Physics 335 - Thermal Physics - Fall 2020
MWF 10:00 - 10:50 AM
Professor Christopher Hawley
Office Hours: Mon. 1-3 PM, Tues. 10 AM – 12 noon
E-mail: hawleycj@lafayette.edu

Required Primary Text: An Introduction to Thermal Physics, Daniel V. Schroeder, 2000

Course Website: We will use Moodle – http://moodle.lafayette.edu. "PHYS 335.01- Fall 2020 Thermal Physics" should be in your list of current courses. Handouts, homework assignments/solutions, supplemental articles, etc., can be downloaded from this site.

Useful supplementary physics texts:

- Thermodynamics and an Introduction to Thermostatistics 2nd ed., H. B. Callen, 1985.
- Thermal Physics 2nd ed., Charles Kittel and Herbert Kroemer, 1980.
- Statistical Physics, 2nd ed., Landau-Lifschitz, 1969.

Suggested supplementary mathematical physics texts:

- Mathematical Methods for Physicists 5th ed., George B. Arfken and Hans J. Weber, 2001.

Class Overview and Goals:

The specific goal of this course is for you to master the concepts and facts of thermal physics, as outlined in the preface and table of contents of your textbook. In brief, you will learn how collections of very large numbers of particles behave, and how to connect their large-scale behavior to the microscopic behavior of the individual particles. Thermal physics provides a vast and fertile playground for the development and application of advanced mathematical techniques, many of which can be transferred with suitable modifications to other branches of physics and even to other fields of study, e.g., biology, medicine and economics.

But I'd rather teach you **how to think** than what to think. Physics is not so much a collection of facts as it is **a way of looking at the world**. My hope is that this course will not only teach you the ideas of thermal physics, but will also improve your skills in careful thinking, problem solving, and clear communication. In this course you will practice and refine your skills in mathematical problem solving using calculus; using a computer to help solve math problems; making rough numerical estimates and more accurate calculations; and communicating the ideas of physics, both qualitatively and quantitatively, through words, pictures, and equations. Whether or not you choose to become a professional physicist, these skills will serve you well for the rest of your life.

Student Learning Outcomes:

- Students will get a mental grip on simple, but elusive thermodynamic concepts, e.g., temperature, heat and entropy.
- Students will be able to apply the laws of thermodynamics to a wide variety of situations, including those encountered in everyday life.
- Students will understand the principles behind the design and operation of heat engines, heat pumps and refrigerators.
- Students will be able (by combining the laws of quantum mechanics and the laws of statistics) to predict the behavior of widely varied, complex systems consisting of a large number of particles.
- Students will see how the principles of statistical mechanics provide an underlying explanation for thermodynamics, in particular, drawing connections between the properties of a macroscopic system and its microscopic constituents.
- Students will appreciate how the probabilistic analysis provided by statistical mechanics explains a mind-boggling array of phenomena in fields as diverse as biology, chemistry, physics, climatology and medicine.
- Students will appreciate the foundational nature of Physics and its relationship to other disciplines as well as its connection with the solution of real-world problems.

Homework:

Preparing for class by doing the readings and doing the homework are critical to your success. Homework assignments will be given nearly weekly and are to be handed in **Wednesdays at the start of class** if not otherwise indicated. Late homework will be accepted ONCE up to 48 hours late with no questions asked – other than that, no late work will be accepted. Solutions to homework will be posted on Moodle.

Seminars:

Occasionally throughout the semester I hope to allow students to receive extra credit towards your homework score by attending physics department seminars. During COVID, this is a bit of an unknown, but if physics-specific seminars do not get scheduled I hope to expand the seminars to science/engineering topics from the Lafayette community where the expected audience is still the Lafayette students/faculty and student questions are allowed. You will be required to turn in a 1-page, double spaced reflection of the seminar critiquing both the good and bad aspects of the talk and anything you found particularly impactful (we will discuss this more in class). I expect these to happen ~1 per month and be worth 20 HW points.

Guidelines for Writing Up Homework:

It is to your advantage to do the assigned homework. I have chosen the problems to help you learn the material. Physics can be a complicated thing, but repeatedly working with it (and at it) is essential in order to gain physical intuition and get comfortable with the mathematical theory.

Feel free to use computational aids for some of the mathematics if you prefer, but note that there is some advantage to working things out by hand. Not being able to solve problems "by inspection" could end up hurting you on an exam where you will not be permitted to use computational tools and, frequently, there are mathematical tricks you can use to easily simplify a problem that you will not appreciate if you ask a program to do the work.

I encourage you to work on these problem sets collaboratively, though I do expect you to take 10-15 minutes to give a problem "the old college try" on your own so you enter into discussion with others having some ideas to contribute. You will make your life easier as well as improve your understanding if you work with others (either by explaining it or having it explained to you). I expect solutions to be written up individually (or, if your handwriting is illegible, typed), and all collaboration should be properly acknowledged.

I expect your problem sets to be clearly and logically organized. This means that:

- Each problem should start **on a new page**.
- Write out the problem (or an abbreviated version containing all relevant information). Draw a picture/diagram if useful.
- Clearly work out the problem, commenting your work as you go. Problem sets should never contain just the math; use words to describe what you are doing and to reference where in the text an equation came from and why it is relevant.
- Remember to keep track of units (by writing them out with all your calculations)! Do the units work out as you expect they ought to at the end of a problem? Dimensional analysis is the easiest check to ensure you have tackled the problem correctly.
- Box your final solutions or major milestones as you do the problem. This makes it easier to grade and also for you to follow your own work when you look it over.
- Comment on the significance of your answer. (Does it make sense? Is it what you expected? Why or why not?)
- Attach a cover page to your problem set. This can be the problem sheet or something else, but it should have your name and a clear acknowledgement of all those you have collaborated with on the assignment. This includes fellow students, faculty, etc. (anyone who you consulted or worked with).
- Please see me if you have any questions about this! I know it seems a bit ridiculous listed out like this, but I promise that it will serve you well in the long run. Writing in science is different from the traditional humanities paper, but the point is the same: to clearly and effectively communicate something. This will help you to accomplish that.

Projects:

At the end of the semester you will work on a capstone project for this course, giving you a chance to investigate a thermal physics problem in more depth and present your results in a formal paper and short slide presentation to your classmates. Detailed guidelines and dates are given in a separate document.

Exams:

The course has two exams, a midterm and a final, on dates specified in the Syllabus. Both exams are closed book and closed notes, no phones or laptops, with calculators allowed. I will provide an equation sheet for the exams and post it ahead of time.

Participation:

Your participation grade will be dependent on watching the posted lecture material within 24 hours of normal class time as well as your active participation with Friday Seminar small group activities.

Seminar Fridays:

Each Friday, at class time, the class will log into Zoom and break into smaller groups (4-5 people) to be led in a discussion by a classmate on the topic indicated on the syllabus. This responsibility will rotate by week and I will move in and out of these groups throughout the hour.

Collaboration:

Collaboration among students on homework is not only allowed, it is very much encouraged! However, any work you turn in must be written by you, in your own words, and faithfully represent your understanding of the course material. Collaboration on exam questions is **never** permitted. Directly copying homework solutions or exam answers will result in a zero for the assignment or exam to failure for the course, depending on the severity and subject of the academic violation.

I encourage all of you to seek help when needed. Generally, the earlier you come the better the results. Interacting with students has been and remains a source of great satisfaction for me – please stop by via Zoom!

Grading:

All grading mistakes have to be resolved within one week after the homeworks or examinations are returned to the students. Attendance is required to be successful in this class. In addition, physics majors are required to attend the colloquia this semester with that attendance reflected in their grade for this course.

10% Participation and Attendance	15% Midterm Exam
40% Homework	20% Final Exam (Cumulative)
15% Project Paper and Presentation	

Course Outline:

	Monday	Wednesday	Friday
Week 1 – Aug 17	Thermal Equilibrium 1.1	Ideal Gas, Equipartition 1.2, 1.3	Heat and Work 1.4, 1.5
Week 2 – Aug 24	Heat Capacity 1.6	Enthalpy 1.6	Microstates 2.1, 2.2
Week 3 – Aug 31	The 2nd Law 2.3	Large Systems 2.4	Ideal Gas 2.5
Week 4 – Sept 7	Entropy 2.6	Temperature 3.1	Entropy and Heat 3.2
Week 5 – Sept 14	Paramagnetism 3.3	Pressure 3.4	Chemical Potential 3.5, 3.6
Week 6 – Sept 21	Heat Engines 4.1	Refrigerators 4.2	Free Energy 5.1
Week 7 – Sept 28	Free Energy and Equilibrium 5.2	Phase Transformations 5.3	More Phase Transformations 5.3
Week 8 – Oct 5	The Boltzmann Factor 6.1	Average Values 6.2	**Midterm**
Week 9 – Oct 12	Catch-Up Day	The Equipartition Theorem 6.3	The Maxwell Speed Distribution 6.4
Week 10 – Oct 19	Partition Functions 6.5	More Partition Functions 6.6	Revisiting the Ideal Gas 6.7
Week 11 – Oct 26	The Gibbs Factor 7.1	Bosons and Fermions 7.2	Degenerate Fermi Gases 7.3
Week 12 – Nov 2	More Degenerate Fermi Gases 7.3	Photon Gas 7.4	Blackbody Radiation 7.4
Week 13 – Nov 9	Debye Theory of Solids 7.5	Bose-Einstein Condensation 7.6	More Bose-Einstein Condensation 7.6
Week 14 – Nov 16	Projects!	Projects!	Projects!

Final Exam (Comprehensive Test) Time TBD by Registrar

Accommodations:

In accordance with Lafayette College policy, reasonable academic accommodation and support services are available to students who have a documented disability. It is your responsibility to provide me with the appropriate paperwork from the Accessibility Services Office. More information is available at https://hub.lafayette.edu/disability-services/.

Gender Inclusion:

This is a gender-inclusive classroom. I have been provided with a class roster and your legal names. I will gladly honor any requests to be addressed by a different name or pronoun than appears on the class. Please make me aware of any preferences.

Moodle Privacy Statement:

Please note that Moodle contains student information that is protected by the Family Educational Right to Privacy Act (FERPA). Disclosure to unauthorized parties violates federal privacy laws. Courses using Moodle will make student information visible to other students in this class. Please remember that this information is protected by these federal privacy laws and must not be shared with anyone outside the class. Questions can be referred to the Registrar's Office.

Federal Credit Hour Compliance Statement:

The student work in this course is in full compliance with the federal definition of a four credit hour course. Please see the Registrar's Office web site (https://registrar.lafayette.edu/wp-content/uploads/sites/193/2013/04/Federal-Credit-Hour-Policy-Web-Statement.doc) for the full policy and practice statement.

Proper Usage of Course Materials and Classroom Recordings:

At Lafayette College, all course materials are proprietary and for class purposes only. This includes posted recordings of lectures, worksheets, discussion prompts, and other course items. Reposting such materials or distributing them through any means is prohibited. Such materials should not be reposted or distributed through any means. You must request my permission prior to creating your own recordings of class materials, and any recordings are not to be shared or posted online even when permission is granted to record. If you have any questions about proper usage of course materials please ask me. Please also be in contact with me if you have any concerns with being recorded during the course.

Online discussions in Moodle occurring during synchronous class sessions should also remain private and not be shared outside of the course. Courses using Moodle will make student information visible to other students in this class. Student information in courses is protected by the Family Educational Right to Privacy Act (FERPA). Disclosure of student information to unauthorized parties violates federal privacy laws and it must not be shared with anyone outside the class. Questions can be referred to the Registrar's Office.