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End Semester Examination of Semester–III, 2015

Subject : PHYSICS (PG)

Paper : PHS–301 (Theory)

Full Marks : 40

Time : 2 Hrs

The figures in the margin indicate the marks corresponding to the question

Candidates are requested to give their answers in their own word as far as practicable.

Illustrate the answers whenever necessary

Use separate Answer scripts for Group A and Group B

Group A (Marks 20)

Answer Question No. 1 and **any one** out of Question No. 2 and Question No. 3.

1. Answer **any five** questions : 2x5=10

   i) Derive the continuity equation for a particle obeying Klein-Gordon equation and find expression for current density.

   ii) Prove that the operator $c\alpha$, where α stands for Dirac matrix, can be interpreted as the velocity operator.

   iii) Helicity operator is defined as

   $$h=\frac{\sigma_d . p}{|p|}=\sigma_d . n \text{ where, } \sigma_d=\begin{pmatrix}\sigma & 0\\ 0 & \sigma\end{pmatrix},$$

Show that (a) h is hermitian. (b) h and H_D commute,

$$H_D = \begin{pmatrix} m_0c^2 & c(\sigma,p) \\ c(\sigma,p) & -m_0c^2 \end{pmatrix}.$$

iv) Show that the Dirac Matrices can only be of even order and their values are ±1.

v) Define differential scattering cross section. For a spherically symmetric scattering potential, show that, the differential scattering cross section is the absolute square of scattering amplitude i.e.. $\sigma(\theta,\varphi)=|f(\theta,\varphi)|^2$.

vi) State and explain optical theorem in scattering using partial wave analyses.

vii) Show that the Klein-Gordon equation is Lorentz invariant.

viii) Under what conditions partial wave method and Born approximation method are applicable for theory of scattering in quantum mechanics?

2. a) Establish the expansion of a plane wave in terms of an infinite number of spherical waves.

b) If the scattering amplitude

$$f(\theta)=\frac{1}{k}\sum_{l=0}^{\infty}(2l+1)e^{i\delta_l}P_l(\cos\theta)\sin\delta_l,$$

find the expressions for differential scattering cross section $\sigma(\theta)$ and total scattering cross section σ_T for s-wave. Evaluate the scattering amplitude in the Born approximation for scattering by the Yukawa potential

$V(r) = \frac{V_0 e^{-\alpha r}}{r}$, where V_0 and α are constants.

2+3

3. a) Explain the problem encountered in interpreting the equation of continuity from Klein-Gorden equation. Obtain the equation of continuity for Dirac equation. 2+3

b) For Dirac particle in central force field show that the total angular momentum $\left(\vec{L}+\frac{1}{2}\hbar\vec{\Sigma}\right)$ is a constant of motion. 5

Group – B (Marks 20)

Answer Question No. 1 and **any one** out of Question No. 2 and Question No. 3.

1. Answer any **five** questions: 2x5=10

i) The partition function of a system is given by $Z=Ae^{bT^4V}$ (where A and b are constants). How will pressure and entropy depend on temperature?

ii) Define chemical potential. What is the value of chemical potential for photons?

iii) A classical particle of mass m is in one dimensional motion lying between x = 0 and x = L. the energy of the particle is between E and E + δE. What is the area of the region of phase space accessible to the particle?

iv) Show that the eigen values of a density matrix are real and non-negative.

v) Explain the meanings of extensive and intensive variables of a thermo dynamical system with example.

vi) Explain the concept of microstate and macrostate with examples.

vii) Explain the concept of ensemble average and time average of a thermo dynamical variable of a system. How are they related?

viii) Show whether the temperature of a an ideal system of N particles is positive infinity or negative infinity its entropy S is always kN *ln*2.

2. a) Derive an expression for the entropy, S, of a system of an ideal gas, considering it to be an element of a micro canonical ensemble. 5

b) Show that S in this case is not an extensive variable. 1

c) Find the specific heat of an ideal gas in the extreme relativistic case, where the energy of a particle is related to the momentum by $\varepsilon = pc$, c being the speed of light. 4

3. a) Find an expression for the probability $P(E_i)$ of a system, an element of a canonical ensemble, so that it has energy eigenvalue E_i, if the system is in thermo dynamical equilibrium. 6

b) The speed distribution function of a group of N particles is given by,

$$dN_v = Kvdv \quad (0 < v < V)$$

$$= 0 \quad (v > V), \text{ where k is a constant.}$$

Sketch the speed distribution. Find the average speed and rms speed of the particles. Hence, obtain the relation between them. 1+2+1