Our Amazing, Powerful Sun Worksheet

This worksheet will step you through how to calculate the: (1) Power of the Sun and (2) lifetime of the Sun.

1. Power of the Sun
The Stefan Boltzmann Law allows us to relate the temperature of a planetary object (like the Sun) to its energy output and is given by:

\[ P = 4\pi r^2 \sigma T^4 \]

where \( P \) is the energy rate output of the object, \( T \) is its temperature, \( r \) is its radius, and \( \sigma \) is the Stefan Boltzmann constant \((5.670 \times 10^{-8} \text{W m}^{-2} \text{K}^{-4})\). If the temperature and radius of the Sun are approximately \( 5800 \text{ K} \) (hot!!) and \( 6.995 \times 10^8 \text{ m} \), respectively, calculate the rate of energy output of the Sun in Watts.

Solution:


2. The Lifetime of the Sun
We learned that the energy emitted from the Sun is formed through nuclear fusion. Specifically, four hydrogen atoms are transformed into one helium atom. From the Periodic Table of Elements, one helium atom has less mass than four hydrogen atoms. We can assume that the Sun will “die” when it runs out of energy.

Upon fusion to helium, about 0.7% of the original mass is lost. Therefore, we can express the total energy, \( E \), of the Sun as \( E = 0.007 mc^2 \), where \( c \) is the speed of light \((c = 299,792,458 \text{ m s}^{-1})\) and \( M \) is the mass in the sun that is capable of going through fusion. If the total mass of the Sun is \( 2 \times 10^{30} \text{ kg} \) and only the hottest center (about 10%) can actually undergo nuclear reactions, calculate the total Energy of the Sun.
Now that we know the total available energy that can undergo a reaction, we will assume that the Sun will “die” when it runs out of this energy. Put into mathematical form, this means:

\[ \text{lifetime} = \frac{\text{total available } E}{\text{rate of } E \text{ output}} \]

Solve for the lifetime (in years) of the Sun. Note that 1 Watt = 1 Joule s\(^{-1}\).

Solution: