Big Idea

The Sun is the primary source of energy for Earth's climate system.
(Climate Science Principle 1)

What You Will Need

- Adult partner
- 1 Black plastic trash bag
- 2 Styrofoam cups, 16 oz capacity
- 1 Wood dowel, about 1/4-inch diameter
- 1 Styrofoam freezer tray
- 2 Straight sewing pins
- 1 Plastic lid (from yogurt, margarine or similar container), about 4-inches diameter
- 2 Metal food cans, tops completely removed
- Masking tape
- Scissors
- Hot glue gun (low temperature)
- Metal file
- Ruler
- Drawing compass
- Unsharpened pencil
- Sharp knife
- Gloves for protection while using the knife

* (adapted from Strahl, 2007; *http://www.instructables.com/id/Solar-Thermal-Motor/)*

Activity 1: The Great, Glowing Orb

What You Will Do: Make a Solar Heat Engine*

When we talk about Earth's climate, we are basically talking about the effects of energy from the Sun, and how much of that energy is received at various places on Earth. This energy heats Earth's land, ocean, and atmosphere. Strong winds and large ocean currents are the results of heat moving from warm areas—like the Equator—to colder areas of our planet—like the North and South Poles. So, some of the Sun's heat energy is changed to motion energy. A Solar Heat Engine is a tool we can build that also changes heat energy from the Sun to motion energy.

How It Works

Many plastics shrink when they are heated. This engine uses strips of plastic attached to a flywheel that is mounted on a drum that can rotate on an axle. When one of the plastic strips is exposed to sunlight, it shrinks and pulls the flywheel off-center. This movement causes the drum to rotate. As the drum rotates, another plastic strip is exposed to the sun, and the motion continues. As the strips move into the shadow of the drum, they cool and lengthen again.

How to Do It

[NOTE: This activity should be done with adult supervision.]

1. Lay a garbage bag flat on a large surface (the floor is fine) and cut the bag into strips that are about three inches wide and ten inches long. You need eight strips to make your engine, but you should cut some extra ones for practice.

2. Stretch each of the plastic strips by holding one end in each hand, gripping the plastic tightly between the ends of your fingers and the base of your palm. Slowly stretch the plastic strip, until it is a little more than twice its original length and is about 1" wide. (Photo 1). Some of the strips will probably break because garbage bags aren't perfect, but be patient and work slowly. When you have six stretched plastic strips, cut about two inches off of each end (the parts that you held onto and didn't get stretched).

3. Measure the diameter of the large and small ends of a Styrofoam cup, and use your compass to draw two circles with the small diameter and one circle with the large diameter on the Styrofoam freezer tray. Use a compass instead of just tracing the circles around the cup so that you will know where the exact centers of the circles are. Cut the circles out with a sharp knife. **(Be careful and wear gloves!)**

Photo 1. Stretching the plastic strips.

Photo 2.

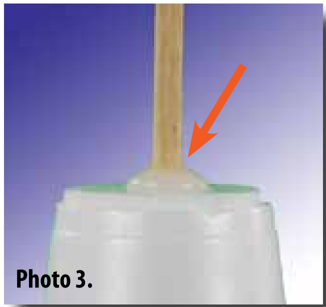
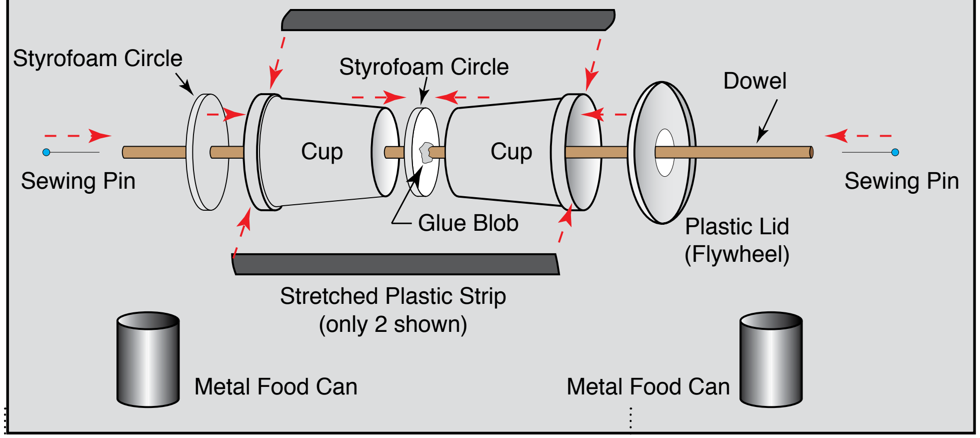


Photo 3.

4. **Prepare the Fixed Cup Assembly**: Make a hole in the bottom of one Styrofoam cup that is the same diameter as your wood dowel. Make a similar hole in the center of the large Styrofoam circle and in the center of one of the small circles that you cut out in Step 3. Use hot glue to fasten these circles to the large and small ends of the cup. Put the wood dowel through both holes in the cup assembly, and adjust the dowel so that about one inch extends past the large end of the cup (Photo 2). Use hot glue on both ends of the assembly to hold the dowel in place. Add extra hot glue around the dowel at the small end of the cup assembly to form a smooth rounded blob that will provide a pivot point around which the Wobble cup can wobble (Photo 3).

5. **Prepare the Wobble Cup Assembly:** Make a hole in the bottom of the remaining Styrofoam cup that is slightly larger than the diameter of your wood dowel. Be sure the hole is large enough so that the cup can wobble freely on the dowel. Make a similar hole in the center of the small Styrofoam circle that you cut out in Step 3. Use hot glue to fasten the small circle to the small end of the cup (Photo 4).

Figure 1. Exploded view of Solar Heat Engine. Red arrows show direction of assembly.



6. Apply a one-inch line of hot glue along the inside lip of the Wobble Cup Assembly (Photo 5), and place the end of one of the plastic strips on top of the glue. Use an unsharpened pencil to hold the plastic in place until the glue sets. Glue seven more strips around the rim of the cup in the same way. The strips should be evenly spaced around the cup with a gap of about 1/4-inch between the strips (Photo 6).

7. Slide the Wobble Cup Assembly onto the dowel so that the small ends of the Styrofoam cups are close together. Use pieces of masking tape to temporarily hold the Wobble Cup so that it is centered on the dowel (Photo 7). Glue the free ends of the plastic strips onto the Styrofoam circle on the Fixed Cup Assembly. Be sure the strips are taut when you glue them, but should not be stretched so tight that they pull the Wobble Cup off center.

8. Cut a one-inch hole in the center of the plastic lid. **(Be careful and wear gloves!)**Remove the masking tape, and glue the plastic lid onto the large end of the Wobble Cup Assembly. Be sure the hole in the plastic lid is centered on the wood dowel. Stick a sewing pin into each end of the dowel. Your engine is finished!

9. Use a metal file to make a small notch in the rim of each metal can. Space the cans so that you can rest the sewing pin at each end of the dowel into the notch on one of the cans. (Photo 8).Test the balance of your engine by slowly spinning it. If one side seems heavy, stick sewing pins into the Styrofoam circle on the opposite side until it seems balanced.

10. Put your assembled engine in the sun, and watch it spin!


Photo 4.

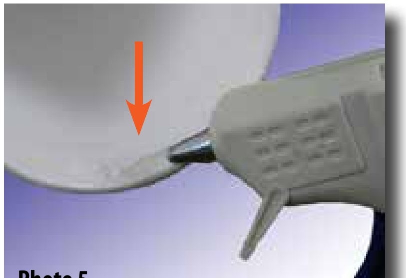


Photo 5.


Photo 6.


Photo 7.

CHALLENGE:
How could you increase the power of this type of solar heat engine?

THINK ABOUT IT:
Would strips made from a white plastic bag work as well as strips made from a black plastic bag? Is it important to consider the principles of heat reflection and heat absorption when choosing the color of plastic strips for this type of heat engine?

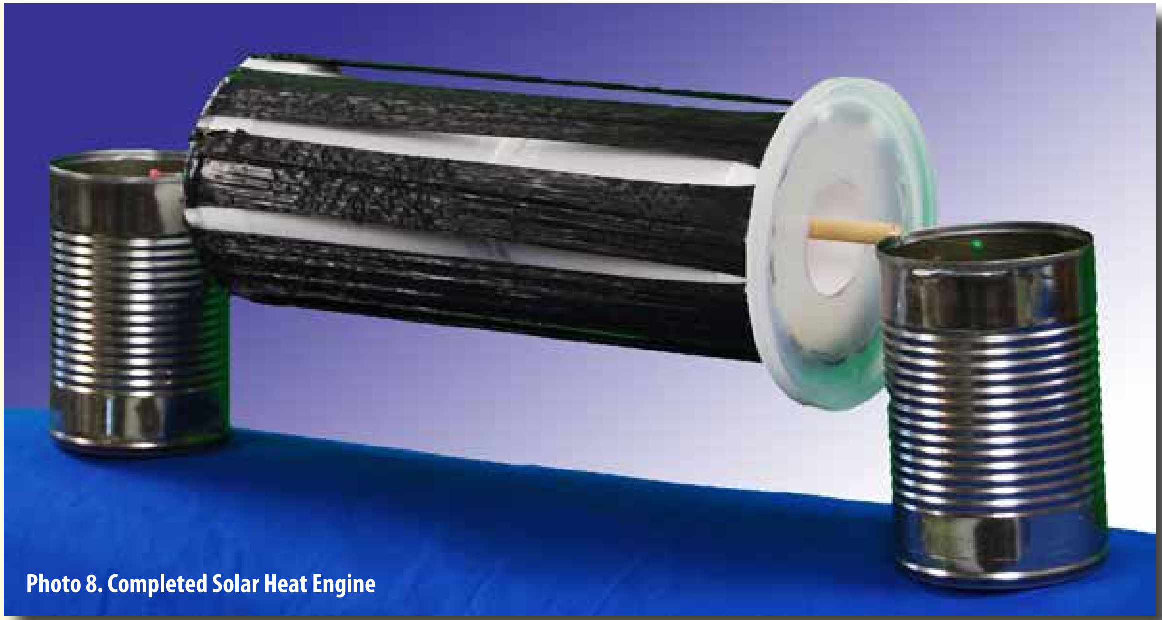


Photo 8. Completed Solar Heat Engine

Your Solar Heat Engine is really just a model, so it isn't powerful enough to do much work; but can you think of any other ways that it could do something useful? Here's one idea: Use a permanent marker to draw a line at one point on the edge of the flywheel (plastic lid). Now you can count the number of revolutions as the Engine spins. You can find out how clouds affect the amount of heat energy that reaches your Engine by counting the number of revolutions in one minute when it is cloudy, and comparing the result to the number of revolutions when there are no clouds. In the same way, you could measure the number of revolutions at different times throughout the day to find the times when the most solar heat energy is received. You could also compare the number of revolutions at different times of the year, but be sure to make your measurements at the same time each day! If you could operate your Solar Heat Engine in two locations at the same time, do you think it would spin faster in Northern Canada or Southern Florida? Hint: Differences in the amount of solar energy that arrives at different latitudes is one of the major controls on climate.

What's Controls Earth's Climate?

Two things happen when sunlight reaches the Earth:

1. Some of the energy is reflected back into space; and
2. Earth's land, ocean, and atmosphere absorb some of the energy and release it as heat.

Earth's overall temperature depends on how much energy is absorbed and how much is released back into space. If the land, ocean, and atmosphere together lose the same amount of energy as they absorb, Earth's energy budget is in balance and its overall average temperature doesn't change. If Earth doesn't release as much energy as it absorbs, its energy budget is not balanced, and our planet will get warmer.

Climate is not the same as weather. Weather describes the temperature, precipitation, and other conditions of Earth's atmosphere at a specific place. Climate lis the result of the long-term average of conditions in the atmosphere, ocean, and ice sheets and sea ice. These conditions are described by statistics, such as means and extremes. Here are some easy ways to remember the difference:

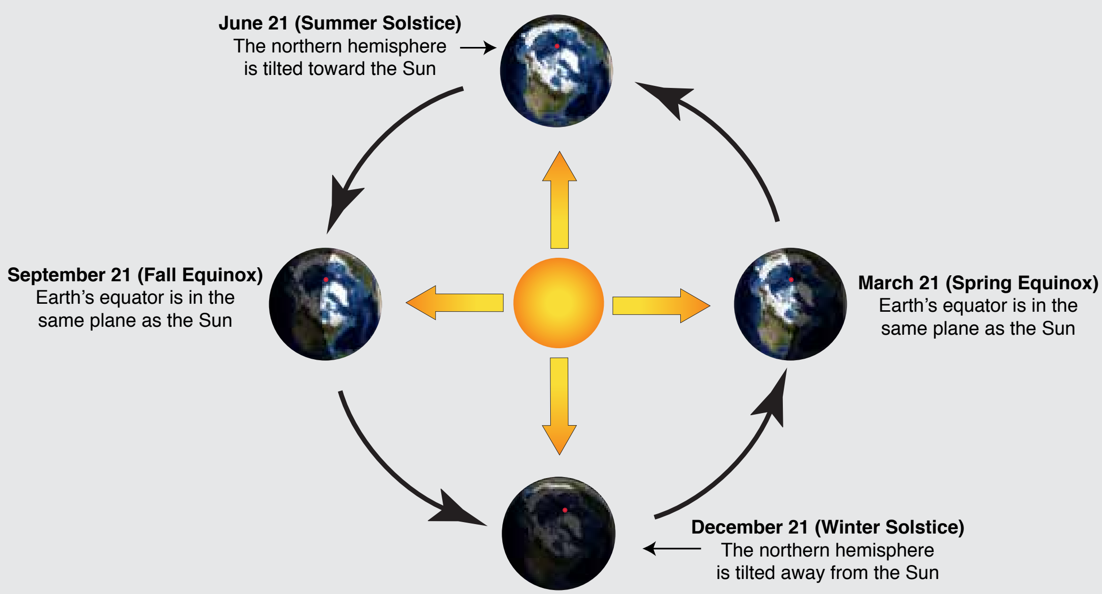
- "Climate is what you expect; weather is what you get." (Robert Heinlein)
- "Climate lasts all the time, weather lasts only a few days." (Mark Twain)
- Weather tells you what to wear on any given day; climate tells you what wardrobe to have.

We know that different places on Earth have different climates (think about Antarctica and the deserts of the Middle East, for example). Since Earth's overall climate is caused by energy from the Sun, places with warmer climates must receive more of the Sun's energy than places with colder climates. The amount of energy that a particular place on Earth receives from the Sun depends upon several things.

We also know that Earth moves! It moves through space, following a path around the Sun that is called an orbit. If you tie a rubber ball onto a piece of string and whirl the ball in a circle, the path of the ball's motion is an orbit. The time needed for Earth to travel one complete orbit around the Sun is how we define the length of a year.

First, Earth is shaped like a ball. The most direct sunlight is received at the equator (the equator is an imaginary line that goes around the Earth halfway between the North and South Poles). The area around the equator is very warm. Places located at high latitudes (far from the equator) receive less direct sunlight than places at low latitudes (close to the equator), so high latitudes have colder climates.

Second, as Earth moves around the Sun through the year, different parts of it receive more direct sunlight and have longer days and shorter nights than others. This is because Earth's axis (an imaginary line that goes through the Earth from the North Pole to the South Pole) is tilted compared to the plane of Earth's orbit. The changing amounts of sunlight cause Earth's seasons. During June, Earth's northern hemisphere is tilted toward the Sun. The day that the northern hemisphere points most directly toward the Sun (on or around June 21) is called the summer solstice. During December, Earth's northern hemisphere is tilted away from the Sun. The day that the northern hemisphere points most directly away from the sun (on or about December 21) is called the winter solstice. When the apparent position of the Sun is halfway between the summer and winter solstices, every place on Earth receives equal periods of day and night (remember, the Sun does not actually move; it is Earth that moves around the Sun). This happens on March 21 and September 21, which are called the spring equinox and fall equinox.



Earth's orbit around the Sun. The illustration shows how Earth would look if you were looking at it from a location beyond Earth's orbital plane. The red dots show the approximate location of the North Pole,which is off center because Earth's axis is not perpendicular to its orbital plane. Note that this illustration is not to scale, because the Sun is actually MUCH larger than Earth! (Image credit: Mel Goodwin, LuAnn Dahlman)

Third, the amount of energy produced by the Sun also changes slightly over time,. Over the past 30 years, the Sun's energy output has changed very slightly; sometimes increasing a little, sometimes decreasing a little. There is no evidence that recent changes in the Sun's energy output have caused much change in Earth's average temperature.

Fourth, over thousands of years, the motions of Earth's rotation on its axis and its orbit around the Sun change very slightly. These gradual changes cause the amount of sunlight received by different parts of Earth to change as well. When less sunlight is received in the northern hemisphere, snow and ice can accumulate there. Then, Earth's average temperature drops and we have ice ages. When more sunlight is received, the average temperature increases and we have warmer periods between the ice ages. For the last one million years, changes in Earth's rotation and orbit have happened in cycles that are about 100,000 years long.

Climate Science Principle 1: The Sun is the primary source of energy for Earth's climate system.