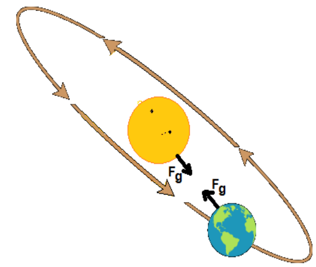
Solar Astronomy Resources

PTRA Summer Institute 2023

Resources used from the Digital Signal Processing in Radio Astronomy (DSPIRA) group at West Virginia University RAIL group.

Resources developed by Kenric Davies for the 2023 Summer PTRA Institute kenric.davies@gmail.com

Using Physics to Find the Speed of the Earth around the Sun



Objective - Using the Universal Law of Gravity and the concept of centripetal force to find the speed of the Earth around the Sun.

This will be a specific example based on what you have learned about Newton's Law of Gravity and centripetal motion.

Questions

1) What is the equation for Universal Law of Gravity?There are two masses in the equation...the 2 masses of consideration, and in this example the 2 objects in the image.
2) What is the equation for Centripetal Force on the smaller object, in terms of mass, radius, and velocity? This time there is only one mass. It is the smaller of the two masses since it is the one exhibiting the circular motion.
3) Equate the above two answers and solve algebraically for velocity (of the Earth)? Put a box around your final result. (Remember, no substitutions, just variables)
4) Find the values and units for the following:

Universal Gravitational Constant	
Mass of the Sun (kg)	
Mass of the Earth (kg)	
Distance between the Earth and Sun (m)	

5) Start by rewriting your derived equation from 3), then process in solving for the velocity of the Earth. Show all work, with units.
6) Optional- Which of the four values from the chart above did you not need to use in your calculations?
7) The speed of the Earth is often given in kilometers per second (km/s) So, convert your answer, to one decimal place, for the speed of the Earth in km/s.

Modeling the Earth's Motion Around the Sun

DSPIRA - Student Activity Sheet

DSPIRA - Student Activity Diagram

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Measuring the Temperature of the Sun

Purpose: In this lab you will measure the solar flux, the amount of energy per unit area per unit time that reaches the Earth from the Sun. From this, you will calculate the temperature of the surface of the sun.

Equipment: Insulated cup, water, ink, thermometer, watch (timer), meter stick, scale, graph paper, and calculator

Introduction

Flux is defined as the amount of energy delivered per unit of area and per unit of time (measured in units of joules per square meter per second). We can use the flux to find out how much energy is delivered by the Sun using the following equation:

$$Energy\ delivered\ by\ Sun = Flux * Area * \Delta t$$

The energy delivered by the sun to the water will cause the water to increase in temperature. There is also a relationship between the amount of energy absorbed and the temperature increase of water given by the following equation:

$$Energy\ absorbed\ from\ the\ Sun = mass * specific\ heat * \Delta Temp$$

Where the specific heat of water is equal to 4186 J/(kg°C).

Setting the two equations equal to each other we can derive an expression to find the Flux.

$$Flux * Area * \ \Delta t = mass * specific\ heat * \Delta T$$

$$Flux = \frac{mass * specific\ heat}{Area} \frac{\Delta T}{\Delta t}$$

Part 1: Gathering Data

From the above equation, it is clear to see that in order to find flux, we will need to measure the mass of the water, area of the cup that sunlight will be falling on, change in temperature, and change in time.

1. Measure the diameter of the cup and divide it by 2 to find the radius:
   Radius = ______________________m
2. Calculate the area of the cup opening:
   Area = _________________________m^2
3. Measure the mass of your empty cup:
   Mass = ________________________kg
4. Obtain some water from a cold source and then measure the mass of your cup with water in it:
   Mass of water & Cup = _______________________kg

   Mass of water inside cup = _____________________kg

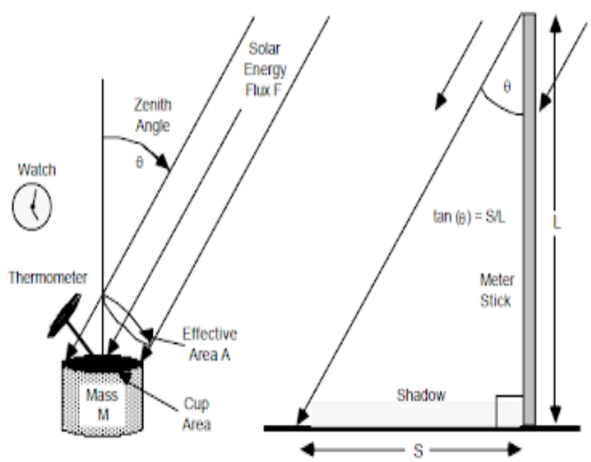
Place a few drops of dark food coloring in the water and mix it up to help the water absorb as much sunlight as possible. You will now take your set up outside.

When ready, place the thermometer in the water and record the temperature of the water at set time intervals for approximately 25-30 min. Record your data in a data table similar to what is shown below.

Data Table: Time and Temperature	
Time (s)	Temperature (°C)
0	
120	

When you have all of your data for temperature and time, graph it on the plot at the back of this lab.

While outside, you may notice that the sun is not directly overhead. This means that the sunlight is not falling on the complete area of the cup but only a portion of it. In order to find the correct area of the cup, you will need to measure the angle the sun is away from Zenith. The easiest way to do this is to measure the shadow length of a specific item like a meter stick.



From the image, you can see that the zenith angle is related to the length of the meter stick (L) and the shadow length (S) by the following relationship:

$$tan\ tan\ (\theta)\ =\ \frac{S}{L}$$

Calculate the zenith angle by using:

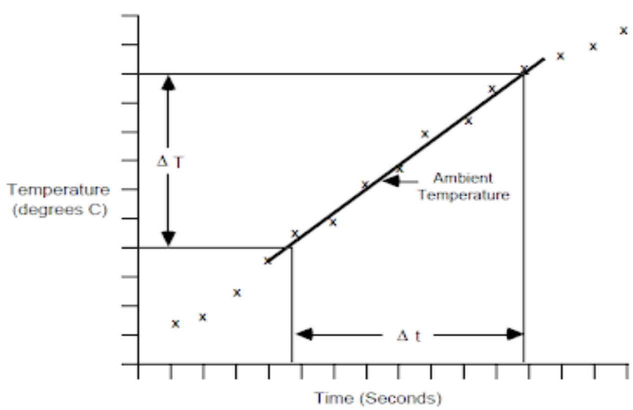
$$\theta\ =\ tan^{-1}\left(\frac{S}{L}\right)= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ °$$

Calculate the correct area by using:

$$A\ =\ A_{cup} * cos\ cos\ (\theta)$$
$$=\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m^2$$

Data Analysis

Time to head back inside and analyze your data to find the solar flux. Your graph should come out to be relatively linear; an example is shown below.



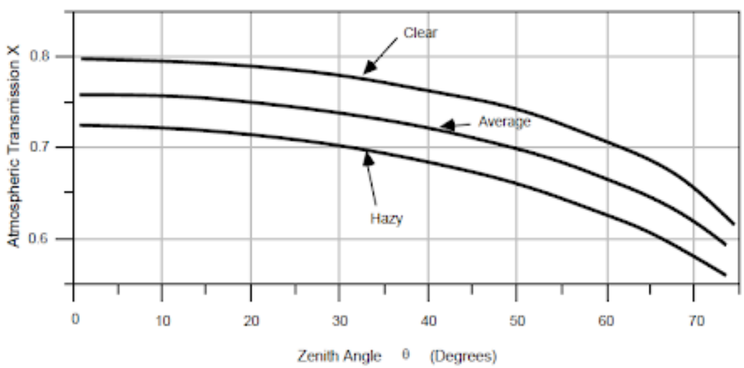
For the part that looks the most linear, you can find the change in temperature and the change in time. Record those values below.

Change in Temperature = ________________________°C

Change in time = _____________________________s

You are now ready to find the solar flux. Use the equation for flux listed in the Introduction section on page 1 and record your value below.

Flux = ____________________________ J/m^2s



Just like the water heats up from the Sun, so does the atmosphere. We will have to adjust the above number using the graph.

Find the Atmospheric Transmission value on the graph by first locating your Zenith angle and deciding whether your skies outside or especially clear, average, or hazy. Then use that number to find the Solar Flux here on Earth by following

$$Solar\ Flux = \frac{calculated\ Flux}{X}$$

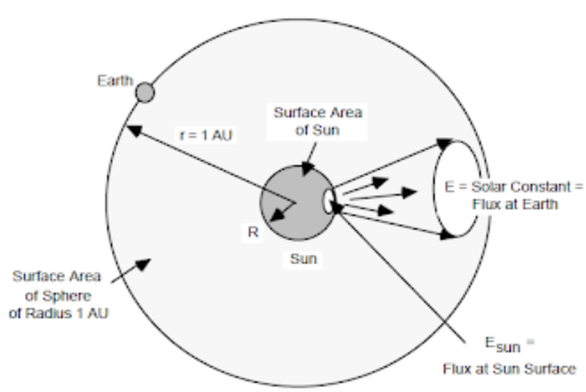
Record your Solar Flux value here: _________________________ J/m^2s

Compare your calculated value for the Solar Flux with the generally accepted value of 1360 J/m^2s (that's equivalent to nearly fourteen 100-W lightbulbs shining onto an area 3 feet by 3 feet!).

Finding the Temperature of the Sun

Your calculated value of the solar flux measured the number of watts striking *one* square meter of surface at a distance of one astronomical unit (1AU = 1.5×10^{11}m) from the Sun. If you multiply the energy hitting one square meter of the Earth by the total number of square meters on a sphere of radius 1 AU you obtain the **luminosity**, or total power output of the SUN!

$$Luminosity = Solar\ Flux * 4\pi(1.5x10^{11}m)^2$$



Now that you know how much *total* energy the Sun puts out, you can also determine how much energy E_{sun} is emitted by each square meter of the solar photosphere. Since the radius of the Sun is about 7.0×10^8 m, we divide the total energy output by its surface area:

$$E_{sun} = \frac{Luminosity}{4\pi(7.0x10^8m)^2}$$

The Sun radiates energy according to the Stefan-Boltzmann law: the power radiated per unit area (E_{sun}) is proportional to the fourth power of its absolute temperature T measured in degrees K:

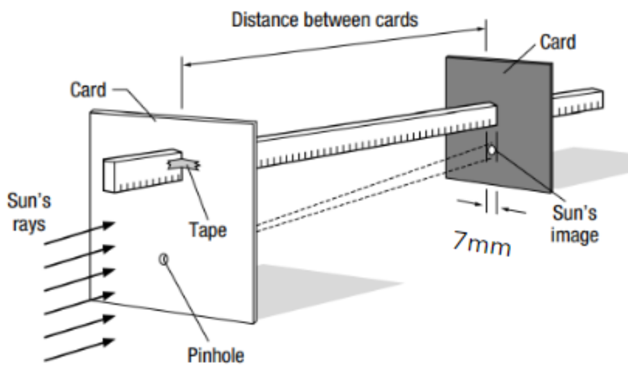
$$E_{sun} = \sigma T^4$$

Where σ (called the Stefan-Boltzmann constant is known from experiments to be 5.69×10^{-8} W/m^2K^4). Calculate the temperature of the photosphere using:

$$T = \left(\frac{E_{sun}}{\sigma}\right)^{1/4}$$

Record the Temperature of the Sun here ______________________________K

Measuring the Diameter of the Sun



Move the cards on the meterstick until you create an image of the Sun that is exactly 7 mm wide. Fill in the data table below.

Scaled Diameter of Sun Image	7 mm (0.7 cm)
Actual Distance Between Sun and Earth	1.5×10^8 km
Scaled Distance Between Sun and Earth	

$$\frac{diameter\ of\ Sun\ (km)}{distance\ to\ Sun\ (km)} = \frac{diameter\ of\ Sun's\ Image\ (cm)}{distance\ to\ Sun's\ Image\ (cm)}$$

Using your measurements and the ratio equation above, determine the diameter of the Sun in kilometers.
Adapted from https://www.fusd1.org/cms/lib/AZ01001113/Centricity/Domain/883/eslb24.pdf