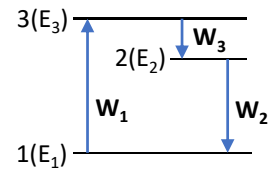


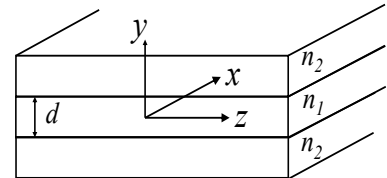
1. A gaseous laser of cavity length $L = 10\text{cm}$ operates in single longitudinal mode with the laser profile centred at wavelength 800 nm . Assume the refractive index of the medium to be 1. Answer the following.
 - 1.1 Which number of the longitudinal mode is contributing to lasing?
 - 1.2 Draw the patterns for TEM_{10} , TEM_{02} and TEM_{21} modes (their intensity patterns).
 - 1.3 How much does the spontaneous life-time of the lasing level estimate to if there is only life-time broadening contributing to the laser line-width?
 - 1.4 In comparison, what would be the cavity effective life-time in this case comprising the realistic mirrors and other components in it?

2. For light interaction with a 3-level atomic system as shown here, optical pumping occurs between level '1' and level '3' while the lasing takes place between level '2' and level '1'.



- 2.1 What should be the condition between rates W_3 and W_2 for obtaining lasing?
- 2.2 What should be the condition between W_1 and W_3 for just initiating lasing?
- 2.3 If the radiative transitions involve frequencies ν_1 and ν_2 then express W_1 , and W_2 in terms of respective intensities.
- 2.4 If the total number of atoms in the medium is $2 \times 10^{18}\text{ cm}^{-3}$, for achieving lasing at frequency $6.25 \times 10^{14}\text{ Hz}$ from the level '2' having its spontaneous life-time $50\text{ }\mu\text{s}$, what should be the threshold pumping power to initiate lasing? The final answer can be written directly in terms of any natural constant(s).

3. For a symmetric, i.e., $n^2(-y) = n^2(y)$, planar waveguide as shown here, there exist three guided modes for excitation light of wavelength λ_0 propagating along the length (x). Consider both the TE and TM.



- 3.1 Find the value of the V-number.
- 3.2 Express mathematically and plot the electric field profiles of the TE modes in the entire region, i.e., including both the core and the clad.
- 3.3 Using proper values of propagation constant(s) for the TM modes, express mathematically the corresponding fields in the entire region.
- 3.4 Order the modes according to the decreasing value of the angle of propagation from the axis of the waveguide. Justify the answer.

4. Consider optical fibers of circular cross-section.

- 4.1 Starting from the MEs, derive the wave equations which provide the solutions for the guided modes of a step index optical fibre having refractive index, $n(r \leq a) = n_1$ and $n(r > a) = n_2$; a is the core radius.
- 4.2 By applying appropriate boundary conditions, find relations that are used to obtain values of the propagation constant.
- 4.3 Draw the radial field profiles for the LP_{02} , LP_{12} and LP_{31} modes and order them according to increasing amount of the field leaking into the clad.
- 4.4 Draw the intensity patterns of these modes such that degeneracy can be clearly seen.

5. A step index fibre with $n_1 = 1.6$, $n_2 = 1.5$, core radius $a = 5 \mu$ is to be used for optical communication at $\lambda_0 = 1.5 \mu m$. If only the waveguide dispersion causes pulse broadening in this case and hence limits the speed of communication, obtain the value of the dispersion coefficient in the units of pulse broadening (ps) per unit length of the fibre (km) per unit spectral bandwidth of the pulse (nm). Given that $f(V) = 0.08$ for the selected mode of the fibre here. *Hint:* By using basic definitions, first obtain the relation for the pulse broadening due to waveguide dispersion.