PHGN 480: Laser Physics due 1 Sept 2011
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) First work through Svelto 2.1 for yourself (solution is in book). Suppose the bandwidth of a HeNe laser is 1.5 GHz. Calculate the bandwidth Δλ in wavelength space. Calculate the number of modes in the 1 cm-cubed box in this case. Calculate the number of modes in this bandwidth if the field is in a linear resonator instead of in a box.

6) Work through Svelto 2.3 for yourself (again, solution is in back). Use Mathematica to numerically solve for the actual peak wavelength of the blackbody curve.

7) A laser beam incident on a sample has an intensity of 1 GW/cm^2. The spectrum has a center wavelength of 1.5μm, and a Gaussian-shape with a full-width at half maximum (FWHM) of 30nm. Calculate the power in an area of 1mm^2 in a bandwidth of 1nm, centered at 1.52μm.