PHYS 316: Thermodynamics & Statistical Mechanics
Spring 2011
Course Information

1. Introduction

When: Class MWF 9:00 – 9:50 a.m. (please be here on time), Office Hours W 12:00 – 1:00 p.m.
Who: You and me (Moh El-Naggar, x 0-2394, mnaggar@usc.edu, SSC 215C)
Where: Class KAP 134, Office Hours SSC 215C
What: Thermal physics, treating both thermodynamics and statistical mechanics side by side. Our text will be *An Introduction to Thermal Physics* by Daniel V. Schroeder, Addison Wesley Longman, 2000.

2. Course Description

To the extent that Energy and Climate Change are the two most important problems facing humanity today, this course may be one of the most important physics classes you will take at USC! Thermal Physics deals with collections of *large* numbers ($\sim 10^{23}$) of constituents, be they electrons, photons, atoms, gas or liquid molecules, and so on. This is a tall order, and yet you will see by the end of the semester that the simple tools you acquired allow you to predict the behavior of a staggering variety of physics systems ranging from droplets of liquid helium to cellular metabolism to black holes. You will quickly find out that there are, broadly, two powerful perspectives on thermal physics:

Thermodynamics: Sometimes you will find that the properties of matter do not necessarily depend on the microscopic details of the atoms, molecules, etc. Heat always flows from hot to cold. Any heat engine has the same upper limit to its efficiency, *regardless of how it's constructed*. Most dilute gases behave the same way. Thermodynamics provides a phenomenological description of such systems in terms of a small number of experimentally measurable parameters. Equipped with the four basic rules of thermodynamic, you will never be fooled by a hack trying to sell you a perpetual motion machine.

Statistical Mechanics: Thermodynamics is great, but *why* does heat always flow from hot to cold? What is it about dilute gases that make them behave according to the ideal gas law? What does entropy actually *mean*? To answer such questions we need to look at the behavior of individual constituents. To actually dig deeper and answer these questions, Statistical Mechanics takes into account the classical or quantum behavior of individual particles and uses statistics to make the connection from a few particles to $\sim 10^{23}$ particles. Sometimes this will be hard to do. Sometimes you will be astonished by how simple it will be.

3. Textbooks and Supplementary Reading

Thermodynamics and Statistical Mechanics sound like nice complementary viewpoints. But here is the kicker. Students, instructors, and textbook authors always disagree about how to present this course material. Should one focus on thermodynamics, it being straightforward and practical? Should one dig deeper and use statistical mechanics *all the time*? I have chosen a textbook that treats both approaches side by side (*An Introduction to Thermal Physics* by Daniel V. Schroeder, Addison Wesley Longman, 2000). That sounds nice, ***but beware***. Using this text may require *a lot* of effort on your part, especially because some of the most important material is ***actually in the problems***. To help deal with this, we will do a lot of problem solving in class, and I will assign a lot of these problems as HW. Also while we will very closely follow our textbook, I strongly encourage you to go out and explore other books. Here are a few suggestions:

H.B. Callen, *Thermodynamics and Introduction to Thermostatics*, J. Wiley, 1985.
The best classical thermodynamics textbook around, bar none.

K.A. Dill and S. Bromberg, *Molecular Driving Forces: Statistical Thermodynamics in Chemistry and Biology*, Garland Science, 2003.
I love this book, partially because I am always biased to biophysics. It does a very good job at combining thermodynamics and statistical mechanics. Totally readable, yet very serious.

D. F. Styer, *Statistical Mechanics*, Oberlin College, 2004.
A draft of lecture notes for a course which used the same textbook. It is available for free at http://www.oberlin.edu/physics/dstyer/StatMech/book.pdf.

H. Gould and J. Tobochnik, *Thermal and Statistical Physics*, STP project at Clark University.
This is a draft of what looks like another nice textbook, which is developed as part of a project to enhance teaching of statistical and thermal physics. It is available at: http://stp.clarku.edu.

E. Fermi, *Thermodynamics*, Dover, 1956.
Fermi. Need I say more? Dover publishes these old books for pretty cheap. Do yourself a favor and get one!

E. Schrodinger, *Statistical Thermodynamics*, Dover, 1989.
Little book. Deep stuff.

Some of these books will be placed on reserve at the library (https://usc.ares.atlas-sys.com/). You need to ask for them at the checkout desk. Finally, for a timeline of the history of thermodynamics and statistical mechanics, check out: http://history.hyperjeff.net/statmech. Physics is a subject with a history – it should be treated that way.

4. Online Course Support

The PHYS 316 home page is maintained at http://blackboard.usc.edu. Under the home page you will find a copy of this course syllabus, solutions to problems discussed in class, current homework assignments together with some hints, solutions to completed homeworks, handouts, grades and perhaps other, hopefully useful, information.

5. Homework Assignments

Homework assignments complement the lectures and constitute an integral part of this course. They're weighted quite heavily in this course (40% of the total grade). The textbook is very problem oriented and many ideas are contained only in problems! Therefore you are encouraged to start thinking about the assigned HW problems as soon as the relevant material is covered in class. Many book problems will be discussed in class as examples. Others will be covered in various ways on homework assignments. There will be one assignment per week, which will be posted on the course webpage.

The solutions to the written assignments are due in class at the beginning, not the end, of the Friday lecture. If for a valid reason you are unable to finish your homework on time, you need to send me an e-mail and ask for an extension **before the homework is due**. Please do not slide your homework under my door or drop it in my mailbox without prior authorization.

I beg you to talk to your classmates as you work on problem sets. You should treat your homework not as a test, but as an opportunity to improve your understanding of the material and to learn from each other. Furthermore, a number of problems should be fun as they deal with the real world and phenomena we observe in everyday life. The solutions should be written up legibly with enough details so that anybody, not just the author, can understand what is going on. **Specifically, be sure to show all intermediate steps and use words, not just equations, to explain the solution.** A solution consisting of a string of equations with no comments, a figure if required, or some minimal explanation will be considered unsatisfactory. Please make sure to staple together multiple homework sheets, as all work submitted as loose, or clipped together pages will not be graded. Finally, please note that you are not allowed to simply copy someone else's work or look up solutions in a solutions manual or on the web. Graded homework will be returned in class and solutions will be posted on the course home page.

6. Examinations

There will be one midterm exam and a final. The midterm will be on Friday, March 4, 8:15-10:00 a.m. It will cover the material from weeks 1-7. The final exam will be given on Friday, May 6, 8-10 a.m. and will be comprehensive of the entire semester. The problems on the exams may resemble homework problems and/or examples discussed in class. Some of them may even be exactly the same.

All exams will be closed book and closed notes. You can bring up to two sheets of paper with important formulae. You can use simple calculators. No cell phones or similar electronic devices will be allowed.

If you cannot attend an exam you must contact me before the exam. **There will be no make-up examinations**.

7. Project

During the last week of classes, you will be organized into teams of ~ 2-3 students per team. Each team will work collaboratively on one of the longer problems in the textbook, or some other problem of my choosing. You will then work out the solution, write up your solution as a short paper, and make a very brief (5-10 minute) presentation to the class on the results. I'll provide more details on project topics and logistics by the middle of the semester. I know some of you may dread the thought of having to do this, but the point is to have fun, and practice a very important skill: not only solving a problem but conveying the information successfully to others while stressing the approach *and* the implications.

8. Grading

The final course grade will be determined according to the following distribution:

Homeworks	**40%**
Midterm	**20%**
Project	**10%**
Final	**30%**

Class participation and progress during the semester will be taken into account. Broadly speaking, grading is by the distribution curve of the combined scores of the exams, homeworks, and projects. I do not use rigid percentage marks (such as e.g., a rule that 90% would correspond to A- or similar). Further details about the grading procedure are given in class.

9. Miscellaneous

Academic Integrity

Students who violate university standards of academic integrity are subject to disciplinary sanctions, including failure in the course and suspension from the university. Since dishonesty in any form harms the individual, other students and the university, policies on academic integrity will be strictly enforced. We expect you will familiarize yourself with the USC academic integrity guidelines.

The Trojan Integrity Guide can be found at

http://www.usc.edu/student-affairs/SJACS/forms/tio.pdf.

The Undergraduate Guide for Avoiding Plagiarism can be found at

http://www.usc.edu/student-affairs/SJACS/forms/tig.pdf.

A Guide for Graduate Students can be found at

http://www.usc.edu/student-affairs/SJACS/forms/GradIntegrity.pdf.

Students with Disabilities

Students who need to request accommodations based on a disability are required to register each semester with the Disability Services and Programs. In addition, a letter of verification to the instructor from the Disability Services and Programs is needed for the semester you are enrolled in this course. If you have any questions concerning this procedure, please contact the course instructor and Disability Services and Programs at (213) 740-0776, STU 301.

10. Important Dates

Midterm exam: Friday, March 4, 8:15 – 9:50 a.m.
Final exam: Friday, May 6, 8:00 – 10:00 a.m.
MLK day: Monday, January 17
President’s day: Monday, February 21
Spring Recess: Monday-Saturday, March 14 – 19

11. Words To The Wise (i.e. how do I do well?)*

Thermal physics differs somewhat from other branches of physics not only in its subject matter (very large systems), but also in its logical structure. There are no grand differential equations (like Maxwell's equations or the Schrödinger equation) that encompass the entire subject. Instead, there are only a few small equations, most of them definitions, together with a bag of tricks for solving a huge variety of problems. Once the basic concepts are defined, almost everything follows from pure logic.

Because the logic of thermal physics is more important than any particular equations, you should concentrate on the logic, more than the equations, as you study. You'll need to understand, and be able to reproduce, most of the "derivations"; otherwise you will find it difficult to apply the ideas to new systems that are different from those we discuss in class. (The number of possible applications is so enormous that we'll have time for only a small fraction of them.)

Physics is not so much a collection of facts as a way of looking at the world. My hope is that this course will not only teach you many of the ideas of thermal physics, but will also improve your skills in careful thinking, problem solving, and precise communication. In this course you will gain lots of experience with qualitative explanations, rough numerical estimates, and careful quantitative problem solving. When you understand a phenomenon on all of these levels, and can describe it clearly to others, you are "thinking like a physicist" (as we like to say). Even if you eventually forget every fact learned in this course, these skills will serve you well for the rest of your life.

* Copied verbatim from the author of the textbook, Daniel V. Schroeder

Physics 316, Spring 2011 (This is a rough guideline of our plan. We will modify as we go along)

Monday	Wednesday	Friday
Jan 10 Thermal Equilibrium 1.1	Jan 12 Ideal Gas, Equipartition 1.2, 1.3	Jan 14 Heat & Work 1.4,1.5
Jan 17 MLK Day	Jan 19 Heat Capacities 1.6	Jan 21 Enthalpy, finish 1.6
Jan 24 Microstates 2.1, 2.2	Jan 26 The 2nd Law 2.3	Jan 28 Large Systems 2.4
Jan 31 Ideal Gas 2.5	Feb 2 Entropy 2.6	Feb 4 Temperature 3.1
Feb 7 Entropy & Heat 3.2	Feb 9 Paramagnetism 3.3	Feb 11 Pressure 3.4
Feb 14 Chemical Potential 3.5, 3.6	Feb 16 Heat Engines 4.1	Feb 18 Refrigerators 4.2 ("browse 4.3, 4.4")
Feb 21 President's Day	Feb 23 Free Energy 5.1	Feb 25 Free Energy & Equilibrium 5.2
Feb 28 Phase Transformations 5.3	Mar 2 More on Phase Transformations 5.3	Mar 4 **MIDTERM, 8:15 – 10 a.m.**
Mar 7 The Boltzmann Factor 6.1	Mar 9 Average Values 6.2	Mar 11 The Equipartition Theorem 6.3
Mar 14	Mar 16 Spring Break	Mar 18
Mar 21 The Maxwell Speed Distribution 6.4	Mar 23 Partition Functions 6.5	Mar 25 More Partition Functions 6.6
Mar 28 Revisiting the Ideal Gas 6.7	Mar 30 No Class	Apr 1 The Gibbs Factor 7.1
Apr 4 Bosons & Fermions 7.2	Apr 6 Degenerate Fermi Gases 7.3	Apr 8 More on Degenerate Fermi Gases 7.3
Apr 11 Photon Gas 7.4	Apr 13 Blackbody Radiation 7.4	Apr 15 Debye Theory of Solids 7.5
Apr 18 Bose-Einstein Condensation 7.6	Apr 20 More on BEC	Apr 22 Free Day (i.e. Work on Projects)
Apr 25	Apr 27 **PROJECT PRESENTATIONS**	Apr 29