PHY 350 – Heat and Thermodynamics

Spring 2022

Instructor Information

Professor: Kevin Aptowicz, Ph.D.
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Office: SECC 365
Office Hours:

Monday: 1 to 3 pm
Tuesday: 11:30 to 12:00 pm
Wednesday: 1 to 3 pm (virtual)
Thursday: 11:30 to 12:00 pm

Materials

Required Textbook:

- Schroeder, Daniel V. "An Introduction to Thermal Physics." (2020) ISBN: 9780192895554

Required Materials:

- A computer that can run Matlab

Recommend Textbook:

- Attaway, S. (2013). *Matlab: A Practical Introduction to Programming and Problem Solving.* Butterworth-Heinemann.

Software

This course relies heavily on Matlab. The University has a site license for Matlab making it free for all students. To install Matlab on your personal computer, use the WCU portal on Mathworks.

Course Description

Equations of state, first and second laws of thermodynamics, ideal and real gases, entropy, and statistical mechanics.

Course Student Learning Outcomes:

1. Student will be able to explain with examples the meaning of thermal equilibrium, mechanical equilibrium, and diffusive equilibrium.
2. Student will be able to describe the physical significance of the Kelvin scale.
3. Student will be able to state the ideal gas law and the relationship between the constant R in the ideal gas law and Boltzmann's constant.
4. Student will be able to state the equipartition theorem and explain its physical significance.
5. Student will be able to explain the meaning 'temperature', 'heat', 'energy', and 'work' from a thermodynamic point of view. Student will be able to compare and contrast the meaning of these words.
6. Student will be able to state the first law of thermodynamics as an expression and explain each term in the expression.
7. Student will be able to define specific heat capacity and explain the relationship between heat capacity and degrees of freedom including explaining the meaning of degrees of freedom being 'frozen out.'

8. Student will be able to define and contrast the terms microstate, macrostate, and multiplicity.
9. Student will be able to describe the Einstein model of a solid.
10. Student will be able to explain why the second law of thermodynamics is less a fundamental law and more a statement about probabilities.
11. Student will be able to explain the significance of the thermodynamic limit.
12. Student will be able to write an expression that defines entropy in terms of multiplicity.
13. Student will be able to explain why the entropy of a monoatomic gas depends on the particles being indistinguishable. Explanation will qualitatively convey how distinguishable particles would impact the calculation of entropy.
14. Student will be able to state the relationship between temperature, entropy, and internal thermal energy including why objects in thermal equilibrium are at the same temperature.
15. Student will be able to describe how changes in entropy can be measured in the lab rather than calculated.
16. Student will be able to state the general relationship between chemical potential and entropy as well as describe the physical interpretation of chemical potential.
17. Student will be able to state the generalized thermodynamic relationship and, from this expression, derive the expressions for temperature, pressure, and chemical potential.
18. Student will be able to explain why all the heat from hot reservoir can't be converted into work in a heat engine.
19. Student will be able to describe the Carnot cycle with a graph and explain the features of this cycle that leads to maximum efficiency.
20. Student will be able to draw diagrams to explain the energy flow and changes of entropy of a heat engine.
21. Student will be able to compare and contrast enthalpy, Helmholtz free energy and Gibbs free energy.
22. Student will be able to explain why PV is positive, but TS is negative in thermodynamic expressions.
23. Student will be able to derive the thermodynamic identity of dG from the definition of G and the thermodynamic identity of dU.
24. Student will be able to find the equilibrium state of a system at constant temperature and pressure by minimizing the Gibbs free energy. Student will be able to explain how this procedure is aligned with second law of thermodynamics.
25. Student will be able to sketch the phase diagram for water and explain the physical significance of a critical point as well as the physical significance of the Clausius-Clapeyron relation.
26. Student will be able to use graphs of the Gibbs Free energy to explain the abrupt change in volume of a phase transition.
27. Student will be able to state the expression and the physical significance of a Boltzmann factor and the partition function.
28. Student will be able to state the equipartition theorem and explain why it can't be applied to a low-temperature solid.
29. Student will be able to explain the difference between the partition function of distinguishable and indistinguishable particles. State why such a difference would arise.
30. Student will be able to explain the difference (both mathematically and physically) between the Boltzmann factor and the Gibbs factor.
31. Student will be able to describe the difference between bosons and fermions.
32. Student will be able to explain the significance of the de Broglie wavelength when considering a quantum gas.
33. Student will be able to sketch the Fermi-Dirac distribution for both low temperatures and high temperatures. Explain the physics behind the difference.
34. Student will be able to sketch the Bose-Einstein distribution and explain the physical interpretation of its shape.
35. Student will be able to compare and contrast a Fermi gas and a Boson gas.

36. Student will be able to explain the significance of the Fermi energy and Fermi temperature.
37. Student will be able to explain the cause of "degeneracy pressure."
38. Student will be able to explain the thinking behind the 'Ultraviolet Catastrophe'. Student will be able to explain how Planck's approach resolves the 'Ultraviolet Catastrophe.' Student will be able to sketch Planck's spectrum and explain what the distribution suggests about the energy of photons emitted by a blackbody.
39. Student will be able to describe a phonon and its physical significance. Student will be able to explain why phonons don't have arbitrary short wavelengths.
40. Student will be able to describe a Bose-Einstein condensate. Student will be able to describe what happens to a gas of weakly interacting atoms as the temperature goes is lowered thorough the condensation temperature.
41. Student will be able to state the physical significance of the density of states. Student will be able to describe what it represents and explain the role of the density of states when determining the heat capacity of an object.

Applicable Programmatic Student Learning Outcomes:

Outcome A: Knowledge and Understanding of the Concepts and Principles of Physics

Upon successful completion this course, students will demonstrate competence solving problems involving the topics listed in the Course Student Learning Outcomes.

Outcome B: Effective Communication

Upon successful completion of this course, students will demonstrate the ability to formulate written solutions to thermodynamic problems and well as explain fundamental concepts of thermodynamics through oral communication.

Meeting & Assessing Student Learning Outcomes:

Outcome A: Knowledge and Understanding of the Concepts and Principles of Physics

Meeting: Students will meet Outcome A by reading the textbook, engaging in lecture, solving weekly assigned pencil-n-paper problems, completing a weekly study-guide, and running simulations in Matlab.

Assessing: Formative assessments will happen throughout the semester. These include feedback in class during discussions and feedback on submitted weekly problem sets. Summative assessments include three in-class exams and the oral final exam.

Outcome B: Effective Communication

Meeting: Students will meet Outcome B by engaging in small group discussions during class time, answering questions posed by the instructor, as well as writing up solutions to problem set questions and study-guide questions.

Assessing: Formative assessments will happen throughout the semester including feedback in class during discussions and feedback on submitted weekly problem sets. Summative assessments include three in-class exams and the oral final exam.

Attendance Policy

Attendance is required and critical to the success of the course. Students are expected to attend all class sessions. If absence is unavoidable, please email the instructor (preferable before the class session).

Evaluation & Grading

45% - Midterm exams (3 × 15% each)
15% - Engagement and participation in lecture
20% - Problem sets
20% - Oral final exam
Total: 100%

A letter grade will be assigned based on performance in the course according to the following scale:

Grade	Quality Points	Percentage Equivalents	Interpretation
A	4.00	93-100	Excellent
A-	3.67	90-92	
B+	3.33	87-89	Superior
B	3.00	83-86	
B-	2.67	80-82	
C+	2.33	77-79	Average
C	2.00	73-76	
C-	1.67	70-72	
D+	1.33	67-69	Below Average
D	1.00	63-66	
D-	0.67	60-62	
F	0	< 60%	Failure

Refer to the Undergraduate Catalog for description of NG (No Grade), W, Z, and other grades.

Exam Make-up Policy:

Student MUST reach out to instructor 24-hours (if possible) prior to missing an exam to discuss alternate plan.

Tentative Course Outline

Content Week	Date Month/Day	Day	Topic
1	1/25	Tuesday	Chapter 1: Energy in Thermal Physics
1	1/27	Thursday	Chapter 1: Energy in Thermal Physics
2	2/1	Tuesday	Chapter 1: Energy in Thermal Physics
2	2/3	Thursday	Chapter 2: The Second Law
3	2/8	Tuesday	Chapter 2: The Second Law
3	2/10	Thursday	Chapter 2: The Second Law
4	2/15	Tuesday	Chapter 3: Interactions and Implications
4	2/17	Thursday	Chapter 3: Interactions and Implications
5	2/22	Tuesday	Chapter 3: Interactions and Implications
5	2/24	Thursday	Chapter 4: Engines and Refrigerators
	3/1	Tuesday	Review
	3/3	**Thursday**	**Exam #1**
6	3/8	Tuesday	Chapter 5: Free Energy and Chemical Thermodynamics
6	3/10	Thursday	Chapter 5: Free Energy and Chemical Thermodynamics
	3/15	Tuesday	*** Spring Break ***
	3/17	Thursday	*** Spring Break ***
7	3/22	Tuesday	Chapter 5: Free Energy and Chemical Thermodynamics
7	3/24	Thursday	Chapter 6: Boltzmann Statistics
8	3/29	Tuesday	Chapter 6: Boltzmann Statistics
8	3/31	Thursday	Chapter 6: Boltzmann Statistics
	4/5	Tuesday	Review
	4/7	**Thursday**	**Exam #2**
9	4/12	Tuesday	Chapter 7: Quantum Statistics
9	4/14	Thursday	Chapter 7: Quantum Statistics
10	4/19	Tuesday	Chapter 7: Quantum Statistics
10	4/21	Thursday	Chapter 7: Quantum Statistics
11	4/26	Tuesday	Chapter 7: Quantum Statistics
11	4/28	Thursday	Chapter 7: Quantum Statistics
	5/3	Tuesday	Review
	5/5	**Thursday**	**Exam #3**
	5/12	Thursday	**Final Exam**

Statements Common to All WCU Undergraduate Syllabi

ACADEMIC & PERSONAL INTEGRITY

It is the responsibility of each student to adhere to the university's standards for academic integrity. Violations of academic integrity include any act that violates the rights of another student in academic work, that involves misrepresentation of your own work, or that disrupts the instruction of the course. Other violations include (but are not limited to): cheating on assignments or examinations; plagiarizing, which means copying any part of another's work and/or using ideas of another and presenting them as one's own without giving proper credit to the source; selling, purchasing, or exchanging of term papers; falsifying of information; and using your own work from one class to fulfill the assignment for another class without significant modification. Proof of academic misconduct can result in the automatic failure and removal from this course. For questions regarding Academic Integrity, the No-Grade Policy, Sexual Harassment, or the Student Code of Conduct, students are encouraged to refer to the Department Undergraduate Handbook, the Undergraduate Catalog, the Ram's Eye View, and the University website at www.wcupa.edu.

STUDENTS WITH DISABILITIES

If you have a disability that requires accommodations under the Americans with Disabilities Act (ADA), please present your letter of accommodations and meet with me as soon as possible so that I can support your success in an informed manner. Accommodations cannot be granted retroactively. If you would like to know more about West Chester University's Services for Students with Disabilities (OSSD), please visit them at 223 Lawrence Center. Their phone number is 610-436-2564, their fax number is 610-436-2600, their email address is ossd@wcupa.edu, and their website is at https://www.wcupa.edu/universityCollege/ossd/. In an effort to assist students who either receive or may believe they are entitled to receive accommodations under the Americans with Disabilities Act and Section 504 of the Rehabilitation Act of 1973, the University has appointed a student advocate to be a contact for students who have questions regarding the provision of their accommodations or their right to accommodations. The advocate will assist any student who may have questions regarding these rights. The Director for Equity and Compliance/Title IX Coordinator has been designated in this role. Students who need assistance with their rights to accommodations should contact them at 610-436-2433.

EXCUSED ABSENCES POLICY

Students are advised to carefully read and comply with the excused absences policy, including absences for university-sanctioned events, contained in the WCU Undergraduate Catalog. In particular, please note that the "responsibility for meeting academic requirements rests with the student," that this policy does not excuse students from completing required academic work, and that professors can require a "fair alternative" to attendance on those days that students must be absent from class in order to participate in a University-Sanctioned Event.

REPORTING INCIDENTS OF SEXUAL VIOLENCE

West Chester University and its faculty are committed to assuring a safe and productive educational environment for all students. In order to comply with the requirements of Title IX of the Education Amendments of 1972 and the University's commitment to offering supportive measures in accordance with the new regulations issued under Title IX, the University requires faculty members to report incidents of sexual violence shared by students to the University's Title IX Coordinator. The only exceptions to the faculty member's reporting obligation are when incidents of sexual violence are communicated by a student during a classroom discussion, in a writing assignment for a class, or as part of a University-approved research project. **Faculty members are obligated to report sexual violence or any other abuse of a student who was, or is, a child (a person under 18 years of age) when the abuse allegedly occurred to the person designated in the University Protection of Minors Policy.** Information regarding the reporting of sexual violence and the resources that are available to victims of sexual violence is set forth at: https://www.wcupa.edu/_admin/diversityEquityInclusion/sexualMisconduct/default.aspx

INCLUSIVE LEARNING ENVIRONMENT AND ANTI-RACIST STATEMENT

Diversity, equity, and inclusion are central to West Chester University's mission as reflected in our Mission Statement, Values Statement, Vision Statement and Strategic Plan: Pathways to Student Success. We disavow racism and all actions that silence, threaten, or degrade historically marginalized groups in the U.S. We acknowledge that all members of this learning community may experience harm stemming from forms of oppression including but not limited to classism, ableism, heterosexism, sexism, Islamophobia, anti-Semitism, and xenophobia, and recognize that these forms of oppression are compounded by racism.

Our core commitment as an institution of higher education shapes our expectation for behavior within this learning community, which represents diverse individual beliefs, backgrounds, and experiences. Courteous and respectful behavior, interactions, and responses are expected from all members of the University. We must work together to make this a safe and productive learning environment for everyone. Part of this work is recognizing how race and other aspects of who we are shape our beliefs and our experiences as individuals. It is not enough to condemn acts of racism. For real, sustainable change, we must stand together as a diverse coalition against racism and oppression of any form, anywhere, at any time.
Resources for education and action are available through WCU's Office for Diversity, Equity, and Inclusion (ODEI), DEI committees within departments or colleges, the student ombudsperson, and centers on campus committed to doing this work (e.g., Dowdy Multicultural Center, Center for Women and Gender Equity, and the Center for Trans and Queer Advocacy).
Guidance on how to report incidents of discrimination and harassment is available at the University's Office of Diversity, Equity and Inclusion.

EMERGENCY PREPAREDNESS
All students are encouraged to sign up for the University's free WCU ALERT service, which delivers official WCU emergency text messages directly to your cell phone. For more information, visit www.wcupa.edu/wcualert. To report an emergency, call the Department of Public Safety at 610-436-3311.

ELECTRONIC MAIL POLICY
It is expected that faculty, staff, and students activate and maintain regular access to University provided e-mail accounts. Official university communications, including those from your instructor, will be sent through your university e-mail account. You are responsible for accessing that mail to be sure to obtain official University communications. Failure to access will not exempt individuals from the responsibilities associated with this course.