B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – DSC 7-1 : STATISTICAL MECHANICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Statistical Mechanics DSC 7-1	4	3	1	0	

COURSE OBJECTIVES

The course aims to:

- Introduce the fundamental concepts of statistical physics such as phase space, microstates, macrostates, and the basic idea of ensembles.
- Provide a thorough understanding of classical (Maxwell-Boltzmann) and quantum (Bose-Einstein and Fermi-Dirac) statistics.
- Develop skills to derive thermodynamic properties of ideal and degenerate gases using partition functions and distribution functions.
- Apply statistical methods to understand physical phenomena such as Bose-Einstein condensation, photon gas and negative temperature.
- Explore the qualitative concept of white dwarf stars and Chandrasekhar mass limit.

LEARNING OUTCOMES

By the end of the course, students will be able to:

- Explain the foundational concepts of phase space, macrostates, microstates, and the basic idea of ensembles.
- Apply the Maxwell-Boltzmann distribution law to calculate thermodynamic quantities of an ideal gas using the partition function.
- Apply the law of equipartition of energy to analyze specific heat capacities of gases and explain its limitations at low temperatures.

- Describe the Bose-Einstein distribution and apply it to systems like photon gas and a two-level system, including concepts like negative temperature and Bose-Einstein condensation.

- Apply the Fermi-Dirac distribution to calculate thermodynamic functions of degenerate fermion systems and describe qualitatively the physics of white dwarf stars and the Chandrasekhar mass limit.

SYLLABUS OF DSC 7
THEORY COMPONENT
(Hours: 45)

Unit I **(6 Hours)**

Introduction to Classical Statistics
Macrostates and Microstates, Phase Space, Entropy and Thermodynamic Probability

Unit II **(12 Hours)**

Maxwell-Boltzmann distribution
Partition function, thermodynamic functions of an ideal gas, Gibbs paradox, Sackur-Tetrode equation; law of equipartition of energy (with proof) – Applications to specific heat of gases and its limitations, thermodynamic functions of a two-level system, negative temperature.

Unit III **(15 Hours)**

Bose-Einstein Statistics
Bose-Einstein distribution law, thermodynamic functions of a strongly degenerate Bose gas (non-relativistic), Bose-Einstein condensation, properties of liquid He (qualitative description only), radiation as a photon gas and thermodynamic functions of photon gas; Derivation of Planck's law using B-E statistics.

Unit IV **(12 Hours)**

Fermi-Dirac Statistics
Fermi-Dirac distribution law, thermodynamic functions of a completely and strongly degenerate Fermions (non-relativistic), specific heat of metals, relativistic Fermi gas, White dwarf stars and Chandrasekhar mass limit (qualitative concepts only).

REFERENCES

Essential Readings

1. Statistical Mechanics - R. K. Pathria & Paul D. Beale, 4th Edition, (Academic Press,2021)
2. Introduction to Statistical Physics, Kerson Huang, 2nd Edition, (Taylor and Francis 2009)
3. Thermodynamics, Kinetic theory and Statistical thermodynamics, Sears and Salinger, PHI

4. Introductory Statistical Mechanics, R. Bowley and M. Sanchez, Oxford Univ. Press
5. Concepts in Thermal Physics, Blundell and Blundell, Oxford University Press
6. Problems and Solutions on Thermodynamics and Statistical Mechanics, Lim Yung-Kou, Sarat Book House
7. Statistical and Thermal Physics, Loknathan and Gambhir, PHI

Additional Readings

1. An Introduction to Statistical Physics, W. G. V. Rosser, Wiley
2. An Introduction to Thermal Physics, D. Schroeder, Pearson
3. Statistical Mechanics, G. Sanon, Narosa Publishers