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Quantum - Physics - Assignment

Q2: Consider an infinite potential well with a width $L = 10nm$ is located in the region $0 < z < L$. Suppose an electron in that infinite potential well is described by wavefunction.

$\phi(z) = Az^2(L-z)$ for $0 < z < L$.

Calculate the expectation value of energy?

A2. Given particle infinite potential well find out energy eigen value of the given system

Consider an infinite potential well with a width $L = 10nm$ is located in the region $0 < z < L$

the wave function

$\phi(z) = Az^2(L-z)$ for $(0 < z < L)$

so normalisation condition,

$$\langle \phi | \phi \rangle = 1$$

$$\int_0^L A^2 z^4 (L-z)^2 dz = 1$$

$$A^2 \int_0^L z^4 (L^2 - 2Lz + z^2) dz = 1$$

$$A^2 \left[L^2 \frac{L^5}{5} - \frac{2Lz^6}{6} + \frac{z^7}{7} \right]_0^L = 1$$

$$A^2 \left[\frac{1}{5} - \frac{1}{3} + \frac{1}{7} \right] L^7 = 1$$

$$A^2 \left[\frac{21 - 35 + 15}{105} \right] L^7 = 1$$

$$A^2 \left[\frac{1}{105} \right] L^7 = 1$$

$$A = \left(\frac{105}{L^7} \right)^{1/2}$$

· The energy expectation value

$$\langle E \rangle = \frac{\langle p^2 \rangle}{2m}$$

$\hat{p}^2 |\phi\rangle = \hbar^2 A [2L -$

$$\hat{p}|\phi\rangle = -i\hbar A \frac{d}{dz}\left(z^2(L-z)\right)$$

$$= -i\hbar A \left[2zL - 3z^2\right]$$

$$\hat{p}^2|\phi\rangle = -\hbar^2 A \left[2L - 6z\right]$$

$$\langle\phi|\hat{p}^2|\phi\rangle = \int_0^L \hbar^2 \left(\frac{105}{L^7}\right) 2z^2(z-L)(L-3z)\,dz$$

$$= \frac{105\hbar^2}{L^7}\int_0^L 2\,(z^3 - Lz^2)(L-3z)\,dz$$

$$= \frac{210\hbar^2}{L^7}\int_0^L \left[z^3L - 3z^4 - L^2z^2 + 3z^3L\right]dz$$

$$= \frac{210\hbar^2}{L^7}\left[\frac{Lz^4}{4} - \frac{3z^5}{5} - \frac{L^2z^3}{3} + \frac{3Lz^4}{4}\right]_0^L$$

$$= \frac{210\hbar^2}{L^7}\left[\frac{1}{4} - \frac{3}{5} - \frac{1}{3} + \frac{3}{4}\right]L^5$$

$$= \frac{210\hbar^2}{L^2}\left(15 - 36 - 20 + 45\right)L^0$$

$$= \frac{210\hbar^2}{L^2}(4) = \frac{840\hbar^2}{L^2}$$

$$\langle E \rangle = \frac{\langle p^2 \rangle}{2m} = \frac{640\hbar^2}{2mL^2}$$

$$\langle E \rangle = \frac{640 \times (6.58 \times 10^{-16})^2}{2 \times (10 \times 10^{-9})^2 \times 0.511 \times 10^6}$$

$$\langle E \rangle = \frac{355.86 \times 10^{-32}}{10^{-16} \times 10^6}$$

$$= 355.86 \times 10^{-20}\ eV$$

$$\langle E \rangle = 355.86 \times 10^{-20}\ eV$$

Q3. What is stark Effect? Explain in detail.

A3. The stark effect is the splitting of spectral lines of atoms and molecules when they are placed in an electric field. The effect is named after the German physicist Johannes Stark, who discovered it in 1913.

The stark effect, a consequence of the interplay between an external electr field and the electric dipole moment inherent in atoms or molecules, plays a pivotal role in deciphering their structural intricacies. This phenomenon manifests as the splitting of spectral lines particularly in the realm of hydrogen atom transitions.

In the quantum mechanical realm, where energy levels are quantized, the imposition of an electric field prompts a mingling of these discrete energy states, resulting in their division into two or more components. The magnitude of this division hinges on the strength of the electric field and the spatial orientation of the atom or molecule concerning this field.

Practical Application :—

1. Spectroscopy and Quantum Chemistry !
It is ~~used~~ extensively used in

spectroscopy to study the structural details of atoms and molecules. It allows scientists to discern the finer nuances of energy states and their interactio

2. Atomic Physics
In the realm of atomic physics, the stark effect aids in ~~determing~~ determining energy levels, contributing crucial data to the understanding of atomic structure

3. Technological advancements
Application:- laser technology leverages the Stark effect for precise frequency control. By manipulating the electric field, Scientists can modulate the frequency of laser lights, enabling applications in diverse fields such as communications and medical diagnostics.

Examples:- Hydrogen Atom's Ha line:-

- observation:- The Ha line, a distinctive red spectral line emitted when hydrogen atoms transition from the third to the second energy level. undergoes splitting in the presence of an electric field.

• Application :- This stark effect example allows researchers to study the impact of external fields on specific atomic transitions, Providing insights into the quantum behavior of hydrog atoms.