

**University of Puerto Rico**  
**Río Piedras Campus**  
**Faculty of Natural Sciences, Department of Physics**  
**Graduate Programme**

**Title: Statistical Mechanics**

**Code:** PHYS 6454

**Number of Credits:** 3

**Number of Hours** 3 hours of classroom lecture per week

**Prerequisites:** PHYS 6452

**Effective date of the syllabus** Second Semester, 2022-2023 academic year

**Instructor** Lutful Bari Bhuiyan  
Office Natural Sciences II, C-350  
Class period: Mondays-Wednesdays, 10 am - 11:20 am Room C-312  
Office hours: Mondays and Wednesdays, 8 am – 10 am, 2 pm – 3.30 pm  
Fridays 8 am – 12 noon, 2 pm – 3.30 pm  
Telephone +1 (787) 764 0000/extn 88438  
e-mail [beena@beena.uprrp.edu](mailto:beena@beena.uprrp.edu), lutful.bhuiyan@upr.edu

## **Description**

Basic concepts, Liouville's theorem for density of points in phase space. Microcanonical ensemble, ergodic theorem, thermodynamic weight, and connection with thermodynamics. Normal systems in Statistical Mechanics, Canonical, Grand-Canonical, and T-P ensembles. Thermodynamic functions associated with various ensembles and the recipes to obtain the thermodynamics. Entropy and its application to ensembles. Fluctuations. Applications of Statistical Mechanics as in Bose-Einstein, Fermi-Dirac, and Maxwell-Boltzmann distributions. Further applications ---- Non-interacting ground state of a Fermi gas, Blackbody radiation, phonons, and Bose-Einstein condensation.

## **Objectives**

After the completion of this course the student

- will learn the basic concepts and techniques of classical and quantum statistical mechanics.
- will be capable of appreciating the statistical mechanics used in the description of condensed matter.
- will have the required background to understand and perform numerical calculations using programming languages to study simple condensed matter systems.
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## **Course Contents**

- **Week 1:** Basic concepts. Brief historical perspective of statistical mechanics, Thermodynamic limit, concepts of micro and macro states, phase space trajectory, ergodic surfaces, Ensemble and distribution function in phase space, Liouville's theorem in classical and quantum statistical mechanics.

- **Week 2:** Fundamental theorem of statistical mechanics - postulate of equal a priori probability, Microcanonical theorem, Ergodic theorem, Thermodynamic Weight, Quantum statistical mechanics, Quantum Liouville's equation, Connection with thermodynamics - statistical mechanical definitions of entropy and temperature, recipe to get thermodynamics from microcanonical ensemble
- **Week 3,4:** Normal systems in statistical thermodynamics, Ansatz for a normal system and general relations for entropy, Equipartition theorem, Virial theorem, Adiabatic theorem, and Gibbs' paradox, Thermal contact between two systems, Thermal and particle transferring contact, Thermal and pressure transmitting contact.
- **Week 5-7:** Various ensembles in statistical mechanics -- Canonical ensemble, Grand canonical ensemble, and T-P ensemble.
- **Week 8-9:** Thermodynamic functions associated with various ensembles, Additivities of free energy, thermodynamic potential, and Gibbs free energy. Recipes to obtain thermodynamics in various ensembles. General expression for entropy and its application to the ensembles. Fluctuations -- in (a) energy, and (b) particle number.
- **Week 10-11:** Application of statistical mechanics -- Bose-Einstein distribution, Fermi-Dirac distribution, The classical limit and the Maxwell-Boltzmann distribution
- **Week 12-13:** Applications of Statistical Mechanics (contd) -- Perfect (non-interacting) ground state of a Fermi gas at  $T = 0$  and  $T < T_F$ , Blackbody radiation (photons), Phonons -- Einstein solid versus Debye solid
- **Week 14-15:** Application of Statistical Mechanics (contd) -- Ising model in 1 and 2 dimensions, Bose-Einstein condensation

### **Instructional Strategy**

The contents of the course will be offered in the form of lectures with emphasis in examples of applications to different branches of Condensed Matter Physics. The students are trained to apply the statistical mechanical techniques learnt to simple physical situations and setting up the problem mathematically, which is then solved using standard mathematical methods. A fair part of the lecturing effort is thus dedicated to the demonstration of solution of problems of kinetic theory, classical and quantum gases.

### **Minimum Facilities Required**

Traditional lecture room, High speed computers with broad band internet connection for the COVID situation.

### **Student Evaluation**

There will be four partial exams of equal weight distributed as follows:  
 Exam 1: Week 3, will include the materials covered in Weeks 1-2,  
 Exam 2: Week 7, will include the materials covered in Weeks 3-6,

Exam 3: Week 9, will include the materials covered in Weeks 7,8,

Exam 4: end-of-semester, will include the materials covered in Weeks 9-12.

There will be practice homework assignments containing problems (similar to the exams) to be solved and later discussed in the classroom. Problems in the exams will be based on examples done in class, suggested problems, and homework assignments.

## **Grading System**

The student completing the course work will be graded according to the standard scale A to F.

## **Text**

*Statistical Mechanics*, Donald A. McQuarrie, University Science Books, 2000, ISBN 978 1891389153

## **Bibliography**

Classic reference *An Introduction to Statistical Mechanics*, Terrell L. Hill, Dover Publications, 1987, ISBN 978 0486652429

**Additional learning resources** <https://www.khanacademy.org> Wikipedia

## **Rights of Students with Disabilities**

UPR complies with all federal and state laws and regulations regarding discrimination, including the Americans with Disabilities Act 1990 (ADA) and the Commonwealth of Puerto Rico Law 51. Students receiving services through Rehabilitaci3n Vocacional must contact the professor at the beginning of the semester in order to plan for a reasonable accommodation and any required support equipment according to the recommendations given by the Oficina de Asuntos para las Personas con Impedimentos (OAPI) of the Dean of Students. Likewise, students with special needs that require some type of accommodation must contact the professor.

## **Acomodo Razonable**

La Universidad de Puerto Rico cumple con todas las leyes federales, estatales y reglamentos concernientes a discriminaci3n, incluyendo "The American Dissabilities Act" (Ley ADA) y la Ley 51 del Estado Libre Asociado de Puerto Rico. Los estudiantes que reciban servicios de rehabilitaci3n vocacional deben comunicarse con el (la) profesor(a) al principio del semestre para planificar el acomodo razonable y equipo de apoyo necesario conforme a las recomendaciones de la Oficina de Asuntos para las Personas con Impedimento (OAPI) del Decanato de Estudiantes. Una solicitud de acomodo razonable no exime al estudiante de cumplir con los requisitos academicos del curso.

## **Academic Integrity**

La Universidad de Puerto Rico promueve los más altos estándares de Integridad académica y científica. El Artículo 6.2 del Reglamento General de estudiantes de la UPR (Certificación Núm. 13, 2009-2010, de la Junta de Síndicos) establece que “la deshonestidad académica incluye, pero no se limita a: acciones fraudulentas, la obtención de notas o grados académicos valiéndose de falsas o fraudulentas simulaciones, copiar total o parcialmente la labor académica de otra persona, plagiar total o parcialmente el trabajo de otra persona copiar total o parcialmente las respuestas de otra persona o las preguntas de un examen, haciendo o consiguiendo que otra tome en su nombre cualquier prueba o examen oral o escrito, así como la ayuda o facilitación para que otra persona incurra en la referida conducta”. Cualquiera de estas acciones estará sujeta a sanciones disciplinarias en conformidad con el procedimiento disciplinario establecido en el Reglamento general de Estudiantes de la UPR vigente.

### **Disciplinary Action in case of academic dishonesty**

Grade D will be given.

## **Hostigamiento**

La Universidad de Puerto Rico prohíbe el discrimen por razón de sexo y género en todas sus modalidades, incluyendo el hostigamiento sexual. Según la Política institucional contra el Hostigamiento Sexual en la Universidad de Puerto Rico, Certificación Núm. 130, 2014-2015 de la Junta de Gobierno, si un estudiante está siendo o fue afectado por conductas relacionadas a hostigamiento sexual, puede acudir ante la Oficina de la Procuraduría Estudiantil, el Decanato de Estudiantes o la Coordinadora de Cumplimiento con Título IX para orientación y/o presentar una queja