Solar Study

Learning goals:

(1) learn how to manipulate numerical data in an Excel spreadsheet,
(2) learn how to graph two quantities to see their relationship,
(3) learn how solar power is related to the relative orientation between a panel and the sun's rays.

Background:

Many of the solar collectors located on the Creighton campus have been installed with a fixed orientation. The exception are the two "tracking" arrays whose orientation is systematically altered throughout the day to best maximize collection of solar radiation. The orientation of the panel relative to the incoming solar rays plays a major role in the overall power generating capacity of the solar collector as illustrated in Fig. 1.

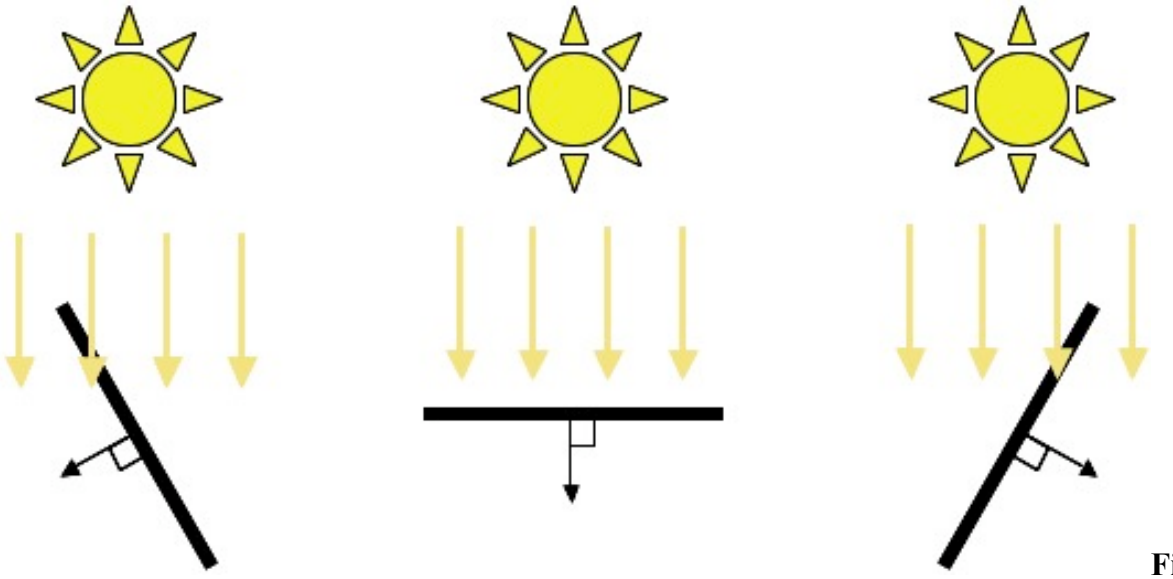

Fig. 1

- When the normal of the panel is parallel with the sun's rays, collection is maximized.
- As the angle between the normal and the sun's rays increases toward 90°, the collected intensity decreases to zero.

Discussion Demo: Obtain a hula hoop (or other looped object) and a flashlight. Position the flashlight on a desktop shining horizontally. Rotate the loop (see Fig. 2) within the beam of the flashlight and ask, as you get to certain orientations, "how much light goes *through* the loop now?".

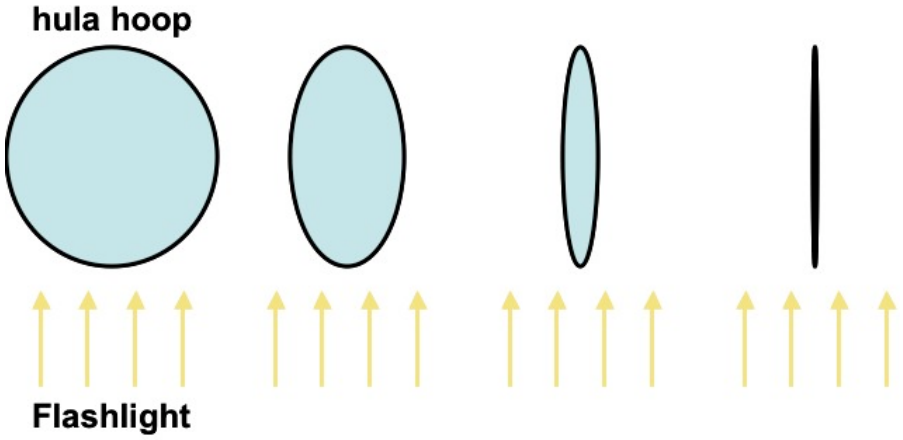

Fig. 2

Students should become aware that the greatest collection of solar rays occurs when the hula hoop is perpendicular to the flashlight beams. The same is true for solar panels: the best collection of solar energy is achieved when the panel is perpendicular to the solar rays.

Thought experiment: Ask your students to imagine a solar panel is lying flat on the ground. Ask them, "At what time of day would you expect the most amount of solar energy to be collected?"

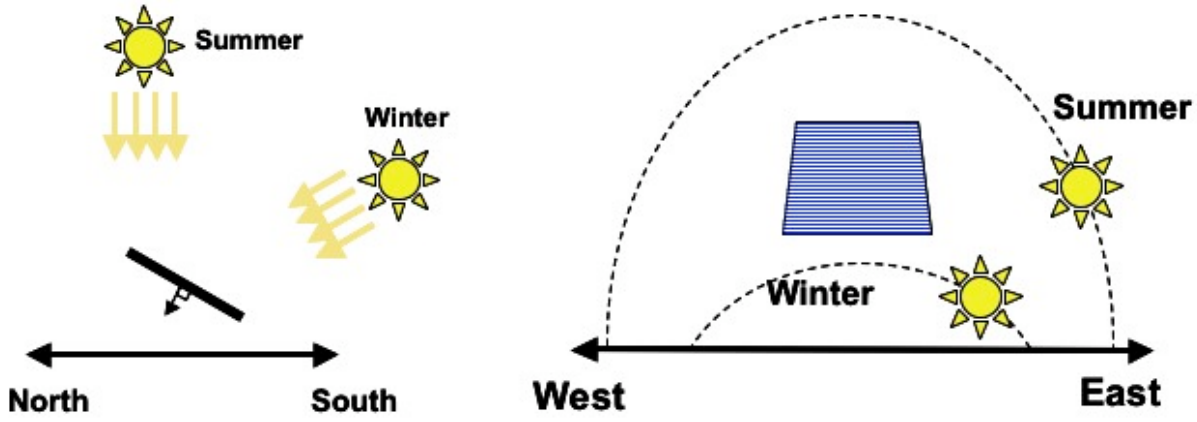

Fig. 3

Activity:

Have students first adopt a hypothesis regarding when they expect maximum solar power to occur. They should include reasons for their hypothesis. Test this by downloading the daily log of power and time for one of the fixed solar arrays into an Excel spreadsheet. Plot power against time of day and determine when the maxiumum power collection actually occurs. Have students also determine when sunrise and sunset occur for that day and estimate at what time the sun is directly overhead. How does this "directly overhead" time compare with the "maximum power" time?

Seasonal extension: As a related study, have students download the yearly log of average daily power and day of the year. Again, plot the power against day of the year and determine where the maximum collection occurs. Ask students to reason why it occurs in the summer near the summer solstice. (Answer: because of the seasonal tilt of the planet earth, the position of the sun appears to move from

South in the winter to North is the summer. The length of the daylight is smallest at the winter solstice (mid December) and longest at the summer solstice (mid June).)

Power versus Energy: As a follow up, recall that energy and power are not the same. Power is the *rate* of energy collection (i.e., energy per unit time) at any given instant. The total energy collected throughout any period of time (like an entire day) is the accumulation of power flow throughout the day. It might help to think about this in terms of a water analogy: Power is like the flow the water through a trough - its the amount of water passing by in a given unit of time (for example, the number of gallons per minute). Energy is the accumulation of the water, say if it were collected by a large tank at the end of the trough (in gallons).

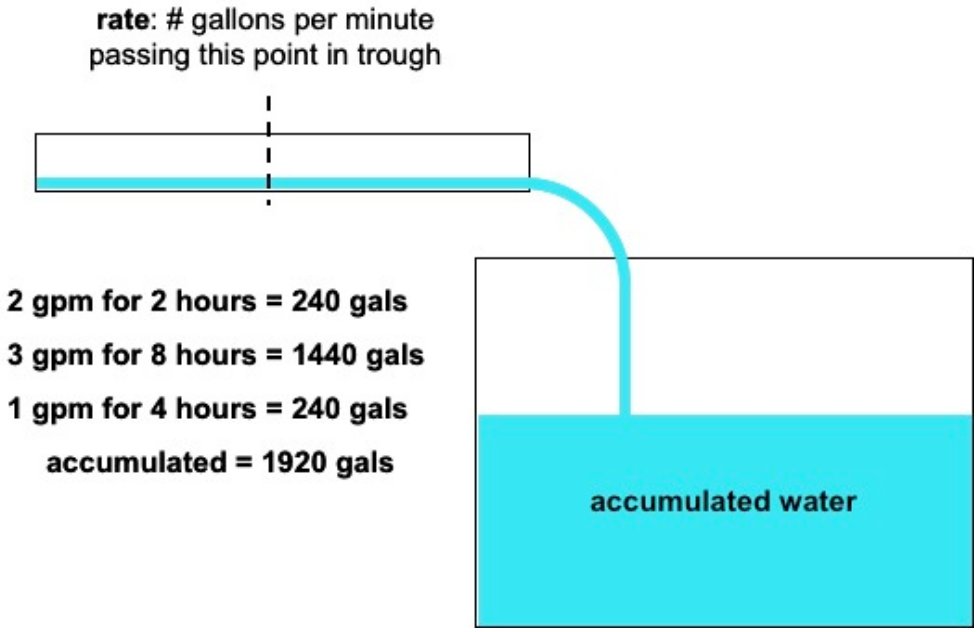

Fig. 4

The day's average power would be sensitive to when the sun is best aligned with the orientation/pitch of the panel. But the total daily energy would be sensitive to the length of daylight (i.e., the total amount of time over which amounts of power are accumulated)! Have students download a yearly record of total daily energy for a given solar collector. Have them graph the total energy versus day of the year. When is the total energy maximum? When is it minimum? How do these findings fit with the seasonal variations of the position of the sun and the length of day?