

Why is it hotter in the summer?

A laboratory experiment from the
Little Shop of Physics at
Colorado State University



Overview

The energy that drives many of our planet's systems, including the ecosystem and climate systems, comes primarily from incoming solar radiation from our Sun. Depending on where you live on Earth and the seasons, the amount of energy varies throughout the year. Most people know that in winter you get much less energy from the Sun than in summer, but just how much less? This exercise will help make comparisons between seasons and how much solar radiation falls on a particular location.

Theory

Sunlight and all electromagnetic radiation travels out from the Sun in all directions. A tiny portion of that light travels the speed of light a distance of 149 million km from the Sun in just over 8 minutes, reaching Earth and supplying the energy for the climate systems as well as our ecosystem and sustaining life as we know it.

At Earth's distance from the Sun the rays are essentially parallel to each other when they arrive. The more directly the light shines from above, the more intense the radiation will be, because the light "beam" is more concentrated than if the beam were shining from an angle closer to the horizon.

You can demonstrate this using a flashlight that also "collimates" its light into a beam. Shine the flashlight from directly above (perpendicular) over a white sheet of paper. Use a pencil to sketch the area the light beam falls on the paper. Now shine the light at an angle (more oblique) to the paper and see how the circular column now appears more elliptical. Again, sketch the area of the light using a pencil. Do you see how the light is more spread-out when shining at an angle? Try several other combinations. Would you ever be able to measure the area if the light source was shining along the length of the paper (parallel)?

Modeling Exercise

In this exercise, students will calculate the amount of sunlight falling at a particular location on the vernal and autumnal equinox as well as the summer and winter solstice. They will measure the light intensity at the different seasons to numerically compare the amount of light available throughout the year.

To do this we will think of the light coming from the Sun as a "tube" or "beam" of light falling in a circular area.

Calculate the light intensity falling at the equator on the equinox:

Necessary materials:

- Beach Ball Earth Globe (27" diameter)
- white tube incoming solar radiation model
- light source/flashlight
- Incoming Solar Radiation worksheets
- CSAP rulers or metric ruler graduated to mm.
- pencil
- calculator

Students should be familiar with the concepts of latitude and longitude as well as calculating the area of an ellipse and a circle (the area of a circle is actually found the same way as an ellipse). Students should also understand the concepts of vernal and autumnal equinox and also the summer and winter solstices.

Light falling at the equator on the equinox comes from directly above, at no angle, and so is most intense. To calculate the intensity, measure the radius of your light tube and then calculate the area of the ellipse (in this case, a circle) that the light is occupying. The radius on the worksheets is .5 cm (diameter 1 cm), so use this value for this initial calculation. Use 3.14 for π and round all calculations to three decimal places.

size of radius: _____ cm

area of ellipse: $\text{area} = \pi \cdot \text{semi - major axis} \cdot \text{semi - minor axis} = \pi \cdot \text{radius} \cdot \text{radius} = \text{_____ cm}^2$

This value will be what you will compare all of your other measurements to when determining the solar intensity for your location and seasonal date.

Calculate the light intensity falling at 40° N on the equinox:

This part of the exercise will vary for people living at different latitudes, but is done here for 40°N, an approximate for Fort Collins and Denver. Look on the Incoming Solar Radiation sheet for the Equinox and note that a location of 40°N lies in parallel light tube #6. Measure the distance between the ends of the arrows as they strike the Earth's surface in the drawing for light tube #6. Be very precise and record this value to 1/10th of a millimeter. Note that the length should be longer than 1 cm as in the example above. This length represents what is called the major axis of an ellipse. Divide the length in half and you now have the semi-major axis of an ellipse.

distance between arrow points (major axis): _____ cm

size of semi-major axis: _____ cm

distance directly across light tube #6 (minor axis): _____ cm

size of semi-minor axis: _____ cm

area of ellipse: $\text{area} = \pi \cdot \text{semi - major axis} \cdot \text{semi - minor axis} = \text{_____ cm}^2$

Now, divide your original area for the equator on the equinox by the area calculated for 40°N on the equinox and multiply this result by 100. This will give you the percentage of light that falls at 40°N compared to the light that falls at the equator on the equinox.

$$\frac{\text{area of ellipse at equator}}{\text{area of ellipse at 40°N}} \cdot 100 = \frac{\text{cm}^2}{\text{cm}^2} \cdot 100 = \text{_____} \% \text{ of light compared to the equator}$$

Calculate the light intensity falling at 40° N on the winter and summer solstice:

Use the same approach as above to calculate the light intensity for the winter and summer solstice for 40°N. Note that the light beams are now #9 for the winter solstice and #3 for the summer solstice. You can use these calculations to make comparisons between seasonal extremes. Use a protractor for locations other than 40°N. Would your measurements work for the southern hemisphere as well as the northern? What might you have to consider when making these comparisons?

Note about Incoming Solar Radiation Worksheets: Care should be made in reproduction of the Incoming Solar Radiation worksheets, as copiers tend to shrink or enlarge when making duplicate of originals. Variations from the original sizes will throw off the measurements used above. Please print the .jpg files directly to your printer in landscape orientation for best results.