EE201/MSE207 Applied Quantum Mechanics

Lecture 1: Introduction

Quantum mechanics (QM) is one of two theories of 20^{th} century physics, which considerably changes our understand of nature.

- Relativity changed our understanding of space and time.
- QM changed the logic of thinking about microscopic objects.

Main philosophical ideas: wave-particle duality and indeterminism

$E = \hbar\omega$ (Planck-Einstein) for particles

$\lambda = \frac{2\pi\hbar}{p}$ (de Broglie) for particles

$\hbar = 1.05 \times 10^{-34}$ J·s

Estimates:

Electron: $\lambda = \frac{2\pi\hbar}{\sqrt{2m_e E}} = 1\ \text{nm}\sqrt{\frac{1.504\ \text{eV}}{E}} = \frac{1.226\ \text{nm}}{\sqrt{E[\text{eV}]}}$

Photon: $\lambda = \frac{2\pi c}{\omega} = \frac{2\pi\hbar c}{E} = \frac{1.240\ \mu\text{m}}{E[\text{eV}]}$

Prehistory of Quantum Mechanics

1) 1900 Max Planck: suggested discrete absorption and emission of light to explain experimental formula for black-body radiation (Nobel Prize 1918)

$E = h\nu = \hbar\omega$ $\quad h = 6.63 \times 10^{-34}$ J·s $\quad \hbar = 1.05 \times 10^{-34}$ J·s

2) 1905 Albert Einstein: theory of photoelectric effect (Nobel Prize 1921)

$h\nu = \Phi + \frac{mv^2}{2}$ $\quad \Phi$ is work function (ionization energy)

3) 1913 Niels Bohr: model of atom (Nobel Prize 1922)

$mvr = n\hbar$

Discrete atomic spectra and Rutherford's experiments (1910-1911, N.P. 1908)

4) 1923 Arthur Compton: scattering of X-rays on electrons (Nobel Prize 1927)

5) 1923 Louis de Broglie: matter waves (theory only, in 1927 confirmed for electrons, Nobel Prize 1929)

$$\lambda = \frac{2\pi\hbar}{p}$$

"Birth" of Quantum mechanics: 1927 (5th Solvay conference, Brussels)

Classical mechanics vs. Quantum Mechanics
(one particle in one dimension)

Classical mechanics:

Position $x(t)$, velocity $v(t) = \frac{dx}{dt}$, acceleration $a(t) = \frac{d^2x}{dt^2}$

$F = -\frac{dV(x)}{dx}$ for a conservative system, $V(x)$ is potential energy

Main evolution equation: $a = \frac{F}{m}$

$$\frac{d^2x}{dt^2} = -\frac{1}{m}\frac{dV}{dx}$$

initial conditions: $x(0), \dot{x}(0)$ $\Longrightarrow$ $x(t)$

Quantum mechanics:

Main evolution equation: Schrödinger equation

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} + V\Psi$$

$\Psi(x,t)$ is a complex function, characterizing the particle state (wave function)

$|\Psi(x,t)|^2 dx$ is the probability to find the particle between x and $x + dx$ at time t (if observed!)

Indeterminacy: particle does not have position (still debates about philosophy)