PHGN 480: Laser Physics due 2 Sept 2010
Homework 1

1) The following are useful for making estimates – you should memorize these relations:
   a. Wavelength of a photon that has 1eV in energy
   b. Energy (in eV) of a photon with wavelength of 1μm.
   c. Energy (in eV) for kT at room temperature (300K).
   d. Show that for light, $\frac{\Delta\lambda}{\lambda_0} = \frac{\Delta\omega}{\omega_0} = \frac{\Delta\nu}{\nu_0} = \frac{\Delta\sigma}{\sigma_0}$, where the Δ's correspond to bandwidth, and the denominators correspond to the central carrier frequency (or wavelength…). The symbols, in order are: wavelength, angular frequency, frequency, and wavenumber. In these expressions, you can drop any sign you get in the derivation. These relations are useful to convert spectral bandwidth into different units.

2) Spectral ranges (see Svelto 1.1 and its solution):
   a. Look up the transmission or reflection spectral ranges for the following materials:
      i. Fused silica
      ii. Crown glass (e.g. BK-7)
      iii. CaF_2
      iv. Silicon
      v. Gold
      vi. Silver
      vii. Aluminum
   b. Look up the spectral range of sensitivity of the following detectors:
      i. Human eye
      ii. Silicon CCD
      iii. InGaAs
      iv. Microbolometer
   c. Look up the spectral ranges of the following categories of lasers:
      i. Ion lasers (Ar-ion, Kr-ion)
      ii. HeNe
      iii. Excimer
      iv. Ti:sapphire
      v. Neodymium-doped material (e.g. Nd:YAG, Nd:glass…)
      vi. Erbium-doped material (Er:)
      vii. CO2
      viii. Semiconductor diode lasers (not LED's)

3) Suppose we have a two-level quantum system, with an energy difference ΔE separating the levels. The two levels have the same degeneracy. Fill in the following table for the thermal equilibrium population ratio N_2/N_1 for the following combinations of temperatures T and energy differences ΔE.

	T = 100K	T = 300K	T = 1000K
ΔE = 0.0001 eV			
ΔE = 0.05 eV			
ΔE = 3 eV			

The lowest energy difference is characteristic of rotational transitions in molecules, the next corresponds to molecular vibrational transitions, and the highest energy difference is of the order of magnitude of electronic transitions in atoms and molecules.

4) For a plane wave of intensity 100 W/m^2 (=10 mW/cm^2),
   a. Calculate the electric field strength and the energy density in SI units, where $I = \varepsilon_0 c n \left\langle |E|^2 \right\rangle$, where the angular brackets denote a time (cycle average). Assume the wave is in vacuum (n=1).
   b. Calculate the corresponding photon flux for a monochromatic beam with wavelengths 500nm and 100μm.

5) The intensity of sunlight at the earth's surface is 1 kW/m^2. Calculate the intensity of an image of the sun on the retina assuming:
- The eye's pupil diameter is 2mm (bright-adapted).
- The focal length of the eye is 22.5mm.
- The sun subtends an angle of 0.5°.

Hint: first calculate the size of the image of the sun on the retina by using similar triangles for rays passing from both edges of the sun through the center of the lens (undeviated), then to the retina at one focal length from the lens.

Compare this with the intensity of a 1mW HeNe laser (λ = 632.8nm) at the retina. The beam is Gaussian in profile and enters the eye with a 1/e^2 diameter of 2mm.
Hint: the 1/e^2 *radius* of a Gaussian beam focused by a lens of focal length f is $w = \frac{2}{\pi}\lambda\frac{f}{D}$, where D is the 1/e^2 *diameter* of the input beam. It is expressed in this way because f/D is the effective F-number of the focus.

6) Svelto 2.1 (solution is in book). Suppose the bandwidth of a HeNe laser is 1.5 GHz. Calculate the bandwidth $\Delta\lambda$ in wavelength space, then calculate the number of modes in the box in this case.

7) Svelto 2.3. Use Mathematica to numerically solve for the actual peak wavelength.