Course Code	Course Name	Credits
26PH510	THERMODYNAMICS AND STATISTICAL MECHANICS	04

Course Objectives

- To estimate and use the statistical concept of entropy and relate its partial derivative with thermo dynamical parameters.
- To understand the concept of ensemble, ensemble averages and partition function and apply them to classical ideal gas and system of harmonic oscillators.
- To study exclusively when and how to use Bose-Einstein (BE) and Fermi-Dirac (FD) statistics.
- To distinguish between classical and quantum statistics and the need to use them for explaining some exotic phenomena in both BE and FD statistics.
- To appreciate and use the concept of fluctuation in statistics. Identify those parameters that are used to classify phase transitions.

Learning Outcomes

Students will have achieved the ability to:

- Find the connection between statistics and thermodynamics.
- Differentiate between different ensemble theories used to explain the behavior of the systems.
- Differentiate between classical statistics and quantum statistics.
- Explain the statistical behavior of ideal Bose and Fermi systems.

Unit 1 - Relation Between Statistical Mechanics And Thermodynamics (12 Hrs.)

Macro and microstates- connection between thermodynamics and statistical mechanics phase space and trajectories –quantization of phase space - ensemble and ensemble averages- equations of motion and Liouville's theorem- micro canonical ensemble (MCE) – ideal gas in MCE – Gibb's paradox – Sackur-Tetrode equation Entropy and probability- classical limit symmetry of wave function (distinguishable and indistinguishable particles) – effect of symmetry on counting - distribution function for Maxwell-Boltzmann(MB), Bose-Einstein(BE) and Fermi –Dirac (FD) statistics .

Unit 2 – Canonical And Grand Canonical Ensembles (12 Hrs.)

System in contact with a heat reservoir- –Most probable distribution in CE- canonical partition function and Helmholtz free energy- relation to thermodynamic variables – classical ideal gas and harmonic oscillator in CE - calculation of statistical quantities – equipartition theorem – two level system – concept of negative temperature – system with internal degrees of freedom – translational, rotational and vibrational partition function System in contact with a particle-energy reservoir - Most probable distribution in GCE grand canonical partition function and Gibb's free energy- relation to thermodynamic variables – classical ideal gas and harmonic oscillator in GCE - calculation of statistical quantities - quantum mechanical ensemble theory.

Unit 3 - Bose – Einstein Statistics (12 Hrs.)

Bose-Einstein Distribution law – black body radiation spectra – photon gas- Planck's distribution law, Rayleigh-Jean's law, Wein's displacement law, Stefan's law phonons- Einstein's and Debye's theory of specific heat- Degeneracy and Bose Einstein condensation- Thermodynamic properties of an ideal Bose-Einstein gas Liquid helium – super fluidity- fountain effect - mechano-caloric effect.

Unit 4 – Fermi-Dirac Statistics (12 Hrs.)

Ideal Fermi gas – Fermi Dirac distribution law- thermodynamic properties of Fermi gas: completely degenerate, degenerate and slightly degenerate – electronic heat capacity –electrons in metals –– Thermionic emission – Pauli paramagnetic susceptibility - White dwarf: non-relativistic and relativistic limits – Chandrasekhar limit – nuclear matter.

Unit 5 - Fluctuations And Phase Transitions (12 Hrs.)

Mean squared deviation- energy fluctuation in canonical ensemble – number fluctuation in grand canonical ensemble Random walk and Brownian motion- First and second order Phase transition- Ising model: one dimensional Ising model- - Landau theory of phase transitions - introduction to non - equilibrium processes - diffusion equation.

Reference Books:

1. Agarwal, B. K., & Eisner, M. (2011). Statistical mechanics (8th ed.). New Age International.
2. Pathria, R. K., & Beale, P. (2021). Statistical mechanics (4th ed.). Elsevier.
3. Greiner, W., Neise, L., &Stöcker, H. (1995). Thermodynamics and statistical mechanics (4th ed.). Springer.
4. Huang, K. (2009). Introduction to Statistical Physics (2nd ed.). CRC Press.

Websites and eLearning Sources:

1. https://onlinecourses.nptel.ac.in/noc25_ph24/preview
2. https://youtu.be/AOhiEXhhC2o?si=_NzwES1zuMqPxMxX
3. https://youtu.be/E6XmzX4Ew9o?si=-XfKhV1X0aZ-ippH

COs and Bloom's Taxonomy Mapping – 26PH510		
Course Outcomes	**On successful completion of this course, students will be able to**	**BTL**
CO1	Recall thermodynamic laws and statistical concepts.	K1, K2
CO2	Apply thermodynamic relations and statistical distributions to systems.	K3
CO3	Analyze ensembles, partition functions, and thermodynamic potentials.	K4
CO4	Evaluate physical systems using statistical mechanics models.	K5
CO5	Develop solutions for complex thermodynamic and statistical problems.	K6

BTL (Bloom's Taxonomy Level) - K1 – Remembering, K2 – Understanding, K3- Applying, K4 – Analyse, K5- Evaluate and K6 - Create

Relationship Matrix – 26PH510												
Course Outcomes	**Programme Outcomes (POs)**						**Programme Specific Outcomes (PSOs)**						**Mean Score of Cos**
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PSO1**	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	
CO1	3	2	1	1	1	1	3	2	1	1	1	1	1.58
CO2	3	3	2	2	1	1	2	3	2	2	2	1	2.00
CO3	3	3	3	2	1	1	2	3	3	2	2	2	2.25
CO4	3	3	3	3	2	1	2	3	3	3	2	2	2.42
CO5	3	3	3	3	2	2	3	3	3	3	3	2	2.75
												Total	2.20

Mean Score: 3- High, 2- Medium/Moderate, 1-Low