

# Thermodynamics

## ME 18b

Spring 2009

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### **The Course:**

This course in Thermodynamics will focus on overall system design of power, propulsion and refrigeration cycles which use either gas phase fluids or two phase (liquid/gas) fluids. The student will be introduced to special thermodynamics topics covering thermochemistry, chemical equilibrium, combustion processes and the internal combustion engine.

### **What you will learn:**

By the end of ME 18b, students will be able to analyze thermodynamic problems using a control-volume or control-mass analysis. Students will know the laws of thermodynamics. Students will be able to analyze and predict the thermal efficiency and output power of a range of thermodynamic systems including a vapor-power cycle, a gas turbine for power and for propulsion, and other forms of power production. Students will also be able to determine the performance of a refrigeration cycle, an internal combustion engine, a combustor, a fuel-cell and the Caltech power plant.

### **Course Grading:**

Homework – 30%

Midterm Exam – 25%

Final Exam – 45%

### **Homework:**

There will be 7 homework assignments given approximately once a week except during exam weeks. Discussion of homework with other students is encouraged; however, each student is responsible for his/her own work. I also ask that each student attempt individually the homework problems before consulting with your peers. You may not use another student's homework to check your own work. Work with another student must be

a collaborative effort. Please do not seek homework advice from students who have previously taken this course.

Homework should be handed in on time. If the homework is late, there are two different processes by which it will be handled.

1) If you have a **very** good reason, such as illness or family emergency, you may be granted an extension. If it is possible, please let me know before the due date that you have a difficulty in completing your homework assignment.

2) If your reasons do not warrant an extension (such as having a major project in another class) you should still do your homework, even if it is very late. Late homework in this category will be marked down 20%.

If you are behind in your work, do not consult the library solutions.

**Recording of hours worked and class attendance:**

On each homework set, please indicate at the top of the sheet the number of hours used to do the work, and the number of class hours attended since the last homework was turned in. I will use this data to make sure that the work load seems appropriate for a 9-unit class.

**Textbook:**

*Fundamentals of Thermodynamics*, Sonntag, Borgnakke & Van Wylen, 6<sup>th</sup> ed., Wiley, 2003. or 7<sup>th</sup> ed, 2009.

The following schedule will be used for this course. The topic chapters are based on 7<sup>th</sup> edition organization of the material. The topic is listed for your reference if you have the 6<sup>th</sup> edition textbook, a detailed Table of Contents 7<sup>th</sup> ed is listed below for cross-reference.

Date	Topics	Reading 7 <sup>th</sup> ed	Assignment Due Dates
3/31	Intro to Power Cycles		
4/2	The Rankine Cycle	11.1 – 11.3	
4/7	Cal Tech Plant Tour		HW #1 (11.1 – 11.3)
4/9	Regeneration/Cogeneration	11.4 – 11.7	
4/14	Refrigeration Systems	11.8 – 11.11	HW #2 (11.4 – 11.7)
4/16	Refrigeration Systems	11.12 – 11.13	
4/21	The Brayton Cycle	12.1 – 12.2	HW #3 (11.8 – 11.13)
4/23	Gas Turbine Cycles	12.3 – 12.4	
4/28	Propulsion/Refrigeration	12.5 – 12.6	HW #4 (12.1 – 12.4)
4/30	Reciprocating Engines	12.7 – 12.8	
5/5	No Class		Mid Term Exam Due
5/7	Engine Power Cycles	12.9 – 12.12	Ch 11 & 12
5/12	Ideal Gas Mixtures	13.1 – 13.2	
5/14	Gas-Vapor Mixtures	13.3 – 13.4	HW #5 (12.5 – 12.12)
5/19	Moist Air Applications	13.5	
5/21	Combustion Processes	15.1 – 15.3	HW #6 (13.1 – 13.5)
5/26	Combustion Analysis	15.4 – 15.7	
5/28	Combustion Applications	15.8 – 15.10	
6/2	Phase Equilibrium	16.1 – 16.3	HW #7 (15.1 – 15.10)
6/4	Chemical Equilibrium	16.4 – 16.6	
6/11			Final Exam Due

Detailed Table of Contents of 7<sup>th</sup> ed for cross-reference for 6<sup>th</sup> ed.

## 11 POWER AND REFRIGERATION SYSTEMS—WITH PHASE CHANGE

- 11.1 Introduction to Power Systems
- 11.2 The Rankine Cycle
- 11.3 Effect of Pressure and Temperature on the Rankine Cycle
- 11.4 The Reheat Cycle
- 11.5 The Regenerative Cycle
- 11.6 Deviation of Actual Cycles from Ideal Cycles
- 11.7 Cogeneration
- 11.8 Introduction to Refrigeration Systems
- 11.9 The Vapor-Compression Refrigeration Cycle
- 11.10 Working Fluids for Vapor-Compression Refrigeration Systems
- 11.11 Deviation of the Actual Vapor-Compression Refrigeration Cycle from the Ideal Cycle
- 11.12 Refrigeration Cycle Configurations
- 11.13 The Ammonia Absorption Refrigeration Cycle

## 12 POWER AND REFRIGERATION SYSTEMS—GASEOUS WORKING FLUIDS

- 12.1 Air-Standard Power Cycles
- 12.2 The Brayton Cycle
- 12.3 The Simple Gas-Turbine Cycle with a Regenerator
- 12.4 Gas-Turbine Power Cycle Configurations
- 12.5 The Air-Standard Cycle for Jet Propulsion
- 12.6 The Air-Standard Refrigeration Cycle
- 12.7 Reciprocating Engine Power Cycles
- 12.8 The Otto Cycle
- 12.9 The Diesel Cycle
- 12.10 The Stirling Cycle
- 12.11 The Atkinson and Miller Cycles
- 12.12 Combined-Cycle Power and Refrigeration Systems

## 13 GAS MIXTURES

- 13.1 General Considerations and Mixtures of Ideal Gases
- 13.2 A Simplified Model of a Mixture Involving Gases and a Vapor
- 13.3 The First Law Applied to Gas-Vapor Mixtures
- 13.4 The Adiabatic Saturation Process
- 13.5 Engineering Applications—Wet-Bulb and Dry-Bulb Temperatures and the Psychrometric Chart

## 15 CHEMICAL REACTIONS

- 15.1 Fuels
- 15.2 The Combustion Process
- 15.3 Enthalpy of Formation
- 15.4 First-Law Analysis of Reacting Systems
- 15.5 Enthalpy and Internal Energy of Combustion; Heat of Reaction
- 15.6 Adiabatic Flame Temperature
- 15.7 The Third Law of Thermodynamics and Absolute Entropy
- 15.8 Second-Law Analysis of Reacting Systems
- 15.9 Fuel Cells
- 15.10 Engineering Applications

## 16 INTRODUCTION TO PHASE AND CHEMICAL EQUILIBRIUM

- 16.1 Requirements for Equilibrium
- 16.2 Equilibrium Between Two Phases of a Pure Substance
- 16.3 Metastable Equilibrium
- 16.4 Chemical Equilibrium
- 16.5 Simultaneous Reactions
- 16.6 Coal Gasification
- 16.7 Ionization
- 16.8 Applications