PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

CSIR NET Physics - Quantum Mechanics

All PYQs (2015-2025) with answer key

154 questions . Answer key included

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Q1. [Dec 2015] . 3.5 marks

Quantum Mechanics > Scattering theory

CSIR NET	2015 Dec	3.5 M

In the scattering of some elementary particles, the scattering cross-section σ is found to depend on the total energy E and the fundamental constants h (Planck's constant) and c (the speed of light in vacuum). Using dimensional analysis, the dependence of σ on these quantities is given by

1. $\sqrt{\frac{\mathrm{hc}}{\mathrm{E}}}$
2. $\frac{\mathrm{hc}}{\mathrm{E}^{3/2}}$
3. $\left(\frac{\mathrm{hc}}{\mathrm{E}}\right)^2$
4. $\frac{hc}{E}$

Q2. [Dec 2015] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2015 Dec	3.5 M

A Hermitian operator $\bar{O}$ has two normalized eigenstates $|1\rangle$ and $|2\rangle$ with eigenvalues 1 and 2 , respectively. The two states

$|u\rangle = \cos\theta|1\rangle + \sin\theta|2\rangle$ and $|v\rangle = \cos\phi|1\rangle + \sin\phi|2\rangle$ are such that $\langle v|\hat{O}|v\rangle = 7/4$ and $\langle u \mid v\rangle = 0$. Which of the following are possible values of θ and ϕ ?

1. $\theta = -\frac{\pi}{6}$ and $\phi = \frac{\pi}{3}$
2. $\theta = \frac{\pi}{6}$ and $\phi = \frac{\pi}{3}$
3. $\theta = -\frac{\pi}{4}$ and $\phi = \frac{\pi}{4}$
4. $\theta = \frac{\pi}{3}$ and $\phi = -\frac{\pi}{6}$

Q3. [Dec 2015] . 3.5 marks

Quantum Mechanics > Variational Principle

CSIR NET	2015 Dec	3.5 M

The ground state energy of a particle of mass m in the potential $V(x) = V_0 \cosh\left(\frac{x}{L}\right)$, where L and V_0 are constants (with $V_0 \gg \frac{\hbar^2}{2ml^2}$) is approximately

1. $V_0 + \frac{\hbar}{L}\sqrt{\frac{2V_0}{m}}$
2. $V_0 + \frac{\hbar}{L}\sqrt{\frac{V_0}{m}}$
3. $V_0 + \frac{\hbar}{4L}\sqrt{\frac{V_0}{m}}$
4. $V_0 + \frac{\hbar}{2L}\sqrt{\frac{V_0}{m}}$

Q4. [Dec 2015] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2015 Dec	3.5 M

Let ψ_{nlm} denote the eigenstates of a hydrogen atom in the usual notation. The state

$$\frac{1}{5}\left[2\psi_{200} - 3\psi_{211} + \sqrt{7}\psi_{210} - \sqrt{5}\psi_{21-1}\right]$$

is an eigenstate of

1. L^2, but not of the Hamiltonian or L_z
2. the Hamiltonian, but not of L^2 or L_z
3. the Hamiltonian, L^2 and L_z
4. L^2 and L_z, but not of the Hamiltonian

Q5. [Dec 2015] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2015 Dec	3.5 M

The Hamiltonian for a spin-$\frac{1}{2}$ particle at rest is given by $H = E_0(\sigma_z + \alpha\sigma_x)$, where σ_x and σ_z are Pauli spin matrices and E_0 and α are constants. The eigenvalues of this Hamiltonian are

1. $\pm E_0\sqrt{1+\alpha^2}$
2. $\pm E_0\sqrt{1-\alpha^2}$
3. E_0 (doubly degenerate)
4. $E_0\left(1 \pm \frac{1}{2}\alpha^2\right)$

Q6. [Dec 2015] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2015 Dec	5 M

A hydrogen atom is subjected to the perturbation

$$V_{\text{pert}}(r) = \epsilon \cos\frac{2r}{a_0}$$

where a_0 is the Bohr radius. The change in the ground state energy to first order in ϵ

1. $\frac{\epsilon}{4}$
2. $\frac{\epsilon}{2}$
3. $\frac{-\epsilon}{2}$
4. $\frac{-\epsilon}{4}$

Q7. [Dec 2015] . 5.0 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2015 Dec	5 M

A positron is suddenly absorbed by the nucleus of a tritium (${}_{1}^{3}H$) atom to turn the latter into a He^{+}ion. If the electron in the tritium atom was initially in the ground state, the probability that the resulting He^{+}ion will be in its ground state is

1. 1
2. $\frac{8}{9}$
3. $\frac{128}{243}$
4. $\frac{512}{729}$

Q8. [Dec 2015] . 5.0 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2015 Dec	5 M

The product of the uncertainties $(\Delta L_x)(\Delta L_y)$ for a particle in the state $a|1,1\rangle + b|1,-1\rangle$ where $|l,m\rangle$ denotes an eigenstate of L^2 and L_z will be a minimum for

1. $a = \pm ib$
2. $a = 0$ and $b = 1$
3. $a = \frac{\sqrt{3}}{2}$ and $b = \frac{1}{2}$
4. $a = \pm b$

Q9. [Dec 2015] . 5.0 marks

Quantum Mechanics > Variational Principle

CSIR NET	2015 Dec	5 M

The ground state energy of a particle in potential $V(x) = g|x|$, estimated using the trail wavefunction

$$\psi(x) = \begin{cases} \sqrt{\frac{c}{a^5}}(a^2 - x^2), & x < |a| \\ 0, & x \geq |a| \end{cases}$$

(where g and c are constants) is

1. $\frac{15}{16}\left(\frac{\hbar^2 g^2}{m}\right)^{1/3}$
2. $\frac{5}{6}\left(\frac{\hbar^2 g^2}{m}\right)^{1/3}$
3. $\frac{3}{4}\left(\frac{\hbar^2 g^2}{m}\right)^{1/3}$
4. $\frac{7}{8}\left(\frac{\hbar^2 g^2}{m}\right)^{1/3}$

Q10. [June 2015] . 3.5 marks

Quantum Mechanics > Potential Well

CSIR NET	2015 June	3.5 M

The ratio of the energy of the first excited state E_1, to that of the ground state E_0, of a particle in a three-dimensional rectangular box of sides L, L and $L/2$, is

I. 3:2

2. $2:1$

3. $4:1$

4. $4:3$

Q11. [June 2015] . 3.5 marks
Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2015 June	3.5 M

The wavefunction of a particle in onedimension is denoted by $\psi(x)$ in the coordinate representation and by $\phi(p) = \int \psi(x)e^{-ipx/h}dx$ in the momentum representation. If the action of an operator $\hat{T}$ on $\psi(x)$ is given by $\hat{T}\psi(x) = \psi(x+a)$, where a is a constant, then $\hat{T}\phi(p)$ is given by

1. $-\frac{i}{h}ap\phi(p)$
2. $e^{-iap/\hbar}\phi(p)$
3. $e^{+iap/h}\phi(p)$
4. $\left(1+\frac{i}{h}ap\right)\phi(p)$

Q12. [June 2015] . 3.5 marks
Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2015 June	3.5 M

If L_i are the components of the angular momentum operator $\vec{L}$, then the operator $\sum_{i=1,2,3}\left[\left[\vec{L}, L_i\right], L_i\right]$ equals

1. $\vec{L}$
2. $2\vec{L}$
3. $3\vec{L}$
4. $-\vec{L}$

Q13. [June 2015] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2015 June	3.5 M

A particle moves in one dimension in the potential $V = \frac{1}{2}k(t)x^2$, where $k(t)$ is a time dependent parameter. Then $\frac{d}{dt}\langle V\rangle$. the rate of change of the expectation value $\langle V\rangle$ of the potential energy, is

1. $\frac{1}{2}\frac{dk}{dt}\langle x^2\rangle + \frac{k}{2m}\langle xp + px\rangle$
2. $\frac{1}{2}\frac{dk}{dt}\langle x^2\rangle + \frac{1}{2m}\langle p^2\rangle$
3. $\frac{k}{2m}\langle xp + px\rangle$
4. $\frac{1}{2}\frac{dk}{dt}\langle x^2\rangle$

Q14. [June 2015] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2015 June	5 M

The differential cross-section for scattering by a target is given by $\frac{d\sigma}{d\Omega}(\theta,\varphi) = a^2 + b^2\cos^2\theta$.

If N is the flux of the incoming particles, the number of particles scattered per unit time is

1. $\frac{4\pi}{3}N(a^2 + b^2)$
2. $4\pi N\left(a^2 + \frac{1}{6}b^2\right)$
3. $4\pi N\left(\frac{1}{2}a^2 + \frac{1}{3}b^2\right)$
4. $4\pi N\left(a^2 + \frac{1}{3}b^2\right)$

Q15. [June 2015] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2015 June	5 M

A particle of mass m is in a potential $V = \frac{1}{2}m\omega^2x^2$, where ω is a constant. Let $\hat{a} = \sqrt{\frac{m\omega}{2h}}\left(\hat{x} + \frac{i\hat{p}}{m\omega}\right)$. In the Heisenberg picture $\frac{d\hat{a}}{dt}$ is given by

1. $\omega\hat{a}$
2. $-i\omega\hat{a}$
3. $\omega\hat{a}^\dagger$
4. $i\omega\hat{a}^\dagger$

Q16. [June 2015] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2015 June	5 M

A particle of energy E scatters off a repulsive spherical potential

$$V(r) = \begin{cases} V_0 \text{ for} & r < a \\ 0 \text{ for} & r \geq a \end{cases}$$

where V_0 and a are positive constants. In the low energy limit, the total scattering crosssection is

$\sigma = 4\pi a^2 \left(\frac{1}{ka} \tanh ka - 1\right)^2$, where

$k^2 = \frac{2m}{h^2}(V_0 - E) > 0$. In the limit $V_0 \to \infty$ the ratio of σ to the classical scattering cross-section off a sphere of radius a is

1. 4
2. 3
3. 1
4. 1/2

Q17. [June 2015] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2015 June	5 M

Two different sets of orthogonal basis vectors $\left\{\begin{pmatrix}1\\0\end{pmatrix}, \begin{pmatrix}0\\1\end{pmatrix}\right\}$ and $\left\{\frac{1}{\sqrt{2}}\begin{pmatrix}1\\1\end{pmatrix}, \frac{1}{\sqrt{2}}\begin{pmatrix}1\\-1\end{pmatrix}\right\}$ are given for a two-dimensional real vector space. The matrix representation of a linear operator $\hat{A}$ in these bases are related by a unitary transformation. The unitary matrix may be chosen to be

1. $\begin{pmatrix}0 & -1\\1 & 0\end{pmatrix}$
2. $\begin{pmatrix}0 & 1\\1 & 0\end{pmatrix}$
3. $\frac{1}{\sqrt{2}}\begin{pmatrix}1 & 1\\1 & -1\end{pmatrix}$
4. $\frac{1}{\sqrt{2}}\begin{pmatrix}1 & 0\\1 & 1\end{pmatrix}$

Q18. [Dec 2016] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2016 Dec	3.5M

Consider the two lowest normalized energy eigenfunctions $\psi_0(x)$ and $\psi_1(x)$ of a one dimensional system. They satisfy $\psi_0(x) = \psi_0^*(x)$ and $\psi_1(x) = \alpha \frac{d\psi_0}{dx}$, where α is a real constant. The expectation value of the momentum operator in the state ψ_1 is

1. $-\frac{\hbar}{\alpha^2}$

2. 0

3. $\frac{\hbar}{\alpha^2}$

4. $\frac{2\hbar}{\alpha^2}$

Q19. [Dec 2016] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2016 Dec	3.5M

Consider the operator $a = x + \frac{d}{dx}$ acting on smooth functions of x. The commutator $[a, \cos x]$ is

1. $-\sin x$

2. $\cos x$

3. $-\cos x$

4. 0

Q20. [Dec 2016] . 3.5 marks

Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2016 Dec	3.5M

Let $a = \frac{1}{\sqrt{2}}(x + ip)$ and $a^\dagger = \frac{1}{\sqrt{2}}(x - ip)$ be the lowering and raising operators of a simple harmonic oscillator in units where the mass, angular frequency and $\hbar$ have been set to unity. If $|0\rangle$ is the ground state of the oscillator and λ is a complex constant, the expectation value of $\langle\psi|x|\psi\rangle$ in the state $|\psi\rangle = \exp\left(\lambda \mathrm{a}^\dagger - \lambda^* \mathrm{a}\right)|0\rangle$, is

1. $|\lambda|$

2. $\sqrt{|\lambda|^2 + \frac{1}{|\lambda|^2}}$

3. $\frac{1}{\sqrt{2}i}(\lambda - \lambda^*)$

4. $\frac{1}{\sqrt{2}}(\lambda + \lambda^*)$

Q21. [Dec 2016] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2016 Dec	5M

A particle is scattered by a central potential $V(r) = V_0 r e^{-\mu r}$, where V_0 and μ are positive constants. If the momentum transfer $\vec{q}$ is such that $q = |\vec{q}| \gg \mu$, the scattering cross-section in the Born approximation, as $q \to \infty$, depends on q as

[You may use $\int x^n e^{ax} dx = \frac{d^n}{da^n} \int 1 \ e^{ax} dx$]

1. q^{-8}
2. q^{-2}
3. q^{2}
4. q^{6}

Q22. [Dec 2016] . 5.0 marks

Quantum Mechanics > Dirac delta potential

CSIR NET	2016 Dec	5M

A particle in one dimension is in a potential $V(x) = A\delta(x-a)$. Its wavefunction $\psi(x)$ is continuous everywhere. The discontinuity in $\frac{d\psi}{dx}$ at $x = a$ is

1. $\frac{2m}{\hbar^2}A\psi(a)$
2. $A(\psi(a) - \psi(-a))$
3. $\frac{\hbar^2}{2m}A$
4. 0

Q23. [Dec 2016] . 5.0 marks

Quantum Mechanics > KG and Dirac equation

CSIR NET	2016 Dec	5M

The dynamics of a free relativistic particle of mass m is governed by the Dirac Hamiltonian

$H = c\vec{\alpha} \cdot \vec{p} + \beta mc^2$, where $\vec{p}$ is the momentum operator and $\vec{\alpha} = (\alpha_x, \alpha_y, \alpha_z)$ and β are four 4×4 Dirac matrices. The acceleration operator can be expressed as

1. $\frac{2ic}{\hbar}(c\vec{p} - \vec{\alpha}H)$
2. $2ic^2\vec{\alpha}\beta$
3. $\frac{ic}{\hbar}H\vec{\alpha}$
4. $-\frac{2ic}{\hbar}(c\vec{p} + \vec{\alpha}H)$

Q24. [Dec 2016] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2016 Dec	5M

A particle of charge q in one dimension is in a simple harmonic potential with angular frequency ω. It is subjected to a time dependent electric field $E(t) = Ae^{-(t/\tau)^2}$, where A and τ are positive constants and $\omega\tau \gg 1$. If in the distant past $t \to -\infty$ the particle was in its ground state, the probability that it will be in the first excited state as $t \to +\infty$ is proportional to

1. $e^{-\frac{1}{2}(\omega\tau)^2}$

2. $e^{\frac{1}{2}(\omega\tau)^2}$

3. 0

4. $\frac{1}{(\omega\tau)^2}$

Q25. [June 2016] . 3.5 marks

Quantum Mechanics > Potential Well

CSIR NET	2016 June	3.5M

The state of a particle of mass m in a one-dimensional rigid box in the interval 0 to L is given by the normalised wavefunction

$\psi(x) = \sqrt{\frac{2}{L}}\left(\frac{3}{5}\sin\left(\frac{2\pi x}{L}\right) + \frac{4}{5}\sin\left(\frac{4\pi x}{L}\right)\right)$. If its energy is measured, the possible outcomes and the average value of energy are, respectively

1. $\frac{h^2}{2mL^2}, \frac{2h^2}{mL^2}$ and $\frac{73}{50}\frac{h^2}{mL^2}$

2. $\frac{h^2}{8mL^2}, \frac{h^2}{2mL^2}$ and $\frac{19}{40}\frac{h^2}{mL^2}$

3. $\frac{h^2}{2mL^2}, \frac{2h^2}{mL^2}$ and $\frac{19}{10}\frac{h^2}{mL^2}$

4. $\frac{h^2}{8mL^2}, \frac{2h^2}{mL^2}$ and $\frac{73}{200}\frac{h^2}{mL^2}$

Q26. [June 2016] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2016 June	3.5M

If $\hat{L}_x, \hat{L}_y$ and $\hat{L}_z$ are the components of the angular momentum operator in three dimensions, the commutator $\left[\hat{L}_x, \hat{L}_x\hat{L}_y\hat{L}_z\right]$ may be simplified to

1. $i\hbar L_x\left(\hat{L}_z^2 - \hat{L}_y^2\right)$

2. $i\hbar\hat{L}_z\hat{L}_y\hat{L}_x$

3. $i\hbar L_x\left(2\hat{L}_z^2 - \hat{L}_y^2\right)$

4. 0

Q27. [June 2016] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2016 June	3.5M

Suppose that the Coulomb potential of the hydrogen atom is changed by adding an inverse-square term such that the total potential is $V(\vec{r}) = -\frac{Ze^2}{r} + \frac{g}{r^2}$, where g is a constant. The energy eigenvalues E_{nlm} in the modified potential

1. depend on n and l, but not on m
2. depend on n but not on l and m
3. depend on n and m, but not on l
4. depend explicitly on all three quantum numbers n, l and m

Q28. [June 2016] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2016 June	3.5M

The eigenstates corresponding to eigenvalues E_1 and E_2 of a time-independent Hamiltonian are $|1\rangle$ and $|2\rangle$ respectively. If at $t=0$, the system is in a state $|\psi(t=0)\rangle = \sin\theta|1\rangle + \cos\theta|2\rangle$ the value of $\langle\psi(t) \mid \psi(t)\rangle$ at time t will be

1. 1

2. $\left(E_1\sin^2\theta + E_2\cos^2\theta\right)/\sqrt{E_1^2 + E_2^2}$

3. $e^{iE_1t/\hbar}\sin\theta + e^{iE_2t/\hbar}\cos\theta$

4. $e^{-iE_1t/\hbar}\sin^2\theta + e^{-iE_2t/\hbar}\cos^2\theta$

Q29. [June 2016] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2016 June	5M

Consider a particle of mass m in a potential $V(x) = \frac{1}{2}m\omega^2x^2 + g\cos kx$. The change in the ground state energy, compared to the simple harmonic potential $\frac{1}{2}m\omega^2x^2$, to first order in g is

1. $g\exp\left(-\frac{k^2\hbar}{2m\omega}\right)$
2. $g\exp\left(\frac{k^2\hbar}{2m\omega}\right)$
3. $g\exp\left(-\frac{2k^2\hbar}{m\omega}\right)$
4. $g\exp\left(-\frac{k^2\hbar}{4m\omega}\right)$

Q30. [June 2016] . 5.0 marks
Quantum Mechanics > WKB Approximation

CSIR NET	2016 June	5M

The energy levels for a particle of mass m in the potential $V(x) = \alpha|x|$, determined in the WKB approximation

$$\sqrt{2m}\int_a^b \sqrt{E - V(x)}dx = \left(n + \frac{1}{2}\right)\hbar\pi$$

(where a, b are the turning points and $n = 0,1,2\cdots$), are

1. $E_n = \left[\frac{\hbar\pi\alpha}{4\sqrt{m}}\left(n + \frac{1}{2}\right)\right]^{2/3}$

2. $E_n = \left[\frac{3\hbar\pi\alpha}{4\sqrt{2m}}\left(n + \frac{1}{2}\right)\right]^{2/3}$

3. $E_n = \left[\frac{3\hbar\pi\alpha}{4\sqrt{m}}\left(n + \frac{1}{2}\right)\right]^{2/3}$

4. $E_n = \left[\frac{\hbar\pi\alpha}{4\sqrt{2m}}\left(n + \frac{1}{2}\right)\right]^{2/3}$

Q31. [June 2016] . 5.0 marks

Quantum Mechanics > Dirac delta potential

CSIR NET	2016 June	5M

A particle of mass m moves in one dimension under the influence of the potential $V(x) = -\alpha\delta(x)$, where α is a positive constant. The uncertainty in the product $(\Delta x)(\Delta p)$ in its ground state is

1. $2\hbar$
2. $\hbar/2$
3. $\hbar/\sqrt{2}$
4. $\sqrt{2}\hbar$

Q32. [June 2016] . 5.0 marks

Quantum Mechanics > Variational Principle

CSIR NET	2016 June	5M

The ground state energy of a particle of mass m in the potential $V(x) = \frac{\hbar^2\beta}{6m}x^4$, estimated using the normalized trial wavefunction

$\psi(x) = \left(\frac{\alpha}{\pi}\right)^{1/4} e^{-\alpha x^2/2}$, is

[Use $\sqrt{\frac{\alpha}{\pi}}\int_{-\infty}^{\infty} dx x^2 e^{-\alpha x^2} = \frac{1}{2\alpha}$

and $\sqrt{\frac{\alpha}{\pi}}\int_{-\infty}^{\infty} dx x^4 e^{-\alpha x^2} = \frac{3}{4\alpha^2}$].

1. $\frac{3}{2m}\hbar^2\beta^{1/3}$
2. $\frac{8}{3m}\hbar^2\beta^{1/3}$
3. $\frac{2}{3m}\hbar^2\beta^{1/3}$
4. $\frac{3}{8m}\hbar^2\beta^{1/3}$

Q33. [June 2016] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2016 June	5M

Consider a gas of Cs atoms at a number density of 10^{12} atoms/cc. When the typical inter-particle distance is equal to the thermal de Broglie wavelength of the particles, the temperature of the gas is nearest to (Take the mass of a Cs atom to be 22.7×10^{-26} kg.)

1. 1×10^{-9} K

2. 7×10^{-5} K

3. 1×10^{-3} K

4. 2×10^{-8} K

Q34. [Dec 2017] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2017 Dec	3.5M

The normalized wavefunction of a particle in three dimensions is given by $\psi(r,\theta,\varphi) = \frac{1}{\sqrt{8\pi a^3}} e^{-r/2a}$ where $a > 0$ is a constant. The ratio of the most probable distance from the origin to the mean distance from the origin, is [You may use $\int_0^\infty dx x^n e^{-x} = n!$]

1. $\frac{1}{3}$
2. $\frac{1}{2}$
3. $\frac{3}{2}$
4. $\frac{2}{3}$

Q35. [Dec 2017] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2017 Dec	3.5M

The state vector of a one-dimensional simple harmonic oscillator of angular frequency ω, at time $t = 0$, is given by $|\psi(0)\rangle = \frac{1}{\sqrt{2}}[|0\rangle + |2\rangle]$, where $|0\rangle$ and $|2\rangle$ are the normalized ground state and the second excited state, respectively. The minimum time t after which the state vector $|\psi(t)\rangle$ is orthogonal to $|\psi(0)\rangle$, is

1. $\frac{\pi}{2\omega}$
2. $\frac{2\pi}{\omega}$
3. $\frac{\pi}{\omega}$
4. $\frac{4\pi}{\omega}$

Q36. [Dec 2017] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2017 Dec	3.5M

The normalized wavefunction in the momentum space of a particle in one dimension is

$\phi(p) = \frac{\alpha}{p^2+\beta^2}$, where α and β are real constants. The uncertainty Δx in measuring its position is

1. $\sqrt{\pi}\frac{\hbar\alpha}{\beta^2}$
2. $\sqrt{\pi}\frac{\hbar\alpha}{\beta^3}$
3. $\frac{\hbar}{\sqrt{2}\beta}$
4. $\sqrt{\frac{\pi}{\beta}}\frac{\hbar\alpha}{\beta}$

Q37. [Dec 2017] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2017 Dec	3.5M

Let x denote the position operator and p the canonically conjugate momentum operator of a particle. The commutator

$$\left[\frac{1}{2m}p^2 + \beta x^2, \frac{1}{m}p^2 + \gamma x^2\right]$$

where β and γ are constants, is zero if

1. $\gamma = \beta$
2. $\gamma = 2\beta$
3. $\gamma = \sqrt{2}\beta$
4. $2\gamma = \beta$

Q38. [Dec 2017] . 5.0 marks
Quantum Mechanics > Scattering theory

CSIR NET	2017 Dec	5M

A phase shift of 30^0 is observed when a beam of particles of energy 0.1 MeV is scattered by a target. When the beam energy is changed, the observed phase shift is 60^0. Assuming that only s-wave scattering is relevant and that the cross-section does not change with energy, the beam energy is

1. 0.4 MeV
2. 0.3 MeV
3. 0.2 MeV
4. 0.15 MeV

Q39. [Dec 2017] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2017 Dec	5M

The Hamiltonian of a two-level quantum system is $H = \frac{1}{2}\hbar\omega\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$ possible initial state in which the probability of the system being in that quantum state does not change with time, is

1. $\begin{pmatrix} \cos\frac{\pi}{4} \\ \sin\frac{\pi}{4} \end{pmatrix}$
2. $\begin{pmatrix} \cos\frac{\pi}{8} \\ \sin\frac{\pi}{8} \end{pmatrix}$
3. $\begin{pmatrix} \cos\frac{\pi}{2} \\ \sin\frac{\pi}{2} \end{pmatrix}$
4. $\begin{pmatrix} \cos\frac{\pi}{6} \\ \sin\frac{\pi}{6} \end{pmatrix}$

Q40. [Dec 2017] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2017 Dec	5M

Consider a one-dimensional infinite square well

$$V(x) = \begin{cases} 0 & \text{for} \quad 0 < x < a \\ \infty & \quad \text{otherwise} \end{cases}$$

If a perturbation

$$\Delta V(x) = \begin{cases} V_0 & \text{for } 0 < x < a/3 \\ 0 & \quad \text{otherwise} \end{cases}$$

is applied, then the correction to the energy of the first excited state, to first order in ΔV, is nearest to

1. V_0
2. $0.16V_0$
3. $0.2V_0$
4. $0.33V_0$

Q41. [Dec 2017] . 5.0 marks
Quantum Mechanics > WKB Approximation

CSIR NET	2017 Dec	5M

The energy eigenvalues E_n of a quantum system in the potential $V = cx^6$ (where $c > 0$ is a constant), for large values of the quantum number n, varies as

1. $n^{4/3}$
2. $n^{3/2}$
3. $n^{5/4}$
4. $n^{6/5}$

Q42. [June 2017] . 3.5 marks
Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2017 June	3.5M

If the root-mean-squared momentum of a particle in the ground state of a one-dimensional simple harmonic potential is p_0, then its root-mean-squared momentum in the first excited state is

1. $p_0\sqrt{2}$
2. $p_0\sqrt{3}$
3. $p_0\sqrt{2/3}$
4. $p_0\sqrt{3/2}$

Q43. [June 2017] . 3.5 marks
Quantum Mechanics > Potential Well

CSIR NET	2017 June	3.5M

Consider a potential barrier A of height V_0 and width b, and another potential barrier B of height $2V_0$ and the same width b. The ratio T_A/T_B of tunnelling probabilities T_A and T_B, through barriers A and B respectively, for a particle of energy $V_0/100$ is best approximated by

1. $exp\left[\left(\sqrt{1.99}-\sqrt{0.99}\right)\sqrt{8mV_0b^2/\hbar^2}\right]$
2. $exp\left[\left(\sqrt{1.98}-\sqrt{0.98}\right)\sqrt{8mV_0b^2/\hbar^2}\right]$
3. $exp\left[\left(\sqrt{2.99}-\sqrt{0.99}\right)\sqrt{8mV_0b^2/\hbar^2}\right]$
4. $\exp\left[\left(\sqrt{2.98}-\sqrt{0.98}\right)\sqrt{8mV_0b^2/\hbar^2}\right]$

Q44. [June 2017] . 3.5 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2017 June	3.5M

A constant perturbation H' is applied to a system for time Δt (where $H'\Delta t \ll \hbar$) leading to a transition from a state with energy E_i to another with energy E_f . If the time of application is doubled the probability of transition will be

1. Unchanged
2. Doubled
3. Quadrupled
4. Halved

Q45. [June 2017] . 5.0 marks
Quantum Mechanics > Scattering theory

CSIR NET	2017 June	5M

Consider the potential

$$V(\vec{r}) = \sum_i V_0 a^3 \delta^{(3)}(\vec{r} - \vec{r}_i)$$

where $\vec{r}_i$ are the position vectors of the vertices of a cube of length a centered at the origin and V_0 is a constant. If $V_0 a^2 \ll \frac{\hbar^2}{m}$, the total scattering cross-section, in the low-energy limit, is

1. $16a^2 \left(\frac{mV_0 a^2}{\hbar^2}\right)$
2. $\frac{16a^2}{\pi^2} \left(\frac{mV_0 a^2}{\hbar^2}\right)^2$
3. $\frac{64a^2}{\pi} \left(\frac{mV_0 a^2}{\hbar^2}\right)^2$
4. $\frac{64a^2}{\pi^2} \left(\frac{mV_0 a^2}{\hbar^2}\right)$

Q46. [June 2017] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2017 June	5M

The Coulomb potential $V(r) = -e^2/r$ of a hydrogen atom is perturbed by adding $H' = bx^2$ (where b is a constant) to the Hamiltonian. The first order correction to the ground state energy is

(The ground state wavefunction is $\psi_0 = \frac{1}{\sqrt{\pi a_0^3}} e^{-r/a_0}$)

1. $2ba_0^2$
2. ba_0^2
3. $ba_0^2/2$
4. $\sqrt{2}ba_0^2$

Q47. [June 2017] . 5.0 marks

Quantum Mechanics > Variational Principle

CSIR NET	2017 June	5M

Using the trial function

$$\psi(x) = \begin{cases} A(a^2 - x^2), & -a < x < a \\ 0 & \text{otherwise} \end{cases}$$

the ground state energy of a one-dimensional harmonic oscillator is

1. $\hbar\omega$
2. $\sqrt{\frac{5}{14}}\hbar\omega$
3. $\frac{1}{2}\hbar\omega$
4. $\sqrt{\frac{5}{7}}\hbar\omega$

Q48. [June 2017] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2017 June	5M

In the usual notation $|n\,l\,m\rangle$ for the states of a hydrogen like atom, consider the spontaneous transitions $|210\rangle \to |100\rangle$ and $|310\rangle \to |100\rangle$. If t_1 and t_2 are the lifetimes of the first and second decaying states respectively, then the ratio $\frac{t_1}{t_2}$ is proportional to

1. $\left(\frac{32}{27}\right)^3$
2. $\left(\frac{27}{32}\right)^3$
3. $\left(\frac{2}{3}\right)^3$
4. $\left(\frac{3}{2}\right)^3$

Q49. [Dec 2018] . 3.5 marks

Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2018 Dec	3.5M

The ground state energy of an anisotropic harmonic oscillator described by the potential

$$V(x,y,z) = \frac{1}{2}m\omega^2x^2 + 2m\omega^2y^2 + 8m\omega^2z^2$$

(in units of $\hbar\omega$) is

1. $\frac{5}{2}$
2. $\frac{7}{2}$
3. $\frac{3}{2}$
4. $\frac{1}{2}$

Q50. [Dec 2018] . 3.5 marks

Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2018 Dec	3.5M

The product $\Delta x \Delta p$ of uncertainties in the position and momentum of a simple harmonic oscillator of mass m and angular frequency ω in the ground state $|0\rangle$, is $\frac{\hbar}{2}$. The value of the product $\Delta x \Delta p$ in the state, $e^{-i\hat{p}\ell/\hbar}|0\rangle$ (where ℓ is a constant and $\hat{p}$ is the momentum operator) is

1. $\frac{\hbar}{2}\sqrt{\frac{m\omega\ell^2}{\hbar}}$
2. $\hbar$
3. $\frac{\hbar}{2}$
4. $\frac{\hbar^2}{m\omega\ell^2}$

Q51. [Dec 2018] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2018 Dec	3.5M

Let the wavefunction of the electron in a hydrogen atom be

$$\psi(\vec{r}) = \frac{1}{\sqrt{6}}\phi_{200}(\vec{r}) + \sqrt{\frac{2}{3}}\phi_{21-1}(\vec{r}) - \frac{1}{\sqrt{6}}\phi_{100}(\vec{r})$$

where $\phi_{nlm}(\vec{r})$ are the eigenstates of the Hamiltonian in the standard notation. The expectation value of the energy in this state is

1. -10.8 eV
2. -6.2 eV
3. -9.5 eV
4. -5.1 eV

Q52. [Dec 2018] . 3.5 marks
Quantum Mechanics > Potential Well

CSIR NET	2018 Dec	3.5M

Three identical spin $\frac{1}{2}$ particles of mass m are confined to a one-dimensional box of length L, but are otherwise free. Assuming that they are non-interacting, the energies of the lowest two energy eigen states, in units of $\frac{\pi^2\hbar^2}{2mL^2}$, are

1. 3 and 6
2. 6 and 9
3. 6 and 11
4. 3 and 9

Q53. [Dec 2018] . 5.0 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2018 Dec	5M

Consider the operator $A_x = L_y p_z - L_z p_y$, where L_i and p_i denote, respectively, the components of the angular momentum and momentum operators. The commutator $[A_x, x]$, where x is the x - component of the position operator, is

1. $-i\hbar(zp_z + yp_y)$
2. $-i\hbar(zp_z - yp_y)$
3. $i\hbar(zp_z + yp_y)$
4. $i\hbar(zp_z - yp_y)$

Q54. [Dec 2018] . 5.0 marks

Quantum Mechanics > WKB Approximation

CSIR NET	2018 Dec	5M

A one-dimensional system is described by the Hamiltonian $H = \frac{p^2}{zm} + \lambda|x|$ (where $\lambda > 0$). The ground state energy varies as a function of λ as

1. $\lambda^{5/3}$
2. $\lambda^{2/3}$
3. $\lambda^{4/3}$
4. $\lambda^{1/3}$

Q55. [Dec 2018] . 5.0 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2018 Dec	5M

If the position of the electron in the ground state of a Hydrogen atom is measured, the probability that it will be found at a distance $r \geq a_0$ (a_0 being Bohr radius) is nearest to

1. 0.91
2. 0.66
3. 0.32
4. 0.13

Q56. [Dec 2018] . 5.0 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2018 Dec	5M

A system of spin $\frac{1}{2}$ particles is prepared to be in the eigenstate of σ_z with eigenvalue +1 . The system is rotated by at angle of 60^0 about the x-axis. After the rotation, the fraction of the particles that will be measured to be in the eigenstate of σ_z with eigenvalue +1 is

1. $\frac{1}{3}$
2. $\frac{2}{3}$
3. $\frac{1}{4}$
4. $\frac{3}{4}$

Q57. [June 2018] . 3.5 marks
Quantum Mechanics > Potential Well

CSIR NET	2018 June	3.5M

In A particle of mass m is confined in a three-dimensional box by the potential

$$V(x, y, z) = \begin{cases} 0, & 0 \leq x, y, z \leq a \\ \infty & \text{otherwise} \end{cases}$$

The number of eigenstates of Hamiltonian with energy $\frac{9\hbar^2\pi^2}{2ma^2}$ is

1. 1
2. 6
3. 3
4. 4

Q58. [June 2018] . 3.5 marks
Quantum Mechanics > Spin Angular momentum

CSIR NET	2018 June	3.5M

The Hamiltonian of a spin $\frac{1}{2}$ particle in a magnetic field $\vec{B}$ is given by $H = -\mu.\vec{B}.\vec{\sigma}$, where μ is a real constant and $\vec{\sigma} = (\sigma_x, \sigma_y, \sigma_z)$ are the Pauli spin matrices. If $\vec{B} = (B_0, B_0, 0)$ and the spin state at time $t = 0$ is an eigenstate of σ_x, then of the expectation values $\langle\sigma_x\rangle, \langle\sigma_y\rangle$ and $\langle\sigma_z\rangle$

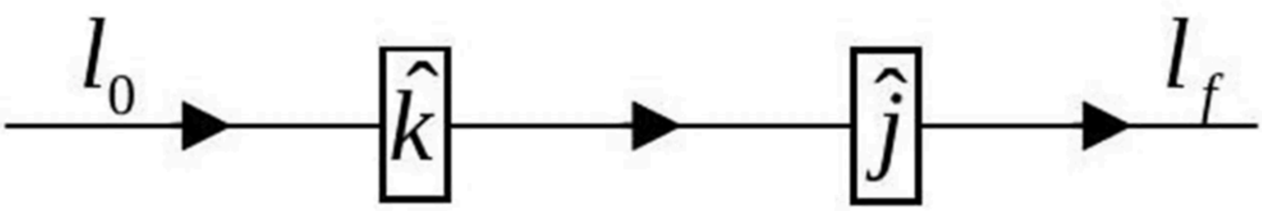
1. only $\langle\sigma_x\rangle$ changes with time
2. only $\langle\sigma_y\rangle$ changes with time
3. only $\langle\sigma_z\rangle$ changes with time
4. all three change with time

Q59. [June 2018] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2018 June	3.5M

Two Stern-Gerlach apparatus S_1 and S_2 are kept in a line (x-axis). The directions of their magnetic fields are along the positive z and y-axes, respectively. Each apparatus only transmits particles with spins aligned in the direction of its magnetic field. If an initially unpolarized beam of spin $\frac{1}{2}$ particles passes through this configuration, the ratio of intensities $I_0 : I_f$ of the initial and final beams is



1. 16:1
2. 2:1
3. 4:1
4. 1:0

Q60. [June 2018] . 3.5 marks
Quantum Mechanics > Pertubation theory

CSIR NET	2018 June	3.5M

A particle of mass m is constrained to move in a circular ring of radius R. When a perturbation

$$V' = \frac{a}{R^2}\cos^2\phi$$

(where a is a real constant) is added, the shift in energy of the ground state, to first order in a, is

1. $\frac{a}{R^2}$
2. $\frac{2a}{R^2}$
3. $\frac{a}{2R^2}$
4. $\frac{a}{(\pi R^2)}$

Q61. [June 2018] . 5.0 marks
Quantum Mechanics > WKB Approximation

CSIR NET	2018 June	5M

The n^{th} energy eigenvalues E_n of a one-dimensional Hamiltonian $H = \frac{p^2}{2m} + \lambda x^4$ (where $\lambda > 0$ is a constant) in the WEB approximation, is proportional to

1. $\left(n+\frac{1}{2}\right)^{4/3} \lambda^{1/3}$
2. $\left(n+\frac{1}{2}\right)^{4/3} \lambda^{2/3}$
3. $\left(n+\frac{1}{2}\right)^{5/3} \lambda^{1/3}$
4. $\left(n+\frac{1}{2}\right)^{5/3} \lambda^{2/3}$

Q62. [June 2018] . 5.0 marks
Quantum Mechanics > Scattering theory

CSIR NET	2018 June	5M

The differential scattering cross-section $\frac{d\sigma}{d\Omega}$ for the central potential $V(r) = \frac{\beta}{r} e^{-\mu r}$, where β and μ are positive constants, is calculated in thee first Born approximation. Its dependence on the scattering angle θ is proportional to (A is a constant below)

1. $\left(A^2 + \sin^2 \frac{\theta}{2}\right)$
2. $\left(A^2 + \sin^2 \frac{\theta}{2}\right)^{-1}$
3. $\left(A^2 + \sin^2 \frac{\theta}{2}\right)^{-2}$
4. $\left(A^2 + \sin^2 \frac{\theta}{2}\right)^{2}$

Q63. [June 2018] . 5.0 marks
Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2018 June	5M

At $t = 0$, the wavefunction of an otherwise free particle confined between two infinite walls at $x = 0$ and $x = L$ is $\psi(x, t = 0) = \sqrt{\frac{2}{L}}\left(\sin\frac{\pi x}{L} - \sin\frac{3\pi x}{L}\right)$. Its wave function at a later time $t = \frac{mL^2}{4\pi h}$ is

1. $\sqrt{\frac{2}{L}}\left(\sin\frac{\pi x}{L} - \sin\frac{3\pi x}{L}\right)e^{i\pi/6}$
2. $\sqrt{\frac{2}{L}}\left(\sin\frac{\pi x}{L} + \sin\frac{3\pi x}{L}\right)e^{-i\pi/6}$
3. $\sqrt{\frac{2}{L}}\left(\sin\frac{\pi x}{L} - \sin\frac{3\pi x}{L}\right)e^{-i\pi/8}$
4. $\sqrt{\frac{2}{L}}\left(\sin\frac{\pi x}{L} + \sin\frac{3\pi x}{L}\right)e^{-i\pi/6}$

Q64. [Dec 2019] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2019 Dec	3.5M

The Hamiltonian of two interacting particles one with spin 1 and the other with spin $\frac{1}{2}$ is given by $H = A\vec{S}_1 \cdot \vec{S}_2 + B(S_{1x} + S_{2x})$, where $\vec{S}_1$ and $\vec{S}_2$ denote the spin operators of the first and second particles, respectively and A and B are positive constants. The largest eigenvalue of this Hamiltonian is

1. $\frac{1}{2}(A\hbar^2 + 3B\hbar)$
2. $3A\hbar^2 + B\hbar$
3. $\frac{1}{2}(3A\hbar^2 + B\hbar)$
4. $A\hbar^2 + 3B\hbar$

Q65. [Dec 2019] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2019 Dec	3.5M

The energy eigenvalues of a particle of mass m, confined to a rigid one-dimensional box of width L, are $E_n (n = 1,2, \dots)$. If the walls of the box are moved very slowly toward each other, the rate of change of time-dependent energy $\frac{dE_2}{dt}$ of the first excited state is

1. $\frac{E_2}{L}\frac{dL}{dt}$
2. $\frac{2E_2}{L}\frac{dL}{dt}$
3. $-\frac{2E_2}{L}\frac{dL}{dt}$
4. $-\frac{E_1}{L}\frac{dL}{dt}$

Q66. [Dec 2019] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2019 Dec	3.5M

A particle of mass m is confined to a box of unit length in one dimension. It is described by the wavefunction $\psi(x) = \sqrt{\frac{8}{5}} \sin\pi x(1 + \cos\pi x)$ for $0 \leq x \leq 1$ and zero outside this interval. The expectation value of energy in this state is

1. $\frac{4\pi^2}{3m}\hbar^2$
2. $\frac{4\pi^2}{5m}\hbar^2$
3. $\frac{2\pi^2}{5m}\hbar^2$
4. $\frac{8\pi^2}{5m}\hbar^2$

Q67. [Dec 2019] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2019 Dec	3.5M

The normalized wavefunction of a particle in three dimensions is given by

$$\psi(x,y,z) = Nz\exp[-a(x^2+y^2+z^2)]$$

where a is a positive constant and N is a normalization constant. If L is the angular momentum operator, the eigenvalues of L^2 and L_z, respectively, are

1. $2\hbar^2$ and $\hbar$
2. $\hbar^2$ and 0
3. $2\hbar^2$ and 0
4. $\frac{3}{4}\hbar^2$

Q68. [Dec 2019] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2019 Dec	5M

Let $\hat{x}$ and $\hat{p}$ denote position and momentum operators obeying the commutation relation $[\hat{x}, \hat{p}] = i\hbar$. If $|x\rangle$ denotes an eigenstate of $\hat{x}$ corresponding to the eigenvalue x, then $e^{ia\hat{p}/\hbar}|x\rangle$ is

1. an eigenstate of $\hat{x}$ corresponding to the eigenvalue x
2. an eigenstate of $\hat{x}$ corresponding to the eigenvalue $(x + a)$
3. an eigenstate of $\hat{x}$ corresponding to the eigenvalue $(x - a)$
4. not an eigenstate of $\hat{x}$

Q69. [Dec 2019] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2019 Dec	5M

Let the normalized eigenstates of the Hamiltonian

$H = \begin{pmatrix} 2 & 1 & 0 \\ 1 & 2 & 0 \\ 0 & 0 & 2 \end{pmatrix}$ be $|\psi_1\rangle, |\psi_2\rangle$ and $|\psi_3\rangle$. The expectation value $\langle H\rangle$ and the variance of H in the state $|\psi\rangle = \frac{1}{\sqrt{3}}(|\psi_1\rangle + |\psi_2\rangle - i|\psi_3\rangle)$ are

1. $\frac{4}{3}$ and $\frac{1}{3}$
2. $\frac{4}{3}$ and $\frac{2}{3}$
3. 2 and $\frac{2}{3}$
4. 2 and 1

Q70. [Dec 2019] . 5.0 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2019 Dec	5M

The wavefunction of a particle of mass m, constrained to move on a circle of unit radius cantered at the origin in the xy - plane, is described by $\psi(\phi) = A\cos^2\phi$, where ϕ is the azimuthal angle. All the possible outcomes of measurements of the z - component of the angular momentum L_z in this state, in units of $\hbar$ are

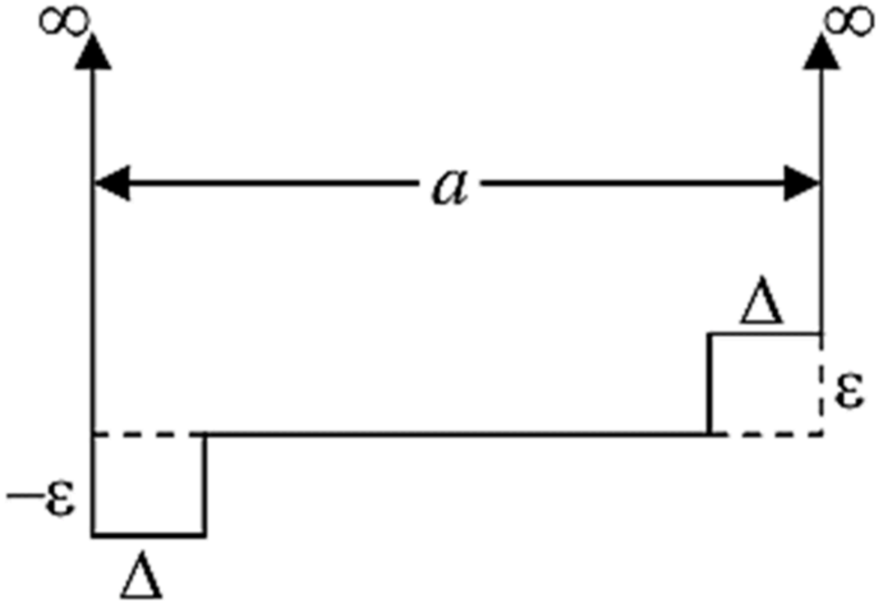
1. ± 1 and 0
2. ± 1
3. ± 2
4. ± 2 and 0

Q71. [June 2019] . 3.5 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2019 June	3.5M

The infinite square-well potential of a particle in a box of size a is modified as shown in the figure below (assume $\Delta \ll a$).



The energy of the ground state, compared to the ground state energy before the perturbation was added

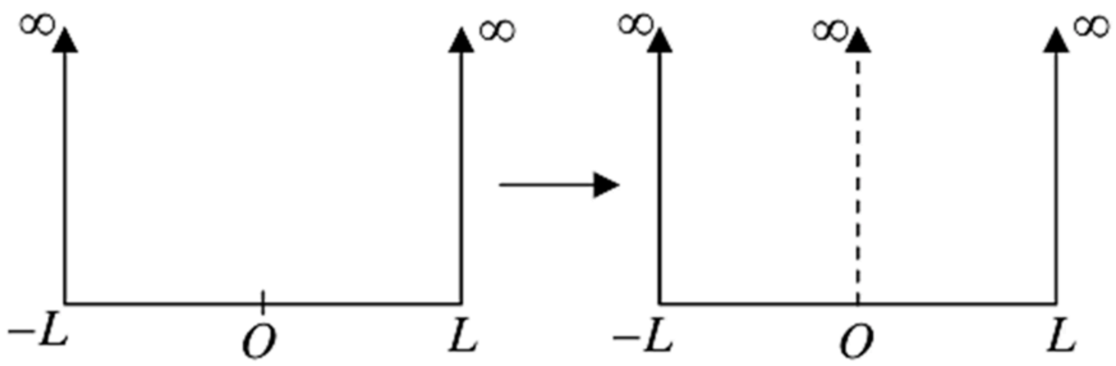
1. increases by a team of order ε
2. decreases by a term of order ε
3. increases by a term of order ε^2
4. decreases by a term of order ε^2

Q72. [June 2019] . 3.5 marks

Quantum Mechanics > Potential Well

CSIR NET	2019 June	3.5M

A quantum particle of mass m in one dimension, confined to a rigid box as shown in the figure, is in its ground state. An infinitesimally thin wall is very slowly raised to infinity at the centre of the box, in such a way that the system remains in its ground state at all times. Assuming that no energy is lost in raising the wall, the work done on the system when the wall is fully raised, eventually separating the original box into two compartments, is



1. $\frac{3\pi^2\hbar^2}{8mL^2}$
2. $\frac{\pi^2\hbar^2}{8mL^2}$
3. $\frac{\pi^2\hbar^2}{2mL^2}$
4. 0

Q73. [June 2019] . 3.5 marks
Quantum Mechanics > Potential Well

CSIR NET	2019 June	3.5M

The wavefunction of a free particle of mass m, constrained to move in the interval $-L \leq x \leq L$, is $\psi(x) = A(L+x)(L-x)$, where A is the normalization constant. The probability that the particle will be found to have the energy $\frac{\pi^2\hbar^2}{2mL^2}$ is

1. 0
2. $\frac{1}{\sqrt{2}}$
3. $\frac{1}{2\sqrt{3}}$
4. $\frac{1}{\pi}$

Q74. [June 2019] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2019 June	3.5M

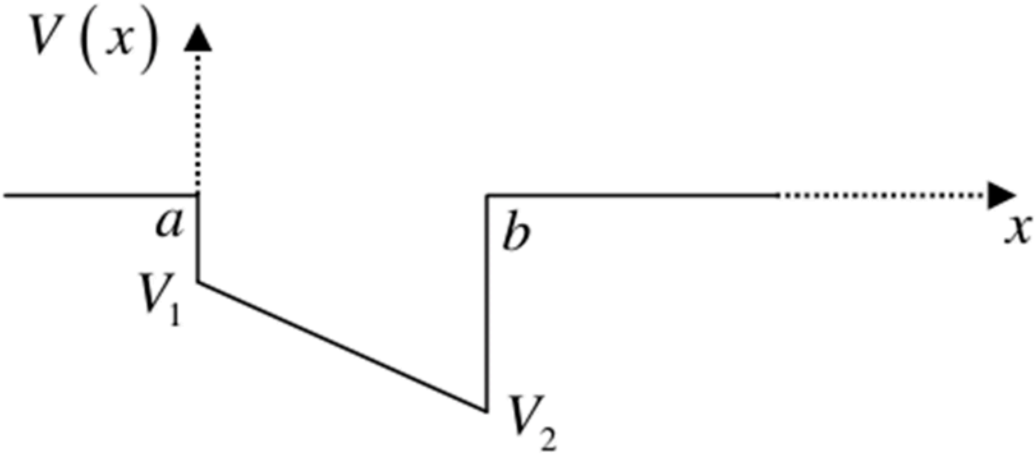
A particle moving in a central potential is described by a wave function $\psi(r) = zf(r)$ where $r = (x, y, z)$ is the position vector of the particle and $f(r)$ is a function of $r = |r|$. If L is the total angular momentum of the particle, the value of L^2 must be

1. $2\hbar^2$
2. $\hbar^2$
3. $4\hbar^2$
4. $\frac{3}{4}\hbar^2$

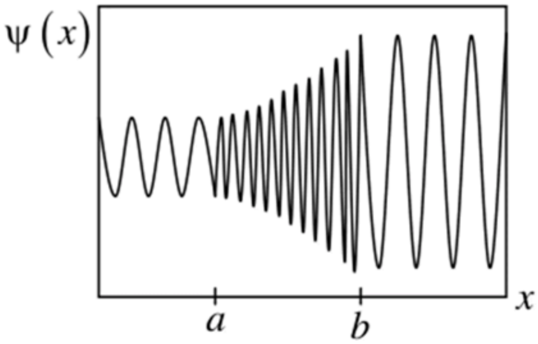
Q75. [June 2019] . 3.5 marks
Quantum Mechanics > Potential Well

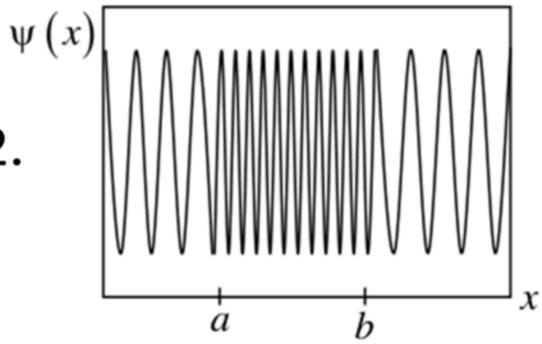
CSIR NET	2019 June	3.5M

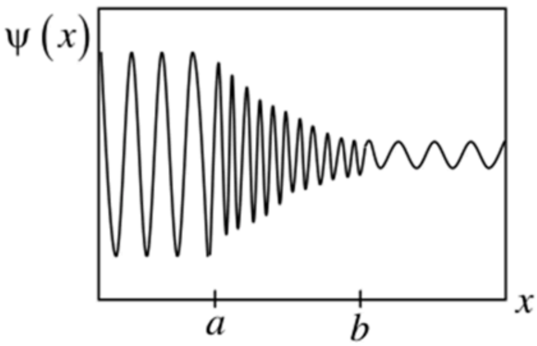
A particle of mass in and energy $E > 0$. in one dimension is scattered by the potential below.

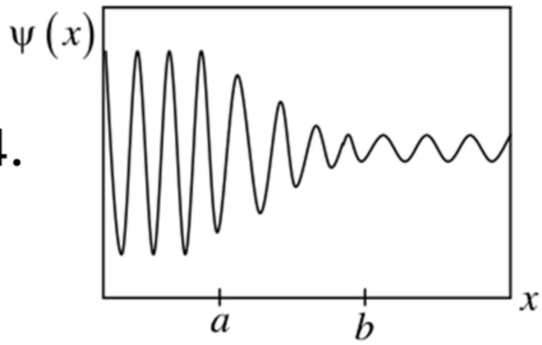


If the particle was moving from $x = -\infty$ to $x = \infty$, which of the following graphs gives the best qualitative representation of the wave function of this particle?

1.


2.


3.


4.


Q76. [June 2019] . 5.0 marks

Quantum Mechanics > WKB Approximation

CSIR NET	2019 June	5M

The Hamiltonian of A quantum particle of mass m is $H = \frac{p^2}{2m} + \alpha|x|^r$, where α and r are positive constants. The energy E_n of the n^{th} level for large n, depends on n as

1. n^{2r}
2. n^{r+2}
3. $n^{1/(r+2)}$
4. $n^{2r/(r+2)}$

Q77. [June 2019] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2019 June	5M

In the partial wave expansion, the differential scattering cross-section is given by

$$\frac{d\sigma}{d(\cos\theta)} = \left|\sum_{l} (2l+1)e^{i\delta_i}\sin\delta_l P_l(\cos\theta)\right|^2$$

where θ is the scattering angle. For a certain neutron-nucleus scattering. it is found that the two lowest phase shifts δ_0 and δ_1 corresponding to s-wave and p-wave, respectively, satisfy $\delta_1 \approx \frac{\delta_0}{2}$. Assuming that the other phase shifts are negligibly small, the differential cross-section reaches its minimum for $\cos\theta$ equal to

1. 0
2. ± 1
3. $-\frac{2}{3}\cos^2\delta_1$
4. $\frac{1}{3}\cos^2\delta_1$

Q78. [June 2019] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2019 June	5M

A charged, spin-less particle of mass m is subjected to an attractive potential

$V(x,y,z)=\frac{1}{2}k\left(x^2+y^2+z^2\right)$, where k is a positive constant. Now a perturbation in the form of a weak magnetic field $B=B_0\hat{k}$ (where B_0 is a constant is switched on. Into how many distinct levels will the second excited state of the unperturbed Hamiltonian split?

1. 5
2. 4
3. 2
4. 1

Q79. [June 2019] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2019 June	5M

The elastic scattering of a charged particle of mass m off an atom can be approximated by the potential $V(r) = \frac{\alpha}{r} e^{-r/R}$ where α and R are positive constants. If the wave number of the incoming particle is k and the scattering angle is 2θ, the differential cross-section in the Born approximation is

(a) $\frac{m^2\alpha^2R^4}{4\hbar^4\left(1+k^3R^2\sin^2\theta\right)}$

(b) $\frac{m^2\alpha^2R^4}{\hbar^4\left(2k^2R^2\sin^2\theta\right)^2}$

(c) $\frac{2m^2\alpha^2R^4}{\hbar^4\left(2k^2R^22\sin^2\theta\right)}$

(d) $\frac{4m^2\alpha^2R^4}{\hbar^4\left(1+4k^2R^2\sin^2\theta\right)^2}$

Q80. [June 2019] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2019 June	5M

The wave number k and the angular frequency ω of a wave are related by the dispersion relation $\omega^2 = \alpha k + \beta k^3$ where α and β are positive constants. The wave number for which the phase velocity equals the group velocity, is

1. $3\sqrt{\frac{\alpha}{\beta}}$
2. $\sqrt{\frac{\alpha}{\beta}}$
3. $\frac{1}{2}\sqrt{\frac{\alpha}{\beta}}$
4. $\frac{1}{3}\sqrt{\frac{\alpha}{\beta}}$

Q81. [June 2019] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2019 June	5M

The operator A has a matrix representation $\begin{pmatrix} 2 & 1 \\ 1 & 2 \end{pmatrix}$ in the basis spanned by $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$. In another basis spanned by $\frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \end{pmatrix}$ and $\frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ -1 \end{pmatrix}$, the matrix representation of A is

1. $\begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$
2. $\begin{pmatrix} 3 & 0 \\ 0 & 1 \end{pmatrix}$
3. $\begin{pmatrix} 3 & 1 \\ 0 & 1 \end{pmatrix}$
4. $\begin{pmatrix} 3 & 0 \\ 1 & 1 \end{pmatrix}$

Q82. [June 2019] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2019 June	5M

The operator $x\frac{d}{dx}\delta(x)$, where $\delta(x)$ is the Dirac delta function, acts on the space of real valued square-integrable functions on the real line. This operator is equivalent to

1. $-\delta(x)$
2. $\delta(x)$
3. x
4. 0

Q83. [June 2019] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2019 June	5M

The range of the inter-atomic potential in gaseous hydrogen is approximately 5Å . In thermal equilibrium, the maximum temperature for which the atom-atom scattering is dominantly s wave, is

1. 500 K
2. 100 K
3. 1 K
4. 1 mK

Q84. [June 2020] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2020 June	3.5M

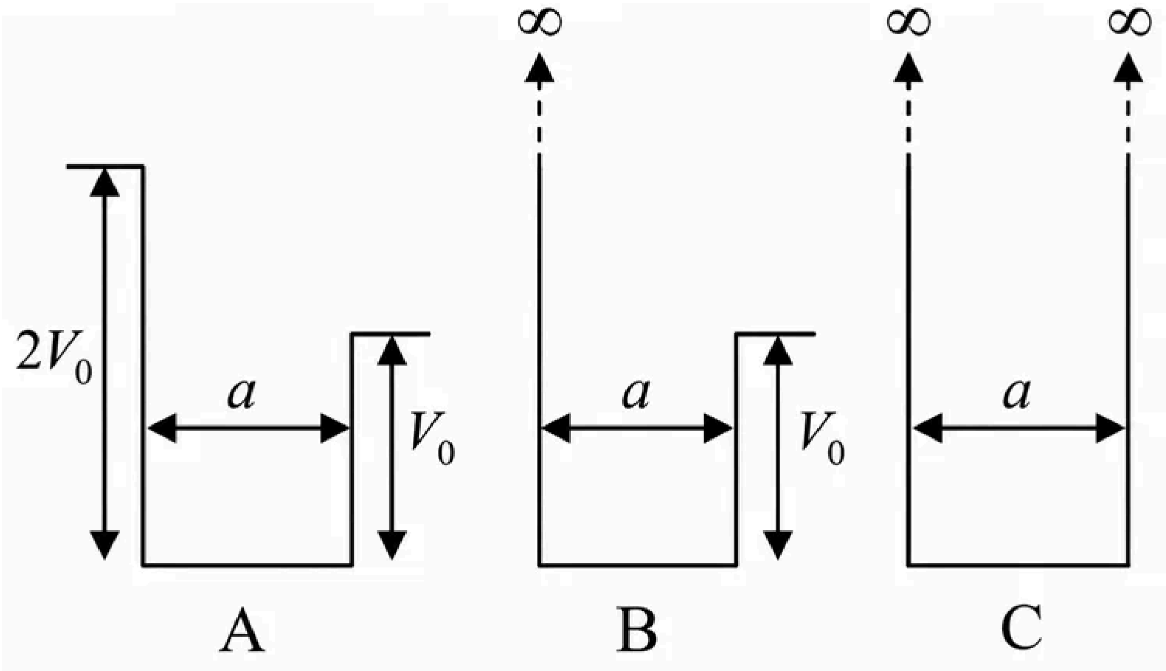
Let $|n\rangle$ denote the energy eigenstates of a particle in a one-dimensional simple harmonic potential $V(x) = \frac{1}{2}m\omega^2x^2$. If the particle is initially prepared in the state $|\psi(t=0)\rangle = \sqrt{\frac{1}{2}}(|0\rangle + |1\rangle)$, the minimum time after which the oscillator will be found in the same state is

1. $3\pi/(2\omega)$
2. π/ω
3. $\pi/(2\omega)$
4. $2\pi/\omega$

Q85. [June 2020] . 3.5 marks
Quantum Mechanics > Pertubation theory

CSIR NET	2020 June	3.5M

For the one dimensional potential wells A, B and C, as shown in the figure, let E_A, E_B and E_C denote the ground sate energies of a particle, respectively.



The correct ordering of the energies is

1. $E_C > E_B > E_A$
2. $E_A > E_B > E_C$
3. $E_B > E_C > E_A$
4. $E_B > E_A > E_C$

Q86. [June 2020] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2020 June	3.5M

An angular momentum eigenstate $|j, 0\rangle$ is rotated by an infinitesimally small angle ε about the positive y-axis in the counter clockwise direction. The rotated state, to order ε (upto a normalisation constant), is

1. $|j, 0\rangle - \frac{\varepsilon}{2}\sqrt{j(j+1)}(|j, 1\rangle + |j, -1\rangle)$
2. $|j, 0\rangle - \frac{\varepsilon}{2}\sqrt{j(j+1)}(|j, 1\rangle - |j, -1\rangle)$
3. $|j, 0\rangle - \frac{\varepsilon}{2}\sqrt{j(j-1)}(|j, 1\rangle - |j, -1\rangle)$
4. $|j, 0\rangle - \frac{\varepsilon}{2}\sqrt{j(j+1)}|j, 1\rangle - \frac{\varepsilon}{2}\sqrt{j(j-1)}|j, -1\rangle$

Q87. [June 2020] . 5.0 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2020 June	5M

The state of an electron in a hydrogen atom is

$$|\psi\rangle = \frac{1}{\sqrt{6}}|1,0,0\rangle + \frac{1}{\sqrt{3}}|2,1,0\rangle + \frac{1}{\sqrt{2}}|3,1,-1\rangle$$

where $|n, l, m\rangle$ denotes common eigenstates of $\hat{H}, \hat{L}^2$ and $\hat{L}_z$ operators in the standard notation.

In a measurement of $\hat{L}_z$ for the electron in this state, the result is recorded to be 0 . Subsequently a measurement of energy is performed. The probability that the result is E_2 (the energy of the $n = 2$ state) is

1. 1
2. $1/2$
3. $2/3$
4. $1/3$

Q88. [June 2020] . 5.0 marks
Quantum Mechanics > Scattering theory

CSIR NET	2020 June	5M

A particle with incoming wave vector $\vec{k}$, after being scattered by the potential $V(r) = \frac{C}{r^2}$, goes out with wave vector $\vec{k}'$. The differential scattering cross-section, calculated in the first Born approximation, depends on $q = |\vec{k} - \vec{k}'|$, as

1. $1/q^2$
2. $1/q^4$
3. $1/q$
4. $1/q^{3/2}$

Q89. [June 2020] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2020 June	5M

A quantum particle in a one-dimensional infinite potential well, with boundaries at 0 and a, is perturbed by adding $H' = \in \delta\left(x - \frac{a}{2}\right)$ to the initial Hamiltonian. The correction to the energies of the ground and the first excited states (to first order in $\in$) are respectively

1. 0 and 0
2. $2 \in/a$ and 0
3. 0 and $2 \in/a$
4. $2 \in/a$ and $2 \in/a$

Q90. [June 2021] . 3.5 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2021 June	3.5M

The Hamiltonian of a particle of mass m in one-dimension is $H = \frac{1}{2m}p^2 + \lambda|x|^3$, where $\lambda > 0$ is a constant. If E_1 and E_2 respectively, denote the ground state energies of the particle for $\lambda = 1$ and $\lambda = 2$ (in appropriate units) the ratio E_2/E_1 is best approximated by

1. 1.260
2. 1.414
3. 1.516
4. 1.320

Q91. [June 2021] . 3.5 marks

Quantum Mechanics > Potential Well

CSIR NET	2021 June	3.5M

A particle of mass m is in a one dimensional infinite potential well of length L, extending from $x = 0$ to $x = L$. When it is in the energy Eigen-state labelled by $n, (n = 1,2,3,..)$ the probability of finding in the interval $0 \leq x \leq L/8$ is $1/8$. The minimum value of n for which this is possible is

1. 4
2. 2
3. 6
4. 8

Q92. [June 2021] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2021 June	3.5M

A two-state system evolves under the action of the Hamiltonian $H = E_0|A\rangle\langle A| + (E_0 + \Delta)|B\rangle\langle B|$, where $|A\rangle$ and $|B\rangle$ are its two orthonormal states. These states transform to one another under parity, i.e. $P|A\rangle = |B\rangle$ and $P|B\rangle = |A\rangle$. If at time $t = 0$ the system is in a state of definite parity $P = 1$, the earliest time t at which the probability of finding the system in a state of parity $P = -1$ is one is

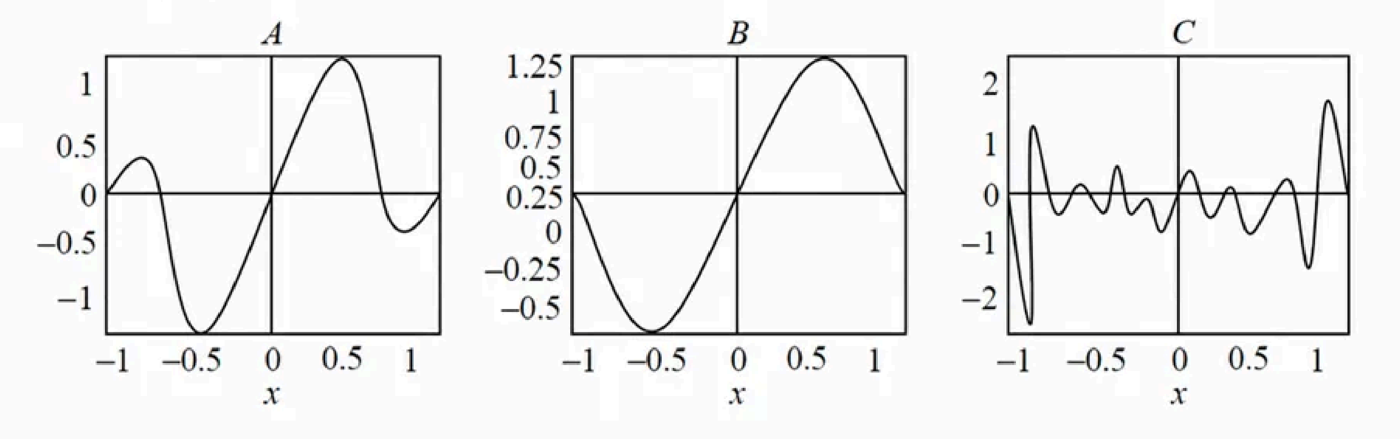
1. $\frac{\pi\hbar}{2\Delta}$
2. $\frac{\pi\hbar}{\Delta}$
3. $\frac{3\pi\hbar}{2\Delta}$
4. $\frac{2\pi\hbar}{\Delta}$

Q93. [June 2021] . 3.5 marks

Quantum Mechanics > Potential Well

CSIR NET	2021 June	3.5M

The figures below depict three different wave functions of a particle confined to a one dimensional box $-1 \leq x \leq 1$.



The wave functions that correspond to the maximum expectation values $|\langle x \rangle|$ (absolute value of the mean position) and $\langle x^2 \rangle$, respectively, are

1. B and C
2. B and A
3. C and B
4. A and B

Q94. [June 2021] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2021 June	3.5M

Which of the following two physical quantities cannot be measured simultaneously with arbitrary accuracy for the motion of a quantum particle in three dimensions?

1. square of the radial position and z-component of angular momentum (r^2 and L_z)
2. x-components of linear and angular momenta (p_x and L_x)
3. x-components of linear and angular momenta (p_x and L_x)
4. squares of the magnitudes of the linear and angular momenta (p^2 and L^2)

Q95. [June 2021] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2021 June	5M

A particle of mass m in one dimension is in the ground state of a simple harmonic oscillator described by a Hamiltonian $H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2x^2$ in the standard notation. An impulsive force at time to $t = 0$ suddenly imparts a momentum $p_0 = \sqrt{\hbar m\omega}$ to it. The probability that the particle remains in the original ground state is

1. e^{-2}
2. $e^{-3/2}$
3. e^{-1}
4. $e^{-1/2}$

Q96. [June 2021] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2021 June	5M

The energies of a two-state quantum system are E_0 and $E_0 + \alpha\hbar$, (where $\alpha > 0$ is a constant) and the corresponding normalized state vectors are $|0\rangle$ and $|1\rangle$, respectively. At time $t = 0$, when the system is in the state $|0\rangle$, the potential is altered by a time independent term V such that $\langle 1|V|0\rangle = \hbar\alpha/10$. The transition probability to the state $|1\rangle$ at times $t \ll 1/\alpha$, is

1. $\alpha^2 t^2/25$
2. $\alpha^2 t^2/50$
3. $\alpha^2 t^2/100$
4. $\alpha^2 t^2/200$

Q97. [June 2021] . 5.0 marks
Quantum Mechanics > Scattering theory

CSIR NET	2021 June	5M

In an elastic scattering process at an energy E, the phase shifts satisfy $\delta_0 \approx 30^\circ, \delta_1 \approx 10^\circ$, while the other phase shifts are zero. The polar angle at which the differential cross section peaks is closest to

1. 20°
2. 10°
3. 0°
4. 30°

Q98. [June 2021] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2021 June	5M

The unnormalized wave function of a particle in one dimension in an infinite square well with walls at $x = 0$ and $x = a$, is $\psi(x) = x(a - x)$. If $\psi(x)$ is expanded as a linear combination of the energy eigenfunctions, $\int_0^a |\psi(x)|^2 dx$ is proportional to the infinite series

(You may use $\int_0^a t\sin t dt = -a\cos a + \sin a$ and $\int_0^a t^2 \sin t dt = -2 - (a^2 - 2)\cos a + 2a\sin a$)

1. $\sum_{n=1}^{\infty} (2n - 1)^{-6}$
2. $\sum_{n=1}^{\infty} (2n - 1)^{-4}$
3. $\sum_{n=1}^{\infty} (2n - 1)^{-2}$
4. $\sum_{n=1}^{\infty} (2n - 1)^{-8}$

Q99. [June 2022] . 3.5 marks
Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2022 June	3.5M

If the expectation value of the momentum of a particle in one dimension is zero, then its (box-normalizable) wave function may be of the form

1. $\sin kx$
2. $e^{ikx} \sin kx$
3. $e^{ikx} \cos kx$
4. $\sin kx + e^{ikx} \cos kx$

Q100. [June 2022] . 3.5 marks
Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2022 June	3.5M

In terms of a complete set of orthonormal basis kets $|n\rangle$, $n = 0, \pm 1, \pm 2, \ldots$, the Hamiltonian is

$$H = \sum_n (E|n\rangle\langle n| + \epsilon|n+1\rangle\langle n| + \epsilon|n\rangle\langle n+1|)$$

where E and $\in$ are constants. The state $|\varphi\rangle = \sum_n e^{in\varphi}|n\rangle$ is an eigenstate with energy

1. $E + \in \cos\varphi$
2. $E - \in \cos\varphi$
3. $E + 2 \in \cos\varphi$
4. $E - 2 \in \cos\varphi$

Q101. [June 2022] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2022 June	3.5M

The momentum space representation of the Schrodinger equation of a particle in a potential $V(\vec{r})$ is $\left(|\vec{p}|^2 + \beta\left(\nabla_p^2\right)^2\right)\psi(\vec{p},t) = i\hbar\frac{\partial}{\partial t}\psi(\vec{p},t)$, where $\left(\nabla_p\right)_i = \frac{\partial}{\partial p_i}$, and β is a constant. The potential is (in the following V_0 and a are constants)

1. $V_0 e^{-r^2/a^2}$
2. $V_0 e^{-r^4/a^4}$
3. $V_0\left(\frac{r}{a}\right)^2$
4. $V_0\left(\frac{r}{a}\right)^4$

Q102. [June 2022] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2022 June	3.5M

Consider the Hamiltonian $H = AI + B\sigma_x + C\sigma_y$, where A, B and C are positive constants, I is the 2×2 identity matrix and σ_x, σ_y are Pauli matrices. If the normalized eigenvector corresponding to its largest energy eigenvalue is $\frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ y \end{pmatrix}$, then y is

1. $\frac{B+iC}{\sqrt{B^2+C^2}}$
2. $\frac{A-iB}{\sqrt{A^2+B^2}}$
3. $\frac{A-iC}{\sqrt{A^2+C^2}}$
4. $\frac{B-iC}{\sqrt{B^2+C^2}}$

Q103. [June 2022] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2022 June	5M

At time $t = 0$, a particle is in the ground state of the Hamiltonian $H(t) = \frac{p^2}{2m} + \frac{1}{2}m\omega^2x^2 + \lambda x \sin\frac{\omega t}{2}$ where λ, ω and m are positive constants. To $O(\lambda^2)$, the probability that at $t = \frac{2\pi}{\omega}$, the particle would be in the first excited state of $H(t = 0)$ is

1. $\frac{9\lambda^2}{16m\hbar\omega^3}$
2. $\frac{9\lambda^2}{8m\hbar\omega^3}$
3. $\frac{16\lambda^2}{9m\hbar\omega^3}$
4. $\frac{8\lambda^2}{9m\hbar\omega^3}$

Q104. [June 2022] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2022 June	5M

To first order in perturbation theory, the energy of the ground state of the Hamiltonian

$$H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2 + \frac{\hbar\omega}{\sqrt{512}}\exp\left[-\frac{m\omega}{\hbar}x^2\right]$$

(treating the third term of the Hamiltonian as a perturbation) is

1. $\frac{15}{32}\hbar\omega$
2. $\frac{17}{32}\hbar\omega$
3. $\frac{19}{32}\hbar\omega$
4. $\frac{21}{32}\hbar\omega$

Q105. [June 2022] . 5.0 marks

Quantum Mechanics > Potential Well

CSIR NET	2022 June	5M

The energy/energies E of the bound state(s) of a particle of mass m in one dimension in the potential $V(x) = \begin{cases} \infty, & x \le 0 \\ -V_0, & 0 < x < a \\ 0, & x \ge a \end{cases}$ (where $V_0 > 0$) is/are determined by

1. $\cot^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = \frac{E-V_0}{E}$
2. $\tan^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = -\frac{E}{E+V_0}$
3. $\cot^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = -\frac{E}{E+V_0}$
4. $\tan^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = \frac{E-V_0}{E}$

Q106. [June 2022] . 5.0 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2022 June	5M

The Hamiltonian for a spin-1/2 particle in a magnetic field $\vec{B} = B_0\hat{k}$ is given by $H = \lambda\vec{S}\cdot\vec{B}$, where $\vec{S}$ is its spin (in units of $\hbar$) and λ is a constant. If the average spins density is $\langle\vec{S}\rangle$ for an ensemble of such non-interacting particles, then $\frac{d}{dt}\langle S_x\rangle$

1. $\frac{\lambda}{\hbar}B_0\langle S_x\rangle$
2. $\frac{\lambda}{\hbar}B_0\langle S_y\rangle$
3. $-\frac{\lambda}{\hbar}B_0\langle S_x\rangle$
4. $-\frac{\lambda}{\hbar}B_0\langle S_y\rangle$

Q107. [Dec 2023] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2023 Dec	3.5 M

The Schrodinger wave function for a stationary state of an atom in spherical polar coordinates (r, θ, ϕ) is

$$\psi = Af(r)\sin\theta\cos\theta e^{i\phi}$$

where A is the normalization constant. The eigenvalue of $\hat{L}_z$ for this state is

1. $2\hbar$
2. $\hbar$
3. $-2\hbar$
4. $-\hbar$

Q108. [Dec 2023] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2023 Dec	3.5 M

The Hamiltonian for two particles with angular momentum quantum numbers $l_1 = l_2 = 1$, is

$$\hat{H} = \frac{\epsilon}{\hbar^2}\left[\left(\hat{L}_1 + \hat{L}_2\right) \cdot \hat{L}_2 - \left(\hat{L}_{1z} + \hat{L}_{2z}\right)^2\right]$$

If the operator for the total angular momentum is given by $\hat{L} = \hat{L}_1 + \hat{L}_2$, then the possible energy eigenvalues for states with $l = 2$, (where the eigenvalues of $\hat{L}^2$ are $l(l+1)h^2$) are

1. $3 \in, 2 \in, -\in$
2. $6 \in, 5 \in, 2 \in$
3. $3 \in, 2 \in, \in$
4. $-3 \in, -2 \in, \in$

Q109. [Dec 2023] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2023 Dec	3.5 M

The normalized wave function of an electron is

$$\psi(\vec{r}) = R(r)\left[\sqrt{\frac{3}{8}}Y_1^0(\theta,\varphi)\chi_- + \sqrt{\frac{5}{8}}Y_1^1(\theta,\varphi)\chi_+\right]$$

where Y_l^m are the normalized spherical harmonics and $\chi_\pm$ denote the wavefunction for the two spin states with eigenvalues $\pm\frac{1}{2}\hbar$. The expectation value of the z component of the total angular momentum in the above state is

1. $-\frac{3}{4}\hbar$
2. $\frac{3}{4}\hbar$
3. $-\frac{9}{8}\hbar$
4. $\frac{9}{8}\hbar$

Q110. [Dec 2023] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2023 Dec	5 M

An incident plane wave with wavenumber k is scattered by a spherically symmetric soft potential. The scattering occurs only in S - and P-waves. The approximate scattering amplitude an angles $\theta = \frac{\pi}{3}$ and $\theta = \frac{\pi}{2}$ are

$$f\left(\theta = \frac{\pi}{3}\right) \approx \frac{1}{2k}\left(\frac{5}{2} + 3i\right) \text{ and } f\left(\theta = \frac{\pi}{2}\right) \approx \frac{1}{2k}\left(1 + \frac{3i}{2}\right)$$

Then the total scattering cross-section is closest to

1. $\frac{37\pi}{4k^2}$
2. $\frac{10\pi}{k^2}$
3. $\frac{35\pi}{4k^2}$
4. $\frac{9\pi}{k^2}$

Q111. [Dec 2023] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2023 Dec	5 M

In a quantum harmonic oscillator problem, $\hat{a}$ and $\hat{N}$ are the annihilation operator and the number operator, respectively. The operator $e^{\hat{N}}\hat{a}e^{-\hat{N}}$ is

1. $\hat{a}$
2. $e^{-1}\hat{a}$
3. $e^{-(\hat{I}+\hat{a})}$
4. $e^{\hat{a}}$

(where $\hat{I}$ is the identity operator)

Q112. [Dec 2023] . 5.0 marks

Quantum Mechanics > Dirac delta potential

CSIR NET	2023 Dec	5 M

A quantum particle of mass m is moving in a one dimensional potential

$$V(x) = V_0\theta(x) - \lambda\delta(x)$$

where V_0 and λ are positive constants, $\theta(x)$ is the Heaviside step function and $\delta(x)$ is the Dirac delta function. The leading contribution to the reflection coefficient for the particle incident from the left with energy $E \gg V_0 > \lambda$ and $\sqrt{2mE} \gg \frac{V_0\hbar}{\lambda}$ is

1. $\frac{V_0^2}{4E^2}$
2. $\frac{V_0^2}{8E^2}$
3. $\frac{m\lambda^2}{2E\hbar^2}$
4. $\frac{m\lambda^2}{4E\hbar^2}$

Q113. [Dec 2023] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2023 Dec	5 M

A quantum system is described by the Hamiltonian

$$H = -J\sigma_z + \lambda(t)\sigma_x,$$

where $\sigma_i (i = x, y, z)$ are Pauli matrices, J and λ are positive constants $(J \gg \lambda)$ and

$$\lambda(t) = \begin{cases} 0 \text{ for } t < 0 \\ \lambda \text{ for } 0 < t < T \\ 0 \text{ for } t > T \end{cases}$$

At $t < 0$, the system is in the ground state. The probability of finding the system in the excited state at $t \gg T$, in the leading order in λ is

1. $\frac{\lambda^2}{8J^2} \sin^2 \frac{JT}{\hbar}$
2. $\frac{\lambda^2}{J^2} \sin^2 \frac{JT}{\hbar}$
3. $\frac{\lambda^2}{4J^2} \sin^2 \frac{JT}{\hbar}$
4. $\frac{\lambda^2}{16J^2} \sin^2 \frac{JT}{\hbar}$

Q114. [June 2023] . 3.5 marks

Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2023 June	3.5M

The Hamiltonian of a two-dimensional quantum harmonic oscillator is

$$H = \frac{p_x^2}{2m} + \frac{p_y^2}{2m} + \frac{1}{2} m\omega^2 x^2 + 2m\omega^2 y^2$$

where m and ω are positive constants. The degeneracy of the energy level $\frac{27}{2}\hbar\omega$ is

1. 14
2. 13
3. 8
4. 7

Q115. [June 2023] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2023 June	3.5M

The value of $\langle L_x^2 \rangle$ in the state $|\varphi\rangle$ for which $L^2|\varphi\rangle = 6\hbar^2|\varphi\rangle$ and $L_z|\varphi\rangle = 2\hbar|\varphi\rangle$, is

1. 0
2. $4\hbar^2$
3. $2\hbar^2$
4. $\hbar^2$

Q116. [June 2023] . 3.5 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2023 June	3.5M

A particle in one dimension is in an infinite potential well between $\frac{-L}{2} \leq x \leq \frac{L}{2}$. For a perturbation $\epsilon \cos\left(\frac{\pi x}{L}\right)$, where ϵ is a small constant, the change in the energy of the ground state, to first order in ϵ, is

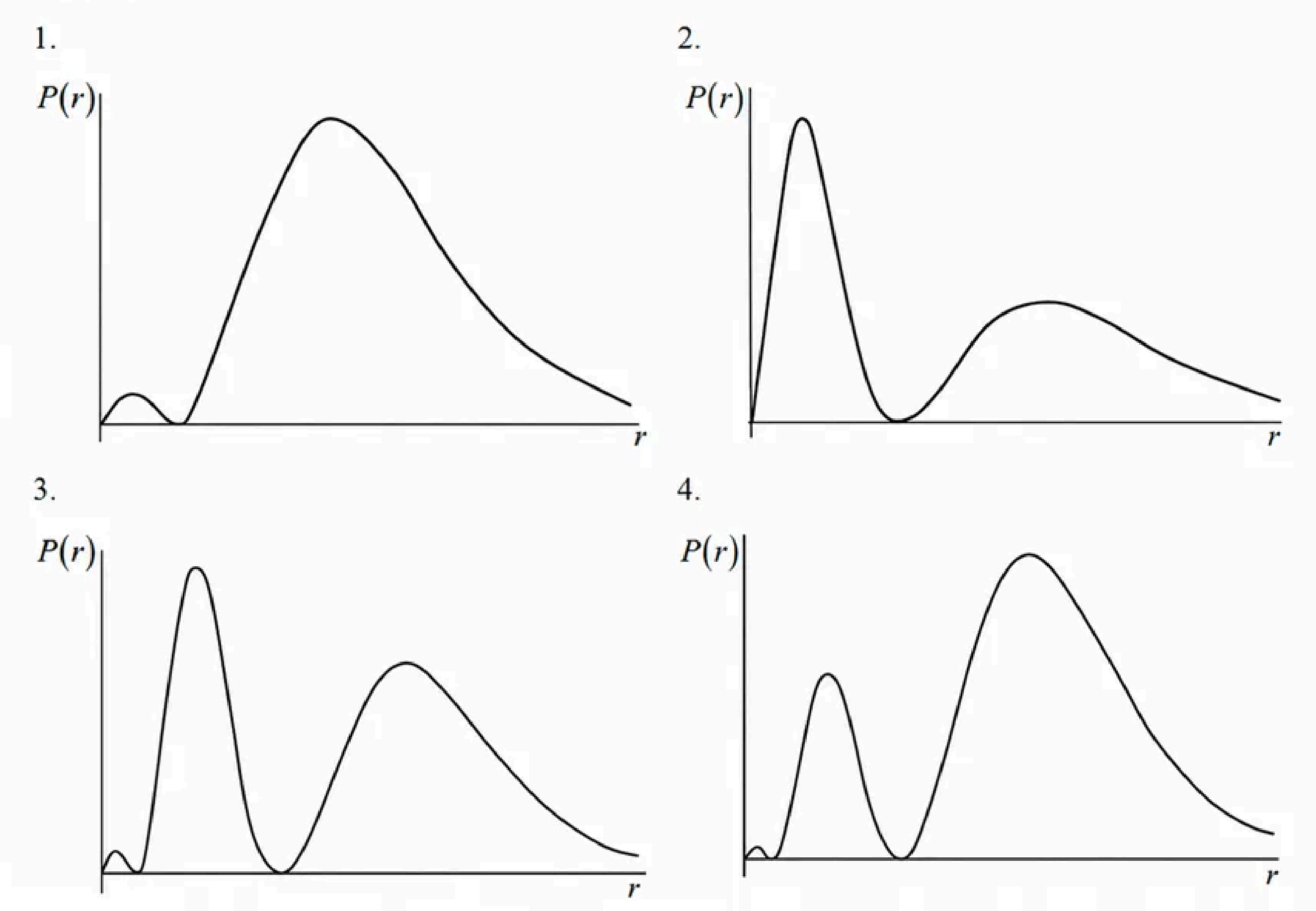
1. $\frac{5\epsilon}{\pi}$
2. $\frac{10\epsilon}{3\pi}$
3. $\frac{8\epsilon}{3\pi}$
4. $\frac{4\epsilon}{\pi}$

Q117. [June 2023] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2023 June	3.5M

The radial wavefunction of hydrogen atom with the principal quantum number $n = 2$ and the orbital quantum number $\ell = 0$ is $R_{20} = N\left(1 - \frac{r}{2a}\right)e^{-\frac{r}{2a}}$, where N is the normalization constant. The best schematic representation of the probability density $P(r)$ for the electron to be between r and r + dr is



Q118. [June 2023] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2023 June	5M

Two operators A and B satisfy the commutation relations $[H, A] = -\hbar\omega B$ and $[H, B] = \hbar\omega A$, where ω is a constant and H is the Hamiltonian of the system. The expectation value $\langle A\rangle_\psi(t) = \psi|A|\psi)$ in a state $|\psi\rangle$, such that at time $t = 0, \langle A\rangle_\psi(0) = 0$ and $B_\psi(0) = i$, is

1. $\sin(\omega t)$
2. $\sinh(\omega t)$
3. $\cos(\omega t)$
4. $\cosh(\omega t)$

Q119. [June 2023] . 5.0 marks

Quantum Mechanics > Two particle System

CSIR NET	2023 June	5M

Two distinguishable non-interacting particles, each of mass m are in a one-dimensional infinite square well in the interval $[0, a]$. If x_1 and x_2 are position operators of the two particles, the expectation value $\langle x_1 x_2 \rangle$ in the state in which one particle is in the ground state and the other one is in the first excited state, is

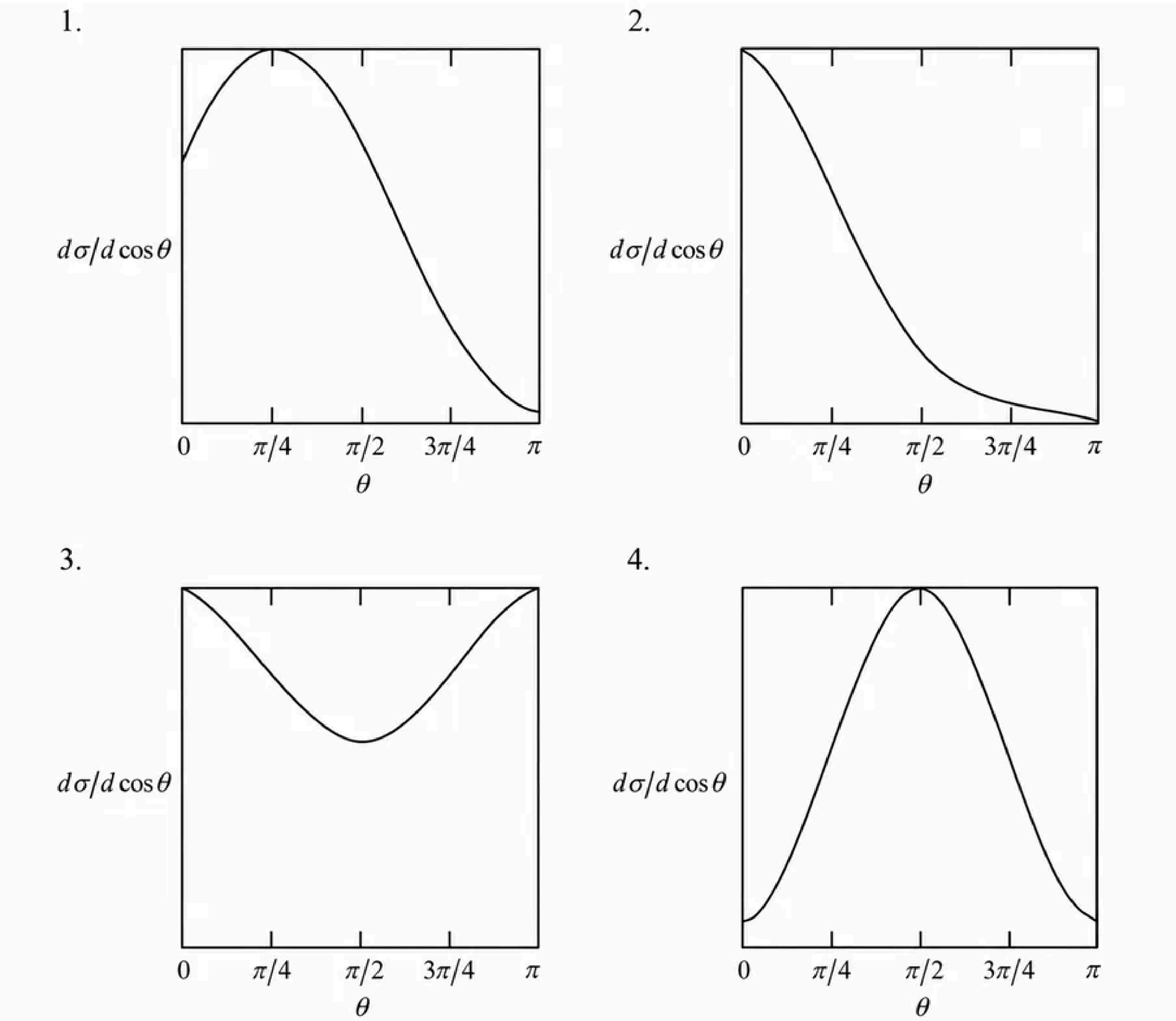
1. $\frac{1}{2}a^2$
2. $\frac{1}{2}\pi^2 a^2$
3. $\frac{1}{4}a^2$
4. $\frac{1}{4}\pi^2 a^2$

Q120. [June 2023] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2023 June	5M

The phase shifts of the partial waves in an elastic scattering at energy E are $\delta_0 = 12^\circ$, $\delta_1 = 4^\circ$ and $\delta_{\ell \geq 2} \approx 0^\circ$. The best qualitative depiction of θ-dependence of the differential scattering cross-section $\frac{d\sigma}{d\cos\theta}$ is



Q121. [June 2023] . 5.0 marks
Quantum Mechanics > Pertubation theory

CSIR NET	2023 June	5M

Electrons polarized along the x-direction are in a magnetic field $B_1\hat{\imath} + B_2(\hat{\jmath}\cos\omega t + \hat{k}\sin\omega t)$, where $B_1 \gg B_2$ and ω are positive constants. The value of $\hbar\omega$ for which the polarization-flip process is a resonant one, is

1. $2\mu_B|B_2|$
2. $\mu_B|B_1|$
3. $\mu_B|B_2|$
4. $2\mu_B|B_1|$

Q122. [Dec 2024] . 3.5 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2024 Dec	3.5M

Consider a particle in a one-dimensional infinite potential well between $0 \leq x \leq L$. If a small perturbation, $V(x) = \lambda \cos\left(\frac{\pi x}{L}\right)$, (where $\lambda \ll 1$) is applied, the firstorder energy correction to the ground state is

1. λ

2. 0

3. $-\lambda$

4. 2λ

Q123. [Dec 2024] . 3.5 marks

Quantum Mechanics > Potential Well

CSIR NET	2024 Dec	3.5M

Two non-interacting identical spin $-\frac{1}{2}$ particles, each of mass m, are placed in a two-dimensional infinite square well of side L. The single-particle spatial wavefunction is given by

$$\varphi_{n_x,n_y}(x,y) = \frac{2}{L}\sin\left(\frac{n_x \pi x}{L}\right)\sin\left(\frac{n_y \pi y}{L}\right)$$

where n_x and n_y are positive integers. If the particles are in a total spin state $|j = 1, m = 0\rangle$, the lowest possible energy eigenvalue is

1. $\frac{5\hbar^2\pi^2}{2mL^2}$
2. $\frac{\hbar^2\pi^2}{mL^2}$
3. $\frac{2\hbar^2\pi^2}{mL^2}$
4. $\frac{7\hbar^2\pi^2}{2mL^2}$

Q124. [Dec 2024] . 3.5 marks
Quantum Mechanics > Spin Angular momentum

CSIR NET	2024 Dec	3.5M

An electron is in the spin state $|\psi\rangle = \frac{1}{5}\binom{3i}{4}$ in the $\hat{S}_z$ basis. A measurement of $\hat{S}_x$ is made on this state. The probabilities of getting $\hbar/2$ and $-\hbar/2$ are

1. $\frac{1}{3}, \frac{2}{3}$
2. $\frac{1}{4}, \frac{3}{4}$
3. $\frac{1}{2}, \frac{1}{2}$
4. $\frac{3}{7}, \frac{4}{7}$

Q125. [Dec 2024] . 3.5 marks

Quantum Mechanics > Potential Well

CSIR NET	2024 Dec	3.5M

A particle of mass m is in a cubic box of side a. The potential inside the box ($0 \leq x \leq a, 0 \leq y \leq a, 0, \leq z \leq a$) is zero and infinite outside. If the particle is in an energy eigenstate with $E = \frac{7\pi^2 h^2}{ma^2}$, a possible wavefunction is

1. $\psi = \left(\frac{2}{a}\right)^{3/2} \sin\left(\frac{\pi x}{a}\right) \sin\left(\frac{\pi y}{a}\right) \sin\left(\frac{2\pi z}{a}\right)$
2. $\psi = \left(\frac{2}{a}\right)^{3/2} \sin\left(\frac{\pi x}{a}\right) \sin\left(\frac{3\pi y}{a}\right) \sin\left(\frac{\pi z}{a}\right)$
3. $\psi = \left(\frac{2}{a}\right)^{3/2} \sin\left(\frac{\pi x}{a}\right) \sin\left(\frac{2\pi y}{a}\right) \sin\left(\frac{3\pi z}{a}\right)$
4. $\psi = \left(\frac{2}{a}\right)^{3/2} \sin\left(\frac{\pi x}{a}\right) \sin\left(\frac{2\pi y}{a}\right) \sin\left(\frac{2\pi z}{a}\right)$

Q126. [Dec 2024] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2024 Dec	5M

The constant B which makes e^{-ax^2} an eigenfunction of the operator $\left(\frac{d^2}{dx^2} - Bx^2\right)$ is

1. $4a^2$
2. 0
3. $2a$
4. 1

Q127. [Dec 2024] . 5.0 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2024 Dec	5M

For a system of two electrons, define an operator

$$\hat{A} = \frac{3}{a^2}\left(\hat{\vec{S}}_1 \cdot \vec{a}\right)\left(\hat{\vec{S}}_2 \cdot \vec{a}\right) - \hat{\vec{S}}_1 \cdot \hat{\vec{S}}_2$$

where $\vec{a}$ is an arbitrary vector, and $\hat{\vec{S}}_1$ and $\hat{\vec{S}}_2$ are spin operators. The eigenvalues of $\hat{A}$ (in units of $\hbar^2$) are

1. $-1, 1, \frac{3}{2}, \frac{3}{2}$
2. $-1, -\frac{1}{2}, -\frac{1}{2}, 0$
3. $\frac{1}{2}, 1, \frac{3}{2}, \frac{3}{2}$
4. $0, \frac{1}{2}, \frac{1}{2}, -1$

Q128. [Dec 2024] . 5.0 marks

Quantum Mechanics > Dirac delta potential

CSIR NET	2024 Dec	5M

A particle of mass m, moving in one-dimension is subjected to the potential

$$V(x) = \begin{cases} V_0\delta(x-a) & 0 < x < 2a \\ \infty & \text{otherwise} \end{cases}$$

The energy eigenvalues E satisfy

1. $\tan\frac{a\sqrt{2mE}}{\hbar} = \frac{\hbar}{V_0}\sqrt{\frac{2E}{m}}$
2. $\tanh\frac{a\sqrt{2mE}}{\hbar} = \frac{\hbar}{V_0}\sqrt{\frac{2E}{m}}$
3. $\tan\frac{a\sqrt{2mE}}{\hbar} = -\frac{\hbar}{V_0}\sqrt{\frac{2E}{m}}$
4. $\tanh\frac{a\sqrt{2mE}}{\hbar} = -\frac{\hbar}{V_0}\sqrt{\frac{2E}{m}}$

Q129. [Dec 2024] . 5.0 marks

Quantum Mechanics > Dirac delta potential

CSIR NET	2024 Dec	5M

A particle of mass m is bound in one dimension by the potential $V(x) = V_0\delta(x)$ with $V_0 < 0$. If the probability of finding it in the region $|x| < a$ is 0.25 , then a is

1. $\frac{\hbar^2}{4mV_0}\ln\frac{3}{4}$
2. $\frac{\hbar^2}{2mV_0}\ln\frac{3}{4}$
3. $\frac{\hbar^2}{4mV_0}\ln\frac{1}{4}$
4. $\frac{\hbar^2}{2mV_0}\ln\frac{1}{4}$

Q130. [Dec 2024] . 5.0 marks
Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2024 Dec	5M

Eigenstates of a system are specified by two non negative integers n_1 and n_2. The energy of the system is given by

$$E_n = \left(n_1 + \frac{1}{2}\right)\hbar\omega + \left(n_2 + \frac{1}{2}\right)2\hbar\omega.$$

If $\alpha \equiv \exp\left(-\frac{\hbar\omega}{k_B T}\right)$, what is the probability that at temperature T the energy of the system will be less than $4\hbar\omega$?

1. $(1-\alpha^2)(1-\alpha)(2+\alpha+2\alpha^2)$
2. $(1-\alpha)^2(1-\alpha)(2+\alpha+\alpha^2)$
3. $(1-\alpha^2)(1+\alpha)(1+\alpha+2\alpha^2)$
4. $(1-\alpha)^2(1+\alpha)(1+\alpha+2\alpha^2)$

Q131. [June 2024] . 3.5 marks

Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2024 June	3.5M

The Hamiltonian for a one-dimensional simple harmonic oscillator is given by $H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2$. The harmonic oscillator is in the state

$$|\psi\rangle = \frac{1}{\sqrt{1+\lambda^2}}\left(|1\rangle + \lambda e^{i\theta}|2\rangle\right),$$

where $|1\rangle$ and $|2\rangle$ are the normalised first and second excited states of the oscillator and λ, θ are positive real constants. If the expectation value $\langle\psi|x|\psi\rangle = \beta\sqrt{\frac{\hbar}{m\omega}}$, the value of β is

1. $\frac{1}{\sqrt{2}(1+\lambda^2)}$
2. $\frac{\sqrt{2}\lambda\cos\theta}{1+\lambda^2}$
3. $\frac{2\lambda\cos\theta}{1+\lambda^2}$
4. $\frac{\lambda^2\cos\theta}{1+\lambda^2}$

Q132. [June 2024] . 3.5 marks
Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2024 June	3.5M

If A and B are Hermitian operators and C is an antihermitian operator, then

1. $[[A,B],C]$ is hermitian and $[[A,C],B]$ is antihermitian
2. $[[A,B],C]$ and $[[A,C],B]$ are both antihermitian
3. $[[A,B],C]$ and $[[A,C],B]$ are both hermitian
4. $[[A,B],C]$ is antihermitian and $[[A,C],B]$ is Hermitian

Q133. [June 2024] . 3.5 marks
Quantum Mechanics > Spin Angular momentum

CSIR NET	2024 June	3.5M

If $\vec{L}$ is the orbital angular momentum operator and $\vec{\sigma}$ are the Pauli matrices, which of the following operators commutes with $\vec{\sigma} \cdot \vec{L}$?

1. $\vec{L} - \frac{\hbar}{2}\vec{\sigma}$
2. $\vec{L} + \frac{\hbar}{2}\vec{\sigma}$
3. $\vec{L} + \hbar\vec{\sigma}$
4. $\vec{L} - \hbar\vec{\sigma}$

Q134. [June 2024] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2024 June	3.5M

A quantum mechanical system is in the angular momentum state $|l = 4, l_z = 4\rangle$. The uncertainty in L_x is

1. $\hbar\sqrt{2}$
2. $2\hbar$
3. 0
4. $\hbar$

Q135. [June 2024] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2024 June	3.5M

A hydrogen atom is in the state

$$|\psi\rangle = \sqrt{\frac{8}{21}}|\psi_{200}\rangle + \sqrt{\frac{3}{7}}|\psi_{210}\rangle + \sqrt{\frac{4}{21}}|\psi_{311}\rangle$$

where $|\psi_{nlm}\rangle$ are normalised eigenstates. If $\hat{L}^2$ is measured in this state, the probability of obtaining the value $2\hbar^2$ is

1. $\frac{13}{21}$
2. $\frac{4}{21}$
3. $\frac{17}{21}$
4. $\frac{3}{7}$

Q136. [June 2024] . 5.0 marks

Quantum Mechanics > Variational Principle

CSIR NET	2024 June	5M

Using a normalized trial wavefunction $\psi(x) = \sqrt{\alpha}e^{-\alpha|x|}$ (α is a positive real constant) for a particle of mass m in the potential $V(x) = -\lambda\delta(x), (\lambda > 0)$, the estimated ground state energy is

1. $-\frac{m\lambda^2}{\hbar^2}$
2. $\frac{m\lambda^2}{\hbar^2}$
3. $\frac{m\lambda^2}{2\hbar^2}$
4. $-\frac{m\lambda^2}{2\hbar^2}$

Q137. [June 2024] . 5.0 marks

Quantum Mechanics > WKB Approximation

CSIR NET	2024 June	5M

The Hamiltonian of a particle of mass m is given by

$$H = \frac{p^2}{2m} + V(x), \text{ with } V(x) = \begin{cases} -\alpha x & \text{for } x \leq 0 \\ \beta x & \text{for } x > 0 \end{cases}$$

where α, β are positive constants. The n^{th} energy eigenvalue E_n obtained using WKB approximation is $E_n^{3/2} = \frac{3}{2}\left(\frac{\hbar^2}{2m}\right)^{1/2} \pi\left(n - \frac{1}{2}\right) f(\alpha, \beta)\ (n = 1, 2, \dots)$

The function $f(\alpha, \beta)$ is

1. $\sqrt{\frac{\alpha^2\beta^2}{2(\alpha^2+\beta^2)}}$
2. $\frac{\alpha\beta}{\alpha+\beta}$
3. $\frac{\alpha+\beta}{4}$
4. $\frac{1}{2}\sqrt{\frac{\alpha^2+\beta^2}{2}}$

Q138. [June 2024] . 5.0 marks

Quantum Mechanics > Dirac delta potential

CSIR NET	2024 June	5M

A particle of energy E is scattered off a one-dimensional potential $\lambda\delta(x)$, where λ is a real positive constant, with a transmission amplitude t_+. In a different experiment, the same particle is scattered off another one-dimensional potential $-\lambda\delta(x)$, with a transmission amplitude t_-. In the limit $E \to 0$, the phase difference between $t_+$and $t_-$is

1. $\pi/2$
2. π
3. 0
4. $3\pi/2$

Q139. [Dec 2025] . 3.5 marks
Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2025 Dec	3.5M	QM

If $\vec{\hat{L}}$ is the angular momentum operator for a quantum particle, then $\vec{\hat{L}} \times \vec{\hat{L}}$ is

1. $\hbar^2$
2. $-i\hbar\vec{\hat{L}}$
3. 0
4. $i\hbar\vec{\hat{L}}$

Q140. [Dec 2025] . 3.5 marks
Quantum Mechanics > Two particle System

CSIR NET	2025 Dec	3.5M	QM

An isolated two-electron quantum state is described by the orbital angular momentum quantum number l and the total spin S. An allowed value of l and S is

1. $S = 1, l = 0$
2. $S = 0, l = 1$
3. $S = 1, l = 1$
4. $S = 1, l = 2$

Q141. [Dec 2025] . 3.5 marks

Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2025 Dec	3.5M	QM

A quantum particle of mass m is moving in a potential

$$V(x,y) = \frac{m\omega^2}{8}\left[5\left(x^2 + y^2\right) + 8xy\right].$$

The lowest energy eigenstate with degeneracy has an energy

1. $\frac{7}{2}\hbar\omega$
2. $\frac{3}{2}\hbar\omega$
3. $4\hbar\omega$
4. $\frac{5}{2}\hbar\omega$

Q142. [Dec 2025] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2025 Dec	3.5M	QM

A spin-$\frac{1}{2}$ particle is in a magnetic field $\vec{B} = B_x\hat{x} + B_y\hat{y}$ for which the spin dependent Hamiltonian is $\hat{H} = -A\hat{\vec{S}} \cdot \vec{B}$ (A is a positive constant and $\hat{\vec{S}}$ is the spin-operator). The eigenvalues of the Hamiltonian are

1. $\pm A\frac{\hbar}{2}\left(B_x + B_y\right)$
2. $\pm A\frac{\hbar}{2}\sqrt{B_x B_y}$
3. $\pm A\frac{\hbar}{2}\left(B_x^2 + B_y^2\right)^{\frac{1}{2}}$
4. 0

Q143. [Dec 2025] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2025 Dec	3.5M	QM

A quantum mechanical particle in a harmonic potential has the wave function $\frac{1}{\sqrt{2}}[\psi_0(x)+\psi_1(x)]$ at $t=0$, where $\psi_0(x)$ and $\psi_1(x)$ are the wave functions of the ground state and the first excited state respectively. If the frequency of the oscillator is ω, the probability density of finding the particle at x after time $t=\frac{\pi}{\omega}$ is

1. $\frac{1}{2}|\psi_1(x)-\psi_0(x)|^2$
2. $\frac{1}{2}|\psi_1(x)+\psi_0(x)|^2$
3. $\frac{1}{2}|\psi_1(x)-i\psi_0(x)|^2$
4. $\frac{1}{2}|\psi_1(x)|^2+\frac{1}{2}|\psi_0(x)|^2$

Q144. [Dec 2025] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2025 Dec	5M	QM

A one-dimensional quantum harmonic oscillator with frequency ω is in its ground state. Its normalized wave function is given by

$$\psi(x) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} \exp\left[-\frac{m\omega}{2\hbar}x^2\right].$$

The frequency is suddenly increased to 2ω. The probability of finding the particle in its new ground state is

1. $\frac{2\sqrt{2}}{3}$
2. $\left(\frac{2\sqrt{2}}{3}\right)^{\frac{1}{2}}$
3. $\frac{2}{3}$
4. $\left(\frac{3}{2\sqrt{2}}\right)^{\frac{1}{2}}$

Q145. [Dec 2025] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2025 Dec	5M	QM

Consider the one-dimensional motion of a particle of positive charge q confined to an infinite potential well

$$V(x) = \begin{cases} 0 \text{ for } 0 \leq x \leq \pi \\ \infty \text{ otherwise} \end{cases}$$

which is subjected to a perturbing electric field $\vec{E} = E_0 \hat{x}$. The shift in the ground state energy, to the first order in q, is

1. $\frac{q\pi E_0}{2}$
2. $-\frac{q\pi E_0}{2}$
3. $q\pi E_0$
4. $-q\pi E_0$

Q146. [Dec 2025] . 5.0 marks
Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2025 Dec	5M	QM

For a particle in the angular momentum state $|l = 4, m_l = 2\rangle$, the expectation value of the operator $L_x L_y$ is

1. $-\hbar^2$
2. $\hbar^2$
3. $-i\hbar^2$
4. $i\hbar^2$

Q147. [June 2025] . 3.5 marks
Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2025 June	3.5M	QM

The energy eigenstates of a one-dimensional harmonic oscillator are denoted by $|i\rangle$, where $i = 0,1,2,3 \ldots.$. If the momentum operator $\hat{p}$ satisfies $\frac{\langle n+1|\hat{p}|n\rangle}{\langle 2|\hat{p}|1\rangle} = \sqrt{2}$, then the value of n is

1. 0
2. 1
3. 2
4. 3

Q148. [June 2025] . 3.5 marks

Quantum Mechanics > Two particle System

CSIR NET	2025 June	3.5M	QM

A system consists of two non-interacting identical spin-$\frac{1}{2}$ particles. The spatial wave functions for the individual particles are given by $\varphi_1(x)$ and $\varphi_2(x)$. Let x_1 and x_2 denote the positions of the particles respectively. The total wave function of the system (not necessarily normalized) can be

1. $[\varphi_1(x_1)\varphi_2(x_2) - \varphi_2(x_1)\varphi_1(x_2)][|\uparrow\rangle_1|\downarrow\rangle_2 + |\downarrow\rangle_1|\uparrow\rangle_2]$
2. $[\varphi_1(x_1)\varphi_1(x_2) + \varphi_2(x_1)\varphi_2(x_2)]|\uparrow\rangle_1|\uparrow\rangle_2$
3. $\varphi_1(x_1)\varphi_2(x_2)|\uparrow\rangle_1|\uparrow\rangle_2$
4. $[\varphi_1(x_1)\varphi_2(x_2) - \varphi_2(x_1)\varphi_1(x_2)][|\uparrow\rangle_1|\downarrow\rangle_2 - |\downarrow\rangle_1|\uparrow\rangle_2]$

Q149. [June 2025] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2025 June	3.5M	QM

A spin-$\frac{1}{2}$ system is prepared in the initial state $|\varphi\rangle = \frac{\sqrt{3}}{2}|\uparrow\rangle + \frac{1}{2}|\downarrow\rangle$ where $|\uparrow\rangle$ & $|\downarrow\rangle$ are eigenstates of $\hat{S}_z$ with eigenvalues $+\frac{\hbar}{2}$ & $-\frac{\hbar}{2}$ respectively. A measurement of $\hat{S}_z$ is followed by a measurement of $\hat{S}_x$ on the system. What is the probability that the measurement of $\hat{S}_x$ yields a value $+\frac{\hbar}{2}$?

1. $\frac{1}{2}$
2. $\frac{2+\sqrt{3}}{4}$
3. $\frac{2-\sqrt{3}}{4}$
4. $\frac{3}{8}$

Q150. [June 2025] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2025 June	3.5M	QM

A particle of mass m is in the third energy eigenstate of an infinite potential well of width a. The time interval in which the phase of this wave function changes by 2π is

1. $\frac{4ma^2}{3\pi\hbar}$
2. $\frac{4ma^2}{9\pi\hbar}$
3. $\frac{8ma^2}{3\pi\hbar}$
4. $\frac{8ma^2}{9\pi\hbar}$

Q151. [June 2025] . 3.5 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2025 June	3.5M	QM

The Hamiltonian of the 1-dimensional quantum harmonic oscillator is given by $H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2$. The expectation value of $[D, H]$ in the ground state, where $D = \frac{1}{2\hbar}(xp + px)$, is (in units of $\hbar\omega$)

1. i
2. $\frac{1}{2}$
3. 3. $\frac{-3i}{2}$
4. 0

Q152. [June 2025] . 5.0 marks

Quantum Mechanics > Quantum Harmonic Oscillator

CSIR NET	2025 June	5M	QM

$|n\rangle$ denotes the eigenvector of the number operator for a particle of mass m in a one-dimensional potential $V = \frac{1}{2}m\omega^2x^2 (n = 0,1,2,\cdots)$. For the state vector $|\varphi(x,t=0)\rangle = \frac{1}{\sqrt{3}}|1\rangle + \sqrt{\frac{2}{3}}|2\rangle$, $\langle\hat{x}(t)\rangle$ is

1. $\frac{2\sqrt{2}}{3}\sqrt{\frac{\hbar}{2m\omega}}\cos\omega t$
2. $\frac{4}{3}\sqrt{\frac{\hbar}{2m\omega}}\cos\omega t$
3. $\frac{2\sqrt{2}}{3}\sqrt{\frac{\hbar}{2m\omega}}\cos2\omega t$
4. $\frac{4}{3}\sqrt{\frac{\hbar}{2m\omega}}\cos2\omega t$

Q153. [June 2025] . 5.0 marks
Quantum Mechanics > Pertubation theory

CSIR NET	2025 June	5M	QM

The ground state wavefunction for the hydrogen atom is $\psi_0 = \sqrt{\frac{1}{\pi a_0^3}}\, e^{-\frac{r}{a_0}}$, where a_0 is the Bohr radius. Considering an additional potential H' as a perturbation to the hydrogen atom Hamiltonian, given by

$$H' = \begin{cases} \frac{e^2}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{1}{R}\right] & \text{for } 0 < r < R, \\ 0 & \text{for } r > R \end{cases}$$

where R is the radius of the proton, $R \ll a_0$. The shift in the ground state energy due to H' is

1. $\left(\frac{e^2}{4\pi\varepsilon_0 a_0}\right)\frac{4R^2}{3a_0^2}$
2. $\left(\frac{e^2}{4\pi\varepsilon_0 a_0}\right)\frac{R}{a_0}$
3. $-\left(\frac{e^2}{4\pi\varepsilon_0 a_0}\right)\frac{2R^2}{a_0^2}$
4. $\left(\frac{e^2}{4\pi\varepsilon_0 a_0}\right)\frac{2R^2}{3a_0^2}$

Q154. [June 2025] . 5.0 marks
Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2025 June	5M	QM

The probability density of a free particle of mass m at time $t = 0$, is given by $A\exp\left(-\frac{x^2}{2\sigma^2(0)}\right)$. At $t > 0$, its probability density is proportional to $\exp\left(-\frac{x^2}{2\sigma^2(t)}\right)$, where $\sigma^2(t)$ is

1. $\sigma^2(0) + \frac{\hbar^2 t^2}{\sigma^2(0) m^2}$
2. $\sigma^2(0) + \frac{\hbar^2 t^2}{4\sigma^2(0) m^2}$
3. $\sigma^2(0) + \frac{4\hbar^2 t^2}{\sigma^2(0) m^2}$
4. $\sigma^2(0) + \frac{2\hbar^2 t^2}{\sigma^2(0) m^2}$

Answer Key

154 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	Quantum Mechanics	Scattering theory	**3**
Q2	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q3	Quantum Mechanics	Variational Principle	**4**
Q4	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**2**
Q5	Quantum Mechanics	Spin Angular momentum	**1**
Q6	Quantum Mechanics	Pertubation theory	**4**
Q7	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q8	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q9	Quantum Mechanics	Variational Principle	**1**
Q10	Quantum Mechanics	Potential Well	**1**
Q11	Quantum Mechanics	Basic Quantum Mechanics	**3**
Q12	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**2**
Q13	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q14	Quantum Mechanics	Scattering theory	**4**
Q15	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q16	Quantum Mechanics	Scattering theory	**1**
Q17	Quantum Mechanics	Basic Quantum Mechanics	**3**
Q18	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q19	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q20	Quantum Mechanics	Quantum Harmonic Oscillator	**4**
Q21	Quantum Mechanics	Scattering theory	**1**
Q22	Quantum Mechanics	Dirac delta potential	**1**
Q23	Quantum Mechanics	KG and Dirac equation	**1**
Q24	Quantum Mechanics	Pertubation theory	**1**
Q25	Quantum Mechanics	Potential Well	**1**
Q26	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q27	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q28	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q29	Quantum Mechanics	Pertubation theory	**4**
Q30	Quantum Mechanics	WKB Approximation	**2**
Q31	Quantum Mechanics	Dirac delta potential	**3**
Q32	Quantum Mechanics	Variational Principle	**4**
Q33	Quantum Mechanics	Basic Quantum Mechanics	**4**
Q34	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q35	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q36	Quantum Mechanics	Basic Quantum Mechanics	**3**
Q37	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q38	Quantum Mechanics	Scattering theory	**2**
Q39	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q40	Quantum Mechanics	Pertubation theory	**None**

Answer Key (cont.)

Q. No	Subject	Topic	Answer
Q41	Quantum Mechanics	WKB Approximation	**2**
Q42	Quantum Mechanics	Quantum Harmonic Oscillator	**2**
Q43	Quantum Mechanics	Potential Well	**1**
Q44	Quantum Mechanics	Pertubation theory	**None**
Q45	Quantum Mechanics	Scattering theory	**3**
Q46	Quantum Mechanics	Pertubation theory	**2**
Q47	Quantum Mechanics	Variational Principle	**2**
Q48	Quantum Mechanics	Pertubation theory	**1**
Q49	Quantum Mechanics	Quantum Harmonic Oscillator	**2**
Q50	Quantum Mechanics	Quantum Harmonic Oscillator	**3**
Q51	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q52	Quantum Mechanics	Potential Well	**2**
Q53	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q54	Quantum Mechanics	WKB Approximation	**2**
Q55	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**2**
Q56	Quantum Mechanics	Spin Angular momentum	**4**
Q57	Quantum Mechanics	Potential Well	**3**
Q58	Quantum Mechanics	Spin Angular momentum	**4**
Q59	Quantum Mechanics	Spin Angular momentum	**3**
Q60	Quantum Mechanics	Pertubation theory	**3**
Q61	Quantum Mechanics	WKB Approximation	**1**
Q62	Quantum Mechanics	Scattering theory	**3**
Q63	Quantum Mechanics	Basic Quantum Mechanics	**4**
Q64	Quantum Mechanics	Spin Angular momentum	**1**
Q65	Quantum Mechanics	Basic Quantum Mechanics	**3**
Q66	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q67	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**3**
Q68	Quantum Mechanics	Basic Quantum Mechanics	**3**
Q69	Quantum Mechanics	Basic Quantum Mechanics	**3**
Q70	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q71	Quantum Mechanics	Pertubation theory	**4**
Q72	Quantum Mechanics	Potential Well	**1**
Q73	Quantum Mechanics	Potential Well	**1**
Q74	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q75	Quantum Mechanics	Potential Well	**3**
Q76	Quantum Mechanics	WKB Approximation	**4**
Q77	Quantum Mechanics	Scattering theory	**3**
Q78	Quantum Mechanics	Pertubation theory	**1**
Q79	Quantum Mechanics	Scattering theory	**4**
Q80	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q81	Quantum Mechanics	Basic Quantum Mechanics	**2**

Answer Key (cont.)

Q. No	Subject	Topic	Answer
Q82	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q83	Quantum Mechanics	Scattering theory	**3**
Q84	Quantum Mechanics	Basic Quantum Mechanics	**4**
Q85	Quantum Mechanics	Pertubation theory	**1**
Q86	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**2**
Q87	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**3**
Q88	Quantum Mechanics	Scattering theory	**1**
Q89	Quantum Mechanics	Pertubation theory	**2**
Q90	Quantum Mechanics	Pertubation theory	**4**
Q91	Quantum Mechanics	Potential Well	**1**
Q92	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q93	Quantum Mechanics	Potential Well	**1**
Q94	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**3**
Q95	Quantum Mechanics	Pertubation theory	**4**
Q96	Quantum Mechanics	Pertubation theory	**3**
Q97	Quantum Mechanics	Scattering theory	**3**
Q98	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q99	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q100	Quantum Mechanics	Basic Quantum Mechanics	**3**
Q101	Quantum Mechanics	Basic Quantum Mechanics	**4**
Q102	Quantum Mechanics	Spin Angular momentum	**1**
Q103	Quantum Mechanics	Pertubation theory	**4**
Q104	Quantum Mechanics	Pertubation theory	**2**
Q105	Quantum Mechanics	Potential Well	**3**
Q106	Quantum Mechanics	Spin Angular momentum	**4**
Q107	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**2**
Q108	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q109	Quantum Mechanics	Spin Angular momentum	**2**
Q110	Quantum Mechanics	Scattering theory	**1**
Q111	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q112	Quantum Mechanics	Dirac delta potential	**3**
Q113	Quantum Mechanics	Pertubation theory	**2**
Q114	Quantum Mechanics	Quantum Harmonic Oscillator	**4**
Q115	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q116	Quantum Mechanics	Pertubation theory	**3**
Q117	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q118	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q119	Quantum Mechanics	Two particle System	**3**
Q120	Quantum Mechanics	Scattering theory	**2**
Q121	Quantum Mechanics	Pertubation theory	**4**
Q122	Quantum Mechanics	Pertubation theory	**2**

Answer Key (cont.)

Q. No	Subject	Topic	Answer
Q123	Quantum Mechanics	Potential Well	**4**
Q124	Quantum Mechanics	Spin Angular momentum	**3**
Q125	Quantum Mechanics	Potential Well	**3**
Q126	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q127	Quantum Mechanics	Spin Angular momentum	**4**
Q128	Quantum Mechanics	Dirac delta potential	**3**
Q129	Quantum Mechanics	Dirac delta potential	**2**
Q130	Quantum Mechanics	Quantum Harmonic Oscillator	**4**
Q131	Quantum Mechanics	Quantum Harmonic Oscillator	**3**
Q132	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q133	Quantum Mechanics	Spin Angular momentum	**2**
Q134	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q135	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q136	Quantum Mechanics	Variational Principle	**4**
Q137	Quantum Mechanics	WKB Approximation	**2**
Q138	Quantum Mechanics	Dirac delta potential	**2**
Q139	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q140	Quantum Mechanics	Two particle System	**3**
Q141	Quantum Mechanics	Quantum Harmonic Oscillator	**4**
Q142	Quantum Mechanics	Spin Angular momentum	**3**
Q143	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q144	Quantum Mechanics	Basic Quantum Mechanics	**1**
Q145	Quantum Mechanics	Pertubation theory	**2**
Q146	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**4**
Q147	Quantum Mechanics	Quantum Harmonic Oscillator	**4**
Q148	Quantum Mechanics	Two particle System	**1**
Q149	Quantum Mechanics	Spin Angular momentum	**1**
Q150	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q151	Quantum Mechanics	Basic Quantum Mechanics	**4**
Q152	Quantum Mechanics	Quantum Harmonic Oscillator	**2**
Q153	Quantum Mechanics	Pertubation theory	**4**
Q154	Quantum Mechanics	Basic Quantum Mechanics	**2**