Module-4
Quantum Mechanics

1. (a) Write down the expression of Eigen wave function and Eigen energy of a particle in a 1-D and 3-D potential box respectively.
(b) What is degeneracy? Write down the energy levels and energy values with degree of degeneracy of (3, 2, 1) and (1, 1, 1).

2. (a) Derive the expression of position and momentum operator in quantum mechanics.
(b) Calculate the value of Compton wavelength. At which angle will the Compton shift be maximum.

3. (a) Write down the Wein's displacement law and Wein's distribution law for blackbody radiation.
(b) Calculate the energy and momentum of a photon having wavelength 1Å.

4. (a) Define phase and group velocity. Establish the relation $v_p v_g = c^2$. Show that group velocity is particle velocity.
(b) On an average, an excited state of system stays for 10^{-11} s. What is the minimum uncertainty in the energy of the excited state?

5. Write down the Heisenberg's Uncertainty Relation of position and momentum. Show that position and momentum operator do not commute.

6. Find out the normalized eigen wave function of a particle in 1-D potential box. What will be the energy difference between two consecutive energy levels? Plot the wave functions for first three states.

7. How the Planck's radiation formula of black body radiation behaves at higher value and lower value of wavelength?

8. Calculate the de Broglie wavelength of a baseball of mass 1 kg, moving at a speed 10 m/s. why we cannot observe the wave in nature?

9. Find out the result of $[\hat{y}, \widehat{p_x}]$.

10. Write down the Rayleigh Jean's law. What is Ultraviolet catastrophe?

11. Show graphically how the energy density versus frequency (or wavelength) plot of black body radiations is changed if the temperature is increased.

12. Write down the Hamiltonian operator and form an eigen value equation.

13. An electron and a proton have the same de Broglie wavelength. Prove that the energy of the electron is greater than that of the proton.

14. Write down expression for position operator and momentum operator. Show that $[x, p_x] = i\hbar$.

15. Find out the degree of degeneracy for the energy $9h^2/(8ml^2)$in 3D potential box.

16. State de Broglie's hypothesis. Find out Bohr quantum condition from de Broglie's hypothesis.

17. If a wave function is $\psi = Ae^{i(kx-\omega t)}$, then check whether it is an eigen function of momentum operator or not and if yes then what is its eigen value?

18. Compute the smallest possible uncertainty in the position of an electron moving with velocity 3×10^7 m/s. The rest mass of electron is 9.1×10^{-31} kg.

19. What is Compton Effect? X-rays of wavelength 2.00 Å are scattered at angle 45^o from a block of carbon. Calculate the Compton shift and the wavelength of the scattered X-ray. Find the wavelength and energy of the incident photon. Why Compton Effect is not visible for ordinary light?

Module-5
Statistical Mechanics

1. (a) Write down the Fermi-Dirac distribution function. Show graphically the behaviour of the FD function at zero and non-zero temperature.
(b) What is Fermi energy? How is it related to the average energy of Fermions (give the expression only). The fermi energy of silver is 5.51 eV. What is the average energy of the free electron in silver at 0 K.

2. Consider a two-particle system, each of which can exist in states E_1, E_2, E_3. What are the possible macrostates and microstates if the particles are (i) bosons (ii) fermions.

3. Define phase space, microstate and macrostate.

4. Compare briefly the three statistics Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics with examples.

5. Derive the expression of density of states within the energy range E and E+dE.