# Heisenberg's Uncertainity Principle (solution)

**1. The uncertainty in position of electron and helium atom are same. If uncertainty in momentum for the electron is $3.2 \times 10^6$ (same units), then the uncertainty in momentum of the helium atom will be —**

**Explanation (simple words):** Heisenberg ke hisaab se $\Delta x\, \Delta p \geq \frac{h}{4\pi}$. Jab $\Delta x$ same ho, to minimum $\Delta p$ *same* rehta hai, mass par depend nahi karta.

**Approach:** Equal $\Delta x \Rightarrow$ equal minimum $\Delta p$.

**Answer:** $\boxed{\boxed{3.2 \times 10^6} (same units as given)}$.

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**2. Calculate uncertainty in position of an electron (mass $9.1 \times 10^{-28}$ g) moving at $3.0 \times 10^4$ cm s$^{-1}$, if the uncertainty in velocity is $0.011\%$. ($h = 6.626 \times 10^{-27}$ erg s)**

**Explanation (simple words):** Pehle $\Delta v$ nikalo, phir $\Delta x = \frac{h}{4\pi m\, \Delta v}$ (cgs units).

**Approach:** $\Delta v = 0.011\% \times 3.0 \times 10^4 = 3.3$ cm s$^{-1}$; $m = 9.1 \times 10^{-28}$ g.

**Steps:**

$$\Delta x = \frac{6.626 \times 10^{-27}}{4\pi\,(9.1 \times 10^{-28})\,(3.3)} = \boxed{1.76 \times 10^{-1}\,\text{cm}} \approx \boxed{0.175\,\text{cm}}$$

**Why this formula?** $\Delta x\, \Delta p = \frac{h}{4\pi}$ and $\Delta p = m\, \Delta v$.

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**3. Heisenberg's uncertainty principle is *not significant* for — (i) motor car, (ii) stationary particle**

**Explanation (simple words):** Macroscopic bodies (motor car) ke liye effect itna chhota hota hai ki practically negligible hai. Completely stationary particle ki exact position-momentum ek saath define karna physically meaningful nahi.

**Answer:** $\boxed{\boxed{(i)\ \&\ (ii)\ \text{both}}}$.

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**4. What should be the momentum of a particle if its de Broglie wavelength is $1\,\text{Å}$? ($h = 6.6252 \times 10^{-27}$ erg s)**

**Explanation (simple words):** de Broglie: $\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda}$.

**Steps:**

$$\lambda = 1\,\text{Å} = 10^{-8}\,\text{cm}, \quad p = \frac{6.6252 \times 10^{-27}}{10^{-8}} = \boxed{6.6252 \times 10^{-19}\,\text{g cm s}^{-1}}$$

**Why this formula?** Matter waves relation directly links momentum and wavelength. .

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**5. Mass of a sodium photon of wavelength $5894\,\text{Å}$ ($c = 3 \times 10^8$ m s$^{-1}$, $h = 6.6252 \times 10^{-34}$ J s) is —**

**Explanation (simple words):** Photon rest mass zero hota hai, but *relativistic mass equivalent*

$m = E/c^2 = \dfrac{h}{\lambda c}$ nikal sakte hain.
**Steps:**

$$\lambda = 5.894 \times 10^{-7}\,\text{m},\ m = \frac{6.6252 \times 10^{-34}}{(5.894 \times 10^{-7})(3 \times 10^{8})} = \boxed{3.75 \times 10^{-36}\,\text{kg}}$$

**Why this formula?** $E = hc/\lambda$ and $E = mc^2$.

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**6. Uncertainty in position of a $0.25\,\text{g}$ particle is $10^{-5}$ m. Find the uncertainty in its velocity. ($h = 6.6 \times 10^{-34}$ J s)**
**Explanation (simple words):** Macroscopic mass ke liye $\Delta v$ bahut chhota aata hai.
**Approach:** $\Delta v = \dfrac{h}{4\pi m\,\Delta x}$ with $m = 2.5 \times 10^{-4}$ kg, $\Delta x = 10^{-5}$ m.
**Steps:**

$$\Delta v = \frac{6.6 \times 10^{-34}}{4\pi\,(2.5 \times 10^{-4})(10^{-5})} = \boxed{2.1 \times 10^{-26}\,\text{m s}^{-1}}$$

**Why this formula?** $\Delta p = m\Delta v$ and $\Delta x\,\Delta p = \dfrac{h}{4\pi}$.

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**7. The position of both an electron and a helium atom is known within $1.0\,\text{nm}$. If the momentum of the electron is known within $5.0 \times 10^{-26}$ kg m s$^{-1}$, what is the *minimum* uncertainty in the momentum of the helium atom?**
**Explanation (simple words):** Minimum $\Delta p$ sirf $\Delta x$ par depend karta hai: $\Delta p_{\text{min}} = \dfrac{h}{4\pi\,\Delta x}$.
**Steps:**

$$\Delta x = 1.0 \times 10^{-9}\,\text{m}, \quad \Delta p_{\text{min}} = \frac{6.626 \times 10^{-34}}{4\pi \times 10^{-9}} = \boxed{5.27 \times 10^{-26}\,\text{kg m s}^{-1}}$$

**Why this formula?** Heisenberg bound mass-se independent hota hai (given same $\Delta x$). .

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**8. If the uncertainties in position and momentum are (numerically) equal, then the uncertainty in velocity is —**
**Explanation (simple words):** Diya hai $\Delta x = \Delta p$ (numerically). Also $\Delta x\,\Delta p = \dfrac{h}{4\pi}$ and $\Delta p = m\,\Delta v$.
**Steps:**

$$(\Delta x)^2 = \frac{h}{4\pi} \quad \Rightarrow \quad \Delta x = \sqrt{\frac{h}{4\pi}}$$
$$\Delta v = \frac{\Delta p}{m} = \frac{\Delta x}{m} = \boxed{\frac{1}{m}\sqrt{\frac{h}{4\pi}}}\ \text{(formal result)}$$

**Why this formula?** Equal numerical uncertainties ke assumption se direct relation milta hai; dimensions practically mix units, isliye isko sirf algebraic condition ke roop me dekhein.

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**9. Measurement of electron position gives uncertainty in momentum $\Delta p = 1.0 \times 10^{-18}$ g cm s$^{-1}$. Find the uncertainty in its velocity. ($m_e = 9.0 \times 10^{-28}$ g)**

**Approach:** $\Delta v = \dfrac{\Delta p}{m}$ in cgs.

**Steps:**

$$\Delta v = \frac{1.0 \times 10^{-18}}{9.0 \times 10^{-28}} = 1.11 \times 10^{9}\,\text{cm s}^{-1} \approx \boxed{1.0 \times 10^{9}\,\text{cm s}^{-1}}$$

**Why this formula?** Momentum per unit mass is velocity.

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**10. The uncertainty in momentum of an electron is $1.0 \times 10^{-5}$ kg m s$^{-1}$. The uncertainty in its position is ($h = 6.62 \times 10^{-34}$ J s) —**

**Approach:** $\Delta x = \dfrac{h}{4\pi\,\Delta p}$.

**Steps:**

$$\Delta x = \frac{6.62 \times 10^{-34}}{4\pi \times 10^{-5}} = \boxed{5.27 \times 10^{-30}\,\text{m}}$$

**Why this formula?** Direct Heisenberg bound inversion.

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**11. The uncertainties in velocities of A and B are $0.05$ and $0.02$ m s$^{-1}$. If $m_B = 5m_A$, find $\dfrac{\Delta x_A}{\Delta x_B}$.**

**Approach:** $\Delta x \propto \dfrac{1}{m\,\Delta v}$, so ratio $= \dfrac{m_B \Delta v_B}{m_A \Delta v_A}$.

**Steps:**

$$\frac{\Delta x_A}{\Delta x_B} = \frac{5m_A \times 0.02}{m_A \times 0.05} = \boxed{2}$$

**Why this formula?** Heisenberg bound equality case.

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**12. For an electron, if uncertainty in velocity is $\Delta v$, then uncertainty in position is —**

**Answer:** $\boxed{\boxed{\Delta x = \dfrac{h}{4\pi m_e\,\Delta v}}}$.

**Why this formula?** $\Delta x\,\Delta p = \dfrac{h}{4\pi}$ and $\Delta p = m_e\,\Delta v$.

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**13. An atom has mass $0.02$ kg and uncertainty in velocity $9.218 \times 10^{-6}$ m s$^{-1}$. Find the uncertainty in position. ($h = 6.626 \times 10^{-34}$ J s) [AIEEE 2002]**

**Steps:**

$$\Delta x = \frac{6.626 \times 10^{-34}}{4\pi\,(0.02)(9.218 \times 10^{-6})} = \boxed{2.86 \times 10^{-28}\,\text{m}}$$

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**14. Uncertainty in position of a 25 g particle is $10^{-5}$ m. Hence the uncertainty in its velocity is — ($h = 6.6 \times 10^{-34}$ J s) [AIEEE 2002]**

**Steps:**

$$\Delta v = \frac{6.6 \times 10^{-34}}{4\pi\,(0.025)(10^{-5})} = \boxed{2.1 \times 10^{-28}\,\text{m s}^{-1}}$$

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**15. An electron ($m = 9.1 \times 10^{-31}$ kg) moves with $v = 300$ m s$^{-1}$ accurate to $0.001\%$. Find uncertainty in position. ($h = 6.63 \times 10^{-34}$ J s)**

**Approach:** $\Delta v = 0.001\% \times 300 = 3.0 \times 10^{-3}$ m s$^{-1}$.

**Steps:**

$$\Delta x = \frac{6.63 \times 10^{-34}}{4\pi\,(9.1 \times 10^{-31})(3.0 \times 10^{-3})} = \boxed{1.93 \times 10^{-2}\,\text{m}}$$

x=$\boxed{1.93 \times 10^{-3}\,\text{m}}$.

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**16. In an atom, an electron moves with speed $600$ m s$^{-1}$ with accuracy $0.005\%$. The certainty with which its position can be located is — ($h = 6.6 \times 10^{-34}$ J s)**

**Approach:** $\Delta v = 0.005\% \times 600 = 3.0 \times 10^{-2}$ m s$^{-1}$.

**Steps:**

$$\Delta x = \frac{6.6 \times 10^{-34}}{4\pi\,(9.1 \times 10^{-31})(3.0 \times 10^{-2})} = \boxed{1.92 \times 10^{-3}\,\text{m}}$$

x=$\boxed{9.6 \times 10^{-3}\,\text{m}}$.

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**17. Uncertainty in position of an electron ($m = 9.1 \times 10^{-28}$ g) moving at $3.0 \times 10^{4}$ cm s$^{-1}$ accurate up to $0.001\%$ is — (Use $h/4\pi$ with $h = 6.626 \times 10^{-27}$ erg s)**

**Approach:** cgs calculation: $\Delta v = 0.001\% \times 3.0 \times 10^{4} = 0.3$ cm s$^{-1}$.

**Steps:**

$$\Delta x = \frac{6.626 \times 10^{-27}}{4\pi\,(9.1 \times 10^{-28})\,(0.3)} = \boxed{1.93\,\text{cm}}$$

**Why this formula?** Same Heisenberg formula in cgs units.

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