Thermal Physics

Comet Hale-Bopp

Problem 1.-

a) Estimate the surface temperature of comet Hale-Bopp when it is at a distance of 200 solar radii from the sun (about the same distance from the sun as the earth). Assume

- The surface temperature of the sun is 6000K.
- The absorptivity of both the sun's and the comet's surface can be approximated as $\alpha(\nu, T) = 1$.
- The comet's temperature changes are only due to its changing distance from the sun.

b) This temperature is a bit high for a comet, which is supposed to be made of frozen components, including H_2O, CO_2, and CH_4. What might cause the actual surface temperature to be lower than that calculated in a)?

c) Does the temperature found in a) seem familiar? Do you think this is a coincidence or is it meaningful? How does the temperature found in a) depend on the radius of the object? What simple evidence do we have that the sun contributes to the heating of the earth's surface? What evidence do we have that there is another heating mechanism as well? What is that other mechanism?

Solution:

a) $$4\pi R^2 \sigma T^4 = \frac{4\pi R_{sun}^2 \sigma T_{sun}^4}{4\pi d^2}\pi R^2 \rightarrow T = T_{sun}\sqrt{\frac{R_{sun}}{2d}} = 6000\sqrt{\frac{1}{2\times 200}} = 300 \text{ K}$$

b) Evaporation would cool down the surface. Also, it would take a while for the whole body to reach equilibrium. Recall that this is a comet that spends most of its time farther away from the sun.

c) The temperature is similar to Earth's. It does not depend on the radius of the object, just the shape. Other mechanisms produce heat on Earth including nuclear decay in the interior of the planet.