# Autumn Semester Examination - 2023

**Course Code:** PHYPGCCT07
**Course Title:** Nuclear and Particle Physics-II
**Department of Appearing Students:** Physics, M. Sc. (1st Yr), SEM-II
**Full Marks:** 40 **Time:** 2.00 hrs

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[All notations bear conventional meaning]
**Use separate answer sheet for Group-A and Group-B**

## Group-A

Answer **any two** questions. Each quesiton carries 10 marks. $2 \times 10 = 20$

1. Define nuclear scattering cross-section (SCS) and nuclear reaction cross-section (NRCS). By the method of partial waves, derive an expression for the nuclear scattering cross-section. Explain why reaction is not possible without scattering. [2+6+2=10]

2. (a) Considering an attractive square-well nucleon-nucleon (NN) potential of depth $V_0$ and width $R_0$ write down the Schrödinger equation for deuteron. Hence obtain its analytical solution applying appropriate boundary conditions.

   (b) Using the above solution, make an estimate of the minimum depth of the square-well potential which is capable of supporting a deuteron bound state at energy 2.226 MeV. Take width of potential $R_0 = 2.4$ fm. , [7+3=10]

3. (a) With a suitable diagram explain the priciple of working of cyclotron. Derive an expression for the kinetic energy of particle of mass m, charge Q moving in a circular orbit of radius r in a cyclotron. Can a cyclotron accelerate electrons to high energies? Give argument in support of your answer.

   (b) A proton and an $\alpha$-particle are accelerated to the same energy in cyclotron. Find the ratio of their frequency of revolutions.

   [(3+2+2)+3 =10]

4. (a) What are the main components of a typical nuclear reactor?

   (b) What are the physical significances of positive and negative scattering lengths? **Or**, How can you distinguish between an orbital eletron and a $\beta^-$ particle?

   (c) Which two states among $^1P_1$, $^3S_1$,$^3P_1$,$^3D_1$ best represent the ground state of deuteron? Give explation in favour of your answer.

   (d) State four important roles of nuclear fusion reactions.

   [3+2+3+2 =10]

# Group-B

Answer **any two** questions. $10 \times 2 = 20$

1. a) Show that in units of $c = 1$, the relativistic factor

$$\gamma = \frac{1}{\sqrt{1 - v^2}} = \frac{E}{m_0}$$

and the velocity of a relativistic particle is given by $\overrightarrow{v} = \frac{\overrightarrow{p}}{E}$.

b) Define Laboratory frame and center-of-mass frame. 5+5

2. a) Show that the thresold kinetic energy of the beam particle in Lab frame is given by

$$T = \frac{m_f^2 - m_i^2}{2m_2}$$

where $m_f, m_i$ are the sum of final and initial masses respectively and $m_2$ is the rest mass of the target in Lab frame.

b) Explain the working principle of Cyclotron with a proper diagram. 5+5

3. a) Fill in the gaps with correct particle satisfying all the relevant conservation laws:

i) $p + \bar{p} \rightarrow n +$ _____
ii) $\tau^- \rightarrow e^- +$ _____ $+ \nu_\tau$
iii) $\pi^+ + n \rightarrow K^+$_____
iv) $p + p \rightarrow p + p + p +$ _____
v) $n + \pi^0 \rightarrow \pi^+$_____

b) Define Baryon number and lepton number. Why were such quantum numbers introduced? 5 + (1+1+3)