Exam.Code:0905
Sub. Code: 6204

2074
B.E., First Semester
ASP-X02: Quantum Physics
(CSE, IT)

Time allowed: 3 Hours **Max. Marks: 50**

NOTE: Attempt five questions in all, including Question No. I which is compulsory and selecting two questions from each Part.

x-x-x

Question 1:

(a) A harmonic oscillator is in the ground state. Where is the probability density maximum?
(b) Can we measure the kinetic and potential energies of a particle, in a constant potential, simultaneously with arbitrary precision?
(c) Find the commutator [x, [x, H]].
(d) Determine Planck's constant h from the fact that the minimum x-ray wavelength produced by 40.0 keV electrons is 3.11×10^{-11} m.
(e) Find the proper length of the rod if the rod moving with a speed of 0.995 c, at an angle of 30°, is observed to have a length of 2m.

(5x2=10)

Part A

Question 2

(a) Derive expression for variation of mass of a body with speed. Also derive the relativistic form of Newton's second law. (6)
(b) An observer O which observes the two flashes from two light sources simultaneously is at rest midway between the two points at x=0 and x=10m. However, a second observer O', moving at a constant speed along the x-axis, finds one source of light flashing 10 ns earlier than the second. Find the velocity of O'. (2)
(c) Calculate the mass that an astronomical body would have to possess in order to become a black hole. (Radius of the body: $R = 9 \times 10^7$ m) (2)

Question 3

(a) Would you expect to observe the Compton effect more readily with scattering targets composed of atoms with high atomic number or those composed of atoms with low atomic number? Explain. Also, derive the relation between the direction of motion of the scattered photon and the recoil electron in the Compton effect. (5)
(b) An atom in an excited state has a lifetime of 2.2×10^{-8}sec; in a second excited state the lifetime is 3.3×10^{-8} sec. What is the uncertainty in energy for the photon emitted when an electron makes a transition between these two levels? (2)
(c) Show that the de Broglie wavelength of a particle, of charge e, rest mass m_o, moving at relativistic speeds is given as a function of the accelerating potential V as $\lambda = \frac{h}{\sqrt{2m_o eV}}(1 + \frac{eV}{2m_o c^2})^{-1/2}$
Show how this agrees with $\lambda = h/p$ in the nonrelativistic limit. (3)

Question 4

(a) Establish the time independent Schrodinger equation for a single particle. (4)
(b) The time-independent wave function of a particle of mass m moving in a potential $V(x) = a^2x^2$ is given by $\Psi(x) = \exp\left(-\sqrt{\frac{ma^2}{2\hbar^2}}\, x^2\right)$, a being a constant. Find the energy of the system. (3)
(c) The waves on the surface of water travel with a phase velocity $v_p = \sqrt{\frac{g\lambda}{\pi}}$, where g is the acceleration due to gravity and λ is the wavelength of the wave. Find the group velocity of a wave packet comprised of these waves. (3)

Part B

Question 5

(a) Explain Fermi Dirac distribution for electrons in a metal. Find the Fermi temperature associated with an electron having Fermi energy, E_F and corresponding wavelength λ_F equal to 0.58 nm. Also show that $\lambda_F = \left(\frac{8\pi V}{3N}\right)^{1/3}$ (5)
(b) State Dulong Petit's law and discuss how the departure from this law at lower temperatures has been explained by Einstein's theory. Show that the Einstein's relation for heat capacity per kmol of a solid reduces to the classical value given by Dulong Petit law for $k_B T \geq h\nu$ (5)

P.T.O.

Question 6

(a) For a particle in a box, show that the fractional difference in the energy between adjacent eigenvalues is

$$\frac{\Delta E_n}{E_n} = \frac{2n+1}{n^2}$$

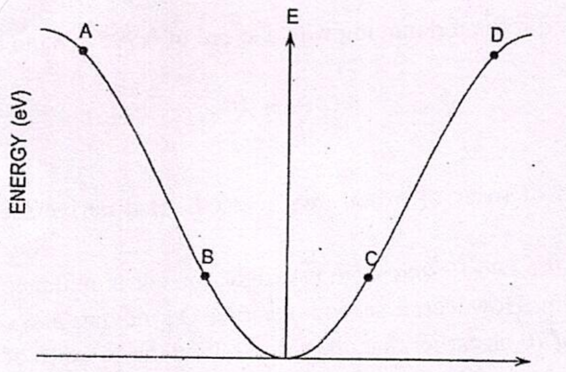
Use this formula to discuss the classical limit of the system. (3)

(b) A stream of particles of mass m and energy E move towards the potential step $V(x) = 0$ for $x < 0$ and $V(x) = V_0$ for $x > 0$. If the energy of the particles $E > V_0$, show that the sum of fluxes of the transmitted and reflected particles is equal to the flux of incident particles. Also show that if the energy of particles $E < V_0$, there is a finite probability of finding the particles in the region $x > 0$. (7)

Question 7

(a) Discuss the motion of electrons in a region of periodic potential using Kronig-Penney Model.Show that if $V = 0$, the energy spectrum becomes continuous and it is that of the free particle. Use physical arguments to justify this result. (6)

(b)



WAVEVECTOR k

Figure shows a band-diagram for some ideal material along one particular direction in **k**-space. Indicate the sign of the effective mass and of the velocity (along the *x*-axis in Fig.) for electrons with wavevectors **k** at each of the points labeled *A*, *B*, *C*, and *D*. (4)

x-x-x