M.Sc. 4th Semester Examination, 2014

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 Gr.-A and Gr.-B

GROUP – A

[*Marks* : 20]

Time : 1 hour

1. Answer any *five* from the following : 2 × 5

(*a*) Using experimental evidence, show that the Deuteron ground state wave function (ψ_0) can be expressed as :

$$\psi_0 = a_0\psi_{1s} + a_2\psi_{1d}$$

(*b*) What are the essential differences between low energy *n-p* and *p-p* scattering ?

(*c*) Present graphically how Bohr-Wheeler used the *liquid-drop* model to explain the process of *nuclear fission*.

(*d*) Stating the deuteron wave function represent it graphically.

(*e*) Using Nordheim's rule find the spin and parity of ${}_{15}P^{30}$ nuclei.

(*f*) Find the spin, parity and magnetic moment of ${}_{16}S^{33}$ nuclei using shell model.

(*g*) State the principles of velocity selector neutron monochromator.

(*h*) Find the relation between scattering length and refractive index of a material using neutron optics.

2. (*a*) State continuum theory of nuclear reaction. 4

(*b*) Deduce Breit Wigner resonance formula for nuclear reaction. 6

Or

3. (*a*) How magic numbers are explained using shell model ? 4

(*b*) Draw potential energy graph of a nucleus. Deduce Bohr-Wheeler's theory of nuclear fission. 1 + 5

GROUP – B

[*Marks* : 20]

Time : 1 hour

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

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

(*a*) Show that the Euler-Lagrange equation for a classical field ϕ given by the Lagrangian density $\mathscr{L}(\phi, \partial_\mu \phi)$ can be derived from the Hamilton's principle.

B refers to the quantum of the scalar field ϕ, e refers to the quantum of the fermionic field ψ, e^+ refers to the position and k, p and p' are the four momentum of the particles.

(*f*) Show that $a^+|n_k>$ and $a\,|n_k>$ are the eigen states of the number operator N_k for a real scalar field.

(*g*) Show that a massless Dirac particle has definite helicity.

2. (*a*) Obtain the Dirac equation from the Lagrangian

$$\mathscr{L} = \overline{\psi}(x)\,(i\gamma^{\mu}\partial_{\mu} - m)\,\psi(x)$$ 1

(*b*) Expanding the Dirac field as an integral over momentum space of the plane wave solutions

$$\psi(x) = \int \frac{d^3p}{\sqrt{(2\pi)^3 2E_p}} \sum_{s=1,2} \begin{bmatrix} b(p,s)u(p,s)\,e^{-ip.x} \\ +d^+(p,s)v(p,s)\,e^{ip.x} \end{bmatrix}$$

Obtain the total Hamiltonian H and show that the normal ordered Hamiltonian is positive definite if upon second quantization the (*b*) Show that the Lagrangian density for a complex scalar field given by the Lagrangian density $\mathscr{L} = \partial_\mu \phi^+ \partial^\mu \phi - m^2 \phi^+ \phi$ is invariant under a global gauge transformation and leads to a conserved charge.

(*c*) Obtain the inhomogeneous Maxwell's equation from the Lagrangian density

$$\mathscr{L} = -\frac{1}{4} F^{\mu\nu} F_{\mu\nu} - J^\mu A_\mu$$

(*d*) Show that the coupling constant g appearing in the Yukawa interaction given by $\mathscr{L}_I = -g\bar{\psi}\psi\phi$ is dimensionless in the natural units where ψ is a dirac field and ϕ is a scalar field.

(*e*) Draw the Feynman diagram for the process $B(k) \to e^-(p) + e^+(p')$ where the process results from the interaction Hamiltonian of the Yukawa interaction

$$\mathscr{H}_I = g : \bar{\psi} \psi \phi : \quad ;$$

3. (*a*) Outline the basic concepts of the Glashow-Salam-Weinberg model involving the leptons quarks, gauge bosons and scalars indicating the gauge symmetries and gauge covariant derivatives involved. 6

(*b*) Indicate through diagrams how the leptons and quarks participate in strong, weak and electromagnetic interactions. 3

(*c*) Comment on the predictions of the model indicating to what extent, they are experimentally verified. 1

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expansion coefficients $b(p, s)$, $b^{+}(p, s)$ $d(p, s)$ and $d^{+}(p, s)$ become operators and satisfy anticommutation relations

$$\left\{b(p,s), b^{+}(p',s')\right\} = \delta_{ss'}\delta^{3}(\vec{p}-\vec{p}')$$

$$\left\{d(p,s), d^{+}(p',s')\right\} = \delta_{ss'}\delta^{3}(\vec{p}-\vec{p}')$$

while all other anticommutation relations are zero. Interpret the operators $b(p, s)$, $b^{+}(p, s)$, $d(p, s)$ and $d^{+}(p, s)$ according to the hole theory. 4

(c) Show that the Lagrian, which is invariant under the transformation

$$\psi(x) \rightarrow \exp(-iq\alpha)\,\psi(x),$$

yields the conserved charge Q and the normal ordered form Q is given by

$$Q := q\int d^{3}p \sum_{s=1,2}\left[b^{+}(s,p)\,b(s,p) - d^{+}(s,p)\,d(s,p)\right]$$

Interpret the result. 2 + 2 + 1