D PHYSICS

CSIR-NET, GATE, SET, JEST, IIT-JAM, BARC, TIFR

Contact: 8830156303 | 8329503213

PHYSICAL SCIENCE

NUCLEAR PHYSICS

Previous Year Questions (Topic-Wise)

With Answer Key

CSIR-NET/JRF,GATE,JEST,TIFR

Basic Nuclear Ground State Properties

❖ **CSIR-NET PYQ**

1. The radius of a ${}^{64}_{29}\mathrm{Cu}$ nucleus is measured to be 4.8×10^{-13} cm.

(A) The radius of a ${}^{27}_{12}\mathrm{Mg}$ nucleus can be estimated to be

[CSIR JUNE 2011]

(a) 2.86×10^{-13} cm (b) 5.2×10^{-13} cm

(c) 3.6×10^{-13} cm (d) 8.6×10^{-13} cm

(B) The root-mean-square (rms) energy of a nucleon in a nucleus of atomic number A in its ground state varies as

[CSIR JUNE 2011]

(a) $A^{4/3}$ (b) $A^{1/3}$

(c) $A^{-1/3}$ (d) $A^{-2/3}$

2. The intrinsic electric dipole moment of a nucleus ${}^{A}_{Z}X$

[CSIR DEC 2013]

(a) increases with Z, but independent of A

(b) decreases with Z, but independent of A

(c) is always zero

(d) increases with Z and A

3. The range of the nuclear force between two nucleons due to the exchange of pions is 1.40fm. If the mass of the pion is $140\mathrm{MeV/c^2}$ and the mass of the rho-meson is $770\mathrm{MeV/c^2}$, then the range of the force due to exchange of rho mesons is

[CSIR JUNE 2017]

(a) 1.40fm (b) 7.70fm

(c) 0.25fm (d) 0.18fm

4. The tensor component of the nuclear force may be inferred from the fact that deuteron nucleus ${}^{2}_{1}\mathrm{H}$ **[CSIR JUNE 2022]**

(a) has only one bound state with total spin $S = 1$

(b) has a non-zero electric quadrupole moment in its ground state

(c) Is stable while triton ${}^{3}_{1}\mathrm{H}$ is unstable

(d) Is the only two nucleon bound state

5. The masses of proton, neutron, Polonium and Lead nuclei are as follows:

$$m_p = 1.007825\mathrm{a.u}, m_n = 1.008665\mathrm{a\cdot u}$$
$$m({}^{210}_{84}\mathrm{Po}) = 209.982876\mathrm{a.u}, m({}^{206}_{82}\mathrm{Pb}) = 205.974455\mathrm{a.u}$$

Binding energy of ${}^{4}_{2}\mathrm{He}$ is 28.80 MeV and

$$1\mathrm{a.u} = 931.99\frac{\mathrm{MeV}}{c^2}$$

The binding energies of ${}^{210}_{84}\mathrm{Po}$, ${}^{206}_{82}\mathrm{Pb}$ and the Q value of the α-decay of ${}^{210}_{84}\mathrm{Po}$ are closest to

[CSIR DEC 2024]

(a) 1645.21MeV, 1622.33MeV, 5.92MeV

(b) 1645.21MeV, 1622.33MeV, −5.92MeV

(c) 1545.21MeV, 1522.33MeV, −5.92MeV

(d) 1645.21MeV, 1522.33MeV, 5.92MeV

6. If the binding energies per nucleon of the nuclei $X(A = 240)$ and $Y(A = 120)$ are 7.6 MeV and 8.5 MeV respectively, the energy released in the symmetric fission, $X \to Y + Y$ is

[CSIR JUNE 2025]

(a) 94 MeV (b) 9.4MeV

(c) 108 MeV (d) 216 MeV

❖ **GATE PYQ**

1. The mean momentum of a nucleon in a nucleus with mass number A varies as **[GATE 2000]**

(a) A (b) A^2

(c) $A^{-2/3}$ (d) $A^{-1/3}$

2. The masses of a hydrogen atom, neutron and ${}^{238}\mathrm{U}_{92}$ are given by 1.0078, 1.0087 and 238.0508 respectively. The binding energy of ${}^{238}\mathrm{U}_{92}$ is therefore approximately equal to (taking 1 a.m.u. = 931.64MeV) **[GATE 2003]**

(a) 120MeV (b) 1500MeV

(c) 1600MeV (d) 1800MeV

3. The volume of a nucleus in an atom is proportional to the

[GATE 2004]

(a) mass number (b) proton number
(c)neutron number (d) electron number

4. The form factor

$$F(\vec{q}) = \int \exp\left(i\vec{q}\cdot\frac{\vec{r}}{\hbar}\right)\bar{\rho}(\vec{r})d^3r$$

of Rutherford scattering is obtained by choosing a delta function for the charge density $\rho(\vec{r})$. The value of the form factor is

[GATE 2004]

(a) unity (b) infinity

(c)zero (d) undefined

5. The order of magnitude of the binding energy per nucleon in a nucleus is

[GATE 2006]

(a) 10^{-5}MeV (b) 10^{-3}MeV

(c)0.1MeV (d) 10MeV

6. An O^{16} nucleus is spherical and has a charge radius R and a volume $V = \frac{4}{3}\pi R^3$. According to the empirical observation of the charge radii, the volume of the $_{54}Xe^{128}$ nucleus, assumed to be spherical is

[GATE 2008]

(a) 8 V (b) 2 V

(c)6.75 V (d) 1.89 V

7. Consider a nucleus with N neutrons and Z protons. If m_p, m_n and BE represent the mass of the proton the mass of the neutrons and the binding energy of the nucleus respectively and c is the velocity of light in free space, the mass of the nucleus is given by

[GATE 2009]

(a) $Nm_n + Zm_p$ (b) $Nm_p + Zm_n$

(c) $Nm_n + Zm_p + \frac{BE}{c^2}$ (d) $Nm_p + Zm_n + \frac{BE}{c^2}$

8. A proton is confined to a cubic box, whose sides have length 10^{-12} m. What is the minimum kinetic energy of the proton? The mass of proton is 1.67×10^{-27} kg and Planck's constant is 6.63×10^{-34}Js

(a) 1.1×10^{-17} J (b) 3.3×10^{-17} J
(c) 9.9×10^{-17} J (d) 6.6×10^{-17} J

9. The mean kinetic energy of a nuclear in a nucleus of atomic weight A varies as A^n, where n is (upto two decimal places)

[GATE 2015]

❖ **JEST PYQ**

1. The binding energy of the k-shell electron in a Uranium atom (Z = 92, A = 238) will be modified due to
(i) screening caused by other electrons and (ii) the finite extent of the nucleus as follows:

[JEST 2013]

(a) Increases due to (i), remains unchanged due to (ii).

(b) Decreases due to (i), decreases due to (ii).

(c)Increases due to (i), increases due to (ii).

(d) Decreases due to (i), remains unchanged due to (ii).

2. The stable nucleus that has $\frac{1}{3}$ the radius of ^{189}Os nucleus is,

[JEST 2015]

(a) ^7Li (b) ^{16}O

(c) ^4He (d) ^{14}N

❖ **TIFR PYQ**

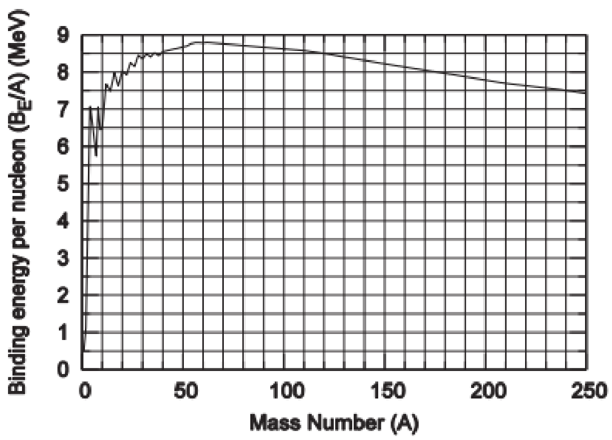
1. A proton is accelerated to a high energy E and shot at a nucleus of Oxygen ($^{16}_{8}O$). In order to penetrate the Coulomb barrier and reach the surface of the Oxygen nucleus, E must be at least

[TIFR 2012]

(a) 3.6MeV (b) 1.8MeV

(c) 45keV (d) 180Ev

2. In a theoretical model of the nucleus, the binding energy per nucleon was predicted as shown in the figure below.



If a nucleus of mass number $A = 240$ undergoes a symmetric fission to two daughter nuclei each of mass number $A = 120$, write down the amount of energy released in this process, in units of MeV, using this theoretical model.

[TIFR 2012]

Ans:240 MeV

❖ Answer Key				
CSIR-NET				
1. c	2. c	3. c	4. b	5. a
6. d				
GATE				
1. d	2. d	3. a	4. a	5. d
6. a	7. c	8. c	9.	
JEST				
1. b	2. a			
TIFR				
1. a	2. 240 MeV			

Properties Of Nuclear Force

❖ **CSIR-NET PYQ**

1. In a classical model, a scalar (spin-0) meson consists of a quark and an antiquark bound by a potential

$$V(r) = ar + \frac{b}{r}$$

where $a = 200\text{MeVfm}^{-1}$ and $b = 100\text{MeVfm}$. If the masses of the quark and antiquark are negligible, the mass of the meson can be estimated as approximately

[CSIR JUNE 2014]

(a) $141\text{MeV}/c^2$ (b) $283\text{MeV}/c^2$

(c) $353\text{MeV}/c^2$ (d) $425\text{MeV}/c^2$

2. The range of the nuclear force between two nucleons due to the exchange of pions is 1.40fm. If the mass of the pion is $140\text{MeV}/c^2$ and the mass of the rho-meson is $770\text{MeV}/c^2$, then the range of the force due to exchange of rho mesons is **[CSIR JUNE 2017]**

(a) 1.40fm (b) 7.70fm

(c) 0.25fm (d) 0.18fm

3. The strong nuclear force between a neutron and a proton in a zero orbital angular momentum state is denoted by $F_{np}(r)$, where r is the separation between them. Similarly, $F_{nn}(r)$ and $F_{pp}(r)$ denote the forces between a pair of neutrons and protons, respectively, in zero orbital momentum state. Which of the following is true on average if the inter-nucleon distance is $0.2\text{fm} < r < 2\text{fm}$?

[CSIR DEC 2019]

(a) F_{np} is attractive for triplet spin state, and F_{nn}, F_{pp} are always repulsive.

(b) F_{nn} and F_{np} are always attractive and F_{pp} is repulsive in this triplet spin state.

(c) F_{pp} and F_{np} are always attractive and F_{nn} is always repulsive.

(d) All three forces are always attractive.

4. The tensor component of the nuclear force may be inferred from the fact that deuteron nucleus ^2_1H **[CSIR JUNE 2022]**

(a) has only one bound state with total spin $S = 1$

(b) has a non-zero electric quadrupole moment in its ground state

(c) Is stable while triton ^3_1H is unstable

(d) Is the only two nucleon bound state

❖ **GATE PYQ**

1. As one moves along the of stability from ^{56}Fe to ^{235}U nucleus, the nuclear binding energy per particle decreases from about 8.8MeV to 7.6MeV. This trend is mainly due to the

[GATE 2004]

(a) short range nature of the nuclear forces

(b) long range nature of the Coulomb forces

(c) tensor nature of the nuclear forces

(d) spin dependence of the nuclear forces

2. With reference to nuclear forces which of the following statements is NOT true? The nuclear forces are

[GATE 2005]

(a) short range

(b) charge independent

(c) velocity dependent

(d) spin independent

3. Weak nuclear forces act on

[GATE 2006]

(a) both hadrons and leptons

(b) hadrons only

(c) all particles

(d) all charged particle

4. A heavy nucleus is found to contain more neutrons than protons. This fact is related to which one of the following statements.

[GATE 2008]

(a) The nuclear force between neutrons is stronger than that between protons.

(b) The nuclear force between protons is of a shorter range than those between neutrons, so that a smaller number of protons are held together by the nuclear force.

(c)Protons are unstable, so their number in a nucleus diminishes

(d) It costs more energy to add a proton to a (heavy) nucleus than a neutron because of the coulomb repulsion between protons

5. Pick the wrong **[GATE 2009]**

(a) The nuclear force is independent of electric charge

(b) The Yukawa potential is proportional to $r^{-1}\exp\left(\frac{mc}{\hbar}r\right)$, where r is the separation betweeing two nucleus

(c)The range of nuclear force is of the order of $10^{-15}\ \mathrm{m} - 10^{-14}\ \mathrm{m}$

(d) The nucleons interact among each other by the exchange of mesons

❖ Answer Key				
CSIR-NET				
1. b	2. c	3. b	4. b	
GATE				
1. b	2. d	3. c	4. d	5. b

Nuclear Model

❖ **CSIR-NET PYQ**

1. According to the shell model the spin and parity of the two nuclei ${}^{125}_{51}\mathrm{Sb}$ and ${}^{89}_{38}\mathrm{Sr}$ are, respectively.

[CSIR DEC 2011]

(a) $\left(\frac{5}{2}\right)^{+}$ and $\left(\frac{5}{2}\right)^{+}$ (b) $\left(\frac{5}{2}\right)^{+}$ and $\left(\frac{7}{2}\right)^{+}$

(c) $\left(\frac{7}{2}\right)^{+}$ and $\left(\frac{5}{2}\right)^{+}$ (d) $\left(\frac{7}{2}\right)^{*}$ and $\left(\frac{7}{2}\right)^{+}$

2. The difference in the Coulomb energy between the mirror nuclei ${}^{49}_{24}\mathrm{Cr}$ and ${}^{49}_{25}\mathrm{Mn}$ is 6.0MeV. Assuming that the nuclei have a spherically symmetric charge distribution and that e^2 is approximately 1.0MeV-fm, the radius of the ${}^{99}_{25}\mathrm{Mn}$ nucleus is

[CSIR DEC 2011]

(a) 4.9×10^{-13} m (b) 4.9×10^{-15} m

(c) 5.1×10^{-13} m (d) 5.1×10^{-15} m

3. The single particle energy difference between the p-orbitals (i.e. $p_{3/2}$ and $p_{1/2}$) of the nucleus ${}^{114}_{50}\mathrm{Sn}$ is 3 MeV . The energy difference between the states in its $1f$ orbital is

[NET Dec. 2012]

(a) -7 MeV (b) 7 MeV

(c) 5 MeV (d) -5 MeV

4. The binding energy of a light nucleus (Z, A) in MeV is given by the approximate formula

$$B(A, Z) \approx 16A - 20A^{2/3} - \frac{3}{4}Z^2A^{-1/3} + 30\frac{(N-Z)^2}{A}$$

where $N = A - Z$ is the neutron number. The value of Z of the most stable isobar for a given A is

[CSIR JUNE 2013]

(a) $\frac{A}{2}\left(1 - \frac{A^{2/3}}{160}\right)^{-1}$ (b) $\frac{A}{2}$

(c) $\frac{A}{2}\left(1 - \frac{A^{2/3}}{120}\right)^{-1}$ (d) $\frac{A}{2}\left(1 + \frac{A^{4/3}}{64}\right)$

5. According to the shell model, the total angular momentum (in units of $\hbar$) and the parity of the ground state of the ${}^{7}_{3}\mathrm{Li}$ nucleus is

[CSIR DEC 2013]

(a) $\frac{3}{2}$ with negative parity

(b) $\frac{3}{2}$ with positive parity

(c) $\frac{1}{2}$ with positive parity

(d) $\frac{7}{2}$ with negative parity

6. A permanently deformed even-even nucleus with $J^P = 2^+$ has rotational energy 93keV. The energy of the next excited state is

[CSIR JUNE 2014]

(a) 372keV (b) 310keV

(c) 273keV (d) 186keV

7. If the binding energy B of a nucleus (mass number A and charge Z) is given by

$$B = a_V A - a_S A^{2/3} - a_{sym}\frac{(2Z-A)^2}{A} - \frac{a_c Z^2}{A^{1/3}}$$

where $a_V = 16\mathrm{MeV}, a_S = 16\mathrm{MeV}, a_{sy\,m} = 24\mathrm{MeV}$ and $a_t = 0.75\mathrm{MeV}$, then the Z for the most stable isobar for a nucleus with $A = 216$ is

[CSIR DEC 2014]

(a) 68 (b) 72

(c) 84 (d) 92

8. The electric quadrupole moment of an odd proton nucleus is

$$\frac{(2j-1)}{2(j+1)}\langle r^2\rangle$$

, where j is the total angular momentum. Given that $R_0 = 1.2\mathrm{fm}$, what is the value, in barn, of the quadrupole moment of the ${}^{27}\mathrm{Al}$ nucleus in the shell model?

[NET Dec. 2015]

(a) 0.043 (b) 0.023

(c) 0.915 (d) 0

9. Let us approximate the nuclear potential in the shell model by a 3-dimensional isotropic harmonic oscillator. Since the lowest two energy levels have angular momenta $l = 0$ and $l = 1$ respectively, which of the following two nuclei have magic numbers of protons and neutrons?

[CSIR JUNE 2015]

(a) ${}_{2}^{4}\mathrm{He}$ and ${}_{8}^{16}\mathrm{O}$
(b) ${}_{1}^{2}\mathrm{D}$ and ${}_{4}^{8}\mathrm{Be}$
(c) ${}_{2}^{4}\mathrm{He}$ and ${}_{4}^{8}\mathrm{Be}$
(d) ${}_{2}^{4}\mathrm{He}$ and ${}_{6}^{12}\mathrm{Be}$

10. Of the nuclei of mass number $A = 125$, the binding energy calculated from the liquid drop model (given that the coefficients for the Coulomb and the asymmetry energy are $a_c = 0.7\mathrm{MeV}$ and $a_{synt} = 22.5\mathrm{MeV}$ respectively) is a maximum for

[CSIR DEC 2015]

(a) ${}_{54}^{125}\mathrm{Xe}$
(b) ${}_{53}^{125}\mathrm{I}$
(c) ${}_{52}^{125}\mathrm{Te}$
(d) ${}_{51}^{125}\mathrm{Sb}$

11. According to the shell model, the nuclear magnetic moment of the ${}_{13}^{27}\mathrm{Al}$ nucleus is (Given that for a proton $g_i = 1, g_i = 5.586$, and for a neutron $g_i = 0, g_i = -3.826$).

[NET June 2016]

(a) $-1.913\mu_N$
(b) $14.414\mu_N$
(c) $4.793\mu_N$
(d) 0

12. Let E_S denote the contribution of the surface energy per nucleon in the liquid drop model. The ratio $E_S({}_{13}^{27}\mathrm{Al}) : E_S({}_{30}^{64}\mathrm{Zn})$ is

[CSIR JUNE 2016]

(a) $2:3$
(b) $4:3$
(c) $5:3$
(d) $3:2$

13. The spin-parity assignments for the ground and first excited states of the isotropy ${}_{28}^{57}\mathrm{Ni}$, in the singlo particle shell model, are

[CSIR DEC 2017]

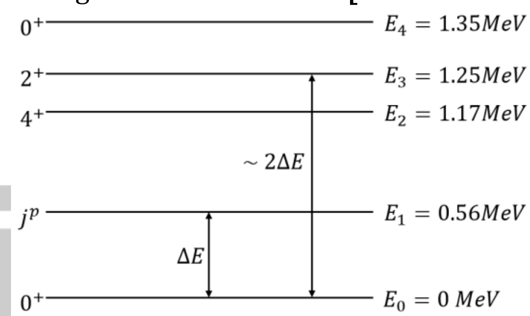
(a) $\left(\frac{1}{2}\right)^-$ and $\left(\frac{3}{2}\right)^-$
(b) $\left(\frac{5}{2}\right)^+$ and $\left(\frac{7}{2}\right)^+$
(c) $\left(\frac{3}{2}\right)^+$ and $\left(\frac{5}{2}\right)^+$
(d) $\left(\frac{3}{2}\right)^-$ and $\left(\frac{5}{2}\right)^-$

14. The first excited state of the rotational spectrum of the nucleus ${}_{92}^{238}\mathrm{U}$ has an energy 45keV above the ground state. The energy of the second excited state (in keV), is

[CSIR DEC 2017]

(a) 150
(b) 120
(c) 90
(d) 60

15. The low lying energy levels due to the vibrational excitations of an even-even nucleus are shown in the figure below. **[CSIR DEC 2018]**



The spin-parity j^p of the level E_1 is

(a) 1^+
(b) 1^-
(c) 2^-
(d) 2^+

16. The Bethe-Weizsäecker formula for the binding energy (in MeV) of a nucleus of atomic number Z and mass number A is **[CSIR DEC 2019]**

$$15.8\mathrm{A} - 18.3\mathrm{A}^{2/3} - 0.714\frac{\mathrm{Z(Z-1)}}{\mathrm{A}^{1/3}} - 23.2\frac{(\mathrm{A}-2\mathrm{Z})^2}{\mathrm{A}}$$

The ratio Z/A for the most stable isobar of $A = 64$ nucleus, is nearest to

[CSIR DEC 2019]

(a) 0.30
(b) 0.35
(c) 0.45
(d) 0.50

17. The binding energy B of a nucleus is approximated by a formula:

$$B = a_1A - a_2A^{2/3} - a_3Z^2A^{-1/3} - a_4(A - 2Z)^2A^{-1}$$

[NET Nov. 2020]

where Z is the atomic number and A is the mass number of the nucleus. If $\frac{a_4}{a_3} = 30$, the atomic number Z for naturally stable isobars (constant value of A) is

(a) $\frac{30A}{60 + A^{2/3}}$
(b) $\frac{30A}{30 + A^{2/3}}$

(c) $\frac{60A}{120 + A^{2/3}}$ (d) $\frac{120A}{60 + A^{2/3}}$

18. The magnetic moments of a proton and a neutron are $2.792\mu_N$ and $-1.913\mu_N$, where μ_N is the nucleon magnetic moment. The values of the magnetic moments of the mirror nuclei ${}^{19}_{9}\mathrm{F}_{10}$ and ${}^{19}_{10}\mathrm{Ne}_{9}$, respectively, in the Shell model, are closest to

[CSIR DEC 2020]

(a) $23.652\mu_N$ and $-18.873\mu_N$

(b) $26.283\mu_N$ and $-16.983\mu_N$

(c) $-2.628\mu_N$ and $1.887\mu_N$

(d) $2.628\mu_N$ and $-1.887\mu_N$

19. The energy (in keV) and spin-parity values $E(J^P)$ of the low-lying excited states of a nucleus of mass number $A = 152$ are $122(2^+), 366(4^+), 707(6^+)$ and $1125(8^+)$. It may be inferred that these energy levels correspond to a **[CSIR JUNE 2023]**

(a) rotational spectrum of a deformed nucleus

(b) rotational spectrum of a spherically symmetric nucleus

(c) vibrational spectrum of a deformed nucleus

(d) vibrational spectrum of a spherically symmetric nucleus

20. In a shell model description, neglecting Coulomb effects, which of the following statements for the energy and spin-parity is correct for the first excited state of $A = 12$ isobars ${}^{12}_{5}\mathrm{B}$, ${}^{12}_{6}\mathrm{C}$, ${}^{12}_{7}\mathrm{N}$?

[CSIR DEC 2023]

(a) same for ${}^{12}_{5}\mathrm{B}$, ${}^{12}_{6}\mathrm{C}$ and ${}^{12}_{7}\mathrm{N}$

(b) different for each ${}^{12}_{5}\mathrm{B}$, ${}^{12}_{6}\mathrm{C}$ and ${}^{12}_{7}\mathrm{N}$

(c) same for ${}^{12}_{6}\mathrm{C}$ and ${}^{12}_{7}\mathrm{N}$, but different for ${}^{12}_{5}\mathrm{B}$

(d) same for ${}^{12}_{5}\mathrm{B}$ and ${}^{12}_{7}\mathrm{N}$, but different for ${}^{12}_{6}\mathrm{C}$

21. A rigid molecule can have two possible rotational states: $j = 0$ or $j = 1$. Its rotational energies are given by $\epsilon_J = \frac{\hbar^2}{2I} j(j+1)$, where I is its moment of inertia. For an ensemble of such molecules in thermal equilibrium at temperature T, the ratio of the number of molecules in the $j = 1$ state (N_1), to those in $j = 0$ state (N_0), is $\frac{N_1}{N_0} = 0.003$. The temperature T (in units of $\frac{\hbar^2}{2Ik_B}$, where k_B is the Boltzmann constant) is closest to

[CSIR JUNE 2025]

(a) 0.29 (b) 0.21

(c) 0.15 (d) 0.34

❖ **GATE PYQ**

1. The nuclear spins of ${}_{6}\mathrm{C}^{14}$ and ${}_{12}\mathrm{Mg}^{25}$ nuclei are respectively

[GATE 2002]

(a) zero and half-integer

(b) half-integer and zero

(c) an integer and half-integer

(d) both half-integers

2. The spin and parity of ${}_{4}\mathrm{Be}^{9}$ nucleus, as predicted by the shell model, are respectively.

[GATE 2002]

(a) 3/2 and odd (b) 1/2 and odd

(c) 3/2 and even (d) 1/2 and even

3. The single particle states occupied by the last proton and the last neutron, respectively, are given by

[GATE 2004]

(a) $d_{5/2}$ and $f_{7/2}$ (b) $d_{3/2}$ and $f_{5/2}$

(c) $d_{5/2}$ and $f_{5/2}$ (d) $d_{3/2}$ and $f_{7/2}$

Common Data for Q. 4 and Q.5:
The nucleus ${}^{41}\mathrm{Ca}$ can be described by the single particle shell model.

4. The ground state angular momentum and parity of ${}^{41}\mathrm{Ca}$ are

[GATE 2004]

(a) $\frac{7}{2^-}$ (b) $\frac{3}{2^+}$

(c) $\frac{5}{2^+}$ (d) $\frac{5}{2^-}$

5. Which of the following expressions for total binding energy B of a nucleus is correct $(a_1, a_2, a_3, a_4 > 0)$?

[GATE 2005]

(a) $B = a_1A - a_2A^{2/3} - a_3\frac{Z(Z-1)}{A^{1/3}} - a_4\frac{(A-2Z)^2}{A} + \delta$

(b) $B = a_1A + a_2A^{2/3} - a_3\frac{Z(Z-1)}{A^{1/3}} - a_4\frac{(A-2Z)^2}{A} + \delta$

(c) $B = a_1A + a_2A^{1/3} - a_3\frac{Z(Z-1)}{A^{1/3}} - a_4\frac{(A-2Z)^2}{A} + \delta$

(d) $B = a_1A - a_2A^{1/3} - a_3\frac{Z(Z-1)}{A^{1/3}} - a_4\frac{(A-2Z)^2}{A} + \delta$

6. According to the shell model, the ground state of ${}^{15}_{8}O$ nucleus is

[GATE 2005]

(a) $\frac{3^+}{2}$ (b) $\frac{1^+}{2}$

(c) $\frac{3^-}{2}$ (d) $\frac{1^-}{2}$

7. The experimentally measured sping factors of proton and a neutron indicate that

[GATE 2006]

(a) Both proton and neutron are elementary point particles

(b) Both proton and neutron are not elementary point particles

(c)While proton is an elementary point particle, neutron is not

(d) While neutron is an elementary point particle, proton is not

8. According to the shell model the ground state spin of the ${}^{17}O$ nucleus is

[GATE 2007]

(a) $\frac{3^+}{2}$ (b) $\frac{5^+}{2}$

(c) $\frac{3^-}{2}$ (d) $\frac{5^-}{2}$

9. The following gives a list of pairs containing (I) a nucleus (ii) one of its properties. Find the pair which is inappropriate.

[GATE 2008]

(a) (I) ${}_{10}Ne^{20}$ nucleus;
(ii) stable nucleus

(b) (I) A spheroidal nucleus;
(ii) an electric quadrupole moment

(c)(I) ${}_{8}O^{16}$ nucleus;
(ii) nuclear spin $J = 1/2$

(d) (I) U^{238} nucleus;
(ii) Binding energy = 1785MeV (approximately)

10. The four possible configuration of neutrons in the ground state of ${}_{4}Be^{9}$ nucleus, according to the shell model, and the associated nuclear spin are listed below. Choose the correct one:

[GATE 2008]

(a) $(1s_{1/2})^2(1p_{3/2})^3; J = 3/2$

(b) $(1s_{1/2})^2(1p_{1/2})^2(1p_{3/2})^1; J = 3/2$

(c) $(1s_{1/2})^1(1p_{3/2})^4; J = 1/2$

(d) $(1s_{1/2})^2(1p_{3/2})^2(1p_{1/2})^1; J = 1/2$

11. The mass difference between the pair of mirror nuclei ${}_{6}C^{11}$ and ${}_{5}B^{11}$ is given to be $\Delta MeV/c^2$.

According to the semi-empirical mass formula, the mass difference between the pair of mirror nuclei ${}_9F^{17}$ and ${}_8O^{17}$ will approximately be (rest mass of proton $m_p = 938.27 MeV/c^2$ and rest mass of neutron $m_n = 939.57 MeV/c^2$)

[GATE 2008]

(a) $1.39\Delta MeV/c^2$

(b) $(1.39\Delta + 0.5) MeV/c^2$

(c) $0.86\Delta MeV/c^2$

(d) $(1.6\Delta + 0.78) MeV/c^2$

12. Consider the following expression for the mass of a nucleus with Z protons and A nucleons:

$$M(A,Z) = \frac{1}{c^2}(f(A) + yZ + zZ^2)$$

. Here f(A) is a function of A

$$y = -4a$$
$$z = a_c A^{-1/3} + 4a_A A^{-1}$$

a_A and a_c are constants of suitable dimensions. For a fixed A, the expression of Z for the most stable nucleus is

[GATE 2009]

(a) $Z = \dfrac{A/2}{1 + \left(\frac{a_c}{a_A}\right) A^{2/3}}$ (b) $Z = \dfrac{A/2}{1 + \left(\frac{a_c}{4a_A}\right) A^{2/3}}$

(c) $Z = \dfrac{A}{1 + \left(\frac{a_c}{4a_A}\right) A^{2/3}}$ (d) $Z = \dfrac{A}{1 + A^{2/3}}$

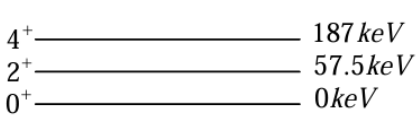
13. In the nuclear shell model the spin parity of ${}^{15}N$ is given by

[GATE 2010]

(a) $\frac{1^-}{2}$ (b) $\frac{1^+}{2}$

(c) $\frac{3^-}{2}$ (d) $\frac{3^+}{2}$

14. The first three energy levels of ${}^{228}Th_{90}$ are show below



The expected spin-pairty and energy of the next level are given by

[GATE 2010]

(a) $(6^+; 400 keV)$ (b) $(6^+; 300 keV)$

(c) $(2^+; 400 keV)$ (d) $(4^+; 300 keV)$

15. The semi – empirical mass formula for the binding energy of nucleus contains a surface correction term. This term depends on the mass number A of the nucleus as

[GATE 2011]

(a) $A^{-1/3}$ (b) $A^{1/3}$

(c) $A^{2/3}$ (d) A

16. According to the single particle nuclear shell model, the spin parity of the ground state of ${}^{17}_{8}O$ is

[GATE 2011]

(a) $\frac{1^-}{2}$ (b) $\frac{3^-}{2}$

(c) $\frac{3^+}{2}$ (d) $\frac{5^+}{2}$

17. Total binding energies of O^{15}, O^{16} and O^{17} are 111.96MeV, 127.62MeV and 131.76 MeV , respectively. The energy gap between ${}^1p_{1/2}$ and ${}^1d_{1/2}$ neutron shells for the nuclei whose mass number is close to 16 , is: **[GATE 2012]**

(a) 4.1 MeV (b) 11.5 MeV

(c) 15.7 MeV (d) 19.8 MeV

Statement for Linked Answer Q. 18 and Q.19:

In the Schmidt modei of nuclear magnetic moments, we have,

$$\vec{\mu} = \frac{e\hbar}{2Mc}(g_l \vec{l} + g_s \vec{S})$$

where the symbols have their usual meaning

18. For the case $J = l + 1/2$, where J is the total angular momentum, the expectation value of $\vec{S} \cdot \vec{J}$ in the nuclear ground state is equal to

[GATE 2013]

(a) $\dfrac{(J-1)}{2}$ (b) $\dfrac{(J+1)}{2}$

(c) $\frac{J}{2}$ (d) $-\frac{J}{2}$

19. For the O^{17} nucleus $(A = 17, Z = 8)$, the effective magnetic moment is given by

$$\vec{\mu}_{eff} = \frac{e\hbar}{2Mc} g\vec{J},$$

where g is equal to, ($g_s = 5.59$ for proton and -3.83 for neutron)

[GATE 2013]

(a) 1.12 (b) −0.77

(c) −1.28 (d) 1.28

20. A nucleus X undergoes a first forbidden β-decay to a nucleus Y. If the angular momentum (I) and parity

(P) denoted by I^P as $\frac{7^-}{2}$ for X, which of the following is a possible I^P value for Y ?

[GATE 2014]

(a) $\frac{1}{2}$ (b) $\frac{1^-}{2}$

(c) $\frac{3^+}{2}$ (d) $\frac{3^-}{2}$

21. In the nuclear shell model, the potential is modeled as $V(r) = \frac{1}{2}m\omega^2 r^2 - \lambda\vec{L}\cdot\vec{S}, \lambda > 0$. The correct spin parity and isospin assignments for the ground state of ^{13}C is

[GATE 2015]

(a) $\frac{1}{2}; -\frac{1}{2}$ (b) $\frac{1^+}{2}; -\frac{1}{2}$

(c) $\frac{3}{2}; \frac{1}{2}$ (d) $\frac{3}{2}; -\frac{1}{2}$

22. According to the nuclear shell model, the respective ground state spin-parity values of $^{15}_{8}O$ and $^{17}_{8}O$ nuclei are

[GATE 2016]

(a) $\frac{1}{2}, \frac{1}{2}$ (b) $\frac{1^-}{2}, \frac{5^+}{2}$

(c) $\frac{3^-}{2}, \frac{5^+}{2}$ (d) $\frac{3^-}{2}, \frac{1^-}{2}$

23. J^P for the ground state of the $^{13}C_6$ nucleus is

[GATE 2017]

(a) 1^+ (b) $\frac{3}{2}$

(c) $\frac{3^+}{2}$ (d) $\frac{1}{2}$

24. For nucleus ^{164}Er, a $J^\pi = 2^+$ state is at 90 keV. Assuming ^{164}Er to be a rigid rotor, the energy of its 4^+ state is keV (up to one decimal place)

[GATE 2018]

300

25. 4MeVγ-rays emitted by the de-excitation of ^{10} F are attributed, assuming spherical symmetry, to the transition of protons from 1 d_{32} state. If the contribution of spin-orbit term to the total energy is written as $C(\hat{l}\_\bar{s})$, the magnitude of C is………… MeV (up to one decimal place).

[GATE 2018]

26. The nuclear spin and parity of $^{40}_{20}$, Ca in its ground state is **[GATE 2019]**

(a) 0^+ (b) 0^-

(c) 1^+ (d) 1^-

27. The total angular momentum j of the ground state of the $^{17}_{8}O$ nucleus is

[GATE 2020]

(a) $\frac{1}{2}$ (b) 1

(c) $\frac{3}{2}$ (d) $\frac{5}{2}$

28. According to the Fermi gas model of nucleus, the nucleons move in a spherical volume of radius $R\left(= R_0 A^{\frac{1}{3}}\right.$, where A is the mass number and R_0 is an empirical constant with the dimensions of length). The Fermi energy of the nucleus E_F is proportional to

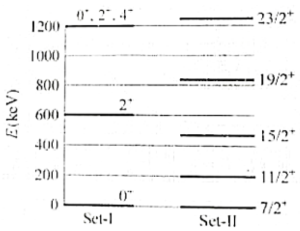
[GATE 2020]

(a) R_0^2 (b) $\frac{1}{R_0}$

(c) $\frac{1}{R_0^2}$ (d) $\frac{1}{R_0^3}$

29. For the given sets of energy levels of nuclei X and Y whose mass number are odd and even, respectively, choose the best suited interpretation.

[GATE 2021]



(a) Set-I: Vibrational band of X

Set-II: Rotational band of Y

(b) Set-I: Rotational band of Y
Set-II: Vibrational band of X

(c)Set-I: Rotational band of X
Set-II: Vibrational band of Y

(d) Set-I: Vibrational band of Y
Set-II: Rotational band of X

30. The Coulomb energy component in the binding energy of a nucleus is 18.432 MeV . If the radius of the uniform and spherical charge distribution in the nucleus is 3 fm , the corresponding atomic number (rounded off to the nearest integer) is

$$\left[\text{Given: } \frac{e^2}{4\pi\varepsilon_0} = 1.44\text{MeVfm}\right]$$

[GATE 2021]

31. In an experiment, it is seen that an electric-dipole ($E1$) transition can connect an initial nuclear state of spin parity $J_i^\pi = 2^+$to final state J_f^π. All possible values of J_f^π are

[GATE 2021]

(a) $1^+, 2^+, 3^+$ (b) $1^-, 2^-$

(c)$1^-, 2^-, 3^-$ (d) $1^+, 2^+$

32. Under parity and time reversal transformations, which of the following statements is (are) TRUE about the electric dipole moment $\vec{p}$ and the magnetic dipole moment $\vec{\mu}$?

[GATE 2023]

(a) $\vec{p}$ is odd under parity and $\vec{\mu}$ is odd under time reversal

(b) $\vec{p}$ is odd under parity and $\vec{\mu}$ is even under time reversal

(c)$\vec{p}$ is even under parity and $\vec{\mu}$ is odd under time reversal

(d) $\vec{p}$ is even under parity and $\vec{\mu}$ is even under time reversal

33. According to the nuclear shell model, the absolute value of the difference in magnetic moments of ${}^{15}_{8}\text{O}$ and ${}^{15}_{7}\text{N}$, in the units of nuclear magneton (μ_N) is a/3. The magnitude of a is (in integer).

[GATE 2024]

❖ **TIFR PYQ**

1. In the semi-empirical mass formula, the volume (V), surface (S), coulomb (C), and pairing (P) contributions to the binding energy of a nucleus ${}^{A}_{Z}X$ vary with mass number A as

[TIFR 2015]

(a) $V \propto A$, $S \propto A^{2/3}$, $C \propto A^{-1/3}$, $P \propto A^{-3/4}$

(b) $V \propto A$, $S \propto A^{1/3}$, $C \propto A^{-1/3}$, $P \propto A^{-3/4}$

(c)$V \propto A$, $S \propto A^{-2/3}$, $C \propto A^{1/3}$, $P \propto A^{-3/4}$

(d) $V \propto A^2$, $S \propto A^{2/3}$, $C \propto A^{-1/3}$, $P \propto A^{-3/4}$

2. The Weizäcker semi-empirical mass formula for an odd nucleus with Z protons and A nucleons may be written as $M(Z,A) = \alpha_1 A + \alpha_2 A^{2/3} + \alpha_3 Z + \alpha_4 Z^2$ where the α_i are constants independent of Z, A. For a given A, if Z_A is the number of photons of the most stable isobar, the total energy released when an unstable nuclide undergoes a single β^-decay to (Z_A, A) is

[TIFR 2016]

(a) α_3 (b) α_4

(c)$\alpha_4 - \alpha_3$ (d) $\alpha_1 + \alpha_2$

3. The semi-empirical mass formula for a heavy nucleon (Z, A) can be written, to some approximation, as

$$M(Z,A)c^2 = ZM_pc^2 + (A-Z)M_nc^2 - \lambda_4 A - \lambda_2 A^{2/3} - \lambda_3 \frac{Z(Z-1)}{A^{1/3}} - \lambda_4 \frac{(A-2Z)^2}{A} - \frac{\lambda_5}{A^{1/2}}$$

where $M_pc^2 = 938\text{MeV}, M_nc^2 = 939\text{MeV}$, and $\lambda_1 = 16, \lambda_2 = 18, \lambda_3 = 0.7, \lambda_4 = 23$, all in MeV, where

$$\lambda_5 = \begin{cases} +12 & \text{MeV for even - even nuclei} \\ -12 & \text{MeV for odd - odd nuclei} \\ 0 & \text{for others} \end{cases}$$

Now, consider a spontaneous fission reaction

$$^{238}_{92}\text{U} \rightarrow {}^{146}_{56}\text{Ba} + {}^{91}_{36}\text{Kr} + {}^{1}_{0}\text{n}$$

The energy released in this reaction will be close to

[TIFR 2019]

(a) 190 MeV (b) 170 MeV

(c)17.92 keV (d) 19.2 MeV

4. In the shell model of the nucleus, it is known that orbitals get filled in the order

$1s_{1/2}\ 1p_{3/2}\ 1p_{1/2}\ 1d_{5/2}\ 2s_{1/2}\ 1d_{3/2}$ and so on …..

[TIFR 2022]

For a nucleus of $^{18}_{8}$O the two neutrons outside the doubly-magic core of $^{16}_{8}$O will occupy the same orbital.

The allowed value of J^p will be

(a) 5^+ (b) 4^+

(c)3^+ (d) 2^-

5. The binding energy ε_b of a nuclide ^Z_AX with atomic number Z and mass number A is given by the semiempirical formula:

|TIFR2023]

$$\varepsilon_b = a_V A - a_S A^{2/3} - a_C \frac{Z(Z-1)}{A^{1/3}} + a_A \frac{(A-2Z)^2}{A}$$

where the constant parameters and source of effect for each term are:

Volume term	Surface term	Coulomb term	Asymmetry term
a_V	a_S	a_C	a_A
15.56 MeV	17.8 MeV	0.7 MeV	23.29 MeV

What is the mass difference between the two-mirror nuclei $^{13}_{6}$C and $^{13}_{7}$ N ? It is known that both of them are spherical in shape and have a uniform charge distribution.

(a) 2.62 MeV (b) 3.40 MeV

(c)1.84 MeV (d) 0.78 MeV

6. The binding energy ε_b of a nuclide $_zX^A$ with atomic number and mass number A is given by the semi-empirical formula

$$\varepsilon_b = a_v A - a_s A^{2/3} - \frac{a_c Z(Z-1)}{A^{1/3}} + a_a \frac{(A-2Z)^2}{A}$$

where the constant parameters and source of effect for each term are

Volume term	Surface term	Coulomb term	Asymmetry term
a_v	a_s	a_c	a_a
15.56 MeV	17.8 MeV	0.7 MeV	23.29 MeV

For a spherical neutron star consisting of only neutrons and having uniform nuclear density throughout its volume, the Coulomb term is replaced by gravitational energy. What would be the smallest radius of this neutron star?

(a) 4.34 km (b) 10.435 km

(c)2.165 km (d) 4.345 km

7. Oxygen (O) nuclei ($Z = 8$) can be approximated as non-interacting protons and neutrons filling up orbitals in the following order.

$1s_{1/2}$, $1p_{3/2}$, $1p_{1/2}$, $1d_{5/2}$, $2s_{1/2}$, $1d_{3/2}$, ...

where the subscript specifies the J quantum number. Given the binding energy of O ($A = 15$) is 111.96MeV, O($A = 16$) is 127.62MeV, and O($A = 17$) is 131.76MeV, what is the difference between the energies of the $1p_{1/2}$ and the $1d_{5/2}$ orbitals? **[TIFR2024]**

(a) 11.52MeV (b) 15.66MeV

(c)4.14MeV (d) 19.81MeV

8. In the shell model of a nucleus, states of nucleons (protons or neutrons) in a spherically symmetric potential are labelled as nL_j, where n is the principal quantum number, L is the angular momentum quantum number (s, p, d, f correspond to $L = 0,1,2,3$ respectively), and $\hat{j} = \hat{L} + \hat{S}$. The spin-orbit interaction is given by

$$\hat{H}_{so} = C\hat{L}.\hat{S}$$

If the strength of spin-orbit interaction is $C = -2$MeV, the energy difference between two nucleonic states $1d_{5/2}$ and $1d_{3/2}$ is given by: **[TIFR2025]**

(a) 5 MeV (b) 2 MeV

(c) 3 MeV (d) 4 MeV

Answer Key				
CSIR-NET PYQ				
1. c	2. b	3. b	4. a	5. a
6. b	7. c	8. a	9. a	10. c
11.	12. b	13. d	14. a	15. d
16. c	17. c	18. d	19. a	20. d
21. a				
GATE PYQ				
1. a	2. a	3. d	4. a	5. a
6. d	7. b	8. b	9. c	10. a
11. b	12. c	13. a	14. a	15. c
16. d	17. b	18. b	19. b	20. c
21. a	22. b	23. d	24. 300	25.
26. a	27. d	28. c	29. d	30.
31. **c**	32. a	33. 2		
TIFR PYQ				
1. a	2. b	3. a	4. b	5. a
6. a	7. a	8. a		

Deuteron Nuclei

❖ **CSIR-NET PYQ**

1. The tensor component of the nuclear force may be inferred from the fact that deuteron nucleus ^2_1H

(a)has only one bound state with total spin $S = 1$

(b)has a non-zero electric quadrupole moment in its ground state

(c)Is stable while triton ^3_1H is unstable

(d)Is the only two nucleon bound state

❖ **GATE PYQ**

1. Deuteron in its ground state has a total angular momentum $J = 1$ and a positive parity. The corresponding orbital angular momentum L and spin S combinations are

[GATE 2004]

(a) $L = 0, S = 1$ and $L = 2, S = 0$

(b) $L = 0, S = 1$ and $L = 1, S = 1$

(c) $L = 0, S = 1$ and $L = 2, S = 1$

(d) $L = 1, S = 1$ and $L = 2, S = 1$

2. To explain the observed magnetic moment of deuteron $(0.8574\mu_N)$, its ground state wavefunction is taken to be an admixture of S and D states. The expectation values of the z-component of the magnetic moment in pure S and pure D states are $0.8797\mu_N$ and $0.3101\mu_N$ respectively. The contribution of the D state to the mixed ground state is approximately

[GATE 2006]

(a) 40% (b) 4%

(c)0.4% (d) 0.04%

3. The ground state wave function of deuteron is in a superposition of s and d states. Which of the following is not true as a consequence?

[GATE 2010]

(a) It has a non-zero quadruple moment

(b) The neutron-proton potential is non central

(c)The orbital wave function is not spherically symmetric

(d) The Hamiltonian does not conserve the total angular momentum

4. Deuteron has only bound state with spin parity 1^+, isospin 0 and electric quadruple moment $0.286 efm^2$. These data suggest that nuclear forces are having

[GATE 2012]

(a) only spin and isospin dependence.

(b) no spin dependence and no tensor components.

(b) no spin dependence but no tensor components.

(d) spin dependence along with tensor components.

5. Consider the scattering of neutrons by protons at very low energy due to a nuclear potential of range r_0. Given that,

$$\cot(kr_0 + \delta) \approx -\frac{\gamma}{k}$$

Where δ is the phase shift, k the wave number and $(-\gamma)$ the logarithmic derivative of the deuteron ground sate wave function the phase shift is

[GATE 2013]

(a)$\delta \approx -\frac{k}{\gamma} - kr_0$ (b) $\delta \approx -\frac{\gamma}{k} - kr_0$

(c)$\delta \approx \frac{\pi}{2} - kr_0$ (d) $\delta \approx -\frac{\pi}{2} - kr_0$

6. Which of the following statements is NOT correct?

[GATE 2016]

(a) A deuteron can be disintegrated by irradiating it with gamma rays of energy 4MeV

(b) A deuteron has no excited states

(c)A deuteron has no electric quadrupole moment

(d) The $^1S_0$ state of deuteron cannot be formed.

7. The deuteron is a bound state of a neutron and a proton. Which of the following statements is(are) CORRECT? **[GATE 2023]**

(a) The deuteron has a finite value of electric quadrupole moment due to nonspherical electronic charge distribution

(b) The magnetic moment of the deuteron is equal to the sum of the magnetic moments of the neutron and the proton

(c)The deuteron state is an admixture of $^3S_1$ and $^3D_1$ states

(d) The deuteron state is an admixture of $^3S_1$ and $^3P_1$ states

❖ **JEST PYQ**

1. Given the mass of the proton $m_p \simeq 1836 m_e$ and mass of the deuteron $m_d \simeq 3670 m_e$, where m_e is the electron mass, find the fractional shift (in parts per million, to the nearest integer) of the ground state energy of the deuterium atom as compared to H -atom.

ANS: 272

❖ Answer Key				
CSIR-NET PYQ				
1. b				
GATE PYQ				
1. c	2. b	3. d	4. d	5. a
6. c	7. ac			
JEST PYQ				
1. 272				

Nuclear Radioactive Decays

❖ **CSIR-NET PYQ**

1. The ground state of $^{207}_{82}$ Pb nuclcus has spin-parity $J^P = \frac{1}{2}$, while the first excited state has $J^F = \frac{5}{2}$. The electromagnetic radiation emitted when the nucleus makes a transition from the first excited state to the ground state are

[CSIR JUNE 2012]

(a) E2 and E3
(b) M2 and E3
© E2 and M3
(d) M2 and M3

2. A radioactive element X decays to Y, which in turn decays to a stable element Z. The decay constant from X to Y is λ_1, and that from Y to Z is λ_2. If, to begin with, there are only N_0 atoms of X, at short times ($t \ll 1/\lambda_1$ as well as $1/\lambda_2$) the number of atoms of Z will be

[CSIR JUNE 2016]

(a) $\frac{1}{2}\lambda_1\lambda_2 N_0 t^2$
(b) $\frac{\lambda_1\lambda_2}{2(\lambda_1+\lambda_2)} N_0 t$
(c) $(\lambda_1+\lambda_2)^2 N_0 t^2$
(d) $(\lambda_1+\lambda_2) N_0 t$

3. If in a spontaneous α-decay of $^{232}_{92}$U at rest, the total energy released in the reaction is Q, then the energy carried by the α-particle is

[CSIR JUNE 2017]

(a) $\frac{57Q}{58}$
(b) $\frac{Q}{57}$
(c) $\frac{Q}{58}$
(d) $\frac{23Q}{58}$

4. A nucleus decays by the emission of a gamma ray from an excited state of spin-parity $2^+$to the ground state with spin-parity 0^+. What is the type of the corresponding radiation ?

[CSIR DEC 2018]

(a) magnetic dipole
(b) electric quadrupole
© electric dipole
(d) m a g netic quadrupole

5. An excited state of a $^8_4$Be nucleus decays into two α particles which are in a spin-parity 0^+state. If the mean life-time of this decay is 10^{-22} s, the spin-parity of the excited state of the nucleus is

[CSIR JUNE 2019]

(a) 2^+
(b) 3^+
(c) 0^-
(d) 4^-

6. The nuclei of ^{137}Cs decay by the emission of β-particles with a half of 30.08 years. The activity (in units of disintegrations per second or Bq) of a 1mg source of ^{137}Cs, prepared on January 1 , 1980 as measured on January 1, 2021 is closest to

[CSIR JUNE 2021]

(a) 1.79×10^{16}
(b) 1.79×10^9
(c) 1.24×10^{16}
(d) 1.24×10^9

7. A ^{60}Co nucleus β-decays from its ground state with $J^P = 5^+$to a state of ^{60}Ni with $J^P = 4^+$. From the angular momentum selection rules, the allowed values of the orbital angular momentum L and the total spin S of the election-antineutrino pair are

[CSIR JUNE 2021]

(a) L = 0 and S = 1
(b) L = 1 and S = 0
(c) L = 0 and S = 0
(d) L = 1 and S = 1

8. The Q-value of the α-decay of ^{232}Th to the ground state of ^{228}Ra is 4082keV. The maximum possible kinetic energy of the α-particle is closest to

[CSIR JUNE 2021]

(a) 4082keV
(b) 4050keV
(c) 4035keV
(d) 4012keV

9. The ground state of $^{207}_{82}$ Pb nucleus has spin-parity

$$J^\pi = \left(\frac{1}{2}\right)^-$$

,while the first excited state has

$$J^\pi = \left(\frac{5}{2}\right)^-$$

. For the transition from the first excited state to the ground state, possible multipolarities of emitted electromagnetic radiation are

[CSIR DEC 2023]

(a)E2, E3 (b)M2, M3

©M2, E3 (d)E2, M3

10. Naturally occurring uranium is a mixture of the $^{238}U(99.28\%)$ and $^{235}U(0.72\%)$ isotopes. The life times are $\tau(^{235}U) = 1 \times 10^9$ years and $\tau(^{238}U) = 6.6 \times 10^9$ years. What is the closest value of the age of the solar system if one assumes that at its creation both isotopes were present in equal quantities? **[CSIR DEC 2024]**

(a)6.2×10^9 years (b)5.8×10^9 years

(c)4.7×10^9 years (d)7.2×10^9 years

11. The masses of proton, neutron, Polonium and Lead nuclei are as follows:

$$m_p = 1.007825\mathrm{a.u}, m_n = 1.008665\mathrm{a \cdot u}$$
$$m(^{210}_{84}\mathrm{Po}) = 209.982876\mathrm{a.}$$
$$\mathrm{u}, m(^{206}_{82}\mathrm{Pb}) = 205.974455\mathrm{a.u}$$

Binding energy of $^4_2$He is 28.80 MeV and $1\mathrm{a.u} = 931.99\frac{\mathrm{MeV}}{\mathrm{c}^2}$.

The binding energies of $^{210}_{84}$Po, $^{206}_{82}$Pb and the Q value of the α-decay of $^{210}_{84}$Po are closest to

[CSIR MARCH 2025]

(a)1645.21MeV, 1622.33MeV, 5.92MeV

(b)1645.21MeV, 1622.33MeV, −5.92MeV

(c) 1545.21MeV, 1522.33MeV, −5.92MeV

(d)1645.21MeV, 1522.33MeV, 5.92MeV

❖ **GATE PYQ**

1. The evidence for the non-conservation of parity in β-decay has been obtained from the observation that the β intensity **[GATE 2005]**

(a) antiparallel to the nuclear spin directions is same as that along the nuclear spin direction

(b) antiparallel to the nuclear spin direction is not the same as that along the nuclear spin direction

© shows a continuous distribution as a function of momentum

(d) is independent of the nuclear spin direction

2. A nucleus having mass number 240 decays by α emission to the ground state of its daughter nucleus. The Q value of the process is 5.26MeV. The energy (in MeV) of the α particle is

[GATE 2005]

(a) 5.26 (b) 5.17

© 5.13 (d) 5.09

3. The number of final states states of electrons corresponding to momenta between p and p + dp is

(c) independent of p

(b) proportional to pdp

© proportional to $\mathrm{p}^2\mathrm{dp}$

(d) proportional to $\mathrm{p}^3\mathrm{dp}$

4. The number of emitted electrons with momentum p and energy E, in the allowed approximation, is proportional to (E_0 is the total energy given up by the nucleus).

[GATE 2006]

(a) $(\mathrm{E}_0 - \mathrm{E})$ (b) $\mathrm{p}(\mathrm{E}_0 - \mathrm{E})$

© $\mathrm{p}^2(\mathrm{E}_0 - \mathrm{E})^2$ (d) $\mathrm{p}(\mathrm{E}_0 - \mathrm{E})^2$

5. Which of the following configurations of the decay products correspond to the largest energy of the antineutrino $\bar{\nu}$? (rest mass of electron $\mathrm{m_e} = 0.51\mathrm{MeV/c^2}$, rest mass of proton $\mathrm{m_p} = 938.27\mathrm{MeV/c^2}$ and rest mass of neutron $\mathrm{m_n} = 939.57\mathrm{MeV/c^2}$)

[GATE 2008]

(a) In the laboratory proton is produced at rest

(b) In the laboratory, momenta of proton electron and the anti-neutrino all have the same magnitude.

© In the laboratory, proton and electron fly-off with (nearly) equal and opposite momenta

(d) In the laboratory, electron is produced at rest

6. Using the result of the above problem answer the following. Which of the following represents approximately the maximum allowed energy of the anti-neutrino $\bar{\nu}$?

[GATE 2008]

(a) 1.3MeV (b) 0.8MeV

© 0.5MeV (d) 2.0MeV

7. The disintegration energy is defined to be the difference in the rest energy between the initial and final states. Consider the following process:

$${}^{240}_{94}\mathrm{Pu} \rightarrow {}^{236}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He}$$

The emitted α particle has a kinetic energy 5.17MeV. The value of the disintegration energy is

[GATE 2009]

(a) 5.26MeV (b) 5.17MeV

© 5.08MeV (d) 2.59MeV

8. In the β decay process, the transition $2^{+} \rightarrow 3^{+}$, is

[GATE 2013]

(a) allowed both by Fermi and Gamow-Teller selection rule

(b) allowed by Fermi and but by Gamow-Teller selection rule

© not allowed by Fermi by allowed by Gamow-Teller selection rule

(d) not allowed by Fermi but allowed by Gamow-Teller selection rule

9. A nucleus X undergoes a first forbidden β-decay to a nucleus Y. If the angular momentum (I) and parity

(P) denoted by I^{P} as $\frac{7^{-}}{2}$ for X, which of the following is a possible I^{P} value for Y ?

[GATE 2014]

(a) $\frac{1}{2}$ (b) $\frac{1^{-}}{2}$

© $\frac{3^{+}}{2}$ (d) $\frac{3^{-}}{2}$

10. A beam of X-ray of intensity I_0 is incident normally on a metal sheet of thickness 2 nm. The intensity of the transmitted beam is $0.025 I_0$. The linear absorption coefficient of the metal sheet (inm^{-1}) is (© one decimal place)

[GATE 2015]

1844.4

11. In the nuclear reaction ${}^{13}\mathrm{C}_6 + \mathrm{v}_e \rightarrow {}^{13}\mathrm{N}_7 + \mathrm{X}$, the particle X is

[GATE 2017]

(a) an electron (b) an anti-electron

© a muon (d) a pion

12. An α particle is emitted by a ${}^{230}_{90}\mathrm{Th}$ nucleus. Assuming the potential to be purely Coulombic beyond the point of separation, the height of the Coulomb barrier is MeV (up to two decimal places). **[GATE 2018]**

$$\left(\frac{e^2}{4\pi\epsilon_0} = 1.44\text{MeV-fm},\ r_0 = 1.30\text{fm}\right)$$

13. A radioactive element **X** has a half-life of 30 hours. It decays via alpha, beta and gamma emissions with the branching ratio for beta decay being 0.75 . The partial half-life for beta decay in unit of hours is **[GATE 2018]**

14. Assumethat ${}^{13}\mathrm{N}(\mathrm{Z} = 7)$undergoesfirstforbidden$\beta^{+}$ decay from its ground state with spin − parity J_i^{π}, to a final state J_f^{π}. The possible values for J_i^{π} and J_f^{π}, respectively, are

[GATE 2021]

(a) $\frac{1^{-}}{2}, \frac{5^{+}}{2}$ (b) $\frac{1^{+}}{2}, \frac{5^{+}}{2}$

(c) $\frac{1^{-}}{2}, \frac{1^{-}}{2}$ (d) $\frac{1^{+}}{2}, \frac{1^{-}}{2}$

15. In an experiment, it is seen that an electric-dipole (E1) transition can connect an initial nuclear state of spin-parity $J_i^{\pi} = 2^+$ to a final state J_f^{π}. All possible values of J_f^{π} are

[GATE 2021]

(a) $1^+, 2^+$

(b) $1^+, 2^+, 3^+$

© $1^-, 2^-$

(d) $1^-, 2^-, 3^-$

16. Match the order of β-decays given in the left column to appropriate clause in the right column. Here $X(I^{\pi})$ and $Y(I^{\pi})$ are nuclei with intrinsic spin I and parity π.

[GATE 2022]

1. $X\left(\frac{1^+}{2}\right) \rightarrow Y\left(\frac{1^+}{2}\right)$

2. $X\left(\frac{1^-}{2}\right) \rightarrow Y\left(\frac{5^+}{2}\right)$

3. $X(3^+) \rightarrow Y(0^+)$

4. $X(4^-) \rightarrow Y(0^+)$

(i) First forbidden β-decay
(ii) Second forbidden β-decay
(iii) Third forbidden β-decay
(iv) Allowed β-decay

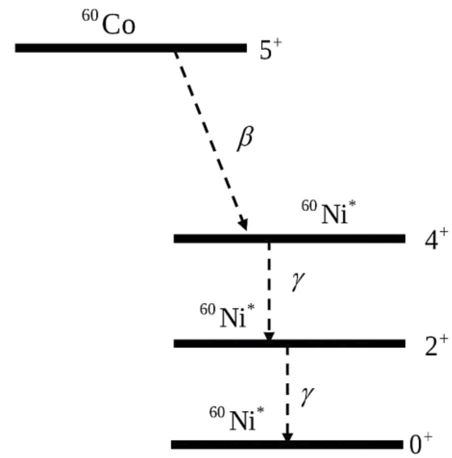
(a) 1 – i, 2 – ii, 3 – iii, 4 – iv

(b) 1 – iv, 2 – i, 3 – ii, 4 – iii

(c) 1 – i, 2 – iii, 3 – ii, 4 – iv

(d) 1 – iv, 2 – ii, 3 – iii, 4 – i

17. A ^{60}Co nucleus emits a β-particle and is converted to ^{60}Ni* with $J^P = 4^+$, which in turn decays to the ^{60}Ni ground state with $J^P = 0^+$ by emitting two photons in succession, as shown in the figure. Which one of the following statements is CORRECT? **[GATE 2023]**



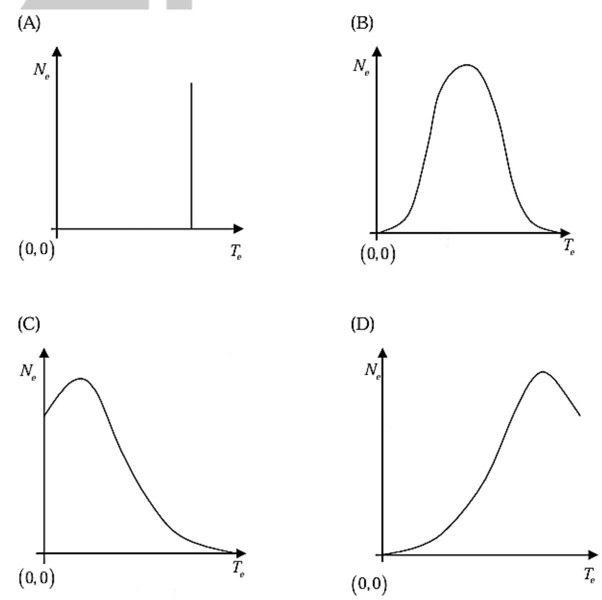
(c) $4^+ \rightarrow 2^+$ is an electric octupole transition

(b) $4^+ \rightarrow 2^+$ is a magnetic quadrupole transition

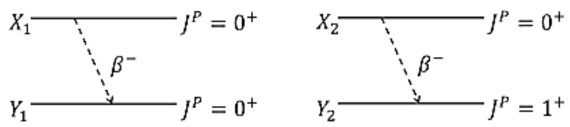
© $2^+ \rightarrow 0^+$ is an electric quadrupole transition

(d) $2^+ \rightarrow 0^+$ is a magnetic quadrupole transition

18. Let N_e and T_e, respectively, denote number and kinetic energy of electrons produced in a nuclear beta decay. Which one of the following distributions is correct? **[GATE 2024]**



19. Consider two hypothetical nuclei X_1 and X_2 undergoing β decay, resulting in nuclei Y_1 and Y_2, respectively. The decay scheme and the corresponding J^P values of the nuclei are given in the figure. Which of the following option(s) is/are correct? (J is the total angular momentum and P is parity) **[GATE 2025]**



(a) $X_1 \rightarrow Y_1$ is Fermi transition and $X_2 \rightarrow Y_2$ is Fermi transition

(b) $X_1 \rightarrow Y_1$ is Fermi transition and $X_2 \rightarrow Y_2$ is Gamow-Teller transition

(c) $X_1 \rightarrow Y_1$ is Gamow-Teller transition and $X_2 \rightarrow Y_2$ is Fermi transition

(d) $X_1 \rightarrow Y_1$ is Gamow-Teller transition and $X_2 \rightarrow Y_2$ is Gamow-Teller transition

❖ **JEST PYQ**

1. ^{238}U decays with a half life of 4.51×10^9 years, the decay series eventually ending at ^{206}Pb, which is stable. A rock sample analysis shows that the ratio of the numbers of atoms of ^{206}Pb to ^{238}U is 0.0058 . Assuming that all the ^{206}Pb has been produced by the decay of ^{238}U and that all other half-lives in the chain are negligible, the age of the rock sample is **[JEST 2013]**

(a) 38×10^6 years (b) 48×10^6 years

© 38×10^7 years (d) 48×10^7 years

2. In the mixture of isotopes normally found on the earth at the present time, $^{238}_{92}U$ has an abundance of 99.3% and $^{235}_{92}U$ has an abundance of 0.7%. The measured lifetimes of these isotopes are 6.52×10^9 years and 1.02×10^9 years, respectively. Assuming that they were equally abundant when the earth was formed, the estimated age of the earth, in years is **[JEST 2014]**

(a) 6.0×10^9 (b) 1.0×10^9

© 6.0×10^8 (d) 1.0×10^8

3. The half-life of a radioactive nuclear source is 9 days. The fraction of nuclei which are left undecayed after 3 days is: **[JEST 2014]**

(a) $\frac{7}{8}$ (b) $\frac{1}{3}$

(c) $\frac{5}{6}$ (d) $\frac{1}{2^{\frac{1}{3}}}$

4. The average lifetime of a muon in its rest frame is 2200 ns . What will be the average distance (in meters, to the nearest integer) travelled by it, when created with a velocity of $\frac{1}{3}c$, before it decays? Here c is the speed of light. **[JEST 2025]**

❖ **TIFR PYQ's**

1. A detector is used to count the number of γ rays emitted by a radioactive source. If the number of counts recorded in exactly 20 seconds is 10000 , the error in the counting rate per second is **[TIFR 2010]**

(a) ± 5.0 (b) ± 22.4

(c) ± 44.7 (d) ± 220.0

2. A lead container contains 1gm of a $^{60}_{27}$Co radioactive source. It is known that a $^{60}_{27}$Co nucleus emits a β particle of energy 316KeV followed by two γ emissions of energy 1173 and 1333KeV respectively. Which of the following experimental methods would be the best way to determine the lifetime of this $^{60}_{27}$Co source? **[TIFR 2010]**

(a) Measure the change in temperature of the source

(b) Measure the weight of the source now and again after one year

(c) Measure the recoil momentum of the nucleus during β emission

(d) Measure the number of γ photons emitted by this source

3. An excited atomic electron undergoes a spontaneous transition

$$3d_{3/2} \rightarrow 2p_{1/2}$$

The interaction responsible for this transition must be of the type **[TIFR 2011]**

(a) electric dipole (E1)	OR	magnetic quadrupole (M2)
(b) electric dipole (E1)	OR	magnetic dipole (M1)
(c)electric quadrupole (E2)	OR	magnetic quadrupole (M2)
(d) electric quadrupole (E2)	OR	magnetic dipole (M1)

4. A standard radioactive source is known to decay by emission of γ rays. The source is provided to a student in a thick sealed capsule of unbreakable plastic and she is asked to find out the half-life. Which of the following would be the most useful advice to the student? **[TIFR 2014]**

(a) The half-life cannot be measured because the initial concentration of the source is not given.

(b) Mount the source in front of a gamma ray detector and count the number of photons detected in one hour.

(c)Measure the mass of the source at different times with an accurate balance having a least count of 1mg. Plot these values on a curve and fit it with an exponential decay law.

(d) Mount the source in front of a gamma ray detector and count the number of photons detected in a specific time interval. Repeat this experiment at different times and note how the count changes.

5. Which of the following radioactive decay chains is it possible to observe? **[TIFR 2015]**

(a) $^{206}_{82}\text{Pb} \to {}^{202}_{80}\text{Hg} \to {}^{202}_{79}\text{Au}$

(b) $^{210}_{83}\text{Bi} \to {}^{210}_{84}\text{Po} \to {}^{206}_{82}\text{Pb}$

(c) $^{214}_{88}\text{Ra} \to {}^{210}_{86}\text{Rn} \to {}^{207}_{82}\text{Pb}$

(d) $^{206}_{82}\text{Pb} \to {}^{202}_{80}\text{Hg} \to {}^{202}_{79}\text{Au}$

6. In an experiment, $^{197}_{79}\text{Au}$ nuclei were bombarded with neutrons leading to formation of $^{198}_{79}\text{Au}$, which is unstable. The half-life of $^{198}_{79}\text{Au}$ was measured to be 2.25 days and it was found later that this measured half-life was an underestimate by 10%. The corresponding percentage error in the estimated population of $^{198}_{79}\text{Au}$ after 9 days is **[TIFR 2015]**

(a) 10% (b) 25%

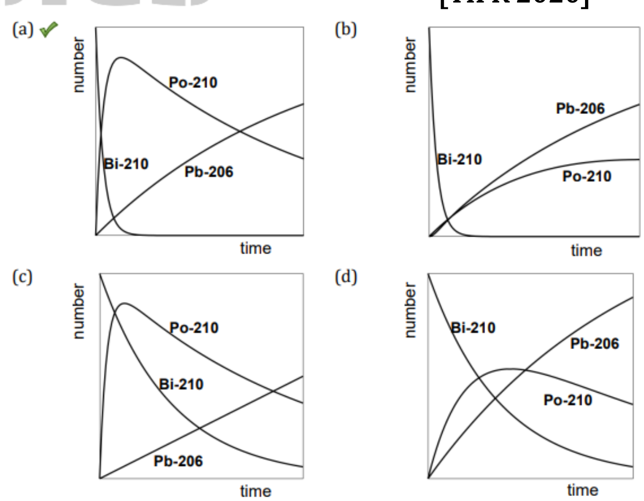
(c)2.5% (d) 15%

7. Cosmic ray muons, which decay spontaneously with proper lifetime 2.2μs, are produced in the atmosphere, at a height of 5 km above sea level. These move straight downwards at 98% of the speed of light.
Find the percent ratio $100 \times (N_A/N_B)$ of the number of muons measured at the top of two mountains A and B, which are at heights 4,848 m and 2,682 m respectively above mean sea level. **[TIFR 2017]**

8. Consider the nuclear decay chain of radio-Bismuth to Polonium to Lead, i.e.

$$^{219}_{83}\text{Bi} \to {}^{210}_{84}\text{Po} \to {}^{206}_{82}\text{Pb}$$

where $\text{Pb}-206(^{206}_{82}\text{Pb})$ is a stable nucleus, and Bi-210 ($^{219}_{83}$Bi) and Po-206 ($^{210}_{84}$Po) are radioactive nuclei with half lives of about 5 days and 138 days respectively.
If we start with a sample of pure $\text{Bi}-210(^{219}_{83}\text{Bi})$, then a possible graph for the time evolution of the number of nuclei of these three species will be **[TIFR 2020]**



9. Natural potassium contains a radioactive component of ^{40}K that has two decay modes.

- In the first mode, ^{40}K undergoes a β decay to the ground state of ^{40}Ca.
- In the second mode, ^{40}K undergoes an electron capture to the excited state of ^{40}Ar, followed by a single γ transition to the ground state of ^{40}Ar.

The amount of radioactive ^{40}K in a natural potassium (atomic weight of 39.089) sample is known to be 0.0118 percent. It is also known that in the decay of ^{40}K, for every 100β particles emitted, there number of γ-photons emitted is 12 If the number of β-particles emitted per second by 1 kg of natural potassium is 2.7×10^4, the mean lifetime of ^{40}K in years is **[TIFR 2022]**

(a) 1.9×10^9 (b) 1.3×10^9

(c) 1.7×10^9 (d) 1.1×10^8

10. A beam of neutrons is incident normally upon a thick sheet of Cadmium. The mass density of Cadmium is $\rho = 8.6 \text{ g cm}^{-3}$. The absorption cross-section of neutrons on Cadmium nuclei is $2.5 \times 10^{-20} \text{ cm}^2$. The atomic weight of Cadmium is known to be 112.40 g/mol. You may take $N_A = 6.02 \times 10^{23}$.

At what depth is the intensity of the beam reduced by a factor $1/e$? **[TIFR 2024]**

(a) 9μm (b) 9fm

(c) 9 nm (d) 900fm

❖ Answer Key

CSIR-NET PYQ				
1. c	2. a	3. a	4. b	5. a
6. d	7. a	8. d	9. d	10. b
11. a				
GATE PYQ				
1. a	2. b	3. c	4. b	5. d
6. b	7. a	8. c	9. c	10. 1844.4
11. a	12.	13. 40	14. b	15. d
16. b	17. c	18. c	19. b	
JEST PYQ				
1. a	2. a	3. d	4. 233	
TIFR PYQ				
1. b	2. d	3. a	4. d	5. b
6. b	7. 194	8. a	9. a	10. a

Radioactivity

❖ CSIR-NET PYQ

1. A radioactive element X decays to Y, which in turn decays to a stable element Z. The decay constant from X to Y is λ_1, and that from Y to Z is λ_2. If, to begin with, there are only N_0 atoms of X, at short times ($t \ll 1/\lambda_1$ as well as $1/\lambda_2$) the number of atoms of Z will be

[CSIR JUNE 2016]

(a) $\frac{1}{2}\lambda_1\lambda_2 N_0 t^2$ (b) $\frac{\lambda_1\lambda_2}{2(\lambda_1+\lambda_2)} N_0 t$

(c) $(\lambda_1+\lambda_2)^2 N_0 t^2$ (d) $(\lambda_1+\lambda_2) N_0 t$

2. The nuclei of ^{137}Cs decay by the emission of β-particles with a half of 30.08 years. The activity (in units of disintegrations per second or Bq) of a 1mg source of ^{137}Cs, prepared on January 1 , 1980 as measured on January 1, 2021 is closest to

[CSIR JUNE 2021]

(a) 1.79×10^{16} (b) 1.79×10^{9}

(c) 1.24×10^{16} (d) 1.24×10^{9}

3. Naturally occurring uranium is a mixture of the $^{238}U(99.28\%)$ and $^{235}U(0.72\%)$ isotopes. The life times are $\tau(^{235}U) = 1 \times 10^9$ years and $\tau(^{238}U) = 6.6 \times 10^9$ years. What is the closest value of the age of the solar system if one assumes that at its creation both isotopes were present in equal quantities?

[CSIR MARCH 2025]

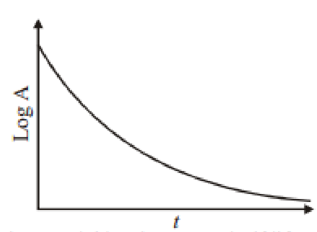
(a) 6.2×10^9 years (b) 5.8×10^9 years

(c) 4.7×10^9 years (d) 7.2×10^9 years

❖ GATE PYQ

1. The plot of log A vs. time t, where A is activity, as shown in the figure, corresponds to decay

[GATE 2005]



(a) from only one kind of radioactive nuclei having same half life

(b) from only neutron activated nuclei

(c) from a mixture of radioactive nuclei having different half lives

(d) which is unphysical

2. Which one of the following disintegration series of the heavy elements will give ^{209}Bi as a stable nucleus ?

[GATE 2006]

(a) Thorium series (b) Neptunium series

(c) Uranium series (d) Actinium series

3. Fission fragments are generally radioactive as

[GATE 2007]

(a) they have excess of neutrons

(b) they have excess of protons

(c) they are products of radioactive nuclides

(d) their total kinetic energy is of the order of 200MeV

4. Half life of a radio-isotope is 4×10^8 years. If there are 10^3 radioactive nuclei in a sample today, the number of such nuclei in the sample 4×10^9 years ago were

[GATE 2007]

(a) 128×10^3 (b) 256×10^3

(c) 512×10^3 (d) 1024×10^3

5. A radioactive element **X** has a half-life of 30 hours. It decays via alpha, beta and gamma emissions with the branching ratio for beta decay being 0.75 . The partial half-life for beta decay in unit of hours is **[GATE 2019]**

40

❖ **JEST PYQ**

1. ^{238}U decays with a half life of 4.51×10^9 years, the decay series eventually ending at ^{206} Pb, which is stable. A rock sample analysis shows that the ratio of the numbers of atoms of ^{206} Pb to ^{238}U is 0.0058 . Assuming that all the ^{206} Pb has been produced by the decay of ^{238}U and that all other half-lives in the chain are negligible, the age of the rock sample is

[JEST 2013]

(a) 38×10^6 years (b) 48×10^6 years

(c) 38×10^7 years (d) 48×10^7 years

2. In the mixture of isotopes normally found on the earth at the present time, $^{238}_{92}$U has an abundance of 99.3% and $^{238}_{92}$U has an abundance of 0.7%. The measured lifetimes of these isotopes are 6.52×10^9 years and 1.02×10^9 years, respectively. Assuming that they were equally abundant when the earth was formed, the estimated age of the earth, in years, is

[JEST 2014]

(a) 6.0×10^9 (b) 1.0×10^9

(c) 6.0×10^8 (d) 1.0×10^8

3. The half-life of a radioactive nuclear source is 9 days. The fraction of nuclei which are left undecayed after 3 days is:

[JEST 2016]

(a) $\frac{7}{8}$ (b) $\frac{1}{3}$

(c) $\frac{5}{6}$ (d) $\frac{1}{2^{\frac{1}{3}}}$

❖ Answer Key				
CSIR-NET				
1. a	2. d	3. b		
GATE				
1. c	2. b	3. a	4. d	5. 40
JEST				
1. a	2. a	3. d		

Nuclear Reaction

❖ CSIR-NET PYQ

1. An atom of mass M can be excited to a state of mass $M+\Delta$ by photon capture. The frequency of a photon which can cause this transition is:

[CSIR DEC 2011]

(a) $\Delta c^2/2h$ (b) $\Delta c^2/h$

(c) $\Delta^2c^2/2Mh$ (d) $\Delta(\Delta+2M)c^2/2Mh$

2. What should be the minimum energy of a photon for it to split an α-particle at rest into a tritium and a proton?
(The masses of ${}^4_2\text{He}$, ${}^3_1\text{H}$ and ${}^H_1\text{H}$ are $4.0026\text{amu}, 3.0161\text{amu}$ and 1.0073amu, respectively, and $1\text{ amu} \approx 938\text{MeV}$).

[CSIR DEC 2016]

(a) 32.2MeV (b) 3MeV

(c) 19.3MeV (d) 931.5MeV

3. The reaction ${}^{63}\text{Cu}_{29}+p \rightarrow {}^{63}\text{Zn}_{30}+n$ is followed by a prompt β-decay of zinc ${}^{63}\text{Zn}_{30} \rightarrow {}^{63}\text{Cu}_{29}+e^{+}+v_e$. If the maximum energy of the position is 2.4MeV, the Q-value of the original reaction in MeV is nearest to [Take the masses of electrons, proton and neutron to be $0.5\text{MeV}/c^2, 938\text{MeV}/c^2$ and $939.5\text{MeV}/c^2$, respectively].

[CSIR JUNE 2018]

(a) -4.4 (b) -2.4

(c) -4.8 (d) -3.4

4. Assume that pion-nucleon scattering at low energies, in which isospin is conserved, is described by the effective interaction potential $V_{eff}=F(r)\vec{I}_x\cdot\vec{I}_N$, where F(r) is a function of the radial separation r and $\vec{I}_m$ and $\vec{I}_N$ denote, respectively, the isospin vectors of a pion and the nucleon. The ratio $\sigma_{I=3/2}/\sigma_{I-\nu/2}$ of the scattering cross-sections corresponding to total isospins $I=3/2$ and 1/2, is

[CSIR DEC 2018]

(a) 3/2 (b) ¼

(c) 5/4 (d) 1/2

5. The elastic scattering of a neutrino v_e by an electron e^-, i.c. the reaction $v_e+e^- \rightarrow v_e+e^-$, can be described by the interaction Hamiltonian

$$H_{int} = \frac{1}{\sqrt{2}}G_F\int d^3x(\bar{\psi}_e(x)\gamma^\mu\psi_{ve}(x))(\bar{\psi}_{ve}(x)\gamma_\mu\psi_e(x))$$

The cross-section of the above process depends on the centre of mass energy E, as depends on the centre of mass energy E, as

[CSIR JUNE 2019]

(a) $1/E^2$ (b) E^2

(c) E (d) $\sqrt{E}$

❖ GATE PYQ

1. The reaction ${}^3\text{H}(p,n)^2\text{He}$ has a Q value of -0.764MeV. Calculate the threshold energy of incident protons for which neutrons are emitted in the forward direction. **[GATE 2001]**

2. Typical energies released in a nuclear fission and a nuclear fusion reaction are respectively

[GATE 2002]

(a) 50MeV and 1000MeV

(b) 200MeV and 1000MeV

(c) 1000MeV and 50MeV

(d) 200MeV and 10MeV

3. Calculate the minimum kinetic energy that the neutron should have in order to induce the reaction $O^{16}(n^1, He^4)C^{13}$
in which C^{13} is left in an excited state of energy 1.79 MeV. Given:

[GATE 2002]

Mass of $O^{16}=16.000000\text{amu}$
Mass of $n^1=1.008986\text{amu}$
Mass of $He^4=4.003874\text{amu}$
Mass of $C^{13}=13.007490\text{amu}$

4. The masses of a hydrogen atom, neutron and ${}^{238}\text{U}_{92}$ are given by 1.0078,1.0087 and 238.0508 respectively. The binding energy of ${}^{238}\text{U}_{92}$ is therefore approximately equal to (taking 1 a.m.u. = 931.64MeV)

[GATE 2003]

(a) 120MeV (b) 1500MeV

(c)1600MeV (d) 1800MeV

Data for Q. No. 5 to 6

An atomic bomb consisting of ^{235}U explodes and releases an energy of 10^{14} J. It is known that each ^{235}U which undergoes fission releases 3 neutrons and about 200MeV of energy. Further, only 20% of the ^{235}U atoms in the bomb undergo fission.

5. The total number of neutrons released is about

[GATE 2003]

(a) 4.7×10^{24} (b) 9.7×10^{24}

(c)1.9×10^{25} (d) 3.7×10^{25}

6. The mass of ^{235}U in the bomb is about

[GATE 2003]

(a) 1.5 kg (b) 3.0 kg

(c)6.1 kg (d) 12 kg

7. A thermal neutron having speed v impinges on a ^{235}U nucleus. The reaction cross-section is proportional to

[GATE 2004]

(a) v^{-1} (b) v

(c)$v^{1/2}$ (d) $v^{-1/2}$

8. The threshold temperature above which the thermonuclear reaction $^3_2\mathrm{He} + ^3_2\mathrm{He} \rightarrow ^4_2\mathrm{He} + 2\,^1_1\mathrm{H} + 12.86\mathrm{MeV}$ can occur is (use $e^{2/4\pi\varepsilon_0} = 1.44 \times 10^{-15}\mathrm{MeVm}$)

[GATE 2005]

(a) 1.28×10^{10} K (b) 1.28×10^{9} K

(c)1.28×10^{8} K (d) 1.28×10^{7} K

9. In the deuterium + tritium (d + t) fusion more energy is released as compared to deuterium + deuterium (d + d) fusion because

[GATE 2007]

(a) tritium is radioactive

(b) more nucleons participate in fusion

(c)the Coulomb barrier is lower for the d + t system than d + d system

(d) the reaction product ^{4}He is more tightly bound

10. The energy released in the fission of 1kg Uranium (Approximately [in joule] **[GATE 2008]**

(a)10^{14} (b)10^{17}

(c)10^{16} (d)10^{10}

11. A neutron scatters elastically from a heavy nucleus. The initial and final states of the neutron have the

[GATE 2007]

(a) same energy

(b) same energy and linear momentum

(c)same energy and angular momentum

(d) same linear and angular momenta

Statement for Linked Answer Questions 12 & 13:

A 16μA beam of alpha particles, having cross-sectional area 10^{-4} m^2, is incident on a rhodium target of thickness 1μm. This produces neutrons through the reaction

$$\alpha + ^{100}Rh \rightarrow ^{101}Pd + 3n$$

12. The number of alpha particles hitting the target per second is

(a) 0.5×10^{14} (b) 1.0×10^{14}

(c) 2.0×10^{20} (d) 4.0×10^{20}

13. The neutrons are observed at the rate of 1.806×10^{8} s^{-1}. If the density of rhodium is approximated as 10^4 kg m^{-3} the cross-section for the reaction (in barns) is

[GATE 2007]

(a) 0.1 (b) 0.2

(c) 0.4 (d) 0.8

14. The disintegration energy is defined to be the difference in the rest energy between the initial and final states. Consider the following process:

$$^{240}_{94}\mathrm{Pu} \to {}^{236}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He}$$

The emitted α particle has a kinetic energy 5.17MeV. The value of the disintegration energy is

[GATE 2009]

(a) 5.26MeV (b) 5.17MeV

(c) 5.08MeV (d) 2.59MeV

15. Total binding energies of O^{15}, O^{16} and O^{17} are 111.96MeV, 127.62MeV and 131.76MeV respectively. The energy gap between $^1p_{1/2}$ and $1d_{5/2}$ neutron shells for the nuclei whose mass number is close to 16 is

[GATE 2012]

(a) 4.1MeV (b) 11.5MeV

(c) 15.7MeV (d) 19.8MeV

16. The atomic masses of $^{152}_{63}\mathrm{Eu}$, $^{152}_{62}\mathrm{Sm}$, $^{1}_{1}\mathrm{H}$ and neutron are 151.921749, 151.919756, 1.007825 and 1.008665 in atomic mass units (amu) respectively. Using the above information the Q-value of the reaction $^{152}_{03}\mathrm{Eu} + n \to {}^{152}_{02}\mathrm{Sm} + p$ is__________ $\times 10^{-3}$am (upto three decimal places)

[GATE 2015]

2.833

17. Consider the reaction $^{54}_{25}\mathrm{Mn} + e^- \to {}^{54}_{24}\mathrm{Cr} + X$. The particle X is

[GATE 2016]

(a) γ (b) v_e

(c) n (d) π^0

18. Protons and $\alpha -$ particles of equal initial momenta are scattered off a gold foil in a Rutherford scattering experiment. The scattering cross sections for proton on gold and α-particle on gold are σ_p and σ_α respectively. The ratio σ_α/σ_p is________.

[GATE 2016]

A

19. An α-particle is emitted from the decay of Americium (Am) at rest, i.e., $^{241}_{94}\mathrm{Am} \to {}^{237}_{92}\mathrm{U} + \alpha$. The rest masses of $^{241}_{94}\mathrm{Am}$, $^{237}_{92}\mathrm{U}$ and α are $224.544\mathrm{GeV/c^2}$, $220.811\ \mathrm{GeV/c^2}$ and $3.728\mathrm{GeV/c^2}$ respectively. What is the kinetic energy (in $\mathrm{MeV/c^2}$, rounded off to two decimal places) of the α-particle? **[GATE 2023]**

20. Consider the induced nuclear fission reaction $^{235}_{92}\mathrm{U} + n \to {}^{93}_{37}\mathrm{Rb} + {}^{141}_{55}\mathrm{Cs} + 2n$ where neutron momenta in both initial and final states are negligible. The ratio of the kinetic energies (KE) of the daughter nuclei,

$$\frac{\mathrm{KE}({}^{93}_{37}\mathrm{Rb})}{\mathrm{KE}({}^{114}_{55}\mathrm{Cs})}$$

is

[GATE 2024]

(a) $\frac{93}{141}$ (b) $\frac{141}{93}$

(c) 1 (d) 0

21. Binding energy and rest mass energy of a two-nucleon bound state are denoted by B and mc^2, respectively, where c is the speed of light. The minimum energy of a photon required to dissociate the bound state is

[GATE 2024]

(a) B (b) $B\left(1+\frac{B}{2mc^2}\right)$

(c) $B\left(1-\frac{B}{2mc^2}\right)$ (d) $B - mc^2$

❖ **JEST PYQ**

1. Consider a point particle A and mass m_A colliding elastically with another point particle B of mass m_B at rest, where $m_B/m_A = \gamma$. After collision, the ratio of the kinetic energy of particle B to the initial kinetic energy of particle A is given by

[JEST 2017]

(a) $\frac{4}{\gamma + 2 + 1/\gamma}$ (b) $\frac{2}{\gamma + 1/\gamma}$

(c) $\dfrac{2}{\gamma + 2 - 1/\gamma}$ (d) $\dfrac{1}{\gamma}$

- **TIFR PYQ's**

1. The binding energy per nucleon for ^{235}U is 7.6MeV. The ^{235}U nucleus undergoes fission to produce two fragments, both having binding energy per nucleon 8.5MeV. The energy released, in Joules, from the complete fission of 1Kg of ^{235}U is, therefore,

[TIFR 2013]

(a) 8000 (b) 10^{35}

(c)450 (d) 20000

(e) 8.7×10^{13} (f) 5.0×10^{8}

2. A fast-moving ^{14} N nucleus collides with an α particle at rest in the laboratory frame, giving rise to the reaction

$$^{14}\,\mathrm{N} + \alpha \rightarrow {}^{17}\mathrm{O} + p$$

Given the masses 14.00307 a.m.u. and 16.99913 a.m.u. for ^{14} N and ^{17}O nuclei respectively, and 4.00260 a.m.u. and 1.00783 a.m.u. for α and p respectively, the minimum kinetic energy in the laboratory frame of the ^{14} N nucleus must be

[TIFR 2011]

(a) 4.20MeV (b) 1.20MeV

(c)5.41MeV (d) 1.55MeV

3. In a nuclear reactor, Plutonium ($^{239}_{94}$Pu) is used as fuel, releasing energy by its fission into isotopes of Barium ($^{146}_{54}$Ba) and Strontium ($^{91}_{38}$Sr) through the reaction

$$^{239}_{94}\mathrm{Pu} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{146}_{56}\mathrm{Ba} + {}^{91}_{38}\mathrm{Sr} + 3 \times {}^{1}_{0}\mathrm{n}$$

The binding energy (B.E.) per nucleon of each of these nuclides is given in the table below:

Nuclide	$^{239}_{94}$Pu	$^{146}_{54}$Ba	$^{91}_{38}$Sr
B.E. per nucleon (MeV)	7.6	8.2	8.6

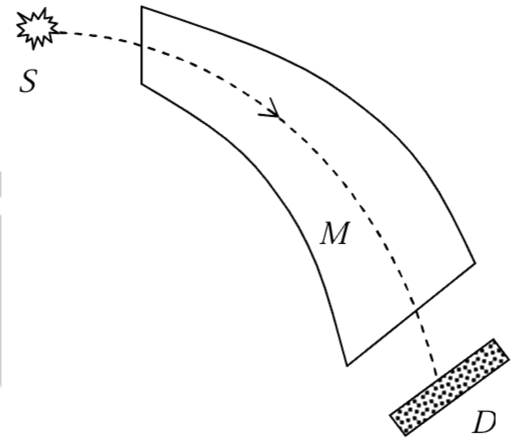
Using this information, one can estimate the number of such fission reactions per second in a 100 MW reactor as **[TIFR 2012]**

(a) 3.9×10^{18} (b) 7.8×10^{18}

(c)5.2×10^{19} (d) 5.2×10^{18}

(e) 8.9×10^{17}

4. In a beta decay experiment, an electromagnet M and a detector D are used to measure the energy of electrons (β^-), as shown in the figure.



The detector D is capable of detecting either electrons (β^-)or positrons (β^+). Now the β^-source is replaced with a β^+source, and we would like to measure the energy of the positrons (β^+)using the same setup. Which of the following is correct? **[TIFR 2014]**

(a) This can be done quite easily, if the polarity of current in the coils of the electromagnet is reversed.

(b) This can be done trivially, without changing anything, since the detector D can detect either β^-or β^+.

(c)There is no way to do this with the given set up, since β^+will have to be converted into β^-, which is obviously not possible.

(d) This cannot be done since the magnet does not have a symmetric shape.

5. It is well-known that the energy of the Sun arises from the fusion of hydrogen nuclei (protons) inside the core of the Sun. This takes place through several mechanisms, each resulting in emission of energy.

Which of the following reactions is NOT possible during the proton fusion inside the Sun? **[TIFR 2014]**

(a) ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{2}\mathrm{He}$

(b) ${}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He}$

(c) ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + e^{+} + v_{e}$

(d) ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2e^{+}$

6. Consider a process in which atoms of Actinium-226 (${}^{226}_{89}\mathrm{Ac}$) get converted to atoms of Radium-226 (${}^{226}_{\mathrm{BB}}\mathrm{Ra}$) and the yield of energy is 0.64MeV per atom. This occurs through **[TIFR 2016]**

Both $p \rightarrow n + e^{+} + v_{e}$

(a) and $p + e^{-} \rightarrow n + v_{e}$

Both $p \rightarrow n + e^{+} + v_{e}$

(b) and $n \rightarrow p + e^{-} + \bar{v}_{e}$

(c) Only $p \rightarrow n + e^{+} + v_{e}$

(d) Only $p + e^{-} \rightarrow n + v_{e}$

7. A deuteron of mass M and binding energy B is struck by a gamma ray photon of energy E_{γ}, and is observed to disintegrate into a neutron and a proton. If $B \ll Mc^{2}$, the minimum value of E_{γ} must be **[TIFR 2017]**

(a) $2B + \dfrac{B^{2}}{2Mc^{2}}$ (b) $B + \dfrac{B^{2}}{Mc^{2}}$

(c) $\dfrac{1}{2}\left(3B + \dfrac{B^{2}}{Mc^{2}}\right)$ (d) $\dfrac{1}{2}\left(2B + \dfrac{B^{2}}{Mc^{2}}\right)$

8. Let E_{N} be the energy released when one mole of pure ${}^{235}\mathrm{U}$ undergoes controlled fission, and E_{C} be the energy released when one mole of pure carbon undergoes complete combustion. The ratio E_{N}/E_{C} will have the order of magnitude **[TIFR 2013]**

(a) 10^{4} (b) 10^{8}

(c) 10^{9} (d) 10^{6}

9. Two atomic nuclei A and B have masses such that $m(B) = 2m(A)$. in the laboratory frame, the nucleus B is kept stationary, while the nucleus A is given a kinetic energy 300MeV and made to collide with B. It is found that the two nuclei fuse to form a compound nucleus C.

If the Q-value of the reaction is -30MeV, the excitation energy of the compound nucleus can be estimated as **[TIFR 2020]**

(a) 81MeV (b) 170MeV

(c) 330MeV (d) 270MeV

10. Consider the alpha decay of ${}^{224}\mathrm{U}$ at rest, to ${}^{220}\mathrm{Th}$. The atomic masses are given below:

$\mathrm{M}_{224\mathrm{U}} = 224.0276\mathrm{amu}$; $\mathrm{M}_{220\mathrm{Th}} = 220.0158\mathrm{amu}$; $\mathrm{M}_{4\mathrm{He}} = 4.0026\mathrm{amu}$.

What is the estimate of the kinetic energy of the emitted alpha (${}^{4}\mathrm{He}$) particle? (One amu corresponds to $931.5\mathrm{MeV/c^{2}}$.) **[TIFR 2025]**

(a) 8.4163 MeV (b) 8.5698 MeV

(c) 8.7261 MeV (d) 8.1066 MeV

❖ Answer Key				
CSIR-NET PYQ				
1. d	2. c	3. a	4. b	5. b
GATE PYQ				
1.	2. d	3.	4. d	5. b
6. c	7. a	8. a	9. a	10. a
11. a	12. a	13. b	14. a	15. b
16. 2.833	17. b	18. 4	19.	20. b
21. b				
JEST PYQ				
1. a				
TIFR PYQ				
1. e	2. c	3. a	4. a	5. d
6. d	7. d	8. b	9. b	10. a

GATE Q1. 1.274 MeV

GATE Q3. 4.25 MeV

GATE Q19. 4.917 MeV

Nuclear Detector

❖ **CSIR-NET PYQ**

1. Thermal neutrons may be detected most efficiently by a

[CSIR JUNE 2022]

(a)Li^6 loaded plastic scintillator

(b)Geiger-Müller counter

(c)inorganic scintillatorCaF2

(d) silicon detector

❖ **GATE PYQ**

1. The Geiger-Muller counter is a device to detect α, β and γ radiations. It is a cylindrical tube filled with monatomic gases like argon, and polyatomic gases such as ethyl alcohol. The inner electrode is along the axis of the cylindrical tube and the outer electrode is the tube. Which of the following statements is (are) CORRECT?

[GATE 2023]

(a) Argon is used so that ambient light coming from the surroundings do not produce any signal in the detector

(b) Ethyl alcohol is used as a quenching gas

(c)The electric field strength decreases from the axis to the edge of the tube and the direction of the field is radially outward

(d) The electric field increases from the axis to the edge of the tube and the field direction is radially inward

2. Nuclear radiation emitted from a ^{60}Co radioactive source is detected by a photomultiplier tube (PMT) coupled to a scintillator crystal. Which of the following option(s) is/are correct? **[GATE 2025]**

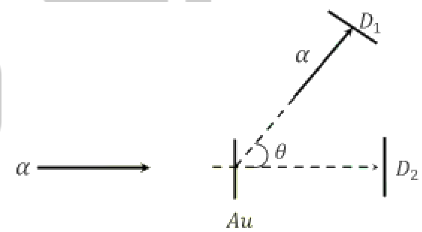
(a)γ radiation from ^{60}Co will directly hit the photocathode of the PMT without interacting with the scintillator crystal and produce a signal

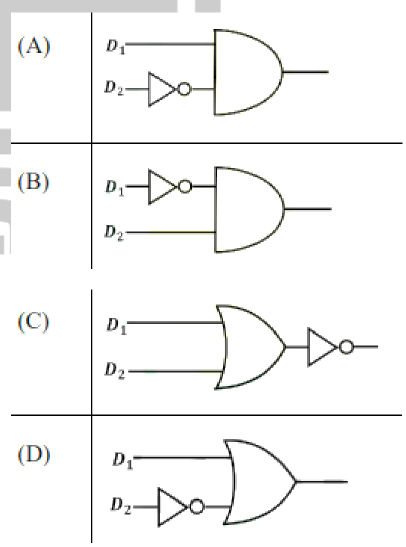
(b)β radiation from radiation, which will hit the photocathode of the PMT and produce a signal

(c)A mu-metal shield is put all around the PMT to nullify the effect of external electric Fields

(d)A mu-metal shield is put all around the PMT to nullify the effect of external magnetic fields

3. An α particle is scattered from an Au target at rest as shown in the figure. D_1 and D_2 are the detectors to detect the scattered α particle at an angle θ and along the beam direction, respectively, as shown. The signals from D_1 and D_2 are converted to logic signals and fed to logic gates. When a particle is detected, the signal is 1 and is 0 otherwise. Which one of the following circuits detects the particle scattered at the angle θ only? **[GATE 2025]**





a

4. Cyclotrons are used to accelerate ions like deuterons (d) and α particles. Keeping the magnetic field same for both, d and α are extracted with energies 10 MeV and 20 MeV with extraction radii r_d and r_α, respectively. Taking the masses $M_d = 2000\text{MeV}/c^2$ and $M_\alpha = 4000\text{MeV}/c^2$, the value of $\frac{r_\alpha}{r_d}$ (in integer) is **[GATE 2025]**

1to 1

Answer Key				
CSIR-NET PYQ				
1. a				
GATE PYQ				
1. abc	2. b,d	3. a	4. 1to1	

❖ **CSIR-NET PYQ**

1. A beam of pions (π^+)is incident on a proton target, giving rise to the process $\pi^+ p \to n + \pi^+ + \pi^+$
(A) Assuming that the decay proceeds through strong interactions, the total isospin I and its third component I_3 for the decay products, are

[CSIR JUNE 2011]

(a)$I = \frac{3}{2}, I_3 = \frac{3}{2}$ (b) $I = \frac{5}{2}, I_3 = \frac{5}{2}$

(c)$I = \frac{5}{2}, I_3 = \frac{3}{2}$ (d) $I = \frac{1}{2}, I_3 = -\frac{1}{2}$

(B) Using isospin symmetry, the cross-section for the above process can be related to that of the process

[CSIR JUNE 2011]

(a) $\pi^- n \to p\pi^-\pi^-$ (b) $\pi^-\bar{p} \to \bar{n}\pi^-\pi^-$

(c)$\pi^4 n \to p\pi^+\pi^-$ (d) $\pi^+\bar{p} \to n\pi^+\pi^-$

2. An atom of mass M can be excited to a state of mass $M + \Delta$ by photon capture. The frequency of a photon
which can cause this transition is:

[NET Dec. 2011]

(a) $\Delta c^2/2\,h$ (b) $\Delta c^2/h$

(c)$\Delta^2 c^2/2Mh$ (d) $\Delta(\Delta + 2M)c^2/2Mh$

3. Consider the decay process $\tau^- \to \pi^- + v_\tau$ in the rest frame of the τ^-. The masses of τ^-, π^- and v_τ are M_t, M_π and zero respectively.
(A) The energy of $\pi^-$is:

[CSIR JUNE 2011]

(a) $\frac{(M_\tau^2 - M_\pi^2)c^2}{2M_\tau}$ (b) $\frac{(M_r^2 + M_\pi^2)c^2}{2M_r}$

(c)$(M_r - M_\pi)c^2$ (d) $\sqrt{M_\tau M_\pi}c^2$

(B) The velocity is $\pi^-$is: **[CSIR JUNE 2011]**

(a) $\frac{(M_\tau^2 - M_\pi^2)c}{M_\tau^2 + M_\pi^2}$ (b) $\frac{(M_r^2 - M_\pi^2)c}{M_r^2 - M_\pi^2}$

(c) $\frac{M_\pi c}{M_\tau}$ (d) $\frac{M_\tau c}{M_\pi}$

4. The elastic scattering of a neutrino v_e by an electron e^-, i.e. the reaction $v_e + e^- \to v_e + e^-$, can be described by the interaction Hamiltonian

$$H_{int} = \frac{1}{\sqrt{2}} G_F \int d^3x(\bar{\psi}_e(x)\gamma^\mu \psi_{ve}(x))\big(\bar{\psi}_{ve}(x)\gamma_\mu \psi_e(x)\big)$$

The cross-section of the above process depends on the centre of mass energy E, as depends on the centre of mass energy E, as

[NET June 2019]

(a) $1/E^2$ (b) E^2

(c)E (d) $\sqrt{E}$

5. The strong nuclear force between a neutron and a proton in a zero orbital angular momentum state is denoted by $F_{np}(r)$, where r is the separation between them. Similarly, $F_{nn}(r)$ and $F_{pp}(r)$ denote the forces between a pair of neutrons and protons, respectively, in zero orbital momentum state. Which of the following is true on average if the inter-nucleon distance is $0.2\text{fm} < \bar{r} < 2\text{fm}$?

[NET Dec. 2019]

(a) F_{np} is attractive for triplet spin state, and F_{nn}, F_{pp} are always repulsive.

(b) F_{nn} and F_{np} are always attractive and F_{pp} is repulsive in this triplet spin state.

(c)F_{pp} and F_{np} are always attractive and F_{nn} is always repulsive.

(d) All three forces are always attractive.

6. hermal neutrons may be detected most efficiently by a

[NET June 2022]

(a) ^{6}Li loaded plastic scintillator

(b) Geiger-Müller counter

(c)inorganic scintillator CaF_2

(d) silicon detector

7. An electron of energy 27GeV collides with a proton of energy 820GeV. The heaviest particle which can be produced in this collision has mass close to

[CSIR DEC 2011]

(a) 300GeV (b) 821GeV

(c)850GeV (d) 1127GeV

8. The dominant interactions underlying the following processes

[CSIR JUNE 2012]

A. $K^- + p \rightarrow \Sigma^- + \pi^+$,
B. $\mu^- + \mu^+ \rightarrow K^- + K' \rightarrow$
C. $\Sigma^t \rightarrow p + \pi^0$ are

(a) A: strong, B: electromagnetic and C : weak

(b) A:strong, B: weak and C: weak

(c)A: weak, B: electromagnetic and C : strong

(d) A: weak, B: electromagnetic and C: weak

9. The muon has mass $105\text{MeV}/c^2$ and mean lifetime $2.2\mu s$ in its rest frame. The mean distance traversed by muon of energy $315\text{MeV}/c^2$ before decaying is approximately

[CSIR DEC 2012]

(a) 3×10^5 km (b) 2.2 cm

(c)6.6μm (d) 1.98 km

10. Consider the following particles: the proton p, the neutron n, the neutral pion π^0 and the delta resonance Δ^+. When ordered in terms of decreasing lifetime, the correct arrangement is as follows:

[CSIR DEC 2012]

(a) π^0, n, p, Δ^* (b) p, n, Δ^+, π^0
(c)p, n, π^0, Δ^+ (d) Δ^+, n, π^0, p

11. Muons are produced through the annihilation of particle a and its antiparticle, namely the process $a + \bar{a} \rightarrow \mu^+ + \mu^-$. A muon has a rest mass of $105\text{MeV}/c^2$ and its proper life time is 2μs. If the center of mass energy of the collision is 2.1GeV in the laboratory frame that coincides with the center-of-mass frame, then the fraction of muons that will decay before they reach a detector placed 6 km away from the interaction point is

[CSIR JUNE 2013]

(a) e^{-1} (b) $1 - e^{-1}$

(c)$1 - e^{-2}$ (d) e^{-10}

12. A spin- 1/2 particle A undergoes the decay $A \rightarrow B + C + D$ where it is known that B and C are also spin- 1/2 particles. The complete set of allowed values of the spin of the particle D is

[CSIR JUNE 2013]

(a) $\frac{1}{2}, 1, \frac{3}{2}, 2, \frac{5}{2}, 3, \ldots \ldots$ (b) 0,1

(c)$\frac{1}{2}$ only (d) $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \frac{7}{2}, \ldots$

13. Consider the following ratios of the partial decay widths

$$R_1 = \frac{\Gamma(\rho^+ \rightarrow \pi^+ + \pi^0)}{\Gamma(\rho^- \rightarrow \pi^- + \pi^0)}$$

and

$$R_2 = \frac{\Gamma(\Delta^{++} \rightarrow \pi^+ + p)}{\Gamma(\Delta^- \rightarrow \pi^- + n)}$$

. If the effects of electromagnetic and weak interactions are neglected, then R_1 and R_2 are, respectively,

[CSIR DEC 2013]

(a) 1 and $\sqrt{2}$ (b) 1 and 2

(c)2 and 1 (d) 1 and 1

14. The recently-discovered Higgs boson at the LHC experiment has a decay mode into a photon and a Z boson. If the rest masses of the Higgs and Z boson are $125\text{GeV}/c^2$ and $90\text{GeV}/c^2$ respectively, and the decaying Higgs particle is at rest, the energy of the photon will approximately be

[CSIR JUNE 2014]

(a) $35\sqrt{3}$GeV (b) 35GeV

(c)30GeV (d) 15GeV

15. In a classical model, a scalar (spin-0) meson consists of a quark and an antiquark bound by a potential

$$V(r) = ar + \frac{b}{r}$$

where $a = 200\text{MeVfm}^{-1}$ and $\text{b} = 100\text{MeVfm}$. If the masses of the quark and antiquark are negligible, the mass of the meson can be estimated as approximately **[CSIR JUNE 2014]**

(a) 141MeV/c^2 (b) 283MeV/c^2

(c) 353MeV/c^2 (d) 425MeV/c^2

16. Consider the four processes

(i) $\text{p}^+ \rightarrow \text{n} + \text{e}^+ + \text{v}_\text{e}$

(ii) $\Lambda^0 \rightarrow \text{p}^+ + \text{e}^+ + \text{v}_\text{e}$

(iii) $\pi^* \rightarrow \text{e}^+ + \text{v}_\text{e}$

(iv) $\pi^0 \rightarrow \gamma + \gamma$

Which of the above is/are forbidden for free particles? **[CSIR DEC 2014]**

(a) only (ii) (b) (ii) and (iv)

(c) (i) and (iv) (d) (i) and (ii)

17. The charm quark is assigned a charm quantum number $\text{C} = 1$. How should the Gellmann-Nishijima formula for electric charge be modified for four flavours of quarks?

[CSIR JUNE 2015]

(a) $\text{I}_3 + \frac{1}{2}(\text{B} - \text{S} - \text{C})$ (b) $\text{I}_3 + \frac{1}{2}(\text{B} - \text{S} + \text{C})$

(c) $\text{I}_3 + \frac{1}{2}(\text{B} + \text{S} - \text{C})$ (d) $\text{I}_3 + \frac{1}{2}(\text{B} + \text{S} + \text{C})$

18. The reaction ${}^2_1\text{D} + {}^2_1\text{D} \rightarrow {}^4_2\text{He} + \pi^0$ cannot proceed via strong interactions because it violates the conservations of

[CSIR JUNE 2015]

(a) angular momentum (b) electric charge

(c) baryon number (d) isospin

19. Consider the following processes involving free particles

(i) $\bar{n} \rightarrow \bar{p} + e^+ + \bar{v}_e$

(ii) $\bar{p} + n \rightarrow \pi^-$

(iii) $p + n \rightarrow \pi^+ + \pi^0 + \pi^0$

(iv) $p + \bar{v}_e \rightarrow n + e^+$

Which of the following statements is true?

[CSIR DEC 2015]

(a) Process (i) obeys all conservation laws

(b) Process (ii) conserves baryon number, but violates energy-momentum conservation

(c) Process (iii) is not allowed by strong interactions, but is allowed by weak interactions

(d) Process (iv) conserves baryon number, but violates lepton number conservation

20. In the large hadron collider (LHC), two equal energy proton beams traverse in opposite directions along a circular path of length 27 km. If the total center of mass energy of a proton-proton pair is 14 TeV, which of the following is the best approximation for the proper time taken by a proton to traverse the entire path?

[CSIR JUNE 2016]

(a) 12 ns (b) $1.2\mu s$

(c) 1.2 ns (d) $0.12\mu s$

21. Which of the following reaction(s) is/are allowed by the conservation laws ?

[CSIR DEC 2016]

(i) $\pi^+ + \text{n} \rightarrow \Lambda^0 + \text{K}^+$

(ii) $\pi^- + \text{p} \rightarrow \Lambda^0 + \text{K}^0$

(a) Both (i)and(ii) (b) Only (i)

(c) Only (ii) (d) Neither(i)nor(ii)

22. A particle, which is a composite state of three quarks u, d and s, has electric charge, spin and strangeness respectively, equal to

[CSIR DEC 2016]

(a) $1, \frac{1}{2}, -1$ (b) $0, 0, -1$

(c) $0, \frac{1}{2}, -1$ (d) $-1, -\frac{1}{2}, +1$

23. SA baryon X decays by strong interaction as $X \rightarrow \Sigma^{+} + \pi^{-} + \pi^{0}$, where $\Sigma^{+}$is a member of the isotriplet $(\Sigma^{*}, \Sigma^{0}, \Sigma^{-})$. The third component I_3 of the isospin of X is

[CSIR JUNE 2017]

(a) 0 (b) 1/2

(c)1 (d) 3/2

24. Which of the following processes is not allowed by the strong interaction but is allowed by the weal interaction?

[CSIR DEC 2017]

(a) $K^{0} + \pi^{0} \rightarrow \bar{K}^{0} + \pi^{+} + \pi^{-}$

(b) $p + n \rightarrow d + p + \bar{p}$

(c)$\Delta^{+} + K^{0} \rightarrow p + n$

(d) $p + \Delta^{+} \rightarrow \bar{n} + \Delta^{++}$

25. Which of the following elementary particle processes does not conserve strangeness ?

[CSIR JUNE 2018]

(a) $\pi^{0} + p \rightarrow K^{+} + \Lambda^{0}$ (b) $\pi^{-} + p \rightarrow K^{0} + \Lambda^{0}$

(c)$\Delta^{0} \rightarrow \pi^{0} + n$ (d) $K^{0} \rightarrow \pi^{+} + \pi^{-}$

26. A deuteron d captures a charged pion π^{-}in the $l = 1$ state, and subsequently decays into a pair of neutrons (n) via strong interaction. Given that the intrinsic parities of π^{-}, d and n are $-1, +1$ and $+1$ respectively, the spin-wavefunction of the final state neutrons is a

[CSIR JUNE 2018]

(a) linear combination of a singlet and a triplet.

(b) singlet

(c)triplet

(d) doublet

27. Consider the decay $A \rightarrow B + C$ of a relativistic spin $-\frac{1}{2}$ particle A. Which of the following statements is true in the rest frame of the particle A ? **[CSIR DEC 2018]**

(a) The spin of both B and C may be ½

(b) The sum of the masses of B and C is greater than the mass of A

(c)The energy of B is uniquely determined by the masses of the particles

(d) The spin of both B and C may be integral

28. Assume that pion-nucleon scattering at low energies, in which isospin is conserved, is described by the effective interaction potential $V_{\text{eff}} = F(r)\vec{I}_x \cdot \vec{I}_N$, where $F(r)$ is a function of the radial separation r and $\vec{I}_m$ and $\vec{I}_N$ denote, respectively, the isospin vectors of a pion and the nucleon. The ratio $\sigma_{I=3/2}/\sigma_{I-\nu/2}$ of the scattering cross-sections corresponding to total isospins $I =$ 3/2 and 1/2, is **[CSIR DEC 2018]**

(a) 3/2 (b) 1/4

(c)5/4 (d) 1/2

29. The mean life-time of the following decays: $\rho_0 \rightarrow \pi^{+} + \pi^{-}, \pi^{0} \rightarrow \gamma + \gamma, \mu^{-} \rightarrow e^{-} + \bar{v}_e + v_\alpha$, are τ_p, τ_π and τ_μ, respectively. They satisfy

[CSIR JUNE 2019]

(a) $\tau_\pi < \tau_\rho < \tau_\mu$ (b) $\tau_\mu < \tau_\rho < \tau_s$

(c)$\tau_p < \tau_\pi < \tau_\mu$ (d) $\tau_\rho < \tau_\mu < \tau_\pi$

30. Which of the following decay processes is allowed ?

[CSIR DEC 2019]

(a) $K^{0} \rightarrow \mu^{+} + \mu^{-}$ (b) $\mu \rightarrow e^{-} + \gamma$

(c)$n \rightarrow p + \pi^{-}$ (d) $n \rightarrow \pi^{+} + \pi^{-}$

31. Charged pions π^{-}decay to muons $\mu^{-}$and anti-muon neutrinos $\vec{v}_\mu; \pi^{-} \rightarrow \mu^{-} + \vec{v}_\mu$. Take the rest masses of a muon and a pion to be 105MeV and 140MeV, respectively. The probability that the measurement of the muon spin along the direction of its momentum is positive, is closest to

[CSIR DEC 2020]

(a) 0.5
(b) 0.75

(c) 1
(d) 0

32. A particle of mass $\frac{1\mathrm{GeV}}{c^2}$ and its antiparticle, both moving with the same speed v, produce a new particle X of mass $\frac{10\mathrm{GeV}}{c^2}$ in a head-on collision. The minimum value of v required for this process is closest to

[CSIR JUNE 2021]

(a) 0.83c
(b) 0.93c

(c) 0.98c
(d) 0.88c

33. In an experiment, the velocity of a non-relativistic neutron is determined by measuring the time (~ 50 ns) it takes to travel from the source to the detector kept at a distance L. Assume that the error in the measurement of L is negligibly small. If we want to estimate the kinetic energy T of the neutron to within 5% accuracy i.e., $\left|\frac{\delta T}{T}\right| \leq 0.05$, the maximum permissible error $|\delta T|$ in measuring the time of flight is nearest to

[CSIR JUNE 2021]

(a) 1.75 ns
(b) 0.75 ns

(c) 2.25 ns
(d) 1.25 ns

34. In the reaction $p + n \to p + K^+ + X$, mediated by strong interaction, the baryon number B, strangeness S and third component of isospin I_3 of the particle X are, respectively

[CSIR JUNE 2021]

(a) $-1, -1$ and -1
(b) $+1, -1$ and -1

(c) $+1, -2$ and $-\frac{1}{2}$
(d) $-1, -1$ and 0

35. The elastic scattering process $\pi^- p \to \pi^- p$ may be treated as a hard-sphere scattering. The mass of

$$\pi^-, m_\pi \simeq \frac{1}{6} m_p$$

, where $m_p \simeq 938\mathrm{MeV}/c^2$ is the mass of the proton. The total scattering cross-section is closest to

[CSIR JUNE 2022]

(a) 0.01 milli-barn
(b) 1 milli-barn,

(c) 0.1 barn,
(d) 10 barn,

36. A neutral particle X^0 is produced in $\pi^- + p \to X^0 + n$ by s-wave scattering. The branching ratios of the decay of X^0 to 2γ, 3π and 2π are 0.38,0.30 and less than 10^{-3}, respectively. The quantum numbers J^{CP} of X^0 are

[CSIR JUNE 2023]

(a) 0^{-+}
(b) 0^{+-}

(c) 1^{-+}
(d) $4 \cdot 1^{+-}$

37. Atmospheric neutrinos are produced from the cascading decays of cosmic pions ($\pi^\pm$) to stable particles. Ignoring all other neutrino sources, the ratio of muon neutrino $(v_\mu + \bar{v}_\mu)$ flux to electron neutrino $(v_e + \bar{v}_e)$ flux in atmosphere is expected to be closest to **[CSIR-DEC 2023]**

(a) 2: 3
(b) 1: 1

(c) 1: 2
(d) 2: 1

38. The nucleus of ^{40}K (of spin-parity 4^+ in the ground state) is unstable and decays to ^{40}Ar. The mass difference between these two nuclei is $\Delta Mc^2 = 1504.4$keV. The nucleus ^{40}Ar has an excited state at 1460.8 keV with spin-parity 2^+. The most probable decay mode of ^{40}K is by

[CSIR JUNE 2023]

(a) a β^+-decay to the 2^+ state of ^{40}Ar

(b) an electron capture to the 2^+ state of ^{40}Ar

(c) an electron capture to the ground state of ^{40}Ar

(d) a β^+-decay to the ground state of ^{40}Ar

39. For the decay of the Δ-baryons, the ratio of the decay rates **[CSIR DEC 2024]**

$$\frac{\Gamma(\Delta^- \to n\pi^-)}{\Gamma(\Delta^0 \to p\pi^-)}$$

is best approximated by

(a) $\frac{3}{2}$
(b) 3

(c)1 (d) $\frac{2}{3}$

40. The ρ-mesons are $J^P = 1^-$particles that decay strongly into pions. The ratio of the particle decay widths

$$\frac{\Gamma(\rho^0 \to \pi^0\pi^0)}{\Gamma(\rho^+ \to \pi^+\pi^0)}$$

is closest to **[CSIR JUNE 2025]**

(a)1 (b) $\frac{1}{2}$

(c)0 (d)2

❖ **GATE PYQ**

1. The cross-sections of the reactions $\mathrm{p} + \Pi^- \to \Sigma^- + \mathrm{K}^+$and $\mathrm{p}^- + \Pi^+ \to \bar{\Sigma}^- + \mathrm{K}^-$at a given energy are the same due to

[GATE 2001]

(a) baryon number conservation

(b) time-reversal invariance

(c)charge conjugation

(d) parity conservation

2. Which of the following functions describes the nature of interaction potential V(r) between two quarks inside a nucleon? (r is the distance between the quarks and a and b positive constants of suitable dimensions)

[GATE 2001]

(a)$\mathrm{V(r)} = \frac{\mathrm{a}}{\mathrm{r}} + \mathrm{br}$ (b) $\mathrm{V(r)} = -\frac{\mathrm{a}}{\mathrm{r}} + \mathrm{br}$

(c)$\mathrm{V(r)} = \frac{\mathrm{a}}{\mathrm{r}} - \mathrm{br}$ (d) $\mathrm{V(r)} = -\frac{\mathrm{a}}{\mathrm{r}} - \mathrm{br}$

3. Which of the following reactions violates lepton number conservation?

(a) $\mathrm{e}^+ + \mathrm{e}^- \to \mathrm{v} + \bar{\mathrm{v}}$ (b) $\mathrm{e}^- + \mathrm{p} \to \mathrm{v} + \mathrm{n}$

(c)$\mathrm{e}^+ + \mathrm{n} \to \mathrm{p} + \mathrm{v}$ (d) $\mu^- \to \mathrm{e}^- + \mathrm{v} + \bar{\mathrm{v}}$

4. The baryon number of proton, the lepton number of proton, the baryon number of electron and the lepton number of electron are respectively

[GATE 2002]

(a) zero, zero, one and zero

(b) one, one, zero and one

(c)one, zero, zero and one

(d) zero, one, one and zero

5. The nucleus of the atom $^9\mathrm{Be}_4$ consists of

[GATE 2003]

(a) 13 up quarks and 13 down quarks

(b) 13 up quarks and 14 down quarks

(c)14 up quarks and 13 down quarks

(d) 14 up quarks and 14 down quarks

6. Which one of the following nuclear reactions is possible?

[GATE 2003]

(a) $^{14}\mathrm{N}_7 \to {}^{13}\mathrm{C}_6 + \beta^+ + \mathrm{v}_\mathrm{c}$

(b) $^{13}\mathrm{N}_7 \to {}^{13}\mathrm{C}_6 + \beta^+ + \mathrm{v}_\mathrm{c}$

(c) $^{13}\mathrm{N}_7 \to {}^{13}\mathrm{C}_6 + \beta^+$

(d) $^{13}\mathrm{N}_7 \to {}^{13}\mathrm{C}_7 + \beta^+ + \mathrm{v}_\mathrm{c}$

7. Suppose that a neutron at rest in free space decays into a proton and an electron. This process would violate

[GATE 2003]

(a) conservation of charge

(b) conservation of energy

(c)conservation of linear momentum

(d) conservation of angular momentum

8. If the photon were to have a finite mass, then the Coulomb potential between two stationary charges separated by a distance r would

[GATE 2003]

(a) be strictly zero beyond some distance

(b) fall off exponentially for large values of r

(c)fall off as $1/r^3$ for large values of r

(d) fall off as $1/r$ for large values of r

9. A stationary particle in free space is observed to spontaneously decay into two photons. This implies that **[GATE 2003]**

(a) the particle carries electric charge

(b) the spin of the particle must be greater than or equal to 2

(c)the particle is a boson

(d) the mass of the particle must be greater than or equal to the mass of the hydrogen atom

10. The resonance widths Γ of ρ, ω and φ particle resonances satisfy the relation $\Gamma_p > \Gamma_\omega > \Gamma_\varphi$. Their life-times τ satisfy the relation

[GATE 2004]

(a) $\tau_p > \tau_\omega > \tau_{ip}$ (b) $\tau_p < \tau_\omega < \tau_\varphi$

(c)$\tau_p < \tau_\omega < \tau_\varphi$ (d) $\tau_p > \tau_\omega < \tau_\varphi$

11. Choose the particle with zero Baryon number from the list given below.

[GATE 2004]

(a) pion (b) neutron

(c)proton (d) Δ^+

12. Which of the following decay is forbidden?

[GATE 2005]

(a) $\mu^- \to e^- + v_\mu + \bar{v}_c$ (b) $\pi^+ \to \mu^+ + v_\mu$

(c)$\pi^+ \to e^+ + v_e$ (d) $\mu^- \to e^+ + e^- + e^-$

13. The interaction potential between two quarks, separated by a distance r inside a nucleon, can be described by (a, b and β are positive constants)

[GATE 2006]

(a)$ae^{-\beta r}$ (b) $\frac{a}{r} + br$

(c) $-\frac{a}{r} + br$ (d) $\frac{a}{r}$

14. Which one of the following nuclear processes is forbidden?

[GATE 2006]

(a) $\bar{v} + p \to n + e^+$

(b) $\pi^- \to e^- + v_e + \pi^0$

(c)$\pi^- + p^- \to n + K^+ + K^-$

(d) $\mu^- \to e^- + \bar{v}_e + v_\mu$

15. The strangeness quantum number is conserved in **[GATE 2007]**

(a) strong, weak and electromagnetic interactions

(b) weak and electromagnetic interactions only

(c)strong and weak interactions only

(d) strong and electromagnetic interactions only

16. A relativistic particle travels a length of 3×10^{-3} m in air before decaying. The decay process of the particle is dominated by

[GATE 2007]

(a) strong interactions

(b) electromagnetic interactions

(c)weak interactions

(d) gravitational interactions

17. The strange baryon Σ^+has the quark structure

(a) uds (b) uud

(c)uus (d) $u\bar{s}$

18. According to the quark model, the K^+meson is composed of the following quarks:

[GATE 2008]

(a) u ud (b) $u\bar{c}$

(c) $u\bar{s}$ (d) $s\bar{u}$

19. Choose the correct statement from the following **[GATE 2008]**

(a) The reaction $K^+K^- \rightarrow p\bar{p}$ can proceed irrespective of the kinetic energies of K^+ and K^-

(b) The reaction $K^+K^- \rightarrow p\bar{p}$ is forbidden by the baryon number conservation

(c) The reaction $K^+K^- \rightarrow 2\gamma$ is forbidden by strangeness conservation

(d) The decay $K^0 \rightarrow \pi^+\pi^-$ proceeds via weak interactions.

20. A neutral pi meson (π°) has a rest-mass of approximately $140\text{MeV}/c^2$ and a lifetime of τsec. A π^0 produced in the laboratory is found to decay after 1.25τsec into two photons. Which of the following sets represents a possible set of energies of the two photons as seen in the laboratory? **[GATE 2008]**

(a) 70 MeV and 70 MeV

(b) 350 MeV and 100 MeV

(c) 75 MeV and 100 MeV

(d) 25 MeV and 150 MeV

21. In the quark model which one of the following represents a proton? **[GATE 2009]**

(a) udd (b) uud

(c) $u\bar{b}$ (d) $c\bar{c}$

22. Consider the operations $P: \vec{r} \rightarrow \vec{r}$ (parity) and $T: t \rightarrow -t$ (time-reversal). For the electric and magnetic fields $\bar{E}$ and $\bar{B}$, which of the following set of transformations is correct? **[GATE 2010]**

(a) $P: \vec{E} \rightarrow -\vec{E}, \vec{B} \rightarrow \vec{B}$
$T: \vec{E} \rightarrow \vec{E}, \vec{B} \rightarrow -\vec{B}$

(b) $P: \vec{E} \rightarrow -\vec{E}, \vec{B} \rightarrow \vec{B}$
$P: \vec{E} \rightarrow \vec{E}, \vec{B} \rightarrow -\vec{B}$

(c) $T: \vec{E} \rightarrow -\vec{E}, \vec{B} \rightarrow \vec{B} \rightarrow -\vec{B}$

(d) $P: \vec{E} \rightarrow \vec{E}, \vec{B} \rightarrow -\vec{B}$
$T: \vec{E} \rightarrow -\vec{E}, \vec{B} \rightarrow \vec{B}$

23. The basic process underlying the neutron β-decay is **[GATE 2010]**

(a) $d \rightarrow u + e^- + \bar{\nu}_e$ (b) $d \rightarrow u + e^-$

(c) $s \rightarrow u + e^- + \bar{\nu}_e$ (d) $u \rightarrow d + e^- + \bar{\nu}_e$

24. In the nuclear shell model the spin parity of ^{15}N is given by **[GATE 2010]**

(1) $\pi^* \rightarrow \mu^+ + \nu_\mu$ (i) Strong
(2) $\pi^0 \rightarrow \gamma + \gamma$ (ii) Electromagnetic
(3) $\pi^0 + n \rightarrow \pi^- + p$ (iii) Weak

(a) (1,iii), (2,ii), (3,i) (b) (1, i), (2,ii), (3,iii)

(c) (1, ii), (2,i), (3,iii) (d) (1, iii), (2, i), (3,ii)

25. The quark content of Σ^+, K^-, π and p is indicated:
$|\Sigma\rangle = |uus\rangle; |K^-\rangle = |s\bar{u}\rangle; |\pi^-\rangle = |\bar{u}d\rangle; |p\rangle = |uud\rangle$
In the process, $\pi^- + p \rightarrow K^- + \Sigma^-$, considering strong interactions only, which of the following statements is true? **[GATE 2010]**

(a) The process is allowed because $\Delta S = 0$

(b) The process is allowed because $\Delta I_3 = 0$

(c) The process is not allowed because $\Delta S \neq 0$ and $\Delta I_3 \neq 0$

(d) The process is not allowed because the baryon number is violated

26. The ground state wavefunction of deuteron is in a superposition of s and d states. Which of the following is NOT true as a consequence? **[GATE 2010]**

(a) It has a non-zero quadruple moment

(b) The neutron-proton potential is non-central

(c)The orbital wavefunction is not spherically symmetric

(d) The Hamiltonian does not conserve the total angular momentum

27. A neutron passing through a detector is detected because of

[GATE 2011]

(a) the ionization it produces

(b) the scintillation light it produces

(c)the electron-hole pair it produces

(d) the secondary particles produced in a nuclear reaction in the detector medium.

28. In the $\beta -$ decay of neutron $n \rightarrow p + e^- + \bar{\nu}_e$, the anti-neutrino $\bar{\nu}_e$ escapes detection. Its existence is inferred from the measurement of

[GATE 2011]

(a) energy distribution of electrons

(b) angular distribution of electrons

(c)helicity distribution of electrons

(d) forward-backward asymmetry of electrons

29. The isospin and the strangeness of Ω^-baryon are

[GATE 2011]

(a) $1, -3$ (b) $0, -3$

(c)1,3 (d) 0,3

30. In case of a Geiger-Muller (GM) counter, which one of the following statements is CORRECT?

(a) Multiplication factor of the detector is of the order of 10^{10}.

[GATE 2012]

(b) Type of the particles detected can be identified.

(c)Energy of the particles detected can be distinguished.

(d) Operating voltage of the detector is few tens of Volts.

31. Deuteron has only one bound state : with spin parity 1^+, isospin 0 and electric quadrupole moment 0.286 efm^2. These data suggest that the nuclear forces are having

[GATE 2012]

(a) only spin and isospin dependence

(b) no spin dependence and no tensor components

(c)spin dependence but no tensor components

(d) spin dependence along with tensor components

32. Choose the correct statement from the following

[GATE 2012]

(a) Neutron interacts through electromagnetic interaction

(b) Electron does not interact through weak interaction

(c)Neutrino interacts through weak and electromagnetic interaction

(d) Quark interacts through strong interaction but not through weak interaction

33. The decay process $n \rightarrow p^+ + e^- + \bar{\nu}_e$ violates

[GATE 2013]

(a) baryon number (b) lepton number

(c)isospin (d) strangeness

34. Consider the decay of a pion into a muon and an anti-neutrino $\pi^{-1} \rightarrow \mu^{-1} + \bar{\nu}_\mu$ in the pion rest frame.

$m_\pi = 139.6\text{MeV/c}^2, m_\mu = 105.7\text{MeV/c}^2, m_\nu \approx 0$

The energy (in MeV) of the emitted neutrino to the nearest integer is________________.

[GATE 2013]

30

35. The isospin (I) and baryon number (B) of the up quark is

[GATE 2013]

(a) $I = 1, B = 1$ (b) $I = 1, B = 1/3$

(c) $I = 1/2, B = 1$ (d) $I = 1/2, B = 1/3$

36. Which one of the following high energy processes is allowed by conservation laws?

[GATE 2014]

(a) $p + \bar{p} \rightarrow \Lambda^{\circ} + \Lambda^{\circ}$ (b) $\pi^{-} + p \rightarrow \pi^{\circ} + n$

(c) $n \rightarrow p + e^{-} + v_{e}$ (d) $\mu^{+} \rightarrow e^{+} + \gamma$

37. The value of the magnetic field required to maintain non-relativistic protons of energy 1 MeV in a circular orbit of radius 100 mm is   Tesla.

[GATE 2014]

(Given: $m_p = 1.67 \times 10^{-27}$ kg, $e = 1.6 \times 10^{-19}$C

38. Which one of the following three-quark states (qqq) denoted by X, cannot be a possible baryon? The corresponding electric charge is indicated in the superscript.

[GATE 2014]

(a) X^{++} (b) X^{+}

(c) X^{-} (d) X^{--}.

39. Consider the process $\mu^{+} + \mu^{-} \rightarrow \pi^{+} + \pi^{-}$. The minimum kinetic energy of the muons (μ) in the centre of mass frame required to produce the pion (π) pairs at rest is____________ MeV (Given: $m_{\mu} = 105\text{MeV}/c^2, m_{x} = 140\text{MeV}/c^2$)

[GATE 2014]

40. The decay $\mu^{+} \rightarrow e^{+} + \gamma$ is forbidden, because it violates

[GATE 2015]

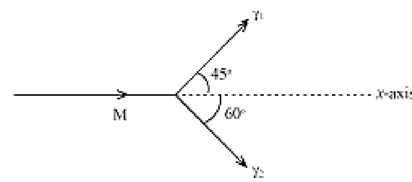
(a) momentum and lepton number conservation

(b) baryon and lepton number conservation

(c) angular momentum conservation

(d) lepton number conservation

41. A particle of rest mass M is moving along the positive x-direction. It decays into two photons γ_1 and γ_2 as shown in the figure. The energy of γ_1 is 1GeV and the energy of γ_2 is 0.82GeV. The value of M (in units of GeV/c^2) is_____ (Give your answer upto two decimal places)



42. In the SU(3) quark model, the triplet of mesons $(\pi^{+}, \pi^{0}, \pi^{-})$has

[GATE 2016]

(a) Isospin = 0, Strangeness = 0

(b) Isospin = 1, Strangeness = 0

(c) Isospin = 1/2, Strangeness = +1

(d) Isospin = 1/2, Strangeness = −1

43. Which of the following statements is NOT correct?

[GATE 2016]

(a) A deuteron can be disintegrated by irradiating it with gamma rays of energy 4 MeV .

(b) A deuteron has no excited states

(c) A deuteron has no electric quadrupole moment

(d) The $^{1}S_{0}$ state of deuteron cannot be formed

44. An alpha particle is accelerated in a cyclotron. It leaves the cyclotron with a kinetic energy of 16 MeV . The potential difference between the D electrodes is 50 kilovolts. The number of revolutions the alpha particle makes in its spiral path before it leaves the cyclotron is

[GATE 2016]

45. Electromagnetic interactions are: **[GATE 2017]**

(a) C conserving

(b) C non-conserving but CP conserving

(c)CP non-conserving but CPT conserving

(d) CPT non-conserving

46. Which one of the following conservation laws is violated in the decay $\tau^+ \to \mu^+\mu^+\mu^-$ **[GATE 2017]**

(a) angular momentum

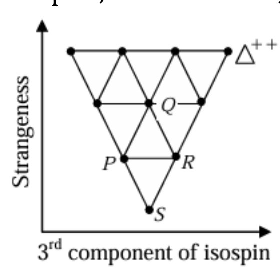
(b) total Lepton number

(c)electric charge

(d) tau number

47. The π^+decays at rest to $\mu^\dagger$ and v_μ. Assuming the neutrino to be mass less, the momentum of the neutrino is _______MeV/c. (up to two decimal places) $\left(m_\pi = 139\text{MeV}/c^2, m_\mu = 105\text{MeV}/c^2\right)$. **[GATE 2017]**

48. The elementary particle Ξ^0 is placed in the baryon decuplet, shown below, at **[GATE 2018]**



(a) P (b) Q

(c)R (d) S

49. In the decay, $\mu^+ \to e^+ + v_e + X$, what is X ? **[GATE 2018]**

(a) γ (b) $\bar{v}_e$

(c)v_μ (d) $\bar{v}_\mu$

50. Considering baryon number and lepton number conservation laws, which of the following processes is/are allowed? **[GATE 2019]**

(i) $p \to \pi^0 + e^+ + v_e$
(ii) $e^+ + v_e \to \mu^+ + v_\mu$

(a) both (i) and (ii) (b) only (i)

(c)only (ii) (d) neither (i) nor (ii)

51. A massive particle **X** in free space decays spontaneously into two photons. Which of the following statements is true for **X** ? **[GATE 2019]**

(a) **X** is charged

(b) Spin of **X** must be greater than or equal to 2

(c)**X** is a boson

(d) **X** must be a baryon

52. Low energy collision (s-wave scattering) of pion (π^+)with deuteron (d) results in the production of two protons ($\pi^+ + d \to p + p$). The relative orbital angular momentum (in units of $\hbar$) of the resulting two-proton system for this reaction is **[GATE 2019]**

(a) 0 (b) 1

(c)2 (d) 3

53. A particle X is produced in the process $\pi^+ + p \to K^+ + X$ via the strong interaction. If the quark content of the $K^+$is $u\bar{s}$, the quark content of X is **[GATE 2020]**

(a) $c\bar{s}$ (b) und

(c)uus (d) $u\bar{d}$

54. A particle Y undergoes strong decay $Y \to \pi^- + \pi^-$. The isospin of Y is **[GATE 2020]**
2

55. In the center of mass frame, two protons each having energy 7000GeV, collide to produce protons and anti-protons. The maximum number of anti-protons produced is (Assume the proton mass to be $1\mathrm{GeV/c^2}$) **[GATE 2020]**

56. The Gell – Mann – Okuba mass formula defines the mass of baryons as

$$M = M_0 + aY + b\left[I(I+1) - \frac{1}{4}Y^2\right]$$

, where M_0, a and b are constants, I represents the isospin and Y represents the hypercharge. If the mass of $\sum$ hyperons is same as that of Λ hyperons, then the correct option(s) is(are)

[GATE 2021]

(a) $M \propto I(I+1)$

(b) $M \propto Y$

(c) M does not depend on I

(d) M does not depend on Y

57. The Ξ^{0^*} particle is a member of the Baryon decuplet with isospin state

$$|I, I_3\rangle = \left|\frac{1}{2}, \frac{1}{2}\right\rangle$$

and strangeness quantum number -2 . In the quark model, which one of the following is the flavour part of the Ξ^{0^*} wavefunction?

[GATE 2023]

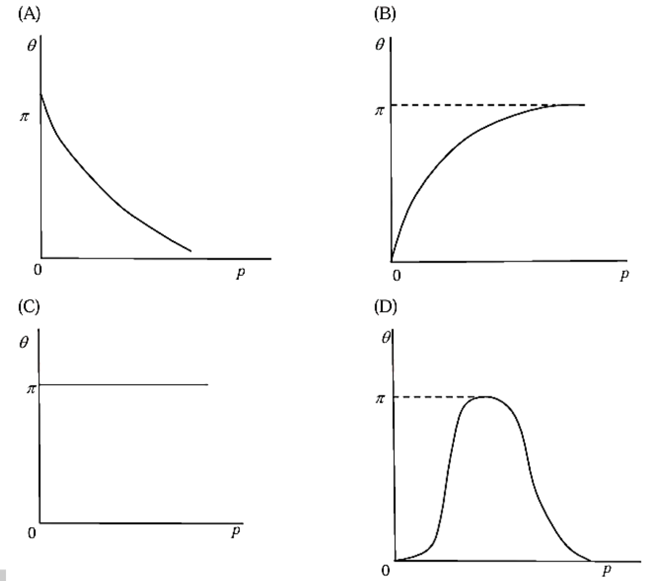
(a) $\frac{1}{\sqrt{2}}(uss - ssu)$

(b) $\frac{1}{\sqrt{3}}(uss + sus + ssu)$

(c) $\frac{1}{\sqrt{2}}(uss + ssu)$

(d) $\frac{1}{\sqrt{3}}(uss - sus + ssu)$

58. In a hadronic interaction, π^0,s are produced with different momenta, and they immediately decay into two photons with an opening angle θ between them. Assuming that all these decays occur in one plane, which one of the following figures depicts the behaviour of θ as a function of the π^0 momentum p ? **[GATE 2023]**



59. A slow moving π^-particle is captured by a deuteron (d) and this reaction produces two neutrons (n) in the final state, i.e., $\pi^- + d \rightarrow n + n$, Neutron and deuteron have even intrinsic parities, whereas π^-has odd intrinsic parity. L and S are the orbital and spin angular momenta, respectively of the system of two neutrons. Which of the following statements regarding the final two-neutron state is (are) CORRECT?

[GATE 2023]

(a) It has odd parity

(b) L + S is odd

(c) $L = 1, S = 1$

(d) $L = 2, S = 0$

60. Let P, Q and R be three different nuclei. Which one of the following nuclear processes is possible?

[GATE 2024]

(a) $v_e + {}^{A}_{z}P \rightarrow {}_{z+1}^{\ A}Q + e^{-1}$

(b) $v_e + {}^{A}_{z}P \rightarrow {}^{\ A}_{z-1}R + e^{+}$

(c) $v_e + {}^{A}_{z}P \rightarrow {}^{A}_{z}P + e^{+} + e^{-}$

(d) $v_e + {}^{A}_{2}P \rightarrow {}^{A}_{2}P + \gamma$

61. Decays of mesons and baryons can be categorized as weak, strong and electromagnetic decays depending upon the interactions involved in the processes. Which of the following option is/are true?

[GATE 2024]

(a) $\pi^0 \rightarrow \gamma\gamma$ is a weak decay

(b) $\Lambda^0 \rightarrow \pi^0 + p$ is an electromagnetic decay

(c) $K^0 \rightarrow \pi^+ + \pi^-$ is a weak decay

(d) $\Delta^{++} \rightarrow p + \pi^+$ is a strong decay

62. Which one of the following baryons has strangeness quantum number $S = -1$? **[GATE 2025]**

(a) Σ^{*0} (b) n

(c) Ξ^{*0} (d) Δ^0

63. The nuclear energy levels of mirror nuclei are similar. Using this empirical fact alone, the nuclear force can be said to be independent of which one of the following properties of the nucleons? **[GATE 2025]**

(a) Mass (b) Spin

(c) Charge (d) Parity

64. Which of the following option(s) is/are correct for photons? **[GATE 2025]**

(a) Its rest mass is zero, but its energy is non-zero

(b) It carries non-zero linear momentum

(c) It carries zero spin angular momentum

(d) It has two linearly independent states of polarization

65. Which of the following consideration(s) is/are showing that nuclear beta decay, $n \rightarrow p + e^- + \bar{\nu}_e$, has to be a three-body decay? **[GATE 2025]**

(a) Continuous distribution of the electron energy

(b) Spin of the final state

(c) Mass of the electron

(d) Mass of the proton

66. The Δ^+ baryon with spin $\frac{3}{2}$, at rest, decays to a proton and a pion ($\Delta^+ \rightarrow p + \pi^0$). The Δ^+ has positive intrinsic parity and π^0 has negative intrinsic parity. The orbital angular momentum of the proton-pion system (in integer) is **[GATE 2025]**

❖ **JEST PYQ**

1. A k meson (with a rest mass of 494MeV) at rest decays into a muon (with a rest mass of 106MeV) and a neutrino. The energy of the neutrino, which can be taken to be massless, is approximately **[JEST 2013]**

(a) 120MeV (b) 236MeV

(c) 300MeV (d) 388MeV

2. The reaction $e^+ - e^- \rightarrow \gamma$ is forbidden because, **[JEST 2015]**

(a) lepton number is not conserved

(b) linear momentum is not conserved

(c) angular momentum is not conserved

(d) charge is not conserved

3. The reaction $e^+ + e^- \rightarrow \gamma$ is forbidden because, **[JEST 2015]**

(a) lepton number is not conserved

(b) linear momentum is not conserved

(c) angular momentum is not conserved

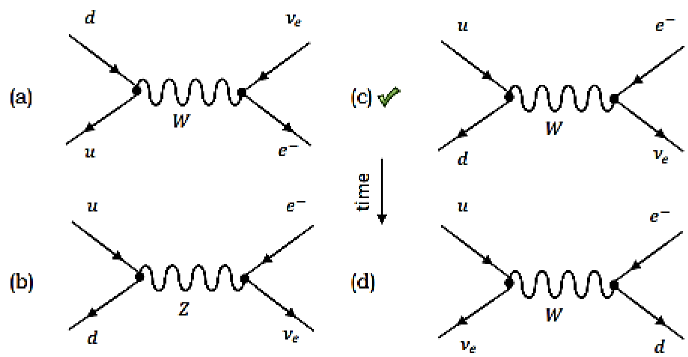
(d) charge is not conserved

❖ **TIFR PYQ**

1. The process of electron capture

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

takes place at the quark level through the Feynman diagram **[TIFR 2013]**



2. A spin- 1/2 particle A decays to two other particles B and C. If B and C are of spin- 1/2 and spin-1 respectively, then a complete list of the possible values of the orbital angular momentum of the final state (i.e. B + C) is

[TIFR 2013]

(a) 0,1 (b) $\frac{1}{2}, \frac{3}{2}$

(c)0, 1, 2 (d) 0, ± 1

3. Cosmic ray muons generated at the top of the Earth's atmosphere decay according to the radioactive decay law

$$N(t) = N(0)\exp\left(-\frac{0.693t}{T_{1/2}}\right)$$

[TIFR 2014]

where $N(t)$ is the number of muons at time t , and $T_{1/2} = 1.52\mu$ s is the proper half-life of the muon, Immediately after generation, most of these muons shoot down towards the Eearth's surface. Some of these muons decay on the way, but their interaction with the atmosphere is negligible. An observer on the top of a mountain of height 2.0 km above mean sea level detects muons with the speed 0.98 c over a period of time and counts 1000 muons. The number of muons of the same speed detected by an observer at mean sea level in the same period of time would be ~.

(a) 232 (b) 539

(c)839 (d) 983

4. A spin-2 nucleus absorbs a spin-1/2 electron and is then observed to decay to a stable nucleus in two stages, recoiling against an emitted invisible particle in the first stage and against an emitted spin-1 photons in the second stage. If the stable nucleus is spinless, then the set of all possible spin values of the invisible particle is

[TIFR 2014]

(a) {1/2,5/2} (b) {3/2,7/2}

(c){1/2,3/2,5/2} (d) {1/2,3/2,5/2,7/2}

5. The interaction strength of the recently-discovered Higgs boson (mass approximately $125\text{GeV}/c^2$) with any other elementary particle is proportional to the mass of that particle. Which of the following decayprocesses will have the greatest probability?

[TIFR 2014]

(a) Higgs boson decaying to a top quark +a top anti-quark

(b) Higgs boson decaying to a bottom quark + a bottom anti-quark

(c)Higgs boson decaying to an electron and a positron

(d) Higgs boson decaying to a neutrino-antineutrino pair.

6. Consider the following reaction involving elementary particles: **[TIFR 2015]**

(A) $\pi^- + p \rightarrow K^- + \Sigma^+$

(B) $K^- + p \rightarrow K^- + \rho^+$

Which of the following statements is true for strong interactions?

(a) (A) and (B) are both forbidden

(b) (B) is allowed but (A) is forbidden

(c)(A) is allowed but (B) is forbidden

(d) (A) and (B) are both allowed

7. In a fixed target experiment, a proton of total energy 200 GeV is bombarded on a proton at rest and produces a nucleus ${}^{2}_{A}N$ and its anti-nucleus ${}^{2}_{A}\bar{N}$

$$p + p \rightarrow {}^{z}_{A}N + {}^{z}_{A}\bar{N} + p + p$$

The heaviest nucleus ${}^{z}_{A}N$ that can be created has atomic mass number $A =$

(a) 15 (b) 9

(c)5 (d) 4

8. Consider the hyperon decay (1) $\Lambda \to n + \pi^0$ followed by (2) $\pi^0 \to \gamma\gamma$. If the isospin component, baryon number and strangeness quantum numbers are denoted by I_z, B and S respectively, then which of the following statements is completely correct?

[TIFR 2016]

(a) In (1)I_z is not conserved, B is conserved, S is not conserved;
In (2)I_z is conserved, B is conserved, S is conserved.

(b) In (1) I_z is conserved, B is not conserved, S is not conserved;
In (2) I_z is conserved, B is conserved, S is conserved.

(c)In (1)I_z is not conserved, B is conserved, S is not conserved;
In (2) I_z is not conserved, B is conserved, S is conserved.

(d) In (1)I_z is not conserved, B is conserved, S is conserved;
In (2)I_z is conserved, B is conserved, S is conserved.

9. A subatomic particle ψ and its excited state ψ^* have rest masses $3.1\text{GeV}/c^2$ and $3.7\text{GeV}/c^2$ respectively. A table of its assigned quantum numbers is given below.

Angular Momentum	Parity	C-Parity	Isospin	Electric charge
$J = 1$	$P = -1$	$C = -1$	$I = 0$	$Q = 0$

If $\pi^{0*\cdot}$ is an excited state of π^0 with a mass about $1.3\text{GeV}/c^2$, which of the following reaction is possible when the above quantum numbers are conserved ?

[TIFR 2017]

(a) $\psi^* \to \gamma\gamma$ (b) $\psi^* \to \psi\pi^+\pi^-$

(c)$\psi^* \to \pi^0\pi^0$ (d) $\psi^* \to \psi\pi^{0*}$

10. The table below gives the properties of four unstable particles $\mu^+, \pi^+, n^0, \Lambda^0$

[TIFR 2019]

Mass

Particle	(MeV $/c^2$)	Spin	Principal decay mode
muon $\dot{\mu}^+$	105.66	1/2	$\mu^+ \to e^+ + v_\mu^+ + \bar{v}_e$
pion π^+	139.57	0	$\pi^+ \to \mu^+ + \dot{v}_\mu$
neutron n^0	939.56	1/2	$n^0 \to p^+ + \dot{e}^- + \bar{y}_e$
Lambda hyperon Λ^0	1,115.68	1/2	$\Lambda^0 \to p^+ + \pi^+$

If arranged in order of DECREASING decay lifetime, the above list will read

(a) $n^0, \mu^+, \pi^+, \Lambda^0$ (b) $\pi^+, n^0, \mu^+, \Lambda^0$

(c)$\mu^+, \Lambda^0, n^0, \pi^+$ (d) $n^0, \Lambda^0, \mu^+, \pi^+$

11. Which of the following decays is forbidden?

[TIFR 2020]

(a) $\pi^0 \to \gamma + \gamma$

(b) $K^0 \to \pi^+ + \pi^- + \pi^0$

(c)$\mu^- \to e^- + v_e + \bar{v}_\mu$

(d) $n^0 \to p^+ + e^- + \bar{v}_e$

12. There are two conceivable channels by which a vector ρ^0 meson can decay into a pair of pseudo scalar pions. These are $\rho^0 \to \pi^0 + \pi^0$ and $\rho^0 \to \pi^+ + \pi^-$. The probability that the decay takes place through the process $\rho^0 \to \pi^+ + \pi^-$is approximately.

[TIFR 2022]

(a) 1 (b) Zero

(c) $\frac{m_{\pi^0}}{2m_{\pi^+}}$ (d) $\frac{m_{\pi^*}^2}{m_\rho^2}$

13. Consider an unstable bound state B of a proton (p) with an antiproton ($\bar{p}$), which is in the S-state ($\ell = 0$) in the spin-singlet configuration. When this state B decays, which of the following final states will NOT be possible?

[TIFR 2024]

(a) $\gamma + \gamma + \gamma$ (b) $\mu^+ + \mu^- + \gamma$

(c)$\gamma + \gamma$ (d) $e^+ + e^- + \gamma$

Answer Key				
CSIR-NET PYQ				
1. c/c	2. d	3. b/a	4. b	5. b
6. a	7. a	8. a	9. b	10. c
11. b	12. c	13. d	14. c	15. b
16. d	17. d	18. d	19. b	20. a
21. a	22. c	23. a	24. a	25. d
26. b	27. c	28. b	29. c	30. a
31. c	32. c	33. d	34. b	35. c
36. c	37. d	38. b	39. b	40. c
GATE PYQ				
1. d	2. b	3. c	4. c	5. b
6. b	7. d	8. b	9. c	10. c
11. a	12. d	13. c	14. b	15. d
16. b	17. c	18. c	19. d	20. c
21. b	22. a	23. a	24. a	25. c
26. d	27. d	28. b	29. b	30. a
31. d	32. a	33. c	34. 30	35. d
36. b	37. 1.44	38. d	39. 35	40. d
41. 1.44	42. b	43. c	44. 80	45. a
46. d	47. 29.84	48. c	49. d	50. c
51. c	52. b	53. c	54. 2	55. 6999
56. bc	57. b	58. a	59. a,c	60. a
61. cd	62. a	63. c	64. abd	65. ab
66. 1to1				
JEST PYQ				
1. b	2. b	3. b		
TIFR PYQ				
1. c	2. c	3. b	4. d	5. b
6. a	7. b	8. a	9. b	10. a
11. c	12. a	13. a		

Miscellaneous

❖ **CSIR-NET PYQ**

1. An atom of mass M can be excited to a state of mass $M+\Delta$ by photon capture. The frequency of a photon
which can cause this transition is:

[NET Dec. 2011]

(a) $\Delta c^2/2\,\text{h}$ ` (b) $\Delta c^2/\text{h}$

(c) $\Delta^2 c^2/2Mh$ (d) $\Delta(\Delta+2\text{M})\text{c}^2/2\text{Mh}$

2. The elastic scattering of a neutrino v_e by an electron e^-, i.e. the reaction $v_e+e^-\to v_e+e^-$, can be described by the interaction Hamiltonian $H_{int}=$
$\frac{1}{\sqrt{2}}G_F\int d^3x(\bar{\psi}_e(x)\gamma^\mu\psi_{ve}(x))(\bar{\psi}_{ve}(x)\gamma_\mu\psi_e(x))$.
The cross-section of the above process depends on the centre of mass energy E, as depends on the centre of mass energy E, as

[NET June 2019]

(a) $1/E^2$ (b) E^2

(c) E (d) $\sqrt{E}$

3. The strong nuclear force between a neutron and a proton in a zero orbital angular momentum state is denoted by $F_{np}(r)$, where r is the separation between them. Similarly, $F_{nn}(r)$ and $F_{pp}(r)$ denote the forces between a pair of neutrons and protons, respectively, in zero orbital momentum state. Which of the following is true on average if the inter-nucleon distance is $0.2\text{fm}<\bar{r}<2\text{fm}$?

[NET Dec. 2019]

(a) F_{np} is attractive for triplet spin state, and F_{nn}, F_{pp} are always repulsive.

(b) F_{nn} and F_{np} are always attractive and F_{pp} is repulsive in this triplet spin state.

(c) F_{pp} and F_{np} are always attractive and F_{nn} is always repulsive.

(d) All three forces are always attractive.

4. Thermal neutrons may be detected most efficiently by a

[NET June 2022]

(a) ^{6}Li loaded plastic scintillator

(b) Geiger-Müller counter

(c) inorganic scintillator CaF_2

(d) silicon detector

❖ **GATE PYQ**

1. The ground state wavefunction of deuteron is in a superposition of s and d states. Which of the following is NOT true as a consequence?

[GATE 2010]

(a) It has a non-zero quadruple moment

(b) The neutron-proton potential is non-central

(c) The orbital wavefunction is not spherically symmetric

(d) The Hamiltonian does not conserve the total angular momentum

2. A neutron passing through a detector is detected because of

[GATE 2011]

(a) the ionization it produces

(b) the scintillation light it produces

(c) the electron-hole pair it produces

(d) the secondary particles produced in a nuclear reaction in the detector medium.

3. In case of a Geiger-Muller (GM) counter, which one of the following statements is CORRECT?
(a) Multiplication factor of the detector is of the order of 10^{10}.

[GATE 2012]

(b) Type of the particles detected can be identified.

(c)Energy of the particles detected can be distinguished.

(d) Operating voltage of the detector is few tens of Volts.

4. Deuteron has only one bound state : with spin parity 1^{+}, isospin 0 and electric quadrupole moment 0.286 efm^2. These data suggest that the nuclear forces are having

[GATE 2012]

(a) only spin and isospin dependence

(b) no spin dependence and no tensor components

(c)spin dependence but no tensor components

(d) spin dependence along with tensor components

5. The value of the magnetic field required to maintain non-relativistic protons of energy 1 MeV in a circular orbit of radius 100 mm is   Tesla.

[GATE 2014]

(Given: $m_p = 1.67 \times 10^{-27}$ kg, $e = 1.6 \times 10^{-19}$C

6. Which of the following statements is NOT correct?

[GATE 2016]

(a) A deuteron can be disintegrated by irradiating it with gamma rays of energy 4 MeV .

(b) A deuteron has no excited states

(c)A deuteron has no electric quadrupole moment

(d) The $^{1}\mathrm{S}_0$ state of deuteron cannot be formed

7. An alpha particle is accelerated in a cyclotron. It leaves the cyclotron with a kinetic energy of 16 MeV . The potential difference between the D electrodes is 50 kilovolts. The number of revolutions the alpha particle makes in its spiral path before it leaves the cyclotron is

[GATE 2016]

❖ **TIFR PYQ**

1. An atom is capable of existing in two states: a ground state of mass M and an excited state of mass $M+\Delta$. If the transtion from the ground state to the excited state procceds by the absorption of a photon, the photon frquency in the laboratory frame (where the atom is initially at rest) is

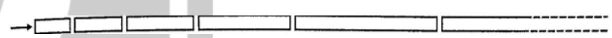
[TIFR 2010]

(a) $\frac{\Delta c^2}{h}$ (b) $\frac{\Delta c^2}{h}\left(1+\frac{\Delta}{2M}\right)$

(c) $\frac{\mathrm{M}c^2}{\mathrm{h}}$ (d) $\frac{\Delta c^2}{h}\left(1-\frac{\Delta}{2M}\right)$

(e) $\frac{Mc^2}{h}\left(1+\frac{\Delta}{2M}\right)$ (f) $\frac{\mathrm{M}c^2}{\mathrm{h}}\left(1-\frac{\Delta}{2\mathrm{M}}\right)$

2. An electron enters a linear accelerator with a speed $v = 10\ \mathrm{m\,s^{-1}}$. A vertical section of the accelerator tube is shown in the figure, where the lengths of the successive sections are designed such that the electron takes the same time $\tau =$ 20 ms to traverse each section.



If the momentum of the electron increases by 2% every time it crosses the narrow gap between two sections, what is the length (in km) of the collider which will be required to accelerate it to 100 km $-$ s^{-1} ?

[TIFR 2018]

3. In an experiment, a counting device is used to record the number of charged particles passing through it. Once this counter records a charged particle, it does not respond for a short interval of time, called the 'dead time' of that counter. This device is used to count the charged particles emitted by a particular radioactive source. It is found that if the source emits 20,000 counts/second at random intervals, the counter records 19,000 particles per second on an average. It follows that the counter dead time must be

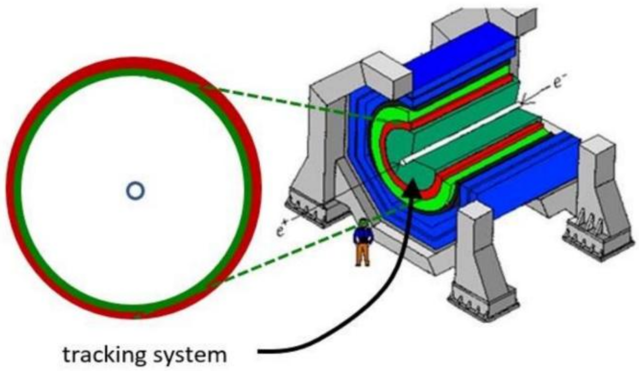
[TIFR 2021]

(a) 2.63 seconds (b) 2.63 microseconds

(c)2.63 nanoseconds (d) 50.0 milliseconds

4. The figure below shows on the right a sketch of an electron-positron collider experiment where the innermost detector (shaded dark green) is a tracking system which records the tracks of charged particles which pass through it. On the left of the figure, a cross-sectional view of the same tracking system is shown. The narrow (white) pipe in the centre is where electrons and positrons are injected as shown and collide in the Centre. (On the left it appears as a small central circle). Inside the tracking system there is a strong uniform magnetic field collinear with the e^+direction.

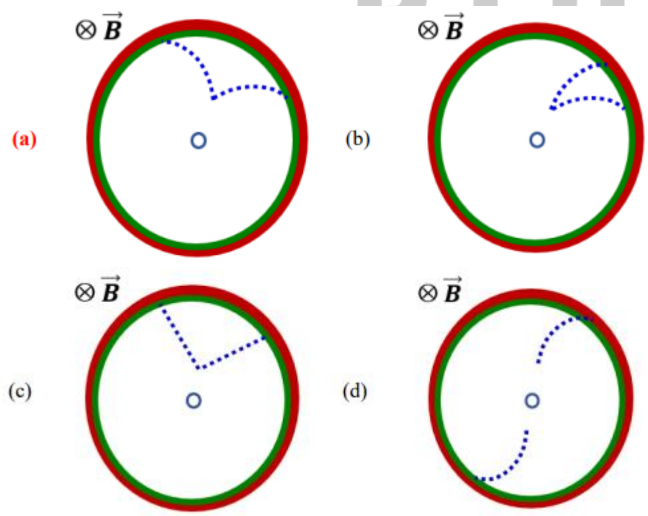
[TIFR 2023]



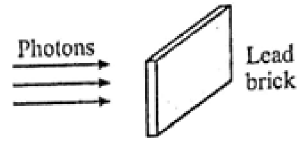
In one of the e^+e^-collisions, a high-energy K_S^0 meson is produced that subsequently decays as follows

$$K_S^0 \rightarrow \pi^+ + \pi^-$$

A possible representation of the tracks (dotted lines) of the pions $\pi^\pm$in the tracking systemwould be



5. A beam of photons of 1 MeV energy each is shot at a 10 mm thick lead brick (see figure).



Given that the density of lead is $11.29 \text{ g} - \text{cm}^{-3}$, its atomic mass is 207.2 amu , and also that the interaction crosssection for these photons with a lead atom is 10^{-23} cm^2, the fraction of the incident photons that will cross the brick without losing any energy is

[TIFR 2023]

(a) 72% (b) 28%

(c)67% (d) 33%

6. The binding energy of the k -shell electron in a Uranium atom ($Z = 92, A = 238$) will be modified due to (i) screening caused by other electrons and (ii) the finite extent of the nucleus as follows:

[JEST 2013]

(a) increases due to (i), remains unchanged due to (ii):

(b) decreases due to (i), decreases due to (ii).

(c)increases due to (i), increases due to (ii).

(d) decreases due to (i), remains unchanged due to (ii).

7. A cyclotron can accelerate deuteron to 16 MeV . If the cyclotron is used to accelerate α-particles, what will be their energy? Take the mass of deuteron to be twice the mass of proton and mass of α-particles to be four times the mass of proton.

[JEST 2019]

(a) 8 MeV (b) 16MeV$^-$

(c)32MeV$^-$ (d) 64 MeV

Answer Key				
CSIR-NET PYQ				
1. d	2. b	3. b	4. a	
GATE PYQ				
1. d	2. d	3. a	4. d	5. 1.44
6. c	7. 80			
TIFR PYQ				
1. b	2. 102	3. b	4. a	5. a
6. b	7. c			