2025-05-05

NUCLEAR AND PARTICLE PHYSICS

Dept of Physics - SEAS

SRM University A.P

Registration Number: _____

Name: _____

Branch & Section: _____

SRM UNIVERSITY AP
Andhra Pradesh

SRM UNIVERSITY – AP, ANDHRA PRADESH

End Term Examination, May 2025

[Question Paper ID: **008592]**

Subject	: NUCLEAR AND PARTICLE PHYSICS	**Subject**	: PHY 305
Title		**Code**	
Batch	: 2022	**Max Marks**	: 50
Degree	: B.Sc.	**Duration**	: 2 hours
Branch	: Scie.	**QP Set**	: ---

Part A (10 × 2 Marks = 20 Marks)

Answer **any 10** Questions

		Marks	BL		CO
1.	Show: $\langle \vec{l}.\vec{s} \rangle_{j=l+1/2} - \langle \vec{l}.\vec{s} \rangle_{j=l-1/2} = \frac{1}{2}(2l+1)\hbar^2$, where $\vec{j}$ is the total angular momentum quantum number, $\vec{j} = (\vec{l} + \vec{s})$. [2]	2	2	3	1,2
2.	Determine the spin and parity of the ground state of ${}^{13}_{6}C$, ${}^{21}_{10}Ne$ in the nuclear shell model. [2]	2	2	3	2,3
3.	During a fission reaction, 0.15% of the mass of a uranium sample is lost. If the sample has a mass of 800 gm, calculate the energy released. [Given: $c = 3 \times 10^8$ m/s]. [2]	2	2	3	2,3
4.	A nucleus ${}^{A}_{Z}X$ emits two alpha and one beta positive particles. What is the final form ${}^{?}_{?}Y$? [2]	2	2	3	2,3
5.	Find the spin and parity of the ground state of ${}^{19}_{9}F$ and ${}^{16}_{8}O$ in nuclear shell model. [2]	2	2	3	2,3
6.	The alpha decay of ${}^{226}_{88}Ra$ is: ${}^{226}_{88}Ra \rightarrow {}^{222}_{88}Rn + {}^{4}_{2}He$. Find the disintegration energy of this process. [Given: Mass of ${}^{226}_{88}Ra$ = 226.02541 u, mas of ${}^{222}_{88}Rn$ = 222.01757 u, mass of ${}^{4}_{2}He$ = 4.0026 u and 1 u = 931.5 MeV/c^2]. [2]	2	2	3	2,3
7.	Can ${}^{19}_{9}F$ decay into ${}^{15}_{7}N$ by emitting an alpha particle? [Given: Masses are ${}^{19}F$ = 19.000 u, ${}^{15}N$ = 15 u and ${}^{4}He$ = 4.0026 u.] [2]	2	2	3	2,3
8.	How long will it take for 75% of a radioactive sample to decay? Given: Half life of the element is 1600 years. [2]	2	2	3	2,3
9.	Find the degeneracy of the 1d level. Also find all possible total angular momentum quantum numbers for this level. What will be the degeneracy of each level depending on the values of the total angular momentum quantum number? [2]	2	2	3	2,3
10.	Using Geiger's law estimate the range of ${}^{232}U$ alpha particles with energy E = 6 MeV. [Given: a = 0.315] [2]	2	2	3	2,3
11.	Find the energies (in eV unit) needed to remove a neutron from ${}^{16}_{8}O$ and then to remove a proton. Given: m_p = 1.0072 u and mass of neutron m_n = 1.0086 u. Masses of ${}^{15}_{8}O$ = 15.0030 u, ${}^{14}_{7}N$ = 14.0030 u and ${}^{16}_{8}O$ = 15.9949 u. [2]	2	2	3	1,2

Part B (3 × 10 Marks = 30 Marks)

Answer **any 3** Questions

		Marks	BL	CO
12.				

(a) Prove that the quantity

$$E^2 - p^2c^2 = m_0^2c^4$$

is Lorentz invariant. [5]

(b) A neutron decays into a proton, an electron, and an antineutrino:

$$n \rightarrow p + e^- + \bar{\nu}_e$$

Using the laws of relativistic kinematics, find the maximum kinetic energy the electron can have in this decay. You may assume $\bar{\nu}_e$ carries neglegible energy and proton is minimally recoiled. [Given: $m_n = 939.5$ MeV, $m_p = 938.2$ MeV and $m_e = 0.5$ Mev. You can use natural unit.] [5]

10	**10**	**3**	**4**	

13. (a) Identify element X and Y in the following reactions. [5]

$$^{60}_{27}Co \rightarrow ^{60}_{28}Ni + X + \bar{\nu}_e$$

$$^{210}_{84}Po \rightarrow ^{210}_{82}Pb + X$$

$$^{32}_{15}P \rightarrow ^{32}_{16}S + X + Y$$

$$^{11}_{6}C \rightarrow ^{11}_{5}B + X + Y$$

$$^{60}_{27}Co^* \rightarrow ^{60}_{27}Co + X$$

(b) Based on the conservation of baryon number, lepton number and charge, which of the following reactions are possible? [Mention about all these conservation explicitly in your answer] [5]

$$n \rightarrow \Lambda^0 + \bar{\nu}_e + \nu_e$$

$$\pi^0 \rightarrow \gamma + \gamma + \gamma$$

$$\mu^- + p \rightarrow n + \nu_\mu$$

$$\mu^- \rightarrow e^- + \nu_\tau + \bar{\nu}_\tau$$

$$\nu_\mu + \nu_\tau \rightarrow \mu^- + \tau^+$$

10	**10**	**4**	**2,3,4**

14. (a) What is the maximum possible shift in wavelength for a photon scattering off a free electron? [Given: $h = 6.62 \times 10^{-34}$ J.s, $m_e = 9.1 \times 10^{-31}$ kg and $c = 3 \times 10^8$ m/s.] [5]

(b) A photon with energy 1 MeV scatters at an angle of $\theta = 120°$. Using Compton theory find the kinetic energy of the recoiling electron. [5]

10	**10**	**3**	**2,3**

15. (a) Calculate the maximum kinetic energy of the beta particle emitted in the decay of ^{14}C $\rightarrow ^{14}$ N $+ e^- + \bar{\nu}$. [Given: Atomic mass of ^{14}C = 14.003242 u, Atomic mass of ^{14}N = 14.003074 u and $1u = 931\text{MeV}/c^2$. Ignore electron mass and use non-relativistic treatment. [5]

(b) A nucleus ^{40}K can decay both by electron capture and beta emission. Which decay mode is energetically more favorable and why? [Given: Atomic mass of ^{40}K = 39.963998 u, atomic mass of ^{40}Ca = 39.962591 u and atomic mass of ^{40}Ar = 39.962383 u]. Ignore electron mass and use non-relativistic treatment. [5]

10	**10**	**3**	**2,3**

16. (a) Determine the minimum energy required by an alpha particle to reach the surface of a $^{208}_{82}Pb$ nucleus. [Given: $Z_{Pb} = 82$, $Z_\alpha = 2$, $A_{Pb} = 208$ and $\frac{1}{4\pi\epsilon_0} = 8.9 \times 10^9\, Nm^2/C^2$] [5]

(b) For impact parameter $b = 0$ calculate the point of closest approach for an 8 MeV alpha particle incident on an Au nucleus. [Given: mass number and atomic number of Au is 197 and 79 respectively] [5]

10	**10**	**3**	**1,2**

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