PHY5500: Thermal Physics Fall 2013
M T Th F 10:40AM - 11:35AM

Instructor: Prof. Boris Nadgorny
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Office hours: Thursday 2 –3 p.m. or by appointment

Texts

1) Harvey Gould and Jan Tobochnik, Statistical and Thermal Physics, Princeton University Press, 2010, ISBN 978-0-691-13744-5 The updated Chapters are available at http://stp.clarku.edu/notes; simulations at http://stp.clarku.edu/simulations

2) Enrico Fermi, Thermodynamics, Dover, New York.

Addition References

Undergraduate Texts:
H.C. van Ness, Understanding Thermodynamics, Dover: qualitative discussion of some basic ideas.
Callen – Thermodynamics and Statistical Physics: good classical thermodynamics reference.
Kittel and Kroemer – Thermal Physics: a very nice book, consistent statistical approach, but is not easy read.

Graduate Texts:
L. D. Landau and E. M. Lifshitz, Statistical Physics: an original approach, some useful topics (e.g. changes of variables, fluctuations).
R. K. Pathria, Statistical Mechanics: a popular graduate textbook
K. Huang, Statistical Mechanics: another common graduate textbook.

Course Description and Objectives
PHY 5500 course is devoted to the study of systems made of a large number of particles, an area of thermal physics and statistical mechanics, which governs transformations of heat into mechanical work, phase transitions, properties of gases and solids, and many other fundamental phenomena. Statistical physics is one of a few indispensable subjects widely used in chemistry, biology, geology, meteorology, environmental science, cosmology, low-

temperature physics, solid state physics, atomic physics, and engineering. Therefore, thorough knowledge of statistical mechanics is of utmost importance to any aspiring scientist or engineer. This course covers the basic principles of thermodynamics and statistical physics. The principal objectives of this introductory course are for you to learn fundamental concepts of thermodynamics and statistical physics and to develop the problem-solving skills to apply these fundamentals. Since professional scientists and engineers must be proficient problem solvers, and it is impossible to really understand any area of physics without solving problems. Sufficient knowledge of calculus of many variables is required.

List of Topics

1. Introduction. The scope of thermal physics. Microstates vs. microstates. Multiplicity. Pressure and temperature.
2. The ensemble average. The ideal gas; the ideal gas law.
3. Thermodynamic concepts and processes. Thermodynamic equilibrium. Temperature. Equation of state.
4. Thermodynamic processes. Work, energy, and heat. The first Law of thermodynamics. Isothermal and adiabatic processes. Energy equation of state. Heat capacities and enthalpy. The Second Law of thermodynamics. Entropy. The Thermodynamic temperature. Heat Engines. The Carnot cycle.
5. Examples of entropy changes. Free expansion of gas. Equivalence of Thermodynamics and Ideal gas temperature scales. The thermodynamic pressure. Fundamental thermodynamics relationship.
6. The entropy of an ideal classical gas. The third law of thermodynamics Free energy (Gibbs, Helmholtz). The grand potential (Landau potential).
7. Thermodynamics derivatives. The Maxwell relations. The chain rules (lecture notes). Relation between heat capacities. Joule –Thompson process.
8. Concept of probability. Mean values. Binominal distribution. Stirling's approximation. Continuous probability distribution. The central limit theorem.
9. Formulation of statistical mechanics. The role of energy. Thermal interaction. Einstein solids. Non-interacting spins. 1D harmonic oscillator. A particle in a box. Calculating the number of microstates. Semi-classical limit.
10. The micro-canonical ensemble. Entropy. The canonical ensemble. The Boltzmann distribution. The partition function. Connection between thermodynamics and statistical mechanics. Distinguishable and indistinguishable particles.
11. Grand canonical ensemble. Fluctuations.
12. Magnetic systems. Noninteracting magnetic moments. The Ising Model (1D). 2D Ising model – computer simulation, mean field theory.

13. Many particle systems. Ideal gas (semi-classical limit). The entropy of an ideal classical gas. Entropy of mixing. The Gibbs paradox. The equipartition theory. The Maxwell velocity distribution. Effusion.
14. Fermi and Bose statistics. Distribution functions of ideal Bose and Fermi gases. Density of states. Photons. Non-relativistic and ultra-relativistic limits. Black body radiation. Ideal Fermi gas. The Einstein solid.
15. Ideal Bose gas. Bose Einstein condensation. Fluctuations in a number of particles (Ch. 6).
16. Chemical potential and phase transformations. Phase diagrams. Clausius – Clapeyron equation. Van der Waals equation of state.

Homework

There will be about 8-10 homework assignments during the semester. To receive full credit, the solutions should be clearly written and explain all the important steps. It is acceptable (and can be very useful) to discuss homework problems with each other and compare different possible solutions. However, you are not allowed to copy the work of others or use problem solutions obtained from any source. If two identical papers are submitted, each student, after receiving a warning, will only be credited 50% of the total score; no score will be given the second time. Late homework will be accepted (until the solutions are posted), but the score will be reduced by 10-25 %.

Exams

There will be one midterm exam and an all-encompassing final exam at the end of the semester. Textbooks, notes, graphing calculators or any other aids will not be allowed at the exams.

Quizzes

In-class quizzes will be given randomly (at the instructor discretion) in the form of short (about 15 minutes) problems or conceptual questions based on recent coursework for at the end of a class on the material discussed earlier in class and/or homework assignments. There will be approximately five of them in the course of the semester.

Bonus Problems

A few bonus problems (typically conceptual problems) will be given in class. Students will be able to discuss them with each other, while the lecturer will moderate the discussion. By the end of the class students will briefly answer the question based on their assessment of the arguments. In addition to scores given for these questions, the students will be able to get participation points during this discussion.

Participation

Your participation will be factored in your final grade. Participation may take different forms: asking questions, making comments, being able to answer questions, and taking part in discussions of bonus questions. In other words, you need to show that you follow the arguments during a lecture (by both asking and answering questions), demonstrate critical thinking in our discussions of bonus problems. In summary, you need to be a thoughtful discussion participant to receive full credit.

Grading

Your total score will be calculated as follows:
Homework 15%
In-class quizzes 20%
Midterm exam 20%
Final exam 40%
In-class participation 5%
Bonus problems 5%

Total: 105

Grades: A [91-100], A- [87-90], B+ [83-86], B [79-82], B- [75-78], C+ [71-74], C [66-70], C- [60-65], D+ [55-60], D [50-55], D- [45-50].

Test policy

You must notify the instructor as soon as possible if you expect to miss or have missed an exam for valid reasons (illness, family emergency, etc). If a student misses a final exam due to these reasons a make-up exam will be administered. For the midterm no make-up exam will be given. However, if a student misses the midterm exam for legitimate reasons, 50% of their score for the final can be used to make up for the missed exam. The scores for all assignments will be posted on Blackboard. Total scores for all students may be adjusted at the instructor discretion.

Students with Disabilities

Students with disabilities are provided with full and equal participation in the services and activities of Wayne State University. Reasonable and effective accommodations, academic adjustments and /or auxiliary aids as determined on a case-by-case basis. More information is available at http://studentdisability.wayne.edu/rights.php