

Homework 3

1.

Photon Energy. (a) What voltage should be applied to accelerate an electron from zero velocity in order that it acquire the same energy as a photon of wavelength $\lambda_o = 0.87 \mu\text{m}$?

(b) A photon of wavelength $1.06 \mu\text{m}$ is combined with a photon of wavelength $10.6 \mu\text{m}$ to create a photon whose energy is the sum of the energies of the two photons. What is the wavelength of the resultant photon? Photon interactions of

Photon Flux. Show that the power of a monochromatic optical beam that carries an average of one photon per optical cycle is inversely proportional to the squared wavelength.

2.

Comparison of Stimulated and Spontaneous Emission. An atom with two energy levels corresponding to the transition ($\lambda_o = 0.7 \mu\text{m}$, $t_{sp} = 3 \text{ ms}$, $\Delta\nu = 50 \text{ GHz}$, Lorentzian lineshape) is placed in a resonator of volume $V = 100 \text{ cm}^3$ and refractive index $n = 1$. Two radiation modes (one at the center frequency ν_o and the other at $\nu_o + \Delta\nu$) are excited with 1000 photons each. Determine the probability density for stimulated emission (or absorption). If N_2 such atoms are excited to energy level 2, determine the time constant for the decay of N_2 due to stimulated and spontaneous emission. How many photons (rather than 1000) should be present so that the decay rate due to stimulated emission equals that due to spontaneous emission?

3.

Rate Equations for Broadband Radiation. A resonator of unit volume contains atoms having two energy levels, labeled 1 and 2, corresponding to a transition of resonance frequency ν_o and linewidth $\Delta\nu$. There are N_1 and N_2 atoms in the lower and upper levels, 1 and 2, respectively, and a total of \bar{n} photons in each of the modes within a broad band surrounding ν_o . Photons are lost from the resonator at a rate $1/\tau_p$ as a result of imperfect reflection at the cavity walls. Assuming that there are no nonradiative transitions between levels 2 and 1, write rate equations for N_2 and \bar{n} .

4.

Comparison of Stimulated and Spontaneous Emission in Blackbody Radiation. Find the temperature of a thermal-equilibrium blackbody cavity emitting a spectral energy density $\rho(\nu)$, when the rates of stimulated and spontaneous emission from the atoms in the cavity walls are equal at $\lambda_o = 1 \mu\text{m}$.

5.

Hint: A & B coefficients