

Useful constants and equations

$$\begin{aligned}
 e &= 1.602 \times 10^{-19} \text{ C} & \frac{1}{4\pi\epsilon_0} &= 9.0 \times 10^9 \text{ N m}^2/\text{C}^2 & \frac{e^2}{4\pi\epsilon_0} &= 1.44 \text{ eV nm} \\
 c &= 3.00 \times 10^8 \text{ m/s} & h &= 6.626 \times 10^{-34} \text{ J s} & &= 4.136 \times 10^{-15} \text{ eV s} & \hbar &= \frac{h}{2\pi} \\
 hc &= 1240 \text{ eV nm} & \hbar c &= 197.3 \text{ eV nm} & 1 \text{ eV} &= 1.602 \times 10^{-19} \text{ J} & R_\infty &= 1.097 \times 10^7 \text{ m}^{-1} \\
 m_e &= 9.11 \times 10^{-31} \text{ kg} & &= 511 \text{ keV}/c^2 & a_0 &= 0.0529 \text{ nm} & E_0 &= -13.6 \text{ eV} \\
 \sigma &= 5.670 \times 10^{-8} \text{ W/m}^2\text{K}^4 & & & & & &
 \end{aligned}$$

Electromagnetic Waves :

$$\begin{aligned}
 c &= \lambda\nu = \omega/k \\
 k &= 2\pi/\lambda \\
 E &= \hbar\omega = pc = hc/\lambda
 \end{aligned}$$

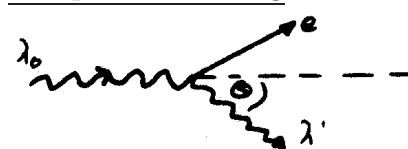
for plane waves :

$$\begin{aligned}
 \vec{E} &= \vec{E}_0 \cos(\vec{k} \cdot \vec{r} - \omega t) \\
 \vec{B} &= \vec{B}_0 \cos(\vec{k} \cdot \vec{r} - \omega t) \\
 \vec{B} &= \frac{1}{\omega} \vec{k} \times \vec{E} \quad \text{and} \quad E_0 = c B_0
 \end{aligned}$$

Particle Waves:

$$\begin{aligned}
 p &= h/\lambda = \hbar k \\
 E &= h\nu = \hbar\omega = \sqrt{(pc)^2 + (mc^2)^2} \\
 v_{\text{phase}} &= \omega/k \\
 v_{\text{group}} &= d\omega/dk|_{k_0} = [v_{\text{phase}} + k dv_{\text{phase}}/dk]_{k_0}
 \end{aligned}$$

Compton Scattering:



$$\lambda' = \lambda_0 + \frac{h}{mc}(1 - \cos \theta)$$

Blackbody radiation: $R = \sigma T^4$ $\lambda_{\text{max}}T = 2.898 \times 10^{-3} \text{ mK}$

Photoelectric effect: $E = h\nu = K_e + \Phi = eV_s + \Phi$

Heisenberg: $\Delta p_x \Delta x \sim \hbar$ $\Delta E \Delta t \sim \hbar$

Schrödinger Equation:

$$\frac{\hbar^2}{2m} \frac{\partial^2 \Psi}{\partial x^2} + U \Psi = i\hbar \frac{\partial \Psi}{\partial t} \quad \text{for } \Psi = \psi(x) e^{-i\frac{E}{\hbar}t} \quad \text{we obtain} \quad -\frac{\hbar^2}{2m} \frac{d^2 \psi(x)}{dx^2} + U(x) \psi(x) = E\psi(x)$$

$$P dx = |\psi|^2 dx \quad \text{and} \quad |\psi|^2 = \psi \psi^*$$

Infinite square well: $\psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi}{L}x\right)$ $E_n = \frac{\pi^2 \hbar^2}{2mL^2} n^2$ $n = 1, 2, 3, 4$

Harmonic Oscillator: $E_n = \left(n + \frac{1}{2}\right) \hbar\omega$ $n = 0, 1, 2, 3$

Operators: $[p_x] = \frac{\hbar}{i} \frac{\partial}{\partial x}$ $[E] = i\hbar \frac{\partial}{\partial t}$ $[KE] = \frac{[p_x^2]}{2m} = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2}$

Reflection coefficient: $R = \left|\frac{B}{A}\right|^2$ for wave $\psi_1 = Ae^{ikx} + Be^{-ikx}$ incident from left on potential step

with: $R + T = 1$ where T is transmission coefficient

Hydrogen Atom: $E = \frac{-13.6 \text{ eV}}{n^2}$ with $n = 1, 2, 3, \dots$ $l < n$ $-l \leq m \leq +l$

Rutherford Scattering: $N(\theta) = k \left(\frac{z \cdot Z}{2K_e}\right)^2 \left(\frac{e^2}{4\pi\epsilon_0}\right)^2 \frac{1}{\sin^4(\theta/2)}$ with $k(= \text{const}) \propto nt$

$\theta =$ scattering angle $n =$ particle density and $t =$ foil thickness