PKC/PG/IIIS/PHS-301/22

2022
M.Sc.
3rd Semester Examination
PHYSICS
PAPER – PHS-301
Full Marks:50
Time: 2 Hours
(PHS 301.1-Quantum Mechanics III)

1. Answer any ***two*** bits: $2\times2 = 4$

(a) What are the differences between scattering and bound state problems?
(b) Under what conditions, the Born approximation method is valid?
(c) Write down the Fermi Golden rule and explain it.
(d) Show the transitions pictorially along with selection rule for normal Zeeman effect for a H-like one electron system from $n'p$ to ns state.

2. Answer any ***two*** bits: $2\times4 = 8$
(a) For stimulated emission, write down the 1st order perturbed amplitude and hence show that $W_{im}^{ind} = W_{mi}^{abs}$ where W is the transition rate of the system (Symbols have their usual meaning). [4]
(b) Derive the oscillator strength sum rule and discuss its implications. [3+1]
(c) Write down the scattering amplitude for partial wave analysis of a central potential *V(r)* and deduce the total cross-section and hence define optical theorem. [1+2+1]
(d) Calculate the lower bound of the 2nd order Stark effect in the ground state of one electron atomic system. [4]

3. Answer ***any one*** of the following: $1\times8 = 8$
(a)
(i) Using Born approximation method calculate the 1st order Born amplitude and differential cross-section for Yukawa potential ($U(r) = \frac{U_0 e^{-\alpha r}}{r}$).
(ii) For anomalous Zeeman Effect, calculate the transitions with pictorial diagrams for $2p_{\frac{3}{2}}, 2p_{\frac{1}{2}}$ and $2s_{\frac{1}{2}}$ levels for H-like one electron ions. [4+4]
(b)(i) A H-atom in the ground state ($|1s>$) is subjected to an electric field which is turned on or off, so that $\vec{E}(t) = \vec{E}_0 e^{-\frac{t^2}{\tau^2}}$. What is the probability that the H-atom ends up in $2p_0$ after a long time ($t \gg \tau$)?

(Turn Over)

(ii) A particle is initially ($t < 0$) in the ground state of an infinite, one-dimensional potential well with walls at $x = 0$ and $x = a$. If the wall at $x = a$ is now suddenly moved ($at\ t = 0)\ to\ x = 8a$, calculate the probability of finding the particle in (i) the ground state, (ii) the first excited state of the new potential well. [4+ (2+2)]

Internal Assessment-05

(PHS 301.2- Statistical Mechanics I)

1. Answer any ***two*** bits: 2×2 = 4

(a) A particle of mass m is free to move in one dimension. Denote its position coordinate by x and its momentum by p. Suppose that this particle is confined within a box so as to be located between $x=0$ and $x=L$, and suppose that its energy is known to lie between E and $E+dE$. Draw the classical phase space diagram of this particle, indicating the regions of this space which are accessible to the particle. 2

(b) A system has two energy levels at energies 0 and ε, and with degeneracies g_0, g_1 respectively. Calculate the mean energy of the system. 2

(c) Assuming that the entropy S and the statistical number Ω of a physical system are related through an arbitrary functional form $S=f(\Omega)$. Show that the additive character of S and the multiplicative character of Ωnecessarily require the function $f(\Omega)$to be of the form $S=k\ln\Omega$. 2

(d) What is Gibbs paradox? 2

2. Answer any ***two*** bits: 2×4 = 8

(a) For a classical system of non-interacting particles in the presence of a spherically symmetric potential $V(r) = \gamma r^3$, what is the mean energy per particle? $\gamma$is a constant. 4

(b)Evaluate the density matrix ρ_{mn} of an electron spin in the representation that makes $\sigma_x$diagonal . 4

(Continued)

(c)Show that the entropy of a macroscopic system can be written as:

$$S = -k_B \Sigma P_r \ln P_r.$$ 4

(d) Consider a system consisting of two particles, each of which can be in any one of three quantum states of respective energies 0, E, and $3E$. The system is in contact with a heat reservoir at temperature T.

(i) Write an expression for the partition function Z if the particles obey classical MB statistics and are considered distinguishable.

(ii) What is Z if the particles obey BE statistics?

(iii) What is Z if the particles obey FD statistics? [1+1+2]

3. Answer ***any one*** of the following: 1×8 = 8

(a) (i) A simple harmonic one dimensional oscillator has energy levels given by $E_n = (n+\frac{1}{2})\hbar\omega$, where ω is the characteristic frequency of the oscillator and the quantum number n can assume the possible integral values $n=0,1,2,....$ Suppose that such an oscillator is in thermal contact with heat reservoir at temperature T low enough so that $\frac{kT}{\hbar\omega} \ll 1$. Assuming that only ground state and first excited state are appreciably occupied, find the mean energy of the oscillator as a function of the temperature T.

(ii) Describe under what condition Fermi-Dirac and Bose-Einstein distributions reduce to Maxwell-Boltzmann distribution. [5+3=8]

(b) (i) Show that the relative RMS fluctuation in energy in canonical distribution varies as $1/\sqrt{N}$.

(ii) If the free energy of a system is $F = -Nk_BT\ln[2\cosh(\frac{\varepsilon}{k_BT})]$

What will be the entropy and the average energy of the system? [4+4=8]

(All the symbols have their usual meanings)

Internal Assessment-05