Physics 375: Thermal Physics — *Spring 2019*

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	Room	Time
Lecture	Gulick 223	11:15-12:10 MWF

Text

- Charles Kittel and Herbert Kroemer, *Thermal Physics*, 2nd Edition (Freeman, 1980)

Recommended Texts

- David L. Goodstein, *States of Matter* (Dover Publications, 1975)
- Charles Kittel, *Elementary Statistical Physics* (Dover Publications, 1958)
- Daniel V. Schroeder, *An Introduction to Thermal Physics* (Addison Wesley, 1999)
- Frederick Reif, *Fundamentals of Statistical and Thermal Physics* (McGraw-Hill, 1965)

Course Objectives
This course is a rigorous introduction to thermal physics using statistical mechanics. After completion of the course, students will be able to analyze simple models for a wide range of physical systems using statistical techniques.

About Physics 375
Thermal Physics is the study of the properties of systems composed of very very large numbers of particles. The main thrust of the course will be the study of statistical mechanics, or the study of the average mechanical properties of a system. We will also briefly touch upon thermodynamics, which is much more phenomenological and more general. Statistical mechanics and thermodynamics apply to an amazingly large range of systems, including neutron stars, black holes, heat engines, rubber bands, gases, chemical reactions, nuclear reactions, electrons in metals, photon gases, magnetic materials, and superfluid liquid helium to name a few. We will start from the consideration of the multiplicity of allowed states in a system and define entropy and temperature. From these definitions follow most of the rest of the course.

As an undergraduate, I did not want to learn thermal physics because I thought that heat engines were not a very interesting topic, certainly not as interesting as electricity and magnetism. My advisor insisted, though. Heat engines were only a small part of the course I took. After I finished the course on thermal physics, I thought that it was the most interesting thing I had learned up to that time. I hope you all will be as happy with the material as I am!

Course Requirements
Regular Homework Problems
2 Exams
Final Exam

Time Requirements
In addition to three lectures a week, students should expect to spend five to ten hours per week on studying and homework.

Office Hours
Office hours initially are Tuesday 11:00 - noon, Friday 2:00 - 4:00, and by appointment.

Attendance Policy
Attendance is not required but spotty attendance will result in a low participation score in the final grade.

Early & Late Policy
Late work will not be accepted without prior approval. Approval will not be granted without a sufficient reason. **There will be no makeup for the final exam and neither will exams be given early.** Athletes engaged in post-season play may take the final exam on the road **at the time set by the Registrar** if it will be closely proctored by a coach.

Grading
Grades in this class will be based on the following elements.

- **Participation** I expect each student to do the assigned readings and problems and to bring questions and comments to class and to participate in class discussions. Implicit in this is the expectation that all students will attend all classes. The grade for participation will be assigned at my discretion at the end of the semester.

- **Homework** Homework will be assigned on a regular basis and collected. Late homeworks will not be accepted without prior approval. You may work together on the homework. Indeed, I encourage you to work together to understand the problems. However, you must each separately write up solutions in your own words (and equations) and may not turn in something you do not understand. (That is, you may not simply paraphrase someone else's solution as your own.) Paraphrasing without understanding, or outright copying, will be considered plagiarism.

- **Exams** There will be two hour exams and a final exam. The final exam will be comprehensive. Dates for the hour exams will be announced in lecture. The final exam will be in the period set by the Registrar, which should be Saturday May 11th at 7:00 PM.

- **Quizzes** There may be quizzes in class, mostly for your own diagnostic use. Any quizzes will be announced in advance and will count towards your participation grade.

The relative weights of each element of the grade for the course is as follows.

Element	Weight
participation	10%
homework	30%
hour exams	30%
final exam	30%

Disability Accommodations
Students with a documented disability for which they may need accommodations should self-identify and register for services with Ms. Christen Davis (x3351), the Coordinator of Disability Services at the CTL. Accommodations and services generally will not be provided until the registration and documentation process is complete. See the guidelines for documenting disabilities.

Academic Integrity
Students should familiarize themselves with the principles of academic integrity in the handbook of community standards. At the advanced level it is very easy to spot work that is not one's own. Work on an exam that is clearly not one's own will receive zero credit. **I must mention any academic dishonesty in any recommendation letter I write.** I consider such deceit to be indicative of untrustworthiness and low moral character in general. Often the thing I remember best about a student years later is that the student was dishonest.

Syllabus Revision Policy
This syllabus is subject to correction and revision. Any revised version will be distributed on my website and notice of revision will be given in class. The grading policy is only subject to revisions that cannot result in a lower letter grade for any set of scores. The latest version will always be at http://people.hws.edu/tjallen/Physics375/Syllabus375-2019S.pdf.

Course Outline

This outline is a bit ambitious, but we should get through most of the material.

I. COUNTING STATES (1.5 weeks)
- *A.* Examples of systems with discrete energy levels.
- *B.* Generating functions & Counting
- *C.* Spin systems and binary alloys.
- *D.* Multiplicity functions.
- *E.* Sharpness of the multiplicity function.

II. ENTROPY & TEMPERATURE (1 week)
- *A.* Fundamental assumption of statistical physics: Microcanonical ensemble.
- *B.* Systems and Reservoirs
- *C.* Probability and counting.
- *D.*Thermal equilibrium & Entropy.
- *E.* Laws of Thermodynamics.

III. BOLTZMANN DISTRIBUTION (1.5 weeks)
- *A.* The Canonical Ensemble: Partition Functions.
- *B.* Thermodynamic relations
- *C.* Helmholtz Free Energy.
- *D.* Example: First look at the ideal gas.
- *E.* Classical Boltzmann distribution: Equipartition theorem.

IV. THERMAL RADIATION (1.3 weeks)
- *A.* System: photons in a box
- *B.* Planck distribution.
- *C.* Planck law.
- *D.* Stefan-Boltzmann law.
- *E.* Phonons in solids: Debye theory.

V. CHEMICAL POTENTIAL & SYSTEMS WITH VARIABLE PARTICLE NUMBER (1 week)
- *A.* Chemical potential.
- *B.* Gibbs factor.
- *C.* Grand Canonical Ensemble: Grand Partition Function.

VI. IDEAL GASES (2.6 weeks)
- *A.* Distribution functions.
- *B.* Classical limit.
- *C.* Thermodynamic processes with ideal gases.
- *D.* Fermi gases, Sommerfeld expansion.
- *E* Bose gases.
- *F.* Applications to white dwarves, metals, nuclear matter.
- *G.* Bose-Einstein condensation. Superfluidity.

VII. HEAT & WORK (1.5 weeks)

- *A.* Heat engines.
- *B.* Isothermal and isobaric processes: Carnot cycle.
- *C.* Reversible and irreversible processes.
- *D.* Carnot inequality.
- *E.* Work in various guises.

VIII. CHEMICAL REACTIONS (1.6 weeks)

- *A.* Generalized thermodynamic identity.
- *B.* Chemical equilibrium: Gibbs free energy.
- *C.* Law of mass action.
- *D.* Gibbs free energy.
- *E.* Dilute solutions and osmotic pressure.
- *F.* Vapor pressure, boiling & freezing points.

IX. PHASE TRANSITIONS (1.3 weeks)

- *A.* Coexistence curve, Clausius-Clapeyron equation.
- *B.* Landau theory of phase transitions.
- *C.* Van der Waals equation of state.
- *D.* Mean field method.