Mid-Term Examination, Spring Semester 2022-23

PHN – 006: Quantum Mechanics and Statistical Mechanics

Duration: 90 minutes Max. Marks: 40 Weightage: 50%

NOTE: ALL QUESTIONS ARE COMPULSORY

Q1 **(a)** Violet light of wavelength 380 nm incidents on a platinum surface, whose work function is 5.6 eV. Find the maximum kinetic energy of the photoelectrons in units of the eV. [2]

(b) If an ultraviolet radiation falls on the same platinum surface and the stopping potential is found to be 1.85 V, determine the frequency of the ultraviolet radiation. [2]

Q2 A photon of energy *E* collides with an electron at rest and scatters in the direction, which makes an angle 65° with respect to the incident direction. The wavelength of the scattered photon is found to be 0.035 nm.

(a) Calculate the energy of the incident photon. [3]

(b) Find the recoil kinetic energy of the electron. [2]

(c) Find the direction of travel of the electron after the collision with respect to the direction of the incident photon. [3]

Q3 **(a)** A quantum oscillator of frequency ν can possess energies $E_n = nh\nu$ with $n = 0, 1, 2, 3....$ The probability of finding an oscillator with energy is $P(E) = A\,exp\,(-E_n/kT)$, with A being the normalization constant. Calculate the average energy of the oscillator. [4]

(b) Show that, at the wavelength λ_{max}, where the spectral energy density $u(\lambda, T)$ of the blackbody has its maximum, $u(\lambda_{max}, T) = 170\pi(kT)^5/(hc)^4$. (Wien's constant, $b = 2.898 \times 10^{-3}$ m-K) [4]

Q4 Calculate the wavelength associated with a (a) 1 MeV (kinetic energy) electron, (b) 1 MeV (kinetic energy) proton, (c) 1 MeV photon. [3+3+2]

Q5 The average life-time of an excited state is 10^{-9} s. If the spectral line associated with the decay of this state is 600 nm, estimate the width of the line. [4]

Q6 A particle of mass m is confined to move in the region $0 < x < L$. It is in a state described by the wave function

$$\psi(x, 0) = A\,[\sin(\tfrac{x}{L}) + \sin(\tfrac{2x}{L})]$$

where *A* and *L* are arbitrary real constants. (a) Find *A*. (b) Find the probability of locating the particle in the interval $L/4 \le x \le 3L/4$. [4+4]