

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

(Turn Over)

are energetically 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.

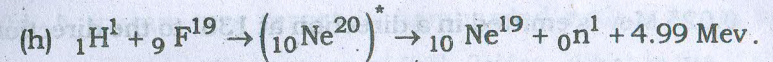
- (e) In p-p scattering at low energy, the differential scattering cross-section is

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

Explain the above terms.

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

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



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  ${}_{19}\text{K}^{39}$  has a hyperfine structure with four components. Find the spin of the nucleus. In what interval ratios in the hyperfine quadrupled 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  $^{14}\text{C}$  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  $135^\circ$  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 :

$${}^9_4\text{Be} \text{ and } {}^{10}_4\text{Be} \quad 2+5+3$$

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  $30^\circ$  to the incident beam ?

$$[{}^1\text{H} = 1.007825\text{u}; {}^3\text{H}_1 = 3.016049\text{u} \text{ and } {}^3\text{He} = 3.016029\text{u}]$$

(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 Describe the experimental arrangement. 5+5

**Group-B***( Field Theory & Particle Physics )*

[ Marks : 35 ]

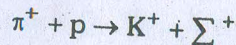
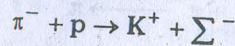
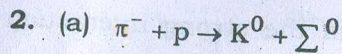
Answer Q. No. 1 and two from the rest.

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  $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$  in the pion rest frame. Find the energy (in Mev) of the emitted neutrino.
- (c) In the elastic proton - proton scattering  $p + p \rightarrow p + p$  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 :
- spin or angular momentum vector  $\vec{\sigma} = \vec{r} \times \vec{p}$
  - Electric dipole moment  $\vec{\sigma} \cdot \vec{E}$
  - Magnetic dipole moment  $\vec{\sigma} \cdot \vec{B}$
- (f) Show that  $\bar{\psi} \gamma^5 \psi$  is a pseudoscalar where  $\psi$  is a Dirac spinor.
- (g) Draw the Feynman diagram for the process :
- $$\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$$
- $$\nu_e + n \rightarrow p + e^-$$
- (h) Show that in SU(3) multiplet
- $$3 \otimes 3 = 6 \oplus \bar{3} \text{ for } qq \text{ combinations.}$$



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  $\phi$ ,

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

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 possess 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 intrinsic 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

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

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

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

5. (a) Show that under local gauge transformation

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

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

(b) Calculate the ratio of the cross sections for the reaction

$\pi^- p \rightarrow \pi^- p$  and  $\pi^- p \rightarrow \pi^0 n$  on the assumption that two I spin amplitudes are equal in magnitude but differ in phase by  $30^\circ$ .

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