Semester-VIII

B.Sc. (Honours) Physics

ISCIPLINE SPECIFIC C ORE COURSE – DSC 20: ADVANCED STATISTICAL MECHANICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Statistical Mechanics DSE 19	4	3	1	0	

COURSE OBJECTIVES

- To introduce the fundamental principles and mathematical framework of statistical mechanics.
- To understand the concept of ensembles (microcanonical, canonical, and grand canonical) and their application to physical systems.
- To introduce quantum statistical concepts such as the density matrix and its applications.
- To introduce basic concepts of interacting system with the Ising model

This course provides a strong foundation for advanced study in theoretical and applied physics, and prepares students for research or technical roles in fields involving thermodynamic systems, statistical modelling and complex systems.

LEARNING OUTCOMES

Upon successful completion of this course, students will be able to:

- Understand fundamental concepts and principles of statistical mechanics including macrostates, microstates, and phase space, and their significance in describing physical systems.
- Formulate the microcanonical ensemble and apply it to model systems such as classical and quantum harmonic oscillators and ideal gases.
- Explain the grand canonical ensemble, including equilibrium with a particle-energy reservoir.
- Establish the relationship between canonical and grand canonical partition functions and use them to evaluate thermodynamic properties of systems with variable particle numbers.
- Describe the basic principles of quantum statistical mechanics including the concept of quantum ensembles and density matrix
- Describe basic principles of statistical mechanics of interacting systems with the help of Ising model

SYLLABUS OF DSE 19
THEORY COMPONENT
(Hours: 45)

Unit I **(8 hours)**

Review of Microcanonical and Canonical Ensembles
Macrostates, microstates, phase space, microcanonical ensemble (no derivation), partition function and its use in finding various thermodynamic quantities (no derivation). Examples of systems with finite and infinite energy levels using microcanonical and canonical ensemble approaches.

Unit II **(12 hours)**

Grand Canonical Ensemble
Equilibrium between a system and a particle-energy reservoir, a system in grand canonical ensemble, physical significance of various statistical quantities, density and energy fluctuations in grand canonical ensemble: correspondence with other ensembles, relation between canonical partition function and grand canonical partition function.

Unit III **(12 Lectures)**

Quantum Mechanical Ensembles
Basic idea of quantum-mechanical ensemble theory. Density matrix of microcanonical, canonical and grand canonical ensembles, Particle in a box and quantum harmonic oscillator.

Unit IV **(13 Lectures)**

Interacting Systems
Introduction to the Ising model. Exact solution of Ising model in one dimension. Mean field approximation.

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. Statistical Physics of Particles, Mehran Kardar (Cambridge University Press, 2007)
4. Statistical and Thermal Physics: An Introduction, Michael J R Hoch, 2nd Edition (CRC Press, 2021)

Additional Readings

1. Statistical Mechanics An advanced course with problems and solutions R. Kubo, First Edition (Elsevier, 2014)
2. Thermodynamics and Statistical Mechanics, Greiner, Neise and Stocker, Springer 1995.
3. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill, Inc., 1967
4. Statistical and Thermal Physics: With Computer Applications, Harvey Gould and Jan Tobochnik

ADVISORY

The course, Advanced Statistical Mechanics, is essential for several courses offered in the one-year M.Sc. program and is also included in the syllabi of various competitive examinations, including CSIR-NET, JEST, and GATE.