# CENG S300E Chemical Engineering Thermodynamics

Instructor: Michael Loewenberg
Email: michael.loewenberg@yale.edu
Class schedule: 6:30-8:00pm MWF

Teaching Fellow: Atsu Kludze
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Recitation: M 8:30-10:00pm, optional (starting in week 2)

## Objectives:

This is a rigorous introductory course in thermodynamics. Material will include the first and second laws of thermodynamics, cyclic processes, and chemical reaction and phase equilibria. The goal of this course is for students to obtain the necessary qualitative knowledge and quantitative skills for solving engineering science problems in thermodynamics.

**Prerequisites:** Multivariable calculus, high school chemistry.

## Texts:

1. Thermodynamics and an Introduction to Thermostatics, H.B. Callen, 2nd Ed., Wiley. ISBN 9780471862567. Required.
   http://cvika.grimoar.cz/callen/Callen,%20Herbert%20B%20-%20Thermodynamics%20and%20an%20Introduction%20to%20Thermostatistics%202nd%20Edition.pdf

2. The Principles of Chemical Equilibrium, K. Denbigh, 4th Ed., Cambridge. ISBN 0521281504. Less required.

## Exams, homework, and in-class work

2 tests, 30% each
4 weekly problem sets, 20%
class participation, 20%

### Class Website

Log in to the Yale Canvas website with your netID to access lecture videos and lecture notes, problem sets and reading assignments, and other handouts.

### Course Expectations

Classes (and active class participation) is essential for learning how to setup and solve the assigned problems. You will be expected to study online course materials (watch videos, read lecture notes and assigned readings) in advance of each class. Collaboration on problem sets is encouraged. The tests are closed book and closed notes.

## Syllabus

### **Week 1:** July 1-5

Heat, work, internal energy, entropy; extensive properties, intensive properties; fundamental equations, equations of state; temperature, mechanical equilibrium, chemical equilibrium.

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|---|---|
| Class 1 | M 6:30-8:00pm |
| Class 2 | W 6:30-8:00pm |
| Class 3 | F 6:30-8:00pm |

### **Week 2:** July 8-12

Problem set 1 due W 11:59pm

Euler equation, Gibbs-Duhem relation; heat capacity, compressibility, coefficient of thermal expansion; specific systems: ideal gas, van der Waals fluid.

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| Class 4 | M 6:30-8:00pm |
| Recitation | M 8:30-10:00pm |
| Class 5 | W 6:30-8:00pm |
| Class 6 | F 6:30-8:00pm |

### **Week 3:** July 15-19

Problem set 2 due W 11:59pm

Feasible processes, maximum work theorem; cyclic processes: heat engines, refrigerators, heat pumps, efficiency; Carnot cycle, other cyclic processes.

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| Class 7 | M 6:30-8:00pm |
| Recitation | M 8:30-10:00pm |
| Class 8 | W 6:30-8:00pm |
| **Test 1** | F 6:30-8:00pm |

### **Week 4:** July 22-26

Problem set 3 due W 11:59pm

Legendre transformations: Helmholtz, enthalpy, Gibbs, and Massieu functions, extremum principle; Maxwell relations. Chemical reaction equilibria. Stability.

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| Class 9 | M 6:30-8:00pm |
| Recitation | M 8:30-10:00pm |
| Class 10 | W 6:30-8:00pm |

Class 11 F 6:30-8:00pm

## **Week 5:** July 29- August 2

Problem set 4 due W 11:59pm

Phase equilibrium in single- and multicomponent systems, phase rule, phase diagrams.

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| Class 12 | M 6:30-8:00pm |
| Recitation | M 8:30-10:00pm |
| Class 13 | W 6:30-8:00pm |
| **Test 2** | F 6:30-8:00pm |