# F23 PHYS 4510: Thermodynamics & Statistical Mechanics

Everything in red is still being reviewed

**General Information**

Office E-mail

Instructor: R. Michalak, 215 PS rudim@uwyo.edu

TA: tba, grader/ discussionTA

**Office hours(RM):** PS215 T 2-3 pm, F 1-2pm or by email appointment

Lecture: TR 1100-1215 pm PS 234

Discussion: **I am excited that we can finally offer a discussion section! It is not hard scheduled, and we will discuss possible times on Monday, first day of class.**

Texts: required: Daniel Schroeder ‘An Introduction to Thermal Physics’

*set up as inclusive access in Wyocourses*

In the past, students have found this text very accessible and readable. The text is unique as it introduces StatMech methods as early as chapter two and mixes it with Thermodynamics right away. Moreover, the “End of Chapter” problems in this text are actually not at the end of the chapter, but appear “just in time” interspersed in the main text. It would be a good idea to try to think about how to solve them as they appear in the text to get a deeper understanding of the subject. You will be ready for them when and where they appear. We will also use many of them during class and discussion. As always, the key is trying to seriously work the problems by yourself before you seek help.

There are many other good texts out there. Unlike in most other courses you took, the different books offer a great variety of approaches to the topic. Here is a list of recommended texts with my short commentary:

• Herbert B. Callen ‘Thermodynamics and an Introduction to Thermostatistics’ *good*

*on presenting thermodynamics and thermodynamic potentials, a bit short on Stat Mech*

*Some good illustrations and examples*

• P.W. Bridgman’s ‘Nature of Thermodynamics’ *gives a more conceptual introduction and is thought provoking. I will use it for some reflective writing tasks. Insightful*

• Frederik Reif ‘Fundamentals of Statistical and Thermal Physics’ *many places used this as the main text about a decade ago, it is however a bit on the difficult and mathematical side, very complete For the mathematically inclined*

• Stephen Brush wrote a noteworthy series of articles on the history of the Kinetic Theory in *The British Journal for the History of Science*, which sheds light on the murkier ingredients, which find only a short mention in today’s undergraduate texts, like the ergodic theory of Boltzmann, its refutation, and his brilliant riposte.

For seeing connections

• *Original books* by Boltzmann and Maxwell help the student of thermodynamics to realize the true scope of the subject and its troubling rough edges. They will not do justice to the StatMech aspect of the field. **Scary for novices.**

• Philip M Morse ‘Thermal Physics’ *is a bit dated, but explains the theoretical steps that are often left out today. A strength is the dealing with other work terms in the 1st Law.*

• Francis Sears ‘An Introduction to Thermodynamics, The Kinetic Theory of Gases, And StatMech’ *is a very thorough text from the ‘50s with many helpful figures which shows many ‘steps in between’*, as does **Shows many steps, assumes you know math.**

• Mark Zemansky ‘Heat and Thermodynamics’*with focus on measurement.* Both are weak on StatMech. I use them in my thermo interlude in the second week of class.

*You may remember the two as the original authors of our Phys 1210/1220 textbook.*

• Richard Tolman’s ‘The Principles of StatMech’ *approaches from a mechanical starting point, matching the end of our Classical Mechanics course.* Will make you realize that we did not cover the whole CM book. **Scary for everyone, but most complete.**

You should not feel like you have to check all of these out. Schroeder will do just fine. But if you need help from a different perspective to make sense out of what you will learn, start with these books. Pick one that sounds as if it will cater to your way of approaching the understanding of a subject.

Webpage: You will find course related information on my website <http://physics.uwyo.edu/~rudim/index_4510.html> (currently with old content) and on Wyocourses. This is necessary because the material exhausts the storage limit on Wyocourses.

Wyocourses: This course is posted on Wyocourses. Any grades that I may post on Wyocourses do not appear in the correct proportion in the Wyocourse gradebook and have to be taken at face value for the assignment and are not to be taken for the course grade.

**Course Content:**

*This course is an introduction to Thermodynamics and Statistical Mechanics. It builds on concepts learned in Phys 1220 or similar college courses. My anecdotal course record shows that students may have had anywhere between three and twelve lecture hours of exposure to Thermodynamics, accompanied by zero to three homework and zero to three laboratory experiments, which usually dealt with the first thermo chapter.*

*Such a wide range of prior knowledge, together with the fact that PHYS 1220 appears three years earlier in the curriculum, makes for a rocky transition period. To smooth the impact, I deviate from Schroeder’s text in the first two to three weeks of class, building stepping-stones, which students should use in conjunction with a rigorous review of the old material to come up to par.*

*We will revisit core concepts from these pre-requisite courses, e.g. the concept of temperature and the First Law of Thermodynamics, and we will expand on them, but a basic familiarity with the old material is expected.*

*Quantum Mechanics (Phys 4310) and Classical Mechanics (Phys 4210) are pre-requisites to this course and concepts and principles from both courses will be employed. Time constraints do not allow for a review of CM or QM methods, but the appendices in Schroeder have a summary. By the time we get into deeper QM it will be about week 13, so if you take Quantum in parallel you should know enough Quantum by then. From the Classical Mechanics course, the Hamiltonian and Liouville’s Theorem matter most (in my 4210 that was discussed in the last lecture).*

*We study the Laws of Thermodynamics, Phase Transitions of Matter, and Classical and Quantum Statistics in their interrelation with Statistical Mechanics. Thermodynamics, Kinetic Theory, and Statistical* *Mechanics are all abstract and difficult subjects. Many teachers say that one can only really understand any part of it completely once one knows the whole. Sometimes they say that one had to learn Thermo twice. More about that in lecture one.*

*I have been working on ways to make the learning more efficient. This includes a certain lecture structure with interactive tasks and supervised reading. The method can only work, if students fully participate in them. To encourage and reward your independent reading, I have added some hw tasks that build specifically on reading.*

*Most students in previous terms found the text quite helpful and very readable. Try to read the upcoming material ahead of time and understand it as best as possible. The material is often too advanced to understand it fully when meeting it for the first time. By coming to class prepared in this way, we should be able to address any problems with your understanding in lecture.*

**All of the following information is tentative and I reserve the right to change any of it as seems necessary to keep the class average on course. Such changes will be announced in class.**

**Lecture** Two lectures per week, each 75 minutes.

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## Laboratory N/A

**Discussion** N/A discussion session once per week. At that time, we will be at the beginning of StatMech and problems can take 30-45 minutes to demonstrate, making it impossible to show After exam 1 I may offer a voluntary problems in a 75 minute lecture. Attendance will be voluntary and no one will miss grade points by not attending discussion. A time will be arranged with students to allow a maximum number of students to have no time conflicts to attend. I will strive to video the discussions on Zoom if a suitable room can be secured.

**Homework** The HW is due at deadlines specified in the tentative schedule below. Late submissions will be accepted for a 5% grade penalty for the first 12 hours late and another 5% for each begun additional 12 hours late. The receiving date in Wyocourses will count as your submission. Late assignments because of university excused events or doctor documented illness will suffer no late penalty, but must be arranged prior to the deadline, if at all possible.

HW that is not fully legible, has confused logic, or offers more than one solution will receive a reduced grade.

HW tasks include written summaries of handouts and text reading assignments or discussion questions regarding the same material. Handouts are provided during lecture. If you miss a lecture, which provides students with a handout, it is your responsibility to make sure you learn about the existence of the handout and to collect it from me at my office in good time before the related work is due. There will be no extension of deadline because of missed handouts.

***Important:***

To master the abstract nature of the material, *each standard hw task shall include a short discussion* of the meaning of the result of each problem. This can typically be done in two or three sentences. I reserve points for these discussions and you lose the points (default: 7.5%, but it may vary in some cases) if you skip the discussion.

***Reflective Writing hw*** *is marked by & in the tentative schedule below. Its purpose is twofold: Our major curriculum is somewhat weak in cogent writing tasks, yet our alumni tell us that effective writing is of ever-increasing importance in their jobs. These hw are intended to make a contribution to training in that respect.*

*Secondly, some students find it difficult to come up with the required scores needed for exams to pass the class. Since this course is not again offered before a senior may have to graduate, written hw provides a different kind of task that may come easier to some students, who struggle with the math or the computational components of standard hw. If you are such a student, you should take the written hw very seriously and make a good effort so that you can earn a high score to make up for possible low scores in the other assignments.*

***Computational component of hw***: Especially the StatMech component of hw deals with very large numbers (see lecture and text for what exactly is meant by that). This can make it impossible to produce calculated curves, unless a computer program is written by the student. Without a curve that visualizes the result, the numbers may appear meaningless or inaccessible. To remedy this I go by Schroeder, who offers a large number of problems, which contain at least in part such programming tasks.

*I am aware that the computational aspect of hw is not a strong point for every student and allow, therefore, collaboration between up to three students to come up with a working version of the computer code for the hw. Every student has to make a good effort to understand why things have been coded the way they were coded so that they can become self-sufficient in later hw. All other parts of the hw have to be independently carried out by each student.*

*Python and C++ are best for solving the computational hw parts. Matlab and similar C++ clones do often reach their capability limits and may not enable you to get full hw scores because they may, for example, not be able to plot a full curve of data.*

If I get the impression that students do not understand the coding and just copy code, I may add tasks that are different for every student to explain an aspect in the coding in the hw. Finally, taking a “free ride” with computational tasks by mindless copying is academic dishonesty. If you use code or parts of code that someone else wrote disclose it properly in a footnote. Always add a note about what you learned to do from the part that you copied. If you fulfil these two conditions, you will still get full credit for that hw part.

*Bonus homework* may be offered after each exam to allow students to make up for poor exam scores. Not doing bonus hw has no negative grade consequences. If you hand such a bonus hw in by the deadline, up to 5% can be earned toward an improved exam score for the relevant exam. The exact bonus depends on the quality of your work and on how much you had to make up for. Students, who had very high exam scores, can also earn the bonus and can then exceed 100% scores.

**Communication with the students**

I will make announcements in class and via Wyocourses/Announcement when changes are made to the tentative schedule. It is the student’s duty to catch up with such news, if they miss class. That is still true if there is a valid university or health related excuse for the student’s absence.

On occasion, I may send an email to the class. It is the student’s duty to check the university email account in a timely manner to benefit from such information.

**Grades**

Homework: 8 40%

Exams: 3 60%

Attendance and Participation:  *40+ +2%, 36-39 +1% bonus*

***Scale:***

A > 90.0% GPA 4.0

B > 80.0% 3.0

C > 70.0% 2.0

D > 55.0% 1.0

F < 55.0% 0.0

**Final grades that you may see in Wyocourses are wrong and will not have the correct weight. I switch this grade off, but after software updates it does sometimes re-occur.**

Grading Key I usually underline a passage and accompany it with a symbol that explains the kind of mistake:

^ correct

(^) mostly correct

~ somewhat correct

vague

(-) incomplete

- missing

? confused or logic cannot be followed

#1 wrong math

#2 wrong reasoning

#3 wrong conclusion

(/) misses the point, off topic

\~/ sloppy, much too short

{} Weak reasoning, weak discussion

{-} missing discussion

[] lack of structure or abrupt change or disconnected/unprepared statement

\* precise or insightful or thoughtful

! strong reasoning, strong discussion

(+) good use of math

!? why?

@ good research

% good quot. use

?@ inappropriate or weak source

Grading of Reflective Writing

Grading categories: point of view (pov) and organization rubric

Letter grade equivalent short hand and meaning

Development of pov: A $1 – complete, effective, and insightful

B $2 - appropriate reasoning, lacking some evidence, or minor mistake

C $3 - incomplete or vague reasoning, insufficient

evidence, or minor mistakes, or one more substantial mistake

D $4 - no viable or severely deficient pov or several substantial mistakes

F $5 - no discernible attempt to develop meaningful

pov; extraordinary mistake

Organization: A \*1 - all of B and written with clarity and concise without leaving out or overly shortening necessary parts

B \*2 - generally organized and focused

C \*3 - some problems with progression of ideas

D \*4 - poor organization, unfocused

F \*5 - incoherent, disorganized to a degree that

understanding is compromised

Unlike in some of my other courses, homework is **not** group work (see the explanations under Computational hw above for an exception). Consult your peers or me or a provider of worked solutions for the general method of how to approach a problem. Do not look up solutions for the actual hw problems and do not copy other students’ work. Make sure you work the main steps for your specific problem on your own after consulting the above listed allowed sources.

# Special accommodations

If you have a physical, learning, or psychological disability and require accommodations, please let me know as soon as possible.  I will try to accommodate your condition as best as circumstances allow. You will need to register with University Disability Support Services (UDSS) in SEO, room 330 Knight Hall, 766-6189, TTY: 766-3073. If you choose to notify me late about such circumstances, you may forfeit your right for special accommodation for that assignment. Take exams with UDSS for overtime and for accommodations, which cannot be reasonably provided in a regular exam room.

**The curriculum addendum as shown in the Wyocourse tab of the same name is in effect. It is your duty to read it and ask questions if you are in doubt whether you understand it. Where the curriculum addendum may contradict my course specific rules, the university regulated course addendum rules prevail.**

***Tentative* Class Schedule Fall 2023 – 4510**

*I reserve the right to adapt the syllabus schedule to actual class progress*

The column in red is still subject to revision

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| --- | --- | --- | --- |
| **Week** | **T**  **11:00-12:15**  \* = not in textbook | **R**  **11:00-12:15**  @ = could be skipped | **Deadlines etc.:**  All hw to be emailed to [rudim@uwyo.edu](mailto:rudim@uwyo.edu) only as pdf or MS Word  *&marks reflective writing hw* |
| 1 Aug 28 – Sep 1 | Syllabus  Intro  *Models, Statistics, and*  *Temperature**& Thermometry* \* | Review 1220  Ch. 1.2 – 1.3  *Kin. Theory ^,*  *Equipartition* |  |
| 2 Sep 4 – Sep 8 | Ch. 1.4 – 1.6  *Equipartition,* Q+W,  Compression W | Ch. 1.6,7  *Rates of processes* @ | *9/4 Labor Day*  ***8/31 last day to add or change 9/7 to drop***  HW1& due **S** 9/9 9pm – *Reading Summary and Discussion* |
| 3 Sep 11 – Sep 15 | *Partials\**  *vd Waals\** | *vd Waals\*,^*  *pVT system calculus* | *Discussion 1 post HW1/pre HW2* |
| 4 Sep 18 – Sep 22 | Ch. 2.1,2  *2-state sys*  *Einstein solids* | Ch. 2.3,4  *Interacting systems*  *Large systems* | HW2 due **S** 9/17 11pm |
| 5 Sep 25 – Sep 29 | Ch. 2.4,5  *Large systems^*  *Ideal Gas* | Ch. 2.6  *Entropy* | *Discussion 2 post HW2/pre HW3* |
| 6 Oct 2 – Oct 6 | Ch. 3.1,.2  *Redefining temp.*  *Entropy and heat* | Ch. 3.3  *Paramagnetism* | HW3 due **S** 10/1 11pm    **10/2 advising week** |
| 7 Oct 9 – Oct 13 | Ch. 3.3  *Paramagnetism* | Ch. 3.3,.4  *Mechanical Equilib.*  *Diff. Equil.* | *Discussion 3 post HW3/pre HW4*  **Exam 1 R 10/12 500- 700pm** |
| 8 Oct 16 – Oct 20 | Ch. 4.1,2  *Heat Engines,*  *Refrigerators*@ | Ch. 4.4  *Low Temperatures,*  *3rd Law*@\* | HW4 due **S** 10/15 11pm    *mid term Oct 20* |
| 9 Oct 23 – Oct 27 | Ch. 5.1  *Free Energy,*  *Thermodyn. Identity* | Ch. 5.1  *Free Energy,*  *Thermodyn. Identity* | *Discussion 4 post HW4/ exam review*  *midterm grades due on Oct 26* |
| 10 Oct 30 – Nov 3 | Ch. 5.2,3  *Chemical Potential*  *Phase Transitions* | Ch. 5.4  *Phase Transitions*  *of mixtures* | HW5& due **S** 10/29 11pm |
| 11 Nov 6 – Nov 10 | Ch. 5.4  *Phase Transitions*  *of mixtures* | Ch. 6.1  *Boltzmann factor,*  *Partition function* | *Discussion 5 pre HW6*  *11/10 last day to withdraw* |
| 12 Nov 13 – Nov17 | Ch. 6.2,3  *Average values,*  *Partition Theorem* | Ch. 6.4  *MaxwellB Speed*  *Distribution* | HW6 due S 11/12 11pm    **Exam 2 Nov 16 500-700pm** |
| 13 Nov 20 – Nov 24 | Ch. 6.4,5,6  *MB Speed Dis*  *Partition Functions* | - | *Discussion 6 post HW6/pre HW7*  ***Thanksgiving “break” 23rd– 24th*** |
| 14 Nov 27 – Dec 1 | 6.7  *Ideal Gas* | Ch. 7.1,2  *Gibbs Factor,*  *Fermions and Bosons* | HW 7 due **W** 11/29 11pm |
| 15 Dec 4 – Dec 8 | Ch. 7.3  *Degenerate Fermi*  *Gas* | Ch. 7.4  *Blackbody*  *Radiation* @ | HW8 due **F** 12/8 11pm  *Dead week: last day of classes 10th*  last day of classes 12/8 |
| 16 Dec 11 – Dec 15  ***exam week*** |  | 10:15-12:15 | **Final exam** *all finals are in the regular classroom unless otherwise announced*  **Final grades due 12/21** |

*Consult the deadline calendar on the Office of The Registrar webpage to double check my deadline dates*

*^ 15 tentative interactive sections with participation component*

*@  6 sections which could be skipped should class fall behind schedule*

*\* 6 sections which are not in textbook or are treated much shorter or much differently in the text*

*& 4 reflective writing hw assignments; requires handouts and some extra reading*