Hong Kong Baptist University
Faculty of Science – Department of Physics

Title (Units): **PHYS 3047** **THERMAL AND STATISTICAL PHYSICS (3, 3, 1)**

Course Aims: This is a foundation course on thermodynamics and statistical physics. The basic postulates and framework of statistical mechanics will be laid out. Connections to Newton's laws in phase space will be included. Different kinds of free energy for different ensembles will be discussed, followed by applications of the statistical formalism to simple thermodynamic systems in physics and/or chemistry. Quantum statistics of bosons and fermions will also be introduced.

Pre-requisite: PHYS 2005 Heat and Motion, or consent of instructor.

Course Reviewed by: Dr. Kin-Yiu Wong and Prof. Michel A. Van Hove.

Course Intended Learning Outcomes (CILOs):

No.	Upon successful completion of this course, students should be able to:
	Knowledge
1.	Explain the concepts of intensive and extensive variables in thermodynamics, which can be used to describe Maxwell relations for different ensembles: microcanonical, canonical, grand canonical, and isothermal-isobaric.
3.	Compare different kinds of thermodynamic energy: internal energy, enthalpy, Helmholtz free energy, Gibbs free energy, grand potential energy, chemical potential.
4.	Establish the relation between Newtonian motions and thermodynamic free energy/partition function in phase space, e.g., the statistical formalism that connects the microscopic energy to macroscopic free energy.
	Skill
5.	Apply math skills: (1) Legendre transformation between intensive and extensive variables in thermodynamics, and (2) the partial differentiation and Lagrange multiplier to extremize the entropy that is consistent with Boltzmann's distribution.
6	Apply Boltzmann's statistical formalism to compute thermodynamic properties of simple systems in physics and/or chemistry.

Teaching & Learning Activities (TLAs)

CILOs	TLAs will include the following:
1-6	Lectures are given to provide a systematic exposition of the subject in relation to the course objectives. Students are encouraged to ask questions during the class, and to make frequent summaries of the classroom discussion.
4-6	Tutorials are organized to train and improve the problem-solving skills of the students. Various techniques, such as graphic representation of functions and analysis of limiting and extremizing situations, will be introduced. Peer learning in the form of student-led discussion of homework problems will be encouraged.
1-6	Students are required to complete a set of homework given out regularly to enforce learning through practice.

Assessment Methods (AMs):

Type of Assessment Methods	Weighting	CILOs to be addressed	Description of Assessment Tasks
Continuous Assessment (e.g., homework, mid-term test)	50%	1-6	Continuous Assessments are designed to measure how well the students have learned the basic concepts and fundamental theory, as well as acquired the relevant problem-solving skills.
Final Examination	50%	1-6	Final Examination is designed to assess how far students have achieved the intended learning outcomes. Questions will primarily be of analytical nature so that the student's versatility in performing the necessary reasoning and calculations can be evaluated.

Learning Outcomes and Weighting:

Content	CILO No.	Teaching (in hours)
I. Newtonian motions and thermodynamic phase space	1-6	24
II. Classical free energy/partition function	4-6	5
III. Quantum free energy/partition function	4-6	7

Textbook: C. Kittel and H. Kroemer, Thermal Physics, 2nd Ed., W.H. Freeman and Company, 1980.

References:

1. F. Mandl, Statistical Physics, 2nd Ed., John Wiley & Sons, 1988.
2. R. Baierlein, Thermal Physics, Cambridge University Press, 1999.
3. D. V. Schroeder, An Introduction to Thermal Physics, Addison Wesley, 2000.
4. F.W. Sears and G.L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, 3rd Ed., Addison Wesley, 1975.
5. H. Gould and J. Tobochnik, Statistical and Thermal Physics With Computer Applications, Princeton University Press, 2010.
6. F. Reif, Fundamentals of Statistical and Thermal Physics, Waveland Press, 2008.
7. L.E. Reichl, A Modern Course in Statistical Physics, 2nd Ed., John Wiley & Sons, 1998.
8. D.A. McQuarrie, Statistical Mechanics, University Science Books, 2000.

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Course Content in Outline:

	Topic	**Hours**
I.	Newtonian motions and thermodynamic phase space	24
	A. Revision of thermodynamics quantities and laws	
	B. Legendre transformation between intensive and extensive variables	
	C. Maxwell relations for different ensembles: microcanonical, canonical, grand canonical, and isothermal-isobaric	
	D. Partition function, internal energy, enthalpy, Helmholtz free energy, Gibbs free energy, grand potential energy	
	E. Relation between Newtonian motions (e.g., microscopic energy) and thermodynamic free energy/partition function in phase space	
	F. Principle of maximum entropy and minimum free energy	
	G. Partial differentiation and Lagrange multiplier	
	H. Boltzmann distribution and chemical potentials	
II.	Classical free energy/partition function	5
	A. Translational free energy/partition function	
	B. Rotational free energy/partition function	
	C. Vibrational free energy/partition function	
	D. Equipartition theorem	
	E. Heat capacity	
III.	Quantum free energy/partition function	7
	A. Fermi-Dirac distribution, Fermi energy	
	B. Bose-Einstein distribution, black-body radiation energy	
	C. Planck’s law, Wien’s Displacement law, Stefan-Boltzmann’s law, Rayleigh-Jeans law	