Free Particle Problem

A free electron has wave function $\Psi(x, t) = \sin(kx - \omega t)$. Determine the electron's de Broglie wavelength (in Å), momentum (in MKS), kinetic energy (in eV) and speed (in m/s) when $k = 50\ nm^{-1}$ and the particle's mass is $m = 9.1 \times 10^{-31}$ kg.

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The wavelength is given by:

$$k = \frac{2\pi}{\lambda}$$

Therefore:

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{50\ x\ 10^{9}\ m^{-1}} = 1.26\ x\ 10^{-10}\ m = 1.26\ \text{Å}$$

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The momentum is given by:

$$p = \hbar k$$

So that

$$p = (1.054\ x\ 10^{-34}\ Js)(50\ x10^{9}\ m^{-1})$$

$$p = 5.26\ x\ 10^{-24}\ kg\ m/s$$

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The energy is given by:

$$E = \frac{\hbar^2 k^2}{2m}$$

So that

$$E = \frac{\hbar^2 k^2}{2m} = \frac{(1.054\ x\ 10^{-34}\ Js)^2 (50\ x10^{9}\ m^{-1})^2}{2(9.1\ x10^{-31}\ kg)}$$

$$E = 1.53\ x\ 10^{-17}\ J \qquad which\ is \qquad \frac{1.53\ x\ 10^{-17}\ J}{1.602\ x10^{-19} C} = 95.2\ eV$$

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The velocity is given by:

$$v = \frac{p}{m} = \frac{\hbar k}{m}$$

So that

$$v = \frac{5.26\ x\ 10^{-24}\ kg\ m/s}{9.1\ x10^{-31}\ kg}$$

$$v = 5.78\ x10^{6}\ m/s$$