

**2018**

**M.Sc. 4th Semester Examination**

**PHYSICS**

**PAPER—PHS-401**

**Subject Code—33**

*Full Marks : 40*

*Time : 2 Hours*

*The figures in the 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 & Group-B**

**Group-A**

[ Marks : 20 ]

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

1. Answer any five bits :

5×2

(a) How many components are there in  $\bar{\psi}\gamma^5\gamma^\mu\psi$  and  $\bar{\psi}\gamma^5\psi$  ?

(Turn Over)

(b) In  $SU(3)$  multiplets prove that

$$3 \otimes 3 = 6 \oplus \bar{3}$$

How many symmetric and antisymmetric states are there ?

(c) Use isospin invariance to show that the reaction cross-section  $\sigma$  must satisfy

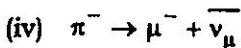
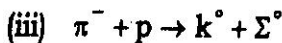
$$\frac{\sigma(pp \rightarrow \pi^+ d)}{\sigma(np \rightarrow \pi^0 d)} = 2$$

given that the deuteron  $d$  has isospin  $I = 0$  and the  $\pi$  has isospin  $I = 1$ .

(d) A pion at rest decays into a muon and a neutrino. If life time of muon is  $\tau$ , how far will the muon will travel (in vacuum) before disintegrating ?

(e) (i)  $\Sigma^0 \rightarrow \Lambda^0 + \gamma$

(ii)  $e^+ + e^- \rightarrow \mu^+ + \mu^-$



Classify the interactions of the above reactions.



If  $\vec{p}$  is the C.M. momentum of the, incident particle and  $\theta$  is the scattering angle prove that Mandelstam variables

$$t = -2p^2(1 - \cos\theta) / c^2$$

$$u = 2p^2(1 + \cos\theta) / c^2.$$

(g) Draw Meson octet model.

(h) 
$$V(\phi) = \frac{1}{2}\mu^2\phi^2 + \frac{1}{4}\lambda\phi^4 \quad (\lambda > 0)$$

Sketch  $V(\phi)$  vs  $\phi$  for +ve and -ve  $\mu^2$ , when symmetry is broken ?

2. (a) State and prove CPT theorem.

(b) Explain how the parity of  $K^-$  meson has been determined experimentally?

(c) A  $\pi^0$  meson at rest decays into two photons of equal energy. What is the wave length (in n.m) of the photons?

$$\left( m_{\pi^0} = 135 \text{ Mev} / c^2 \right)$$

4+4+2

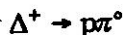
3. (a) Two particles X and Y can be produced by strong interaction

$$K^- + p \rightarrow K^+ + X$$

$$K^- + p \rightarrow \pi^0 + Y$$

Identify the particles X (1, 321 Mev) and Y (1, 192 Mev) and deduce their quark content. If their decay schemes are  $X \rightarrow \Lambda + \pi^-$  and  $Y \rightarrow \Lambda + \gamma$  give a rough estimate of their life time.

- (b) Calculate the branching ratio for the decay of the resonance  $\Delta^+$  (1232) which has two decay modes.



- (c) In which isospin states can (i)  $\pi^+\pi^-\pi^0$  (ii)  $\pi^0\pi^0\pi^0$  exist?

4+4+2

### Group-B

[ Marks : 20 ]

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

1. Answer any five bits :

2×5

- (a) Write down the equation of state for BE/FD gas.

- (b) Consider a system of particles in two dimension with momentum  $\vec{p}$  and energy  $E = c|\vec{p}|$ ,  $c$  being a constant.

The system is maintained at inverse temperature  $\beta$ , volume  $V$  and chemical potential  $\mu$ . What is the grand partition function of the system?

- (c) Prove that compressibility of Bosonic atoms at temperature  $T$  is

$$\frac{1}{k_B T n} \left( \frac{1}{1 - \frac{\lambda^3 n}{2^{3/2}}} \right)$$

where  $n$  is the atomic density and  $\lambda$  is the average thermal de-Broglie wavelength.

- (d) Prove that Dirac flux quantum is  $\left( \frac{hc}{e} \right)$ .

- (e) Prove that for non-degenerate Fermi gas

$$E_f = k_B T \ln \left( \frac{n \lambda^3}{2} \right) \text{ in 3D.}$$

- (f) What is Rushbrooke inequality?

(g) Plot magnetization  $M(T, H)$  vs  $T$  for  $H > 0$ ,  $H < 0$ ,  $H \rightarrow 0$  at  $T < T_c$ .

(h) Plot field-free specific heat of an Ising lattice in Bethe pearl and Bragg-William approximation in 2D with mathematical expression.

2. (a) For a zero-dimensional quantum system consisting of a single two-state object whose Hamiltonian can be expressed as

$$H = \begin{pmatrix} \epsilon & -\Delta \\ -\Delta & -\epsilon \end{pmatrix}$$

Prove that partition function can be expressed in terms of the partition function of an Ising model in one-dimensional chain of  $N$  sites. Also prove that ordering field

$$h = \frac{1}{2} \ln \left( \frac{N - \beta\epsilon}{N + \beta\epsilon} \right).$$

- (b) Find an expression of cut-off frequency of  $n$ -dimensional solid in Debye model. (3+2)+5

3. (a) Find an expression of density of states for n-dimensional free electron gas.
- (b) Prove that average energy per photon at  $10^3\text{k}$  is 0.56 eV.
- (c) A lattice of  $(N + 1)$  sites has spins  $S_i = \pm 1$  at each site, all of which are acted on by a magnetic field.

$$H = -h \sum_{i=0}^N S_i - J_c \sum_{i=1}^N S_i S_0.$$

Calculate  $\langle S_i \rangle$  and  $\langle S_0 S_i \rangle$ . (3+2)+(2+3)

---