taped cardboard disk to the dowel so that it rests on the edge of the cardboard box. Finally, glue the other cardboard disk to the dowel on the outside of the cardboard box with the clear taped side facing it.

H. Test the Wind Turbine

The wind turbine electric generator is now ready to be tested.

1. Using the multimeter, turn it to the resistance setting (200Ω), connect the test leads to apparatus. Record the resistance of the four-coil setup.
   a. If you are not getting a reading, check the connections between individual coils, and between the test leads and coils.
2. Place the apparatus in the wind tunnel. Following the directions given on site, adjust the wind velocity and measure/record the current and voltage produced at three different velocities.
   a. To measure voltage, connect the multimeter to the apparatus and use the AC Volt (V~) setting.
   b. To measure current to turn the multimeter to the AC Current (A~) setting.
   c. Connect your LED to the device and see if it lights up or not, if it does, do you notice anything about how it lights up? Record your results.
   d. Repeat these steps for three different wind speeds.
3. Come up with a way to roughly measure the area of one spoon, you will use this measurement when calculating wind power.
4. Calculate the electrical power of the generator and the power of the wind; then calculate the efficiency of the generator.
5. Fill in your data on the chart below.

Data

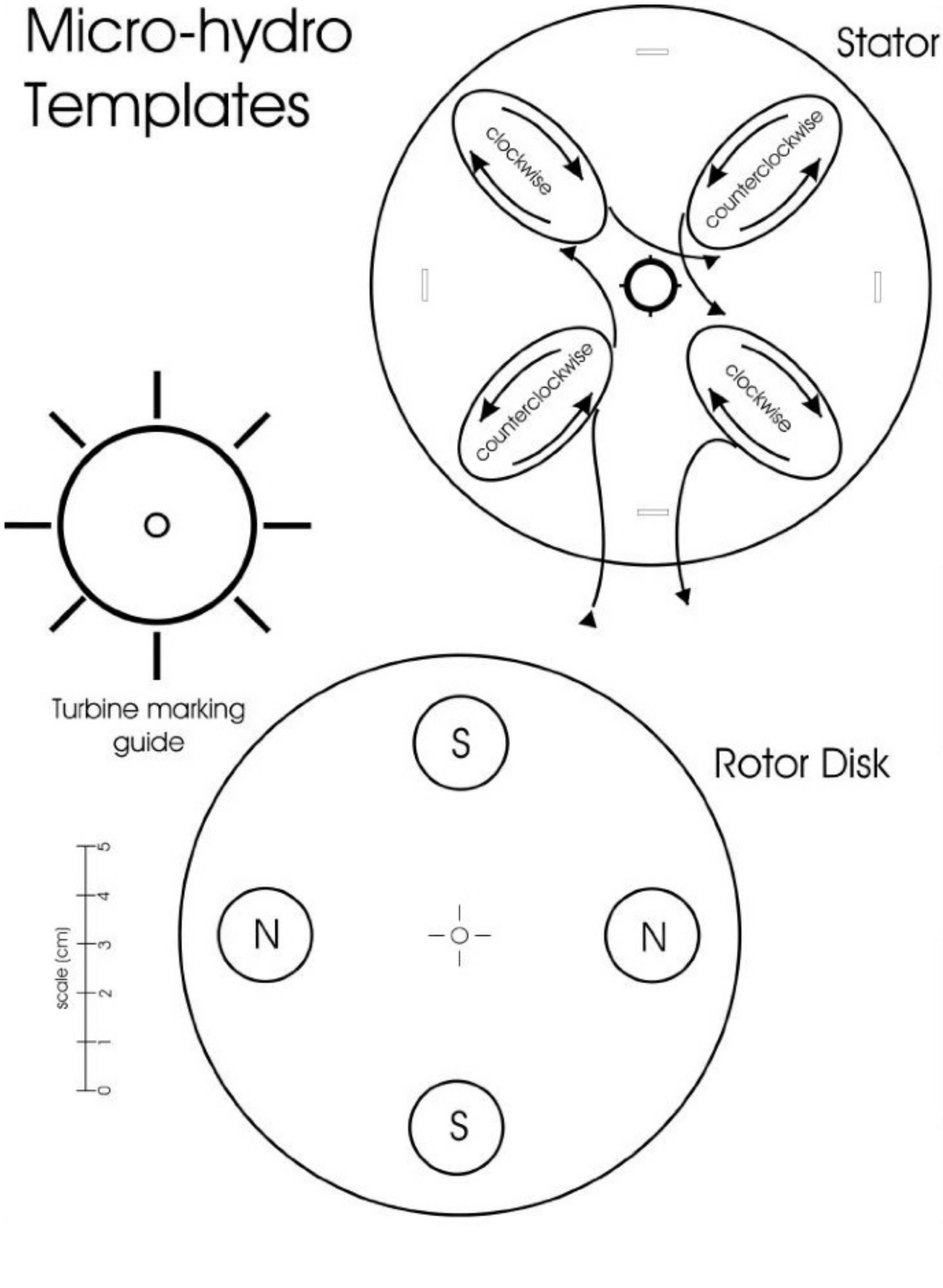
Velocity (m/s)	Current (A)	Voltage (V)	Power (W)	Wind Power (W)	Efficiency (η)

Electrical Power = Current*Voltage

Wind Power = 0.5 x Area x Air Density x Velocity^3

Efficiency = Electrical Power / Wind Power

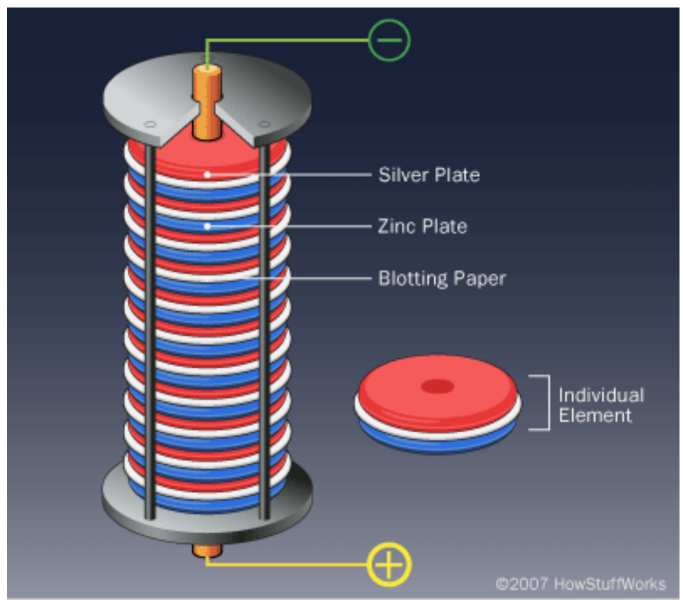
Micro-hydro Templates



4.0. Spare Change Flashlight

4.1. Battery introduction

(Adapted from reference 10) Today, batteries are all around us. They power computers, phones, smoke detectors, etc. Batteries are critical not only for current power demands but they will play a critical role in increasing implementation of renewable energy technologies due to the non-overlapping times of power generation and societies power consumption. While there are many different types of batteries, the basic concept by which they function remains the same. When a device is connected to a battery, a reaction occurs that produces electrical energy. This is known as an **electrochemical reaction**. Italian physicist Count Alessandro Volta first discovered this process in 1799 when he created a simple battery from metal plates and brine-soaked cardboard or paper – like you will be doing shortly.



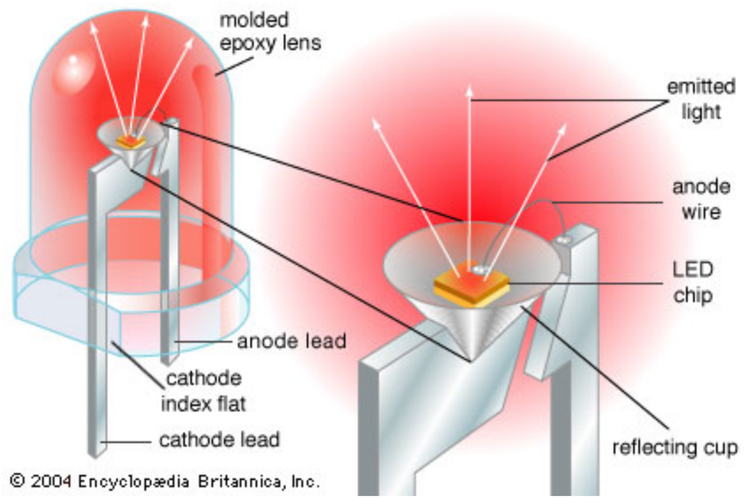
The internal workings of a battery are typically housed within a case. Inside this case are a **cathode**, which connects to the positive terminal, and an **anode**, which connects to the negative terminal. These components, more generally known as **electrodes**, occupy most of the space in a battery and are the place where the chemical reactions occur. A **separator** creates a barrier between the cathode and anode, preventing the electrodes from touching while allowing electrical charge to flow freely between them. The medium that allows the electric charge to flow between the cathode and anode is known as the **electrolyte**. Finally, the **collector** conducts the charge to the outside of the battery and through the load.

When a load completes the circuit between the two terminals, the battery produces electricity through a series of electromagnetic reactions between the anode, cathode and electrolyte. The anode experiences an **oxidation reaction** in which **ions** (electrically charged atoms or molecules) from the electrolyte combine with the anode, producing a compound and releasing one or more electrons. At the same time, the cathode goes through a **reduction reaction** in which the cathode substance, ions and free electrons also combine to form compounds. The reaction in the anode creates electrons, and the reaction in the cathode absorbs them. The net product is electricity. The battery will continue to produce electricity until one or both of the electrodes run out of the substance necessary for the reactions to occur. Batteries are normally grouped together in a **serial arrangement** to increase the **voltage** or in a **parallel arrangement** to increase **current**. In series, the voltage is increased, and in parallel the current increases. Batteries are rated in amp-hours, or, in the case of smaller household batteries, milliamp-hours (mAH). A typical household cell rated at 500 milliamp-hours should be able to supply

500 milliamps of current to the load for one hour. You can slice and dice the milliamp-hour rating in many different ways in terms of current and time.

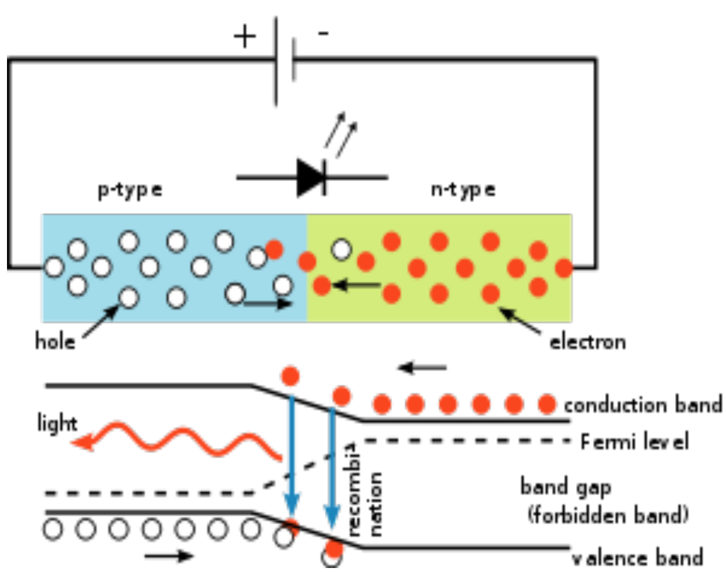
Cool video on how batteries work: www.youtube.com/watch?v=CX84l5ZZHVg

4.2. Light Emitting Diode (LED) introduction



(Adapted from how stuff works) Light emitting diodes (LEDs) are quite different than ordinary incandescent bulbs, they don't have a filament that will burn out, and they don't get especially hot. LEDs are illuminated solely by the movement of electrons in a semiconductor, and they last just as long as a standard transistor. The lifespan of an LED surpasses the short life of an incandescent bulb by thousands of hours.

Broadly speaking, a semiconductor is a material with a varying ability to conduct electrical current. Most semiconductors are made of a poor conductor that has had impurities (atoms of another material) added to it. The process of adding impurities is called doping. In doped material, additional atoms change the balance, either adding free electrons or creating holes where electrons can go. Either of these alterations make the material more conductive. A semiconductor with extra electrons is called *n*-type material, since it has extra negatively charged particles. In n-type material, free electrons move from a negatively charged area to a positively charged area. A semiconductor with extra holes is called *p*-type material, since it effectively has extra positively charged particles. Electrons can jump from hole to hole, moving from a negatively charged area to a positively charged area. As a result, the holes themselves appear to move from a positively charged area to a negatively charged area.



A diode consists of a section of n-type material bonded to a section of p-type material, with electrodes on each end. Applying a voltage to the diode pushing electronic from the *n*-type region to the p-type region. Once the electron crosses the junction and into the *p*-type region it sees the extra holes, and fills the hole. The filling process is called recombination, and in LEDs this typically results in light emission, or so-called, radiative recombination. Radiative recombination emits a photon – or a quanta of light. Lots of recombination events (~10^{12}) are required for the LED to become a bright light. As free electrons move across a diode and fall into empty holes in the *p*-type layer. This involves a drop from the electron conduction band to a lower energy state and the energy of the photon is directed related to the magnitude of this energy difference.

In conventional incandescent bulbs, the light-production process involves generating a lot of heat (the filament must be warmed). This is completely wasted energy, unless you're using the lamp as a heater, because a huge portion of the available electricity isn't going toward producing visible light. LEDs generate very little heat, relatively speaking. A much higher percentage of the electrical power is going directly to generating light, which cuts down on the electricity demands considerably.

4.3. Spare Change Battery Activity

Who: Group of 4 students
What: Build a battery out of pennies to light up an LED. The purpose of this activity is to learn concepts of energy storage, electricity, light, energy conversion from electrochemical energy to light energy.
Where: Classroom
Time: 4 hours

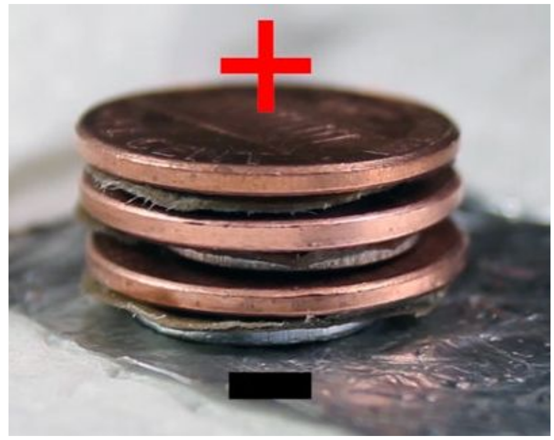
Supplies:

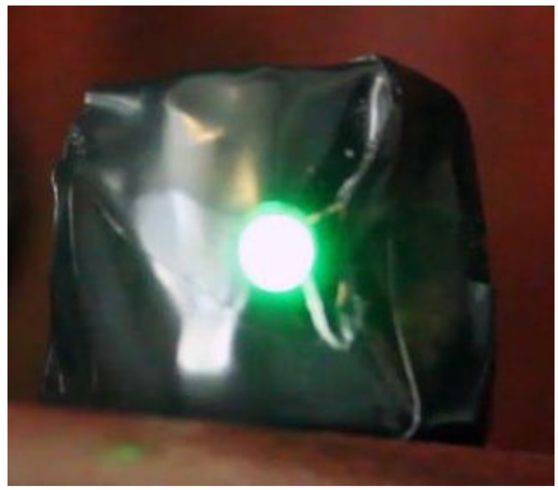
Item (Consumables)	Quantity	Check-out	Check-in	Notes
Pennies (1944-1982)	10		NA	
Zinc washers	10		NA	
Al foil – square	1		NA	
Cardboard – square 4”x4”	1		NA	
Multimeter	1			
Vinegar bottle	1			
LED - red	1			
LED – green	1			
LED – blue	1			
Scissors	1			
Electrical tape role	1			

Objective:

- Construct a simple battery using pennies, and electrolyte and zinc washers.
- Explore effects of series and parallel circuit configurations.
- Power an LED with the battery

Procedure:





1 Using scissors cut the cardboard into 10 small circular pieces, slightly larger than a penny.
2 Soak the cardboard pieces in your electrolyte (the salt water, lemon juice or vinegar) for 2-3 minutes.
3 While the cardboard is soaking, take your aluminum foil and place it in your workspace. Place a zinc washer on it.
4 Remove the cardboard from the electrolyte solution, using a paper towel blot each piece dry. This is just to keep the pieces from dripping, do not over dry the cardboard.
5 Place a single piece of cardboard on top of the zinc washer in your workspace.
6 Place a penny on top of the cardboard and you have finished the battery; however, we will use this as just one cell of our battery.
7 Using the DC voltage setting on the multi-meter, measure the voltage of the individual cell. You can do this by placing one lead of the meter on the aluminum foil and the other on the penny, make note of this reading (below). Using the DCA setting, measure the current of the cell as well.
8 Pick an LED, make sure to look at the required voltage.
9 Using the voltage reading from the first cell, and the required voltage of the LED, determine how many cells you will need to power the LED. The voltage of n number of cells can be found by V=n*voltage of one cell. Build the required number of cells and stack them together, the sequence from bottom to top should be: foil, washer, cardboard, penny, washer, cardboard, penny...
10 Test the voltage and current of your battery using the multi-meter. Compare these numbers to those of the individual cell, and calculated values.
11 Connect the LED to the battery, touch the long lead (positive) of the LED to the top of the penny and the short lead (negative) to the aluminum foil, it should illuminate.

12 Remove the aluminum foil from the bottom of the stack. Using the electrical tape wrap up the battery (with the LED connected). You now have a self powered LED, it could last anywhere from one to 16 days!
13 Attempt to make a switch for your LED flashlight such that you can turn on the light on demand.

Note:

- If the cardboard pieces touch while in the battery, the battery could short out and experience performance issues.
- The battery could be used to power other low current devices as well if wires were attached.
- The reason for wrapping the battery in electrical tape involves it's life span. Once the cardboard dries out, all the electrolyte, which drives the battery, is gone and it will not operate. The battery is wrapped in tape in an effort to provide an airtight seal, slow the drying process, and extend the battery's lifespan.
- This experiment can also be conducted by using pennies dated 1982 or later and sanding off one face of the penny to expose the zinc core while leaving the other side copper.
- The date range of pennies needs to be specified for this experiment due to the change of composition throughout history. Between 1944 and 1981 pennies were 95% copper and 5% tin, zinc or a mixture. Since 1982 pennies have been made of copper plated zinc cores (97.5% zinc, 2.5% copper).

Worksheet

Number of cells	Voltage Measured
1	
2	
3	
4	
5	
6	
7	

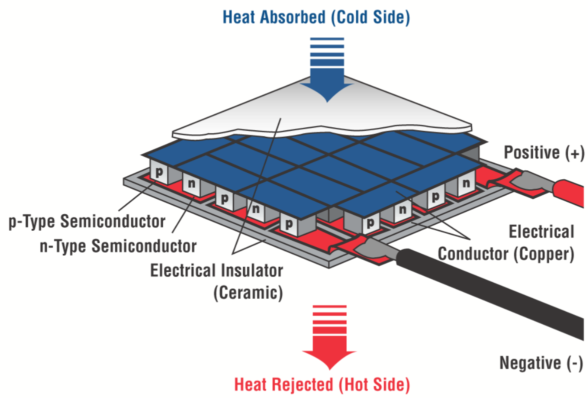
LED color	Voltage need	No. of cells to light LED

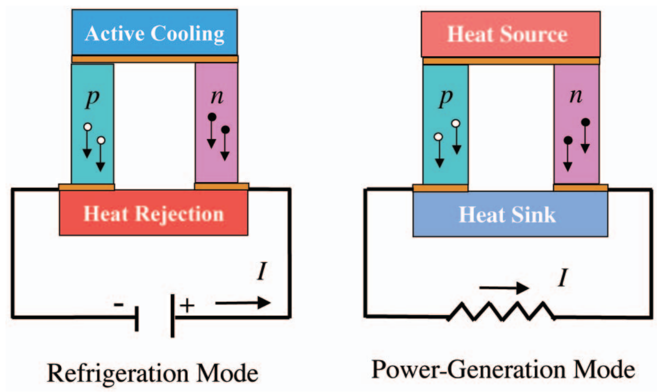
Notes:

5.0. Thermoelectric Power and Cooling

5.1. Introduction to Thermoelectrics

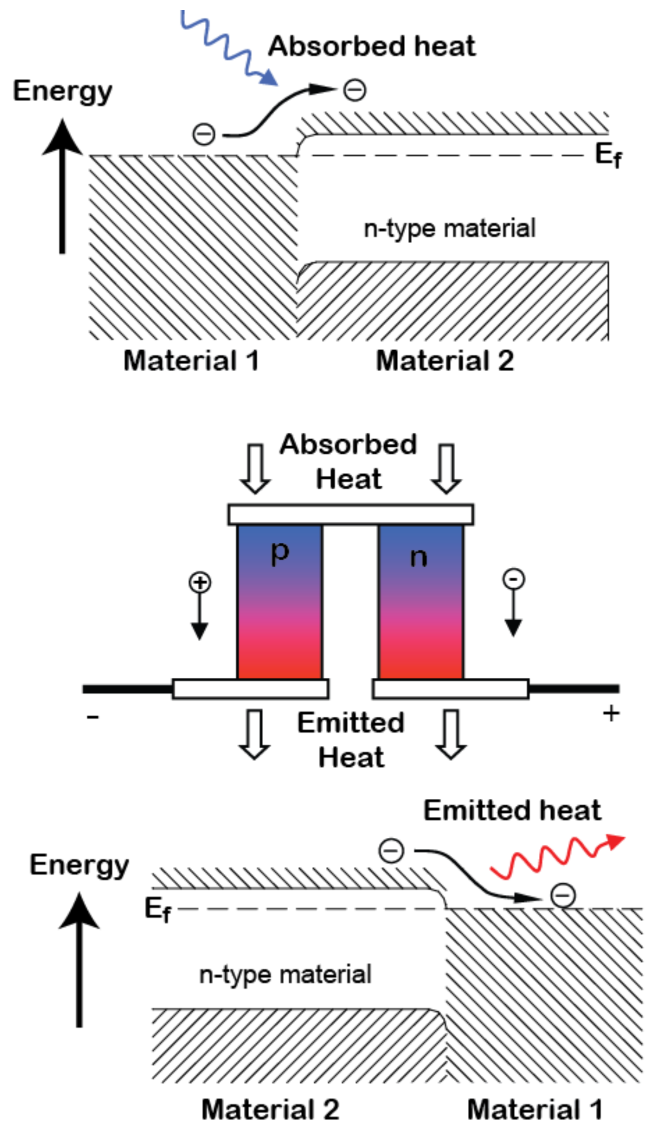
The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers (e.g. electrons) in the material to diffuse from the hot side to the cold side. This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers and coolers. (Source: Wikipedia)





(Adapted from Dr. Hogan, Mich State) In 1822, Seebeck observed that when two electrically conducting materials are connected in a closed loop and a temperature difference exists at the two junctions *T*1 and *T*2, then there was a deflection of the magnetic needle in his measurement apparatus. The deflection was dependent on the temperature difference between junctions and the materials used for the conductors. Many scientists subsequently researched this relationship, and it was discovered that the observation by Seebeck was not caused by a magnetic polarization, but was caused by electrical current flowing in the closed loop circuit. Twelve years after Seebeck's discovery, a watchmaker and scientist named Jean Peltier reported a temperature anomaly at the junction of two dissimilar materials as a current was passed through the junction. It was unclear what caused this anomaly and while Peltier attempted to explain it on the basis of the electrical conductivities and/or hardness of the two materials, Lenz removed all doubt in 1838 with one simple experiment. By placing a droplet of water in a dimple at the junction between rods of bismuth and antimony, Lenz was able to **freeze the water** (!) and subsequently melt the ice by changing the direction of current through the junction. In this way, Lenz had made the first thermoelectric cooler. The rate of heat absorbed (Q) or liberated from the junction was later found to be proportional to the current or, Q = pi*I, where pi is the Peltier coefficient and I is the current.

Physically, what is happening as the charge carriers move through the conductors is complex. To get a relatively simple view of the heat absorption or emission process, we need to consider the charge carrier energy levels in the materials – simplified as energy bands. Electrical engineers often use band diagrams to describe electrical processes in materials. A band diagram showing the changing energy levels of the charge as it moves through a material and the resulting absorption or emission of thermal energy due to this change in energy level is given in the figure to the right.



5.2. Thermoelectric Activity

Who: Group of 5 students
What: This is a solid-state energy conversion demonstration with a thermoelectric device using heat to power a fan, and using power to freeze water. The purpose of this activity is to look at multiple energy conversion processes between heat, electricity, and shaft power.
Where: Classroom
Time: 4 hours

Supplies:

Item	Quantity	Check-out	Check-in	Notes
Peltier Cooler (12 V, 5.5 A)	1			
Aligator clips	2			
Cardboard sheet (4 in x 6 in)	1		NA	
Heat sink fins	2			
DC motor	1			
D-cell batteries	8			
Batter pack	1			
Plastic trays	2			
Plastic cup	1			
Metal tin tray (from Al foil)	1			
Thermal interface grease	1			
1 cup of boiling water	1			

Learning Objectives:

- Hands on experiment exposing students to energy conversion, thermal energy, electric work, and shaft power. Build knowledge in electrical wiring and energy conversion systems.
- Introduce concepts of heat transfer, and conservation of energy
- Introduce concept of power generation and refrigeration

SAFETY NOTES

- **Burn hazard**: Dealing with boiling water that can cause serious burns
- **Electricity**: Electrical wiring and power devices

Activities:

A. Use heat to power a fan

Procedure

1. Construct a fan blade from the cardboard provided and glue it to the shaft of the small DC motor. Allow glue to dry.
2. Apply a thin layer of thermal interface grease to the heat sink fins and attached the thermoelectric device. Connect heat sink fins on both sides of the device.

3. Connect the alligator clips to the electrical leads of the thermoelectric device, and then connect the other side of the alligator clips to the small DC motor.
4. Poor boiling water from kettle into a ceramic mug
5. Poor the hot water into the plastic container filling to a height of approximately 1.5 cm.
6. Place 1 side of the heat sink fins in the hot water. Does the fan rotate?
7. Disconnect the motor from the thermoelectric generator and connect the leads to 1 D-cell battery. Does the fan rotate? Is there a difference in speed? Why?

B. Use power to make a thermoelectric cooler

Procedure

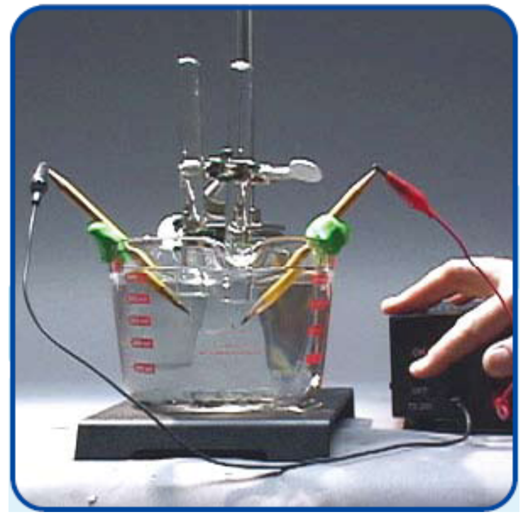
1. Place a heat sink fin on one side of the thermoelectric device using a thin layer of thermal interface grease between the materials.
2. Place cold water in the plastic tray, and place the heat sink fins into the cold water
3. Make a small tray with aluminum foil that will hold a small amount of water, roughly 1 ml of water.
4. Put thermal interface grease on the exposed side of the thermoelectric device and carefully place the aluminum tray on top.
5. Put the D-cell batteries into the battery pack, and use the alligator clips to connect the battery pack to the electric leads of the thermoelectric device.
6. What are your observations?

Additional details will be provided in an additional handout.

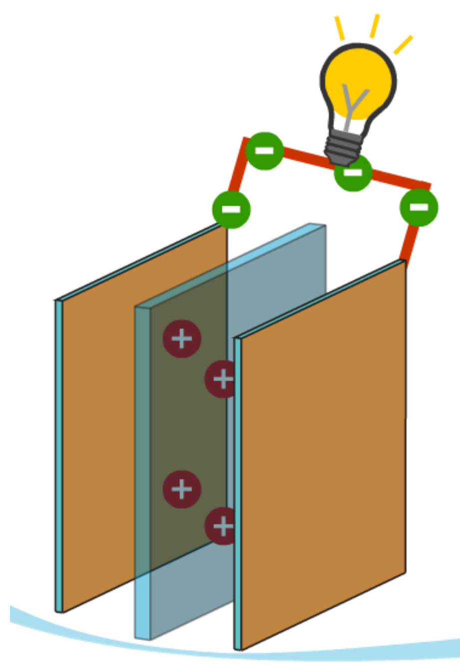
OBSERVATIONS AND NOTES

6.0. Electrolysis and Fuel Cell Car

6.1. Background on Electrolysis and Fuel Cells



Hydrogen is one of the most abundant elements on earth, but very little pure hydrogen exists naturally. What makes it such a useful fuel source is the ease with which its chemical energy can be transferred to electric energy. Electrolysis is the process of using electricity to break water into hydrogen and oxygen. The process utilizes no moving parts and produces ultrapure hydrogen (>99.999 %). Technologies for producing Hydrogen through electrolysis are currently about 75% energy efficient. Hydrogen gas formed from this method is perfect for use with hydrogen fuel cells. Fuel cells have the ability to fulfill all global power needs through highly efficient, low pollution technology. Electrolysis can be seen in two main designs: unipolar and bipolar. For our experiments, we will make use of the unipolar design. This method utilizes submerging both electrodes (anode and cathode) into an electrolyte water solution. The electrodes are used to send a current through the solution and the electrolyte is used to lessen the resistivity of the water (Pure water has an electrical conductivity about one millionth that of seawater). Salt will be our electrolyte in this situation, and the aluminum will be our positive and negative electrodes.



As fossil fuels become scarcer, fuel cell technology is presenting itself as a promising replacement for powering the automotive market. Fuel cells will allow for low emission, high efficiency vehicles while fuel could be locally harvested from renewable sources replacing imported fossil fuels.

There are many different types of fuel cells. In this activity we will be using a reversible Polymer Electrolyte Membrane (PEM) fuel cell. It consists of positively (cathode) and negatively (anode) charged plates separated by an electrolyte membrane. Hydrogen is split on the anode side where protons travel through the electrolyte membrane to the cathode and electrons are carried over an external circuit load. They combine on the cathode side with oxygen to produce water as a byproduct.

6.2. Fuel Cell Car Activities

Who: Individual
What: Use a polymer electrolyte fuel cell powered by hydrogen created through hydrolysis to run a toy car. The purpose of this activity is to learn about chemical energy, and conversion to mechanical power.
Where: Classroom
Time: 3 hours

Supplies:

Item	Quantity	Check-out	Check-in	Notes
Fuel Cell car kit	1		NA	
Paper clips	4			
Distilled water – plastic cup	1			
Plastic tray	1			
Tape	1			
Test tube	1			
Al foil - sheet	1			
AA batteries	2			Included
Salt container	1			Shared
Scissors	1			Shared

SAFETY NOTES

- **Fire Hazard**: Hydrogen gas is extremely flammable

Objective:

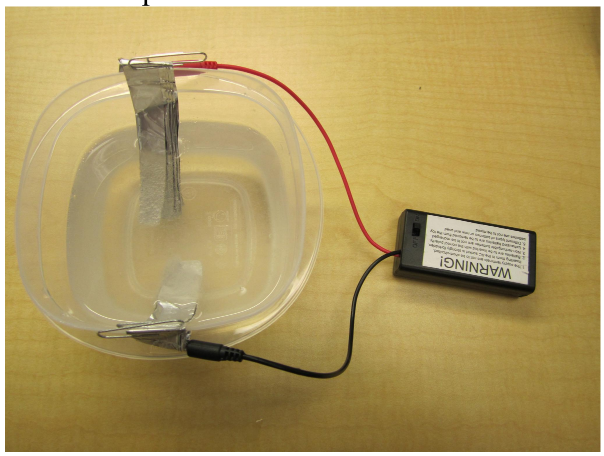
- Explore the electrolysis method of splitting hydrogen and oxygen in water
- Construct a hydrogen fuel cell powered car
- Test efficiency of solar vs battery charging of a fuel cell car

Electrolysis Procedure:

1 Cut two 4 in x 6 in sections of aluminum foil and fold them accordion style as seen below. Then fold the end as shown.

2 Fill the tray with about an inch of distilled water. Stir in salt. Attach the aluminum foil to the edges of the tray with paper clips. Make sure to bend the foil at an angle into the water, not straight down.

3 Connect the battery pack from the Fuel Cell Car Kit to the tops of the aluminum foil and switch them to the 'On' position.



4 Bubbles will begin to form near both aluminum electrodes. Notice one side producing more bubbles? Since water is H_2O, which electrode do you think is producing the hydrogen bubbles? Try moving the electrodes closer together, or splay the aluminum foil so more water is in contact with the surface. How does this affect the experiment?

5 As the bubbles rise up, they can be captured by the test tube if positioned correctly. If the tube is positioned above the negative electrode and filled with the gas, a match will very easily determine whether the process is working! Allow the instructor to carry out this process as hydrogen is extremely flammable.

Fuel Cell Car Procedure:

1 Cut two 1. 5in sections of rubber tubing from the long tubing provided in the kit. Put a black pin in one tube and a red pin in another tube.

2 Attach the tubes to the lower nozzles on either side of the fuel cell.

3 Connect the wheels to the body of the car by pressing them until a snap is heard.

4 Insert the fuel cell into the body of the car so that it is snug. Also insert the Hydrogen and Oxygen storage cylinders into the car body.

5 After removing the pin from the oxygen side tube of the fuel cell, use the syringe to inject distilled water until the cell is full. Replace the pin once finished.
6 Fill the Hydrogen and Oxygen storage cylinders up to the ‘0’ line with distilled water. Then place the inner hemispherical containers into the storage cylinders, making sure that air can escape through the top. Be careful to not let the water overflow from the storage cylinders.
7 Connect the other end of the inner containers tubes to their respective nozzles on the fuel cell.
8 The car is charged by splitting the water inside the fuel cell into Oxygen and Hydrogen, with the gasses going into the respective storage cylinders. This can be done in two ways.
    a Solar Panel: Connect the solar panel using the red and black cables to the matching ports on the fuel cell.
    b Battery Pack: Connect the battery pack to the fuel cell making sure to match the red and black cables with their ports.
9 When the car is fully charged (the storage containers cannot hold any more gas), unplug the solar cell or battery pack and connect the red and black wires from the motor. LED lights should light up to indicate the motor is running.

Measure the voltage across the fuel cell when fully charged. Now measure the amperes. Also take note of how long your car takes to stop running.

Voltage V (Volts)	Amperes I (Amperes)	Time t (Seconds)

Now you can calculate the electric power (P), by following the power equation given below. To determine the electric energy (E) used to run the car, use the energy formula. In order to adapt to a more commonly referred to energy unit, you will need to convert to kilowatt-hours. Now it’s time to find out how much the electric company would have billed you. Using an example cost of $.096 per kilowatt-hour, you can estimate how much money you saved by using the sun to charge your fuel cell car!

Power P (Watts) $\boldsymbol{P = V * I}$	Energy $\boldsymbol{E_{ws}}$ (Watt-second) $\boldsymbol{E_{ws} = P * t}$	Energy $\boldsymbol{E_{kwh}}$ (kilowatt-hours) $\boldsymbol{E_{kwh} = \frac{E_{ws} * 60 * 60}{1000}}$	Cost C (Dollars $) $\boldsymbol{C = E_{kwh} * .096}$

REFERENCES & MORE INFORMATION

References

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More Information

1. Free book: *Sustainable Energy Book: Without the Hot Air*
http://www.withouthotair.com