PHY 350 Heat and Thermodynamics
Fall 2013

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TEXT: Classical and Statistical Thermodynamics, Ashley H. Carter (2001).

FALL SEMESTER SCHEDULE

26 Aug	8 a.m.	Mon	University classes begin
27 Aug	11 a.m.	Tues	First PHY 350 class
2 Sept		Mon	Labor Day; no classes
3 Oct	11 a.m.	Thurs	***First Hour Exam***
7-8 Oct		Mon-Tues	Fall Break – No classes
12 Nov		Tues	***Second Hour Exam***
27-29 Nov		Wed-Fri	Thanksgiving Recess
5 Dec	11 a.m.	Thurs	Last PHY 350 class
9 Dec		Mon	Last day of classes
			Final Exam

COURSE GOALS, DIRECTION AND OBJECTIVES

In this course we will examine on a fundamental level the thermodynamics of matter and energy. We will begin with a traditional introduction to the classical theory. Early on, emphasis is placed on the advantages of expressing the fundamental laws in terms of state variables, quantities whose differentials are exact. The elaboration of the First Law is followed by applications and consequences. Entropy is presented both as a useful physical variable and also as a phenomenological construct necessary to explain why processes permitted by the First Law exist but that do not occur in nature. This leads us to the Second law. We examine in detail the changes in entropy for various reversible and irreversible processes. The thermodynamic potentials are introduced via the Legendre transformation, and we examine the condition for stable thermodynamic equilibrium. After building a foundation in classical theory, we develop the kinetic theory of gases. It represents, both logically and historically, the transition between classical thermodynamics and statistical theory. Finally, we examine the underlying principles of equilibrium statistical thermodynamics.

Throughout this course, we will develop many mathematical tools and techniques to aid us in the description of thermodynamic systems. We will continue to systematically develop problem-solving skills, an important requisite in the critical and logical analysis of the physical world. Our goal is to be able to identify which physical principles are useful in understanding a particular thermodynamic system and to use those principles to obtain experimentally verifiable information about it.

COURSE CONTENT AND SYLLABUS

1. The nature of thermodynamics
    - a. What is thermodynamics?
    - b. Definitions
    - c. The kilomole
    - d. Limits of the continuum
    - e. More definitions
    - f. Units
    - g. Temperature and the Zeroth Law of Thermodynamics

2. Equations of state
    - a. Introduction
    - b. Equation of state of an ideal gas
    - c. Van der Waals' equation of state
    - d. P-v-T surfaces of real substances
    - e. Expansivity and compressability
    - f. Applications

3. The First Law of Thermodynamics
    - a. Configuration work
    - b. Dissipative work
    - c. Adiabatic work and internal energy
    - d. Heat
    - e. Units of heat
    - f. The mechanical equivalent of heat
    - g. Summary of the First Law
    - h. Applications to calculations of work

4. Applications of the First Law
    - a. Heat capacity
    - b. Mayer's equation
    - c. Enthalpy and heats of transformation
    - d. Relationships involving enthalpy
    - e. Comparison of u and h
    - f. Work done in an adiabatic process

5. Consequences of the First Law
    - a. The Guy-Lussac-Joule experiment
    - b. The Joule-Thomson experiment
    - c. Heat engines and the Carnot cycle

6. The Second Law of Thermodynamics
    - a. Introduction
    - b. The mathematical concept of entropy
    - c. Irreversible processes

d. Carnot's theorem
e. The Clausius inequality and the Second Law
f. Entropy and available energy
g. Absolute temperature
h. Combined First and Second Laws

7. Applications of the Second Law
   a. Entropy changes in reversible processes
   b. Temperature-entropy diagrams
   c. Entropy changes of the surroundings for a reversible process
   d. Entropy change for an ideal gas
   e. The Tds equations
   f. Entropy changes in irreversible processes
   g. Free expansion of an ideal gas
   h. Entropy change for a liquid and solid

8. Thermodynamic potentials
   a. Introduction
   b. the Legendre transformation
   c. Definitions of thermodynamic
   d. The Maxwell relations
   e. The Helmholtz function
   f. The Gibbs function
   g. Application of the Gibbs function to phase transformations
   h. An application of the Maxwell relations
   i. Conditions for stable equilibrium

9. The chemical potential and open systems
   a. the chemical potential
   b. Phase equilibrium
   c. The Gibbs phase rule
   d. Chemical reactions
   e. Mixing processes

10. The Third Law of Thermodynamics
   a. Statements of the Third Law
   b. Methods of cooling
   c. Equivalence of the statements
   d. Consequences of the Third Law

11. The kinetic theory of gases
   a. Basic assumptions
   b. Molecular flux
   c. Gas pressure and the ideal gas law
   d. Equipartion of energy and caveats
   e. Specific heat capacity of an ideal gas

f. Distribution of molecular speeds
g. Mean free path and collision frequency
h. Effusion
i. Transport processes

12. Statistical thermodynamics
a. Introduction
b. A coin-tossing experiment
c. Assembly of distinguishable particles
d. Thermodynamic probability and entropy
e. Quantum states and energy levels
f. Density of quantum states

PROBLEM ASSIGNMENTS

Due dates for the assigned problems will be announced in class. The submission of solutions to assigned problems is required. Solutions will be evaluated, but no letter grade will be given. Solutions consisting of disembodied equations without expository text are unacceptable. Discussions concerning the problems and their solutions are encouraged among the members of the class and between the class and the instructor. As upper-division students you undoubtedly and keenly know the importance of completing the assigned problems (which should be viewed as a minimum assignment). As a guide to the proper elements of a solution, you can find below a document prepared by Dr. Caler that lists criteria for quality. The submitted solutions must ultimately be the work of each individual. [Appropriate acknowledgement, of course, of contributions made by classmates or the instructor is expected.] Solutions to homework problems will be made available at the course web site after they are due.

Chapter 1: 2, 3, 5-8, 11
Chapter 2: 1, 2, 4, 9-11, 13
Chapter 3: 1-4, 6-8, 10
Chapter 4: 1-3, 5, 6, 8, 9, 11, 12, 14
Chapter 5: 1, 2, 5-9, 12
Chapter 6: 2-6, 9, 10, 12
Chapter 7: 1-3, 5, 7-9, 13, 14, 16
Chapter 8: 3-6, 10, 14
Chapter 9: 1, 3, 6, 7, 10
Chapter 10: 1, 4
Chapter 11: 2-5, 8, 9, 11, 13, 17, 18
Chapter 12: 1-6, 8, 12

FINAL GRADE

Your final grade will be based on the instructor's evaluation of the work you submit in connection with this course and your participation during class sessions.

COURSE POLICIES

Academic Integrity: All graded work is to be done by the student receiving the grade. Plagiarized or academically dishonest work may receive zero credit, may result in a failure of the class, and potentially suspension or expulsion from the university. If you have any questions concerning what is or is not considered a violation, please see one of the instructors *before* you decide to act and please consult the Undergraduate Student Academic Integrity Policy. It is <u>your responsibility</u> to know what is considered academic dishonesty.

Learning Disabilities: In order to request academic accommodations due to a disability, please contact the Office of Services for Students with Disabilities (OSSD) at (610) 436-3217. If you have a letter from their office indicating that you have a disability that requires alternative academic accommodations, please present the letter to one of the instructors *in advance* of any assessments so we can discuss the accommodations that you might need in this class. We share the University's desire to comply with the ADA of 1990.

Public Safety Emergency Contact Number: The Emergency Communication Committee has made the recommendation that the emergency phone number for WCU's Department of Public Safety be listed on all course syllabi. That number is **610-436-3311**. This specific recommendation is made to help the campus be prepared in case of an emergency situation.

Intellectual Property Statement: The instructor for this course utilizes copyrighted materials under the "Freedom and Innovation Revitalizing United States Entrepreneurship Act of 2007" (Fair Use Act). Apart from such copyrighted materials, all other intellectual property associated with this course is owned and copyright protected by the instructor, including, but not limited to, course notes and discussions, supplementary materials posted or provided to students, assessment instruments such as quizzes and exams, and Power Point presentations. No recording, copying, storage in a retrieval system, or dissemination in any form, whether electronic or other format, by any means of the intellectual property of the instructor, either in whole or in part, is permitted without the prior written permission of the instructor. When such permission is granted, it must specify the utilization of the intellectual property and all such permissions and waivers shall terminate on the last day of finals in the semester in which this course is held. Links and references to on-line resources provided by the instructor may lead to other sites. The instructor does not sponsor, endorse or otherwise approve of any information appearing in those sites, nor are they responsible for the availability of, or the content located on or through, external sites. Apart from materials used in accordance with the Fair Use Act, the instructor takes no responsibility for material that is otherwise offered at web sites and makes no warranty that such material does not infringe any third party rights. However, should any of this type of material be present and this fact is brought to the attention of the instructor, references to it will be removed from course materials.

Information on General Policies: For questions regarding Academic Dishonesty, the No-Grade Policy, Sexual Harassment, or the Student Code of Conduct, students are encouraged to refer to the Department's Handbook for Physics Majors, the Undergraduate Course Catalogue, the Rams Eye View, and the University Web Site. Please understand that improper conduct in any of these areas will not be tolerated and may result in immediate ejection from the class.

PHY 300 Dr. Caler Fall 2013

HOMEWORK GRADING RUBRIC

The below criteria apply to problems seeking a numerical answer as well as those that require a proof or an illustration.

Grading Criteria	Point Value[1]
• The problem is properly set up • Your methodology is clear and it is correct • Expository text guides the reader through the problem • Your math is correct, or contains a minor algebraic error • The result is correct, or contains a minor algebraic error • All collaborators are cited	5 points
• The problem is properly set up • Your methodology is clear, but it contains a major error • Expository text guides the reader through the problem • Your math is consistent with your methodology error, or has a minor algebraic problem • The result is not correct • All collaborators are cited	4 points
• The problem is properly set up • Your methodology is not clear, but it seems to be correct • No expository text exists • Your math seems to be correct, or seems to contain a minor algebraic error • The result is correct, or contains a minor algebraic error • No collaborators are cited	3 points
• The problem is properly set up • Your methodology is clear, but contains more than one major error • Expository text guides the reader through the problem • You have several math errors • The result is not correct • All collaborators are cited	2 points
• You made an attempt to set the problem up • Your methodology is not clear, and it appears to contain at least one major error • No expository text exists • You have several math errors, or your math ends abruptly • The result is incorrect or unclear • No collaborators are cited	1 point
• You have not done the problem, or what you have submitted is meaningless or indecipherable[2]	0 points

1: If the problem is a multiple-part problem, the below grading criteria will be applied to each individual part; however, the point values will be scaled such that the entire problem is worth a maximum of 5 points.

2: Work that cannot be ***easily*** read will not be graded.