# 2016

## M.Sc. Part-II Examination

## PHYSICS

### PAPER—IX

*Full Marks : 75*

*Time : 3 Hours*

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

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

*Illustrate the answers wherever necessary.*

***Use separate answer-scripts for Group-A and Group-B***

### Group-A

*( Nuclear Physics )*

[ Marks : 40 ]

Answer Q. No. *1, 2,* and any *two* from the rest.

**1.** Answer any *six* of the following : 6×2

(a) How can you conclude that a heavy $(A \geq 150)$ nuclides are energitically unstable against $\alpha$-decay ?

(b) Discuss the magic number and magic nuclei.

(c) Show that the classical cross-section for elastic scattering of point particle from an infinitely massive sphere (hard sphere) of radius R is isotropic.

(d) Show that the maximum energy shift that can be observed for a body whose quadrupole moment is Q of can be written as $\Delta U = \frac{1}{8} eQ \left( \frac{\partial^2 \phi}{\partial z^2} \right)_0 \frac{2I-1}{I+1}$ where $\phi$ is the electric potential.

(e) In p – p scattering at low energy, the differential scattering cross-section is

given by $\frac{d\sigma}{d\Omega} = |f(\theta)|^2 + |f(\pi - \theta)|^2$

$$- \text{Re}\left[ f^*(\theta) f(\pi - \theta) \right]$$

Explain the above terms.

(f) Explain Heisenberg and Barlett forces in Nuclear Physics.





(g) Deduce $1/v$ law in nuclear reactions.

(h) ${}_1H^1 + {}_9F^{19} \rightarrow \left({}_{10}Ne^{20}\right)^* \rightarrow {}_{10}Ne^{19} + {}_0n^1 + 4.99$ Mev.

Calculate the energy of relative motion.

(i) Neutrons cannot produce scintillations, but can be detected by scintillation counters, How ?

**2.** Answer any *two* of the following : 2×4

(a) Setup the wave equation for the ground state of the deuteron starting clearly the assumptions made.

(b) Show that electron-positron pair cannot be created by an isolated photon.

(c) A $D_{5/2}$ term in the optical spectrum of ${}_{19}K^{39}$ has a hyperfine structure with four components. Find the spin of the nucleus. In what interval ratios in the hyperfine quadrupted are expected ?

(d) Discuss the various experimental techniques involved in neutron spectroscopy for the detection of neutron.

3. Write and discuss the mathematical expression of the Isobaric mass parabola $^{14}C$ disintegrates by $\beta$-emission with an end point energy of 0.155 Mev. A $\beta$-particle with an energy of 0.025 Mev is emitted in a direction at 135° to the direction of motion of the recoil nucleus. Determine the momenta of all the three particles involved in this disintegration. 4+6

4. What are magic numbers ?

Consider a nuclear level corresponding to a closed shell plus a single proton in a state with the angular momentum quantum numbers $l$ and j.

prove that $g_j = \frac{2j-1}{2j} + \frac{g_p}{2j}$ for $l + \frac{1}{2} = j$

$$= \frac{1}{j+1}\left[j + \frac{3}{2} - \frac{g_p}{2}\right] \text{ for } l - \frac{1}{2} = j.$$

(c) Show by way of computation, which nuclei you would expect to be more stable :

$_4Be^9$ and $_4Be^{10}$. 2+5+3





5. (a) $x + X \rightarrow Y + y + Q$ (X is at rest)

Find an expression of Q.

(b) A tritium gas target is bombarded with a beam of monoenergetic protons of K.E. 3 Mev. What is the K.E. of the neutrons emitted at 30° to the incident beam ?

[$^1H = 1.007825u$ ; $^3H_1 = 3.016049u$ and $^3He = 3.016029u$.] (Atomic masses). 5+5

6. (a) For Stable heavy nuclei, the number of neutrons is substantially greater than the number of protons. Using B.E. relations, prove that more energy is required to remove a proton than a neutron.

(b) Discuss the basic principle of the Rabi's method for determination of magnetic moment of nuclei and Discrible the experimental arrangement. 5+5

## Group–B

*( Field Theory & Particle Physics )*

[ Marks : 35 ]

Answer Q. No. *1* and *two* from the rest.

1. Answer any five bits: 5×3

(a) Consider the process $\mu^+ + \mu^- \longrightarrow \pi^+ + \pi^-$, Find the minimum kinetic energy of the muons ($\mu$) in the centre of mass frame required to produce the pion ($\pi$) pairs at rest. (Given $m_\mu = 105 \text{ Mev}/c^2$, $m_\pi = 140 \text{ Mev}/c^2$)

(b) Consider the decay of a pion into a muon and anti-neutrino $\pi^- \to \mu^- + \overline{\nu_\mu}$ in the pion rest frame. Find the energy (in Mev) of the emitted neutrino.

(c) In the elastic proton - proton scattering $p + p \to p + p$ the sum of the Mandelstam variables s, t and u predicts : $s + t + u = 4M^2$ where M is the mass of the proton.





(d) The G-parity conservation in the strong interaction predicts that the reaction $\pi^+ + \pi^- \longrightarrow \pi^+ + \pi^- + \pi^0$ is forbidden.

(e) How the following quantities will transform under space inversion (P) and T (time reversal) operation :

(i) spin or angular momentum vector $\vec{\sigma} = \vec{r} \times \vec{p}$

(ii) Electric dipole moment $\vec{\sigma}.\vec{E}$

(iii) Magnatic dipole moment $\vec{\sigma}.\vec{B}$

(f) Show that $\overline{\psi}\gamma^5\psi$ is a pseudoscalar where $\psi$ is a Dirac spinor.

(g) Draw the Feynman diagram for the process :

$\mu^- \to e^- + \nu_\mu + \overline{\nu_e}$

$\nu_e + n \to p + e^-$

(h) Show that in SU(3) multiplet

$3 \otimes 3 = 6 \oplus \overline{3}$ for qq combinations.

2. (a) $\pi^- + p \rightarrow K^0 + \Sigma^0$

$\pi^- + p \rightarrow K^+ + \Sigma^-$

$\pi^+ + p \rightarrow K^+ + \Sigma^+$

Find the ratio of cross-sections for the above reactions assuming C.M. energy is such that the channel $I = \frac{3}{2}$ dominates. What if the energy is such that the $I = \frac{1}{2}$ channel dominates ? 5

(b) Consider the Lagrangian of a real scalar field $\phi$,

$$L = \frac{1}{2}\left(\partial_\mu \phi\right)^2 - v(\phi)$$

Where, $v(\phi) = \frac{1}{2}\mu^2\phi^2 - \frac{1}{4}\lambda\phi^4$ with $\lambda > 0$.

(i) What is the symmetry under which the above Lagrangian is invariant ?





(ii) Sketch the potential $v(\phi)$ for $\mu^2 < 0$ and $\mu^2 > 0$.

(iii) Consider the quantum fluctuations $\eta(x)$ about the minimum for $\mu^2 < 0$ case. How is the above Lagrangian modified under the transformation $\phi(x) = v + \eta(x)$ ; $v$ is minimum for $\mu^2 < 0$ case. What can you conclude from the new Lagrangian ? Does this Lagrangian posses the above symmetry determined in (i) ? 5

3. (a) Assuming invariance of the Dirac equation under parity operation obtain the parity operator for the Dirac field. 4

(b) Show that the relative intrisic parity of a fermion-antifermion pair at rest is odd. 2

(c) Discuss how the intrinsic parity of the pi-meson can be determined from the reaction $\pi^- + d \rightarrow n + n$. 4

4. (a) For Dirac field

$$L = \overline{\psi}\left(i\gamma^\mu \partial_\mu - m\right)\psi$$

Show that $\pi(x) = i\psi^{+}(x)$.

(b) and $: H := \sum_{S}\left(N^{(k,s)}_{e^-} - N^{(k,s)}_{positron}\right)$ 4+6

5. (a) Show that under local gauge transformation

$\psi'(x) = \bar{e}^{iq\alpha(x)}\,\psi(x)$

$L'_{Dirac} - L_{Dirac} = q\,\bar{\psi}(x)\,\gamma^{\mu}\,\psi\,\partial_{\mu}\alpha(x)$.

(b) Calculate the ratio of the cross sections for the reaction $\pi^{-}p \to \pi^{-}p$ and $\pi^{-}p \to \pi^{o}n$ on the assumption that two I spin amplitudes are equal in magnitude but differ in phase by 30°.

(c) What is time ordering for Dirac field ? 4+4+2

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