Problem sets 10/02/2008

1) Define what is commonly referred to as the "spectroscopic trading rules".

2) Name the four radiation laws for thermal emitters, define their contents in words, and list the defined quantities with typical symbols and units.

3) A 100-W tungsten filament lamp operates at 2000 K. Assume that the filament has an emissivity of 0.27, and emits according to Plancks law:

$$\rho_\nu(T) = \frac{8\pi h\nu^3}{c^3}\,\frac{1}{e^{h\nu/kT} - 1}$$

3a) What is the total power emitted between 6000 Å and 6001 Å ? Note that $I_\nu = c/4\ \rho_\nu$ follows from geometrical considerations.

3b) How many photons per second are emitted in this wavelength interval ?

4a) Discuss the four competing radiative processes in a lasing medium. What is the frequency dependence of each of these processes? Note: consider Einstein coefficients as listed in Bernath, chapter 1.

4b) What process affects the width of any transition of a lasing medium (CW or pulsed)?

4c) What additional source of line broadening do you need to consider when working with a short-pulse (ns or fs) laser light source ?

5a) Calculate the maximal energy density ρ_ν of blackbody radiation at interstellar space temperature T_1 = 3K, the Earth mean temperature $T_2 \approx$ 288K, a flame temperature T_3 = 2250K, and the sun surface temperature T_4 = 6000K. Note: use IGOR to plot the energy density as a function of frequency, and plot this function for the above temperatures.

5b) Calculate the spectral intensity I_ν for these four blackbody radiation sources. Note: use IGOR to plot the spectral intensity functions at the above temperatures.

5c) Create a Table where you list for each of the four temperatures (i) the maximal spectral intensity I_ν value, (ii) the frequency of the maximum, (iii) the wavelength, and (iv) the integral intensity over all frequencies.

5d) Interpret the Table. What power law do you find for the relation between the maximal spectral intensity and temperature? What relation do you find for the relation between the maximal wavelength and temperature? Note: Use data from the Table in 5c to support your argument.

5e) Compare the temperature dependence of spectral intensity I_v to that of intensity I (Stefan Boltzmann law). Note: list the ratio of I_2/I_1 in a forth column of the Table.

5f) Does the maximum spectral intensity depend as strongly on temperature as intensity? Give a plausible explanation for your result.

6) Consider a 5mW laser operating at 10640 A operating in CW mode with a linewidth of 0.01 cm^{-1}. What is the approximate reduction in spectral intensity if the laser is operated in pulsed mode, with pulse durations of 10fs, 1 ps, 10ns and 1µs ?

7) Compare the total power emitted between at 532 nm and 532.1 nm from the following light sources:

7a) A 500 W Xe-arc lamp operating at 6000K. Note: consider the Xe-arc lamp emits as a grey body with a plasma emissivity $\varepsilon = 0.05$.

7b) A 100 W tungsten lamp operating at 2000K. Note: consider the tungsten lamp emits as a grey body with a tungsten emissivity $\varepsilon = 0.27$.

7c) A 3 W white LED. Assume the LED emits with equal intensity over the wavelength range from 400 – 800nm. Note: take into consideration that the energy of a photon at 400nm has double the energy as a photon at 800nm.

7d) How many photons are emitted per second for the above lightsources ?

7e) Compare the spectral output from each light source on a relative basis, and set this relative spectral output in relation to the relative power consumption of the above light sources.

7f) Interpret the results from 7e.