03

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Q.1) Quantum mechanics is the branch of physics where we studied about to tiny particle which deals with the wave mechanices.

Postulates:-

(i) ~~It~~ must be differential

(ii) ~~It~~ must be continus

(iii) ~~It~~ must be normalized

(iv) It must have a Singled value

(v) It must flow the norlized ~~Contural~~ condition from all space.

(vi) It must have $|\psi|^2$

(vii) the State of System must be defind by $\psi$

(viii) The probality of finding the particle is given by $|\psi|^2$

(ix) The probality of finding any particle is positive so wave function is given as $|\psi|^2$

(x) It must be Squre Integral.

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(b) $|\psi_0\rangle = \frac{1}{\sqrt{2}}|\phi_1\rangle + \frac{i}{2}|\phi_2\rangle + \frac{1}{2}|\phi_3\rangle$ .... (Given

$|\psi_1\rangle = \frac{1}{\sqrt{3}}|\phi_1\rangle + \frac{i}{\sqrt{3}}|\phi_3\rangle$ ..... (Given)

Soln:-

$|\psi_0\rangle = \frac{1}{\sqrt{2}}|\phi_1\rangle + \frac{i}{2}|\phi_2\rangle + \frac{1}{2}|\phi_3\rangle$ — (i)

$\langle\psi_0| = \frac{1}{\sqrt{2}}|\phi_1\rangle + -\frac{i}{2}|\phi_2\rangle + \frac{1}{2}|\phi_3\rangle$ — (ii)

for normalise $\langle\psi_0|\psi_0\rangle = 1$

$\therefore \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{2}} - \frac{i}{2} \times \frac{i}{2} + \frac{1}{2} \times \frac{1}{2}$

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$= \frac{1}{2} + \frac{1}{4} + \frac{1}{4}$

$= \frac{1}{2} + \frac{2}{4}$

$= \frac{1}{2} + \frac{1}{2}$

$= 1$

Hence $|\psi_0\rangle$ is normalised

Now;

$|\psi_1\rangle = \frac{1}{\sqrt{3}}|\phi_1\rangle + \frac{i}{\sqrt{3}}|\phi_3\rangle$ ... (from Given) — (i)

$\langle\psi_1| = \frac{1}{\sqrt{3}}|\phi_1\rangle + -\frac{i}{\sqrt{3}}|\phi_3\rangle$ — (ii)

$\therefore$ Now: for normalised condition

$\langle\psi_1|\psi_1\rangle = 1$

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$$\therefore \frac{1}{\sqrt{3}} \times \frac{1}{\sqrt{3}} - \frac{i}{\sqrt{3}} \times \frac{i}{\sqrt{3}}$$

$$\therefore \frac{1}{3} + \frac{1}{3}$$

$$\therefore \frac{2}{3} \neq 1$$

$\therefore |\psi_1\rangle$ is not normalised

Here; $\langle \psi_0| = \frac{1}{\sqrt{2}} |\phi_1\rangle - \frac{i}{2} |\phi_2\rangle + \frac{1}{2}|\phi_3\rangle$ and ... (from 1)

$$|\psi_1\rangle = \frac{1}{\sqrt{3}} |\phi_1\rangle + \frac{i}{\sqrt{3}} |\phi_3\rangle \quad \text{... (from Given)}$$

$$\therefore \langle \psi_0|\psi_1\rangle = \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{3}} - \frac{i}{2} + \frac{i}{\sqrt{3}} \times \frac{1}{2}$$

$$= \frac{1}{\sqrt{6}} - \frac{i}{2} + \frac{i}{2\sqrt{3}}$$

$$= \frac{1}{\sqrt{6}} - i\left(\frac{1}{2} - \frac{1}{2\sqrt{3}}\right)$$

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$$\boxed{\langle \psi_0|\psi_1\rangle = \frac{1}{\sqrt{6}} - i\left(\frac{\sqrt{3}-1}{2\sqrt{3}}\right)}$$

and

$\langle \psi_1| = \frac{1}{\sqrt{3}} |\phi_1\rangle - \frac{i}{\sqrt{3}} |\phi_3\rangle \qquad |\psi_0\rangle = \frac{1}{\sqrt{2}} |\phi_1\rangle + \frac{i}{2} |\phi_2\rangle + \frac{1}{2}|\phi_3\rangle$

$$\therefore \langle \psi_1|\psi_0\rangle = \frac{1}{\sqrt{6}} + \frac{i}{2} - \frac{i}{2\sqrt{3}}$$

$$= \frac{1}{\sqrt{6}} + i\left(\frac{1}{2} - \frac{1}{2\sqrt{3}}\right)$$

$$\boxed{\langle \psi_1|\psi_0\rangle = \frac{1}{\sqrt{6}} + i\left(\frac{\sqrt{3}-1}{2\sqrt{3}}\right)}$$

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(3) $V(x) = \infty \quad x < 0 \text{ and } x > a$

$= -V_0 \quad 0 < x < \frac{a}{2}$

Solution:-

Here $\psi(x) = \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right)$

Now 1st order correction is given as

$\cancel{E_n^{(1)} = \langle \psi_n^{(0)} | H' | \psi_n^{(0)} \rangle}$

$$E_n^{(1)} = \int_{-\infty}^{\infty} \psi_n^{*(0)} H' \psi_n^{(0)} \, dx$$

$$= \int_0^a \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right) \times (-V_0) \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right) dx$$

$$= \frac{2}{a}(-V_0) \int_0^a \sin^2\left(\frac{n\pi x}{a}\right) dx$$

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$$= \frac{2}{a}(-V_0) \int_0^a \frac{1 - \cos\left(\frac{2n\pi x}{a}\right)}{2} dx$$

$$= -\frac{V_0}{a} \int_0^a 1 - \cos\left(\frac{2n\pi x}{a}\right) dx$$

$$= -\frac{V_0}{a} \left[ \int_0^a 1 \, dx - \int_0^a \cos\left(\frac{2n\pi x}{a}\right) dx \right]$$

$$= -\frac{V_0}{a} \left[ x \right]_0^a - \left[ \sin\left(\frac{2n\pi x}{a}\right) \times \frac{a}{2n\pi} \right]_0^a$$

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$$\therefore -\frac{V_0}{a}\left[x\right]_0^a - \left[\sin\left(\frac{2n\pi a}{a}\right)\times\frac{a}{2n\pi} - \sin(0)\times\frac{a}{2n\pi}\right]$$

$$\therefore -\frac{V_0}{a}\left[a-0\right] - 0$$

$$= -\frac{V_0}{a}(a)$$

$$= -V_0$$

$$\therefore \boxed{E_n^{(1)} = -V_0}$$

(c) Soln:

$$H_0 = \begin{bmatrix} E_0+E & 0 \\ 0 & E_0-E \end{bmatrix} \quad \text{and} \quad H' = \begin{bmatrix} 0 & A \\ A & 0 \end{bmatrix}$$

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Soln:

here $|H' - E^n I| = 0$

$$\therefore \left| \begin{bmatrix} 0 & A \\ A & 0 \end{bmatrix} - E_n^{(1)} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right| = 0$$

$$\therefore \left| \begin{bmatrix} 0 & A \\ A & 0 \end{bmatrix} - \begin{bmatrix} E_n^{(1)} & 0 \\ 0 & E_n^{(1)} \end{bmatrix} \right| = 0$$

$$\therefore \begin{vmatrix} -E_n^{(1)} & A \\ A & -E_n^{(1)} \end{vmatrix} = 0$$

$$\therefore (E_n^{(1)})^2 - A^2 = 0$$

$$\therefore (E_n^{(1)})^2 = A^2$$

$$\therefore \boxed{E_n^{(1)} = \pm A}$$

1st Order Correction of Energy

For 2nd Order

$$E_n^{(2)} = \frac{\langle \psi_{n}^{(1)} | H' | \psi_{m}^{0} \rangle}{E_n^{(1)} - E_m^{(2)}}$$

$$E_n^{(2)} = \frac{A^2}{2\lambda}$$

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(5)

(a) It is an mathematical term used as the notation in the Quantum mechanics as the wave function such that

$$\delta(x) = 0 \quad \{x \neq 0$$
$$= \infty \quad \{x = \infty\}$$

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on changing the scale

$$\delta(x - x_0) = 0 \quad \{x \neq x_0$$
$$= \infty \quad x = 0\}$$

Here $\delta(x)\,\delta(x-x_0) = 1$

Properties

(i) $\int_{-\infty}^{\infty} \delta(x)\,\delta(x-x_0) = 1$

(ii) $\int_{-\infty}^{\infty} \delta(x)\,\delta(x-x_0) = f(x_0)$

(i) $\int_{-\infty}^{\infty} f(x)\,\delta(x-c) = f(c)$

as c lies between a and b

(ii) $\int_{-\infty}^{\infty} f(x)\,\delta(x-c) = 0$

as c does not lies in between a and b

(iii) $\delta(ax) = \frac{1}{|a|}\delta(x)$

(iv) $\delta(-x) = \delta(x)$

(v) $\frac{d}{dx} f(x) = \delta(x)$

(vi) $x \cdot \delta(x) = 0$

(vii) $\delta(a-x)\,\delta(x-b) = \delta(a-b)$

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| | (viii) | $\delta(a-b) = \delta(b-a)$ |
| | (ix) | $\int_{-\infty}^{\infty} \delta(x) = 1$ |
| | (x) | $\int_{-\infty}^{\infty} f(x)\,\delta(x) = 1$ |
| | (c) | Soln: |

$$\hat{x} = \left(\frac{\hbar}{2m\omega}\right)^{1/2} (a + a^{+})$$

External perturbation $H' = bx$

Now,

1st order correction to the Energy of the Oscillator is given as

$$E_n^{(1)} = \langle \psi_n^{(0)} | H' | \psi_n^{(0)} \rangle$$

$$= \langle \psi_n^{(0)} | b\hat{x} | \psi_n^{(0)} \rangle \quad (a+a^{+})$$

$$= \langle \psi_n^{(0)} | \left(\frac{\hbar}{2m\omega}\right)^{1/2} b_x | \psi_n^{(0)} \rangle$$

$$= \left(\frac{\hbar}{2m\omega}\right)^{1/2} b \langle \psi_n^{(0)} | (a + a^{+}) | \psi_n^{(0)} \rangle$$

$$= \left(\frac{\hbar}{2m\omega}\right)^{1/2} b \langle \psi_n^{(0)} | (a + a^{+}) | \psi_n^{(0)} \rangle$$

$E_n^{(1)} = 0$ //

as $|a + a^{+}| = 0$

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| Question | Marks | Time | Evaluator |
|---|---|---|---|
| Q1 | 0 | 11/28/2025, 5:35:26 PM | jwerry@gmail.com |
| Q1 | 10 | 11/28/2025, 5:35:30 PM | jwerry@gmail.com |
| Q2 | 10 | 11/28/2025, 5:35:35 PM | jwerry@gmail.com |
| Q3 | 10 | 11/28/2025, 5:35:41 PM | jwerry@gmail.com |
| Q4 | 10 | 11/28/2025, 5:35:50 PM | jwerry@gmail.com |
| Q5 | 10 | 11/28/2025, 5:35:55 PM | jwerry@gmail.com |
| Q6 | 10 | 11/28/2025, 5:36:00 PM | jwerry@gmail.com |
| Q10 | 10 | 11/28/2025, 5:36:25 PM | jwerry@gmail.com |
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**Total Marks: 90**