PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

Pertubation theory - CSIR NET Physics PYQs

Quantum Mechanics . All PYQs (2015-2025) with answer key

23 questions . Answer key included

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Q1. [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. $\frac{-\epsilon}{4}$

Q2. [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. $\frac{1}{(\omega\tau)^2}$

Q3. [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. $g\exp\left(-\frac{k^2\hbar}{4m\omega}\right)$

Q4. [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

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

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. $0.33V_0$

Q5. [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

Q6. [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. $\sqrt{2}ba_0^2$

Q7. [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 $|210\rangle \rightarrow |100\rangle$ and $|310\rangle \rightarrow |100\rangle$. 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. $\left(\frac{3}{2}\right)^3$

Q8. [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

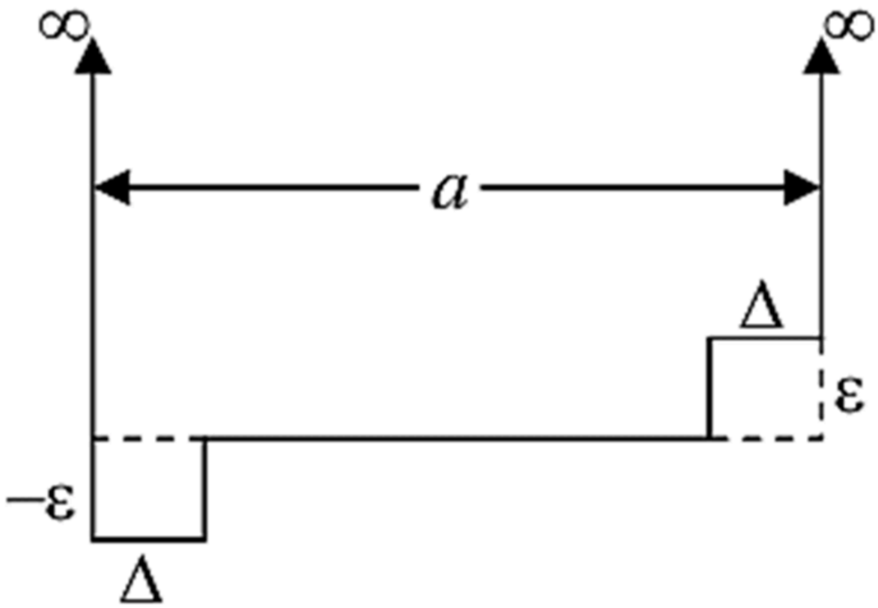
1. $\frac{a}{R^2}$
2. $\frac{2a}{R^2}$
3. $\frac{a}{2R^2}$
4. $\frac{a}{(\pi R^2)}$

Q9. [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

Q10. [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?

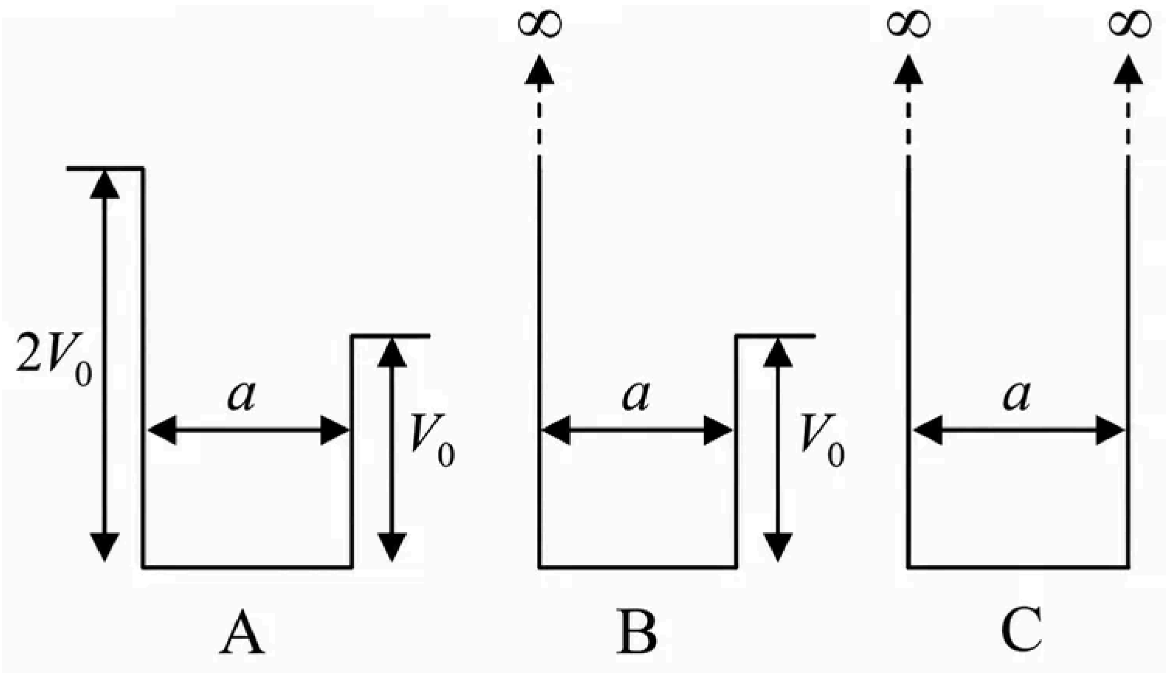
1. 5
2. 4
3. 2
4. 1

Q11. [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. $E_B > E_A > E_C$

Q12. [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 $2 \in/a$

Q13. [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

Q14. [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. $e^{-1/2}$

Q15. [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. $\alpha^2 t^2/200$

Q16. [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. $\frac{8\lambda^2}{9m\hbar\omega^3}$

Q17. [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. $\frac{21}{32}\hbar\omega$

Q18. [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. $\frac{\lambda^2}{16J^2} \sin^2 \frac{JT}{\hbar}$

Q19. [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. $\frac{4\epsilon}{\pi}$

Q20. [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 $B_1\hat{i} + B_2(\hat{j}\cos\omega t + \hat{k}\sin\omega t)$, 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. $2\mu_B|B_1|$

Q21. [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

Q22. [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. $-q\pi E_0$

Q23. [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. $\left(\frac{e^2}{4\pi\varepsilon_0 a_0}\right)\frac{2R^2}{3a_0^2}$

Answer Key

23 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	Quantum Mechanics	Pertubation theory	**4**
Q2	Quantum Mechanics	Pertubation theory	**1**
Q3	Quantum Mechanics	Pertubation theory	**4**
Q4	Quantum Mechanics	Pertubation theory	**None**
Q5	Quantum Mechanics	Pertubation theory	**None**
Q6	Quantum Mechanics	Pertubation theory	**2**
Q7	Quantum Mechanics	Pertubation theory	**1**
Q8	Quantum Mechanics	Pertubation theory	**3**
Q9	Quantum Mechanics	Pertubation theory	**4**
Q10	Quantum Mechanics	Pertubation theory	**1**
Q11	Quantum Mechanics	Pertubation theory	**1**
Q12	Quantum Mechanics	Pertubation theory	**2**
Q13	Quantum Mechanics	Pertubation theory	**4**
Q14	Quantum Mechanics	Pertubation theory	**4**
Q15	Quantum Mechanics	Pertubation theory	**3**
Q16	Quantum Mechanics	Pertubation theory	**4**
Q17	Quantum Mechanics	Pertubation theory	**2**
Q18	Quantum Mechanics	Pertubation theory	**2**
Q19	Quantum Mechanics	Pertubation theory	**3**
Q20	Quantum Mechanics	Pertubation theory	**4**
Q21	Quantum Mechanics	Pertubation theory	**2**
Q22	Quantum Mechanics	Pertubation theory	**2**
Q23	Quantum Mechanics	Pertubation theory	**4**

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