SUMMARY

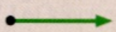
The goal of Chapter 25 has been to explore the limits of the wave and particle models.

General Principles

The two basic models of classical physics

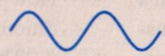
The particle model

A particle is localized at one point in space.
A particle follows a well-defined trajectory.



The wave model

A wave is spread out through space.
A wave exhibits interference and diffraction.



The breakdown of classical physics

A closer look at light and matter finds that these classical models are not sufficient. Light and matter are neither particles nor waves, but exhibit characteristics of both.

Important Concepts

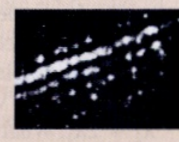
Light

- Exhibits interference and diffraction

  Wave-like: $c = \lambda f$
- Detected at localized positions

  Particle-like: $E = hf$
- Particle-like "chunks" of light are called photons.

Matter



- Detected at localized positions

  Particle-like: $E = \frac{1}{2}mv^2$
- Exhibits interference and diffraction

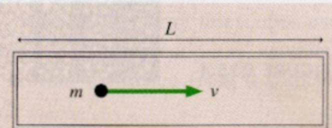
  Wave-like: $\lambda = h/p$
- The wavelength is called the **de Broglie wavelength.**

Quantization

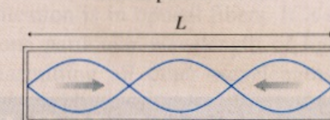
A "particle" confined to a one-dimensional box of length L sets up a standing wave with the de Broglie wavelength. Because only certain wavelengths can oscillate, only certain discrete energies are allowed:

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

Energy is quantized into discrete levels rather than being continuous as it is in classical physics. Quantization is not important for macroscopic objects, but energy quantization plays a very large role at the atomic level.



Classical particle in a box



Quantum particle in a box

Applications

Hydrogen spectrum

The wavelengths in the spectrum of hydrogen atoms are

$$\lambda = \frac{91.18\text{ nm}}{\left(\frac{1}{m^2} - \frac{1}{n^2}\right)} \qquad \begin{array}{l} m = 1, 2, 3, \ldots \\ n = m+1, m+2, \ldots \end{array}$$

The series of spectral lines with $m = 2$ is the Balmer series.

Diffraction by atomic crystals

X rays and matter particles with wavelength λ undergo strong reflections from atomic planes spaced by d when the angle of incidence satisfies the Bragg condition:

$$2d\cos\theta = m\lambda \qquad m = 1, 2, 3, \ldots$$

Terms and Notation

spectrometer	line spectrum	Bragg condition	de Broglie wavelength
spectrum	Balmer series	photon	quantization
discrete spectrum	x ray	photon model	quantum number, n
spectral line	x-ray diffraction	Planck's constant, h	energy level, E_n