SUMMARY

The goal of Chapter 39 has been to understand the quantization of energy for light and matter.

General Principles

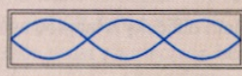
Light has particle-like properties

- The energy of a light wave comes in discrete packets called light quanta or photons.

- For light of frequency f, the energy of each photon is $E = hf$, where h is **Planck's constant.**
- For a light wave that delivers power P, photons arrive at rate R such that $P = Rhf$.
- Photons are "particle-like" but are not classical particles.

Matter has wave-like properties

- The **de Broglie wavelength** of a "particle" of mass m is $\lambda = h/mv$.
- The wave-like nature of matter is seen in the interference patterns of electrons, neutrons, and entire atoms.
- When a particle is confined, it sets up a de Broglie standing wave. The fact that standing waves have only certain allowed wavelengths leads to the conclusion that a confined particle has only certain allowed energies. That is, energy is quantized.



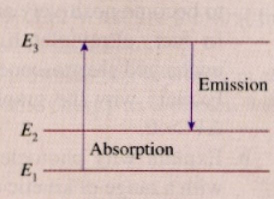
Important Concepts

Einstein's Model of Light

- Light consists of quanta of energy $E = hf$.
- Quanta are emitted and absorbed on an all-or-nothing basis.
- When a light quantum is absorbed, it delivers all its energy to *one* electron.

Bohr's Model of the Atom

- An atom can exist in only certain stationary states. The allowed energies are quantized. State n has energy E_n.
- An atom can jump from one stationary state to another by emitting or absorbing a photon with $E_{photon} = hf = \Delta E_{atom}$.
- Atoms can be excited in inelastic collisions.
- Atoms seek the $n = 1$ **ground state.** Most atoms, most of the time, are in the ground state.



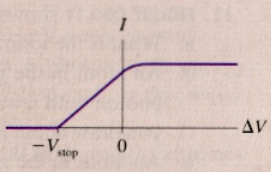
Applications

Photoelectric effect

Light can eject electrons from a metal only if $f \geq f_0 = E_0/h$, where E_0 is the metal's **work function.**

The **stopping potential** that stops even the fastest electrons is

$$V_{stop} = \frac{h}{e}(f - f_0)$$



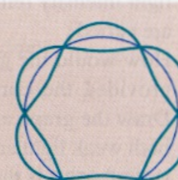
Particle in a box

A particle confined to a one-dimensional box of length L sets up de Broglie standing waves. The allowed energies are

$$E_n = \frac{1}{2}mv_n^2 = n^2\frac{h^2}{8mL^2} \qquad n = 1, 2, 3, \ldots$$

The Bohr hydrogen atom

The stationary states are found by requiring an integer number of de Broglie wavelengths to fit around the circumference of the electron's orbit: $2\pi r = n\lambda$.



This leads to energy quantization with

$$r_n = n^2 a_B \qquad v_n = \frac{v_1}{n} \qquad E_n = -\frac{13.60\,\text{eV}}{n^2}$$

where $a_B = 0.0529$ nm is the **Bohr radius.** The Bohr hydrogen atom successfully predicts the Balmer formula for the hydrogen spectrum. Angular momentum is also quantized, with $L = n\hbar$.