Total points: 100
ATOC 1060-002 Homework #2

INSTRUCTIONS: Make sure that you answer all of the questions for maximum credit. Use appropriate units on all numerical answers and answer non-numerical questions with complete sentences. Please write neatly when completing this assignment – if we can't read your answer you will not get credit for it.

1. 1a) Which one has higher energy, a photon of x-ray or a photon of UV? (3pts) Explain your answer using the relationship between the energy of a photon (E) and the wavelength (λ) of electromagnetic radiation. (5pts)

   A photon of x-ray has higher energy than a photon of UV. This is because the energy E of a photon is inversely proportional to the wavelength:

   $$E = \frac{hc}{\lambda}$$

   where h is planck's constant and c=300,000km/s, The shorter the wavelength, the more energy of a photon. Because x-ray has a shorter wavelength than UV, the x-ray has higher energy.

   1b). If the air temperature is 25ºC, how much it is in Fahrenheit? How much it is in Kelvin? (6pts)

   T(ºF)=[T(ºC)x1.8]+32=[25x1.8]+32=77(ºF) (3pts)
   T(K)=T(ºC)+273.15=298.15K. (3pts)

2. Radiation laws

The mean temperature of the Earth's surface is about 15ºC; the mean temperature of yourself is about 37.5ºC; and the temperature of the Sun is about 5500ºK. Assume radiation of the Earth, yourself, and the Sun can be viewed as blackbody radiation.

2a) At what specific wavelength (in μm) does the Earth radiate its maximum (peak) energy? (5pts) Is this wavelength in the infrared or visible light range? (3pts) (Accurate to 2 decimal points)

Wien's Law: $$\lambda_{\max} \approx \frac{(2898 \mu m K)}{T}$$

First, change the unit of temperature from ºC to ºK.
T= 273.15+15=288.15(K)

$$\lambda_{max} = \frac{2898 \mu m K}{T(K)} = \frac{2898}{288.15} = 10.06 \mu m$$

This wavelength falls in the infrared range. So, the Earth's peak radiation is IR.

NOTE: Only the final unit (μm) is required. It is also ok if the students write down units in the equations but miss it in the end. Deduct 1pt by missing units.

2b) At what specific wavelength (in μm) do you radiate your peak energy? (5pts) Is this wavelength in the infrared or visible light range? (3pts)
(Accurate to 2 decimal points in your calculation)

Wien's Law: $$\lambda_{\max} \approx \frac{(2898 \mu m K)}{T}$$

First, change the unit of temperature from °C to °K.
T= 273.15+37.5=310.65(K)

$$\lambda_{max} = \frac{2898 \mu m K}{T(K)} = \frac{2898}{310.65} = 9.33 \mu m$$

This wavelength falls in the infrared range. So, my peak radiation is IR.

2c) At what specific wavelength (in μm) does the Sun radiate its maximum (peak) energy? (5pts) Is this wavelength in the infrared, visible light, or UV range? (3pts)
(Accurate to 2 decimal points in your calculation)

$$\lambda_{max} = \frac{2898 \mu m K}{T(K)} = \frac{2898}{5500} = 0.53 \mu m$$

This wavelength is in the visible light range. This says that the Sun's peak radiation is visible light.

2d) Use Stefan-Boltzmann Law to demonstrate that flux of the Sun's radiation is much larger than that of the Earth. (5pts)

Stefan-Boltzmann Law is:, $F = \sigma T^4$,
where F is the heat flux and T is the temperature of the blackbody, and is a constant. Because the Sun's temperature is much higher than the temperature of the Earth, its flux is much higher than the Earth's flux. This is because the flux of a blackbody is proportional to the fourth power of the temperature of the body.

3. Explain why O_2 and N_2 are not greenhouse gases. (5pts)

O_2 and N_2 are poor absorbers of IR radiation –which is the peak radiation of the Earth, thus they are not considered greenhouse gases. As O_2 and N_2 are totally symmetric molecules, electromagnetic waves pass by such molecules without being absorbed. [First sentence 4pts, and second sentence 1pt]

4. List all atmospheric greenhouse gases that are most important to the modern global warming. (6pts) What is the CO_2 concentration in 2008? (2pt)

   Water vapor H_2O, Carbon dioxide CO_2, Methane CH_4, Nitrous oxide N_2O, Ozone O_3, and Freon. The CO_2 concentration in 2008 is 390ppm by volume. (NOTE: both "Freon" and "Freon-11 and Freon-12" are correct.)

5. Explain why atmospheric temperature decreases with altitude in the troposphere, but increases with altitude in the stratosphere. (10pts)

   Since the Earth's surface absorbs a large portion of solar radiation, it has to transfer all the heat into the atmosphere in order to keep the heat balance. Therefore, the Earth's surface is a heating source that heats up the atmosphere. Surface atmosphere is warm because it is near the heat source, and gets colder and colder when it is farther away from the heat source. In the Stratosphere, ozone absorbs UV and thus increases its temperature in the upper stratosphere, causing the temperature increase with altitude.

6. How do the low, thick stratus clouds affect the Earth's surface temperature? (4pts) How do the high and thin cirrus clouds affect the Earth's surface temperature? (4pts) What is the major difference between the effects of the cirrus clouds and stratus clouds? (2pts)

   Low, thick clouds, such as stratus clouds, generally cool the surface because their primary influence is to reflect incoming solar radiation. High, thin clouds, such as cirrus clouds, tend to warm the surface because they contribute more to the greenhouse effect than to the planetary albedo. The major difference between the effects of the two types of clouds is that the former is dominated by reflection of solar radiation and thus cool the Earth, but the latter is dominated by absorption of infrared radiation and thus tends to warm the Earth.

7. Describe the water vapor feedback loop in Earth's climates system. (5pts) Is this a positive or negative feedback loop, and why? (3pts)

   An increased Earth's temperature increases evaporation and thus increases water vapor in the atmosphere. The increased water vapor enhances greenhouse effects and thus increases the Earth's temperature. The water vapor feedback is a positive feedback because it tends to amplify small temperature perturbations.

8. Describe the snow and ice albedo feedback loop in Earth's climates system. (5pts) Is this a positive or negative feedback loop, and why? (3pts)

An increased Earth's temperature reduces snow and ice cover (because higher temperature tends to melt snow and ice). A reduced ice and snow cover reduces the Earth's albedo, and thus increases Earth's temperature.
The ice albedo feedback is another positive feedback because it tends to amplify changes to the Earth's surface temperature.

9. Describe the IR flux/temperature feedcback loop in Earth's climates system (5pts) Why is Earth's climate stable despite some destabilizing, positive feedbacks? (3pts)

An increased Earth's temperature increases the outgoing IR flux (according to Stefan-Boltzmann law); an increased radiation or IR tends to reduce the Earth's temperature. This is an important negative feedback loop.

Earth's climate is stable because of the negative feedback between the surface temperature and the flux of outgoing infrared radiation. This negative feedback acts to reduce changes of the Earth's surface temperature and thus plays an important role in stabilizing the Earth's climate system. [Note: saying the first sentence gets 4pts]