Physics 370 Thermal Physics Fall 2024

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Class Times: MWF 10:50-11:50 (Trexler 272)
Office Hrs: M 2-4, Th 2-4
(Make appts at calendly.com/daniel_robb)

Course Description:
Thermal behavior of systems; energy and entropy; equations of state; changes of phase; elements of continuum and statistical approaches

Textbook:
• *Thermal Physics* by Ralph Baierlein. Cambridge University Press, 1999. (Available in paperback) ISBN-13: 978-0521658386.

Purpose of the Course:
What do automobile engines, cloud formations and rubber bands have in common? The behavior of each of these systems depends on the flow of matter and energy among the constituent elements of these systems and the surrounding environment. Whereas mechanics, electricity and magnetism, and quantum mechanics describe the behavior of individual particles under the influence of forces, thermal physics attempts to explain and predict the behavior of large collections of particles.

"A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Hence the deep impression that classical thermodynamics made upon me. It is the only physical theory of universal content concerning which I am convinced that, within the framework of the applicability of its basic concepts, it will never be overthrown" – Albert Einstein.

This course will give you a practical understanding of how to use classical thermodynamics, as well as an appreciation for its wide range of applicability. We will work hard to understand the link between the mathematical formalism of statistical mechanics, which is rooted in the microscopic properties of systems, and the macroscopic properties (temperature, pressure, volume, etc.) described by classical thermodynamics. Finally, we will look at an application of thermal physics – the modeling of the Earth's climate – gaining an understanding of the types of models used, as well as separating fact from fiction in the current "climate debate".

Specific Goals of the Course:
1. Acquire the ability to apply classical thermodynamics to physical systems, and understand the Three Laws of Thermodynamics
2. Understand the link between statistical mechanics and thermodynamics, and gain a beginning proficiency in "stat mech"
3. Study an issue at the intersection of science and politics (climate change)

Feedback and Evaluation:
I will assign numerical grades to all your work. I *may* curve your final grades (upward); otherwise you can expect to receive an A for a 93-100 semester average; A- for 90-92; B+ for 87-89; B for 83-86; B- for 80-82; C+ for 77-79; C for 73-76; C- for 70-72; D+ for 67-69; D for 60-66; F for 0-59. These are the categories and percentages:

Problem sets:	35% (5 @ 7 % each)	Tests:	30% (2 @ 15 % each)
Final exam:	20%	Writing Assignment:	10%
Participation:	5%		

Problem sets: I encourage you to discuss problems with other students, but the work you turn in should be your own (i.e., don't copy work from another student, or allow another student to copy your work.) See below for the policy on late work.

Tests during the semester will be given in our classroom during class periods. Each test will consist of several conceptual questions requiring written responses, and several calculation problems. The first test will cover the first two course units, i.e., classical thermodynamics and kinetic/transport theory. The second test will cover the third course unit on statistical mechanics. Note that *you will be given all necessary formulas on each test.*

The final exam will be comprehensive, including all four course units. It will also include conceptual questions and calculation problems.

The writing assignment will concern our short unit on theories of Earth's climate. You will summarize and critique two online articles in light of our study of climate modeling and currently available climate data. No collaboration is allowed on this assignment (except with me), and you must cite any sources you have used in footnotes. You will be required to turn in a rough draft (worth 1/3 of the grade), and then to revise your draft based on my comments (2/3 of the grade). See below for the policy on late work.

Your participation grade is based on your reflections on (at least) two MCSP Colloquium Series talks, as well as on your class attendance.

MCSP Colloquium Series:
This semester a series of talks will be offered which appeal to a broad range of interests related to math, computer science and physics. Members of this class are invited to attend all of these talks; however, participation in **at least two** is mandatory. Within **one week** of attending a talk you must submit (via Inquire) a one-page single-spaced paper. This paper should not only include a summary of the main content of the talk, but also a personal contemplation of the experience.

Policy on Late Work:
I will grade an assignment with a 10% lateness deduction for each successive school day it is late (schooldays are M-F; days end at 5:00 PM). Thus after one week, assignments receive a 50% deduction. After two weeks, assignments receive a 100% deduction; that is, no assignment will be accepted if more than two weeks late. I will consider adjusting the late policy for an assignment only under extreme circumstances.

Academic Integrity:
The College's academic integrity policies will be enforced. Although you are encouraged to work in groups on your problem sets, all work turned in for a grade must be your own. See above for guidelines on the written assignment. Please familiarize yourself with the College's academic integrity policies. Be aware that I am contractually obligated to report student(s) if I suspect that they have engaged in academic dishonesty. Lastly, unless otherwise directed, cell phones should be silenced and out of sight during all class periods.

Regarding the use of generative AI tools such as ChatGPT, you may use such tools as a last resort to generate ideas on a problem on a problem set. However, be aware that these tools' solutions are not always fully correct. You must write up problem-set solutions on your own in any case. You may not use generative AI tools on the writing assignment in this course.

Make-up Tests:
Make-up tests will not be given. If you miss a test, and have an official college excuse for that absence, then your final exam grade will count for the missed test.

Attendance Policy:
You are expected to attend every class. Attendance is checked at each class meeting. If you are going to be absent from class for a valid (excused) reason, I must be notified in advance. Your fourth and each additional unexcused absence will result in a 2-point deduction in your final course grade. Furthermore, you are accountable for all work missed because of any absence. I will provide class materials for a missed class but will not re-teach a missed class during office hours.

Use of Electronic Devices:
In class, you may use personal laptops or tablets, but only for course-related purposes. All other electronic devices must be turned off. On tests, you may use a scientific calculator; all other electronic devices must be turned off and out of sight. Violation of this policy on tests will be treated as a violation of the Academic Integrity policy.

Accessible Education Services:
Accessible Education Services (AES) is located in the Goode-Pasfield Center for Learning and Teaching in **Fintel Library**. AES provides reasonable accommodations to students with documented disabilities. To register for services, students must self-identify to AES, complete the registration process, and provide current documentation of a disability along with recommendations from the qualified specialist. Please contact Dustin Persinger, Assistant Director of Academic Services for Accessible Education, at 540-375-2247 or by e-mail at aes@roanoke.edu to schedule an appointment. If you have registered with AES in the past and would like to receive academic accommodations for this semester, please contact Dustin Persinger at your earliest convenience to schedule an appointment and/or obtain your accommodation letter for the current semester.

The Writing Center @ Roanoke College, located on the Lower Level of Fintel Library (Room 15), offers free tutorials focused on writing projects and oral presentations for students working in any field. Writers and presenters at all levels of competence may visit the Writing Center at any point in their process—including brainstorming, drafting, organizing, editing, or polishing presentation skills—to talk with trained peer tutors in informal, one-on-one sessions. The Writing Center is open Sunday through Thursday from 4 to 9 PM. Simply stop in, or schedule an appointment at www.roanoke.edu/writingcenter. Questions? Email writingcenter@roanoke.edu or call 540-375-4949.

#	Date	Topic	Reading	Due
		UNIT 1: Classical thermodynamics		
1	Aug. 28	Introduction and preview	--	
2	30	Heat, temperature and the 1st Law	1.1-1.4	
3	Sept. 2	Adiabatic processes	1.5-1.7	
4	4	Multiplicity and the 2nd Law	2.1-2.3	
5	6	Entropy I	2.4-2.8	
6	9	The Carnot cycle	3.1-3.4	
7	11	Reversibility and real engines	3.5-3.7	
8	13	Problem set workshop		
		UNIT 2: Transport theory		
9	16	Random walks	15.1-15.2	PS 1
10	18	Momentum transport and viscosity	15.3-15.4	
11	20	Thermal transport and diffusion	15.5-15.6	
12	23	Climate modeling I	6.4, Handouts	
13	25	Climate modeling II	Handouts	PS 2
14	27	Review and catch-up		
15	30	**TEST 1**		
		UNIT 3: Statistical mechanics		
16	Oct. 2	Density of states	4.1	
17	4	General definition of temperature	4.2-4.4	Paper draft
18	7	Thermal probabilities	5.1-5.3	
19	9	The partition function	5.4-5.5	
20	11	The canonical distribution	5.6-5.8	Paper final, PS 3
	12-20	**FALL BREAK**		
21	21	Chemical potential I	7.1	
22	23	Chemical potential II	7.2-7.5	
23	25	Ideal gas: quantum treatment	8.1-8.3	
24	28	Ideal gas: classical limits	8.4	
25	30	Free energy	10.1-10.3	
26	Nov. 1	"Minimize the free energy"	10.4-10.8	
27	4	Chemical equilibrium	11.1-11.2	
28	6	Chemical equilibrium II	11.3	PS 4
29	8	Classical stat mech	13.1-13.2	
30	11	No class		
31	13	Equipartition theorem	13.3	
32	15	**TEST 2**		
		UNIT 4: Phase Transitions and the 3rd Law		
33	18	Phases of matter I	12.1-12.3	
34	20	Phases of matter II	12.4-12.5	
35	22	Fermions at low temperature I	9.1	
36	25	Fermions at low temperature II	9.1	
	27-Dec 1	**THANKSGIVING BREAK**		
37	2	Prelude to the 3rd Law	14.1-14.3	PS 5
38	4	The 3rd Law	14.4-14.5	
39	6	Review and catch-up		
		FINAL: Tues, Dec 10, 8:30-11:30 am		

Note: You should expect to spend a combined total of 12 hours per week on lecture, homework, and reading for PHYS 370.