Fundamentals of Spectroscopy for (Optical) Remote Sensing

Homework #1 (Basic Concepts of Quantum Physics)

1. The work function of cesium is about 1.9ev. How much is the threshold of its photoelectric effect in frequency and wavelength respectively? In order to get a photoelectron with 1.5ev kinetic energy, what kind of wavelength of the light source do you need to have?

2. The light intensity for sunlight arriving at the top of Earth's atmosphere ($1.5\text{x}10^{11}$m from the Sun) is about 1.4kW/m^2.

(1) Compute the average radiation pressure exerted on a 100% reflectivity metal reflector facing the Sun.

(2) Approximate the average radiation pressure at the surface of the Sun whose diameter is $1.4\text{x}10^9$m.

3. From Planck's blackbody radiation Law $\rho(\nu) = \dfrac{8\pi h\nu^3}{c^3}\dfrac{1}{\exp(h\nu/k_B T)-1}$,

   (1) Derive Wien's Displacement Law: $\lambda_{\max} T = \dfrac{hc}{4.9651 \cdot k_B} = 2.898 \times 10^{-3}\, m \cdot k$.

   (2) Derive Stefan-Boltzmann Law: $\rho = \int_0^\infty \rho(\nu)d\nu = \dfrac{4}{c}\sigma T^4$, where $\sigma = \dfrac{2\pi^5 k_B^4}{15h^3c^2}$.

   (3) The Sun's blackbody temperature is close to 5,778 K and here we ignore Fraunhofer lines. Compute and plot the solar irradiance (i.e., light intensity) spectrum versus wavelength under blackbody radiation assumption. What is the wavelength corresponding to the Sun peak irradiance?

4. (1) Derive the ionization energy of hydrogen atom from Bohr's theory.

   (2) Given the ratio of Rydberg constants for hydrogen (H) and hydrogen isotope (D) as R_H/R_D = 0.999728, and the ratio of their nuclear mass as m_H/m_D = 0.50020, please calculate the ratio of proton mass to electron mass.

5. The population distribution for different energy levels follows the Boltzmann distribution law when the atoms are in the thermal dynamic equilibrium. The number of atoms at an excited state with energy level E_n is given by $N_n = N_1(g_n/g_1)\exp[-(E_n-E_1)/kT]$.
   N_1 is the number of the atoms at the state with energy level E_1. k is the Boltzmann constant. g_n and g_1 are the statistical weight factors of energy level E_n and E_1. At 20 degrees centigrade and one atmospheric pressure, for pure Hydrogen atomic gas in a bottle, how much volume is needed if you can have one H atom at the first excited state? Given g_1=2 for the ground state and g_2=8 for the first excited state for H atom.

6. In Young's Experiment, use 632.8 nm He-Ne laser illuminating the source slit. The distance between the two slits S_1 and S_2 is 0.5mm. The screen is 2m away from them. How far will the consecutive maxima of the fringe be separated on the screen? If you are using an electron gun rather than the laser and you can change the distance between the two slits, how far you need to separate them in order to get similar fringe? Given the acceleration voltage for the electron is 2000V.