Course: M.Sc (Physics)

Semester	1
Paper Number	3 (MPHC4103)
Paper Title	Electronics and Statistical Mechanics I
No. of Credits	6
Course description/objective	**Group A:** The objective of the course on electronics is to understand the physics of semiconductors and to interpret the results and formulae (known from a first course on electronics) from that perspective. The first point is to note that the electrons in a semiconductor reside in a periodic potential of nuclei. Due to their proximity with each other, Pauli's exclusion principle applies and one must implement the Fermi-Dirac distribution to describe the electrons. Students are expected to understand and appreciate the band structure of semiconductors from this perspective. This idea is used to explore the difference between direct and indirect semiconductors. One of the main objectives of the course is to instill the idea of the Fermi level in various types of semiconductors, like intrinsic and extrinsic semiconductors; non-degenerate and degenerate semiconductors. With this background, the students learn the physics of p-n junction, metal-semiconductor junction, etc. under thermal equilibrium condition, with or without bias. They also learn about various types of recombination processes. A crucial objective of this course is that the students will be able to apply these concepts to study and appreciate the characteristics of Schottky diode, Tunnel diode, UJT and BJT, and FET devices. **Group B:** The course objective of Statistical Mechanics I is to understand the behaviour of macroscopic systems, composed of a large number of particles, by considering the behaviour of their constituent particles at the microscopic level. The main goal is to derive the macroscopic properties of a system, such as its temperature, pressure, and energyfrom the microscopic properties. The central idea of classical statistical mechanics is that the behaviour of a large number of particles can be described statistically by considering the probability distribution of their positions and momenta. The properties of the system can then be calculated from the statistical properties of the particles.The main learning objectives of classical statistical mechanics include understanding the concepts of three ensembles, partition functions, and thermodynamic potentials, as well as the laws of thermodynamics and their relation to statistical mechanics. It also involves learning about the various models used in classical statistical mechanics, such asfluctuation in energy and particles, the ideal gas model and their limitations. Additionally, students are expected to be able to apply these concepts to solve problems in areas such as thermodynamics and condensed matter physics.
Course Outcome	**Group A** CO1: With the knowledge of the physics of the semiconductors, the students will fathom the origin of several formulae (e.g. diode current equation) they often use. CO2: Study of the junctions from the perspective of the band structure and Fermi level will equip a student with physical intuition and they have to memorize less information. CO3: The study of the role of quantum tunneling in Zener breakdown mechanism will reduce the apparent gap between the fundamentals and an application oriented subject. **Group B:** CO1: With the introduction to Classical statistical mechanics, students will be able to understand the foundation of this subject with clear idea of Density of phase points,

	postulate of equal a priori probability, Liouville's theorem, ergodic hypothesis, H-theorem. They will be able to solve various problems related to these concepts. CO2: After the discussion onthree ensembles: Microcanonical, Canonical and Grand Canonical, students will able to calculate different thermodynamic quantities and theywill be able to understand its meaning and implications. CO3: Students will be able to understand the equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators etc. They will beable to calculate the fluctuation in energy and particles.
Syllabus	**<u>Group A: Electronics</u>** Semiconductor Physics: Direct and indirect semiconductors; intrinsic and extrinsic semiconductors; energy band diagram; carrier concentration in both cases; non degenerate and degenerate semiconductors. [4 lectures] Carrier transport phenomena: Mobility; Hall effect; diffusivity; generation and recombination; direct and indirect recombination; surface and Auger recombination. Continuity equation: Utilised for steady state injection from one-side. [6 lectures] P-N Junction diode: Equilibrium Fermi level constant; built in potential, depletion layer width, depletion layer width and energy band diagram of a p-n junction diode under various biasing conditions (a) Thermal equilibrium condition (b) forward biasing conditions (c) reverse bias conditions. Depletion capacitance, capacitance voltage characteristics. Avalanche and Zener breakdown, Zener diode, Varactor diode [6 lectures] Metal semiconductor junction, Schottky barrier. Bipolar junction transistor equation for Ebers Moll model. Tunnel diode: order of the width of the depletion region; reverse and forward bias ~~is~~ showing positions of Fermi levels. Explanation of I-V characteristics using the diagrams; Tunnel diode as oscillator, other applications. [6 lectures] Unijunction transistor (UJT) applications as a relaxation oscillator. MOSFET: MOS diode and drain current drain voltage characteristics. JFET: Structure, Operation, Principle I-V characteristics. Logic families: DTL, TTL, TTL Schottky, Low Power Schottky, CMOS ADC and DAC [14 lectures] **<u>Group B: Statistical Mechanics I</u>** Introduction: Objective of statistical mechanics, specification of the state of a many particle system, phase space, counting the number of microstates in phase space, phase points, statistical ensemble, Density of phase points, postulate of equal a priori probability, Liouville's theorem, ergodic hypothesis, H-theorem, probability calculation, thermal, mechanical and general interaction. [8 lectures] Microcanonical ensemble: Thermal interaction between systems in equilibrium,

	temperature, heat reservoirs, sharpness of the probability distribution, applications. [6 lectures] Canonical ensemble: System in contact with a heat reservoir, Boltzmann distribution, canonical partition function, calculation of mean values in canonical ensemble, connection with thermodynamics, entropy of an ideal gas, Gibbs' paradox, applications. [8 lectures] Grand canonical ensemble: System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number, chemical potential of an ideal gas, applications. [8 lectures] Fluctuation in energy and particles. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Para magnetism, concept of negative temperature. [6 lectures]
	Group A: 1. S. M. Sze(2nd edition), Semiconductor Devices - Physics and Technology 2. J. Millman and C. Halkias: Integrated Electronics 3. J. Kennedy: Electronic Communication Systems 4. J. Millman and A. Grabel: Microelectronics 5. B.G. Streetman, S. Banerjee: Solid State Electronic Devices 6. Digital Circuits (Vol I and II), D. Roy Choudhury, Platinum Publishers Group B: 1. F. Reif, Fundamentals of Statistical and Thermal Physics. 2. K. Huang, Introduction to Statistical Mechanics 3. R. K. Pathria, Statistical Mechanics 4. David Chandler, Introduction to Modern Statistical Mechanics 5. R. Kubo, Statistical Mechanics (Collection of problems). 6. An Introductory Course of Statistical Mechanics, Palash B. Pal, Alpha Sciences. 7. Statistical Physics, J. K. Bhattacharjee 8. Statistical Mechanics: An elementary outline, Abhijit Lahiri 9. Equilibrium and Non-Equilibrium Statistical Thermodynamics, Michel Le Bellac, Maurice Le Bellac, Fabrice Mortessagne, G. George Batrouni, George Batrouni, CUP.
Evaluation	Total: 100 CIA: 10 (Group A) + 10 (Group B) End Semester Examination: 40 (Group A) + 40 (Group B)