# M.Sc. 3rd Semester Examination, 2013

## PHYSICS

PAPER—PHS-301(A + B)

*Full Marks* : 40

*Time* : 2 hours

*The figures in the right-hand margin indicate marks*

*Candidates are required to give their answers in their own words as far as practicable*

*Illustrate the answers wherever necessary*

## PHS-301(A)

( *Relativistic Quantum Mechanics* )

[ *Marks* : 20 ]

*Time* : 1 hour

**Answer all questions**

**1.** Answer any *three* bits : 2 × 3

(*a*) Show that Dirac matrices can only be of even order and their eigenvalues are ± 1.

( *Turn Over* )

(*b*) Express Dirac equation in covariant form and express the properties of $\gamma$ matrices.

(*c*) Derive the continuity equation for spin half particle and explain the terms.

(*d*) Show that

$$\left(\vec{\alpha}.\vec{A}\right)\left(\vec{\alpha}.\vec{B}\right)=\vec{A}.\vec{B}+i\vec{\sigma}^{d}.\left(\vec{A}\times\vec{B}\right)$$

(*e*) Obtain eigenvalues of the operator

$$k=\frac{\beta\left(\vec{\sigma}^{d}.\vec{L}+\hbar\right)}{\hbar}$$

**2.** Answer any *one* bit : 4

(*a*) Find a relation for the time derivative of $x$ component of spin angular momentum, $\frac{dS_x}{dt}$, for a free Dirac particle.

(*b*) Write the Dirac equation in two component form and from there obtain the energy eigen-values for a free Dirac particle. Discuss the importance of negative energy solution.

3. Answer any *one* bit : 10

(*a*) Write Dirac equation for a spin half particle in presence of Electromagnetic field and show that in the nonrelativistic limit the interaction term corresponding to orbital motion and spin with magnetic field appears naturally.

(*b*) Obtain the radial equation for a spin zero charged particle in a central coulomb potential and obtain the expression for energy eigenvalue. Explain each term in the energy eigenvalue expression.

PHS-301(B)

( *Statistical Mechanics*-I )

[ *Marks* : 20 ]

*Time* : 1 hour

Answer **Q. No. 1** and any **one** from the rest

1. Answer any *five* bits : 2 × 5

(*a*) A system of three cells such that $N_1 = 5$, $N_2 = 3$, $N_3 = 2$; $E_1 = 0$, $E_2 = 2$, $E_3 = 4$ joules per particle. If total no. of particles and energy are constant and $\delta N_3 = -2$ then find $\delta N_1$ and $\delta N_2$.

(*b*) A system of $N$ particles is enclosed in a volume $V$ at a temperature $T$. The logarithmic of the partition function is given by

$$\ln Q = N \ln\left[(V - Nb)(k_B T)^{3/2}\right],$$

where '$b$' is a constant with appropriate dimensions. If $P$ is the pressure of the gas. Find the equation of state.

(*c*) Explain why the electron gas at room temperature is highly degenerate.

(*d*) Explain density of states and probability density.

(*e*) An ensemble of $N$ three level systems with energies $\epsilon = -\epsilon_0, 0, +\epsilon_0$ is in thermal equilibrium at temperature $T$. If $\beta\epsilon_0 = 2$. Calculate the probability of finding the system in the level $\epsilon = 0$.

(*f*) A monoatomic crystalline solid comprises of $N$ atoms. Out of which $n$ atoms are in interstitial positions of the available interstitial sites are $N_1$, find the number of possible microstates.

(*g*) Explain pure and mixed state in the light of density matrix.

**2.** (*a*) Deduce an expression of *B-E* distribution function from grand partition function.

(*b*) For photon gas if the grand partition function

$$\{ = \prod_{i=0}^{\infty} \frac{1}{1-\exp(-\beta \epsilon_i)}$$

show that free energy

$$F(T,V) = -\frac{1}{3} bV T^4$$

where '$b$' is a constant.

also prove that entropy $S' = \frac{4}{3} bV T^3$. 5 + 4 + 1

3. (*a*) Prove that r.m.s. fluctuation in energy in canonical distribution is $\sim \frac{1}{\sqrt{N}}$.

(*b*) Find an expression of density matrix for a particle in box of size '*a*' with infinite potential at the wall in coordinate representation. 5 + 5

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