

Homework 1

10

Name:

Number:

UN: 1

Instructions:

- To be submitted by **March 31st, 2026**.
- Answer all questions in the space provided.
- Show all your work for full credit.
- Use appropriate units and significant figures in your answers.

If you have any questions, please contact me:

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Use the following constants in your calculations:

Planck's constant: 6.626×10^{-34} J s

Electron charge: 1.6×10^{-19} C

Speed of light: 3×10^8 m/s

Atomic mass unit: 1.66×10^{-27} kg

Boltzmann's constant: 1.38×10^{-23} J/K

Avogadro's number: 6.02×10^{23} mol⁻¹

Question: 1**1 Point**

What wavelength and frequency of light is absorbed by a two-level system with energy levels $E_1 = 1.9$ eV and $E_2 = 3.1$ eV? (Write your answer in THz and nanometers)

Answer:

$$\nu = \frac{\Delta E}{h} = 290 \text{ THz}$$

$$\lambda = \frac{c}{\nu} = 1035 \text{ nm}$$

Question: 2**2 Point**

For a system similar to question 1, (A) calculate the spontaneous emission rate A_{21} if the lifetime of the upper energy level is 1 ns. (Write your answer in s^{-1})

(B) Calculate the stimulated emission coefficient B_{21} (Write your answer in $m^3 J^{-1} s^{-2}$)

(C) What is the ratio of the stimulated emission rate to the spontaneous emission rate if the photon density is $\eta_\nu = 1 \times 10^9 \text{ m}^{-3}$

$$A_{21} = \frac{1}{\tau} = 10 \times 10^8 \text{ s}^{-1}$$

$$B_{21} = \frac{c^3}{8\pi h \nu^3 \tau} = 6664 \times 10^{19} \text{ m}^3 \text{ J}^{-1} \text{ s}^{-2}$$

$$\rho_\nu = \eta_\nu h \nu = 0.19 \times 10^9 \text{ J m}^{-3}$$

$$\text{Ratio} = \frac{\rho_\nu B_{21}}{A_{21}} = 1.28 \times 10^4$$

Question: 3**1 Point**

A beam of light is transmitted ($T = 45\%$) through a medium of length 1 m. Calculate the absorption coefficient α of the medium (Write your answer in m^{-1}) and the transmission percentage through a 0.1 m length of the same medium.

$$\alpha = -\frac{\ln\left(\frac{T}{100}\right)}{l} = 79.9 \times 10^{-2} \text{ m}^{-1}$$

$$T_2 = 100 \exp(-\alpha * 0.1) = 92.3\%$$

Question: 4**2 Point**

A cavity with a gain medium of length 0.3 m has a gain coefficient of $k = 0.1 \text{ m}^{-1}$, and an effective loss coefficient of $\gamma = 0.04 \text{ m}^{-1}$. (A) Calculate the required reflectivity of the output mirror R_2 to achieve a stable laser output ($G = 1$), assuming the other mirror is perfectly reflective ($R_1 = 100\%$) (Write your answer in percentage). (B) calculate the threshold gain coefficient k_{th} required to achieve stable lasing if $R_2 = 81\%$ (Write your answer in m^{-1})

$$R_2 = \exp(-2(k - \gamma)L) = 96.5\%$$

$$k_{th} = \gamma + \frac{1}{2L} \ln\left(\frac{100}{R_2}\right) = 0.391 \text{ m}^{-1}$$

Question: 5**2 Point**

Calculate (A) the spectral broadening due to the Doppler effect for a laser medium at a temperature of 350 K, with a central wavelength of 488 nm, and an atomic mass of 40. (Write your answer in GHz). (B) If the small-signal gain coefficient is $k = 0.11 \text{ m}^{-1}$ at $\Delta\nu = 1 \text{ GHz}$, what is the new small-signal gain coefficient at the Doppler broadened linewidth calculated in part (A)? (Write your answer in m^{-1})

$$\Delta\nu = \frac{2v}{\lambda} = 1.11 \text{ GHz}$$

$$k_{new} = k \frac{\Delta\nu_0}{\Delta\nu} = 0.1 \text{ m}^{-1}$$

Question: 6**2 Point**

Calculate the frequency separation between axial modes for a laser with a resonator length of 1 m and a gain bandwidth of 1.5 GHz. How many axial modes can be amplified within the gain bandwidth? (Write your answer in MHz and number of modes)

$$\Delta\nu_{\text{sep}} = \frac{c}{2L} = 150 \text{ MHz}$$

$$N = \frac{\Delta\nu}{\Delta\nu_{\text{sep}}} = 10 \text{ Modes}$$