CL8_Q1. The Uncertainty principle is not significant in the case of macro-bodies. Justify.

Answer

The Heisenberg's Principle is of no practical importance for heavy bodies where the de Broglie wavelength is negligibly small.

For example, let us take the case of a cricket ball of mass 0.5kg in flight. The indeterminacy in the position of the ball is, say, 1 mm. We can determine the indeterminacy of the velocity of the ball from the uncertainty principle.

$$\Delta p.\,\Delta \mathrm{x} \approx \frac{h}{4\pi}$$

$$\mathrm{m}\Delta v.\,\Delta \mathrm{x} \approx \frac{h}{4\pi}$$

$$\Delta v \approx \frac{h}{4\pi m \Delta \mathrm{x}} = \frac{6.62 \times 10^{-34}}{4 \times 3.142 \times 0.5 \times 10^{-3}} = 1.05 \times 10^{-31} m/s$$

The above inaccuracy is negligible and not detectable. It implies that the uncertainties are of no importance in the case of macro bodies; and the position and velocity of a macro body can be simultaneously determined with a high degree of accuracy. As a result, the macroscopic body follows a well-defined trajectory.

CL8_Q2. Monochromatic light passes through a shutter that opens for a time $\Delta t=10^{-10}$ s. What is the spread in the frequency caused by the shutter?

Answer

We know that the statement of Heisenberg's Uncertainty Principle $\Delta E.\,\Delta t \geq \frac{h}{4\pi}$

$$\mathrm{h}\Delta \nu.\,\Delta t \geq \frac{h}{4\pi}$$

$$\Delta \nu = \frac{1}{\Delta t\ 4\pi}$$

$$\Delta \nu = \frac{1}{10^{-10}\ 4\pi}$$

$$\Delta \nu = 0.079 \times 10^{10}\mathrm{Hz}$$

CL8_Q3. An electron and a 150 gm baseball are travelling at a velocity of 220 m/s, measured to an accuracy of 0.065%. Calculate and compare the uncertainty in position of each.

Answer

The uncertainty in the velocity is $\Delta v = v \times 0.065\% = 220 \times \frac{0.065}{100} = 0.143\ m/s$

The uncertainty in the position of an electron is,

$$\Delta x_e \approx \frac{h}{4\pi \mathrm{m} \Delta v} = \frac{6.62 \times 10^{-34}}{4 \times 3.142 \times 9.1 \times 10^{-31} \times 0.143} = 0.4mm$$

The uncertainty in the position of baseball is,

$$\Delta x_b \approx \frac{h}{4\pi \mathrm{m} \Delta v} = \frac{6.62 \times 10^{-34}}{4 \times 3.142 \times 0.15 \times 0.143} = 2.5 \times 10^{-33} m$$

CL8_Q4. What are the implications of Uncertainty Principle?

Answer

The uncertainty Principle points out that in the microscopic world,

1. The dynamical variables of a particle are combined in sets of simultaneously determined quantities which are known as complete sets of quantities
2. The coordinates and momentum components of a particle etc. are pairs of concepts which are interrelated and fall in different complete sets of quantities. They cannot be defined simultaneously in a precise way.

Thus, the uncertainty principle implies that we can never define the path of an atomic particle with the absolute precision indicated in classical mechanics. Therefore, concepts such as velocity, position, and acceleration are of limited used in the quantum world. To describe the quantum particle the concept of energy becomes important since it is related to the state of the system rather than to its path.