COURSE INFORMATION

Physics 2201, Introductory Thermodynamics and Statistical Physics

Course Prerequisites: Completion of PHYS 1301/1302, 1401/1402, 1501/1502 or equivalent. Completion of two semesters of calculus.

Instructor: Paul Crowell
Office: PAN 220
Phone: 4-4828
Email: crowell@umn.edu (Email is not recommended as a means to contact me about routine class matters. Please take full advantage of the opportunity to talk to me before or after lectures as well as during my scheduled office hours.)
Office hours: To be determined

Teaching Assistants:
Chris Conklin, conk0044@umn.edu
Bo Xiong, xion1301@umn.edu
Office hours: Time and place to be determined

Course Web Page:

https://www.physics.umn.edu/classes/phys/2017/fall/Phys%202201.100/index.html

I will also make use of the course Moodle page for discussion. I encourage you to use the Moodle page to post questions.

Course announcements and assignments will be posted on this page. You are responsible for any announcements or assignments made on the web page, in class, or by email. The course email list will be based on the official list generated by the university. Please do not ask us to change to any other email address.

Lectures: MWF 09:05 in Tate B20
Discussion Sections: Tuesdays, as scheduled

TEXTBOOK

The required textbook is “An Introduction to Thermal Physics”, by Daniel V. Schroeder, published by Addison Wesley.

There are numerous textbooks on thermodynamics and statistical mechanics. These include “Thermal Physics” by R. Baierlein; “Thermal Physics”, by C. Kittel and H. Kroemer; “Concepts in Thermal Physics,” by S. Blundell and K. M. Blundell. These books are on reserve in Walter Library

You must complete the recommended reading BEFORE the relevant lectures. This is not introductory physics. The concepts are hard. Any honest faculty member will tell you that they still struggle with aspects of thermodynamics and statistical mechanics. There is also an extensive vocabulary required to understand the subject and communicate with your instructor and
EXAMS AND HOMEWORK

QUIZZES - One-hour problem-solving quizzes will be held on October 11 and November 15 in this classroom. Grades earned on these quizzes will be credited towards your final course grade. Quizzes will be closed-book. The use of calculators (but not computers) will be allowed. NO MAKE-UP QUIZZES WILL BE GIVEN. Exceptions to this policy, in accordance with University-wide rules, will be considered only for those cases specified by policy:

http://www.policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html

Note that for the special cases covered by this policy, particularly intercollegiate athletic events and religious observances, you must advise me well in advance (in person and by confirming email) so that appropriate arrangements can be made. Note that illness is generally not a consideration in making exceptions to the exam policy unless a physician explains in writing that you were physically unable to take the exam.

FINAL EXAM - The result of a three-hour final exam will be credited toward your course grade. This exam will be held on Tuesday, December 19, 1:30 – 4:30 PM at a place to be determined. The final exam will be closed-book and must be taken at the specified time and place. Exceptions to this rule will be granted only according to the university policies noted above.

HOMEWORK: Each week on Friday a number of problems will be posted on the course website. Homework will be due in class on Tuesday or Friday of the following week. I may use one or both days for collecting homework. Late homework will not be accepted or graded.

There is nothing more important to success in this course than mastery of the material as evidenced by problem solving. Do all of the problems assigned each week and then some more. Although you must submit your own answers to graded problems, discussion of homework problems with your peers is encouraged. Start EARLY on the homework. I am likely to suggest that certain problems be completed (or at least attempted) before a particular lecture or discussion section.

I reserve the right to make additional assignments or rearrange assignments. This may include use of the class Moodle Page, which I will also use for on-line discussion and posting corrections or “hints” to problem sets. Make sure that you can access the Moodle Page for this class.

Remarks on grading - Problems on quizzes and the final exam will be graded based on your success in communicating a logical and organized path towards their correct solution, grounded in a correct assessment of the underlying physics. Diagrams, written explanations
and especially a logical algebraic development done neatly and including well-defined variables and a consistent notation are key elements of the correct solution of problems. Disconnected diagrams, equations or answers simply written down without explanation will not receive credit. Partial credit will be given for steps of an organized solution up to the point where a departure from the correct solution path occurs, but only if these steps can be clearly understood by looking at the paper you submitted. Again: a grader looking at your paper must be able to understand what you have done, how and why you did it, and to discern the correctness of your reasoning.

**ACADEMIC CONDUCT**

Students in this course must adhere to all policies of the University of Minnesota and the College of Science and Engineering with respect to scholarship and conduct. These policies are available for review at:


In particular, you are encouraged to read the statements on scholastic dishonesty, disruptive behavior, and the use of electronic devices during exams (see detailed policy descriptions below). Violations of these policies will lead to penalties, up to and including a failing grade “F” in the course and expulsion from the University.

**Note that copying solutions to homework problems from a fellow student or a solution manual (printed or online) is a violation of the student conduct code. Collaborating on homework is fine, but the written solution you hand in must be your own work.**

**Classroom etiquette:** Cell phones must be turned off. Computers may be used only for notetaking, accessing your textbook, or accessing online course resources as required during the lecture (this will be rare). All other forms of electronic communication and web access are not allowed at any time. Note that the use of any electronic devices, except handheld calculators without wireless capability, is forbidden during exams. Lectures will require active verbal communication (both ways!) between students and the instructor. Anything that impedes this process (from web browsing to reading the newspaper) is rude and disruptive.

**COURSE GOALS AND OBJECTIVES**

This course provides an introduction to the physics of systems containing a large number of particles. In daily practice, “large” means of order $10^{23}$. We will see that it is neither necessary nor desirable to “solve” for the motions of all the particles in such a system in the manner that you undertook for one or two particles in introductory physics. In fact, an exact solution (for $10^{23}$ particles) is impossible even with the most powerful computers available to us. Nevertheless, concepts from introductory physics, particularly conservation laws, play a major role in the development of thermal physics. Historically, the treatment of macroscopic systems started with *thermodynamics*, which accounts for the exchange of energy in various forms.
between a system and its environment. This requires the introduction of concepts such as heat, temperature, entropy, chemical potential, and thermodynamic potentials.

In the first few weeks of the course, it will become apparent that the condition of a “large” number of particles lends itself to a statistical description of such systems. Insights of the late 19th century made the connection between this statistical description and classical thermodynamics. This approach, known as statistical mechanics, provided a rigorous foundation for the concept of entropy, and it provided a new framework (ensembles) for understanding large systems in terms of probability distributions. Armed with statistical mechanics and some insights from quantum mechanics, physicists of the early 20th century made dramatic progress in understanding the behavior of systems of particles.

Nowadays, thermodynamics and statistical mechanics are used throughout physics. Every research field in physics represented in our department makes use of them: nuclei, electrons in a quantum dot, ions in a cell, solids and liquids, beams of particles in a high-energy accelerator, the earth’s atmosphere, stars, galaxies, clusters of galaxies, the universe as a whole, etc... We need thermodynamics and statistical mechanics to understand these. The subject is so important that you will see it twice (PHYS 2201 and PHYS 4201). Do not expect to “get it all” this semester. I have struggled with the subject for over 30 years!

**SCHEDULE**

A rough schedule is as follows:

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Topics</th>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>First law of thermodynamics</td>
<td>1</td>
</tr>
<tr>
<td>3-5</td>
<td>Second law; entropy</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Quiz 1</td>
<td></td>
</tr>
<tr>
<td>6-7</td>
<td>Temperature; pressure; chemical potential</td>
<td>3</td>
</tr>
<tr>
<td>8-9</td>
<td>Engines, refrigerators, Carnot efficiency</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Quiz 2</td>
<td></td>
</tr>
<tr>
<td>10-11</td>
<td>Boltzmann Statistics</td>
<td>6</td>
</tr>
<tr>
<td>12-13</td>
<td>Free energy; chemical thermodynamics</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GRADING**

Your grade in this course will be based on the following:

Homework: 35%
Midterms: 30%
Final Exam: 35%

Grades will conform to University-wide policy:
A - Represents achievement that is outstanding relative to the level necessary to meet course
requirements.
B - Represents achievement that is significantly above the level necessary to meet course
requirements.
C - Represents achievement that meets the course requirements in every respect.
D - Represents achievement that is worthy of credit even though it fails to meet fully the course
requirements.

As a rule, I do not curve grades, because it is usually not necessary. Historically, the mean grade in
this class is approximately B-. I will provide feedback as the semester progresses. A random
observation: I do not think that I have ever given a grade less than C- to anyone who has attended
every class and discussion section and satisfactorily completed all of the homework assignments
for a class. This is not a promise, but it does indicate the important role of discipline and
homework in mastering the material.

LIBERAL EDUCATION (required statement as per university policy)

This class exposes the student to physical principles and concepts, demonstrates how these
principles can be applied to quantitatively describe natural phenomena, and provides the student
with an opportunity to perform hands-on experiments and measurements that model how physical
knowledge is obtained. The basic principles of electricity and magnetism are described with
particular emphasis on their application in current technology, using mathematical analysis at the
level of calculus. The development of conceptual understanding of physical principles and their
quantitative application are further deepened in the discussion section, where students practice
problem solving skills. In addition, familiarity with the methods and findings of the physical
sciences not only forms a crucial component of a common education, but also prepares students to
be scientifically literate citizens.

DEPARTMENTAL POLICIES

ATHLETES must provide their official University of Minnesota athletic letter containing the
approved competition schedule to their instructor and the staff in Williamson Hall 145. Away
exams will be arranged with the athletic adviser traveling with the team. Accommodations will be
made for official university sports only (i.e. no accommodations will be made for intramurals, club
sports, etc.)

DISABILITY SERVICES: If you have accommodations for this course (see policy below), please
provide the staff in Williamson Hall 145 with a copy of your accommodation letter for the current
semester. Exams will be arranged according to accommodations and sent to the testing center for
administration.

UNIVERSITY POLICIES

- Student conduct code

- Scholastic Dishonesty
Student Conduct Code

The University seeks an environment that promotes academic achievement and integrity, that is protective of free inquiry, and that serves the educational mission of the University. Similarly, the University seeks a community that is free from violence, threats, and intimidation; that is respectful of the rights, opportunities, and welfare of students, faculty, staff, and guests of the University; and that does not threaten the physical or mental health or safety of members of the University community.

As a student at the University you are expected to adhere to Board of Regents Policy: Student Conduct Code. To review the Student Conduct Code, please see: http://regents.umn.edu/sites/regents.umn.edu/files/policies/Student_Conduct_Code.pdf

Note that the conduct code specifically addresses disruptive classroom conduct, which means "engaging in behavior that substantially or repeatedly interrupts either the instructor's ability to teach or student learning. The classroom extends to any setting where a student is engaged in work toward academic credit or satisfaction of program-based requirements or related activities."

Use of Personal Electronic Devices in the Classroom
Using personal electronic devices in the classroom setting can hinder instruction and learning, not only for the student using the device but also for other students in the class. To this end, the University establishes the right of each faculty member to determine if and how personal electronic devices are allowed to be used in the classroom. For complete information, please reference: http://policy.umn.edu/education/studentresp.

Scholastic Dishonesty

You are expected to do your own academic work and cite sources as necessary. Failing to do so is scholastic dishonesty. Scholastic dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis. (Student Conduct Code: http://regents.umn.edu/sites/regents.umn.edu/files/policies/Student_Conduct_Code.pdf)

If it is determined that a student has cheated, he or she may be given an "F" or an "N" for the course, and may face additional sanctions from the University. For additional information, please see: http://policy.umn.edu/education/instructorresp.

The Office for Student Conduct and Academic Integrity has compiled a useful list of Frequently Asked Questions pertaining to scholastic dishonesty: http://www1.umn.edu/oscai/integrity/student/index.html. If you have additional questions, please clarify with your instructor for the course. Your instructor can respond to your specific questions regarding what would constitute scholastic dishonesty in the context of a particular class—e.g., whether collaboration on assignments is permitted, requirements and methods for citing sources, if electronic aids are permitted or prohibited during an exam.

Makeup Work for Legitimate Absences

Students will not be penalized for absence during the semester due to unavoidable or legitimate circumstances. Such circumstances include verified illness, participation in intercollegiate athletic events, subpoenas, jury duty, military service, bereavement, and religious observances. Such circumstances do not include voting in local, state, or national elections. For complete information, please see: http://policy.umn.edu/education/makeupwork.

Appropriate Student Use of Class Notes and Course Materials

Taking notes is a means of recording information but more importantly of personally absorbing and integrating the educational experience. However, broadly disseminating class notes beyond the classroom community or accepting compensation for taking and distributing classroom notes undermines instructor interests in their intellectual work
product while not substantially furthering instructor and student interests in effective learning. Such actions violate shared norms and standards of the academic community. For additional information, please see: http://policy.umn.edu/education/studentresp.

**Grading and Transcripts**

The University utilizes plus and minus grading on a 4.000 cumulative grade point scale in accordance with the following:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Numerical Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.000</td>
<td>Represents achievement that is outstanding relative to the level necessary to meet course requirements</td>
</tr>
<tr>
<td>A-</td>
<td>3.667</td>
<td></td>
</tr>
<tr>
<td>B+</td>
<td>3.333</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>3.000</td>
<td>Represents achievement that is significantly above the level necessary to meet course requirements</td>
</tr>
<tr>
<td>B-</td>
<td>2.667</td>
<td></td>
</tr>
<tr>
<td>C+</td>
<td>2.333</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>2.000</td>
<td>Represents achievement that meets the course requirements in every respect</td>
</tr>
<tr>
<td>C-</td>
<td>1.667</td>
<td></td>
</tr>
<tr>
<td>D+</td>
<td>1.333</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1.000</td>
<td>Represents achievement that is worthy of credit even though it fails to meet fully the course requirements</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>Represents achievement that is satisfactory, which is equivalent to a C- or better.</td>
</tr>
</tbody>
</table>

For additional information, please refer to: http://policy.umn.edu/education/gradingtranscripts.

**Sexual Harassment**

"Sexual harassment" means unwelcome sexual advances, requests for sexual favors, and/or other verbal or physical conduct of a sexual nature. Such conduct has the purpose or effect of unreasonably interfering with an individual’s work or academic performance or creating an intimidating, hostile, or offensive working or academic environment in any University
activity or program. Such behavior is not acceptable in the University setting. For additional information, please consult Board of Regents Policy: http://regents.umn.edu/sites/regents.umn.edu/files/policies/SexHarassment.pdf

Equity, Diversity, Equal Opportunity, and Affirmative Action

The University provides equal access to and opportunity in its programs and facilities, without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression. For more information, please consult Board of Regents Policy: http://regents.umn.edu/sites/regents.umn.edu/files/policies/Equity_Diversity_EO_AA.pdf.

Disability Accommodations

The University of Minnesota is committed to providing equitable access to learning opportunities for all students. The Disability Resource Center is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations.

If you have, or think you may have, a disability (e.g., mental health, attentional, learning, chronic health, sensory, or physical), please contact Disability Resource Center at 612-626-1333 to arrange a confidential discussion regarding equitable access and reasonable accommodations.

If you are registered with Disability Resource Center and have a current letter requesting reasonable accommodations, please contact your instructor as early in the semester as possible to discuss how the accommodations will be applied in the course.

For more information, please see the Disability Resource Center website, https://diversity.umn.edu/disability/.

Mental Health and Stress Management

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may reduce your ability to participate in daily activities. University of Minnesota services are available to assist you. You can learn more about the broad range of confidential mental health services available on campus via the Student Mental Health Website: http://www.mentalhealth.umn.edu.

Academic Freedom and Responsibility: for courses that do not involve students in research
Academic freedom is a cornerstone of the University. Within the scope and content of the course as defined by the instructor, it includes the freedom to discuss relevant matters in the classroom. Along with this freedom comes responsibility. Students are encouraged to develop the capacity for critical judgment and to engage in a sustained and independent search for truth. Students are free to take reasoned exception to the views offered in any course of study and to reserve judgment about matters of opinion, but they are responsible for learning the content of any course of study for which they are enrolled.*

Reports of concerns about academic freedom are taken seriously, and there are individuals and offices available for help. Contact the instructor, the Department Chair, your adviser, the associate dean of the college, or the Vice Provost for Faculty and Academic Affairs in the Office of the Provost. [Customize with names and contact information as appropriate for the course/college/campus.]

* Language adapted from the American Association of University Professors "Joint Statement on Rights and Freedoms of Students".