| Course Code | Course Title | L | P | U |
|---|---|---|---|---|
| **PHY223T** | **Statistical Mechanics and Plasma Physics** | **4** | **0** | **4** |

**Course Objective**:

Statistical Mechanics and Plasma Physics is a core course in B. Sc. (Honors) Physics curriculum. The course endeavors to present the basics of Statistical Mechanics and Plasma Physics together with a number of elementary applications of these basic principles. After a discussion of the concepts of probability, the postulates of classical mechanics are developed in various ensembles of physical relevance. The ideas thus developed for the classical systems will be shown to have serious limitations when applied to quantum systems. Subsequently, we develop the correct theory of statistical mechanics for quantum systems and show that classical results can be recovered from the quantum theories in the high temperature - low density limit. Finally, the course would cover basics of plasma physics with focus on charge neutrality, plasma oscillations and the Debye length, collisions, thermal plasmas and shock waves in plasmas.

**Course Outcome**:

On completion of the course, the student should be able to:

(i) give an account of the relevant quantities used to describe macroscopic systems, thermodynamic potentials and ensembles.

(ii) give an account of the macroscopic and microscopic description of temperature, entropy and free energy and their descriptions in terms of probabilities

(iii) give an account of the theory of statistical mechanics and the approximations making a statistical description possible

(iv) apply the theory to understand gases and crystals and in addition be able to construct microscopic models and from these derive thermodynamic observables

(v) describe the importance and consequences of quantum mechanics for macroscopic particle systems

(vi) understand the strength and limitations of the models used and be able to compare different microscopic models

(vii) describe transport phenomena and show an understanding on how diffusion coefficients are computed

(ix) define plasma state, give examples of different kinds of plasma and explain the parameters characterizing them

(x) analyze the motion of charged particles in electric and magnetic fields

(xi) explain the concept of quasi-neutrality and describe plasma interaction with

(xii) formulate kinetic and fluid descriptions of plasma, and understand the applicability of the appropriate approximations (ideal MHD, single fluid description, many fluid model).

**Syllabus:**

**Unit I: Basic Concepts of Statistical Mechanics**: Introduction to the course. Basic terminology of elementary probability theory. Elementary combinatorics. Random variables, Description of aSystem in Equilibrium. Bridging Microscopic and Macroscopic View-points, The DistributionFunction. Maxwell-Boltzmann distribution. Phase integral.

**Unit II: The Partition Function :** The Partition Function of an Ideal Monatomic Gas. Thermodynamic Functions. Gibbs Paradox, The Sackur-Tetrode Formula, Diatomic Gases. Rotational and Vibrational Partition Functions. Heat Capacity of Hydrogen.

**Unit III: Towards Quantum Statistics** : Heat Capacity of Solids. The problem of black-body radiation.

**Unit IV: Ideal Bose-Einstein Gas**: Bose-Einstein Distribution Function., Bose's Derivation of Planck's Law. Radiation Pressure and Entropy of Photons, Liquid $^4$He and Bose-Einstein Condensation.

**Unit V: Ideal Fermi-Dirac Gas**: Fermi-Dirac Distribution Function, Fermi Energy. Electronic Heat Capacity.

**Unit VI: Plasma Concepts:** Charge neutrality, plasma oscillations and the Debye length. Collisions, Thermal plasmas: relaxation time and mean free path. The stopping of fast particles by a plasma. Transport phenomena: viscosity, The effect of strong magnetic fields. Shock waves inplasmas.

**Problem Solving Skill Development Course.**

**Text books(s):**

**T1:** IGNOU Study Materials: PHE-06: *Thermodynamics and Statistical Mechanics*

**T2:** *Thermal Physics*: A. B. Gupta, H. P. Roy, Books and Allied (P) Ltd; Fourth Edition (Reprinted: 2019)

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Kamalghat, Tripura (West).

**T3:** *Accretion Power in Astrophysics:* Third Edition, J. Frank, A. King, and D. Raine, Cambridge Univ Press; 2002 (ISBN: 0-521-620538)

**Reference book(s):**

**R1:** *Thermodynamics & Statistical Physics:* S.S. Singhal, J.P. Agarwal, Satya Prakash, Pragati Prakashan, 2017

**R2:** *Heat Thermodynamics and Statistical Physics:* Subrahmaniyam N. & et Al., S. Chand & Company Ltd., Revised Edition 2007.

**Lecture-wise plan**:

| Lecture Nos. | Topics to be covered | Chap./Sec. (Text Book) |
|---|---|---|
| 1-5 | **Basic Concepts of Statistical Mechanics**: Introduction to the course. Basic terminology of elementary probability theory. Elementary combinatorics. Random variables. | T1: 13.1 - 13.2 |
| 6-9 | Description of a System in Equilibrium. Bridging Microscopic and Macroscopic View-points | T1: 13.3 |
| 10-13 | The Distribution Function. Maxwell-Boltzmann distribution. Phase integral. | T1: 13.4 – 13.5 |
| 14-18 | **The Partition Function :** The Partition Function of an Ideal Monatomic Gas. Thermodynamic Functions. Gibbs Paradox. | T1: 14.1 – 14.2 |
| 19-21 | The Sackur-Tetrode Formula. | T1: 14.3 |
| 22-25 | Diatomic Gases. Rotational and Vibrational Partition Functions. Heat Capacity of Hydrogen. | T1: 14.4 – 14.5 |
| 26-29 | **Towards Quantum Statistics** : Heat Capacity of Solids. The problem of black-body radiation. | T1: 15.1 – 15.2 |
| 30-34 | **Ideal Bose-Einstein Gas**: Bose-Einstein Distribution Function. | T1: 15.3 |
| 35-39 | Bose's Derivation of Planck's Law. Radiation Pressure and Entropy of Photons. | T1: 15.3 |
| 40-43 | Liquid $^4$He and Bose-Einstein Condensation. | T1: 15.3 |
| 44-48 | **Ideal Fermi-Dirac Gas**: Fermi-Dirac Distribution Function. | T1: 15.4 – 15.5 |
| 49-52 | Fermi Energy. Electronic Heat Capacity. | T1: 15.4 – 15.5 |

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|---|---|---|
| 53-56 | **Plasma Concepts:** Charge neutrality, plasma oscillations and the Debye length. Collisions. | T3: 3.1 – 3.3 |
| 57-58 | Thermal plasmas: relaxation time and mean free path. The stopping of fast particles by a plasma. Transport phenomena: viscosity. | T3: 3.4 – 3.6 |
| 59-60 | The effect of strong magnetic fields. Shock waves in plasmas. | T3: 3.7 – 3.8 |

**Evaluation Scheme:**

| Component | Duration | Weightage (%) | Remarks |
|---|---|---|---|
| Internal I | | 25 | Assignments/Quiz/Viva |
| Midterm | 2 hours | 20 | Closed Book |
| Internal II | | 25 | Assignments/Quiz/Viva |
| Comprehensive | 3 hours | 30 | Closed Book |

**Attendance Policy:** A Student must normally maintain a minimum of 75% **attendance** inthe course without which he/she shall be disqualified from appearing in the respective examination.

**Make-up Policy:** A student, who misses any component of evaluation for genuine reasons, must immediately approach the instructor with a request for make-up examination stating reasons. **The decision of the instructor in all matters of make-upshall be final.**

**Chamber Consultation Hours:** During the Chamber Consultation Hours, the student canconsult the respective faculty in his/her chamber without prior appointment.

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