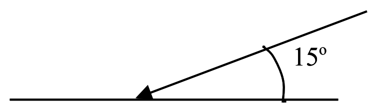
Light Intensity and its Dependence on Angle

Before you measure the solar constant, you should determine whether the angle that light strikes a surface changes the intensity of the light on the surface. In class, light intensity was discussed when you studied the absorption of ultraviolet light by the ozone layer. Intensity is the amount of energy per unit time per unit area. It can be put in the form of an equation, Intensity = $\frac{energy}{time \cdot area}$. The MKS units for intensity are $\frac{J}{m^2 \cdot s}$.

If you have a light source that puts out a constant value of energy per unit time such as the sun or a flashlight, do you think the angle light strikes the surface affects the intensity? If the angle affects the intensity, at what angle would you have the greater intensity? Light striking the surface at a 90º angle (perpendicular to the surface) or light striking the surface at a glancing angle, say 15º ?



Now you will determine whether the angle makes a difference in the intensity.

Exercise:

1. Hold a flashlight directly above the graph paper so the light strikes the paper at a 90º angle. Measure the distance the flashlight is above the paper. One person hold the flashlight at that distance while the other traces the outside of the light beam.
2. Now tilt the light so it strikes the paper at about 45°, keeping the flashlight the same distance above the paper that you used in Step 1. Trace the beam shape as you did in Step 1.

Questions:

1.a. What type of pattern does the light make on the paper when the light strikes the paper at 90º ? a circle? a square? an ellipse? a parabola?

1.b. What type of pattern does the light make on the paper when the light strikes the paper at 45º ?

2. You should have found that the light makes approximately a circular pattern at 90º and an ellipse at 45º. Measure the diameter of the circle formed by 90º light and the diameters of the major and minor axes for the ellipse formed by 45º light. Dia. circle = __________; dia. major axis = __________; dia. minor axis = ___________.

How does the diameter of the minor axis compare to the diameter of the circle?

3. At which angle does the light have the greatest area on the paper? 90° ? or 45° ?

4. Estimate how much greater the area is? 50% greater? 10% greater?

5. At which angle does the light have the greater intensity? 90° ? or 45° ?

6. How does your answer in Question 3 compare with the prediction you made before the exercise?

7. If you measure the intensity with the flashlight at 45°, how would you correct the intensity you measured to get the intensity at 90° ? Could you use the ratio of the areas at 45° and 90° ? How would you use this ratio?

8. If d is the diameter of the circle, d_1 is the diameter of the minor axis of the ellipse; and d_2 is the diameter of the major axis of the ellipse, then the area of the circle is

$$A_{circle} = \pi\left(\frac{d}{2}\right)^2$$, and the area of the ellipse is

$$A_{ellipse} = \pi\left(\frac{d_1}{2}\right)\left(\frac{d_2}{2}\right).$$

Instead of using the ratio of the areas to correct the intensity, can you find the ratio of two distances to make that correction? Hint: Put the equations for the areas in the ratio and see what cancels.

Check your answers with the TA before proceeding.