I. Objectives

1. Investigate basic principles of electromagnetic radiation theory and how those relate to the energy output of the Sun.
2. Apply the inverse square law of light to help calculate the amount of solar energy reaching the Earth.
3. Calculate the solar irradiance at the top of the Earth's atmosphere.

II. Introduction

The main source of energy available on Earth is the electromagnetic radiation (E&M) emitted by the Sun. This E&M radiation is transported to Earth at the speed of light. The amount of solar radiation received per unit time, per unit horizontal area at the top of the Earth's atmosphere, at the average distance between Earth and Sun, is known as the *solar constant*.

III. Prelab Definitions

1. electromagnetic radiation

2. solar luminosity

3. inverse square law of light

4. Astronomical Unit [A.U.]

5. perihelion

6. aphelion

7. energy

8. power

9. joule

10. watt

11. irradiance

12. insolation

IV. Lab Procedure

The main goal in this exercise is to step by step, from first principles, calculate a reliable value for the solar constant. To do this we will utilize accurate values of the Sun's energy output derived from astronomical observations and theory, along with knowledge scientists have of Earth's exact distance from the Sun.

Useful spherical geometry formula:

The surface area of a sphere is given as:
$A_{sphere} = 4\pi r^2$, where r is the radius of the sphere.

Procedure

The Sun's radiant energy output varies slightly over the course of a 22 year solar cycle.
For our purpose however, we will assume it is constant. For the calculations you make below, assume the solar luminosity is:

$L_{sun} = 3.84 \times 10^{26}$ joules/sec (total E&M energy output from the Sun per unit time)

Assume the average distance of the Earth from the Sun, defined as one Astronomical Unit [A.U.] is:

$r_{sun\text{-}earth} = 1.496 \times 10^8$ km

Answer the following, writing your answers in the space provided for each question. Show all calculations and unit conversions.

1. What is the solar luminosity in units of watts?

   L_{sun} (watts) = ________________

2. What is the average Sun-Earth distance in meters?

   $r_{sun\text{-}earth}$ (meters) = ________________

3. What is the surface area of the sphere whose radius equals the Sun-Earth distance? Write its formula and compute its numerical value.

$A_{\text{sphere (sun-earth)}}$ = ________________________________

4. What units are attached to the quantity you have calculated in question 3?

5. To arrive at the final answer for the solar constant value we need to perform one more calculation. Look again at the precise definition of the solar constant given in the introduction above. What units must it have?

6. The solar radiation generated inside the Sun is emitted from its surface uniformly (or very nearly so) in all directions to space. By the time it travels 1 A.U. to the vicinity of Earth, that solar energy has been distributed evenly across the entire gigantic spherically shaped surface of space you found in question 3. The solar power produced in passing across a 1 m^2 area oriented perpendicular to the direction of the incoming sunlight *is* the solar constant (**study the diagram in Resource 3 listed above**). Therefore, what arithmetic operation, *multiplication* or *division* do you have to perform using the numbers you found in questions 1 and 3?

7. Perform the arithmetic requested in question 6. Using the abbreviation "SC" for the solar constant, what is your answer? **Include both the numerical value and the units.**

SC = ________________________________

8. Consult the websites listed above to check your answer against the currently accepted range of values determined from calibrated satellite measurements and other ground-based methods. What is the range of values found from those scientific observations? Does your answer lie in that range?

V. Lab Discussion

The solar constant is defined for a reference distance of exactly 1.00 A.U. from Sun to Earth. Satellites measurements designed to infer the solar constant are taken typically at high altitudes at the extreme boundary at the top of Earth's atmosphere. An adjustment to a particular satellite-measured value can then be made using the inverse square law of light. Here's how it is scaled:

Solar irradiance at 1.00 A.U. = SC
Solar irradiance at some other distance (d, expressed in A.U.s) = SC x $(1/d^2)$

1. In early January, the Earth is at *perihelion*, If $d_{perihelion}$ = 0.982 A.U., what is the solar irradiance at $d_{perihelion}$, expressed as a factor times the solar constant)?

2. In early July, the Earth is at *aphelion*. If $d_{aphelion}$ = 1.015 A.U., what is the solar irradiance at $d_{aphelion}$ expressed as a factor times the solar constant?

Lab courtesy of Dr. Dana Kerola