SOLAR ENERGY

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TRANSFORMING SOLAR ENERGY INTO HEAT, MOTION, AND ELECTRICITY

Time Frame:	**Standards:**
2 class periods of 45-60 minutes for radiometer and solar sections. (**1 class period each**) These can be used separately or together.	8-9.PS(ES).1.2.1 Use observations and data as evidence on which to base scientific explanations. 8-9.PS(ES).1.6.3 Use appropriate technology and mathematics to make investigations. 8-9.PS.2.3.2 Classify energy as potential and/or kinetic and as energy contained in a field. 7.S.1.2.2 Use observations to make defendable inferences. 7.S.1.6.2 Use appropriate tools and techniques to gather and display data. 7.S.1.6.3 Evaluate data in order to form conclusions. 7.S.1.6.4 Use evidence and critical thinking to accept or reject a hypothesis. 7.S.5.3.1 Identify alternative sources of energy.

Objectives:

Transform radiant energy into thermal energy, motion and electricity.
To decide which light source is the best for producing motion from the vanes of a radiometer.
To decide which wavelength is the best for producing electricity from a solar panel.

Background Information:

In the first section you will be using a radiometer to show that radiant energy is transformed into thermal energy and then into motion.

In a radiometer, there is very little air inside it. It is almost a vacuum. When a radiometer is put into the light, the vanes absorb sunlight. The radiant energy is changed into thermal energy. The air molecules inside the bulb bounce off the vanes with more energy. The black side of the vanes is absorbing more energy than the white side. When the air molecules hit the black side, they bounce back with more energy than when they hit the white side. When the air molecules bounce off the black side they push it harder than on the white side. This starts the vanes turning. The more radiant energy that reaches the radiometer, the more thermal energy is produced and the faster the vanes turn. Included in additional content is a diagram that you can use to help explain to students why the radiometer works.

In the second section you will be using a solar panel to convert radiant energy into

electrical energy.
Most of the electricity we use today comes from the sunlight stored in fossil fuels such as coal or oil. With solar panels, changing the sunlight directly into electricity is clean and simple but it is very expensive. Solar power costs about four times as much as coal or nuclear power.

Photovoltaic comes from the words *photo* meaning *light* and *volt*, a measurement of electricity. Photovoltaic cells are also called PV cells or solar cells for short. PV cells are made of two thin pieces of silicon, the substance that makes up sand and the second most common substance on earth. One piece of silicon has a small amount of boron added to it, which gives it a tendency to attract electrons. It is called the p-layer because of its positive tendency. The other piece of silicon has a small amount of phosphorous added to it, giving it an excess of free electrons. This is called the n-layer because it has a tendency to give up electrons, a negative tendency. When the two pieces of silicon are placed together, some electrons from the n-layer flow to the p-layer and an electric field forms between the layers. The p-layer now has a negative charge and the n-layer has a positive charge.

When the PV cell is place in the sun, the radiant energy energizes the free electrons. If a circuit is made connecting the layer, electrons flow from the n-layer through the wire to the p-layer. The PV cell is producing electricity-the flow of electrons. If a load such as a light bulb is place along the wire, the electricity will do work as it flows. The conversion of sunlight into electricity takes place silently and instantly. There are no mechanical parts to wear out.

Compared to other ways of producing electricity, PV systems are expensive. It costs 10-20 cents a kilowatt-hour to produce electricity from solar cells. On average, people pay about 8 cents a kilowatt-hour for electricity from a power company using fuels like coal, uranium, or hydropower.

Solar Energy

Solar energy is energy from the sun. The sun is a giant ball of hydrogen and helium gas. The enormous heat and pressure in the interior of the sun causes the nuclei of the two hydrogen atoms to fuse, producing one helium atom in a process called fusion. During fusion, nuclear energy is converted into thermal (heat) energy and radiant energy. The radiant energy is emitted from the sun in all directions and some of it reaches Earth. Radiant energy is energy that travels in electromagnetic waves or rays. Radiant energy includes visible light, x-rays, infrared rays, microwaves, gamma rays, and others. These rays have different amounts of energy depending upon their wavelength. The shorter the wavelength, the more energy they contain.

When radiant energy hits objects, it can be reflected or absorbed. The absorbed radiant energy can be converted into heat (thermal energy). Black objects tend to absorb radiant energy. Shiny objects tend to reflect radiant energy. White objects tend to reflect radiant energy. Radiant energy can be by the sun or by an artificial source. Radiant energy can pass through transparent materials such as plastic wrap, but thermal energy (heat) does not. These properties can be used to heat water or homes, cook meals, purify water, and generate electricity.

Information taken from the NEED Project's 2008 Science of Energy and 2008 Exploring Solar Energy student guide. http://www.need.org

Materials:

6 radiometers
5 dark colored cloths 8 in x 8 in
1 dark colored cloth 12 in x 12 in
1 UV light (Black light) bulb
1 incandescent light bulb
1 CFL light bulb
1 infrared light bulb

Bright Sunlight
6 small solar panels
6 small motors
6 small fans
5 gooseneck lamps (one for each type of bulb and one for demonstration)
Lab sheets outlining activity (example below)

Procedure:

Safety Tips:

1. Remind students not to look straight at the lights, especially the black light, as this can possibly cause damage to their eyes.
2. Be careful around any glassware (radiometers, bulbs and PV cells). If it breaks it can cut the students.
3. Remind students to be careful around the fans and not to put fingers or other body parts into the fan blades.

Preparation:

1. Set up 5 centers in your classroom. 4 of the stations will have a lamp and a cloth at them. The last station needs to be set up in sunlight and have a cloth as well. Each station can be used for both activities.
2. Set up a radiometer, lamp, and larger cloth at your demonstration table. This will be the start out activity to engage the students.

Procedure:

In the first activity the students will be exploring which of the lights make the radiometer spin the most.
In the second activity the students will be using the same lights and exploring which of them makes the most electricity through the PV cell. This will be measured by how fast

the fan spins that is hooked to the motor run by the PV cell.
One question to ask the students after doing both activities is: Is there a correlation between which light made the radiometer spin the most and which light ran the fan the fastest?

Radiometer Activity

1. Start out with a demonstration of the radiometer. Have the radiometer covered and the lamp shining on it when the students come into the classroom.
2. Pull the cloth off the radiometer. It should start spinning when you pull the cloth off. Tell the students it is a radiometer and introduce the activity.
3. Pose the question of what is making the vanes of the radiometer spin. Gather answers from the class. Ask another question of what would happen if you moved the radiometer out of the light. Discuss with the students and then turn off the lamp. The radiometer vanes should stop or slow down depending on the amount of light in the room. You may need to turn out the lights to stop the vanes completely.
4. Discuss what makes the vanes on the radiometer work. You can use the diagram in the additional content as a overhead to help explain how the radiometer works.
5. Explain the activity and pass out the lab sheet. Pose this question: Which type of light bulb will cause the radiometer to spin the fastest or will sunlight spin it the fastest? Tally the student predictions on the board and have them write down their predictions as a hypothesis on their lab sheets.
6. Split the students into five groups. Each group will receive a radiometer and are assigned to a station to start at. Remind the students to be careful with the radiometers as they are easily broken.
7. At each station students will put the radiometer under their light source for 2 minutes. Have them record how fast the radiometer is spinning (i.e. barely moving, slowly, medium, fast and very fast (just a blur)). Record the results on a data table.
8. Have the students cover the half of the bulb for 2 minutes. Does it make a difference in how fast the radiometer is spinning? Record the results on a data table.
9. Have the students change stations and repeat steps 7 and 8 until each group has been to all 5 stations.
10. Have the students examine their data and come to a conclusion. Have them write down their conclusions on their lab sheets. Did their conclusions match their prediction? How was it different or the same?
11. After the students have written their conclusions have them tally their conclusions on the board below the predictions. Do the conclusions match their predictions? Were everyone's conclusions the same? Why do they think they were the same or different? Discuss this as a class.

Photovoltaic Cell activity

1. Have the radiometer and a PV cell sitting on the table at the front. Remind the students of how radiant energy made the vanes of the radiometer spin. Go on to explain the radiant energy can do much more than cause the vanes on a radiometer spin. People can use it for many other things, one of which is creating electricity.
2. Explain what a photovoltaic cell is and how it works. Demonstrate how the light on the PV cell generates electricity for the motor which then turns the fan.
3. Pose the question of what would happen if you moved the PV cell away from the light. Discuss with the students and then move it away from the light.
4. Explain the activity and pass out the lab sheet. Pose this question: Which type of light bulb will cause the PV cell to generate the most electricity to spin the fan the fastest or will sunlight spin it the fastest? Tally the student predictions on the board and have them write down their predictions as a hypothesis on their lab sheets.
5. Split the students into five groups. Each group will get a radiometer and then are assigned to a station to start at. Remind the students to be careful with the PV cells and motors with as they are easily broken and the fans can be a little painful if they put their fingers in the blades.
6. At each station students will put the PV cell under their light source for 2 minutes. Have them record how fast the fan is spinning i.e. barely moving, slowly, medium, fast and very fast (just a blur). Record the results on a data table.
7. Then have the students cover the half of the PV cell with the cloth for 2 minutes. Does it make a difference in how fast the fan is spinning? Record the results on a data table.
8. Have the students change stations and repeat steps 7 and 8 until each group has been to all 5 stations.
9. Have the students examine their data and come to a conclusion. Have them write down their conclusions on their lab sheets. Did their conclusions match their prediction? How was it different or the same?
10. After the students have written their conclusions have them tally their conclusions on the board below the predictions. Do the conclusions match their predictions? Were everyone's conclusions the same? Why do they think they were the same or different? How did these conclusions compare to the conclusions from the radiometer activity? Was the best light for the radiometer the same as the best light for the PV cell? What could PV cells also power? How else could people use radiant energy? Discuss this as a class.

Extension of the lesson

One way to extend this lesson is to have the student come up with ways that they could use radiant (solar) energy in their home, school, or community. Have them research the different ways to use radiant energy and write a report on their findings.

The students research different ways to use radiant energy and in groups create a design for using radiant energy in their home or school complete with drawings of their design and reasons why their design should be used. Have the groups present their designs to the class.

Assessment:

This activity can be assessed by their class participation in the discussions as well as by the lab sheets with their hypotheses, data tables, and conclusions.

Additional Content:

Here is an example of a lab sheet for the activities.

Radiometer Activity

Objective: To find which light source makes the vanes of the radiometer spin the fastest.

Materials: Radiometer, UV (black light) light, incandescent light, CFL light, infrared light, sunlight (one light at each station), and 1 cloth at each station

Hypothesis: Read through the lab. Write down your hypothesis on which light will make the vanes of the radiometer spin the fastest.

Procedure:

1. Put the radiometer under the light source for 2 minutes. Create a data table and record how fast the vane in the radiometer is spinning. i.e. barely moving, slowly, medium, fast and very fast (just a blur).
2. Cover half the radiometer with the cloth for 2 minutes while it is under the light source. Does it make a difference in how fast it is spinning? Record how fast it is spinning on your data table.
3. At the teacher's signal change stations and repeat steps 1 and 2. Do this until you have completed all the stations.
4. Look at your results and answer these questions in your conclusion. Was your hypothesis correct? Why or why not? Which radiant energy source made the vanes spin the fastest? Which source made it spin the slowest? Did covering half of the radiometer make a difference?

PV CELL Activity

Objective: To find which light source makes a fan attached to a motor run by a PV cell spin the fastest.

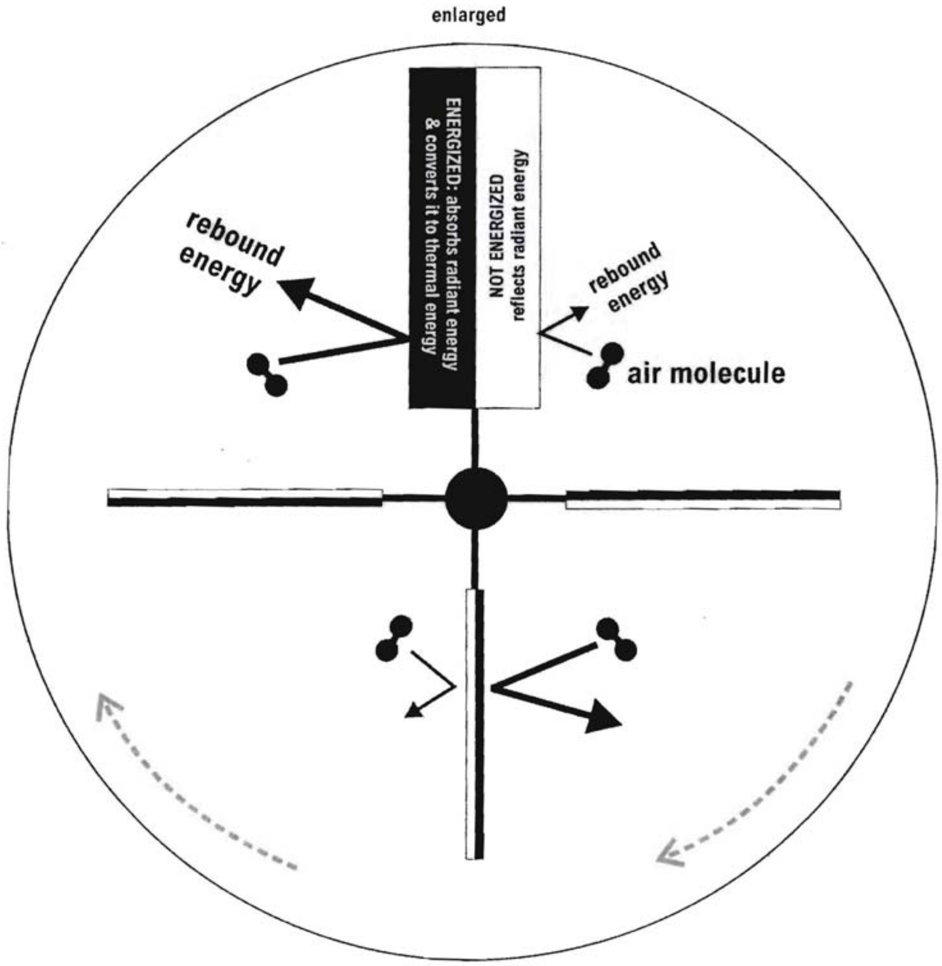
Materials: PV cell attached to a motor with a fan, UV (black light) light, incandescent light, CFL light, infrared light, sunlight (one light at each station), and 1 cloth at each station

Hypothesis: Read through the lab. Write down your hypothesis on which light will make the fan spin the fastest.

Procedure:

5. Put the PV cell under the light source for 2 minutes. Create a data table and record how fast the fan is spinning. i.e. barely moving, slowly, medium, fast and very fast (just a blur).
6. Cover half the PV cell with the cloth for 2 minutes while it is under the light source. Does it make a difference in how fast the fan is spinning? Record how fast it is spinning on your data table.
7. At the teacher's signal change stations and repeat steps 1 and 2. Do this until you have completed all the stations.
8. Look at your results and answer these questions in your conclusion. Was your hypothesis correct? Why or why not? Which radiant energy source made the fan spin the fastest? Which source made it spin the slowest? Did covering half of the PV cell make a difference?

TOP VIEW OF RADIOMETER



References:

Background information taken from the NEED Project's 2008 Science of Energy and 2008 Exploring Solar Energy. http://www.need.org

Lesson created by Jill Williams as part of the INL Educational Science writing team