Berkeley Engineers and Mentors

Big BEAM Energy

Target Grade: Elementary/Middle School
Author: Aaron He*
Term: Autumn 2019

Brief Overview

In this lesson, we will introduce the mentees to the concept of renewable and sustainable energy. We will be exploring the several forms of renewable energy as alternatives to our current resources. In the first module, we will utilise the power of sunlight to make some delicious s'mores. In the second module, we will explore lifting loads with concepts of hydropower. Finally, in the last module, we will be teaching the mentees about wind power by designing sail cars.

Teaching Goals

- **Renewable Energy:** Energy that is collected from a source that can be naturally and continuously replenished. In this lesson we will introduce three types of renewable energy:
- **Wind Power:** harnesses the kinetic energy of wind through the usage of windmills and wind turbines
- **Hydropower:** harnesses the kinetic and potential energy of moving water through the usage of turbines
- **Solar Power:** harnesses the energy from solar radiation (sunlight) through the usage of photovoltaic (PV) cells and mirrors
- **Engineering Design Process:** The process of constantly testing and refining models through trial and error.

Careers and Applications

Renewable energy is emerging as one of the most studied fields around the STEM world. Non-renewable energy is limited and also often linked to deleterious impacts on the environment. Because of this, there is a search to find cleaner solutions to our increasing demand for energy and the clean energy industry is rapidly expanding. Researchers such as **environmental engineers** and **chemical engineers** study the efficiency of renewable energy as a viable alternative to traditional energy sources.

*Adapted from Alternative Energy by Lindsey Zhang & Yessica Wiryawan AND Big BEAM Energy by Stephanie Huang, Zachary Huang and Nicole Zhu

Agenda

- Introduction (5 min)
- Module 1: Gimme S'more!! (10 min)
- Module 1.5: Love means nothing to Tennis Players (10 min)
- Module 2: Water You Up to? (10 min)
- Module 3: You Blew Me Away (20 min)
- Conclusion (5 min)

Introduction

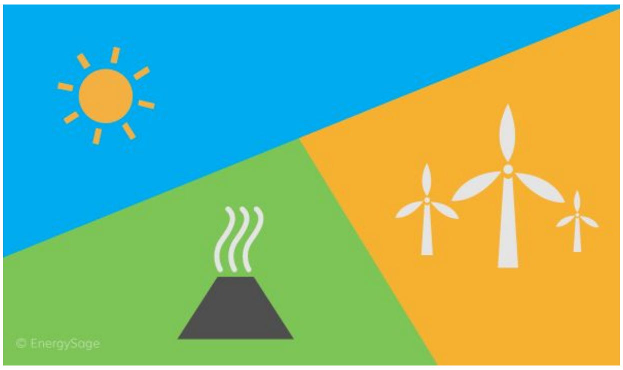
Energy is probably the single most important property of the universe. The Earth requires energy to maintain its climate. Machines need energy to power their moving parts. Humans need energy to complete daily tasks. To generalise, energy is the capacity to do work.

There are many ways for a country to produce the energy needed for its economy. In 2017, the United States produces about 80% of its energy from non-renewable fossil fuels, 11% from renewable sources, and 9% from nuclear energy.

Many of our traditional sources of energy, such as gasoline and natural gas, have a finite reserve. They can be depleted in a few hundreds or even tens of years. In addition, burning these resources can release greenhouse gases, such as CO2, NOx and SOx. A large concentration of these toxic gases will increase the global temperature and have devastating impacts on the environment. Because of this, it is critical that we explore new sources of renewable and clean energy.

Renewable energy is energy that is collected from renewable resources, which are naturally and continuously replenished on a human timescale. They also have a fortuitous side effect of being **carbon-free** or **carbon-neutral**. In other words, they do not emit additional (or any) greenhouse gases into the atmosphere.

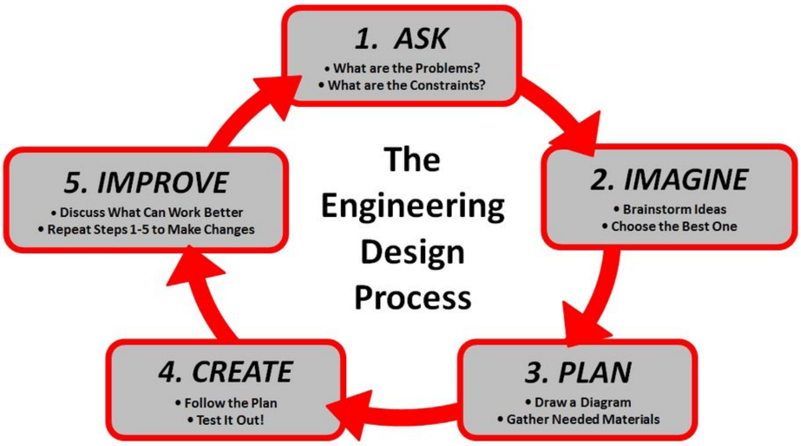
Depending on their grade, some mentees might have heard about the different types of energy sources as well as renewable energy. Try asking the mentees to name a few types of resources. Then, ask them if each of them is renewable and why. Here's a list of some renewable / non-renewable sources that the mentees might answer.



Non-Renewable Energy	Renewable Energy
• Coal • Natural Gas • Petroleum • Other fossil fuels • Hydrogen*** • Nuclear**	• Hydropower • Wind • Solar • Biofuel** • Geothermal / Ocean Thermal • Tidal • Marine Current • Osmotic Power • Wave

**Debatable
***Non-renewable because most hydrogen today comes from fossil fuels

Read More:
- http://www.phmc.state.pa.us/portal/communities/energy/



Module 1: Gimme S'more!! (Solar Power)

Introduction

In this module, mentees will be learning about how to harness solar energy by making s'mores in solar powered ovens.

Teaching Goals

1. **Solar Energy:** The heat and light from the sun that can be converted into usable energy, commonly through photovoltaic cells
2. **Electromagnetic Radiation**: The emission of energy as electromagnetic waves or as moving subatomic particles
3. **Photons:** energy-possessing particles that make up electromagnetic radiation

Background for Mentors

Solar energy originates from the radiant light of the sun. Sunlight is made out of particles called **photons**. Each photon possesses a certain amount of electromagnetic radiant energy, whose magnitude is inversely proportional to its wavelength. When these photons contact another object, they will transfer this energy onto that object as different forms of energy.

Currently, the most developed and efficient way to harness the energy of sunlight is through photovoltaics (PV). This is the technology used in solar panels and solar cells. Another method is to transfer its energy into thermal energy by heating up a substance, such as water or air. In this module, we will demonstrate how the energy of sunlight can be used to cook s'mores!

Read more:
https://docs.google.com/document/d/1xI1xPvt-saGFOuGzELQu3R1gZzjnwHzdOkHxTpsvPs0/edit?usp=sharing

Materials

- Solar powered oven - 2 per site
- Kraft marshmallows - 1 per student
- Hershey milk chocolate bars - 3 per student
- Skewers - 2 per site
- Honey Maid Graham Crackers - 2 per student
- Gloves

Procedure

1. Give the mentees a demo of the solar powered oven. Facilitate their understanding by asking some of the following questions:
    a. What is the purpose of the aluminum foil? - to reflect and capture more sunlight
    b. How exactly does sunlight heat up the food inside? - the energy in the photons are converted to thermal energy
    c. Why is solar power renewable? - because sunlight can be naturally and continuously replenished (well for another 5 billion at least)
2. Find a location with ample sunlight and place the oven towards the sun.
3. Prop the oven door open using two wooden skewers. Any angle from 45° to 90° should be good depending on the location of the sun.

4. Place a piece of black paper on the bottom of the oven.
5. Place graham crackers, chocolate, and marshmallows inside the on top of the paper. **Allow the s'mores to cook for the duration of the lesson.** (I recommend only putting the graham cracker on the bottom first to expose the marshmallow more)
6. If the weather is not that sunny, or if the marshmallows are not cooked by the end of the lesson, torch them using hairdryer. (be careful)

Notes for mentors

- Graham Crackers contain **gluten**; chocolate contains **milk**; marshmallows contains a lot of **sugar**. Make sure that the mentees are not allergic or diabetic.
- The chocolate takes about 5 minutes to melt
- The marshmallows take a rather long time to cook - usually close to an hour
- **IMPORTANT**: While setting up the oven, do not let the mentees see the s'mores, or they would be hella distracted for the rest of the lesson. Even if they see it, emphasise that they can't eat them until the lesson is finished.

Module 1.5: Love Means Nothing to Tennis Players

Introduction

Energy comes in many different forms. Sunlight is a type of electromagnetic radiant energy that is often converted to thermal energy. These forms are rather complicated. In this module, mentees will be learning about some simpler forms of energy (kinetic, potential) using tennis balls.

Teaching Goals

1. **Kinetic Energy:** The energy that an object possesses due to its motion
2. **Potential Energy**: The energy possessed by a body by virtue of its position relative to others
3. **Conservation of Energy**: a principle stating that energy cannot be created or destroyed, but can be altered from one form to another

Background for Mentors

Kinetic Energy is the energy a body possesses by being in motion. Any moving object with a nonzero mass possesses kinetic energy. The equation of kinetic energy is

$$\frac{1}{2}mv^2 \text{ or } \frac{1}{2}\rho v^2$$

where m is the mass, v is the velocity, and ρ is density of an object. Wind power harnesses this kinetic energy of wind and convert it into electricity or work.

Potential Energy is the "potential" for an object to do work. It can be considered as stored energy that can be released at a later time. It can also be easily converted to other forms of energy, such as kinetic and chemical. An object at a higher place possess greater potential energy because it has the "potential" to fall, thereby converting this energy to kinetic. The equation of potential energy is

$$mgh \text{ or } \rho gh$$

where m is the mass, h is the height, and ρ is density of an object, g is the acceleration due to gravity.

Energy is in the unit of $\frac{kg*m^2}{s^2}$, or a **Joule** (J).

Materials

- Tennis Ball - 1 per site

Procedure

1. **Intro**: Ask the mentees what they remember from the tennis ball demo in the first lesson (Marshmallow Catapult). It would be a good idea to recheck their understanding of velocity and acceleration. For the following parts, feel free to calculate the exact magnitude of the energy if you're at a middle school site. I recommend using imperial units with elementary sites, and metric units with middle school sites for calculations. (The mass of a tennis ball is 0.058 kg and the constant g is 9.8 $\frac{m}{s^2}$).

2. **Part one**: Free Fall
    a. Take the tennis ball and hold it around 1.5 metres (5 feet) from the ground.
        i. How far approximately the ball is from the ground? - 1.5 m
        ii. What is the velocity of the ball? - 0 m/s
        iii. Does the ball have kinetic energy? - No because the velocity is 0
        iv. Does the ball have potential energy? - Yes because the height isn't 0

    b. Now, drop the tennis ball.
        i. How far is the ball from the ground now? - 0 m
        ii. Was the ball speeding up, slowing down, or traveling at the same speed? - speeding up
        iii. Was the ball gaining or losing kinetic energy - Gaining because it was speeding up
        iv. Was the ball gaining or losing potential energy - Losing because it was dropping
        v. When was the ball travelling the fastest? - Right before the ball hit the ground
        vi. When does the ball possess the greatest kinetic energy? - Right before the ball hit the ground
        vii. When does the ball possess the greatest potential energy? - When the ball was at its initial position

3. **Part two**: Ball Toss (Optional)
    For advance sites, feel free to start the demo by tossing the ball upwards, which initialises the ball at a nonzero velocity. You can ask the mentees the same questions as part one, but for all three stages of the motion (rising, falling, and stopping).

4. **Conclusion**:
    a. Ask the mentees what happens to the ball's kinetic energy when the potential energy decreases, and vice versa. Ask them what they can conclude about the sum of the ball's kinetic and potential energy. Explain that this sum is always constant, because **energy is conserved**!
    b. Transitioning into the next two modules, explain that we can harness the potential and kinetic energy of natural resources (such as air and water). For example, wind power converts the kinetic energy of wind into work or electricity; likewise, hydropower converts the potential energy (and kinetic) of

water into work or electricity.

Module 2: Water You Up to? (HydroPower)

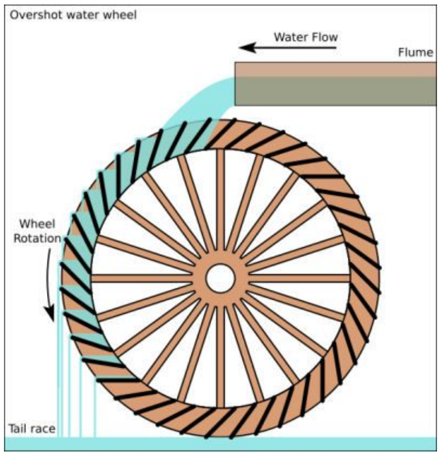
Introduction

In this module, students will build upon the concepts of kinetic energy and potential energy to examine how a watermill can convert the movement of water into work.

Teaching Goals

1. **Hydropower:** a form of renewable energy, the power created from harnessing the energy of water.
2. **Torque:** A force acting upon an object that causes it to rotate.

Background for Mentors



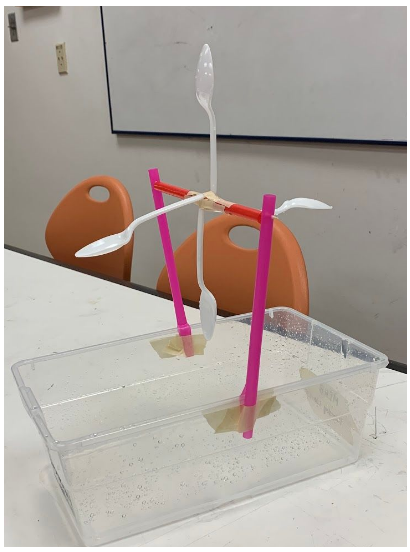
Hydropower is power generated by harnessing the kinetic energy of water. Hydropower plants first store the **potential energy** of water by collecting it with dams. When the collected water flow through the dam due to gravity, the **kinetic energy** of falling water produces electricity through the usage of turbines.

The flow of this water applies **torque,** the twisting or turning force that tends to cause rotation around an axis. The torque spins the watermill or the turbine, producing either work or electricity.

In the demo, the falling of water applies torque on the spoons in water watermill, causing it to spin. This spinning motion can be used to do useful work, such as lifting weights.

Read more:
https://docs.google.com/document/d/1HFzi0Vf8RrlRsCluRDYV8O1NkQSZO4hlDg9pOO9Qmoo/edit?usp=sharing

Materials



- Watermill (1 per site)
- Water (500 mL per site)
- Strings (50 cm per site)
- Tape (2 rolls per site)
- (Weights)

Procedure

1. Attach the windmill to the sides of the material box.
2. Slowly pour water onto the spoons to demonstrate how the moving water is transferring its energy to the watermill.
3. Attach an object (less than 100g) to the central straw

4. Pour water again. The attached weight should be lifted because the central straw is spinning. Explain that this is one example of how hydropower can provide useful work.
5. **Optional**: If time allows, use the electric fan and try to spin the mill. Since it's difficult to maintain the same flow rate between air and water, we can't really provide a fair comparison between the two sources of energy. Instead, I encourage you guys to play around with both methods and see which one could lift the heavier weight. In theory, assuming that the same volume of both fluids flows at the same velocity, the water powered mill should be able to lift more weight, because water has a higher density than air.
6. Ask the mentees these questions:
    - How does the windmill function similarly to the watermill?
    - How does it differ?
    - How might engineers apply these concepts to power large scale projects?
    - Which form(s) of energy do mills harness?

Module 3: You Blew Me Away (Wind Power)

Introduction

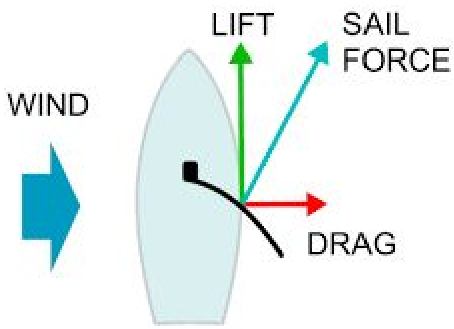
Through designing their own wind powered cars, mentees will be learning about what wind is and how it can provide energy. In addition, the movement of wind and sail cars will teach the concepts of **kinetic energy**.

Teaching Goals

1. **Wind energy** is a form of renewable energy that harnesses the energy of wind, which is the flow of gas molecules.
2. **Drag** is the longitudinal force exerted by air or other fluid surrounding a moving object
3. **Engineering Design Process**: The process of constantly testing and refining models through trial and error.

Background for Mentors

Wind is the flow of gases on a large scale. Since it has a nonzero mass and velocity, it possesses **kinetic energy**. In this module, we will be building sail cars that can harness the kinetic energy of wind. Moving air will interact with the sail and transfers its kinetic energy, propelling the car itself. The force that propels the car is called **drag**. The amount of drag depends on the size, shape, and speed of an object. Therefore, in designing sail cars, different sizes and shapes of sails should be tested to determine what makes the cars go the fastest and furthest.



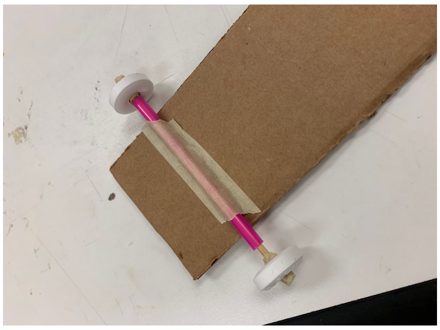
Read more:
https://docs.google.com/document/d/1TkNVcKHozlpgph68J9xKzkddaYD71OfoUNC3EVf8N2Y/edit?usp=sharing

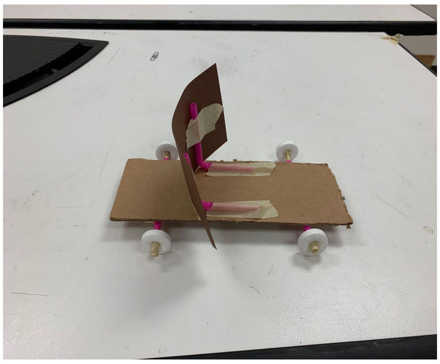
Materials

- Origami paper - 0.5 sheet per student
- Wooden sticks - 1 per student
- Bendable straws - 1 per student
- Tape - 2 rolls per site
- Electric Fan - 1 per site
- Cardboard pieces
- Scissors - 2 pair per site
- Life saver mints - 2 per student

Procedure

1. Organise the mentees into pairs
2. Hand each pair 1 piece of cardboard, 4 life savers mints, 2 wooden sticks, 1 piece of paper, and 2 bendable straws.
3. Pass out the tape and scissors
4. Students will cut the straws and use the straight pieces first, taping one at the front end of the cardboard and one at the back end.
5. Then, the wooden sticks will be placed in the straw and life savers will be taped to the end of each wooden stick.
6. The student is then free to use the wooden sticks, straws, and paper in whatever way they choose to make a sail. Many types of paper will be provided so mentees can choose their favourites.
7. At this point, mentors should be asking students to apply what they learned about drag to make the best sail.
8. Finally, students will test their sail cars using an electric fan and use a timer to measure how long their sail car takes to make it to a certain point. Each student will test their car and the winner will be named at the end. Be sure to get creative with more competitions if you have time! You can see which car rolls the furthest or which car can carry the most candies.





Conclusion

To wrap up the lesson, have a discussion with the kids! This lesson is a science lesson, but it more importantly explores the issues our world currently faces, and the critical role engineers play in exploring the fields of renewable energy and green chemistry. Talk about the different types of both renewable and non-renewable types of energy, and the pros and cons of each.

References

- Renewable Energy Project for Kids: Power from Water, Justine Rembac, Education.com. https://www.education.com/
- Hydroelectric Power: How it Works, USGS. https://www.usgs.gov/special-topic/water-science-school/science/hydroelectric-power

-how-it-works?qt-science_center_objects=0#qt-science_center_objects
- The Basics of Wind Energy. https://www.awea.org/wind-101/basics-of-wind-energy

Summary Materials Table

Material	Amount per Group	Expected $$	Vendor (or online link)
Construction Paper	1 per 2 students	0	Inventory
Wooden Sticks	1 per student + 2 more per site	0	Inventory
Tape	2 rolls per site	0	Inventory
Bendable Straws	1.5 per student	0	Inventory
Boba Straws	1.5 per student	0	Inventory
Plastic spoons	4 per site	0	Inventory
String	1 roll per site	0	Inventory
Life Saver Mints	12 bags	$31	Safeway
Cardboard	~200 cm^2 (31 in^2) per 2 students	0	Inventory
Marshmallows	6 bags	$12	Amazon
Hershey's Milk Chocolate Bars	2 boxes	$40	Amazon
Graham Crackers	4 boxes	$12	Amazon (Safeway)
Electric Fan	8 fans	$40	Amazon
Water	500 mL per site	0	Inventory
Pizza box	1-2 per site	0	Inventory
Scissors	2-3 per site	0	Inventory
Aluminum foil	2 rolls	$9.49	Probably Amazon
Tennis balls	1 per site	0	Nico

Lab Decal notes:
https://docs.google.com/document/d/1YMl4DBH4Ou8KQTaGNzZ6dWp3BX9K0eYOgE5DZBridQg/edit