Division of Engineering and Mathematics
School of Science, Technology, Engineering, and Mathematics
University of Washington Bothell

B ME 331 A Thermodynamics (4 cr)

Autumn 2019

Time and Location: MW 11:00 - 1:00, UW2 031

Instructor: Steven W. Collins, Ph.D., P.E.
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Office Hours: MW 9 - 11 am and by appointment

Canvas Homepage: https://canvas.uw.edu/courses/1332525

Course Description

This course introduces *thermodynamics*, the study of energy and energy transfer as heat and work. Topics include mass and energy conservation, energy transfer as heat and work, thermodynamic properties of substances, and analysis of devices based on principles of thermodynamics, including compressors, turbines, power plants, and refrigeration systems.

Learning Outcomes

At the end of this course, students will be able to:
1. Evaluate thermodynamic properties of solids, liquids, and gases.
2. State the first law of thermodynamics, and apply it to solve energy balance problems for closed and open systems.
3. State the second law of thermodynamics, and apply it, together with the first law, in the analysis of power and refrigeration cycles.
4. Define entropy, calculate entropy change in processes, and use entropy to determine isentropic efficiencies for various thermo-mechanical devices.
5. Describe and distinguish among Carnot, Otto, Diesel, Brayton, Rankine, and vapor compression cycles, and evaluate power and refrigeration systems based on them.
6. Assess arguments for and against nuclear power as a sustainable energy technology.

ABET Learning Outcomes

The learning outcomes for this course correspond to ABET outcomes (a), (e), and (h):
(a) An ability to apply knowledge of mathematics, science, and engineering.
(e) An ability to identify, formulate and solve engineering problems.
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

Assignments and Grading Criteria

Homework (20 %): Homework problem sets will be posted regularly in Canvas. Solutions will be posted after the due date. Each set has two parts:

- Part 1 consists of problems you are required to work. Each problem must be worked by hand, in pencil, on green engineering paper, using the guidelines for problem solving attached to this syllabus. Begin each problem on a separate page; write your name on the page, the problem number, and due date. On the due date, I will collect one of these problems in class, chosen at random, to collect and grade. The last two homework assignments (HW 10 and 11) will not be collected or graded.
- Part 2 consists of optional problems to work for additional practice. These problems will not be collected.

Concept quizzes (5 %): Most classes will start with a concept quiz that I will project from the overhead projector. Each quiz consists of a few multiple choice, true-false, or fill-in-blank questions. Questions will be drawn from the reading and my notes assigned for the previous class meeting (for example, a quiz given Monday would be based only on concepts from reading/notes assigned the previous Wednesday). You will write answers on your own paper. I will collect and grade them on some days, and on other days I won't collect them. Since you won't know in advance on which days I collect them, you won't want to miss any class meeting!

Two in-class midterm exams (20 % each, 40 % total). Exams are closed book and notes. For the first exam, you may use one 8-1/2 inch x 11 inch "cheat sheet" with equations and whatever other information you would like to have as a reference. For the second exam, you may use the sheet you wrote for the first exam, together with one new 8-1/2 inch x 11 inch sheet, for a total of two reference sheets. Constants, unit conversions, and property data will be provided with the exam. All writing will be done on the exam pages. You must write in pencil (bring erasers and extra pencils!), and use one of the permissible calculators.

Take-home final exam (20 %): This exam will be posted in Canvas on December 4 and must be submitted no later than 11:59 pm December 9. It will cover material since the second in-class exam. You may use any resource EXCEPT other students. You are not to discuss the exam with any student until after the due date. You may word-process the solutions or write them out by pencil/pen; if you write with pencil/pen, you must scan the pages into your computer. Start each solution on a new page. Assemble all pages into a pdf file, and submit the final document into Canvas by the due date.

Essay on energy and society (15 %): In this assignment, you will write an essay of about 750 words (the length of a newspaper op-ed article) on the following prompt:

Should the US phase out nuclear power as part of a transition to green, sustainable energy?

Upload your essay to Canvas by 11:59 pm November 25. Use no fewer than three written sources (not including the textbook) from reputable magazines, newspapers, trade journals, and scholarly journals; cite them, and list them in a References section at the end. Articles found in general internet searches will have a high chance of not being reputable. Try searching the UW Libraries data bases or Google Scholar. Trusted sources include magazines like Mechanical Engineering Magazine from ASME, IEEE Spectrum, New York Times, Wall Street Journal, The Economist, Science Magazine, Scientific American, and Nature. Also consider the online versions of *Power Magazine* (https://www.powermag.com) and *Power Engineering Magazine* (https://www.power-eng.com). Other good industry news sources are Utility Dive (https://

www.utilitydive.com) and Greentech Media (https://www.greentechmedia.com). Though its focus is general, Vox (https://www.vox.com) provides good coverage of energy, especially articles by David Roberts.

Take care not to plagiarize. Your essay will be processed by a plagiarism detection system in Canvas. Learn to spot and to avoid plagiarism. For more information, see http://guides.lib.uw.edu/c.php?g=345664&p=2329452
Resources on writing and properly citing sources can be found here: http://guides.lib.uw.edu/bothell/ai

Prof. Collins' absence from class: I will leave for Japan on November 21 and will be there on a project with our partner university in Matsuyama through December 21. Consequently, I won't be here in person for our last four regular class meetings. I'll leave you instead with recorded lecture and notes. I'll also be available for questions through Canvas, Zoom, and Skype. My faculty colleagues will cover for me should you need an in-person meeting during my absence.

Required Materials

Yunus A. Cengel and Michael A. Boles, *Thermodynamics: An Engineering Approach*, 8th Edition, McGraw-Hill, 2014.

Calculator: For in-class exams, you may use only calculators designated by the National Council of Examiners for Engineering and Surveying for use on engineering licensing exams. A list of these calculators can be found here: https://ncees.org/exams/calculator/

Canvas: For help with Canvas, see https://www.uwb.edu/digital-learning/canvas

Policies and Campus Resources

Grading: Exams will be graded on a 100-point scale. Grades are converted from the 100-point scale (x) to the 4-point scale (y) according to the following rule:

If $x > 95$, then $y = 4.0$

If $62 \le x \le 95$, then $y = x/10 - 5.5$ If $x < 62$, then $y = 0$

Homework, quizzes and essays are graded directly on the 4-point scale. More information on the UW grading system can be found here:
http://www.washington.edu/students/gencat/front/Grading_Sys.html

Late and missed assignments: Homework will not be accepted after the due date. Missed quizzes cannot be made up. If you know you will be absent on the day of an exam, and you have a legitimate reason, it may be possible to take the exam *before* it is given in class. Unless a verifiable emergency prevents your sitting for an exam, a missed exam cannot be made up. In any event, makeup exams will given at my discretion. Late final exams and essays will receive an automatic deduction 10% in the Canvas grade book for each day they are late.

Religious accommodations: Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at Religious Accommodations Policy

(https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/). Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form (https://registrar.washington.edu/students/religious-accommodations-request/).

Academic integrity: Engineering is a profession demanding a high level of personal honesty, integrity and responsibility. Therefore, it is essential that engineering students, in fulfillment of their academic requirements and in preparation to enter the engineering profession, adhere to the University of Washington's Student Code of Conduct (https://www.washington.edu/cssc/for-students/student-code-of-conduct/). Acts of academic misconduct may include but are not limited to

- Cheating, which includes working collaboratively and sharing answers on exams and other assignments, unless explicitly authorized to do so.
- Plagiarism, defined as representing the work of others as your own and not giving appropriate attribution to the author(s) whose work you are using in your research.

Concerns about these or other behaviors prohibited by the Student Conduct Code will be reported to the Student Conduct Office (https://www.uwb.edu/studentaffairs/studentconduct). Students who have engaged in academic misconduct on a particular assignment will receive a zero on the assignment, and the case will be referred to the Student Conduct Office for possible further action.

Disability resources: If you have already established accommodations with Disability Resources for Students (DRS), please communicate your approved accommodations to me at your earliest convenience so we can discuss your needs in this course. If you have not yet established services through DRS, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), you are welcome to contact DRS at 425-352-5307 or uwbdrs@uw.edu. Reasonable accommodations are established through an interactive process between student, instructor, and DRS. For more information: https://www.uwb.edu/studentaffairs/drs

For more a complete listing of STEM School Policies, see https://www.uwb.edu/getattachment/stem/about/stem-policies/Classroom-Policies-STEM-FC-1-12-17.pdf

Other Information

Ethics and professionalism: As a Professional Engineer (PE), I am obliged to adhere to the NSPE Code of Ethics for Engineers. I urge all my students to study the code and endeavor to live by it: https://www.nspe.org/resources/ethics/code-ethics

ASHRAE Student Branch: ASHRAE is the professional association for engineers engaged in the design and installation of building energy systems—including heating, air conditioning, ventilation, refrigeration, plumbing, electric power, and energy management systems. These fields all build on a foundation of thermodynamics, fluid mechanics, and heat transfer. As the branch faculty advisor, I encourage my ME students to check it out and consider joining. For more information, see the branch's Facebook page at https://www.facebook.com/groups/367937123772670/ or email ashraeUWB@gmail.com. Also check out ASHRAE's student resource page at https://www.ashrae.org/communities/student-zone.

B ME 331 Thermal Fluids I Schedule (Autumn 2019)

	Date	Topic	Reading*	Assignment**
1	9/25	Intro; definitions; units	Ch 1 (all)	
2	9/30	Forms of energy; heat, work; first law	Ch 2 (all)	HW 1
3	10/2	Properties of pure substances	Ch 3: 3-1 to 3-4	HW 2
4	10/7	Property tables; enthalpy; gas laws	Ch 3: 3-5 to 3-8	HW 3
5	10/9	First law in closed systems	Ch 4 (all)	
6	10/14	First law in open systems/Review	Ch 5: 5-1 to 5-3	HW 4
7	10/16	Exam 1 on Chapters 1-4		Exam 1
8	10/21	Pumps, turbines and other devices	Ch 5: 5-4 to 5-5	
9	10/23	Second Law	Ch 6: 6-1 to 6-4	HW 5
10	10/28	Reversible processes, Carnot cycle	Ch 6: 6-5 to 6-11	
11	10/30	Entropy	Ch 7: 7-1 to 7-7	HW 6
	11/1	Optional tour of UWS steam plant***		
12	11/4	Entropy change, isentropic processes	Ch 7: 7-8 to 7-12	
13	11/6	Entropy balance, exergy	Ch 7: 7-13, Ch 8	HW 7
	11/11	Veterans Day (no class)		
14	11/13	Otto and Diesel cycle engines/Review	Ch 9: 9-1 to 9-6	HW 8
15	11/18	Exam 2 on Chapters 5-8		Exam 2
16	11/20	Brayton cycle power plants	Ch 9: 9-8 to 9-11	HW 9
	11/21	Prof. Collins leaves for Japan		
17	11/25	Rankine cycle power plants	Ch 10: 10-1 to 10-6	Essay
18	11/27	Advanced steam power cycles	Ch 10: 10-8 to 10-9	HW 10
19	12/2	Refrigeration cycles	Ch 11: all except 11-5	
20	12/4	Wrap-up, post take-home Final Exam		HW 11
	12/9			Final Exam

*Readings are from Cengel, *Thermodynamics: An Engineering Approach*.
**Most class meetings will begin with a short concept quiz.
***Meet at UW Seattle steam plant at 10:30 for a 60-90 minute tour. Details to come.
See https://www.youtube.com/watch?v=UNazXV2RBQs