AME 310 Engineering Thermodynamics I

Fall 2023

Lectures: SLH 100 (MW 12:00 – 1:50)

Discussion section: SLH 102, Tuesday 3:30 – 4:20 pm.

Units: 4 – 110 min lecture twice weekly, 50 min discussion

Location: SLH 100

Instructor: Julian A. Domaradzki
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Discussion section: SLH 102, Tu 3:30 – 4:20 pm
Office Hours: , VHE 202, Tu 4:30-5:30, W 9:00-11:00 (and by email appointment)

Course Description

Fundamental laws of thermodynamics applied to actual and perfect gases and vapors; energy concepts, processes, and applications. Energy, entropy, and exergy analysis. Power and refrigeration systems.

AME 310 introduces undergraduate aerospace, astronautical and mechanical engineering students to the most important engineering principles of basic thermodynamic processes. The subject of Thermodynamics deals with the science of energy, focusing specifically on energy conversion processes that involve heat effects in addition to mechanical work. This course will teach students the basic principles of classical thermodynamics involving both closed and open systems. Students will be trained to identify, formulate and solve engineering problems involving thermodynamic processes by developing skills in applying both 1st and 2nd law analysis methods to thermodynamic processes and devices such as power plants, engines, refrigeration, and A/C systems.

Learning Objectives

AME 310 is one of the core engineering courses where Viterbi students will develop analytical skills and be strong contributors in designing rocket engines, understanding renewable energy, what process is possible, and how to calculate the efficiency of their designed machines, etc.

Throughout the semester students will demonstrate their proficiency in applications of the following concepts and principles pertaining to Thermodynamics:

1) Properties, states, equilibrium, and apply the concept of non-equilibrium
2) Using Tables, equations of state, and the compressibility chart to determine unknown thermodynamic quantities for single and multiple phases of pure substances
3) Formulate mechanical work and heat transfer in thermodynamic processes and their role in 1st law of thermodynamics
4) Using 1st law of thermodynamics to find heat and changes in internal energy and enthalpy for thermodynamics processes for single and multiple phases of pure substances
5) Using specific heats to find heat and changes in internal energy and enthalpy for thermodynamic processes for ideal gases and for incompressible solids/liquids
6) Examine coefficients of performance for cyclical devices (heat engine, heat pump, air conditioner/refrigerator) and efficiency of the Carnot cycle
7) Applying the Clausius inequality and 2nd law of thermodynamics either in Clausius or Kelvin-Planck formulation to thermodynamic processes
8) Evaluate entropy changes for reversible thermodynamic processes for single and multiple phases of pure substances and for incompressible solids/liquids and gases using Tables and formulas
9) Analyze entropy changes for irreversible thermodynamic processes and entropy generation for a system and net entropy generation (system + surroundings).
10) Using 1st and 2nd laws for control volume to analyze devices operating under steady-state conditions (heat exchanger, nozzle, throttle, turbine, compressor, pump) and to analyze time-dependent, transient thermodynamic processes
11) Using the concept of exergy to determine the maximum work possible for steady state and transient processes.
12) Using the second-law efficiency to determine the actual efficiency of thermodynamic devices.
13) Design of power and refrigeration systems with fluids experiencing phase change: the Rankine cycle; the reheat cycle; the regenerative cycle; the vapor-compression cycle.
14) Design of power and refrigeration systems with gaseous working fluids: the Brayton cycle; gas-turbine power cycles; the air-standard cycle for jet propulsion; the air standard refrigeration cycle.
15) Design of reciprocating engine power cycles: the Otto cycle; the Diesel cycle; the Stirling cycle.

Prerequisite(s): MATH 226 or MATH 227 or MATH 229
Co-Requisite (s): n/a
Concurrent Enrollment: n/a
Recommended Preparation: PHYS-151L

Course Notes

This is a Letter grading type course. Copies of lecture slides and other class information will be posted on Blackboard.

Technological Proficiency and Hardware/Software Required

Ability to access the course Blackboard for course information and submission of homework assignments.

Required Readings and Supplementary Materials

C. Borgnakke and S. E. Sonntag, *Fundamentals of Thermodynamics*. The latest edition is **10th edition** (Wiley, 2020 ISBN: 978-1-119-72365-3) but earlier editions (e.g., **9th** (Wiley, 2017), **8th** (Wiley, 2013), **7th** (Wiley, 2009)) can be used as well and hardcopies are less expensive. However, electronic version is available from Wiley only for the 10th edition.

Description and Assessment of Assignments

There will be two Midterm Exams held during the regular lecture time and the Final Exam as prescribed by the registration calendar**.** The format for the written exams is **open book and calculator**, but no notes or homework solutions are allowed. You may use an electronic textbook on your laptop.

There will be 13 homework assignments but only 10 with the highest scores will count. Each assignment is worth 2% irrespective of the number of problems in the assignment. Homework assignments will consist of relevant problems selected from the textbook that will be posted on Blackboard every week. Homework assignments will be due the following week when solutions will be posted on Blackboard (there might be exceptions due to midterms and holidays that will be announced separately). Once solutions are posted no homework will be accepted and graded.

Homework must be completed as an individual. Failure to comply with this requirement will result in a failing grade for the course (read the section titled **Academic Conduct** below).

Grading Breakdown

See Course Schedule for Exams and Homework due dates. There will be 13 homework assignments but only 10 with the highest scores will count, i.e., three assignments can be missed, no questions asked. There will be no makeup exams. Missing an exam will result in a score of 0. All exams count towards the final grade.

Table 1 Grading Breakdown

Assessment Tool (assignments)	Points	% of Grade	Dates
Homework	100	20	weekly
Midterm 1	100	20	Sept 13
Midterm 2	100	20	Oct 11
Final	200	40	Dec 8
TOTAL	500	100	

Assignment Submission Policy

Each homework assignment should be **submitted electronically as a single PDF file** via the course Blackboard website. Links on Blackboard will be provided for uploading the assignments. For a paper-based version of your homework assignment, you can use a scanner or any existing smartphone app that uses the phone camera as a scanner. Please make sure to append all pages into a single PDF document before submitting.

Course Evaluations

Course evaluation occurs at the end of the semester university-wide. It is an important review of students' experience in the class. Students will receive an email with a link to the online evaluation form.

Class Schedule:

Week	Dates	Lecture Topics	Deliverables	Readings
1	Aug 21, 23	Syllabus. Ch. 1: Thermodynamic systems, state, and properties (pressure, density, temperature). Thermodynamic equilibrium, processes, and cycles; systems of units.		Chapter 1
2	Aug 28, 30	Ch. 2: Pure substance; phase transitions and phase diagrams; saturated water/vapor; quality. Independent thermodynamic properties; plots and tables of properties; examples of use.	Hw #1	Chapter 2
3	Sep 4 (Labor Day) Sept 6	Ch. 2: P-v-T diagram; equation of state; ideal gas; compressibility factor. Examples of using the equation of state and the compressibility chart.	Hw #2	Chapter 2
4	Sep 11	Ch. 3: 1st law of thermodynamics. Mechanical work; boundary work in compressible system. Polytropic processes; examples of computing work; other expressions for work.	Hw #3	Chapter 3
	Sept 13	Midterm 1		Chapter 1-2
5	Sep 18 Sept 20	Ch. 3: Definition of heat; comparison of work and heat; heat transfer modes; examples. Internal energy and enthalpy; examples. Specific heats for solids, liquids, and gases. Examples of calculations of enthalpy and energy for ideal gases.	Hw #4	Chapter 3
6	Sept 25, 27	Ch. 4: The 1st law for C.V.; mass, energy, enthalpy flow. Steady state process. Steady state process applications: heat exchanger, nozzle, throttle, turbine, compressor.	Hw #5	Chapter 4
7	Oct 2, 4	Ch. 5: 2nd law vs. 1st law; heat engine, refrigerator, AC, heat pump; thermal efficiency. Ch. 5: Clausius and Kelvin-Planck formulations of 2nd law; reversible and irreversible processes.	Hw #6	Chapter 5
8	Oct 9	Ch. 5: Carnot cycle. Efficiency of reversible/irreversible cycles; Carnot propositions; thermodynamic temperature scale and absolute temperature. Heat engines and heat pumps. Ideal vs. real efficiencies. The inequality of Clausius. Steam power plant.	Hw #7	Chapter 5
	Oct 11	Midterm 2		Chapter 3-5
9	Oct 16, 18	Ch. 6: Definition of entropy. Computation of entropy for reversible processes. Gibbs' relations. Calculating entropy changes for incompressible solid/liquid. Entropy changes for compressible gases (ideal gas). Polytropic processes. Entropy generation for a system.	Hw #8	Chapter 6

10	Oct 23, 25	Ch. 6: Principle of the increase of entropy. Net entropy generation (system+surroundings). The entropy rate equation for control mass. Ch. 7: The 2nd law for a control volume. Steady state processes. Reversible steady state processes. Transient processes.	Hw #9	Chapter 6 - 7
11	Oct 30 Nov 1	Ch. 8: Exergy, reversible work, irreversibility. Exergy balance equation. The 2nd law efficiency. Examples of engineering applications.	Hw #10	Chapter 8
12	Nov 6, 8	Ch. 9: Introduction to power systems. The Rankine cycle, reheat cycle, regenerative cycle. Ideal and actual power cycles; losses in actual cycles.	Hw #11	Chapter 9
13	Nov 13,15	Ch. 9: Introduction to refrigeration systems. The vapor compression cycle. Refrigerants. Ideal and actual refrigeration cycles; losses in actual cycles.	Hw #12	Chapter 9
14	Nov 20 Nov 22 (Thanksgiving)	Ch. 10: Power and refrigeration cycles for gaseous working fluids. The Brayton cycle. The gas-turbine cycle with a regenerator. The air-standard cycle for jet propulsion. The air-standard refrigeration cycle.	Hw #13	Chapter 10
15	Nov 27, 29	Ch. 10: Reciprocating engine power cycles. The Otto cycle. The Diesel cycle. The Stirling cycle.		Chapter 10
16	Dec 8 (Friday) 11:00 – 1:00	**Final Exam:** Refer to the final exam schedule in the USC *Schedule of Classes* at classes.usc.edu.		

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Statement on Academic Conduct and Support Systems

Academic Integrity:

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work,

comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://dsp.usc.edu/ provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* http://emergency.usc.edu will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.