atisfies

DHWU

M.Sc. (1st Year) 2nd Semester Examination, 2018

Subject: Physics

Paper: Phy/Th/2S/201/18

Quantum Mechanics II

Full Marks: 40 **Time: 2 Hours**

The figures in the margin indicate full marks.

Answer any two questions from each group

*(Use **separate** answer scripts for each group)*

Group-A

1. a) The operators S_x and S_y are defined as : $S_x = \frac{1}{2}\hbar\{|+><-| + |-><+|\}$ and $S_y = \frac{1}{2}\hbar\{-i|+><-| + i|-><+|\}$. Obtain the matrix representation of $S_\pm$.

   b) Find the outer product $|\alpha><\beta|$ where $<\alpha| = \{+3i, 2-i, 4\}$ and $<\beta| = \{2, +i, 2+3i\}$.

   c) Construct the spherical tensor of rank 2 out of two different vectors $\bar{U}$ and $\bar{V}$. Express $T^{(2)}_{\pm 2}$ and $T^{(2)}_0$ in terms of $U_{x,y,z}$ and $V_{x,y,z}$. 3+3+4=10

2. a) Two spin 1 objects interact with each other with an external vector field $\bar{A}$ in such a way that the Hamiltonian for the system can be written as

   $H = \frac{A}{\hbar^2}(\bar{S}_1 \cdot \bar{S}_2) + \frac{\bar{A}\cdot(\bar{S}_1+\bar{S}_2)}{\hbar}$, where $\bar{A} = |A|$ is the magnitude of the field $\bar{A}$. Find the energies and degeneracies of the ground state and 1st excited state.

   b) Write down Dirac equation in momentum space for particle. Hence, show that $\bar{u}^{(s)}u^{(s)} = 2m$ .Notations have their usual meaning.

   c) Classify the following operators as *polar vectors*, *pseudovectors*, *ordinary scalars* and *pseudoscalars* : a) $\bar{L}\cdot\bar{S}$; b) $\bar{L}\cdot(\bar{x}\times\bar{S})$ 5+3+2=10

3. a) Show that orbital angular momentum is not conserved for free Dirac particle. How is the concept of spin introduced in this regard?

   b) Dirac spinor for particle is given by :

   $$u^{(s)} = N\begin{pmatrix} \chi^{(s)} \\ \frac{\bar{\sigma}\cdot\bar{p}}{E+m}\chi^{(s)} \end{pmatrix}, \text{ where } N = \sqrt{E+m}\,;$$

   Show that $\sum_{s=1,2} u^{(s)}(\bar{p})\,\bar{u}^{(s)}(\bar{p}) = \not{p} + m$ (Notations have their usual meaning.)

   (3+3)+4=10

4. a) Starting from the expression of the infinitesimal rotation operator given by:

$\mathcal{D}(\hat{\boldsymbol{n}}, d\varphi) = 1 - i\frac{\vec{J}\cdot\hat{\boldsymbol{n}}}{\hbar}d\varphi$ establish the fundamental commutation relations of angular momentum , where $\mathcal{D}(\hat{\boldsymbol{n}}, d\varphi)$ is the rotation operator about an axis characterized by unit vector $\hat{\boldsymbol{n}}$ by an infinitesimal angle $d\varphi$ and $\vec{J}$ is the angular momentum operator.

b) Discuss the Feynman-Stuckelberg interpretation of negative energy solutions.

c) Obtain the Klein-Gordon equation from Dirac equation. 4+3+3+10

Group-B

5. (a) Starting from standard expression of 1st order transition amplitude $C_k^{(1)}(t)$, for a harmonic perturbation: $H'(\mathbf{r},t') = 2\,H'(\mathbf{r})\cos(\omega t')$, obtain transition probability from a discrete state i to a discrete state k for stimulated emission and absorption.

(b) An atom is place in an electromagnetic field. Using dipole approximation, obtain an expression of transition probability induced by the radiation.

Why does the dipole transition must be accompanied by a parity change between the states?

4+(5+1)=10

6. (a) Assuming the asymptotic solution of the Schrodinger equation for scattering of a particle by a spherically symmetric potential V(r) being of the form (terms having their usual meanings):

$$\Psi(\mathbf{r}) = e^{ikz} + f(\theta,\phi).\frac{e^{ikr}}{r},$$

obtain an expression of total scattering cross section using partial wave decomposition method. Obtain optical theorem from it.

Given $\Psi_{in}(\mathbf{r}) = e^{ikz} = \sum_{l=0}^{\infty} A_l j_l(kr) P_l(cos\theta)$ with $A_l = (2l+1)i^l$.

(b) How will the expression of scattering cross section be modified for indistinguishable particles?

(c) Write down all possible wave functions (spin-orbitals) of the ground and 1st excited state of He atom. 5+2+3=10

7. (a) Find the total scattering cross section of a particle, in the low energy limit, by a square well potential of the form

$$V(r) = -V_0, \quad \text{for } 0 < r < a$$
$$= 0, \quad \text{for } r \geq a, \ a=\text{width of the potential well.}$$

What is the maximum value of the above total scattering cross section?

(b) What is first Born approximation in connection with the scattering problem?

Using standard expression of scattering amplitude $f(\theta, \phi)$ due to 1st Born approximation, find an expression of the differential scattering cross section for a shielded Coulomb potential of the form: $V(r) = \frac{Z_1 Z_2 e^2 e^{-r/l}}{r}$, l being the shielding distance. Show that under certain condition it reduces to Rutherford scattering formula.

(4+1)+(3+2)=10

8. (b) Starting from standard expression of 1st order transition amplitude $C_k^{(1)}(t)$, obtain Fermi Golden rule in connection with transition due to time dependent perturbation.

(b) Obtain selection rule for electric dipole transition of a linear harmonic oscillator.

(c) Assuming the asymptotic solution of the Schrodinger equation for scattering of particle by a spherically symmetric potential of the form (terms having their usual meanings):

$$\Psi(\mathbf{r}) = e^{ikz} + f(\theta, \phi).\frac{e^{ikr}}{r},$$

find the relation of differential scattering cross section with scattering amplitude.

(d) Write down the wave functions in terms of space and spin orbitals ^1S-state of two-electron atom.

3+3+3+1=10

Moderated By :
DHWU

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M.Sc. 2[ND] SEMESTER EXAMINATION 2018

Subject : Physics

Paper : Phy/Th/2S/202

Statistical Mechanics

Time : 2 Hours **Full Marks : 40**

The figures in the margin indicate full marks.

Answer two questions from each group

(*Use **separate** answer script for each group*)

Group – A

1. a) Show that for a system in a canonical ensemble $<(\Delta E)^2> = k_B T^2 C_V$ where C_V is the specific heat at constant volume.

b) A solid containing non-interacting paramagnetic atoms, each have a magnetic moment equal to 1 Bohr Magneton (BM), is placed in a megnetic field of 3 Tesla. Assuming that the atoms are in thermal equilibrium with the surrounding. Find the temperature at which the solid must be cooled so that more than 60% of atoms are polarised with magnetic moment parallel to magnetic field. (1BM = 9.27×10^{-24} J/T)

c) If a system consisting of two subsystems is in mechanical equilibrium and the volume V_1 and V_2 of two sub-systems are in such a way that the entropy S is maximum, then show that statistical pressure may be defined by

$\frac{\pi}{\tau} = \left(\frac{\partial S}{\partial V}\right)_{U,N}$ where terms have their usual meaning.

d) Under what conditions the postulates of equal a-priori probability are applicable?

3+3+3+1 = 10

2. a) What is Gibb's paradox? How it is resolved?

b) Derive Sackur-Tetrode equation for entropy of an ideal gas.

c) Show that the partition function Z_N for an extreme relativistic gas consisting of N-non-interacting molecules with energy-momentum relationship $\varepsilon = cp$ is given by

$Z_N = \frac{1}{N}\left[8\pi V\left(\frac{kT}{hc}\right)^3\right]^N$. Hence find an expression for the pressure of the gas.

(1+2)+3+(3+1) = 10

3. a) For a two dimensional system, show that the density of states is given by

$D(\varepsilon) = \frac{gm}{2\pi\hbar^2}$ for non-relativistic energy.

$= \frac{gE}{2\pi(\hbar c)^2}$ for relativistic energy, where the symbol have their usual meaning.

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b) Establish the relation $C_v = k\beta^2\left(\frac{\partial}{\partial\beta^2}(\beta F)\right)_V$ where F is the free energy and the symbols have their usual meaning.

c) A system consisting of N spatially separated sub-systems, is in thermal equilibrium with a heat reservoir at absolute temperature $T=\frac{\varepsilon}{k}$, where ε is the energy. If each sub-system has non-degenerate energy levels of energy $0, \varepsilon, 2\varepsilon, 3\varepsilon$ find

i) the partition function,

ii) the mean energy, and

iii) the entropy of the system. (2+2)+3+3 = 10

Group – B

4. a) Defining the density matrix ($\hat{\rho}$) for a pure quantum statistical state, establish the Liouville's theorem.

b) What are the basic differences between classical and quantum statistical mechanics?

c) Can you interpret the following matrix,

$$\hat{\rho}=\begin{pmatrix} \frac{1}{\sqrt{2}} & 0 \\ 0 & \frac{1}{\sqrt{2}} \end{pmatrix}$$

as a density matrix? Justify your answer. (2+5)+2+1 = 10

5. a) What do you mean by the Bose-Einstein (BE) condensation temperature (T_0) for an ideal Bose gas? Why there is a sharp decay in the amplitude of the specific heat (C_v) below T_0? Why the Bose-Einstein condensation sometimes called as "condensation in momentum space"?

b) Show that the entropy of an ideal Bose gas for $T < T_0$ is

$$S=\frac{2}{3}(C_v)_{T<T_0}$$

Given that the energy of the ideal Bose gas for $T<T_0$ is $E_{T<T_0}=\frac{3}{2}\frac{F^{(0)}_{\frac{5}{2}}}{F^{(0)}_{\frac{3}{2}}}nkT\left(\frac{T}{T_0}\right)^{\frac{3}{2}}$

where the symbols carry their usual meaning. (2+2+2)+4 = 10

6. a) What do you mean by weak and strong degeneracies for an ideal *Fermi-Dirac* gas?

b) Establish a relation between the energy (E) and the volume (V) for an ideal *Fermi* gas and show that the pressure can be written as

$$P=\frac{2E}{3V}.$$

c) Compare the energies of the ideal Bose-Einstein and ideal Fermi-Dirac gas while the temperatures of both the gases are tending towards absolute zero. Discuss about the energy degeneracies for both the gases at that temperature. (1+1)+(2+2)+(2+2) = 10

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M.Sc. 2ND SEMESTER EXAMINATION 2018

Subject : Physics

Paper : Phy/Th/2S/203

General Electronics

Time : 2 Hours **Full Marks : 40**

The figures in the margin indicate full marks.

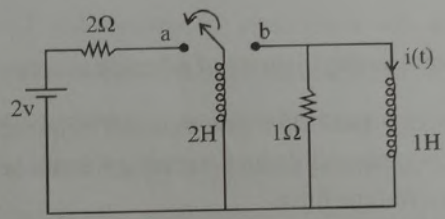
Answer two questions from each group

*(Use **separate** answer script for each group)*

Group – A

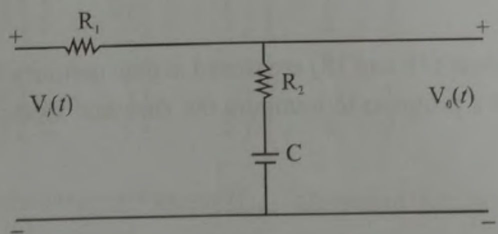
1\. a) Draw sketches to show the construction and equivalent circuit of a unijunction transistor (UJIT). Explain its principle of action using the characteristic curves.

b) The circuit in the fig. below was initially in steady state with switch 'S' is position 'a' at $t=0$. The switch then goes from 'a' to 'b' position. Find i(t) for the following network using Laplace transforms at $t>0$.



(1+1+4)+4 = 10

2\. a) Define transfer function in connection with Laplace transformation. Find the transfer function for the following network.



b) Is it possible to decrease the non linear distortion in a feedback amplifier using a negative feedback? Explain.

c) Determine the highest angular frequency allowed in a demodulation circuit in terms of capacitance and resistance of the circuit with the angular frequency of input signal.

d) The peak to peak value of an AM voltage has a maximum value of 8V and a minimum value of 2V. What are the percentage modulation and the amplitude of the unmodulated carrier?

(1+3)+2+2+2 = 10

Please Turn Over

3. a) Draw the circuit diagram of a two stage RC coupled amplifier. Calculate the low frequency voltage again of a RC coupled one stage amplifier. Finally show that at low frequency the value of phase angle is greater than 180°.

b) A single tuned amplifier has the following parameters :

$L = 120\,\mu H$	$h_{oe} = 50 \times 10^{-6}\,\Omega^{-1}$
$C = 100\,\mu H$	$h_{fe} = 100$
$R = 10\,\Omega$	$h_{ie} = 2.5\,k\Omega$ and load resistance $R_T = 10\,k\Omega$

Calculate (i) the resonant frequency, (ii) the bandwidth and (iii) the maximum voltage again.

(1+3+2)+(1+2+1) = 10

Group – B

4. a) Draw the circuit diagram of an integrator using op-amp. Obtain the output voltage form when 1 V dc is applied to its input with $R = 500\,k\Omega$, $C = 1\,\mu F$ and supply voltage $= \pm 12$ V.

b) Draw the circuit diagram and explain the working principle of a weighted digital-to-analog converter. What is the disadvantage of this D/A converter and how can we overcome this?

(1+3)+(4+1+1) = 10

5. a) Draw the circuit diagram and timing diagram of a decade counter. What is RAM?

b) Design a first order active high-pass filter with a cut-off frequency of 1 kHz and a pass band gain of 2. (Give circuit diagram and deduce necessary formula to design). Give the basic circuit diagram of this passive-type filter.

(3+1)+(5+1) = 10

6. a) Draw the circuit diagram of an astable multivibrator and obtain an expression of its frequency. To obtain a square wave of frequency f = 1 kHz, give the values of the necessary circuit components?

b) Two digit of BCD numbers (16 and 18) are stored at data memory location X and X + 1 of a micro-processor. Write a program to compute the sum and store the decimal result at the location X + 2.

(5+2)+3 = 10