ESS 314: Space physics and radiation homework.

Assigned October 4th, Due October 11th

I want to see neat versions of your answers, and a linear sequence of reasoning. Work them out on a scrap of paper first if needs be, and then write them down on the paper you turn in. I don't want to see multiple crossings-out or hard-to-follow working that jumps around on the page. Read the guidance handout from the start of the class, and follow the style suggested. Sloppy and untidy work will be penalized heavily, even if the answer is right. See week 1 web page for the expected standards.

1. **Order of magnitude estimate.** The world's largest cruise ship "The Oasis of the Seas" is about 360m long, and 60m wide. Making reasonable assumptions about the size of a cabin, about how many decks would it need for the entire population of the world to go cruising?

2. Calculate the distance from the center of Earth that you would have to place a satellite in order to have it stay exactly above a fixed point on the equator.

3. The Martian moon Phobos has a nearly circular orbit of radius 9,376 km.
   (a) What is its orbital period?
   (b) Why does it move from west to east in the Martian sky? (opposite to how Earth's Moon moves in Earth's sky)

4. Consider a Solar Wind proton moving at 400 km/s in a magnetic field of 100 nT. Its charge is 1.6 x 10^{-19} coulomb and its mass is 1.67 x 10^{-27} kg.
   (a) Show that its radius of gyration about the magnetic field line is about 42 km.
   (b) What would be the radius of gyration for an electron with the same *velocity* as the proton? (The mass of an electron is 1/2000 of that of a proton.)
   (c) What would be the radius of gyration for an electron with the same *kinetic energy* as the proton?

Formulas and numbers useful for problems 2 to 4:

Kinetic Energy $E = \frac{1}{2}mv^2$ Gyration angular frequency $\Omega = \frac{q|\mathbf{B}|}{m}$ radians/second

Period $T = \frac{2\pi}{\Omega}$ seconds Gyration radius $r = \frac{\sqrt{2mE_\perp}}{q|\mathbf{B}|} = \frac{mv_\perp}{q|\mathbf{B}|}$

Period of a satellite $T = 2\pi\sqrt{\frac{R^3}{GM}}$

Mass of Earth: 6×10^{24} Kg Mass of Mars: 0.11 times mass of Earth

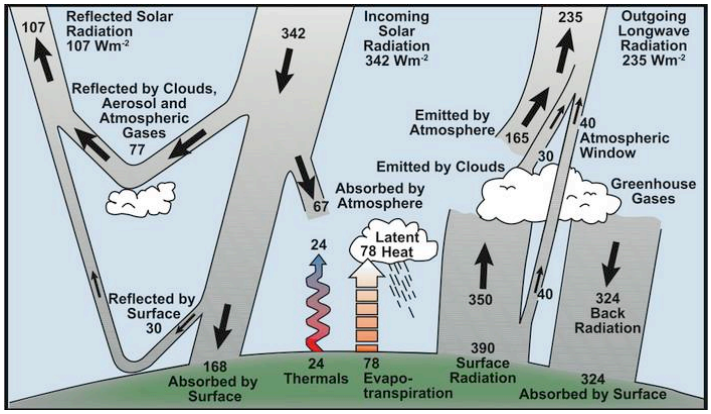
5*). Equilibrium temperatures for other planets:*
In class we worked through how to calculate the equilibrium blackbody temperature for Earth. This problem asks you to do the same for the planet Mercury, and for a new 'dwarf planet', found recently, Sedna.

Take care to ensure you keep track of units (difference between m and km for example), and remember temperature is measured in Kelvin! Take care that your answer makes sense and comment if it does not.
a) For each planet calculate solar energy per unit area at that distance.
b) Using this number, the Stefan-Boltzmann law, and conservation of energy, calculate the equilibrium temperature for these bodies.

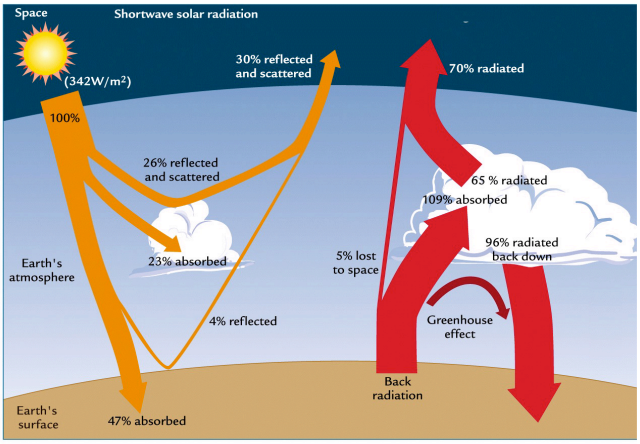
Needed facts:
Total output from sun: 3.9×10^{26}J/s
Stefan-Boltzmann constant 5.67×10^{-8} $Wm^{-2}K^{-4}$.
And for Mercury:- average distance from sun: 5.8×10^{7} km; albedo = 0.1
For Sedna:- average distance from sun = 1.3×10^{10}km; albedo = 0.3 (a guess)

6: Energy fluxes in the atmosphere.

Part 1: The figure on the right shows the various energy pathways that exist in the atmosphere. Verify (and show working) that the sources and sinks of energy **to the atmosphere** are in balance.



Part 2: I used to use this second figure on the right in class, until someone asked a question that had no good answer. Find two things wrong with it.



7: Seattle downtown temperatures.

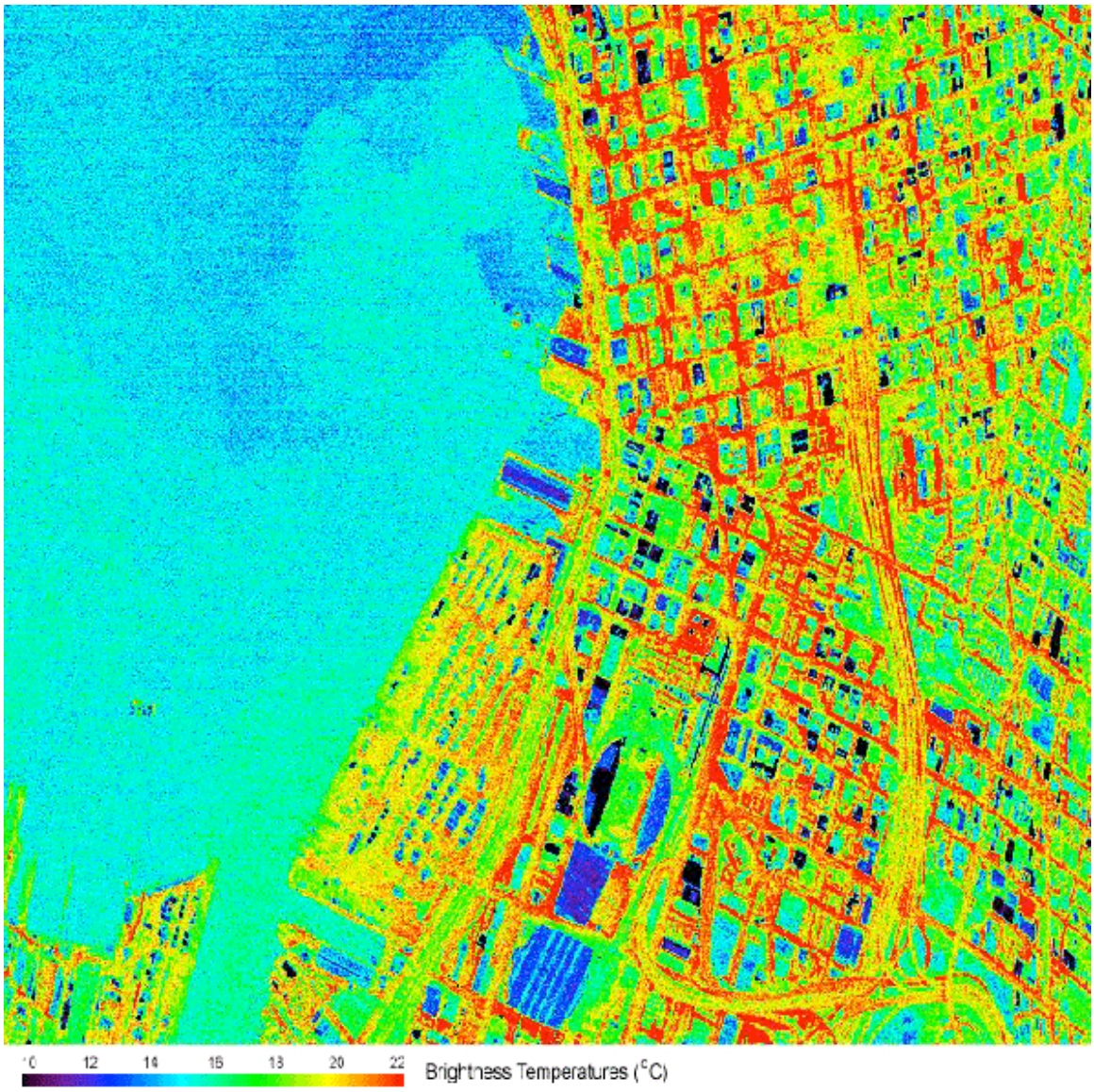
On the next page is a color figure that is an infrared image (~9 μm) taken of downtown Seattle on 30th August, 2001 at 11 pm in the evening. Image resolution is 5 m. A scale is shown for the brightness temperature (the same basic measurement that our lab radiometers would give).

a) Explain the temperature of the roads relative to the city blocks. Give possible reasons why some roads appear yellower (i.e. cooler) than others. Hint - think about the heat capacity of the different materials things are made of, and what happens to the daily temperature cycles for those materials and what time of day it is.

b) Find Seahawks (Qwest) stadium and Safeco field – why are the roofs cold? Is it a home game for the Mariners?

c) How would the image look different if it were taken on a sunny morning at the same time of year? Hint – it is a different time of day from part a).

d) Are cloudy nights warmer or colder than clear nights? Why?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12
14
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22
Brightness Temperatures (°C)