CH301 H Fall 2011 Homework 5

1. Best place to start is w/ $E = h\nu$

let $E = 1J$

$h = 6.626 \times 10^{-34}$ Js

$$\nu = \frac{E}{h} = \frac{1J}{6.626 \times 10^{-34} Js} = 1.509 \times 10^{33} s^{-1} = Hz$$

so $1J = 1.509 \times 10^{33}$ Hz

$$\lambda = \frac{c}{\nu} = \frac{3.0 \times 10^{8} m/s}{1.509 \times 10^{33} s^{-1}} = \underline{\underline{1.99 \times 10^{-25} m = 1J}}$$

$$\frac{1}{1J} = 5.03 \times 10^{-24} m^{-1} \left(\frac{0.01 cm^{-1}}{1m^{-1}}\right) = \underline{\underline{5.03 \times 10^{26} cm^{-1} = 1J}}$$

	eV	J	cal	Hz	cm^{-1}
eV	1	1.602×10^{-19}	3.826×10^{-20}	2.242×10^{14}	8058
J	6.242×10^{18}	1	0.2388	1.509×10^{33}	5.03×10^{22}
cal	2.613×10^{19}	4.1868	1	6.33×10^{33}	2.10×10^{23}
Hz	4.13×10^{-15}	6.627×10^{-34}	1.58×10^{-34}	1	3.33×10^{-11}
cm^{-1}	1.24×10^{-4}	1.99×10^{-23}	4.75×10^{-24}	3.00×10^{10}	1

2. Although the unit of nm is convenient for describing the wavelength of light in the visible region of the spectrum, it is a poor unit of energy. This is because of the relationships of the units of distance (wavelength) and energy.

$$E = h\nu \quad ; \quad c = \lambda\nu$$

$$\nu = \frac{c}{\lambda}$$

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

So while energy is directly proportional to frequency, it is inversely proportional to wavelength.

$$100\,cm^{-1} = 0.01\,cm\left(\frac{1m}{100cm}\right)\left(\frac{10^9 nm}{1m}\right) = 100000\,nm$$

$$200\,cm^{-1} = 50000\,nm$$

$$300\,cm^{-1} = 33333\,nm$$

] So a jump in E of equal proportion in cm^{-1} is not of equal proportion in nm

- So while it is easy to convert between nm and any unit of energy, there is not a simple proportional conversion factor to do this easily. Thus one should not use units of nm in any serious way.

3. $\lambda = 488\,nm$

$$E = \frac{hc}{\lambda}, \quad c = \lambda \nu, \quad \nu = \frac{c}{\lambda} = \frac{3.0\times10^{8}\ \cancel{m}/s}{488\times10^{-9}\ \cancel{m}}$$

$$\boxed{\nu = 6.15\times10^{14}\ s^{-1}}$$

For this problem, the frequency of light doesn't matter – the speed of light doesn't change.

Total distance $= 7.6\times10^{5}\ m$

$$\text{time} = \frac{d}{\text{speed}} = \frac{7.6\times10^{5}\ \cancel{m}}{3.0\times10^{8}\ \cancel{m}/s}$$

$$\boxed{t = 2.5\times10^{-3}\ s}$$

4. $\lambda_{max} = 1.05\,mm$ = far Infrared (FIR) region of the spectrum

$$\lambda_{max} = \frac{0.2\,hc}{k_B T}; \quad T = \frac{0.2\,hc}{k\,\lambda_{max}} = \frac{(0.2)(6.626\times10^{-34}\ J\cancel{s})(3.0\times10^{8}\ \cancel{m}/\cancel{s})}{(1.38\times10^{-23}\ \frac{m^2 kg}{s^2 k})(1.05\times10^{-3}\ \cancel{m})}$$

$$T = 2.74\ \frac{\cancel{J}\,k}{\cancel{\frac{m^2 kg}{s^2}}} = \boxed{2.74\,k = T\,(\text{universe})}$$

NB: $1J = 1\frac{kg\,m^2}{s^2}$

This was a very important discovery that led to a deeper understanding of the nature of the universe.

5. $\Delta E = 4.9\times10^{-19}\ J\left(\frac{5.03\times10^{22}\ cm^{-1}}{J}\right) = 24600\ cm^{-1} = 4.06\times10^{-5}\ cm$

$\Delta E = 4.06\times10^{-5}\ cm\left(\frac{1m}{100cm}\right)\left(\frac{10^9\ nm}{1m}\right)$

$\boxed{\Delta E = 406\ nm}$ this spectrum will therefore appear blue.

6. Both of these chlorophyll molecules absorb light in the blue and red regions of the spectrum, (~450 nm and ~650 nm), but not in the middle of the spectrum (~550nm). They therefore remove light from the blue and red regions, allowing only the green (middle) region of the spectrum to be reflected. Since this is the only light getting through, the leaf appears green.

b) If plants were black, that would mean that they were absorbing the green light as well as the red and blue light. That would mean that they were harvesting the visible electromagnetic spectrum more efficiently (instead of letting the green light through unused). Since the visible spectrum dominates the spectrum from the sun (i.e. the plant's energy source) that makes it through the earth's atmosphere, it seems like plants are not fully optimized to be efficient. If they had a pigment to absorb the green light as well, they could harvest more of the electromagnetic spectrum and produce more fuel. People like to argue things like this, although the fact that most plants are green is a product of evolution, not of human optimization. Being so inefficient has obviously been good enough, and plants can be green if evolution so desires.

7. Na-D line = 589.3 nm

$$\lambda = 589.3\,nm = 589.3 \times 10^{-9}\,m$$

$$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,Js)(3.0\times10^{8}\,m/s)}{(589.3\times10^{-9}\,m)}$$

$$\boxed{E = 3.37\times10^{-19}\,J}$$

Light emitted at 589 nm is at the red edge of green, so the Sodium-D emission line is yellow.

b) Because the sodium-D emission is at a known wavelength, the observatory can simply install light filters at this ~~line~~ emission wavelength which block out only light of 589.3nm. That means the telescopes can collect starlight, and by specifically blocking the 589.3 nm line, can eliminate light pollution from the city as a source of background from their measurements.