Physics of atoms and molecues

Quiz 1

1. Show how the vector potential amplitude A_0 would change if the number density of photon $n(\omega)$ doubles for given ω.[2]

Hint: $A_0(\omega) = \sqrt{\frac{n(\omega)\hbar}{2\omega\epsilon_0}}$; start with the expression of field energy density

2. For $\vec{A}(\vec{r},t) = \vec{A}_0 e^{i\vec{k}.\vec{r}}\delta(t)$ show what will be the ratio of $E_0(\omega)$ and $E_0(2\omega)$ and also of $I(\omega)$ and $I(2\omega)$.[2+2]

Hint: Delta pulse means all $A_0(\omega)$ for all ω has same value.
Use : $E_0 = -2\omega A_0(\omega)\hat{E}$; $\rho(\omega) = 2\epsilon_0\omega^2 A_0(\omega)$ derive and use in $I(\omega)$.

3. Consider two molecules which are exposed to perfect light pulse described by the $\vec{A}(\vec{r},t)$ given in question 2, are undergoing transition, one from energy levels 1 Hartree to 3 Hartree and the other from 2 Hartree to 4 Hartree (remember atomic units) respectively. If the maximum transition rates in the two transitions are same then what can you infer about the corresponding dipole transition matrix elements.[3]

Hint: Use $W^D_{ba} = \frac{\pi^2}{\hbar c}\frac{e^2}{4\pi\epsilon_0} I(\omega_{ba})|\vec{r}_{ba}|cos^2\theta$; choose θ for max W; get $I(\omega)$ as above.

If a system, let us say the first one, rotates in the plane perpendicular to the direction of propagation of light with an angular velocity $\omega_1$then schematically plot the absorption spectra.[2]

Hint : the $cos^2\theta$ in expression of W^D.

What will be ratio of the absorption cross-sections of the two processes described above ?[3]

Hint: $\sigma = \frac{\hbar\omega_{ba}W^D_{ba}}{I(\omega_{ba})}$ sustitute $I(\omega)$ from above and W^D as said.

4. Argue that in any system 2s states will have a large lifetime.[2]

Hint: $\Delta l = \pm 1$

5. Show that $\Delta m = 0, \pm 1, \pm 2$ for the electric quadrupole transition term. [3]

Hint: Work out the azimuthal (ϕ) part of $\langle l, m|r_i r_j|l \pm 1, m'\rangle$, where $r_{1,2,3} = x, y, z$, using the spherical harmonics ; In class I have already showed for $\langle b|xz|a\rangle$.