Thermodynamics
Instructor: Kristin Persson (kristinpersson@berkeley.edu)
GSI: David Mrdjenovich (dmrdj@berkeley.edu)

Lectures: Mo Wed Fri 10am-11am remote* (Kristin Persson)
Discussion: Tu 5pm-6pm, remote* (David Mrdjenovich)
Office hrs: Kristin: Fri 1pm-2pm remote*; David: Tu 3:30-4:30pm remote*
Course material: DeHoff "Thermodynamics in Materials Science" and handouts from Gaskell "Introduction to the Thermodynamics of Materials" and Cengel and Boles "Thermodynamics: An Engineering Approach"
**Zoom links provided on bCourses*

Objectives: The course is aimed to introduce and build up the powerful framework of thermodynamics. We will cover the fundamental concepts which will enable the students to understand and apply thermodynamics to simple one-component systems, thermodynamic cycles, electrochemistry etc. Examples in materials science, phase diagrams, Pourbaix diagrams, heat engines and operating cycles will be covered.

Outcomes:
- Understanding of the framework, basic principles and laws of thermodynamics
- Exposure of the functions, their applicability and usefulness in engineering
- Applications including single component phase diagrams, thermodynamic cycles, heat engines, turbines, Pourbaix diagrams

Week		Topics	Reading	Instructor	Items Due
1	Wed 8/26	**Lecture:** Course overview and logistics. Motivation. Definition of a system. State functions and process variables	DeHoff Chapter 1; 2.1-2.2.2	K. Persson	
	Fri 8/28	**Lecture:** Extensive and intensive variables; the first law of thermodynamics; internal energy; work performed on a system	DeHoff Chapter 2.2.3-2.5; 3.1	K. Persson	HW1 given
2	Mon 8/31	**Lecture:** The second law of thermodynamics; entropy	DeHoff Chapter 3.2-3.4	K. Persson	
	Tu 9/1	**Discussion:** Select intro problems		D. Mrdjenovich	
	Wed 9/2	**Lecture:** reversible and cyclic processes; heat; heat death of the universe; third law of thermodynamics	DeHoff Chapter 3.4-3.6		
	Fri 9/4	**Lecture:** Combine first and second law; examples; differentials	DeHoff Chapter 4.1	K. Persson	HW1 due HW2 given
3	Mon 9/7	**Labor day: no lecture**			
	Tu 9/8	**Discussion:** HW1		D. Mrdjenovich	
	Wed 9/9	**Lecture:** start to introduce new thermodynamic functions and variables; motivate enthalpy as new thermodynamic function	DeHoff Chapter 4.1 - 4.1.2.1	K. Persson	
	Fri 9/11	**Lecture:** heat capacity, ideal gas, reversible processes for ideal gas;	DeHoff parts of 4.1.2.1 4.1.4 - 4.2.4	K. Persson	HW2 due HW3 given

4	Mon 9/14	**Lecture:** Helmholtz free energy Gibbs free energy; coefficient relations;	DeHoff 4.1.3, 4.1.2.2 - 4.1.2.3		
	Tu 9/15	**Discussion:** HW2		D. Mrdjenovich	
	Wed 9/16	**Lecture:** thermodynamic relations, Maxwell relations; C_v and C_p;	DeHoff 4.1.4 – 4.2.3	K. Persson	
	Fri 9/18	**Lecture:** heat engines; efficiencies;	Gaskell - Carnot PDF	K. Persson	HW3 due HW4 given
5	Mon 9/21	**Lecture:** Carnot Cycle; **demo**	DeHoff Appendix H	K. Persson	
	Tu 9/22	**Discussion:** HW3		D. Mrdjenovich	
	Wed 9/23	**Lecture:** Applications to gases, solids and liquids; equilibrium conditions	DeHoff 5.3-5.5	K. Persson	
	Fri 9/25	**Lecture:** entropy maximum; chemical potential; minimum Gibbs free energy	DeHoff 5.3-5.5,	K. Persson	HW4 due
6	Mon 9/28	**Lecture:** latent heat, reactions, examples	DeHoff 7.1	K. Persson	
	Tu 9/29	**Discussion:** HW4		D. Mrdjenovich	
	Wed 9/30	**MIDTERM 1**			
	Fri 10/2	**Lecture:** single component first order phase transformations; examples	DeHoff 7.1-7.2	K. Persson	HW5 given

7	Mon 10/5	**Lecture:** Gibbs free energy curves; metastability; Le Chatelier	DeHoff 7.1.4		
	Tu 10/6	**Discussion:** Midterm 1		D. Mrdjenovich	
	Wed 10/7	**Lecture:** vaporization and sublimation, triple point	DeHoff 7.3.1 – 7.4		
	Fri 10/9	**Lecture:** Clausius-Clapeyron; vaporization and sublimation	DeHoff 7.2-7.3	K. Persson	HW5 due HW6 given
8	Mon 10/12	**Lecture:** Combining the knowledge: pressure-temperature phase diagrams for unary systems	DeHoff 7.4-7.5	K. Persson	
	Tu 10/13	**Discussion:** HW5		D. Mrdjenovich	
	Wed 10/14	**Lecture:** cont'd phase diagrams, critical point, examples	7.5-7.6	K. Persson	
	Fri 10/16	**Lecture:** interacting gases; van der Waals gas; equation of state	Vander Waals EOS PDF		HW6 due HW7 given
9	Mon 10/19	**Lecture:** van der Waals theory of vapor-liquid transition	Vander Waals EOS PDF	K. Persson	
	Tu 10/20	**Discussion:** HW6		D. Mrdjenovich	
	Wed 10/21	**Lecture:** unary phase diagrams; further examples, multiphase equilibria; H2O	DeHoff 7 + examples	K. Persson	

	Fri 10/23	**Lecture:** temperature and pressure-induced transitions in unary phase diagrams	DeHoff 7 + examples	K. Persson	HW7 due HW8 given
10	Mon 10/26	**Lecture:** steady flow systems	C&B Ch. 3 Ch. 5	K. Persson	
	Tu 10/27	**Discussion:** HW7		D. Mrdjenovich	
	Wed 10/28	**Lecture:** turbines; thermodynamic analysis of control volumes	C&B Ch. 3 Ch. 5	K. Persson	
	Fri 10/30	**Lecture:** Rankine cycle	C&B Ch. 3 Ch. 5	K. Persson	HW8 due
11	Mon 11/2	**MIDTERM 2**			
	Tu 11/3	**Discussion:** HW8		D. Mrdjenovich	
	Wed 11/4	**Lecture:** Solutions: partial molar properties	DeHoff 8.1	K. Persson	
	Fri 11/6	**Lecture:** Cont'd Solutions: partial molar properties; A-B mixtures	DeHoff 8.1-8.3	K. Persson	HW9 given
12	Mon 11/9	**Lecture:** ideal gas mixture; ideal solutions; real gases ; activities;	DeHoff 8.5.1-8.6	K. Persson	
	Tu 11/10	**Discussion:** Midterm 2		D. Mrdjenovich	
	Wed 11/11	**Veteran's Day: no class**			
	Fri 11/13	**Lecture:** Fugacity; Henry's law and Raoult's law	DeHoff 8.5-8.6	K. Persson	

13	Mon 11/16	**Lecture:** Regular solution model	DeHoff 8.7	K. Persson	
	Tu 11/17	**Discussion:** HW8		D. Mrdjenovich	
	Wed 11/18	**Lecture:** Multicomponent phase diagrams; miscibility gap;	Select from DeHoff 9	K. Persson	
	Fri 11/20	lever rule, cont'd multicomponent phase diagrams;	Select from DeHoff 9	K. Persson	HW9 due HW10 given
14	Mon 11/23	Specialty phase diagrams; Ellingham Diagrams and Pourbaix diagrams	DeHoff 15	K. Persson	
	Tu 11/24	**Discussion:** HW9		D. Mrdjenovich	
	Wed 11/25	**Thanksgiving: no class**			
	Fri 11/27	**Thanksgiving: no class**			
15	Mon 11/30	BACKUP			HW10 due
	Tu 12/1	**Discussion:** HW10		D. Mrdjenovich	
	Wed 12/2	BACKUP		K. Persson	
	Fri 12/4	BACKUP		K. Persson	
16	Mon 12/7 – Fri 12/11	Reading/Review/Recitation Week			
	Mon 12/14	**FINAL EXAM 8–11 am**			

Grading:

As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others.

Please remember that this is your honor code. It is a simple pledge that will serve you well during your academic career, and provide a solid foundation for success in your career as a practicing professional, when you will be held to even higher standards.

10 Homework sets	30% of total credit (3% each)
Two Midterms	30% of total credit (15% each)
Final exam	40% of total credit

Homework Assignments:

Ten homework assignments will be given that are due the same week. Homework should be submitted online on bcourses, one original from each student by 10:00am of the due date. **Late assignments will be penalized by 50% mark-down.** No raw "word processing" documents are accepted; submissions must be converted to pdf to preserve formatting, which is common professional engineering practice. Deadlines are **firm**, to allow for timely uploading of solutions as additional study guides.

Importantly: The topmost objective of your homework assignments is to guide your self-learning. Homework is not meant to be "group learning" exercise, and certainly not an artistic alteration of answers from others to avoid a plagiarism charge. Your homework submissions MUST be your own work; consultation with others is strictly forbidden. Homework sets that contain similar solutions may be considered academic dishonesty, in which case zero points will be awarded for the assignment and a report to the Center for Student Conduct may be considered.

Midterms and final Exam:

Two 50 mins midterm exams will be given. Midterm 1 will be given on **Wednesday September 30** and **Midterm 2 on Monday November 2.** The midterms begin at 10:10 AM and ends at 11:00 AM sharp. **Please mark your calendar**. The midterm exams will focus on sequential coverage with a focus on the topics covered since last midterm. By contrast, the final examination on Monday December 14 is a fully "comprehensive" one, covering all concepts developed throughout the semester. It is a 3-hour exam (no 10-minute delay at start).

Due to COVID-19 circumstances, all three exams will be performed by remote proctoring via zoom. To ensure as similar conditions as possible to a normal classroom exam, I ask all students to keep the video on and not to employ a virtual background. Students are advised to ensure there is nothing they don't want others to see in the view of their camera and to make sure that there is sufficient wifi access during the exam.

Studying for exams can be done effectively as a group effort. This is not plagiarism. Please consider organizing/joining study groups and challenging one another on the concepts covered in lecture and in the homeworks. Your lecture notes, and the lecture postings are your best guide to examination content. If a topic is not covered in lecture or discussion, it will not be on the exam, even if it is covered in the text. No electronic devices other than a calculator are permitted. Cell phones must be turned OFF. You are allowed a supply of pencils and pens, erasers, and a straightedge (long enough to construct figures across an 8.5x11 inch page). **Both midterms and the final exam will allow the student to bring one letter-sized single-page formula sheet.**

September 28, 2020	Midterm 1 **(15% CREDIT)**
November 2, 2020	Midterm 2 **(15% CREDIT)**
December 14, 2020 (8-11am)	Final Exam **(40% CREDIT)**

Optional/Additional Readings:

Occasionally we may assign reading materials for the discussion, in which case we will post it on the bcourses website. We may also recommend optional reading which will also be posted there.