## Course: M.Sc (Physics)

| | |
|---|---|
| Semester | 2 |
| Paper Number | 7 (MPHC4203) |
| Paper Title | Statistical Mechanics II and Relativity & Relativistic Electrodynamics |
| No. of Credits | 6 |
| Course description/objective | **Group A:**<br><br>The course objective of Statistical Mechanics II includes understanding the concept of the density matrix, which is used to describe the statistical behaviour of quantum particles, and its relation to the thermodynamic properties of the system. Other important concepts include the partition function, quantum ensembles, and thermodynamic potentials. Additionally, students of quantum statistical mechanics are expected to be able to apply these concepts to solve problems in areas Condensed matter Physics, Astro Physics etc. They should also be able to understand the various approximations and models used in quantum statistical mechanics, such as the ideal Bose and Fermi gases, and their limitations. Students will be able to understand the concept of interacting systems and apply to study 1-d Ising model.<br><br>**Group B:**<br>The course objectives of Relativity & Relativistic Electrodynamics include the understanding of the Lorentz transformation equations and their applications like length contraction, time dilation, simultaneity etc. Students must learn the transformation equations for velocity, acceleration etc. Lorentz invariance of various expressions and the geometrical representation of space-time should be thoroughly studied. Students must learn the four-vector formalism and its various applications. Theyshould have a clear idea of tensor calculus and its usefulness as an important tool in special relativity. Students must study the relativistic analysis of classical electrodynamics. They should learn the covariance of Maxwell's equations, Lorentz force law etc., represented in terms of the electromagnetic field tensors. They must know the rules of transformation for electro-magnetic field components from one frame to another. |
| Course Outcome | **Group-A**<br>CO1: With the introduction to Quantum statistical mechanics, students will be able to understand the foundation of this subject with clear idea of the density matrix formalism for three ensembles. They willbe able to solve various problems related to these concepts.<br>CO2: Students will be able to apply BE and FD distributions to Ideal Bose and Fermi gas, statistics of occupation number, equation of state, BE condensation, thermodynamic behaviour of an ideal Bose gas, blackbody radiation, thermodynamic behaviour of ideal Fermi gas, the electron gas in metals and in statistical equilibrium of white dwarf stars to solve problems related to these concepts.<br>CO3: Students will be able to understand the concept of Interacting systems and apply to study 1-d Ising model.<br><br>**Group-B**<br>CO1. Four-vector formalism: four-vectors as contravariant tensors of rank one. Covariant forms. Metric tensor. Scalar product. Invariance properties. Differential operators.<br>CO2. Calculations involving space-time diagrams.<br>CO3. Invariance of Continuity equation and Lorentz force law under Lorentz transformation.<br>CO4. Maxwell's equations and electromagnetic field tensors.<br>CO5. Properties of transformation of the components of electric and magnetic field from one reference frame to another. |

| | |
|---|---|
| Syllabus | **Group A: Statistical Mechanics II**<br><br>Density matrix: Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Quantum Liouville's theorem, density matrices for micro-canonical, canonical, grand canonicalensembles<br><br>Pure and Mixed states. Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field. Density matrix for a beam of spin ½ particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector.<br>[12 lectures]<br><br>Systems of indistinguishable particles – BE and FD distributions, Ideal Bose and Fermi gas, statistics of occupation number, equation of state, BE condensation, Thermodynamic behaviour of an ideal Bose gas, blackbody radiation, thermodynamic behaviour of ideal Fermi gas, the electron gas in metals, statistical equilibrium of white dwarf stars.<br><br>[12 lectures]<br><br>Interacting systems: Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian. Equivalence of the Ising model to other models: Lattice Gas and Binary alloy. Spontaneous Magnetization. Exact solution of one-dimensional Ising system (Matrix methods).<br>[12 lectures]<br><br>**Group B: Relativity & Relativistic Electrodynamics**<br><br>Postulates of the special theory of relativity. Galilean & Lorentz transformation. Applications of Lorentz transformation: Length contraction, time dilation, simultaneity, transformation equations for velocity and acceleration. Thomas Precession. Space-like, time-like and light-like intervals. Lorentz invariance of space-time intervals. Relativistic mass & energy. Conservation of momentum and energy. Geometric representation of space-time: Minkowski diagrams and applications. Twin paradox.<br><br>[10 lectures]<br><br>Four-vectors: Definitions and components, transformation properties. Time derivative of a four-vector. Scalar product of four-vectors and its invariance under Lorentz transformation. Orthogonality. Lorentz invariance of four-dimensional differential volume element. Interaction of particles: conservation of momentum four-vector.<br><br>Tensors: contravariant & covariant, rank of a tensor, transformation properties, contraction, symmetric and anti-symmetric tensors, metric tensor. Four-gradient, four-divergence. Four-dimensional Laplacian operator. Wave number four-vector and Doppler effect. Relativistic Lagrangian and Hamiltonian.<br>[10 lectures]<br><br>Relativistic electrodynamics: Maxwell's equations, scalar and vector potentials, four-vector representation of electromagnetic potentials. Transformation of charge density. Current four-vector. Continuity equation: covariant form. Maxwell's equations in terms of potential four-vector and current four-vector. Electromagnetic field tensor and its transformation properties. Lorentz force law in terms of field tensor and its covariance. Covariance of Maxwell's equations. Dual field strength tensor and its |

| | |
|---|---|
| | application. Electromagnetic field invariants. Transformation laws for the components of electric field and magnetic field. Fields due to a point charge in uniform motion.<br><br>Electric & magnetic fields produced by an accelerated charge.<br>[16 lectures] |
| References | **Group A:**<br>1. K. Huang, Introduction to Statistical Mechanics<br>2. R. K. Pathria, Statistical Mechanics<br>3. David Chandler, Introduction to Modern Statistical Mechanics<br>4. Kadanoff, Statistical Mechanics. World Scientific.<br>5. R. Kubo, Statistical Mechanics. (Collection of problems)<br>6. M. Plischke and B. Bergersen, Equilibrium Statistical Physics, World-Scientific.<br><br>**Group B:**<br>1. Relativity, Gravitation and Cosmology by, Robert J. A. Lambourne (Cambridge University Press, 2010).<br>2. The Special Theory of Relativity by Dennis Morris (Mercury Learning and Information)<br>3. Classical Theory of Fields by Landau and Lifshitz (Butterworth-Heinemann; 4th edition, 1987)<br>4. Introduction to Electrodynamics by, D J Griffiths (Prentice Hall, 1999.)<br>5. The Special Theory of Relativity by Banerji & Banerjee (Prentice Hall of India, 2006)<br>6. Electricity and Magnetism by, Nayfeh & Brussel (John Wiley & Sons, 1985)<br>7. Classical Electrodynamics by J D Jackson (John Wiley, 2007)<br>8. Classical Electricity and Magnetism by Panofsky & Phillips (Dover Publications, 2005) |
| Evaluation | Total: 100<br>CIA: 10 (Group A) + 10 (Group B)<br>End Semester Examination: 40 (Group A) + 40 (Group B) |