3. Problems and solution in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan & Ravi Varshney.
4. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
5. Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.
6. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.

References for Laboratory Work:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
3. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Pres.
4. Engineering Practical Physics, S. Panigrahi & B.Mallick,2015, Cengage Learning India Pvt. Ltd.

CC-XIV: Statistical Mechanics
(32221602)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

Statistical Mechanics deals with the derivation of the macroscopic parameters (internal energy, pressure, specific heat etc.) of a physical system consisting of large number of particles (solid, liquid or gas) from knowledge of the underlying microscopic behavior of atoms and molecules that comprises it. The main objective of this course work is to introduce the techniques of Statistical Mechanics which has applications in various fields including Astrophysics, Semiconductors, Plasma Physics, Bio-Physics etc. and in many other directions.

Course Learning Outcomes

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

- Understand the concepts of microstate, macrostate, phase space, thermodynamic probability and partition function.
- Understand the use of Thermodynamic probability and Partition function forcalculation of thermodynamic variables for physical system (Ideal gas, finite level system).

- Difference between the classical and quantumstatistics
- Understand the properties and Laws associated with thermal radiation.
- Apply the Fermi- Dirac distribution to model problems such as electrons in solids and white dwarf stars
- Apply the Bose-Einstein distribution to model problems such as blackbody radiation and Helium gas.
- In the laboratory course, with the exposure in computer programming and computational techniques, the student will be in a position to perform numerical simulations for solving the problems based on Statistical Mechanics.

Unit 1

Classical
Statistics: Macrostates and Microstates, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur-Tetrode equation. Saha's Ionization Formula. Law of Equipartition of Energy (with proof)– Applications to Specific Heat of gas and solids and its Limitations, Thermodynamic Functions of a Finite Level System, Negative Temperature.

(24 Lectures)

Unit 2

Bose-Einstein Statistics: B-E Distribution law, Thermodynamic functions of a strongly degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law.

(12 Lectures)

Unit 3

Fermi-Dirac Statistics: Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly degenerate Fermi Gas, Fermi Energy Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit**.**

(12 Lectures)

Unit 4

Theory of Radiation: Properties of Thermal Radiation and Radiation Pressure. Blackbody Radiation and its spectral distribution. Kirchhoff law. Stefan-Boltzmann law and its Thermodynamic proof. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law. Ultraviolet Catastrophe. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation Deduction of Wien's Distribution Law, Rayleigh-Jeans Law, Stefan-Boltzmann Law and Wien's Displacement law from Planck's law.

(12 Lectures)

Practical: 60 Hours

Use C/C++/Scilab/Python/other numerical simulations for solving the problems based on Statistical Mechanics like:

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:

a) Study of local number density in the equilibrium state (i) average; (ii) fluctuations
b) Study of transient behavior of the system (approach to equilibrium)
c) Relationship of large N and the arrow of time
d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution.

2. Plot the probability of various macrostates in coin-tossing experiment (two level system) versus number of heads with 4, 8, 16 coins etc.

3. Computation of the partition function Z(b) for the systems with a finite number of single particle levels (e.g., 2 level, 3 level etc.) and finite number of non-interacting particles N under Maxwell-Boltzmann/ Fermi-Dirac/Bose Einstein statistics:

a) Study the behavior of Z(b), average energy, C_v, and entropy and its dependence upon the temperature, total number of particles N and the spectrum of single particle energy states.
b) Plot the probability of occupancy of all the states w.r.t. temperature.

4. Plot the Maxwell speed distribution function at different temperatures in a 3-dimension system. Calculate the average speed, root mean square and most probable speed

5. Plot Specific Heat of Solids w.r.t temperature

a) Dulong-Petit law,
b) Einstein distribution function
c) Debye distribution function

6. Plot the following functions with energy at different temperatures
a) Maxwell-Boltzmann distribution
b) Fermi-Dirac distribution
c) Bose-Einstein distribution

7. Plot the distribution of particles w.r.t. energy (dN/de versus e) in 3 Dimensions for
a) Relativistic and non-relativistic bosons both at high and low temperature.
b) Relativistic and non-relativistic fermions both at high and low temperature.

8. Plot Planck's law of Black body radiation w.r.t. wavelength/frequency at different temperatures. Compare it with Rayleigh-Jeans Law and Wien's distribution law for a given temperature.

References for Theory:

Essential Readings:

1. Statistical Mechanics: R.K. Pathria and P. D. Beale(Academic Press)
2. Introductory Statistical Mechanics: R. Bowley and M. Sanchez (Oxford Univ.Press)
3. Statistical Physics: F. Mandl (Wiley)
4. A treatise on Heat : M.N. Saha and B.N. Srivastava (Indian Press)
5. Problems and Solutions on Thermodynamics andStatistical Mechanics : Lim Yung-Kou (Sarat Book House)

Additional Readings:

1.Statistical Physics: Berkeley Physics Course, F. Reif, (McGraw-Hill)
2.An Introduction to Statistical Physics: W.G.V. Rosser(Wiley)
3. An Introduction to Thermal Physics: D. Schroeder (Pearson)
4. Concepts in Thermal Physics: Blundell and Blundell (Oxford Univ. press)
5. Statistical and Thermal Physics:Loknathan and Gambhir (PHI)

References for Laboratory work:

1. Elementary Numerical Analysis: K.E. Atkinson (Wiley)
2. Introduction to Modern Statistical Mechanics: D. Chandler (Oxford University Press)
3. Thermodynamics, Kinetic Theory and Statistical Thermodynamics : F . W. Sears and G. L. Salinger (Narosa)
4. Modern Thermodynamics with Statistical Mechanics: Carl S. Helrich(Springer)
5. Statistical and Thermal Physics with Computer Applications : H. Gould and J.Tobochnik(Princeton University Press)