Solutions For Homework #1

Problem 1:

If c is the speed of light, λ is the wavelength and f is the frequency, the equation $c = \lambda \cdot f$ can be used to calculate one of the the three values, if the two others are given. The speed of light is defined to be exactly $299792458\,\mathrm{m/s}$ ($\approx 3 \cdot 10^8\,\mathrm{m/s}$). Thus, for a frequency of $f = 10\,\mathrm{GHz} = 10 \cdot 10^9\,\mathrm{Hz}$,

$$\lambda = \frac{c}{f} = \frac{299792458\,\mathrm{m/s}}{10\,\mathrm{GHz}} \approx \frac{3 \cdot 10^8\,\mathrm{m/s}}{10^{10}\,\mathrm{Hz}} = 0.03 = 3\,\mathrm{cm}$$

and for a wavelength of $\lambda = 25\ cm = 0.25\ m$

$$f = \frac{c}{\lambda} = \frac{299792458\,\mathrm{m/s}}{0.25m} \approx 12 \cdot 10^8\,\mathrm{Hz} = 1.2\,\mathrm{GHz}$$

Problem 2:

The boiling temperature of water at sea level is 100^oC. To convert this to degrees Kelvin, just add 273.15:

$$100^oC = (273.15 + 100)K = 373.15K$$

Problem 3:

The formula for the wavelength of the energy emission peak is

$$\lambda_{max} = \frac{2898\,\mu\mathrm{m}\,K}{T}$$

where T is the black-body temperature. Using the temperatures for the surface of the sun ($T = 6000K$) and an effective value for the earth ($T = 255K$), we get

sun: $0.483\,\mu\mathrm{m}$
earth: $11.4\,\mu\mathrm{m}$

Because the reflected radiation has the same spectrum as the light incident from the sun, the peak wavelength is also the same, $0.483\,\mu$m.

Problem 4:

Using the equation from problem 3 and the surface temperature of venus ($T_{Venus} = 750K$), we get

$$\lambda_{max} = \frac{2898\,\mu\mathrm{m}\,K}{750K} = 3.86\,\mu\mathrm{m}$$

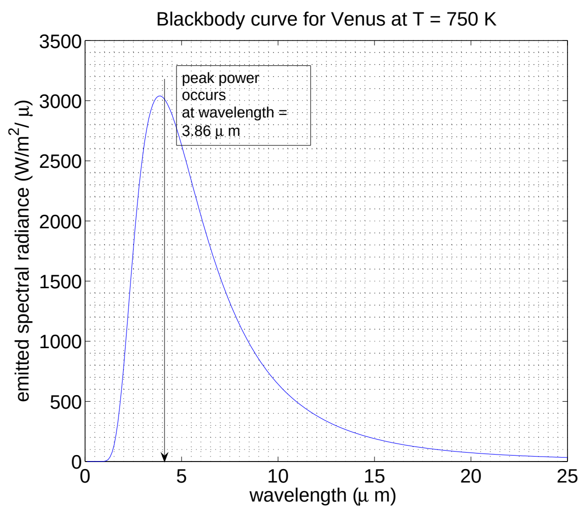

Figure 1: Blackbody curve of Venus at a temperature of $T = 750K$.

The emmitted spectral radiance values were calculated using Planck's formula:

$$S(\lambda) = \frac{2\pi hc^2}{\lambda^5}\frac{1}{e^{ch/\lambda kT} - 1}$$

Problem 5:

The industrial pollutant would not be a concern for global warming. The principle atmospheric windows in the thermal infrared band are between $3-5\,\mu$m and

$8 - 14\,\mu\mathrm{m}$. Wavelengths in these windows absorb the most energy which is transmitted through the Earth's atmosphere, and therefore contribute the most to the greenhouse effect. The pollutant in question absorbs radiation at a $28\,\mu\mathrm{m}$ wavelength, which is not in or near the atmospheric window and would not contribute to the greenhouse effect.

Note: The fact that the $28\,\mu\mathrm{m}$ wavelength does not coincide with either the sun's or the earth's peak emission wavelength does not mean that there is no significant amount of radiation at this wavelength.

Problem 6:

Estimate how much the sea level would rise if the entire Antarctic ice cap were to melt by converting the volume of the ice cap to its water equivilant and then dividing the volume by the surface area of the world ocean. The area of Antartica (from encarta website) is approximately 14,000,000 km^2. Using the approximate ice cap thickness of 3000 m (3 km):

$$area = (14,000,000 km^2)(3km) = 42,000,000\,km^3$$

Convert the ice volume to water volume:

$$water\ volume = (42,000,000\,km^3)(0.9) = 37,800,000\,km^3$$

The surface area of the world ocean (from Wikipedia website) is approximately 361,000,000 km^2.

$$sea\ level\ rise = \frac{37,800,000\,km^3}{361,000,000\,km^2} \approx 0.105\,km\ or\ 105\,m$$

This 105 m rise in sea level would put Stanford under water because its elevation at Mitchell is about 32 meters (check out http://seamless.usgs.gov for elevations).

Problem 7:

The distance in pixels between Hoover tower and Memorial church can be calculated with the Pythagorean theorem:

$$d = \sqrt{(400-300)^2 + (250-300)^2} \approx 112\,pixels$$

The distance in meters (estimated from a campus map) is approximately 325 meters. Thus, the pixel spacing is

$$\Delta d = \frac{325m}{112} = 2.9\ m$$

Problem 8:

Your hometown lab exercise