ASTR/GEOL-2040-001: Search for Life in the Universe

Homework #4 Due: Wednesday Oct 4, 2017

Show all steps of your work. Using rounded values is acceptable as long as the steps of the calculation are correct. Remember to staple all your sheets and don't forget your name.

1. Temperatures on planets. To a good approximation, stars and planets emit their energy like a black body, which means the energy flux (energy per unit area and per unit time) at the solar surface (radius $R_{\rm Sun} = 7 \times 10^8\,{\rm m}$) is given by

$$F = \sigma_{\rm SB} T^4, \tag{1}$$

where $\sigma_{\rm SB} = 5.67 \times 10^{-8}\,{\rm W\,m^{-2}\,K^{-4}}$ is the Stefan-Boltzmann constant.

(i) The surface of the Sun has a temperature of $T = 6000\,{\rm K}$. What is the energy flux F for a black body at this temperature? [2pts]

(ii) The energy flux we just calculated is the power per square meter of the Sun's surface area. What is the power emitted by the entire Sun? (Hint: The surface area of a sphere of radius r is $S = 4\pi r^2$) [2pts]

(iii) This light spreads out as it leaves the surface of the Sun. For any distance, d, the Sun's power is must be spread out over a sphere of that radius. What is the energy flux (in ${\rm W\,m^{-2}}$) from the solar surface if you are standing on Earth? ($d = 1\,{\rm AU} = 1.5 \times 10^{11}\,{\rm m}$) [2pts]

(iv) We just calculated the power from the Sun per square meter. What is the total power (in watts) the Earth receives? How does this compare with the total power consumption of all the humans on Earth, which is $\approx 10^{13}\,{\rm W}$? (Hint: the area of Earth's surface which is facing the Sun is $\pi R_{\rm Earth}^2$, where $R_{\rm Earth} = 6 \times 10^6\,{\rm m}$ is the Earth's radius) [2pts]

(v) Next, take into account that 30% of sunlight is reflected (e.g., by clouds and ice). What is the power that makes it to the Earth's surface? [2pts]

(vi) The Earth also radiates energy, granted at a much lower temperature than the Sun. How much power does the Earth emit at its surface, assuming an average temperature $T = 300\,{\rm K}$? (Hint: the calculation should go much the same as for the Sun in parts i and ii.) [2pts]

(vii) Compare your answers from parts (iv) and (vi). Explain why the Earth appears to release more power than it receives from the Sun. (Hint: imagine how your temperature changes if you wrap yourself up in a blanket.) [2pts]

2. Name that "–troph". Iron-reducing bacteria make their biological living by performing the following reaction

$$2{\rm H_2O} + {\rm Fe_2O_3} \rightarrow 2{\rm Fe(OH)_2} + \tfrac{1}{2}{\rm O_2}.$$

In this reaction, iron (Fe) plays the same role that inorganic carbon (C) would play in "regular" biological reactions like photosynthesis. (Thus, instead of a carbon source, look for an iron source instead when making your choice.)

With this in mind, determine what kind of -troph this iron-reducing bacteria would be. Hint: determine where the energy comes from (sunlight/molecules), whether electron donor (molecule with lots of H) is (organic/inorganic), and whether the carbon (here iron) source is (organic/inorganic). Thus, determine whether it is a (photo/chemo)–(organo/litho)–(hetero/auto)–troph. Justify each of the prefixes used in your answer. [6pts]