Waves & Oscillations, Geometrical Optics and Wave Mechanics (Phy 159)

Lectures 1-3: Principles of statistical physics, Probabilities, Classical statistics, Quantum statistics.

Lectures 4-6: Bose-Einstein statistics, Fermi-Dirac statistics and their applications.

Lectures 7-9: Fundamental postulates of wave mechanics, Time dependent Schrodinger equation.

Lectures 10-13: Schrodinger equation for one-electron atom and its solution

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Outcome:

- Learn the basic knowledge of classical statistics and quantum statistics.
- Understand the characteristics of classical particles and quantum particles.
- Know the concept of quantum mechanics.
- Able to solve the quantum mechanical problems.
- Wave mechanics for your future studies and research.

Reference Book:

- Concepts of Modern Physics; Arthur Beiser
- Physics for Engineers Part -2; Gias Uddin Ahmad

Concepts of Statistical Mechanics

- Statistical mechanics are not concerned with calculating the exact outcome of single isolated events, but rather predicting the average outcome of many cooperative events, based on the statistical distribution.

- It is not concerned with the actual motions or interactions of individual particles, but rather with their most probable behaviour.

- It can be applied with equal facility to classical systems (molecules in a gas) and to quantum mechanical systems (photon in a cavity and free electrons in a metal).

Phase Space, Phase Point, Cell

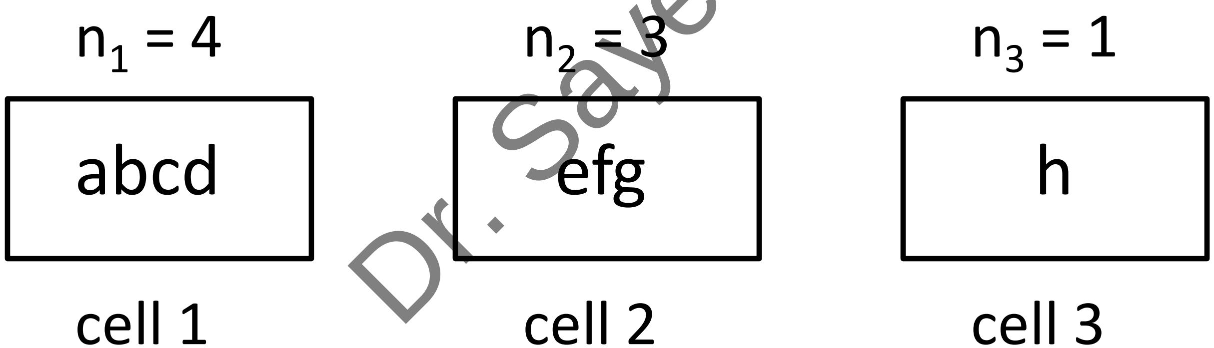
- To specify the position of a molecule inside a gas, three space coordinates x, y, z and three momentum coordinate p_x, p_y, p_z has been considered. From purely mathematical concept, this six dimensional space for a single molecule is called **phase space.**

- The instantaneous state of a particle in the phase space is represented by a point known as **phase point**.

- A six dimensional element of volume dx, dy, dz, p_x, p_y, p_z called a **cell**. Thus the phase space may be divided into large number of cells, each cell may contain a large number of phase points.

Macroscopic and Microscopic States

A macrostate of the system, in general, correspond to a large number of microstates. It is only natural to assume that at any time the system is equally likely to be in any one of these microstates.



Number of cells in phase space: 3

Cell 1 containing phase point $n_1 = 4$

Cell 2 containing phase point $n_2 = 3$

Cell 3 containing phase point $n_3 = 1$

Macroscopic and Microscopic States (cont.)

The macrostate in the phase space is specified merely by giving the phase points $n_1 = 4$, $n_2 = 3$ and $n_3 = 1$ of different cells.

If the phase point a and b from cell 1 or e and f in cell 2 are interchanged, the microstate is changed because the positions of the two phase points are changed.
Again, if a and e from cell 1 and 2 are interchanged, the microstate is also changed. But the macrostate remains unchanged as the number of phase points in each cell remains the same. Thus different microstates may correspond to the same macrostate.

Ensemble

A system is defined as a collection of a large number of particles. An ensemble is defined as a collection of a large number of macroscopically identical, but essentially independent systems.

By macroscopically independent is meant that each of the systems constituting the ensemble satisfies the same macroscopic conditions, i.e., volume, energy, pressure, particles number. The term independent mean that the systems constituting the ensemble are mutually non-interacting. In an ensemble the systems play the same role as the non-interacting molecules do in a gas.

Postulates of Statistical Mechanics

- **Any gas consists of a large number of molecules which are always in motion and behave like very small elastic spheres.**
- **All the cells in the phase space are of equal size.**
- **All accessible microstates corresponding to possible macrostates are equally probable. This is called the postulate of equal a priori probability.**
- **The equilibrium state of a gas corresponds to the macrostates of maximum probability.**
- **The total number of molecules is constant.**
- **The total energy of the system is constant.**

Statistical Distribution Law

The three most probable distribution laws used in practice are:

- **Maxwell-Boltzmann distribution law (M-B distribution)**
- **Fermi-Dirac distribution law (F-D distribution)**
- **Bose-Einstein distribution law (B-E distribution)**

M-B distribution is applicable for classical particles whereas F-D and B-E distribution is applicable for quantum particles.

M-B is classical statistics, but F-D and B-E are quantum statistics.

Quantum Statistical vs. Classical Statistics

Many ordinary observed phenomena such as temperature, pressure, energy etc, could be successfully interpreted with the help of classical statistics of Maxwell-Boltzmann law.

However, it failed to explain several other experimentally observed phenomena such as black body radiation, photoelectric effect, specific heat capacity at low temperature. This failure of classical statistics led to the development of quantum statistics in which the discrete energy system instead of continuous distribution of energy has been considered.

Example of Classical Statistical vs. Quantum Statistics

- ❑ M-B: Identical but distinguishable particles. Molecules of a gas follow M-B statistics.

- ❑ B-E: Identical but indistinguishable particle of zero or integral spin. Photon is this kind of particle. Particles are called **Bosons**. Remembering that this statistics is discovered by S. N. Bose in Dhaka (around 1926) when he was a professor of Physics of Dhaka University.

- ❑ F-D: Identical but indistinguishable of spin ½. Electrons, Protons, neutrons are the particles of this kind. They obey Pauli's exclusion principle. Particles are known as **Fermions.**