

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

Title: Thermodynamics and Statistical Mechanics

Code: PHYS 4057

Number of Credits: 3

Number of Hours: 3 hours of lecture per week

Prerequisites: PHYS 4031 (Mathematical Physics I)

PHYS 4051 (Classical Mechanics I)

Co-requisites: PHYS 4032 (Mathematical Physics II)

Effective date of the syllabus: First Semester, 2024-2025 academic year

Instructor Lutful Bari Bhuiyan

Office Natural Sciences II, C-350

Class period: Tuesdays and Thursdays, 1 pm - 2:20 pm Room C-311

Office hours: Mondays and Wednesdays, 8 am – 1 pm, 2 pm – 3.30 pm

Fridays 8 am – 12 noon, 2 pm – 3.30 pm

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Description

The zeroth law of thermodynamics and the concept of temperature. The First law and the conservation of energy. The Second law and the direction of natural process. Carnot's engine. Concept of entropy. Absolute scale of temperature. The Third law and simple applications. The principle of statistical mechanics: Thermodynamic weight, Statistical mechanical ideas of entropy and the connection with thermodynamics; the Maxwell-Boltzmann, the Bose-Einstein, and the Fermi-Dirac distributions.

Objectives

After completing this course the students will know the basic principles and laws of thermodynamics and statistical thermodynamics and their mathematical formulation as well as methods of investigations of basic thermodynamic phenomena. They will have clear idea about the limits of applicability of physical model and theories used in this course. The students will know the role of thermodynamics and statistical mechanics in the scientific and technical progress and will be able to apply these to actual physical problems. The student will have mastered and practiced the application of simple mathematical techniques to solve basic problems.

Course Content

- **Week 1,2:** Basic concepts -- Brief historical perspective – thermodynamics and statistical physics, Definitions of various thermodynamic terms, Concepts of work, energy, temperature and temperature scales. *Zeroeth Law of thermodynamics*, State functions.
- **Week 3,4:** *First Law of thermodynamics*. Equivalence of heat and mechanical energy

---- Joule's experiment . First Law of thermodynamics as a statement of conservation of energy. Internal energy ---- a state function, dQ equations. Applications of the First Law. Joule's free expansion, Specific heats of bodies, Internal energy of an ideal gas, Works done on an ideal gas in isothermal and adiabatic processes.

- **Week 5,6,7:** Enthalpy, Adiabatic processes. *Second Law of thermodynamics* and the direction of a natural process. Kelvin versus Clausius statements of the Second Law. Carnot engine and its efficiency. Carnot's theorem and the absolute scale of temperature. Concept of absolute zero. Concept of entropy and Clausius' theorem.
- **Week 8,9:** Properties of entropy, statistical mechanical ideas of entropy as a measure of disorder. Examples of Calculations of entropy – perfect gas, van der Waals gas. TdS equations.
- **Week 10,11:** Equilibrium of systems and thermodynamic potentials. Isolated systems, entropy never decreases. Constant volume processes and Helmholtz free energy. Constant pressure processes and Gibbs free energy. Maxwell's laws.
- **Week 12,13:** *Third Law of thermodynamics* or the Nernst Heat theorem -- Unattainability of absolute zero. Experimental evidence of Third Law – Lange's experiment. Some applications of the Third Law. Simple thermodynamic analysis of systems -- Van der Waal's equation and law of corresponding states, Blackbody radiation.
- **Week 14,15,16:** Statistical Mechanics. Brief history of the development of statistical mechanics. Basic concepts ---- microstates & macrostates, phase space trajectory. Ensemble, ergodic theorem. Fundamental postulate – postulate of equal a priori probability. Thermodynamic weight W and total number of possible microstates. Counting W -- cases of indistinguishable and distinguishable particles. Bose-Einstein, Fermi-Dirac, and Maxwell-Boltzmann statistics. Connection with thermodynamics.

Instructional Strategy

The content of the course will be offered in the form of lectures with emphasis in examples of applications to different branches of Condensed Matter Physics.

Minimum Facilities Required

Traditional lecture room.

Student Evaluation

There will be four partial exams of equal weight distributed as follows:

Exam 1: Week 5, will include the materials covered in Weeks 1-4,

Exam 2: Week 10, will include the materials covered in Weeks 5-9,

Exam 3: Week 14, will include the materials covered in Weeks 10-13,

Exam 4: end-of-semester, will include the materials covered in Weeks 14-16.

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

“Thermodynamics, Kinetic Theory, and Statistical Thermodynamics” III Edition ,1975, Authors F. W. Sears and G. L. Salinger, Addison- Wesley. ISBN 978 0201068948

Bibliography

Some useful references....

1. Jefferson W. Tester and Michael Modell, *Thermodynamics and Its Applications*
2. Dilip Kondepudi and Ilya Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures*, Wiley
3. Charles E. Hecht, *Statistical Thermodynamics and Kinetic Theory*

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 m1s altos est1ndares de Integridad acad3mica y cient3fica. El Art3culo 6.2 del Reglamento General de estudiantes de la UPR (Certificaci3n N1m. 13, 2009-2010, de la Junta de S3ndicos) establece que “la deshonestidad acad3mica incluye, pero no se

limita a: acciones fraudulentas, la obtenci3n de notas o grados acad3micos vall1ndose 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.

