Introduction to Quantum Mechanics

Lecture I

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Evaluation

Mid-semester: (Completed)	30% (10% online + 10% online + 10% remote)
Continuous Evaluation:	25% (includes quizzes along with surprise tests, assignments etc.)
End-semester:	45%

Syllabus

•*Introduction to Quantum Mechanics*- Failure of classical mechanics, Double-slit experiment, de Broglie's hypothesis. Uncertainty Principle, Wave-Function and Wave-Packets, Phase- and Group-velocities. Schrödinger Equation. Probabilities and Normalization. Expectation values. Eigenvalues and Eigen functions. Applications of Schrödinger Equation: Particle in a box, Finite Potential well, Harmonic oscillator, Hydrogen Atom problem.

Concepts of Modern Physics	A. Beiser, Sixth Edition.

Triumph of Classical Physics: The Conservation Laws

- **Conservation of energy**: The total sum of energy (in all its forms) is conserved in all interactions.

- **Conservation of linear momentum**: In the absence of external forces, linear momentum is conserved in all interactions.

- **Conservation of angular momentum**: In the absence of external torque, angular momentum is conserved in all interactions.

- **Conservation of charge**: Electric charge is conserved in all interactions.

Classical Physics of the 1890s

Mechanics

Newton's Laws of Motion

$$\vec{F} = m\vec{a} \quad \text{or} \quad \vec{F} = \frac{d\vec{p}}{dt}$$

$$\vec{F}_{21} = -\vec{F}_{12}$$

Electromagnetism

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 I$$

Thermodynamics

- **First law**: The change in the internal energy ΔU of a system is equal to the heat Q added to a system plus the work W done by the system

$$\Delta U = Q + W$$

- **Second law**: It is not possible to convert heat completely into work without some other change taking place.
- **The "zeroth" law**: Two systems in thermal equilibrium with a third system are in thermal equilibrium with each other.
- **Third law**: It is not possible to achieve an absolute zero temperature

No idea about condensed matter, why do gold and iron have vastly different properties?? No rational way of designing materials for some specific purpose …

Waves and Particles

Two ways in which energy is transported:

Point mass interaction: transfers of momentum and kinetic energy: *particles*

Extended regions wherein energy transfers by way of vibrations are observed: *waves*

Two distinct phenomena describing physical interactions

- Both require "Newtonian mass"
- Particles in the form of point masses and waves in the form of perturbation in a mass distribution, i.e., a material medium
- The distinctions are observationally quite clear; however, not so for the case of visible light
- Thus by the 17th century begins the major disagreement concerning the nature of light

Newton promotes the corpuscular (particle) theory

- Particles of light travel in straight lines or rays
- Explains reflection and refraction

Christian Huygens promotes the wave theory

- Light propagates as a wave of concentric circles from the point of origin
- Explains reflection and refraction

The Wave Theory Advances…

- Contributions by Huygens, Young, Fresnel and **Maxwell**
- Double-slit interference patterns
- Refraction of light from air into a liquid, a spoon appears to be bend
- ***Light is an electromagnetic phenomenon***
- ***Establishes that light propagates as a wave***

- *Problem: all other waves need a medium to travel in, light also travels in a vacuum*

- Visible light covers only a small range of the total electromagnetic spectrum. All electromagnetic waves travel in a vacuum with a speed *c* given by:

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \lambda f$$

(where μ_0 and ε_0 are the respective permeability and permittivity of “free” space)

Electromagnetic waves can have very different wavelengths and frequencies, but they all travel with the speed of light

Unresolved Questions of 1895 and New Horizons

- The atomic theory controversy raises fundamental questions
  - Revolutionary idea, properties of matter should be due to their structure (rather than their very nature)

Three fundamental problems:

- The necessity of the existence of an "electromagnetic medium" for light waves to travel in
- The problem of observed differences in the electric and magnetic field between stationary and moving reference systems
- The failure of classical physics to explain blackbody radiation – modern physics starts from the necessity of energy in bound systems to be quantized in order for Max Planck's theory to fit experimental data over a very large range of wavelengths

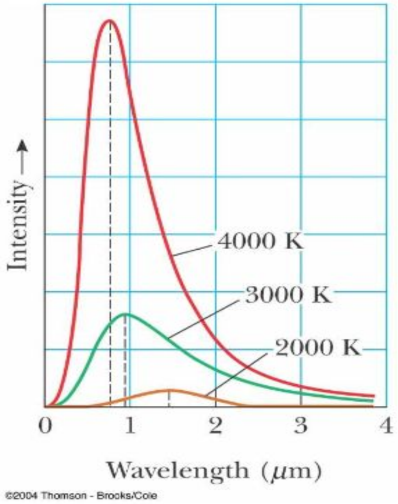
Additional discoveries that complicate classical physics interpretations

- Discovery of x-rays (1895), Discovery of radioactivity (1896), Discovery of the electron (1897), Discovery of the Zeeman effect (1897)

Blackbody Radiation Problem:

- Hot filament glows.
- Classical physics cant explain the observed wavelength distribution of EM radiation from such a hot object.
- This problem is historically the problem that leads to the rise of quantum physics during the turn of 20th century

- The intensity increases with increasing temperature
- The amount of radiation emitted increases with increasing temperature
  - The area under the curve
- The peak wavelength decreases with increasing temperature



- An object at any temperature is known to emit thermal radiation
  - Characteristics depend on the temperature and surface properties
  - The thermal radiation consists of a continuous distribution of wavelengths from all portions of the em spectrum

- At room temperature, the wavelengths of the thermal radiation are mainly in the infrared region
- As the surface temperature increases, the wavelength changes
  - It will glow red and eventually white
- The basic problem was in understanding the observed distribution in the radiation emitted by a black body
  - Classical physics didn't adequately describe the observed distribution

Thank
You