M.Sc. 4th Semester Examination, 2013

PHYSICS

PAPER—PHS-402 (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

Use separate scripts for different Groups

PHS - 402 (A)

[*Marks* : 20]

1. Answer any *five* questions : 2 × 5

   (*a*) Write down the Meson theory of nuclear force.

   (*b*) What do you mean by nuclear reaction cross-section ? How is it related with level width ?

(*Turn Over*)

(*c*) State and explain Nordheim's rule for the determination of spin of a nuclei.

(*d*) How fission can be explained on the basis of liquid drop model ?

(*e*) Using the single particle shell model predict the ground state spin and parities of ${}_{13}Al^{27}$.

(*f*) Classify neutrons according to energy with significance.

(*g*) State different types of exchange force with explanation of potential.

(*h*) Find the magnetic moment of the grond state of ${}_{8}O^{17}$ due to odd neutron considering shell model.

2. Answer any *one* question :

(*a*) Write down the Schrodinger equation for the ground state of deuteron and solve it for appropriate boundary conditions. Represent the wave function graphically. Find the relation of the range and depth of the potential. Comment on the excited states of deuteron. (1 + 4) + 1 + 2 + 2 (*b*) What do you mean by Q-value of a nuclear reaction ? Show that an exo-ergic reaction may happen even for zero energy of the incident particle. Find the expression for threshold energy (E_{th}) for an endo-ergic reaction. Hence show that

$$(E_{th})_{\theta=0} = -Q\left(1+\frac{m_x}{M_X}\right)$$

where m_x and M_X are the masses of the incident particle and target nucleus. 1 + 3 + 4 + 2

PHS - 402 (B)

[*Marks* : 20]

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

1. Answer any *five* questions : 2 × 5

(*a*) The space-time co-ordinates of two frames of reference are related by the Lorentz transformation : $x' = \wedge x$ where X denotes a four vector. Show that det $\wedge = \pm 1$. Interpret the result.

(*b*) Explain the natural units. State the mass dimension of the Dirac (ψ) and Maxwell (Au)

fields and hence show that the electromagnetic coupling e appearing in the Lagrangian density :

$$\mathscr{L} = -e\overline{\psi}\, r^{u} \psi\, Au$$

is dimensionless in the natural units.

(c) Explain the time-ordered product of fields and show that the vacuum expectation value of a scalar field is one of the Green's function of the Klein Gordon operator i.e.

$$G_F(x'-x) = i\left\langle 0 \,|\, T\phi^{+}(x)\phi(x) \,|\, 0\right\rangle$$

(d) The real scalar field $\phi(x)$ in the Heisenberg representation can be written as

$$\phi(x) = \int \frac{d^3K}{(2\pi^3 2w_k)^{1/2}}\left[a(k)e^{-ik\cdot x} + ae^{+ik\cdot x}\right].$$

Show that the commutar

$$[\phi(x),\ \pi(x')] = i\,\delta^3(x - x')$$

where each symbol has its usual meaning.

(e) Show that the stress energy tensor T^{uv} for a scalar field ϕ satisfies the continuity equation :

$$\partial_u T^{uv} = 0 \cdot$$

where

$$T^{uv} = \frac{\partial \mathscr{L}}{\partial(\partial_u \phi)} \partial^v \phi - g^{uv}.$$

(*f*) Show that the eigenvalues of the number operator for a Dirac field can be zero and unity.

(*g*) Obtain the charge conjugation operator for a Dirac particle in an electromagnetic field satisfying the equation

$$\left(i\gamma^u \partial_u - e\, A_u(X)\right) \psi(X) = 0.$$

(*h*) State and explain the Wick's theorem for a product of *n*-fields.

2. (*a*) The Lagrangian density for the complex scalar field is given by

$$L = \partial_\mu \phi^+ \partial_\mu \phi + m^2 \phi^+ \phi.$$

Obtain the field equation. Is the Lagrangian density invariant under a global gauge transformation ? If so, identify the conserved quantity.

2 + 1 + 1

(*b*) Carry out canonical quantization of the system to obtain an expression for the number operator to show that it refers to quanta of opposite charges. 6

3. (*a*) Discuss gauge invariance in the quantum electrodynamics (QED) by considering the Lagrangian density of a matter field(ψ) of charge e and electromagnetic field A_u under the gauge transformations : $\psi(x) \to e^{-ie\alpha(x)}\psi(x)$ and $A_u(x) \to A_u(x) + \partial_u \alpha(x)$ and show that the principle of gauge invariance determines the coupling between the matter field and the electromagnetic field so that the QED Lagrangian can be written as

$$\mathscr{L}_{\text{QED}} = \bar{\psi}\,[i\gamma^u D_u - m]\psi$$

where the gauge covariant derivative is given by $D_u = \partial_u + ie A_u$.

(*b*) Extend the idea of gauge invariance to the model of leptons of Glashow, Salam and Weinberg based on the group su(2) × $U(1)$ where the total charge of the lepton is given by

$$Q = I_3 + \frac{Y}{2};$$

I is the weak isospin generator of su(2) with I_3 being its 3rd component and Y is the generator known as weak hyper charge of $U(1)$. Write down the gauge covariant derivative for the model. State how many gauge bosons arise in the model indicating the weak and neutral gauge bosons.

(*c*) Draw the Feynman diagrams for the process $V_e + e^- \rightarrow V_e + e^-$ 4 + 4 + 2