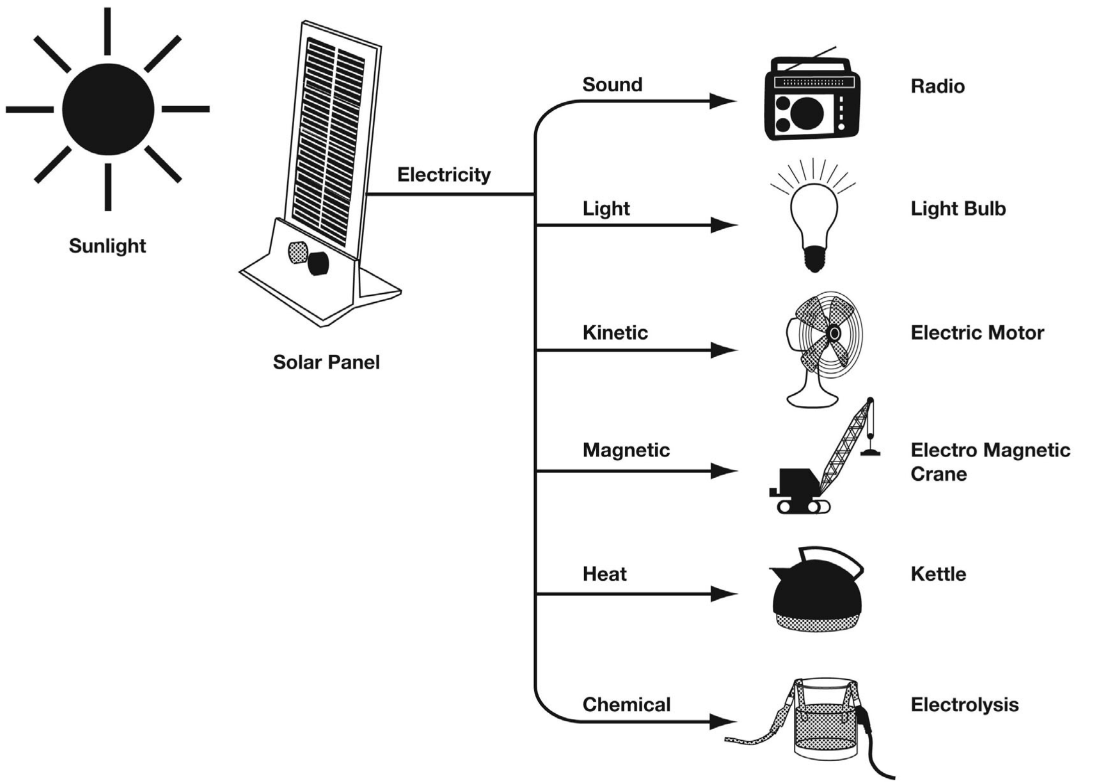
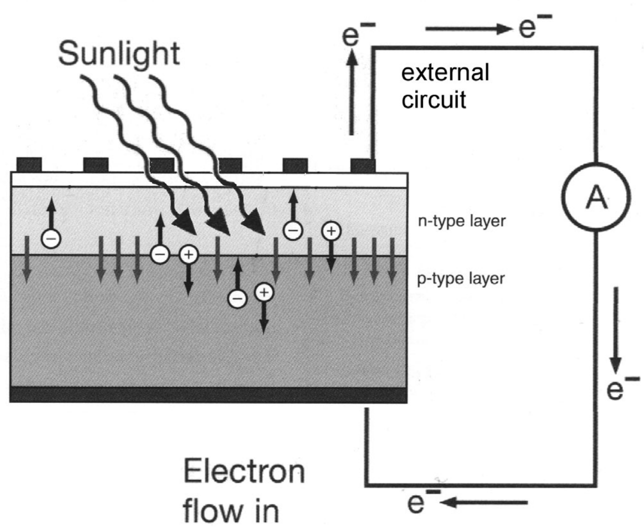
Investigation 2:
Solar Panel Orientation

Individual solar cells convert the radiant energy of sunlight into electricity. The solar panel that we are using consists of several solar cells connected in series. The panel can generate enough electricity to power an electrolyzer in some of the following investigations. The principle of a solar cell is that it converts a stream of **photons** (the radiant energy of sunlight) into a stream of **electrons** (electricity). The conversion, or transfer of energy from one form to electricity is the principle behind any **electrical generator**. Electrical generators include solar panels, diesel or gas engine generators, hydroelectric turbines and fuel cells. Perhaps you can think of more examples.



Solar cells are examples of very useful electrical technology as they can transform the renewable energy of sunlight into electricity. The light source we are using in our investigations is an incandescent lamp but in practical applications sunlight is used. Throughout the world we have sunlight at various times throughout the day. However we often need electrical power when sunlight is not available, for example at nighttime. If a solar cell is connected to an electrolyzer, the radiant energy of the sunlight can be stored as hydrogen and oxygen gas. A fuel cell can use these gases to make electricity when it is needed.

A solar cell contains layers of two types of silicon. Photons striking its surface knock electrons loose from one layer. The electrons are drawn to the other layer. If the two layers are connected through an external circuit, electrons will flow though that circuit. The flow of electrons is observed as an electric current. As more light is supplied to the solar cell, more photons are available to knock the electrons loose, and more current is generated.

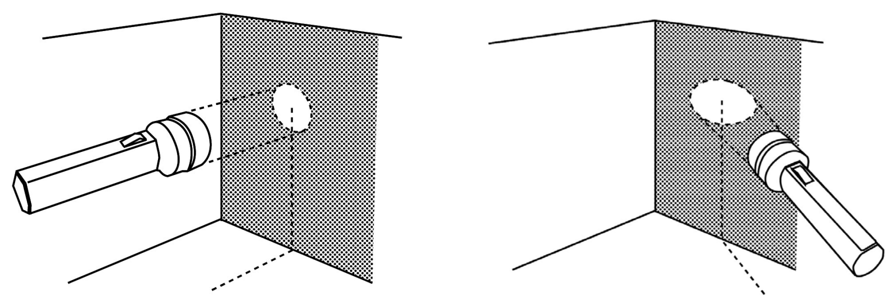


Electron flow in solar cell

This flow of electrons may be thought of as similar to a waterfall and has two values that are easily measured. One measurement is like the height of the waterfall, which is a fixed value. In electrical units, this is the **electric potential**, measured in **volts**. The other measurement is like the amount of water that falls down the waterfall, and allows us to actually do work with the water. In electrical units, this is called the **current,** measured in **amperes** (or simply **amps**). Thousandths of an ampere are called milliamperes, or mA. One interesting property of solar cells is that as the intensity of supplied light increases, the current increases but the voltage remains almost the same.

The sun is earth's nearest star and the sun seems to move across our sky each day. But in fact, earth travels in an orbit around the sun, spinning (once a day) as it goes. This means that if we want to collect the most sunlight we can with a solar cell array that cannot move, we have to place it in the best position to receive the maximum amount of energy available. In this investigation we will explore how to find the best position for the solar cell placement and whether this difference is worth considering.

*Imagine a flashlight beam aimed directly at a chalkboard from a distance of 1 meter. The illumination in the beam is distributed over a certain area. As the angle of this **incident** light is increased from 0 degrees (straight-on) to a greater angle, say 45 degrees, the beam becomes spread out over a larger area. The number of photons from that light source on a particular area of the blackboard is reduced. Thus if a light is tilted at an angle to the solar cell, the solar cell will not receive as many photons, or as much energy, as if the lamp was placed perpendicular to the plane of the solar cell. As a result the solar cell will generate less current.*



Your teacher will shine a flashlight directly at a chalkboard so that it is exactly 1 meter away from the board and the angle at which the light strikes the blackboard is 0 degrees (perpendicular, straight-on). We can say the **angle of incidence** is 0 degrees at a distance of 1 meter. The outline of this circular spot of light will be marked in chalk. If we now change the angle of incidence to 45 degrees the spot of light will be an ellipse, which will be marked in chalk as before. In both cases, the flashlight is 1 meter away from the center of the spot of light it makes on the board. But is the area inside each chalk figure the same?

If the flashlight is emitting the same number of photons in each case we should be able to compare the areas of the circle and the ellipse to see if there is a difference. If there is a difference then the smaller area is receiving a larger number of photons per unit of area and a solar cell placed flat on the chalkboard in this area would generate more current.

Now, let's see if the orientation of a solar panel really makes much (or any) difference in the current produced.

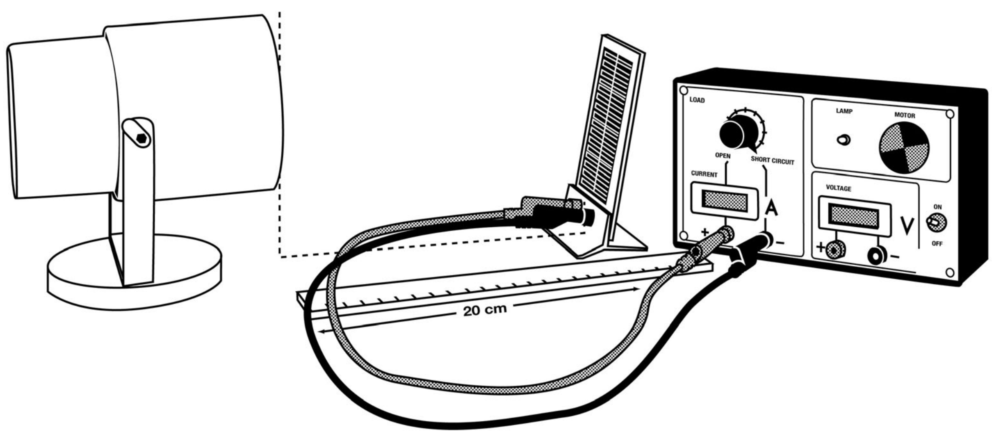
How can we maximize the electrical power coming from the solar panel?

You will need:

- solar panel from the *Fuel Cell Model Car Kit*
- load box from the *Fuel Cell Model Car Kit*
- two patch cords, red and black
- 75 watt PAR30 incandescent lamp, or equivalent light source
- protractor to measure angles (or make your own paper protractor from the template on page 2-8)

Procedure

1. Ensure the load box switch is in the **OFF** position. Use the patch cords to connect the solar panel to the load box **CURRENT** terminals—red to red and black to black. Turn the Load selector knob to **SHORT CIRCUIT**. Move the load box switch to **ON** and see if a number appears in the "Ampere" meter. If nothing appears, then check your connections. If a negative number appears, you have the connections reversed.



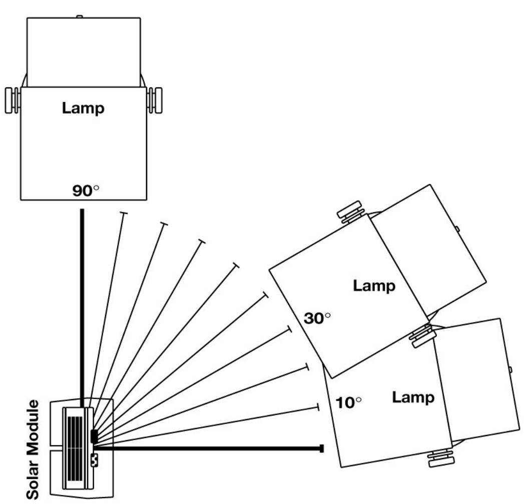
2. Adjust your solar panel and light source so the angle of incidence is exactly at 0 degrees. (The panel directly facing the light source.) Ensure the solar panel is placed exactly 20cm from the light source, or at whatever distance your teacher recommends. Measure this distance, and write it here. Then turn on the light.

3. Look at the current as displayed in the ammeter window. Write this number in the table below.

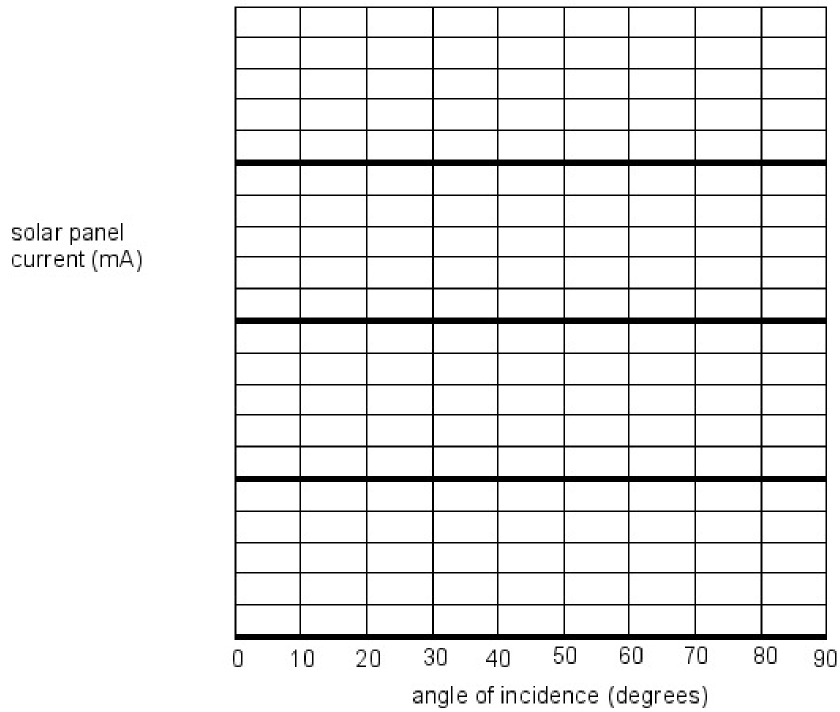
Notice that the displayed number has a leading decimal point. For example the number ***.105A*** *represents a little more than a tenth of an ampere, or 105 milliamperes.*

Angle of incidence (degrees)	Predicted Current (mA)	Actual Current (mA)
0º		
10º		
20º		
30º		
40º		
50º		
60º		
70º		
80º		
90º		

4. Now place your solar panel so the angle of incidence is exactly 90 degrees from the light source, taking care to keep the center of the solar panel exactly the same as before. In your table, write the current as displayed in the ammeter window.
5. What do you think the reading will be at a 10-degree angle of incidence. Write your prediction in the table.
6. Using your protractor template, adjust the angle of incidence of the solar panel to 10 degrees still keeping the center of the solar panel exactly the same as before. Record the actual milliamp reading in your table.
7. Continue predicting and measuring in this way at 10 degree intervals until you reach 80 degrees. Make sure you check the distance to the center of your solar panel for each measurement.



8. When you have made and recorded your measurements then use your data from your measurements to draw a graph indicating your findings in the space below.



9. Disassemble the equipment carefully and return it.

Questions

1. What is an ampere? What is a milliamp?

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2. Are milliamps a useful measure to see at which angle our solar cells work best?

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3. What did you find out about the orientation of your solar cell to the light source?

____

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4. Why is it important to keep the center of the solar panel the exact same distance away from the light source for each different angle? Is this important when using sunlight as a source?

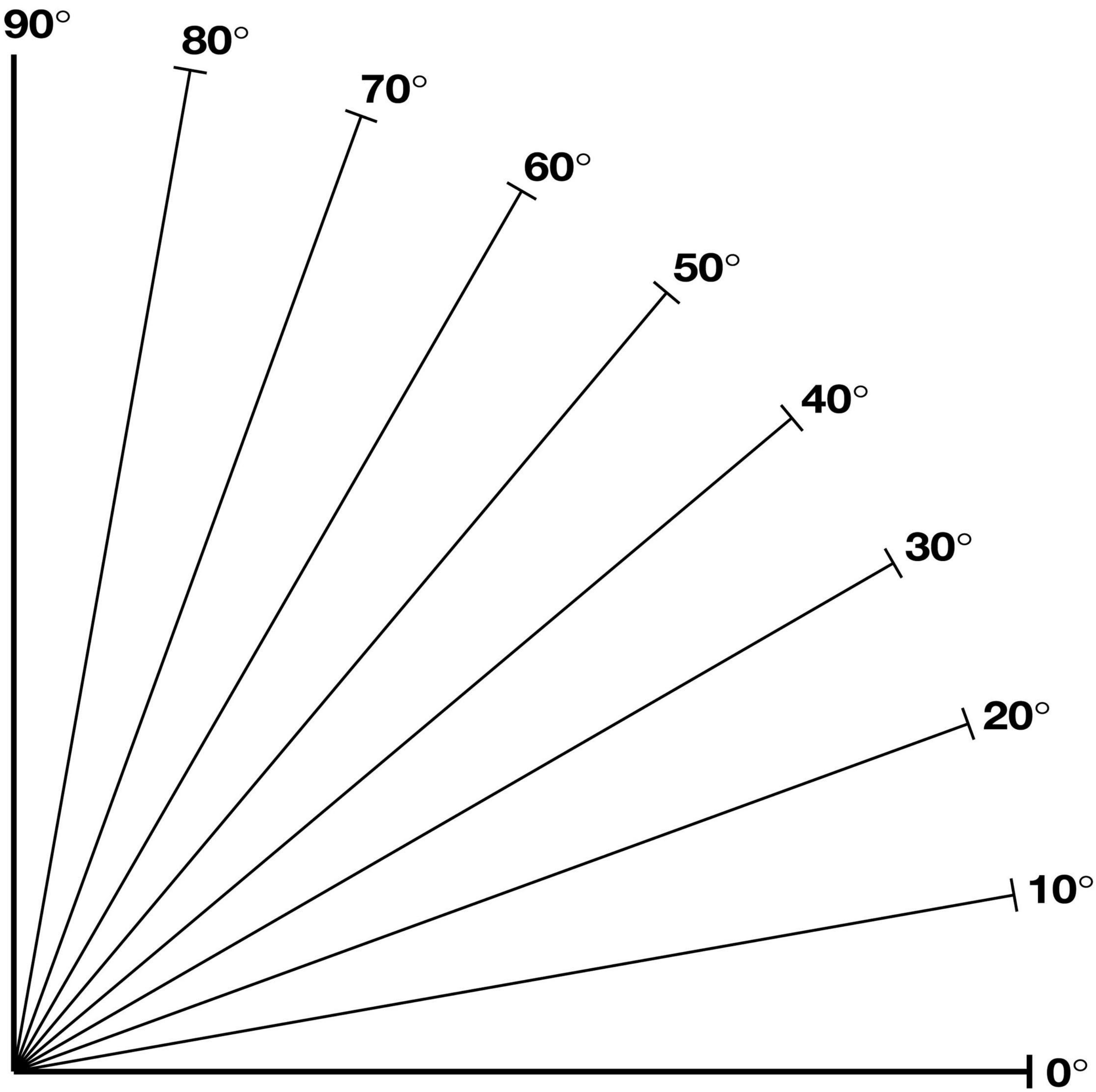
5. How did your prediction for the 10-degree angle compare with your actual result? How did you adjust your predictions for the other angles? Did they become more accurate as a result of your actual measurements?

6. With your graph could you make a fairly accurate prediction of the milliamp reading for 25 or 75 degrees? Is there any way to check your predictions for 25º and 75º?

7. In this investigation we have placed the light source and the solar panel in the same plane. In real life the sun appears to move both horizontally and vertically. What would you need to know before you permanently position a solar panel on top of your school?

8. Will the rate of electrical energy production be the same for every day of the year? Why or why not? How could you plan for this? Would your solution necessarily be a practical one?

9. What is the answer to the question at the beginning of this investigation: *How can we maximize the electrical power coming from the solar panel?*


90°
80°
70°
60°
50°
40°
30°
20°
10°
0°

Teaching supplement for Investigation 2: *Solar Panel Orientation*

The objective of this investigation is to allow students to explore how the orientation of solar cells can result in the maximizing of the electrical power produced by the solar cell.

The objectives may be written:

- Students will record the current produced by different orientations of their solar cell to the incident light after predicting from previous results.
- Students will use this data to produce a table and a graph that will allow them to predict the amount of electrical power produced by their solar cell at different orientations.

Teacher notes

It may be helpful to produce a simple template that can be placed on the table to allow for rapid orientation of the solar cell. An example of such a template is provided.

Try out the system beforehand to ensure that the light source is positioned so it will provide maximum light on the panel without overheating it.

Remind your students to measure the distance to the center of the panel each time so distance from the light source does not become another variable.

1. *What is an ampere? What is a milliamp?*

   An ampere is a measurement of electrical current. A milliamp is one one-thousandth of an ampere.

2. *Are milliamps a useful measure to see at which angle our solar cells work best?*

   Milliamps are a useful measure of the angle at which our solar cells work best as it is a small measure suited to our solar cell array and it is sensitive enough to allow us to see how the angle of incidence of the light source affects the current flowing from the solar cell.

3. *What did you find out about the orientation of your solar cell to the light source?*

   I found out that as the light source changed from a low angle of incidence to a higher angle of incidence the current decreased.

4. *Why is it important to keep the center of the solar panel the exact same distance away from the light source for each different angle? Is this important when using sunlight as a source?*

   It is important to keep the center of the solar panel the exact same distance away from the light source for each different angle if we want to compare the results with each other. When we use sunlight as the light source it is so far away from the solar panel that the distance on our tabletop is insignificant.

5. *How did your prediction for the 10-degree angle compare with your actual result? How did you adjust your predictions for the other angles? Did they become more accurate as a result of your actual measurements?*

   My prediction for the 10-degree angle was different from my actual result. I thought there would be a greater difference. The differences between each measurement grew larger as the angle of incidence increased so I increased the differences each time.

6. *With your graph could you make a fairly accurate prediction of the milliamp reading for 25 or 75 degrees? Is there any way to check your predictions for 25º and 75º?*

   We could check my predictions for 25 degrees and 75 degrees by actually doing it and getting the results from the ammeter.

7. *In this investigation we have placed the light source and the solar panel in the same plane. In real life the sun appears to move both horizontally and vertically. What would you need to know before you permanently position a solar panel on top of your school?*

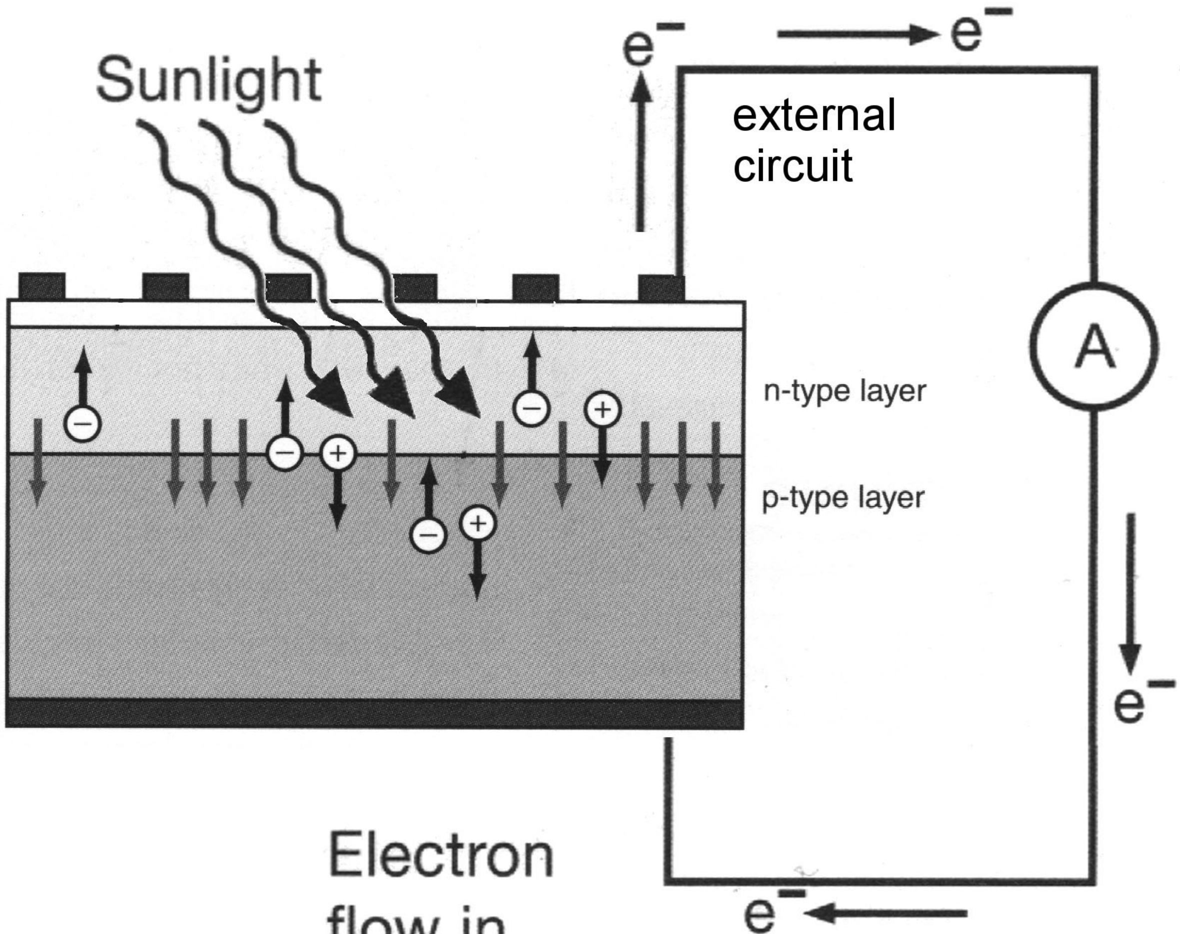
   I would need to determine my latitude and where geographic south is before I permanently position a solar panel on top of my school. It would be similar to positioning a sundial correctly.

8. *Will the rate of electrical energy production be the same for every day of the year? Why or why not? How could you plan for this? Would your solution necessarily be a practical one?*

   The rate of electrical energy production will not be the same for every day of the year because of the weather or time of the year. I might be able to make a motorized mount for a solar panel that would automatically track the sun wherever it is or find the brightest spot in an overcast sky. It might be too expensive to set it up this way and might present more problems or things that could go wrong.

9. *What is the answer to the question at the beginning of this investigation:* How can we maximize the electrical power coming from the solar panel?

   We can maximize the electrical energy coming from the solar cell if we position it correctly.



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