CAE 208 / MMAE 320: Thermodynamics

Fall 2023

August 22, 2023

Course overview and introduction to the units

Built
Environment
Research
@ IIT

Advancing energy, environmental, and sustainability research within the built environment

www.built-envi.com

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Illinois Institute of Technology
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INTRODUCTION

About Me

- B.S.E., Mechanical Engineering
  - ❑ Sharif University of Technology Tehran, Iran, 2006
- M.S.E., Architectural Engineering
  - ❑ The Pennsylvania State University, 2011
- Ph.D., Mechanical Engineering
  - ❑ The Pennsylvania State University, 2014

- Experience relevant to this course
  - ❑ ASHRAE, DOE, EPA, HUD, NSF, and industry projects
  - ❑ University of Maryland College Park
  - ❑ Licensed Professional Engineer
  - ❑ ASHRAE New Investigator
  - ❑ Developed and taught several courses at Illinois Tech
  - ❑ Recipient of the Michael J. Graff Award for Innovation in Teaching

Introduce Yourself

- Please introduce yourself
- What concentration or major are interested in?
- What do you expect from the course?
- Do you do have any relevant internship/work experience?
- What is the fun activity that you did this summer?
- Do you have any experience in working with a software programming language or hands-on tasks in a lab?

Course

Classroom and Meeting Time:

- CAE 208 Section 01: 10116 – In Person
- CAE 208 Section 02: 15456 – Online (Only for remote graduate students with a permit)
- MMAE 320: Section 02: 11208 – In Person

Classroom and Meeting Time:

- Location: WS 116
- Tuesdays and Thursdays, 8:35 AM – 9:50 AM

Course Website:

- All content will be provided on Blackboard

Course

Previous Lecture Notes

The Built Environment Research Group

advancing energy, environmental, and sustainability research within the built environment at Illinois Institute of Technology

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CAE 208/MMAE 320: Thermodynamics (Fall 2022)

CAE 208/MMAE 320 covers basic principles of thermodynamics applied to engineering systems using pure substances and mixtures as working fluids as well as covering direct application of the laws of thermodynamics to analysis of closed and open systems, mass and energy flow.

Course Syllabus

- Syllabus

Lecture Notes

- Lecture 01: Course overview and introduction
- Lecture 02: Basic concepts of thermodynamics (I)
- Lecture 03: Basic concepts of thermodynamics (II)
- Lecture 04: Basic concepts of thermodynamics (III)
- Lecture 05: Energy and energy analysis (I)
- Lecture 06: Energy and energy analysis (II)
- Lecture 07: Energy and energy analysis (III)
- Lecture 08: No Class
- Lecture 09: Properties of pure substances (I)
- Lecture 10: Properties of pure substances (II)
- Lecture 11: Properties of pure substances (III)
- Lecture 12: Properties of pure substances (IV)
- Lecture 13: Energy analysis of closed systems (I)

http://built-envi.com/courses/cae-208-thermodynamics-fall-2022/

Course Catalog Description

- Basic principles of thermodynamics applied to engineering systems using pure substances and mixtures as working fluids
- Direct application of the laws of thermodynamics to analysis of closed and open systems, mass and energy flow
- Extensive analysis of isentropic processes in cycles, analysis of gas mixtures and psychometrics in heating and cooling systems
- Introduction to fluid mechanics and analysis of fluid statics problems

Instructor's Course Objectives & Learning Outcomes

To introduce students to fundamentals and theory of thermodynamics. By taking this course students will be able to:

1. Learn properties of pure substances and their implications for building science
2. Understand fundamentals of fluid and energy flows both for open and closed systems
3. Acquire a knowledge of first and second laws of thermodynamics
4. Become proficient in understanding and applications of power cycles and vapor compression cycles

Office Hours

Instructor:

- Stop by when you see my office door open to see if I'm free. I have an open-door policy. Or you can email me to schedule an appointment or if you have any questions.
  - ❑ Office: Alumni Memorial Hall Room 204
  - ❑ Email: muh182@iit.edu
  - ❑ Phone: (312) 567-3426

Office Hours

Teaching Assistant:

- TBD
  - ❑ Name: Saman Haratian, Ph.D. Student, Architectural Engineering
  - ❑ Email: sharatian@hawk.iit.edu

Office Hours

ARC SI:

- Name: SuJung Park
- Email: spark95@hawk.iit.edu

Textbook

- Cengel, Y.A., Cimbala, J.M., Ghajar, A.J., *Fundamentals of Thermal-Fluid Sciences*, 6th Edition, 2022. 126059758X 9781260597585

The 5th and 4th edition or any older editions are also accepted. The same authors also have another book with the title Thermodynamics. The recent editions of that book should work. Overall, the concepts in Thermodynamics are similar in all books. You need a Thermodynamics book to use for the Thermodynamics Properties Tables and Charts. You do not need the book to see the problems of the assignments. The problems in assignments will be posted on Blackboard.

GRADING AND COURSE POLICIES

Homework Assignments

- There will be a total of ***10 homework*** assignments
- The best of ***8 assignments*** will be used in the final grade
- Homework sets will be assigned based on lecture coverage
- Each homework will be assigned at ***least a week before*** the homework due date
- You must work on the homework assignments ***individually***
- Each assignment accounts for 2% of the total grade

Exams

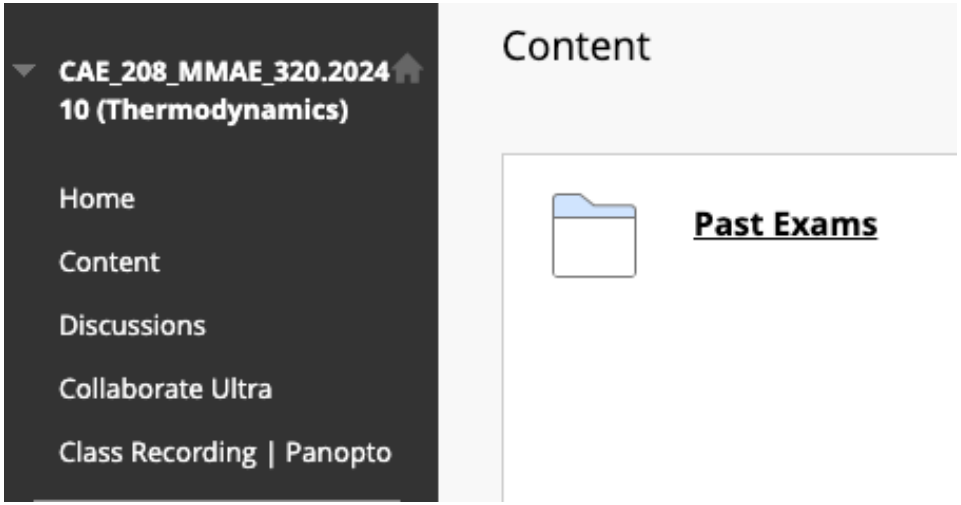
- There will be three exams focused on the fundamental concepts learned in the course:
  - ❑ Two exams will be during the semester
  - ❑ Third exam will be the final exam
- Each exam has two parts:
  - ❑ A closed book/notes part
  - ❑ An open book/notes part
- During the closed book/notes, students are only allowed to have a one-page cheat sheet that they prepared
- During the open book/notes, students can use the hard copy of the book only

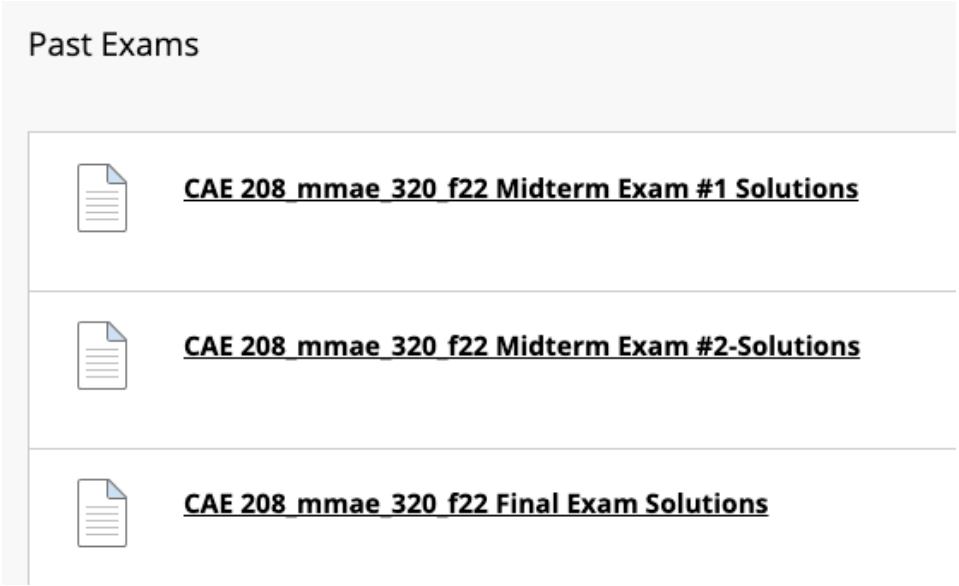
Exams

- The first exam will cover materials till the last week before the exam
- The second exam will only cover materials that are not covered in Exam 1
- Exam 3 will cover all the materials in the course
- The ***best of two exams*** will be used for the grade
- ***Missing*** the exam will lead to ***zero grade*** for the exam

Exams

- Past exams are posted on Blackboard:





Quizzes

- There will be random in-class pop quizzes
- The quizzes are short and usually they can be solved within 10 minutes
- The instructor will randomly assign quizzes in class (i.e., there might be two quizzes in a given week)

Attendance

- All students are expected to attend classes regularly
- Excessive absences may be grounds for a failing grade
- Quizzes and random attendance checks will serve as the only means to assess the student attendance
- Students who attend the quizzes will receive bonus point:
  - ❑ Attending all the quizzes: 4% bonus points
  - ❑ Attending 90% of the quizzes: 2.5% bonus points
- Students should familiar themselves with the attendance Illinois Tech's attendance policy here: http://bulletin.iit.edu/undergraduate/academic-policies-procedures/registration/

Late Homework Assignment and Report Policy

- Homework assignments are due at the ***midnight on the day that it is due***

- Homework assignments will receive a ***5-point deduction*** for every day that it is late before the solution is posted on Blackboard

- After the ***solution is posted***, the blackboard submission page ***is closed for that particular homework***

Course Grading

Grading	Quantity	% of Total for Each	% of Total
Homework	10	2	16 (Best of eight)
Exams	3	37	74 (Best of two)
Quizzes	Vary	Depends on the number of quizzes	10
Attendance	-	-	Max 4

** If the final exam grade is greater than the best of two exams, the entire final exam grade will be counted as 74.*

Grading scale	A	B	C	D	F
UG and G	90% and up	80.0-89.9%	70.0-79.9%	60.0-69.9%	<60.0%

Bonus Activity

- Each semester some students usually ask for bonus points. This course offers two options which require students to start early if they are interested in receiving these extra points towards their final grade and also engaging further with the concepts presented in the class
  1. Given the importance of data science and coding for all disciplines, especially engineers, some assignments and mini project(s) will be provided with some training how to use a software program for deploying Thermodynamics concepts.
  2. A hands-on activity to build a small mock-up vapor compression cycle that can be used in this course and future students. Resources and directions will be provided. Bonus points can account for up to an extra 10 points.

- More details will be provided throughout the semester.

Course Topics

Week	Date	Topics	Reading	Assignment Due
1	08/22/23	Course overview and introduction to the units	Ch. 1	
	08/24/23	Basic concepts of thermodynamics (I)	Ch. 2	
2	08/29/23	Basic concepts of thermodynamics (II)	Ch. 2	
	08/31/23	Basic concepts of thermodynamics (III)	Ch. 2	Assignment 1
3	09/05/23	Energy, energy transfer, and general energy analysis (I)	Ch. 3	
	09/07/23	Energy, energy transfer, and general energy analysis (II)	Ch. 3	Assignment 2
4	09/12/23	Energy, energy transfer, and general energy analysis (III)	Ch. 3	
	09/14/23	Properties of pure substances (I)	Ch. 4	Assignment 3
5	09/19/23	Properties of pure substances (II)	Ch. 4	
	09/21/23	Properties of pure substances (III)	Ch. 4	Assignment 4

Course Topics

Week	Date	Topics	Reading	Assignment Due
6	09/26/23	Properties of pure substances (IV)	Ch. 4	
	09/28/23	Energy analysis of closed systems (I)	Ch. 5	Assignment 5
7	10/03/23	Energy analysis of closed systems (II)	Ch. 5	
	10/05/23	Energy analysis of closed systems (III)	Ch. 5	
8	10/10/23	**Exam 1**		
	10/12/23	Mass and Energy Analysis of Control Volumes (I)	Ch. 6	
9	10/17/23	Mass and Energy Analysis of Control Volumes (II)	Ch. 6	
	10/19/23	Mass and Energy Analysis of Control Volumes (III)	Ch. 6	Assignment 6
10	10/24/23	Mass and Energy Analysis of Control Volumes (IV)	Ch. 6	
	10/26/23	The Second Law of Thermodynamics (I)	Ch. 7	Assignment 7

Course Topics

Week	Date	Topics	Reading	Assignment Due
11	10/31/23	The Second Law of Thermodynamics (II)	Ch. 7	
	11/02/23	The Second Law of Thermodynamics (III)	Ch. 7	Assignment 8
12	11/07/23	**Exam 2**		
	11/09/23	Entropy (I)	Ch. 8	
13	11/14/23	Entropy (II)	Ch. 8	
	11/16/23	Entropy (III)	Ch. 8	Assignment 9
14	11/21/23	Entropy (IV)	Ch. 8	
	11/23/23	**Thanksgiving – No Class**		
15	11/28/23	Power and Refrigeration Cycles (I)	Ch. 9	
	11/30/23	Power and Refrigeration Cycles (II)	Ch. 9	Assignment 10
	TBD	**Exam 3 (Final Exam Scheduled by IIT)**		

Academic Honesty

- It is your responsibility to be familiar with IIT's Code of Academic Honesty. The Code of Academic Honesty can be found online: https://www.iit.edu/student-affairs/student-handbook/fine-print/code-academic-honesty

- You must submit your ***own work for homework***. You are encouraged to discuss and even work with other students on homework (unless explicitly told otherwise), but material that is submitted must be ***your own work***

Academic Honesty

- For a ***first violation*** of the IIT Code of Academic Honesty for a homework or project, the homework will receive a grade of ***zero for all involved students*** and the students will be reported to the Designated Dean for Academic Discipline (DDAD)

- For a first violation of the Code of Academic Honesty for a ***major project*** or an examination, the student will ***receive a failing grade*** for the course and the student will be reported to the DDAD. For a second violation, the student will receive also failing grade for the course and be reported to the DDAD

Personal Problems

- If you have illness or personal problems that will affect your performance during the course of the semester, please let me know ***as soon as possible***

- ***"After the fact"*** provides little protection unless there are extreme circumstances. Contact the instructors by phone or e-mail at any time

Personal Problems

- Academic Regulations: https://web.iit.edu/student-affairs/handbook/fine-print/academic-and-department-regulations

*"All students are **expected to attend classes regularly**. Excessive absences may be grounds for a failing grade. Non-attendance does not constitute an official withdrawal. When illness or emergency requires a student to miss an exam and/or more than two days of class, the student must notify the course instructor. It is also recommended that the student **contact the office of the Dean of Students (dos@iit.edu) to request an excused absence.** It will be necessary to provide written documentation of the reason for the absence(s). The Office of Student Affairs manages the process for requesting and documenting excused absences but the decision to excuse an absence is generally made by the Professor. Faculty members determine their own policies for attendance and make-up work."*

Students with Disabilities

- Reasonable accommodations will be made for students with documented disabilities. In order to receive accommodations, students must obtain a letter of accommodation from the Center for Disability Resources

- The Center for Disability Resources (CDR) is located in Life Sciences Room 218, telephone (312) 567-5744 or email: disabilities@iit.edu

FE Exam

- This is an important course for your Fundamental of Engineering (FE) exam. For students in Architectural Engineering, there are 9 to 14 questions in Section “14. Thermodynamics and Heat Transfer”:
  A. Thermodynamic laws (e.g., first law, second law)
  B. Thermodynamic equilibrium
  C. Thermodynamic properties (e.g., entropy, enthalpy, heat capacity)
  D. Thermodynamic processes (e.g., isothermal, adiabatic, reversible, irreversible)
  E. Heat transfer (e.g., conduction, convection, radiation)
  F. Mass and energy balances
  G. Property and phase diagrams (e.g., T-s, P-h, P-v)
  H. Combustion and combustion products (e.g., CO, CO2, NOX, ash, particulates)
  I. Psychrometrics (e.g., relative humidity, wet bulb)

FE Exam

- Most of the topics will be covered in this course and the heat transfer topics will be covered in CAE 209 and CAE 331. Architectural engineering students are encouraged to visit this page: https://ncees.org/wp-content/uploads/FE-Other-Disciplines-CBT-specs.pdf

- Similarly, FE exam for mechanical engineering students includes 10 to 15 questions. Mechanical engineering students are encouraged to visit the Mechanical Engineering Exam requirements here: https://ncees.org/wp-content/uploads/FE-Mechanical-CBT-specs.pdf

INTRO TO THERMODYNAMICS

Intro to Thermodynamics

- Thermodynamics can be defined as the science of energy "ability to cause changes":

  - First law of thermodynamics "Conservation of Energy"

  - Second law of thermodynamics "define quality and quantity of energy" as well as "direction of decreasing quality of energy"

Intro to Thermodynamics

- There are two main approaches to look at Thermodynamics

  - ❑ Macroscopic approach rather than individual particles or known as “classical thermodynamics”

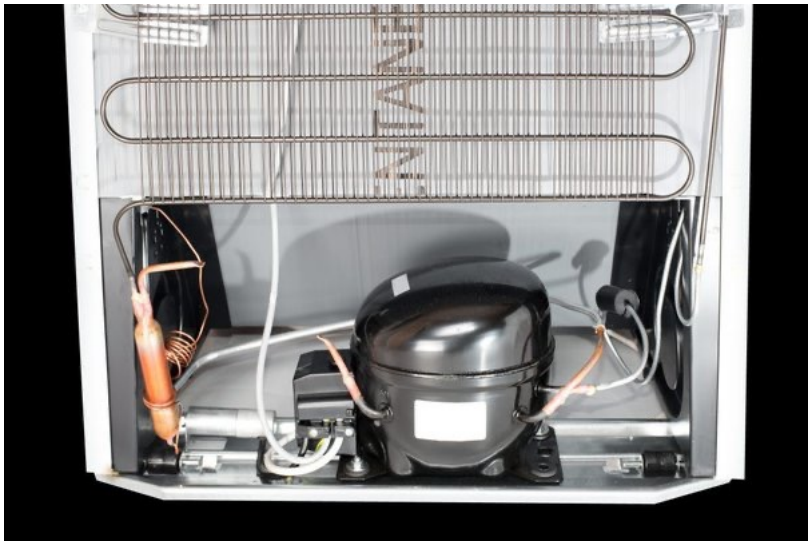
  - ❑ Microscopic approach meaning average of individual particles or known as ”statistical thermodynamics”

Intro to Thermodynamics

- Another concept to consider is heat transfer:
  - ❑ Primarily interested in heat and its rate
  - ❑ Heat is defined as the form of energy that can be transferred from one system to another as a results of temperature difference
  - ❑ Rates of such energy “heat” transfer is heat transfer
  - ❑ What’s the driving force?

Intro to Thermodynamics

- Applications



https://en.wikipedia.org/wiki/List_of_coal-fired_power_stations_in_the_United_States & https://www.quora.com/Which-type-of-motar-is-used-in-a-refrigerator & https://www.tastingtable.com/759410/heres-how-you-should-cool-down-hot-coffee-according-to-science/
https://www.cars24.com/blog/how-a-car-engine-works/

UNITS AND DIMENSIONS

Units and Dimensions

- Dimensions defines any physical quantity

- The magnitude of dimensions is expressed in units

Units and Dimensions

- Relevant primary or fundamental units are:
  - ❑ Temperature (T)
  - ❑ Length (L)
  - ❑ Time (t)
  - ❑ Mass (m)

- Others are secondary or derived:
  - ❑
  - ❑
  - ❑

Units and Dimensions

- Two systems of units are
  - SI
  - IP or English

Units and Dimensions

- Common units are:

Dimension	SI Unit	IP Unit
Length		
Mass		
Time		
Temperature		

See Table 1-1 and 1-2

Units and Dimensions

- Examples:
  - 1 lbm = 0.45359 kg
  - 1 ft = 0.3048 m
  -
  -
  -
  -
  -
  -

Units and Dimensions

- Some important SI and IP units
  - Force = (Mass)(Acceleration)

Units and Dimensions

- Some important SI and IP units
  - Weight = (Mass)(Gravitational Acceleration)

Units and Dimensions

- Some important SI and IP units
  - Work = (Force)(Distance)

Units and Dimensions

- Some important SI and IP units
  - Power = Rate of Energy