# Assignment-1

**A. Very Short Answer Questions** **(10)**

1. Why Compton Scattering is better observed with incident X-rays and not incident visible rays?

2. Write the Heisenberg Uncertainty Principle in position and momentum, energy and time?

3. Define phase velocity and group velocity and write the relation between them.

4. What is the physical significance of a wave function in quantum mechanics?

5. State the condition of orthogonality in quantum mechanics and hence its physical significance.

B. **Answer the following briefly** **(21)**

1. a) Calculate the wavelength shift in Compton scattering when X-rays of wavelength 0.1 nm are scattered at an angle of 60 degrees.
   b) Calculate the kinetic energy of recoil electron when X-rays of wavelength 0.1 nm are rebound back in Compton Experiment. (7)

2. a) A particle is confined in a one-dimensional box of length 2 nm. Calculate the energy of the particle in the first and second excited states.
   b) Determine the probability of a 5 eV electron tunneling through a potential barrier of height 10 eV and width 1 nm. (7)

3. Explain the working principle of scanning tunneling microscopes and their significance in studying quantum mechanical effects at the atomic level. (7)

C. **Answer the followings explicitly.** **(33)**

1. Discuss the development of quantum mechanics. Derive a relation for Compton shift of incident photon. Also derive the formula for kinetic energy of recoil electron, direction of scattered photon. Give reasons why Compton Effect occurs with loosely bound/free electrons?
   (2+3+4+2)
2. a) Write the postulates of quantum mechanics. (3)
   b) Write time dependent and time independent Schrodinger equation. Solve the time independent Schrodinger equation for a particle in a 1-D box of length 'a' with infinite potentials on the wall and zero inside also energy of system is independent of time. Plot the wave function and probability for first 3 energy levels. (8)

3. Solve the time independent Schrodinger equation for particle in a 3-D box and hence explain the concept of degeneracy with suitable example. What is the order of degeneracy for given condition $a=b\neq c$ and $n_x+n_y+n_z=6$ where a, b, c represents the size of box and $n_x$, $n_y$, $n_z$ represent energy level in x, y, and z direction respectively? (4+4+3)

# Assignment-2

**A. Very Short Answer Questions** **(10)**

1. Write two failures of classical free electron theory. (2)

2. Write the names of two widely used intrinsic semiconductors and mention their energy band gap. (2)

3. What is the role of the band gap in determining the electrical properties of a semiconductor? (2)

4. Write the expression for conductivity for extrinsic semiconductors. (2)

5. Define mobility. How it is related to conductivity in semiconductors. (2)

B. **Answer the following briefly** **(21)**

1. The Fermi function is give by

$$F(E)_{FD} = \frac{1}{1 + e^{\frac{E - E_F}{K_B T}}}$$

Using the above expression briefly explain the response of $F(E)_{FD}$ with temperature when $E=E_F$, $E<E_F$, $E>E_F$ with suitable plots and hence define Fermi energy. (7)

2. Given that the number density of conduction electrons in a metal is $5.8\times10^{28}\ m^{-3}$, calculate the Fermi energy $E_F$ of the metal. Using the Fermi function, evaluate the temperature at which there is 1% probability that an electron in a solid will have energy 0.5 eV above $E_F$. (7)

3. Define specific heat. Give a brief qualitative description of how Einstein theory improved the Dulong-Petit theory of specific heat $C_v$ for solids. Also explain qualitatively the improvement made by Debye to calculate $C_v$ at low temperature over Einstein theory. (7)

C. **Answer the followings explicitly.** **(33)**

1. Explain how Sommerfeld free electron theory improves upon the classical theory of free electron. Mention postulates of Sommerfeld free electron theory and derive the expression for density of states. (11)

2. Taking the example of sodium explain the formation of bands in solids and hence explain the classification of conductors insulators and semiconductors. Draw the necessary diagrams (11)

3. Using the expression for density of states derive the expression for carrier concentration in intrinsic semiconductors. Show that in intrinsic semiconductors the Fermi level lies exactly between the highest energy of valence band and lowest energy of conduction band.

# Assignment-3

**A. Very Short Answer Questions** **(10)**

1. Define coherence. What is the difference between coherent and incoherent light? (2)
2. Define longitudinal coherence length and latitudinal coherence length. (2)
3. Write the full form of acronym LASER. (2)
4. Define spontaneous and stimulated emission of radiation. (2)
5. What are homojunction and hetrojunction LASERS? (2)

B. **Answer the following briefly** **(21)**

1. Derive the mathematical expression for spectral purity factor. A monochromatic light source with a wavelength of 600 nm has a line width of 1 GHz. Calculate the temporal coherence time $\tau_c$. Determine the coherence length $L_c$. (7)
2. With the help of diagram explain the construction and working of semiconductor LASER. How population inversion is obtained in semiconductor LASER? (7)
3. Write a short note on Q-switching and mode locking for a LASER. (7)

C. **Answer the followings explicitly.** **(33)**

1. Determine the Einstein's coefficients for lasing action and hence explain the necessary conditions for lasing action. Consider a two-level atomic system with energy levels $E_1$ (lower) and $E_2$ (higher), separated by energy $E_2 - E_1 = h\nu$, where $\nu$ is the frequency of the emitted or absorbed photon. The following data is given for this system: Frequency of the photon: $\nu = 4\times10^{14}$ Hz. Einstein coefficient for spontaneous emission $A_{21} = 1\times10^{8}\ s^{-1}$. Energy density of the radiation field $u(\nu) = 0.05\ J\cdot m^{-3}$. Assume that the population of the upper level, $N_2$ $1\times10^{20}$ atoms$\cdot m^{-3}$. Calculate the rate of stimulated emission. (11)
2. a) Using the concept of spatial coherence derive an expression for limitations on size of source which would produce coherent light.
   b) Define spectral purity factor, quality factor, visibility for light sources of same intensity and different intensity and hence degree of coherence. (11)
3. What are the necessary components of LASER identify them in He-Ne LASER? Using schematic diagram and energy level diagram explain the construction and working of He-Ne LASER. What is role of Ne atoms in He-Ne LASER? (11)

# Assignment-4

**A. Very Short Answer Questions** **(10)**

1. Explain the principle of holography. (2)
2. Why is a coherent light source essential for creating a hologram? (2)
3. Write any two differences between holography and photography. (2)
4. Define numerical aperture in an optical fiber. (2)
5. Define fractional refractive index of optical fiber? (2)

**B. Answer the following briefly** **(21)**

1. Write short note on application of holography in a) microscopy and b) interferometry. (7)
2. An optical fiber has a core refractive index of 1.50 and a cladding refractive index of 1.45.
   (a) Calculate the numerical aperture (NA) of the fiber.
   (b) Determine the acceptance angle (in air) for light to be guided within the fiber. (Assume air's refractive index as 1.0.) (7)
3. An optical fiber has a core with a refractive index of 1.48 and a cladding with a refractive index of 1.44
   (a) Calculate the critical angle at the core-cladding interface.
   (b) If light enters the fiber at an angle of 20° with respect to the axis, will it propagate through the core? Show calculations to support your answer. (7)

**C. Answer the followings explicitly.** **(33)**

1. With suitable diagrams explain the construction and working of an Optical fiber. Derive the expression for numerical aperture and acceptance angle for an optical fiber. (11)
2. Using the schematic diagrams explain (qualitatively) how a holographic image is obtained (construction) and how to we can see the same (reconstruction)? (11)
3. a) What are major applications of optical fiber? Explain any three applications in detail.
   b) What are major differences between single mode and multi mode optical fiber? (11)