Physics 81 Set 2 Solutions

1. **Blankets:** The fundamental difference between a sleeping person and the planet is that the planet is surrounded by empty space, and thus loses heat solely through radiation. A person is surrounded by a bath of cold air, so most heat is lost by conduction and convection.

   The atmosphere warms the earth by stopping radiative heat loss to space. It has nothing to do with conduction (since space is a vacuum). There is convection within the atmosphere and that indeed does change the temperature difference between the surface and the lower atmosphere, but this has a relatively small effect on the overall magnitude of the greenhouse effect.

   A blanket that you use for sleeping also stops radiative heat loss. However, you stay warm under a blanket primarily because it stops convection, and is a poor conductor of heat. The layer of air that you warm next to your skin stays there, and the heat doesn't diffuse easily through the blanket.

2. **Mountaineering photos:** At high altitudes, a given volume of air does not contain many molecules (i.e. the atmosphere is very thin). Thus, very little sunlight is scattered. So, as soon as you look away from the sun, there is very little light (of any color) to be seen. What little light that is scattered is blue, so you see a very deep blue sky.

3. **Black Body Curves:** From figure 3.8, you can see that in the parts of the spectrum where water vapor is the principle emitter, the spectrum looks like a black body at 2°C. If you then look at Figure 3.9, you see that this temperature exists only in the troposphere and the thermosphere. Since water originates at the earth's surface, you would certainly expect to find water vapor in the troposphere.

   What about the thermosphere? Since water originates at the earth's surface, vapor would have to travel up through the stratosphere and mesosphere (very cold) before reaching the thermosphere. This wouldn't happen, because as the air rises and chills, the water all condenses out as rain and snow and falls to the ground. Thus, the air above the troposphere is essentially free of water.

4. **Philander: Appendix 3, Exercise 1**

$$\lambda_{max} = 0.475\mu m = \frac{a}{t} \Rightarrow T = \frac{a}{\lambda_{max}} = \frac{2897\mu m \cdot K}{0.475\mu m} = 6099K$$

5. **Philander: Appendix 3, Exercise 2** Stars are hot enough so that the light we see from them is essentially blackbody radiation that is peaked in the visible part of the spectrum. Planets also give off blackbody radiation, but they are so much cooler that their radiation is entirely invisible to us (it's in the infrared). Instead, the light we see from planets is reflected light. Oceans reflect blue light, trees reflect green, deserts reflect brown and clouds (and snow) reflect all colors (white). The sun emits at all visible wavelengths and some of these come back at us as reflections.

6. **Philander: Appendix 3, Exercise 5** At a distance D_1 from the sun, the earth receives energy Q_1. This means the blackbody temperature is

$$Q_1 = \sigma T_1^4 \Rightarrow T_1 = \left(\frac{Q_1}{\sigma}\right)^{\frac{1}{4}}$$

At a distance D_2, the same relation holds:

$$T_2 = \left(\frac{Q_2}{\sigma}\right)^{\frac{1}{4}}$$

Now, if D_1 represents the closes point in the earth's orbit (January) and D_2 represents the most distant point (July), then $D_2 = 1.03D_1$.

The inverse square dependence of Q on D tells us that

$$Q \propto \frac{1}{D^2} \Rightarrow Q_1 \propto \frac{1}{D_1^2} \Rightarrow Q_2 \propto \frac{1}{D_2^2} = \frac{1}{1.03^2 D_1^2}$$

Thus, the ratio of temperatures is

$$\frac{T_1}{T_2} = \left(\frac{Q_1}{Q_2}\right)^{\frac{1}{4}} = \left(\frac{D_2^2}{D_1^2}\right)^{\frac{1}{4}} = \left(\frac{(1.03D_1)^2}{D_1^2}\right)^{\frac{1}{4}} = 1.0149$$

If $T_1 \simeq 288K$ then

$$T_2 = \frac{T_1}{1.0149} = 283.8K$$

From this, $\Delta T \simeq 4K$.

7. **More blackbodies:**

   (a) $R = 2m$ so $A = 4\pi R^2 = 50.26m^2$. $T = 293K$ and $Q = \sigma T^4 = (5.67 \times 10^{-8})(293^4) = 418W/m^2$. Thus, total power radiated is $Q \times A = 21,002W$

   (b) At $10°C$, $Q = (5.67 \times 10^{-8})(283^4) = 363.7W/m^2$. Now $A = 201m^2$ so total power is $73,126W$