20 April 2004
Instructor: Dr. A. Mekki

Name: Key Id:

1. To "observe" small objects, one measures the diffraction of particles whose de Broglie wavelength is approximately equal to the object's size. Find the kinetic energy (in eV) required for electrons to resolve a large organic molecule of size 10 nm:

\[ \lambda = \frac{h}{p} \]

\[ k = \frac{1}{2} m_e \frac{v^2}{2} \Rightarrow p = \sqrt{2m_k} \]

\[ \Rightarrow \lambda = \frac{h}{\sqrt{2m_e} \sqrt{k}} \Rightarrow K = \frac{h^2}{2m_e \lambda^2} \]

\[ K = 2.41 \times 10^{-12} J = 0.015 \text{ eV} \]

2. A proton has a kinetic energy of 1.0 MeV. If its momentum is measured with an uncertainty of 5.0%, what is the minimum uncertainty in its position?

\[ \Delta x \cdot \Delta p = \frac{\hbar}{2} \]

\[ k = \frac{p^2}{2m} \Rightarrow p = \sqrt{2m_k} = 2.3 \times 10^{-20} \text{ kg} \cdot \text{m/s} \]

\[ \frac{\Delta p}{p} = 0.05 \Rightarrow \Delta p = 1.1 \times 10^{-21} \text{ kg} \cdot \text{m/s} \]

\[ \Delta x = \frac{\hbar}{2 \Delta p} = \frac{1.05 \times 10^{-34}}{2 \times 1.1 \times 10^{-21}} = 4.5 \times 10^{-14} \text{ m} \]