Quantum Mechanics

Physics 4330

What is Quantum Mechanics?
Quantum Mechanics

- studies motion
- studies motion of microscopic objects
- Nonrelativistic quantum mechanics—Motion at low speed
- Relativistic quantum mechanics—Motion at high speed

Quantum Mechanics

- If you are not confused by quantum physics then you haven’t really understood it.
  
  Niels Bohr

- I think I can safely say that nobody understands quantum mechanics.
  
  Richard Feynman

The Origins of Quantum Mechanics

- Classical Physics
- Quantum Mechanics
  - Atomic Physics
  - Nuclear Physics
  - Particle Physics
  - Condensed Matter Physics
Quantum Physics vs. Classical Physics

- Determinism of classical mechanics vs. Uncertainty of quantum mechanics
- Wave nature of light vs. Quantum nature of light
- Continues vs. Quantum nature of physical quantities
- Interaction of experiment and observer

Phenomena which can not be explained by means of classical physics

- Black body radiation (Planck 1901, Nobel Prize 1918)
- The photoelectric effect (Einstein 1905, Nobel Prize 1921)
- The Compton effect (Compton 1922, Nobel Prize 1927)
- Wave properties of electrons (de Broglie 1925, Nobel Prize 1929)
- The Bohr’s atom (Bohr 1913, Nobel Prize 1922)

Black Body Radiation

- A cavity with a small hole in thermal equilibrium with surroundings
Experimental Results

- Kirchhoff’s law: The intensity of radiation emitted by a black body is a universal function of temperature $T$ and the wavelength (frequency) of the radiation.

$w(\lambda, T) = \frac{4}{c} E(\lambda, T)$

Intensity of radiation in the wavelength range is related to energy density of radiation

Experimental Results

- Wien’s Law

$w(\lambda, T) = \frac{f(\lambda T)}{\lambda^5}$,

$u(\nu, T) = f\left(\frac{cT}{\nu}\right)\nu^3$,

$\lambda_{\text{max}} = \frac{x_{\text{max}}}{T} = \frac{2.898 \times 10^{-3} mK}{T}$

The Rayleigh-Jeans Formula

$u(\nu, T) = \frac{8\pi \nu^2}{c^3} kT$
Plank's Formula

\[ u(v, T) = \frac{8\pi h}{c^3} \frac{v^3}{h^2 e^{\frac{kT}{h}} - 1}, \]

\[ h = 6.6261 \times 10^{-34} \text{Js} \]

Stefan-Boltzmann Law

\[ U(T) = aT^4, \]

\[ a = 7.5662 \times 10^{-16} \text{J/m}^3 \text{K}^{-4} \]

Examples