Activity 18 Solutions: Uses of Solar Energy

18.1 Alternative Energy Sources

1) Comparison of energy sources

List the advantages and disadvantages of the various energy sources discussed (fossil fuels, nuclear, tidal, hydroelectric, geothermal, wind, biomass) Which are ultimately forms of solar energy?

All of the above energy sources are ultimately forms of solar energy except nuclear, tidal, and geothermal.

Fossil fuels have the advantage of currently being cheap and rather plentiful. On the other hand, supplies are believed to be limited, mining and drilling for coal, oil and gas can be environmentally destructive, burning fossil fuels creates pollution and releases greenhouse gasses.

Nuclear power plants do not release greenhouse gasses or give off pollution. There is a safety problem with older nuclear power plants and all nuclear power plants generate radioactive waste, a problem for which there is yet no feasible solution.

Tidal, hydroelectric, geothermal, wind, and biomass energy sources do not produce pollution but can still harm the ecosystem in their implementation (damming rivers can kill off fish which spawn upstream, drilling geothermal wells may be a threat to certain ecosystems such as the rain forests in Hawaii.)

Solar energy seems to be the most environmentally friendly energy source. However, the manufacturing of solar cells can involve CFCs, which destroy the ozone layer. Furthermore, solar energy is still too expensive to be cost effective in many instances. This is the result of a combination of manufacturing costs and low efficiency of solar cells. Hopefully, solar energy will soon become much cheaper and its advantages will outweigh its disadvantages.

18.2 Using Solar Energy

2) Solar insolation

a) What is solar insolation?

Solar insolation is the amount of solar power received by a given area. (Note: insolation should not be confused with insulation, which is used to restrict the flow of heat.)

b) What factors affect how much insolation a given region receives?

The latitude, the time of year, the time of day, and the amount of cloud cover all affect the amount of solar insulation.

c) Which regions of the United States receive greater insolation? Why?

The southwestern portion of U.S. receives the most solar insolation. Regions nearer the equator (southern portions of the U.S.) receive more insolation than regions near the poles. Drier regions (such as the desert southwest) receive more insolation than wetter (cloudier) climates (such as in the southeast).

d) What is the average solar insolation received in Columbus, Ohio, in the summer?
1,340 watts/m^2

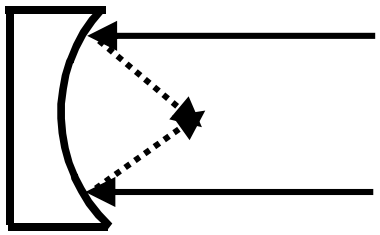
What is the average solar insolation received in Columbus in the winter?
200 watts/m^2

3) *Converting solar energy into thermal energy*

We will attempt to boil water in a metal cup using a mirror and the radiant energy from a spotlight.

a) Why is the mirror concave? On the diagram, draw light rays to indicate the path light rays follow after striking the mirror.

The concave mirror focuses the light reflected from it to a focal point.



Concave Mirror

b) Estimate where you should place the cup of water for maximum heat. Then check your estimate using a piece of paper to determine the focal point of the light.

A piece of paper can be centered in front of the mirror and moved until the reflected light appears to be concentrated on the paper. This is the focal point of the reflected light where the cup should be placed.

c) Group Discussion Question: Did the water in your cup start to steam or even come to a boil? Do you think this could be a practical method for converting radiant energy into thermal energy?

4) Solar water heaters

a) How does the solar water heater seen in class work? Is a pump needed to circulate water through the heater's tubes? Why or why not?

The warmed water is less dense and rises through the tubes of the solar heater. Cool water flows into the bottom of the heater. The convection currents in the heater circulate the water. A pump is not needed. The surface of the heater is painted black for maximum absorption of photons.

b) Would it make economic sense to use a solar water heater in Ohio?

While solar-powered devices would be most effective in a sunnier region (such as southwest U.S.), a solar water heater in Ohio may be used to supplement a gas or electric heater. The cost of any feature must be weighed against its potential savings to determine its payback time (the time required for the feature's savings to cover the initial cost).

c) How should a solar collector be positioned in Columbus, Ohio, on a sunny day?

On a sunny day, the most efficient position is an angle where the incoming light rays strike the panel as close to perpendicular as possible. Since Columbus is at a latitude of 40° North, the collector should be placed at an angle of 40° to the ground. (Notice that the sun's position above the horizon is not a constant 40° but varies according to the time of day and time of year.)

d) If a solar collector is moveable, how should it be moved throughout the day?

On sunny days, the collector is moved so that it tracks the motion of the Sun. At sunrise, the collector is positioned vertically, facing east. As the sun rises higher in the sky, the collector rotates to the west and is tilted so that the sun's rays strike its surface as close as possible to perpendicularly.

e) Should a solar collector be placed in a more horizontal or a more vertical position during the winter?

Since the Sun is lower in the sky during the winter, the collector should be placed in a more vertical position.

f) Group Discussion Question: If a solar collector is moveable, how should it be positioned on a cloudy day?

5) Converting solar energy into electrical energy

a) How efficient are the solar cells used in class?

Connect a 1 watt flashlight bulb to a solar cell and shine a standard 100 watt bulb onto the solar cell. Does the radiation from the 100 watt bulb produce enough electricity to light the small bulb**? Probably not**

If not, repeat the experiment by shining the 150 watt spotlight onto the solar cell. Does the small bulb light? **probably yes**

b) Using your results from part a), estimate the efficiency of the solar cell.

The solar cells we have in class seem to be not much more than 1% efficient. The 100 watt bulb generally cannot make a 1 watt bulb connected to a solar cell light, since only a fraction of that 100 watts is converted into light that actually shines on the solar cell. In addition to having a greater wattage, the 150 watt spotlight is constructed so that its light does not shine in all directions.

c) Using the efficiency you estimated in part b), calculate the average electrical power this solar cell could generate if it was positioned perpendicular to the Sun on a sunny day in summer in Columbus.

P = I x A x Eff = 1,340 watts/m^2 x (0.2 m x 0.15 m) x 0.01 = 40.2 watts

18.3 Energy Efficient Buildings

6) Energy efficiency and insulation

Your instructor will demonstrate radiant energy from light bulbs directed at panels made of wood, aluminum, and plexiglass.

a) The thermometer that shows the most rapid increase in temperature is attached to which panel?

Prediction: _____ Answer:_**The thermometer attached to the plexiglass shows the most rapid temperature increase, followed by the aluminum and then the wood** __

b) This panel was heated by which of the three types of thermal energy transfer?

The clear plexiglass allows for the transfer of heat by radiation. Heat is transferred through the metal and wood panels by conduction. The metal has a high thermal conductivity and the wood has a lower thermal conductivity.

c) Your instructor will demonstrate a model "room" with and without insulation. What is the temperature increase inside the room when it is covered with insulation?

d) To retain the most heat inside of a home, should you choose insulation with a high or a low R-value?

a high R-value

e) Group Discussion Question: Is home insulation necessary in warm climates?

7) Energy efficient homes

a) Describe the features of an energy-efficient passive solar home.

Features of an energy-efficient passive solar home:

1. **Deciduous trees or a roof overhang on the south side of a house to shade windows from the direct sun in the summer (when the sun is higher above the horizon), but allow the sun to shine in through windows in the winter (when the sun is lower).**
2. **Embankments and non-deciduous trees on the north side of the house to block winter winds.**
3. **A thermal mass may be used to store solar energy gathered during the day for use at night when the temperature drops.**
4. **Rooftop solar collectors to supplement the heating system and to generate electricity.**
5. **Fiber optic light pipes to bring outside light into the interior of the house.**
6. **Insulation of walls and attic to reduce heat transfer.**
7. **Vents to exhaust hot air from the house.**