Goal 4.3.7: Radiation balance and the natural greenhouse effect

1. Stefan-Boltzmann Law:

\[ F = \sigma T^4 \]

\[ \sigma = \text{Stefan-Boltzmann constant} = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4 \]

\[ T = \text{temperature} \]

Recall: \( K = \frac{\text{absolute zero}}{273.15} \)

\[ 273.15K = 0°C = -27°C \]

\[ K = 1°C \]

\[ T = \frac{K - 273.15}{0°C} = \frac{K - 273.15}{1°C} \]
2. Radiation balance: energy in = energy out

\[
\text{Solar flux in} = \text{reflected} + \text{flux from Earth} + \text{flux out to space}
\]

\[
\frac{F_s}{\sigma T_E^4} = AF_s + \frac{1}{\sigma T_E^4}
\]

Let \( A = \text{albedo} = \text{fraction solar radiation reflected out to space} \)

Some reasonable numbers:
\( A \approx 0.3 \)
\( F_s = 342 \text{ W/m}^2 \)

\[
T_E = \sqrt[4]{\frac{(1-0.3)(342 \text{ W/m}^2)}{5.67 \times 10^{-8} \text{ W/m}^2 \text{K}^4}} \approx 255 \text{ K}.
\]

\( = -18 \text{ \degree C} \).
1. Use Wien’s Displacement Law to estimate the wavelength at which the radiative flux from the 20W halogen lamp is maximum, assuming the bulb is radiating at about 400K. In what part of the radiative spectrum (ultraviolet, visible, infrared) does your calculated $\lambda_{max}$ fall? How does this compare to the $\lambda_{max}$ we calculated for the Sun? (10pts)

2. Draw a side view of the experiment we’ve set up, including the halogen lamps, the thermometers, and the petri dishes filled with water. Call the thermometer over the empty petri dish $T_1$ and the one over the petri dish filled with water $T_2$. Why are we able to see writing on the paper underneath the petri dish filled with water? (10pts)

3. How do you expect the temperatures for each thermometer to change when we switch on the lamps? Why? (10pts)