Course Syllabus

Course Information

PHYSICS 5313: STATISTICAL PHYSICS
Section 001: January 13 – April 30, 2009
Classes: TR 11:30 am – 12:45 pm in GR 4.204

Contact Information

INSTRUCTOR: Dr. Yuri Gartstein					
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Office hours: TBA		Extra sessions: As needed			
Web communication and access to course materials: http://webct6.utdallas.edu					

Course Pre-requisites, Co-requisites, and/or Other Restrictions

It is assumed that students have a basic working knowledge of classical and quantum mechanics, including Hamiltonian formulation and density matrices.

Goals and Student Learning Objectives/Outcomes

This is a graduate level course on principles of statistical mechanics and their applications to various physical systems. Quoting from Richard Feynman, "The key principle of statistical mechanics is as follows: If a system in equilibrium can be in one of [n=1,...,] N states, then the probability of the system having energy E_n is $(1/Q)\exp(-E_n/kT)$, where $Q=\Sigma_n \exp(-E_n/kT)$, k = Boltzmann's constant, and T = temperature... This fundamental law is the summit of statistical mechanics, and the entire subject is either the slide-down from this summit, as the principle is applied to various cases, or the climb-up to where the fundamental law is derived and the concepts of thermal equilibrium and temperature T clarified." In this course we will spend more time on the "slide-down", pragmatically studying how general principles of statistical mechanics actually work in some simple and complex systems, and what powerful notions and ideas have been developed to approach complex cases. Our focus will be on exploring relationships between macroscopic properties of "large" systems and microscopic behavior of the particles these systems are comprised of. The richness and complexity of behavior exhibited by many-particle systems is incredible; in this course, however, we would be able to touch upon only very few illustrating examples.

We will be dealing with elements of statistical thermodynamics, elements of kinetics and elements of the theory of phase transitions. Upon completion of the course, the instructor would like to have students clearly understand basic principles, be able to see relationships between ideas, and, most importantly, be "fluent" in using principles and ideas in "calculating" properties of simpler statistical systems. Students in this class will

- Learn different statistical ensembles, their distribution functions, ranges of applicability and the corresponding thermodynamic potentials
- Apply classical and quantum distributions in circumstances varying from standard examples to statistics of charge carriers in semiconductors, chemical reactions and ions in electrolyte solutions
- Learn relationship between equilibrium distributions and kinetic processes leading to equilibrium
- Become aware of the richness and complexity of statistical behavior exhibited by interacting systems and various approaches (phenomenological and microscopic) developed to comprehend such systems

I can't help ending with another quotation, from Leo Kadanoff: "Why should one study statistical physics?... First of all, it is in itself a beautiful subject... In addition, of course, statistical physics is important as a tool... Subjects as diverse as chemical reaction rates, the structure of black holes, the behavior of stock prices... are all studied with the aid of tools which are part of statistical mechanics. Another reason... is that it is a subject of up-to-date research interest. [Many topics]... are, to a large extent, not really understood."

Course Description

This brief high-level description is intended just to give you a glimpse of the subjects, a selection of topics from which we will be discussing (not necessarily in the same order and to different depths). More detailed subject listings will be available online as we proceed along.

FOUNDATIONS OF STATISTICAL MECHANICS AND THERMODYNAMICS
Thermal equilibrium and thermodynamic limit; Averages and fluctuations; Macro- and microstates; Phase space, distribution functions and density matrices; Liouville's theorem and its quantum analogue; Statistical entropy and principle of maximum entropy; Ensembles: microcanonical, canonical and grand canonical; Partition function and chemical potential; Thermodynamic potentials and laws of thermodynamics.

APPLICATIONS TO NON-INTERACTING SYSTEMS
Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein distributions; Equations of state for ideal gases; Non-equilibrium ideal gases; Thermodynamic properties of non-interacting magnetic moments, oscillators and simple gases; Degenerate electron gas, its specific heat and magnetism; Statistics of carriers in semiconductors; Bose-Einstein condensation; Black-body radiation; Phonons and specific heat of solids.

FLUCTUATIONS AND ELEMENTS OF KINETICS
Boltzmann transport equation and H-theorem; Pressure of an ideal gas; Relaxation time and conductivity of metals; Brownian motion, random walks and Langevin equation; Einstein's relation; Gaussian distributions and fluctuations in ideal gases; Linear response, susceptibility and correlation functions; Fluctuation-dissipation theorem

PHASES AND PHASE TRANSITIONS
Phases and phase diagrams; Discontinuities and phase transitions of the first and second order; Ising and other lattice spin models; Ordering, order parameters and broken symmetries; Mean-field theory of ferromagnetism; Landau theory of phase transitions; Ginzburg-Landau theory; Fluctuations and long-range order; Some exact results; Modern theory of critical phenomena: ideas of universality, scaling and renormalization, critical exponents.

NON-IDEAL GASES, POLYMERS, SUPERFLUIDS AND ALL THAT
Virial and cluster expansions, van der Waals equation of state; Pair correlation function; Screening of charges: Poisson-Boltzmann and Thomas-Fermi equations; Random walks and

conformations of polymer chains; Bose-Einstein condensate, superfluidity and the nature of the superfluid order parameter; Elementary excitations in liquid He^4 and Landau theory.

Textbooks and Materials

For a host of topics, many graduate and advanced undergraduate level textbooks that you already may have should work to a large extent. Listed below are some texts that I personally happen to use materials from and which you could also find useful. No special priority is intended in the sequence of the books and **there is no need** to spend substantial amounts to acquire original editions (some are available in inexpensive editions) or to have many books. I will show you more books in class that you may like on a personal basis.

1. **F. Schwabl, "Statistical Mechanics"** (2002), ISBN 3540431632.
2. **R.K. Pathria, "Statistical Mechanics"** (2nd edition, 1996), ISBN 0750624698.
3. **L.D. Landau and E.M. Lifshitz, "Statistical Physics (Part 1)"** (3rd edition, 1980), ISBN 0750633727. This is volume 5 of the famous Course of Theoretical Physics.
4. **G.H. Wannier, "Statistical Physics"**. ISBN 048665401X.
5. **K. Huang, "Statistical Mechanics"** (2nd edition, 1987), ISBN 0471815187.
6. **K. Huang, "Introduction to Statistical Physics"** (2001), ISBN 0748409424. This book is available online through the UTD library. It is aimed at advanced undergrads but without losing the physical depth and perspective.

Assignments, Evaluation and Grading Policy

In accordance with the course objectives, conceptual understanding and ability to apply principles to actual problem solving is the key to high grades. The final grade will be comprised of contributions from the homework (~60%), the course project (~20%) and the final exam (~20%). Your consistent effort during the whole semester is evidently highly valued. Homework assignments are expected to be done by the due date, however an extra week may be given to submit improved versions; it is the intent of the instructor to have open discussions of some homework problems during classroom hours. The homework may include not only problems but also self-study topics. The course project is an individual topic/problem given by the instructor (students' suggestions are welcome) that a student would have an ample time to prepare using various resources with the final delivery in the form of a short paper and a presentation to the class. The final exam or meeting takes place on UTD schedule (**May 12** at **11:00 am**).

Course & Instructor Policies

Every attempt will be made to give students an opportunity to improve their standing. That includes the possibility of individual make-up testing at the end of the semester. A proactive student's position in and out of the classroom is encouraged and expected, and your feedback is always welcome. Attendance of lectures is strongly advised but not required. The integrity of students' behavior matters - working in groups and using various materials is encouraged but it is the individual understanding of the subject and results that will be tested: a student should be able to explain his/her solution. All special student needs should be reported within first two weeks of the course.

Communication of all grades and announcements will be through WebCT, it is the **responsibility of students** to regularly check their WebCT pages and email.

Last but not least, the instructor strongly feels that satisfaction one gets from the learning accomplishments makes "grades" a much less sensitive issue. My general position is that "I am here not to make your life harder but to help you learn". I would like to invite all students to have more fun from learning and worry less about grading.

Off-campus Instruction and Course Activities

Off-campus, out-of-state, and foreign instruction and activities are subject to state law and University policies and procedures regarding travel and risk-related activities. Information regarding these rules and regulations may be found at the website address http://www.utdallas.edu/BusinessAffairs/Travel_Risk_Activities.htm. Additional information is available from the office of the school dean.

Student Conduct & Discipline

The University of Texas System and The University of Texas at Dallas have rules and regulations for the orderly and efficient conduct of their business. It is the responsibility of each student and each student organization to be knowledgeable about the rules and regulations which govern student conduct and activities. General information on student conduct and discipline is contained in the UTD publication, *A to Z Guide*, which is provided to all registered students each academic year. The University of Texas at Dallas administers student discipline within the procedures of recognized and established due process. Procedures are defined and described in the *Rules and Regulations, Board of Regents, The University of Texas System, Part 1, Chapter VI, Section 3*, and in Title V, Rules on Student Services and Activities of the university's *Handbook of Operating Procedures*. Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations (SU 1.602, 972/883-6391). A student at the university neither loses the rights nor escapes the responsibilities of citizenship. He or she is expected to obey federal, state, and local laws as well as the Regents' Rules, university regulations, and administrative rules. Students are subject to discipline for violating the standards of conduct whether such conduct takes place on or off campus, or whether civil or criminal penalties are also imposed for such conduct.

Academic Integrity

The faculty expects from its students a high level of responsibility and academic honesty. Because the value of an academic degree depends upon the absolute integrity of the work done by the student for that degree, it is imperative that a student demonstrate a high standard of individual honor in his or her scholastic work.

Scholastic dishonesty includes, but is not limited to, statements, acts or omissions related to applications for enrollment or the award of a degree, and/or the submission as one's own work or material that is not one's own. As a general rule, scholastic dishonesty involves one of the following acts: cheating, plagiarism, collusion and/or falsifying academic records. Students suspected of academic dishonesty are subject to disciplinary proceedings. Plagiarism, especially from the web, from portions of papers for other classes, and from any other source is unacceptable and will be dealt with under the university's policy on plagiarism (see general catalog for details). This course will use the resources of turnitin.com, which searches the web for possible plagiarism and is over 90% effective.

Email Use

The University of Texas at Dallas recognizes the value and efficiency of communication between faculty/staff and students through electronic mail. At the same time, email raises some issues concerning security and the identity of each individual in an email exchange. The university encourages all official student email correspondence be sent only to a student's U.T. Dallas email address and that faculty and staff consider email from students official only if it originates from a UTD student account. This allows the university to maintain a high degree of confidence in the identity of all individual corresponding and the security of the transmitted information. UTD furnishes each student with a free email account that is to be used in all communication with university personnel. The Department of Information Resources at U.T. Dallas provides a method for students to have their U.T. Dallas mail forwarded to other accounts.

Withdrawal from Class

The administration of this institution has set deadlines for withdrawal of any college-level courses. These dates and times are published in that semester's course catalog. Administration procedures must be followed. It is the student's responsibility to handle withdrawal requirements from any class. In other words, I cannot drop or withdraw any student. You must do the proper paperwork to ensure that you will not receive a final grade of "F" in a course if you choose not to attend the class once you are enrolled.

Student Grievance Procedures

Procedures for student grievances are found in Title V, Rules on Student Services and Activities, of the university's *Handbook of Operating Procedures*. In attempting to resolve any student grievance regarding grades, evaluations, or other fulfillments of academic responsibility, it is the obligation of the student first to make a serious effort to resolve

the matter with the instructor, supervisor, administrator, or committee with whom the grievance originates (hereafter called "the respondent"). Individual faculty members retain primary responsibility for assigning grades and evaluations. If the matter cannot be resolved at that level, the grievance must be submitted in writing to the respondent with a copy of the respondent's School Dean. If the matter is not resolved by the written response provided by the respondent, the student may submit a written appeal to the School Dean. If the grievance is not resolved by the School Dean's decision, the student may make a written appeal to the Dean of Graduate or Undergraduate Education, and the deal will appoint and convene an Academic Appeals Panel. The decision of the Academic Appeals Panel is final. The results of the academic appeals process will be distributed to all involved parties. Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations.

Incomplete Grade Policy

As per university policy, incomplete grades will be granted only for work unavoidably missed at the semester's end and only if 70% of the course work has been completed. An incomplete grade must be resolved within eight (8) weeks from the first day of the subsequent long semester. If the required work to complete the course and to remove the incomplete grade is not submitted by the specified deadline, the incomplete grade is changed automatically to a grade of **F**.

Disability Services

The goal of Disability Services is to provide students with disabilities educational opportunities equal to those of their non-disabled peers. Disability Services is located in room 1.610 in the Student Union. Office hours are Monday and Thursday, 8:30 a.m. to 6:30 p.m.; Tuesday and Wednesday, 8:30 a.m. to 7:30 p.m.; and Friday, 8:30 a.m. to 5:30 p.m.
The contact information for the Office of Disability Services is:
The University of Texas at Dallas, SU 22
PO Box 830688
Richardson, Texas 75083-0688
(972) 883-2098 (voice or TTY)
Essentially, the law requires that colleges and universities make those reasonable adjustments necessary to eliminate discrimination on the basis of disability. For example, it may be necessary to remove classroom prohibitions against tape recorders or animals (in the case of dog guides) for students who are blind. Occasionally an assignment requirement may be substituted (for example, a research paper versus an oral presentation for a student who is hearing impaired). Classes enrolled students with mobility impairments may have to be rescheduled in accessible facilities. The college or university may need to provide special services such as registration, note-taking, or mobility assistance.
It is the student's responsibility to notify his or her professors of the need for such an accommodation. Disability Services provides students with letters to present to faculty members to verify that the student has a disability and needs accommodations. Individuals requiring special accommodation should contact the professor after class or during office hours.

Religious Holy Days

The University of Texas at Dallas will excuse a student from class or other required activities for the travel to and observance of a religious holy day for a religion whose places of worship are exempt from property tax under Section 11.20, Tax Code, Texas Code Annotated. The student is encouraged to notify the instructor or activity sponsor as soon as possible regarding the absence, preferably in advance of the assignment. The student, so excused, will be allowed to take the exam or complete the assignment within a reasonable time after the absence: a period equal to the length of the absence, up to a maximum of one week. A student who notifies the instructor and completes any missed exam or assignment may not be penalized for the absence. A student who fails to complete the exam or assignment within the prescribed period may receive a failing grade for that exam or assignment. If a student or an instructor disagrees about the nature of the absence [i.e., for the purpose of observing a religious holy day] or if there is similar disagreement about whether the student has been given a reasonable time to complete any missed assignments or examinations, either the student or the instructor may request a ruling from the chief executive officer of the institution, or his or her designee. The chief executive officer or designee must take into account the legislative intent of TEC 51.911(b), and the student and instructor will abide by the decision of the chief executive officer or designee.

These descriptions and timelines are subject to change at the discretion of the Professor.