

## **Syllabus, PHYS 307, Thermal Physics, Spring 2023**

Time: 1:30-2:45pm, MW

Location: Enterprise Hall 274

Instructor: Erhai Zhao

Email: [ezhao2@gmu.edu](mailto:ezhao2@gmu.edu)

Office: Planetary Hall 207

Office hour: tentatively Tuesday 1:30-3:30 PM (I have another class at 4:30PM).

How to reach me: A good place to ask questions is during or right after the class. You can also send me emails, please be mindful that I only check it a few times during the work day. If you need immediate response, drop by my office or call my office phone.

### **Textbook**

*Concepts in Thermal Physics, 2nd Ed*, by S. J. Blundell and K. M. Blundell (Oxford). This is the text used at Oxford University.

The GMU Library offers ebook versions of this book. You may want to bookmark the link:

<https://doi-org.mutex.gmu.edu/10.1093/acprof:oso/9780199562091.001.0001>

There are many other textbooks on thermodynamics and statistical mechanics. Previous instructors have used *An Introduction to Thermal Physics*, by D. Schroeder (Addison-Wesley), and *Fundamentals of Statistical and Thermal Physics*, by F. Reif (McGraw-Hill).

### **Grades**

Midterm (30%), final (30%), homework (40%).

### **Blackboard**

Announcements, course materials, homework assignments, and possible Zoom meeting links will be posted on Blackboard. You are responsible for checking it on regular basis.

### **Lectures**

Lectures will be delivered in classroom using the white board. Please note the content or order of the lecture will deviate from the textbook. So if you miss a lecture, the best way to make up is to borrow notes from a peer. Projectors will be used to show graphics and animations.

### **Homework**

Homework will be assigned on Blackboard with due date indicated. Solving the homework problems independently is crucial to your success in this class. Discussion with peers is encouraged but copying solutions from each other, or from solutions from any source, is a violation of the GMU honor code and will lead to zero credit or an F grade.

Each homework will be graded using a coarse scale (e.g. 0 to 5 out of 5). Late homework will not be accepted unless a written notice with a valid excuse is sent to the instructor before the due date. Solution to homework problems will be given.

### **Exams**

There is one midterm exam, covering the first half of the semester. The final exam will cover topics in the second half semester. Most exam problems will be similar to those in homework in terms of difficulty levels, but some may be harder. You can bring a self-prepared formula sheet (one sheet of paper, letter sized, both sides may be used) to the exam. No cell phones, laptops, books, or notes are allowed. Solution to exam problems will not be distributed.

### **Prerequisites**

Mature math skills are assumed. You should be familiar with partial derivatives, multiple integrals, sum & product of series, probability and statistics. Work through appendix B and C of the textbook to get an idea of the math level involved.

To get the most out of this course, you are also assumed to have

- (1) a solid grasp of classical mechanics (kinetic and potential energy, momentum and collision, rotations, harmonic oscillators, waves...);
- (2) basic ideas of quantum mechanics (energy levels, Planck's constant, quantum numbers etc., at the level of Young and Freedman, University Physics, chapter 38-41);
- (3) **basic knowledge of thermodynamics, at the level of PHYS 266, Introduction to Thermodynamics (e.g. Young and Freedman, University Physics, chapter 17-20).**

### **Topics [subject to change]**

Our plan is to cover the essentials of statistical mechanics and thermodynamics. We will skip chapter 10, 25, 27, 31-37 of the book. Some chapters, e.g. 8-9, 15, 22-24 and 30, will be condensed.

#### **I. Kinetic theory of gas**

1. Thermodynamic systems, equation of state, ideal gas and spin chain.
2. Large numbers, Stirling formula, macro vs microstates, entropy defined.
3. Thermal equilibrium, zeroth law, statistical definition of temperature.
4. Boltzmann distribution, applied to two-state systems.
5. Probability distribution, random variables, standard deviation, binormal and Gaussian distribution.
6. Kinetic theory of gases, Maxwell distribution, Gaussian integrals, effusion, mean free path, diffusion.

#### **II. Thermodynamics**

7. Internal energy, the first law, heat and heat capacity, isothermal and adiabatic processes.
8. Heat engines, Carnot's theorem, the second law (Kelvin vs Clausius), Clausius theorem/inequality.
9. Thermodynamic entropy, computing the entropy change of ideal gases.

#### [Midterm Exam]

10. Thermodynamic potentials U, H, F, G; natural variables; Partial derivatives of entropy.
11. Availability, minimization of free energy; Maxwell relations. Third law.

#### **III. Statistical mechanics**

12. Fundamental postulate. Gibbs entropy and its maximization. Three kinds of Ensembles.
13. Canonical ensembles, partition function. Sausage machine. Two-level system, spin chain again.
14. Ideal gas revisited. Thermal de Broglie wave length. Density of states.
15. Classical stat mech. Harmonic oscillator. Equipartition theorem. Diatomic gas.
16. Grand canonical ensemble, chemical potential. Grand partition function and grand potential.
17. van der Waal gas, liquid-gas transition, critical phenomena.
18. Clausius-Clapeyron equation, classification of phase transitions, Ising model in 2D.
19. Quantum statistics. Bose and Fermi gases. Photons and phonons.

#### [Final Exam]

#### **Safety**

All students taking courses with a face-to-face component are required to follow the university's public health and safety precautions and procedures outlined on the university Safe Return to Campus webpage (<https://www2.gmu.edu/safe-return-campus>). Students are required to follow Mason's current policy about facemask-wearing. An appropriate facemask must cover your nose and mouth at all times in our

classroom. If this policy changes, you will be informed; however, students who prefer to wear masks either temporarily or consistently will always be welcome in the classroom.

### **Course Materials and Student Privacy**

All course materials posted on Blackboard are private to this class; by federal law, any materials that identify specific students (via their name, voice, or image) must not be shared with anyone not enrolled in this class.

Sharing of instructor-created materials, particularly materials relevant to assignments or exams, to public online “study” sites may be considered a violation of Mason’s Honor Code. Always ask for instructor’s permission before distributing lecture notes or homework solutions to anyone not enrolled in this class.

### **Academic Integrity**

The George Mason University Honor Code can be found at the Office of Academic Integrity website <http://oai.gmu.edu>. It contains guidelines regarding cheating, plagiarism, and other academic misconduct.

### **Accommodations**

Disability Services at George Mason University is committed to providing equitable access to learning opportunities for all students by upholding the laws that ensure equal treatment of people with disabilities. If you are seeking accommodations for this class, please first visit <http://ds.gmu.edu/> for detailed information about the registration process, then discuss your approved accommodations with me. Disability Services is located in Student Union Building I (SUB I), Suite 2500. Email: [ods@gmu.edu](mailto:ods@gmu.edu); Phone: (703) 993-2474.

### **Diversity and Inclusion**

Please refer to Mason’s Non-Discrimination Policy, <https://universitypolicy.gmu.edu/policies/non-discrimination-policy/>, and the Mason Diversity Statement, <https://stearnscenter.gmu.edu/knowledge-center/general-teaching-resources/mason-diversity-statement/>.

### **More University Resources**

Learning Services (<https://learningservices.gmu.edu/>)  
Student Support and Advocacy Center (<https://ssac.gmu.edu/>)  
Counseling and Psychological Services (<https://caps.gmu.edu/>)  
Mason’s Title IX Coordinator (703-993-8730, [titleix@gmu.edu](mailto:titleix@gmu.edu))