**Chemistry 620**
**Analytical Spectroscopy**
**PROBLEM SET 2: Due 02/28/08**

1. The dielectric constant of water (not ice or steam) varies from 88.00 at 0°C to 55.33 at 100°C. Explain this behavior. Over the same range in temperature, the index of refraction ($\lambda$ = 589.3 nm) goes from roughly 1.33 to 1.32. Why is the change in *n* so much smaller than the corresponding change in $\varepsilon$?

2. Consider a linearly polarized plane electromagnetic wave traveling in the +x direction in a dielectric that has refractive index equal to 1.77 and the xy plane as its plane of vibration. Given that its frequency is 614.3 THz and its amplitude is $E_0$ = 0.25 V/m,
    a. find the period and wavelength of the wave,
    b. write an expression for E(t) ,
    c. find the irradiance of the wave falling on a detector (outside the dielectric)

3. A plane, harmonic, linearly polarized light wave traveling in a piece of glass has an electric field intensity given by

$$E_z = E_0 \cos\left(\pi 10^{15}\left(t - \frac{z}{0.59c}\right)\right)$$

   Calculate
   a) the wavelength of the light in the glass,
   b) the index of refraction of the glass,
   c) the phase shift between the wave entering and exiting the glass if the glass is 1 mm thick.

4. Show that for an ideal substance that has a single resonant frequency $\omega_0$, the index of refraction is approximated by

$$n \approx 1 + \frac{Ne^2}{2m_e\varepsilon_0(\omega_0^2 - \omega^2)}$$

5. At 500 nm, germanium has a refractive index of 3.47-1.4i. Calculate the absorption coefficient of germanium at this wavelength.

6. Calculate the electric field and irradiance necessary for the polarization due to second-order effects to be a third as large as the polarization due to first-order effects. Assume the second-order electric susceptibility for the material irradiated is 0.005 times the first-order susceptibility.

7. One of the ways investigators extend the spectral range of Ti:sapphire lasers deeper into the IR is to mix the output with that of a monochromatic laser. Select a laser for this purpose and estimate the range of IR wavelengths that would be available by mixing the Ti:sapphire fundamental ($\lambda$~ 650 - 1100 nm) with it.

8. Ordinarily, the efficiency of SHG is very low. However, when special efforts are made to achieve phase matching, the SHG production is so efficient that the depletion of the pump beam must be considered. In this case the SHG production is given by

$$\mathcal{E}_{SHG} = 2\frac{\omega^2 d^2 l^2}{n_1^2 n_2 c^3 \varepsilon_0}(1)^2 \mathcal{E}_{fun}^2$$

Calculate the efficiency of SHG for a 10 W pulsed Nd:YAG laser beam focused down to 800 $\mu m^2$ on a $KD_2PO_4$ surface if $n_1$ and $n_2$ are 1.495 and 1.515, respectively, l is the coherence length and the pulse duration is 1 ps and rep rate is 1 MHz. The effective non-linear optical coefficient of $KD_2PO_4$ is a single element tensor, $d_{eff}$ = 5.25e-24 $mV^{-1}$.