

NUCLEAR AND PARTICLE PHYSICS SOLUTIONS

GATE-2010

Q1. The basic process underlying the neutron β -decay is

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

Ans: (a)

Q2. In the nuclear shell model the spin parity of ^{15}N is given by

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

Ans: (a)

Solution: $Z = 7$; $(s_{1/2})^2 (p_{3/2})^4 (p_{1/2})^1$ and $N = 8$

$$l = 1, J = \frac{1}{2} \Rightarrow \text{parity} = (-1)^l = -1, \quad \text{spin - parity} = \left(\frac{1}{2}\right)^-$$

Q3. Match the reactions on the left with the associated interactions on the right.

- (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)

Ans: (a)

Q4. 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?

- (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

Ans: (d)

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
 Near IIT, Hauz Khas, New Delhi-16
 Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
 28-B/6, Jia Sarai, Near IIT
 Hauz Khas, New Delhi-16

Q5. The first three energy levels of $^{228}\text{Th}_{90}$ are shown below

4 ⁺	_____	187keV
2 ⁺	_____	57.5keV
0 ⁺	_____	0keV

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

- (a) (6⁺; 400 keV) (b) (6⁺; 300 keV) (c) (2⁺; 400 keV) (d) (4⁺; 300 keV)

Ans: (a)

Solution: $\frac{E_2}{E_1} = \frac{J_2(J_2+1)}{J_1(J_1+1)} \Rightarrow \frac{E_6}{E_4} = \frac{6(6+1)}{4(4+1)} \Rightarrow E_6 = 393\text{keV}$

GATE-2011

Q6. 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

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

Ans: (c)

Q7. According to the single particles nuclear shell model, the spin-parity of the ground state of $^{17}_8\text{O}$ is

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

Ans: (d)

Solution: $Z = 8$ and $N = 9$; $(s_{1/2})^2 (p_{3/2})^4 (p_{1/2})^2 (d_{5/2})^1$

$$l = 2, J = \frac{5}{2} \Rightarrow \text{parity} = (-1)^2 = +1, \text{ spin - parity} = \left(\frac{5}{2}\right)^+$$

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16

- Q8. In the β -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
- (a) energy distribution of electrons (b) angular distribution of electrons
(c) helicity distribution of electrons (d) forward-backward asymmetry of electrons

Ans: (a)

- Q9. The isospin and the strangeness of Ω^- baryon are
- (a) 1, -3 (b) 0, -3 (c) 1, 3 (d) 0, 3

Ans: (b)

GATE-2012

- Q10. 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
- (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

Ans: (d)

- Q11. 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?

- (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

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16

Ans: (c)

Solution: $\pi^- + p \rightarrow k^- + \Sigma^+$

$$S: \quad 0 \quad 0 \quad -1 \quad -1 \text{ (not conserved)}$$

$$I_3: \quad -1 \quad +\frac{1}{2} \quad -\frac{1}{2} \quad +1 \text{ (not conserved)}$$

For strong interaction S and I_3 must conserve. Therefore this process is not allowed under strong interaction

Q12. Which one of the following sets corresponds to fundamental particles?

- (a) proton, electron and neutron
- (b) proton, electron and photon
- (c) electron, photon and neutrino
- (d) quark, electron and meson

Ans: (a)

Q13. In case of a Geiger-Muller (GM) counter, which one of the following statement is CORRECT?

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

Ans: (c)

Q14. Choose the CORRECT statement from the following

- (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

Ans: (d)

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16

GATE-2013

- Q15. The decay process $n \rightarrow p^+ + e^- + \bar{\nu}_e$ violates
- (a) Baryon number (b) lepton number (c) isospin (d) strangeness

Ans: (c)

- Q16. The isospin (I) and baryon number (B) of the up quark is
- (a) $I = 1, B = 1$ (b) $I = 1, B = 1/3$
 (c) $I = 1/2, B = 1$ (d) $I = 1/2, B = 1/3$

Ans: (d)

- Q17. In the β decay process, the transition $2^+ \rightarrow 3^+$, is
- (a) allowed both by Fermi and Gamow-Teller selection rule
 (b) allowed by Fermi and but not by Gamow-Teller selection rule
 (c) not allowed by Fermi but allowed by Gamow-Teller selection rule
 (d) not allowed both by Fermi and Gamow-Teller selection rule

Ans: (c)

Solution: According to Fermi Selection Rule:

$$\Delta I = 0, \quad \text{Parity} = \text{No Change}$$

According to Gamow-Teller Selection Rule:

$$\Delta I = 0, \pm 1, \quad \text{Parity} = \text{No Change}$$

In the β decay process, the transition $2^+ \rightarrow 3^+$,

$$\Delta I = \pm 1, \quad \text{Parity} = \text{No Change} .$$

GATE-2014

- Q18. Which one of the following is a fermions'?
- (a) α -particle (b) ${}_4\text{Be}^7$ nucleus
 (c) Hydrogen atom (d) deuteron

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
 Near IIT, Hauz Khas, New Delhi-16
 Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
 28-B/6, Jia Sarai, Near IIT
 Hauz Khas, New Delhi-16

Ans: (b)

If a nucleus contains odd number of nucleons, it is fermions. If a nucleus contains even number of nucleons, it is a boson.

Q19. 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.

- (a) X^{++} (b) X^+ (c) X^- (d) X^{--}

Ans: (d)

Solution: $X = qqq$

$$X^{++} (uuu) \frac{2}{3} + \frac{2}{3} + \frac{2}{3} = \frac{6}{3} = 2 \text{ (two unit positive charge)}$$

$$X^+ (uud) \frac{2}{3} + \frac{2}{3} - \frac{1}{3} = \frac{4}{3} - \frac{1}{3} = 1 \text{ (single unit positive charge)}$$

$$X^- (ddd) = -\frac{1}{3} - \frac{1}{3} - \frac{1}{3} = -1 \text{ (single unit negative charge)}$$

X^{--} [Not possible with qqq]. So the correct option is (d)

Q20. 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 .

Ans: 81.7

Solution: Use conservation of energy and momentum in relativistic form.

$$m_\mu = 105 \text{ MeV} / c^2 \quad \text{and} \quad m_\pi = 140 \text{ MeV} / c^2$$

$$E_\mu = \frac{(m_{\pi^+} + m_{\pi^-})^2 c^2 - (m_{\mu^+} + m_{\mu^-})^2 c^2}{2m_\mu} \Rightarrow E_\mu = \frac{(280)^2 \text{ MeV} - (210)^2 \text{ MeV}}{2 \times 105} = 163.3 \text{ MeV}$$

For pair it will be $\frac{163.3}{2} \text{ MeV} = 81.7 \text{ MeV}$

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16

- Q21. A nucleus X undergoes a first forbidden β -decay to 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 ?
- (a) $\frac{1^+}{2}$ (b) $\frac{1^-}{2}$ (c) $\frac{3^+}{2}$ (d) $\frac{3^-}{2}$

Ans: (c)
For first forbidden β -decay; $\Delta I = 0, 1$ or 2 and Parity does change.

GATE-2015

- Q22. The decay $\mu^+ \rightarrow e^+ + \gamma$ is forbidden, because it violates
- (a) momentum and lepton number conservations
(b) baryon and lepton number conservations
(c) angular momentum conservation
(d) lepton number conservation

Ans.: (d)

Solution: $\mu^+ \rightarrow e^+ + \gamma$. In this decay lepton number is not conserved.

- Q23. A beam of X -ray of intensity I_0 is incident normally on a metal sheet of thickness 2 mm . The intensity of the transmitted beam is $0.025 I_0$. The linear absorption coefficient of the metal sheet (in m^{-1}) is _____ (upto one decimal place)

Ans.: 1844.4

Solution: $I = I_0 e^{-\mu x} \Rightarrow \mu = \frac{1}{x} \ln \left(\frac{I_0}{I} \right) = \frac{1}{2 \times 10^{-3}} \ln \left(\frac{I_0}{0.025 I_0} \right) = \frac{1}{2 \times 10^{-3}} \ln(40)$

$$\Rightarrow \mu = \frac{2.303}{2 \times 10^{-3}} [\log_{10} 40] = 1.151 \times 10^3 [2 \times 0.3010 + 1] = 1844.4 \text{ m}^{-1}$$

- Q24. The mean kinetic energy of a nucleon in a nucleus of atomic weight A varies as A^n , where n is _____ (upto two decimal places)

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16

Ans.: -0.67

$$\text{Solution: } \langle T \rangle = \frac{\int_0^R -\frac{\hbar^2}{2m} \left(\frac{d^2}{dr^2} + \frac{2}{r} \frac{d}{dr} \right) 4\pi r^2 dr}{\int_0^R 4\pi r^2 dr} = \frac{-\frac{\hbar^2}{2m} 4\pi \int_0^R (2+2) dr}{\int_0^R 4\pi r^2 dr} = \frac{-\frac{\hbar^2}{2m} 4\pi \times 4R}{4\pi R^3 / 3}$$

$$\Rightarrow \langle T \rangle \propto \frac{R}{R^3} \propto \frac{1}{R^2} = \frac{1}{\left(R_0 A^{\frac{1}{3}} \right)^2} = \frac{1}{A^{\frac{2}{3}}} \Rightarrow n = -\frac{2}{3} = -0.667 = -0.67$$

Q25. The atomic masses of ${}_{63}^{152}\text{Eu}$, ${}_{62}^{152}\text{Sm}$, ${}_1^1\text{H}$ 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 ${}_{63}^{152}\text{Eu} + n \rightarrow {}_{62}^{152}\text{Sm} + p$ is _____ $\times 10^{-3}$ amu (upto three decimal places)

Ans.: 2.833

$$\text{Solution: } Q = 152.930414 - (152.927581) = 2.833 \times 10^{-3} \text{ a.m.u.}$$

Q26. 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 ${}^{13}\text{C}$ is

- (a) $\frac{1^-}{2}; \frac{-1}{2}$ (b) $\frac{1^+}{2}; \frac{-1}{2}$ (c) $\frac{3^+}{2}; \frac{1}{2}$ (d) $\frac{3^-}{2}; \frac{-1}{2}$

Ans.: (a)

Solution: ${}^{13}\text{C}_6$, $N = 7, Z = 6$

$$\text{For } N = 7; \left(1S_{\frac{1}{2}} \right)^2 \left(1P_{\frac{3}{2}} \right)^4 \left(P_{\frac{1}{2}} \right)^1 \Rightarrow j = \frac{1}{2} \text{ and } l = 1$$

Thus spin-parity is $\left(\frac{1}{2} \right)^-$.

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16

GATE-2016

Q27. In the $SU(3)$ quark model, the triplet of mesons (π^+, π^0, π^-) has

- (a) Isospin = 0 , Strangeness = 0 (b) Isospin = 1 , Strangeness = 0
 (c) Isospin = $\frac{1}{2}$, Strangeness = +1 (d) Isospin = $\frac{1}{2}$, Strangeness = -1

Ans.: (b)

Solution: π^+, π^0, π^- are not strange particle thus strangeness = 0

Since meson group contain 3 particles, thus $I = 1$

Q28. Consider the reaction ${}_{25}^{54}\text{Mn} + e^- \rightarrow {}_{24}^{54}\text{Cr} + X$. The particle X is

- (a) γ (b) ν_e (c) n (d) π^0

Ans.: (b)

Q29. Which of the following statements is NOT correct?

- (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 1S_0 state of deuteron cannot be formed.

Ans.: (c)

Q30. According to the nuclear shell model, the respective ground state spin-parity values of ${}_{8}^{15}\text{O}$ and ${}_{8}^{17}\text{O}$ nuclei are

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

Ans.: (d)

Solution: ${}_{8}^{15}\text{O}$; $Z = 8$ and $N = 7$; $N = 7: (s_{1/2})^2 (p_{3/2})^4 (p_{1/2})^1$

$$\Rightarrow j = \frac{1}{2} \text{ and } l = 1. \text{ Thus spin and parity } = \left(\frac{1}{2}\right)^-$$

${}_{8}^{17}\text{O}$; $Z = 8$ and $N = 9$; $N = 9: (s_{1/2})^2 (p_{3/2})^4 (p_{1/2})^2 (d_{5/2})^1$

$$\Rightarrow j = \frac{5}{2} \text{ and } l = 2. \text{ Thus spin and parity } = \left(\frac{5}{2}\right)^+$$

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
 Near IIT, Hauz Khas, New Delhi-16
 Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
 28-B/6, Jia Sarai, Near IIT
 Hauz Khas, New Delhi-16

GATE-2017

Q31. Which one of the following conservation laws is violated in the decay $\tau^+ \rightarrow \mu^+ \mu^+ \mu^-$

- (a) Angular momentum (b) Total Lepton number
(c) Electric charge (d) Tau number

Ans. : (d)

Solution:

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

$$q = +1 \quad +1 \quad +1 \quad -1 \text{ conserved}$$

$$L = +1 \quad +1 \quad +1 \quad -1 \text{ conserved}$$

$$L_\tau = +1 \quad 0 \quad 0 \quad 0 \text{ Not conserved}$$

$$\text{spin} = 1/2 \quad \frac{1}{2} \quad \frac{1}{2} \quad \frac{1}{2} \text{ conserved}$$

Tau number is not conserved

Q32. Electromagnetic interactions are:

- (a) C conserving
(b) C non-conserving but CP conserving
(c) CP non-conserving but CPT conserving
(d) CPT non-conserving

Ans. : (a)

Solution: In electromagnetic interaction C is conserved

CPT : Conserved in all interaction

CP : Conserved in EM and Strong interactions

$$E_n = \frac{-13.6}{n^2} (eV)$$

For $n = 1$ $E_1 = -13.6eV$ Ground state

For $n = \infty$ $E_\infty = 0$ Highest state

Thus correct option is (a)

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16

Q33. In the nuclear reaction $^{13}\text{C}_6 + \nu_e \rightarrow ^{13}\text{N}_7 + X$, the particle X is

- (a) an electron (b) an anti-electron
(c) a muon (d) a pion

Ans. : (a)

Solution: $^{13}\text{C}_6 + \nu_e \rightarrow ^{13}\text{N}_7 + X$

$$\Rightarrow ^{13}\text{C}_6 \rightarrow ^{13}\text{N}_7 + X + \bar{\nu}_e$$

$$L_e = 0 \quad 0 \quad +1 \quad -1$$

To conserve the Lepton number L_e , x should be e^-

Q34. J^P for the ground state of the $^{13}\text{C}_6$ nucleus is

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

Ans. : (d)

Solution: $^{13}\text{C}_6 : Z = 6, N = 7$

$$N = 7 : (s_{1/2})^2 (p_{3/2})^4 (p_{1/2})^1$$

$$\Rightarrow j = \frac{1}{2} \text{ and } l = 1. \text{ Thus spin and parity } = \left(\frac{1}{2}\right)^-$$

Q35. The π^+ decays at rest to μ^+ and ν_μ . Assuming the neutrino to be massless, the momentum of the neutrino is..... MeV/c . (up to two decimal places)

$$(m_\pi = 139 \text{ MeV}/c^2, m_\mu = 105 \text{ MeV}/c^2)$$

Ans. : 29.84

$$\text{Solution: } E_\nu = \frac{(m_\pi^2 - m_\mu^2)c^2}{2m_\pi} = p \times c$$

$$\text{So } p = \frac{(m_\pi^2 - m_\mu^2)c}{2m_\pi} = \frac{19321 - 11025}{2 \times 139} = 29.84$$

Head office

fiziks, H.No. 23, G.F, Jia Sarai,
Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498

Branch office

Anand Institute of Mathematics,
28-B/6, Jia Sarai, Near IIT
Hauz Khas, New Delhi-16