1. (2 points) If the average surface temperature of the earth is 288 K and its radius, r, is 6367 km, estimate
   a) the average intensity of infrared radiation emitted from the earth’s surface in W/m², using \( \sigma T^4 \), where \( \sigma = 5.67 \times 10^{-8} \) W/m²-K⁴, and
   b) the total power in Watts emitted by the earth. [The surface area of a sphere is \( 4 \pi r^2 \).]

2. (2 points) The average emitted infrared radiation intensity is equal to the average absorbed incoming radiation. If all of the incoming radiation went into evaporating water, estimate how much water could be evaporated in one day from a typical square meter of ocean surface. [1 day \( \sim 10^5 \) s; latent heat of vaporization is \( 2.5 \times 10^6 \) J/kg; water density is 1000 kg/m³; 1 W = 1 J/s].

3. (4 points) The radiative equilibrium temperature of a planet is governed by Energy In = Energy Out: \( \sigma T^4 = \frac{(1-A)S_o}{4} \), where A is albedo, \( S_o \) is solar constant for that distance from the sun, and the Stefan - Boltzmann constant is \( \sigma = 5.7 \times 10^{-8} \) J m⁻² K⁻⁴ s⁻¹.
   a) Calculate \( T \) for the earth, where \( A=0.3 \) and \( S_o=1370 \) W/m². [You will need to push the square root button twice on your calculator using the solution \( T = \left( \frac{S_o}{4 \sigma} (1 - A) \right)^{1/4} \).]
   b) From about what altitude in the earth’s atmosphere is the earth emitting infrared to space at the temperature you found in a)?
   c) During the first billion years the solar output was only about 75% of its modern value. Estimate \( T \) using \( A=0.3 \) for this ancient situation.
   d) A big volcanic eruption, or the growth of a big continental glacier such as the Laurentide Ice sheet of 20,000 years ago, could increase the earth’s albedo. Calculate \( T \) for \( A=0.4 \) \([S_o=1370 \) W/m²\]].

4. (2 pts) We can include the extra emission of infrared by the atmosphere down to the surface (the greenhouse effect) by adding an extra incoming energy term:
   \[
   T_s^4 = \frac{(1 - A)S_o}{4\sigma} + \epsilon T_a^4,
   \]
   where \( T_s \) is the surface temperature, \( T_a \) is the atmospheric temperature, and \( \epsilon \) is the atmospheric emissivity (which is equal to its absorptivity).
   a) For \( A=0.3 \), \( S_o=1370 \) W/m², \( \epsilon=0.63 \), and \( T_a=255 \) K, estimate \( T_s \).
   b) Anthropogenic trace gas increases are leading to an increase in the atmospheric absorptivity (and emissivity) in the infrared. Estimate \( T_s \) for a future atmosphere with \( \epsilon=0.77 \).