

# ME 527: Macroscale Thermodynamics

<i>Course description:</i>	Advanced thermodynamic analysis and optimization of thermodynamic systems.
<i>Prerequisites by course:</i>	Undergraduate courses in thermodynamics, fluid mechanics, and heat transfer.
<i>Textbooks/other required materials:</i>	<ol style="list-style-type: none"><li>1. (required) Bejan, A., "Advanced Engineering Thermodynamics: 4<sup>th</sup> Edition" Wiley (2016). (Also available as an e-book from WSU libraries)</li><li>2. (recommended) Klein, S.A., and G.F. Nellis, "Thermodynamics" Cambridge University Press (2012). (Also available as an e-book from WSU libraries)</li><li>3. (recommended) Leachman, J., et al. "Thermodynamic Properties of Cryogenic Fluids: 2<sup>nd</sup> Edition," Springer (2017).</li></ol>
<i>Software</i>	<ol style="list-style-type: none"><li>1. Klein, S.A., "Engineering Equation Solver (EES)," F-Chart Software (2015). Available for download at <a href="http://mme.wsu.edu/ees">http://mme.wsu.edu/ees</a></li><li>2. Lemmon, E.W., "REFPROP," National Institute of Standards and Technology (NIST) (2015). Available for download at <a href="http://www.boulder.nist.gov/div838/theory/refprop/MINIREF/MINIREF.HTM">http://www.boulder.nist.gov/div838/theory/refprop/MINIREF/MINIREF.HTM</a></li><li>3. Course discussion page: <a href="https://wsu527.slack.com">https://wsu527.slack.com</a></li><li>4. Content page: <a href="https://hydrogen.wsu.edu/me-527-macroscale-thermodynamics/">https://hydrogen.wsu.edu/me-527-macroscale-thermodynamics/</a></li></ol>
<i>Course objectives:</i>	<ol style="list-style-type: none"><li>1. Establish a proficiency with energy, entropy, and exergy balances within the context of the thermodynamic problem solving process.</li><li>2. Understand the inter-relationships between thermodynamic properties and how software uses these relationships to calculate properties from equations of state.</li><li>3. Conduct combined thermodynamic law design optimizations within the context of applied research.</li></ol>
<i>Topics covered:</i>	<ol style="list-style-type: none"><li>1. Balances: 1<sup>st</sup> Law, 2<sup>nd</sup> Law, Exergy, and cycles</li><li>2. Efficiencies of engineering components and systems</li><li>3. Ideal gases, incompressible substances, real fluids, and fluid mixtures</li><li>4. Derivation of thermophysical properties</li><li>5. Equations of State (EOS)</li><li>6. Constructal Law optimization</li></ol>
<i>Class schedule:</i>	Three 50-minute lecture sessions per week, for one semester.

Prepared by: J. Leachman

Date: January 1, 2018

## *Policie:*

- A. Reasonable Accommodation** Reasonable accommodations are available for students with a documented disability. If you have a disability and need accommodations to fully participate in this class, please either visit or call the Access Center (Washington Building 217; 509-335-3417) to schedule an appointment with an Access Advisor. All accommodations MUST be approved through the Access Center.
- B. Academic Integrity** WSU expects all students to behave in a manner consistent with its high standards of scholarship and conduct. Students are expected to uphold these standards both on and off campus and acknowledge the university's authority to take disciplinary action. The Standards of Conduct for Students can be found at <http://conduct.wsu.edu>.
- C. WSU Safety** WSU is committed to maintaining a safe environment for its faculty, staff, and students. Safety is the responsibility of every member of the campus community and individuals should know the appropriate actions to take when an emergency arises. In support of our commitment to the safety of the campus community the University has developed a [Campus Safety Plan \(http://safetyplan.wsu.edu\)](http://safetyplan.wsu.edu). It is highly recommended that you visit this web site as well as the University emergency management web site at <http://oem.wsu.edu/> to become familiar with the information provided.
- D. Classroom Safety** Classroom and campus safety are of paramount importance at Washington State University, and are the shared responsibility of the entire campus population. WSU urges students to follow the "Alert, Assess, Act" protocol for all types of emergencies. Remain ALERT (through direct observation or emergency notification), ASSESS your specific situation, and ACT in the most appropriate way to assure your own safety (and the safety of others if you are able). Please sign up for emergency alerts on your account at [MyWSU](http://MyWSU). For more information on this subject, campus safety, and related topics, visit the [WSU safety portal \(https://faculty.wsu.edu/classroom-safety/\)](https://faculty.wsu.edu/classroom-safety/).

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## Specifics for Spring 2018

**MEETING TIME AND LOCATION:** Sloan Hall 163, MWF 12:10 - 1 PM

**INSTRUCTOR:** Dr. Jacob Leachman, Office: Sloan 217, Phone: 509-335-7711 (office), 208-816-0288 (cell), e-mail: [jacob.leachman@wsu.edu](mailto:jacob.leachman@wsu.edu) \*\* I'm usually in meetings or my lab, seldom in my office, and receive more email than I can keep ahead of. Please call my cellphone if it's urgent.

**PARTICIPATION:** This is a graduate class and the material is mostly new, as such, attendance in class is mandatory. If you are going to be absent, let me know in advance. You will be given participation credit for completing periodic (~weekly) qualitative writing assignments. These responses will be posted to the course Slack page and it is expected that you participate in the group discussions.

**HOMEWORK:** You will be given periodic (~weekly) quantitative homework assignments. Students must complete all parts of the homework on their own; however, it is encouraged to discuss homework with friends. Your brain needs the empathic experience of helping someone else in addition to the tactile experience of entering the information yourself in order to increase the likelihood you know and remember the information. Copying, pasting, reusing code, or handing in the same work with different names will result in immediate submission to the student conduct board.

**PROJECT:** Homework will stop in the latter half of the semester so that you can work on your course project. The goal of the course project is a paper that could be submitted for publication in a journal that applies material learned from this class to your graduate research. The project requires completion of 1) a paper that covers a. the motivation and need for the study, b. the gap in the literature you seek to fill, c. the theory from class being applied, d. the analysis/results, e. conclusions and recommendations for further research. You will give a 10 minute presentation with this information during the last week of class.

**GRADING:** Participation: 50%; Homework: 25%; Project: 25%. Distribution: 100–93 (A), 93–90 (A-), 90–87 (B+), 87–83 (B), 83–80 (B-), 80–77 (C+), 77–73 (C), 73–70 (C-), 70–60 (D), 60–0 (F), incomplete (I), integrity violation (X).

**SCHEDULE:** \*\*the class schedule topics may change during the semester

Dates		Week Topic	Readings	
1/8-1/12	Balances Review	1. Mass and Energy Balances -- 1 <sup>st</sup> Law -- Part 1	Chapter 1	
1/15		<b>Martin Luther King Jr. Day – No Class</b>		
1/17-1/19		2. Components & Efficiencies -- 1 <sup>st</sup> Law -- Part 2	Chapter 1	
1/22-1/26		3. Entropy & Carnot Efficiencies -- 2 <sup>nd</sup> Law -- Part 1	Chapter 2	
1/29-2/2		4. Entropy Balances -- 2 <sup>nd</sup> Law -- Part 2	Chapter 2	
2/5-2/9		5. Cycle Exergy Analysis – Combined Law – Part 1	Chapters 3,5,8	
2/12-2/16		6. Cycle Exergy Analysis – Combined Law – Part 2	Chapters 3,5,10	
2/19	<b>President's Day – No Class</b>			
2/21-2/23	Props & EOS	7. History of Fluid Behavior	Chapters 4,6	
2/26-3/2		8. Thermodynamic Property Relations	Chapter 4	
3/5-3/9		9. Equations of State (EOS)	Chapter 6	
3/12-3/16		<b>Spring Break – No Class</b>		
3/19-3/23		10. Multi-phase and Corresponding States	Chapter 6	
3/26-3/30	11. Types and Properties of Mixtures	Chapter 6		
4/2-4/6	Optimizations	12. Mass Transport Optimization – The Shape of a Tree	Chapters 11,13	
4/9-4/13		13. Thermal Transport Optimization – Snowflakes & HEXs	Chapters 11,13	
4/16-4/20		14. General Transport Optimization -- ???	Chapters 11,13	
4/23		Project Presentations – Part 1		
4/25		Project Presentations – Part 2		
4/27		Project Presentations – Part 3		