Worksheet 14B: Black Body Radiation, Wien, and The Greenhouse Effect

Objective 14F: Basic Heat Transfer

Questions:

1. List ways you can help/prevent heat transfer via conduction, convection, evaporation, and radiation.
2. Why is it that the earth can exchange heat with the rest of the universe only by radiation?

Objective 14I: Wien Displacement law

Questions:

3. In the night sky, there are reddish stars, and bluish stars. Which are the hotter stars? (Look up the visible light spectrum. Note that the red is the long wavelength end of the spectrum, and blue is the short)

Problems:

4. The sun's surface temperature is 5,778 K. What is the peak black body radiation emitted by the sun? What part of the EM spectrum does this wavelength come from? (Use your Google machine) (502 nm - visible)
5. The average temperature of the Earth is 14 ^{o}C. What is that in Kelvins, and what is the peak black body radiation for that temperature? What part of the EM spectrum does that radiation come from? (287 K, 10.1 μm - IR)
6. A distant star had a BBR peak of 410 nm. What is the temperature of the surface of the star in K? (7,070 K)
7. Another star has a BBR peak of 780 nm. What is the temperature of the surface of the star in K? (3720 K)

Objective 14J: Radiative Heat Transfer

Questions:

8. How is it possible for the ground to get colder than the air on a cold clear night?
9. Why does making something silvery or polished reduce the heat transfer by radiation?

Problems:

10. The Sun has a surface temperature of 5,778 K, a radius of 6.96×10^{8} m. Assuming it is a perfect black body, calculate the total power output of the sun. (3.85×10^{26} W)
11. The earth has an average surface temperature of 287 K and a radius of 6.38×10^{6} m. At what rate does it radiate energy to space? (1.97×10^{17} W)
12. A 100. Watt incandescent light bulb has a filament temperature of 2810 K. What is the area of the filament in m^2 if the emissivity is 0.55? (What is the peak BBR for this filament? Visible light is 400 to 700 nm...) (5.1×10^{-5} m^2, 1.0×10^{-6} m or 1.0 μm)
13. A person with a skin surface area of 1.6 m^2 and temperature of 32 ^{o}C is in a room where the dark absorptive walls are at a temperature of 18 ^{o}C. What is the net rate of heat transfer if the emissivity of their skin and clothing is about 0.68? ($P = e\sigma A(T^4 - T^4)$) (92 W)
14. A radiator in a room is radiating energy at a rate of 345 Watts through a radiant area of 1.80 square meters. It has an emissivity of 0.890, and the room it is in has an ambient temperature of 18.0 ^{o}C. What is the temperature of the radiator in degrees Celsius? (50.6 ^{o}C)

Objective 14K: Albedo

Problems:

15. An aluminum roof has an albedo of 0.890. If 1200 Wm^{-2} of solar radiation is incident on the roof, what is the reflected intensity, and what is the absorbed intensity? (1070 Wm^{-2} reflected, 132 Wm^{-2} absorbed)
16. A black asphalt roof has an albedo of 0.0900. If 1200 Wm^{-2} of solar radiation is incident on the roof, what is the reflected intensity, and what is the absorbed intensity? (108 Wm^{-2} reflected, 1092 Wm^{-2} absorbed)
17. What should the albedo be of a solar heater if it is to absorb 95.0% of the incoming light? (0.050)
18. A piece of metal lying in the sun measures 0.680 m by 0.543 m and has an albedo of 0.68. If it is absorbing 416 Wm^{-2}, what must be the intensity of the light hitting it? (1300 Wm^{-2}) What amount of energy will it absorb in a minute? (9.22 kJ)
19. A solar water heater has an albedo of 0.0452. What area must it have if it is to absorb 11.6 MJ in one hour when the intensity of the solar radiation is 1150 W m^{-2}? (2.93 m^2)

Objective 14L: The Greenhouse Effect

Problems:

20. A star has a radius of 3.50×10^{8} m and a temperature of 4280 K. What is the power output of the star? (Its luminosity) What is the intensity of light from it in Wm^{-2} if you are 1.30×10^{11} m from it? (2.93×10^{25} W, 138 Wm^{-2})
21. The intensity of a star is 1650 Wm^{-2} from a distance of 1.40×10^{11} m. What is the power output of the star? What is the temperature of the star's surface if it has a radius of 9.30×10^{8} m? (4.06×10^{26} W, 5070 K)
22. 1450 Wm-2 of energy is incident on a planet whose upper atmosphere has an albedo of 0.230. What intensity of light gets through the upper atmosphere, and what is the average intensity over the whole surface of the planet? (1116.5 Wm^{-2}, 279 W/m^{-2})
23. A planet has an average absorbed incoming energy intensity over its entire surface of 295 Wm^{-2}, and its upper atmosphere has an albedo of 0.330. What is the energy intensity incident from space on the upper atmosphere? (1761 Wm^{-2})
24. What would be the equilibrium temperature of the earth if is absorbing on the average 258 Wm^{-2} from the sun (it isn't), and we ignored the greenhouse effect? (we can't) (260. K)
25. A planet with no atmosphere has an average surface temperature of 316 K. What is the average absorbed energy intensity over the surface of the planet from the star it orbits? What is the maximum intensity incident on planet? (565 Wm^{-2}, 2261 Wm^{-2})
26. A planet has an upper atmosphere albedo of 0.105 and is at an equilibrium temperature of 13.0 ^{o}C with space. What is the incoming solar intensity from the star it orbits? (Assume there is no greenhouse effect due to the atmosphere) (1699 Wm^{-2})