Thermal Physics Final Project Guidelines

The typical physics course routine—lectures, problem sets, and tests—is a marvelously efficient way to shovel large amounts of physics content into your brain. But this routine will *not* make you into a physicist, because it emphasizes breadth over depth and gives you few opportunities to think creatively and communicate what you have learned. In this course I've tried to partially address this shortcoming by assigning a "formal writeup" problem with each problem set. These give you a chance to think a little more deeply about a calculation, but the time you have to spend on them is still limited.

The final project in this course will further address the need for depth. It will give you a chance to explore a topic of your choice over a period of several weeks, write a formal paper on that topic, and present what you've learned to your classmates.

This project is not a mere "book report" in which you talk *about* something; the core of your project must be a genuine, nontrivial calculation. That's why your starting point should be a problem (or group of closely related problems), normally chosen from the attached list.

On the other hand, this project will involve much more than just "solving" a textbook-style problem and getting an "answer." Your task is not merely to solve a problem but also to think deeply about it. Why is the problem interesting? What does the answer mean? How does it tie in to the other things you've learned, and to the rest of the marvelous universe where we live? Your paper and presentation will include not just the problem solution but also a good deal of context.

Still, you need to start with a problem. Besides the recommended problems on the list, you may wish to explore some of the problems in sections of the book that we're not covering. You may also think of some other problem to solve that is not in the book. Either way, be sure to check with me at an early stage to be sure that the topic is appropriate for this assignment.

Once you've chosen your problem, the next step is to solve it like any other textbook problem. This time, of course, you *must* solve it correctly and completely. I'll gladly give hints if you get stuck, so don't hesitate to ask. But you should also check your method and your answer(s) in every way you can think of (short of looking up answers on the internet, which is always prohibited). And start thinking about whether the answer makes intuitive sense.

Adding appropriate context and discussion to flesh-out your project is a more open-ended task. The details will depend on what problem you've chosen, and also on your personal interests and judgment and creativity. One absolute requirement is that you must be able to *motivate* your problem to the satisfaction of yourself and your classmates; you don't want to start your presentation with words like "I chose this problem because it seemed as good as any of the others," or "The problem said to calculate such-and-such and so I did."

Not all of the listed problems have the same length and difficulty. But rather than searching for the one that seems technically easiest, I would encourage you to search for the one that interests you the most. Then the motivation should take care of itself—just explain why *you* thought the problem seemed interesting! If you choose a shorter or easier problem, you'll have to work harder to expand it into an interesting paper and presentation. If you choose a problem that's longer or harder to begin with, you won't need to be as creative in adding context to it.

The final outcomes of your project will be a paper and a presentation. Here are some specific guidelines for each.

Paper: Type your paper in the style of a journal article, divided into sections and illustrated with figures as appropriate. The introductory section should provide the context and motivation to grab the reader's interest. The middle sections should present your problem solution, presented in a logical and organized way. The concluding section should not be overly repetitive, but might review the big picture or raise some further questions. At the very beginning of the paper, write a high-level, one-paragraph summary of the whole thing, called an *abstract*. Put your bibliographic citations at the end of the paper, and note in the text (with note numbers or authors' names) where you're relying on each cited work.

As an example of how to format a scientific journal article, please download the file at http://web.mit.edu/rhprice/www/Contributors/SampleManuscript.zip (an archive containing four items) and look at the pdf sample manuscript. While you needn't be quite so formal in this class assignment, the basic ideas are still applicable. I also encourage you to use the LaTeX software package to typeset your paper. LaTeX is installed in the Computational Physics Lab and accessible there through a front-end application called TeXstudio; you can also install it on your own computer by following the instructions at www.latex-project.org, or use a very convenient cloud-based LaTeX systems called Overleaf (www.overleaf.com). The sample manuscript file explains why LaTeX is so widely used for mathematical papers, and serves as a tutorial for learning this software. Still, LaTeX has a bit of a learning curve and can be a bit frustrating at first, until you learn how to get started with it. Please don't hesitate to ask me for help! But if you prefer not to use LaTeX that's fine, so long as your final product looks reasonably similar to the sample manuscript.

Formatting aside, your paper should be written in your best English, composed of grammatically correct sentences and well-organized paragraphs, at a level that is appropriate for your classmates. Please refer to the Mathematical Writing Checklist for rules about incorporating math into prose. Be sure to include illustrations wherever possible. Clear and effective communication is an important skill for a physicist, and your grade will reward your efforts in this regard.

The length of your paper should be somewhere in the range of 6 to 12 pages, including figures, when double-spaced and formatted in the style of the sample manuscript. If for some reason you think your paper's length will fall outside this range, please consult me to see whether you might be doing something wrong. Within the usual page range, quality is more important than quantity.

Presentation: To a first approximation, your presentation should simply be an oral version of your paper. It should be similarly organized, with a brief overview (somewhat like an abstract), an introduction that motivates the problem, and so on. The main difference is that you'll be under a strict 12-minute time limit (including time for questions), so you'll have to leave out the minor details while working hard to efficiently convey as much information to your classmates as you can.

For visual aids, please prepare a set of 5 to 10 slides in PowerPoint or pdf or some other suitable format for use with a computer and digital projector. Do not plan to use the marker board, which would take up too much of your time. Make your slides as clear and legible as possible, using pictures wherever you can and equations where necessary, while avoiding long passages of text (since your audience can't read a lot of words while simultaneously listening to what you're saying). Please email me a copy of your slides on the day of your presentation.

Please inquire if you are unsure about what is expected to complete a your project. In all cases, if you do especially good work, you may receive some extra credit.

See the following pages for a list of suggested project problems, and for a schedule of important dates and deadlines.

Project Problem Suggestions

(Notes are on the reverse side.)

Topic	**Problem number(s)**	**Notes**
The virial expansion	1.17	C
Effusion	1.22	
MD atmosphere	MD13	MD
The speed of sound	1.39	
Convection in earth's atmosphere	1.40	
Isothermal compressibilities	1.46	
Negative heat capacities of stars	1.55, 3.4, 3.15	
Black hole thermodynamics	2.42, 3.7, 7.53	
Thermodynamics of rubber	3.34	
Basic MD thermodynamics	MD6, MD7	MD
Optimizing a Carnot engine for power	4.6	
Stirling engine	4.21	
Toward absolute zero	4.35, 4.36, 4.37	
Thermodynamics of muscle contraction	5.6, 5.7	
Partial derivative trickery	3.33, 5.12, 5.14	1
Thermodynamics of magnetic systems	5.17, 5.47	2
Grand free energy	5.23, 7.7	
Aluminosilicate phases	5.29, 5.39	
Ice engine paradox	5.33	
Relative humidity and cloud formation	5.42, 5.43, 5.44	3
Nucleation of cloud droplets	5.46	
Energy fluctuations at fixed temperature	6.17, 6.18, 6.19	
Anharmonic oscillators	6.21	C
Paramagnetism for higher spins	6.22	
Parahydrogen and orthohydrogen	6.30	C
A model of thermal expansion	6.32	4
The Kac model	(not in book)	5
MD Brownian motion	MD15, MD16	MD
MD Fluctuations	MD17	MD
Cooperative adsorption in hemoglobin	7.1, 7.2	
Semiconductor impurities	7.5	
An elementary model of fermions	7.16, 7.27	C
White dwarf stars	7.23	
Numerical treatment of a Fermi gas	7.32	C
Statistics of pure semiconductors	7.33, 7.34	
Paramagnetism in a Fermi gas	7.36	
Spontaneous and stimulated emission	7.41	
Formation of H atoms in the early universe	7.47	
The cosmic neutrino background	7.48	
Electron-positron pairs in the early universe	7.49, 7.50	C,6
The greenhouse effect on Venus	7.55, 7.56	
Spin waves in a ferromagnet	7.64	
Numerical calculations for a Bose gas	7.69, 7.70	C
BEC in a harmonic trap	7.73	
BEC in a harmonic trap, numerical treatment	7.74	C
Quantum gases in the high-T limit	7.75	

Notes on selected projects

C: These problems require some nontrivial use of a computing environment such as a spreadsheet or Mathematica, at a level comparable to that of the assigned homework problems that make use of this software.

MD: These problems are "numerical experiments" that use the Interactive Molecular Dynamics simulation program. The problem statements can be found at http://physics.weber.edu/schroeder/md/exercises.html, and the problem numbers (e.g., "MD13") correspond to the numbering on that page. Other projects using this simulation are also possible; feel free to ask for ideas or suggest one.

1: This set of problems uses the results of Problem 1.46. You could optionally incorporate Problem 1.46 into the project.

2: These problems involve concepts of electromagnetic theory (as taught in Physics 3510).

3: Problem 5.44 makes use of the result of Problem 1.40. You could optionally incorporate Problem 1.40 into the project.

4: You could optionally augment this project by including Problem MD14. There is an apparent discrepancy in the results that I don't fully understand, so if you can figure it out, I'll be very interested!

5: This is a computer simulation exercise that gives an alternative approach to understanding the Maxwell speed distribution (Section 6.4). It requires that you write a short computer program, at the level of our Physics 2300 course, in a language of your choice (e.g., Python or Mathematica). Please see me for details if you are interested in this project.

6: These problems build on Problems 7.46(d) and 7.48, which you would have to work first (though not necessarily include in your paper and presentation).

Important dates

- Monday, March 16: Inform me (by written note or email) of your top three project topic choices, and of your preferred presentation date(s). I will then resolve any conflicting choices and finalize the topic assignments and presentation schedule by the end of the week.
- Monday, March 30: Turn in a hand-written solution to your problem(s), in the same style that you would use to write up a regular homework solution, by 4:00 pm.
- Friday, April 3 (or sooner): Schedule a date and time to practice your presentation.
- April 10 through 15: Class time will be devoted to lectures on further topics not covered on your homework or tests. Attendance is expected. Meanwhile, work on your project outside of class.
- April 13: Turn in a complete typed draft of your paper (in hard copy) by 4:00 pm. I will return it with comments at least two days before your scheduled presentation.
- April 17 and 20: Student presentations during our regular class time. Attendance is expected.
- April 22: Student presentations during our scheduled final exam time (11:00 – 12:50 am). Refreshments will be served. Attendance is expected. Final papers are due at 4:00 pm.