AST 102 – Astronomy II
The Solar Constant

Introduction

In this lab we will make a measurement of the solar constant. The solar constant is a measure of the intensity of the sun at the surface of Earth. It is expressed in units of W/m^2. To measure the constant, we will use water to absorb solar energy for a certain amount of time. From the temperature rise of the water, we can determine how much energy it absorbed, and since we know the area of the container and how long it absorbed energy, we can determine the intensity.

Procedure

Be sure to fill in all blanks and answer all questions posed in the procedure section.

A. Set-up

1. Determine the mass of the water.

Use the electronic scale to record the mass of the empty bottle in g with the stopper in.

Mass empty bottle with stopper: _________

Fill the bottle with water and slowly put the cork allowing any excess water to overflow. Dry the outside of the bottle and determine the mass in g.

Mass bottle with water and stopper: ________

Determine the mass of the water in the bottle by subtracting the two masses.

Mass water: m = __________

2. Add a drop or two of black ink to the water so that the water becomes black.

Q1) Why do we want the water to be black?

3. Place the bottle outside in the shade for 20 minutes or so until it is at ambient temperature, i.e. at the same temperature as it is outside.

Q2) Why do we want the water to be at outside temperature?

Q3) Why do we want to allow the water to come to ambient temperature in the shade?

4. Insert the digital thermometer.

Make sure that the digital thermometer is reading in Celsius. Place the probe of the digital thermometer into the hole in the stopper and wrap the stopper with parafilm so that no water will leek out the opening in the stopper.

B. Data Acquisition

5. Record the initial temperature of the water.
Allow the thermometer to come to a steady reading and record the initial temperature.

Initial temperature of water: T_i = ____________

6. Place the bottle on its side in the sun in a safe place. *Start the stopwatch*. Allow the temperature of the water to climb 5 to 10 C°. You should check on the bottle every few minutes.

7. Record the final temperature of the bottle
Stop the stopwatch, and record the final temperature of the water.
Final temperature of water: T_f = ____________

Record the time in seconds

Duration of Experiment: ____________ s

Bring the bottle and thermometer back inside once you have recorded the final temperature.

Data Analysis

Ideally this procedure should be performed as close as possible to noon.
Q4) What effect - i.e. too big, too small, no difference - will the time of day that you made the measurement have on the value that you measure for the solar constant? Explain your answer.

Q5) Describe the weather conditions when you made this measurement.

Q6) What effect might the weather conditions have on the value you determine for the solar constant?

8. Determine the amount of energy absorbed by the water
The amount of energy gained by the water can be determined from
Energy = 4.186 J/(g C°) x m x (T_f – T_i) where the value 4.186 J/(g C°) is called the specific heat of water and measures how much energy it takes per to change the temperature of water. J stands for joule which is a unit of energy.

Determine the energy added to the water.
E = 4.186 J/(g C°) x _________ g x (_________ C° - ____________ C°) = _________ J

9. Determine the power
The power is how much energy per time was added to the water. To find the power divide the energy added to the water, in J, by the duration of the experiment in s. This will give the power in units of watts, W.

P = __________________ J / ________________ s = _____________ W

10. Determine the cross-sectional area
To find the intensity we need to divide the power by the area through which the light was absorbed. We will assume that the area is a rectangle with width equal to the diameter of the bottle and length equal to the length of the bottle. Measure the appropriate dimensions in units of meters and record below. Note that 1 cm = .01 m.
Length = _______m
Width = _______m

Area = Length x Width = ________ m x ___________ m = ___________ m^2

Check your answer for the area with another group to make sure you handled the units correctly.

11. Determine the intensity
We're at our last step. Intensity is power per area. Find the intensity. This intensity is your determination of the solar constant.

Intensity = Power/Area = ________ W/ _________ m^2 = ___________W/m^2

Q7) Note that our procedure for determining the area probably over estimates the area. What effect will this have on the value we determine for the solar constant? Explain.

12. Compare answers.
The value usually quoted for the solar constant is 1000 W/m^2.
Q8) How does the value you determined for the solar constant compare to the accepted value – i.e. too big, too small, just right?

Q9) Is this consistent with the effects of time of day, weather, and over estimating the area?

Q10) Another significant effect is the time of year. The 1000 W/m^2 is valid for the sun directly overhead. What effect on your measurement of the solar constant might the time of year have?

Application
We can use are determination of the solar constant to make an estimate of the luminosity of the sun. The solar constant tells us how much power from the sun is hitting 1 square meter of Earth.

Q11) How can you find the luminosity of the sun from the soar constant?

Q12) What additional data do you need to find the luminosity? Use your textbook to find the data you need.

Q13) Determine the luminosity of the sun using the value you determined for the solar constant. Hint the surface area of a sphere is given by the formula $A = 4\pi r^2$.

Q14) The usual value given for the luminosity of the sun is 4×10^{26} W. How does the value you determined compare to the value for the sun? Is this consistent with how your value for the solar constants compared?