Course Syllabus

1 Syllabus Description

This course examines the basic principles of statistical mechanics and their relation to the laws of thermodynamics and the concepts of temperature, work, heat, and entropy. Microcanonical, canonical, and grand canonical distributions; applications to lattice vibrations, ideal gas, photon gas, quantum statistical mechanics; Fermi and Bose systems, interacting systems.

2 Educational objectives

The objectives of this course are to

1. provide an introduction to statistical mechanics.
2. establish the link to continuum mechanics and thermodynamics.
3. present statistical treatment of transport phenomena.
4. overview areas of applications in current technologies.
5. cover some of the challenges and future directions.

3 Textbook

The suggested text is *The Principles of Statistical Mechanics* by R. Tolman (Oxford University Press).

4 Problem sets, exams and grading

The final grade in the course will be based upon analytical homework assignments, a midterm, and a project class performance weighted as follows:

- 20 % Homework assignments: Problem Sets will be assigned and collected at the end of the lecture on the due date.
- 30 % Mideterm: 120 minutes. Open book. Will be given in class.
- 50 % Final: 180 minutes. Open book. Will be given in class.

5 Short Course outline

1. Introduction: motivation, historical overview, statistical mechanics vs. quantum mechanics, statistical mechanics and thermodynamics. Statistical mechanics applications in MEMS and NEMS.

2. Review of thermodynamics and transport phenomena.

3. Principles of classical Newtonian Mechanics (classical relativistic mechanics briefly covered in exercises): generalized coordinates and velocities, Lagrangian, Hamiltonian and generalized momenta. Equations of motion in Lagrangian form and canonical form and their relation to Newton's second law. Time rate of change of physical quantities. canonical transformations.

4. Probability and Random Variables: Random Variables: Discrete, Continuous, and Mixed, Multiple Variables: Joint and Conditional Densities, Functions of a Random Variable, Sums of Random Variables. Relevant examples.

5. Statistical ensembles in classical mechanics. Ensembles and phase space. Distribution density and ensemble average. Change of distribution density with time. Conditions for statistical equilibrium. The Uniform ensemble. The Microcanonical ensemble. The Canonical ensemble. The postulate of equal a priori probabilities in phase space. Choice of representative ensemble for a system of interest. How valid is statistical mechanics.

6. The Maxwell-Boltzmann distribution law as an example of microcanonical ensemble representing system at equilibrium. Equipartition.

7. Collisions. Reversibility. Reflectability. Molecular states, constellations and collisions. Applying conservations laws to collisions and the probability coefficients of collisions.

8. How does quantum mechanics make it necessary to modify the classical ideas? Quantization effects in molecular gases; phonons, photons; density matrix formulation. Degenerate quantum gases; Fermi liquids; Bose condensation; superfluidity.

9. Statistical thermodynamics. Analogues of the laws of thermodynamics. Statistical-mechanics analogues of entropy, temperature and free-energy. Interacting and non-interacting systems.

7 References

1. Huang, Kerson. Statistical Mechanics. 2nd ed. New York, NY: Wiley, 1987. ISBN: 0471815187.

2. Pathria, R. K. Statistical Mechanics. New York, NY: Pergamon Press, 1984. ISBN: 0080189946.

3. Pippard, A. B. Elements of Classical Thermodynamics for Advanced Students of Physics. Cambridge, UK: University Press, 1966.

4. Ma, Shang-keng. Statistical Mechanics. Translated by M. K. Fung. Philadelphia, PA: World Scientific, 1985. ISBN: 9971966069 (Singapore), 9971966077 (Singapore: pbk).

5. Landau, L. D., and E. M. Lifshitz. Statistical Physics. Part 1. 3rd ed. New York, NY: Pergamon, 1980. ISBN: 0080230385.

6. Reif, Frederick, ed. Fundamentals of Statistical and Thermal Physics. New York, NY: McGraw-Hill, 1965.

7. Feynman, Richard Phillips. Statistical Mechanics. Reading, MA: Addison-Wesley, 1998. ISBN: 0201360764.