Our Star: The Sun

Its appearance on Wednesday, October 1,
Your Photometer

A light source makes the wax in the photometer glow.

You moved the wax photometer until the two sides were equally bright.

Recall from the lecture on light, Brightness = \( \frac{F}{4\pi r^2} \)
with \( F = \) intrinsic output of the source (luminosity) and \( r = \) distance of the source. We can write an equation for the brightness of each source, the light bulb and the Sun.

Photometer: a device for measuring light intensity (brightness)
Translating an Observation into an Equation

In your observation, you moved the wax blocks until both sides were equally bright:

\[
\begin{align*}
\text{Brightness}_{\text{Light Bulb}} &= \frac{L_{\text{Light bulb}}}{4\pi d^2_{\text{Light bulb}}} \\
\text{Brightness}_{\text{Sun}} &= \frac{L_{\text{Sun}}}{4\pi D^2_{\text{Sun}}} \\
\text{Brightness}_{\text{Light bulb}} &= \text{Brightness}_{\text{Sun}}
\end{align*}
\]

So

\[
\frac{L_{\text{Light bulb}}}{4\pi d^2_{\text{Light bulb}}} = \frac{L_{\text{Sun}}}{4\pi D^2_{\text{Sun}}}
\]

\(L_{\text{Sun}}\) is what we want to learn from this observation.
What Do the Numbers Mean?

\[
\frac{L_{\text{Light bulb}}}{4\pi d_{\text{Light bulb}}^2} = \frac{L_{\text{Sun}}}{4\pi D_{\text{Sun}}^2} \Rightarrow L_{\text{Sun}} = \frac{D_{\text{Sun}}^2}{d_{\text{Light bulb}}^2} L_{\text{Light bulb}}
\]

You measure \( d_{\text{Light bulb}} \), you know \( L_{\text{Light bulb}} \) (300 watts) and the homework says that \( D_{\text{Sun}} = 1.5 \times 10^8 \) km so you can solve for \( L_{\text{Sun}} \) (be careful to have \( D_{\text{Sun}} \) and \( d_{\text{Light bulb}} \) in the same units such as meters).

Recall why we first thought about nuclear reactions powering the Sun: a high rate of energy production is required over a very long time (billions of years).

*How long can the Sun continue to shine at its current rate?*
How long can the Sun continue to shine at its current rate?

Need to know how much fuel is burned every second to make the Sun shine and how much total fuel is available to burn.

Nuclear fusion converts 4 H atoms to 1 He atom with a net loss of 0.7% of the original mass converted to energy which can be computed from $E = mc^2$ so mass is disappearing every second to make the Sun shine.

Energy/second = mass/second x $c^2$  \[ L_{\text{Sun}} = \text{mass converted/second} \times c^2 \]

You can convert your luminosity measurement into how much mass is being consumed every second and knowing the mass of the Sun’s core, you can then compute how long the Sun can shine.

Fuel burned per second $\Leftrightarrow$ Luminosity
Total fuel available $\Leftrightarrow$ Mass of the Sun’s core
Some Math Help

Question 1b:

Value for $L_{\text{bulb}}$ Watts
1.00

Your value for $d_{\text{bulb}}$, in meters
1.00

Value for $D_{\text{sun}}$ in meters
1.00

$\frac{L_{\text{sun}} = L_{\text{bulb}} \times D_{\text{sun}}^2}{d_{\text{bulb}}^2} = 1.00 \times 1.00 = 1.00 \times 10^0$ Watts

Question 3:

Speed of light $c = 1.00 \text{ m/sec}$

$\frac{L_{\text{sun}}}{c^2} = 1.00 \times 10^0 \text{ kg/sec}$

Rate of H conversion to He = $1.43 \times 10^2 \text{ kg/sec}$ (0.7 % of $L_{\text{sun}}/c^2$)

Mass of the Sun = 1.00 kg

Mass of the Sun's core = $0 \times 10^{-1} \text{ kg}$ (10% of Sun's mass)

Time to convert all H in core to He = $rac{\text{Mass of core}}{\text{Rate of H conversion to He}} \text{ kg/s} = 1.00 \times 10^0 \text{ Seconds}$

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