Chapter 29: Particles and Waves

Essential Concepts and Summary
Wave-Particle Duality

- Waves can exhibit particle-like characteristics, and particles can exhibit wave-like characteristics.
- Can be seen through a version of Young's experiment, using a beam of electrons.
Blackbody Radiation and Planck's Constant

- All bodies radiate E/M waves continually.
- Assuming energy quantization, Planck obtained energy of these waves.
- Suggests light consists of energy packets, not continuous waves.

\[ E = n hf \]
\[ n = 0, 1, 2, 3, \ldots \]
\[ h = 6.63 \cdot 10^{-34} \text{ J} \cdot \text{s} \]
Photons and Photoelectric Effect

- Photoelectric effect: electrons emitted from metal surface when light shines on it.
- Because electrons ejected with aid of light, called photoelectrons.
- Einstein proposed energy of a photon given by relation between Planck's constant and frequency, not light intensity.
- Work function is energy necessary to eject electron.

\[ E = hf \]

\[ hf = KE_{\text{max}} + W_0 \]
Momentum of Photon

- Compton effect: X-ray photon scattered from electron, with scattered photon having smaller frequency than incident photon.

- Using Compton photon and conservation of momentum, we can derive momentum of photon

\[ \lambda - \lambda' = \frac{h}{mc} (1 - \cos \theta) \]

\[ p = \frac{E}{c} = \frac{hf}{f \lambda} = \frac{h}{\lambda} \]
De Broglie made proposal that wavelength of particle is governed by the same relation as what applies to a photon.

Waves of particles are waves of probabilities, whose magnitudes give indication of probability that particle will be found at that point.
Heisenberg Uncertainty Principle

- There are limits on the accuracy with which momentum and position can be determined.
- These are fundamental limits, not measuring errors.
- There are limits between momentum and position; between energy and time.

\[
(\Delta p_y)(\Delta y) \geq \frac{\hbar}{4\pi}
\]

\[
(\Delta E)(\Delta t) \geq \frac{\hbar}{4\pi}
\]
Summary of Equations

\[ E = hf \]

\[ hf = KE_{\text{max}} + W_0 \]

\[ \lambda' - \lambda = \frac{h}{mc} (1 - \cos \theta) \]

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

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

\[ (\Delta p_y)(\Delta y) \geq \frac{h}{4\pi} \]

\[ (\Delta E)(\Delta t) \geq \frac{h}{4\pi} \]
References