

MECHANICAL ENGINEERING

Sample Syllabus

ME 410: Heat Transfer

Fall 2024

Department of Mechanical Engineering The Pennsylvania State University

Course description:	<u>ME 410 Heat Transfer</u> is an undergraduate course on the three modes of heat transport: conduction, convection, and radiation; additionally, the fundamentals of heat exchanger design and numerical methods are studied. One-dimensional steady and transient conduction methods are developed for planar, cylindrical, and spherical geometries. Convection heat transfer is studied in both formats, forced and natural, in internal and external conditions and under laminar and turbulent flow regimes. Radiation heat transfer is studied by considering both, the general characteristics of radiation and the properties of radiating surfaces, under simplifications that allow for easy directional and spectral analyses. Methods for solving multi-mode heat transfer are presented throughout the course. Heat exchangers and heat transfer from extended surfaces are two applications studied in this course.
Course objectives:	 After taking this course, students should be able to: Distinguish between the heat transfer modes and make simplifications to formulate multimode heat transfer problems. Generate mathematical models of one-dimensional heat transfer in steady and transient state. Use convection correlations for different kinds of geometries and flow conditions. Use the concept of thermal resistance to analyze radiation between surfaces. Size and predict the performance of heat exchangers operating in single-phase conditions.
Prerequisites:	Fluid mechanics: AERSP 308, AERSP 311, BME 409, CE 360, ME 320. Programming in engineering: CMPSC 200 or CMPSC 201. Ordinary differential equations: MATH 220 or NUCE 309; MATH 251.
Textbook:	T. L. Bergman and A. S. Lavine, Fundamentals of Heat and Mass Transfer, 8th or 7th ed., John Wiley & Sons (2017).
Instructor:	Dr. Derek M. Hall, Assistant Professor, Department of Mechanical Engineering. Energy and Environment Laboratory, Room 168, Email: <u>Hall@psu.edu</u>
Office hours:	TBD
Web resources:	 <i>Canvas</i>: lecture notes, homework assignments, solutions, and other materials. <i>WebApps</i> (<u>https://weblabs.psu.edu/</u>): online access to specialized software, a bit slower than VDI.
Class time and format	MoWeFr 12:20PM - 1:10PM EST, MWF, Reber Building, 135 A few classes will be held on Zoom but they will be announced via email.
	Course Evaluation
Homework:	Homework will be posted on Canvas under Assignments. Three are expected. Homework will involve conceptual questions, detailed analytical, and/or numerical solutions of different heat transfer problems. Collaborative work is acceptable, but you need to submit your own intellectual work. <i>Late submission policy</i> : NO LATE submissions are accepted, except for a pre-approved excuse (with a

request made 24 hours in advance of the deadline). If it is less than 24 hours, I will deduce 15% for every day it is late.



Format policy: All submissions must be high quality typed reports. This means no hand-drawn or hand-written content will be accepted. This includes digital images of handwritten items. All steps must be clearly shown, points will be taken off for poor style and unclear labeling.

- **Quizzes:** 10 equally weighed quizzes will be administered through Canvas. These are designed as learning exercises to help you practice the material in a low-stakes environment. The lowest quiz grade will be dropped. *Late submission policy*: NO LATE submissions are accepted, except for a pre-approved excuse (24 hours in advance).
- **Exams** Three equally weighed exams will be administered through Canvas via the testing center (unless otherwise stated). They will be heavily based on theory and simple calculations tailored towards assessing the learning outcomes of each module.

Attendance/ Attendance will NOT be taken, and participation will not be enforced, but it is encouraged. **participation**

Grading	Quizzes:	30% (10 Quizzes)
percentage:	Homework:	35% (3 Assignments)
	Exams	35% (3 Exams)

Letter grade scores are given in the following table:

Score Cut-off	93	90	87	83	80	77	70	60	Under 60
Letter Grade	А	A-	B+	В	B-	C+	С	D	F

Academic honesty: Academic integrity and honesty are essential to achieve high-quality education and to keep the prestige of the institution. I will not tolerate any academic misconduct, such as cheating or other violations of the Penn State code: http://senate.psu.edu/policies-and-rules-for-undergraduate-students/47-00-48-00-and-49-00-grades/#49-20. Cheating includes, but it is not limited to: copying directly from unauthorized source, such as friends, classmates or a solutions manual; allowing another person to copy your work; taking an exam in someone else's name, or having someone else take an exam in your name; or asking for regrade of a HW that has been altered from its original form.

Grade appeal: If you feel that there is an error in the grading on a homework or quiz, a regrading request should be submitted with a brief description of the error <u>within one week of being handed back</u>. Scores will not be reconsidered after one week.

Late drop deadline – **November 10th:** As a reminder, you may drop the course until November 11th. A WP (passing), WF (failing), or WN (no grade) will be entered on your academic record depending on your performance prior to dropping the course. Typically, a 70% average is sufficient to obtain a WP.

Week	Due	Topic(s)	Reading assignment	Practice problems, 7 th Ed
1	Quiz 1	<u>Module 1</u> : Lesson 1 – heat transfer modes, energy conservation and heat transfer (heat transfer and thermodynamics), importance of heat transfer.	Ch. 1.1 - 1.7	Ch. 1: 1, 5, 9, 12, 22, 35
2	Quiz 2	<u>Module 2</u> : Lesson 2 – Introduction to conduction: heat diffusion equation, boundary conditions, formulation and solution of simple heat transfer problems.	Ch. 2.1 - 2.5	Ch. 2: 6, 8, 18, 19, 22, 44

Tentative Course Schedule



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3	Quiz 3	<u>Module 2</u> : <i>Lesson 3</i> – Steady state one-dimensional conduction: thermal resistance formulation, conduction with internal energy "generation".	Ch. 3.1 - 3.5	Ch. 3: 3a, 5, 16, 45, 47, 57, 59, 64, 74, 86
4	HW #1	<u>Module 2</u> : <i>Lesson 4</i> – Steady state one-dimensional conduction: extended surface analysis, fins, fin effectiveness, fin efficiency, analysis of finned surfaces.	Ch. 3.6	Ch. 3: 92, 99, 104a, 114a, 115, 125
5	Quiz 4	<u>Module 2</u> : <i>Lesson 5</i> – Transient conduction: lumped capacitance method, one-term approximation.	Ch. 5.1 - 5.6	Ch. 5: 6, 11, 16, 38, 53, 59
6	Quiz 5	<u>Module 2</u> : <i>Lesson 6</i> – Transient conduction: one-term approximation and the semi-infinite solid	Ch. 5.6 - 5.10	Ch. 5: 67, 70, 88, 106
7	Exam #1 Module 1- Module 2	<u>Module 3</u> : <i>Lesson 7</i> – Introduction to convection: boundary layers, governing equations, similarity, scale analysis.	Ch. 6.1 - 6.7	Ch. 6: 1, 5, 6, 15, 18, 29, 30
8	Quiz 6	<u>Module 3</u> : <i>Lesson</i> 8 – External forced flow convection: flat plates (scale analysis, similarity and integral solutions), blunt objects in cross flow, correlations for turbulent flow, banks of tubes.	Ch. 7.1 - 7.5	Ch. 7: 10, 16, 19, 40, 41, 66, 72
9	HW #2	<u>Module 3</u> : <i>Lesson 9</i> – Internal forced flow convection: review of hydrodynamics of confined flow, the entry regions, fully developed laminar convection, developing laminar convection, correlations for turbulent flow.	Ch. 8.1 - 8.6	Ch. 8: 2, 8, 10, 16, 17, 27, 38, 49, 63
10	Quiz 7	<u>Module 3</u> : <i>Lesson 10</i> – Natural convection: natural convection as a thermal engine, governing equations and the Boussinesq approximation for vertical plates (scale analysis, similarity and integral solutions), correlations for horizontal plates and blunt objects in laminar and turbulent conditions.	Ch. 9.1 - 9.8	Ch. 9: 7, 15, 24, 26, 28, 41, 48, 52
11	Exam #2 Module 3	<u>Module 4:</u> <i>Lesson 11</i> – classification of heat exchangers, energy balance in heat exchangers, simplifications of conduction and convection.	Ch. 11.1 - 11.2	Ch. 11: 2a-b, 7, 8
12	Quiz 8	<u>Module 4:</u> Lesson 12 – the log-mean temperature difference method (LMTD), the effectiveness-number-of transfer-units method (ϵ -NTU).	Ch. 11.3 - 11.5	Ch. 11: 10, 15, 16, 30, 32, 41
13	Quiz 9	<u>Module 5</u> : <i>Lesson 13</i> – Fundamentals of radiation: concepts and radiation fluxes, radiation intensity and fluxes, blackbody radiation and real surfaces	Ch. 12.1 - 12.8	Ch. 12: 1, 3, 4, 9, 10, 12, 15
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14	HW #3	<u>Module 5</u> : Lesson 14 – Kirchhoff's law, radiative properties, gray surfaces.		Ch. 12: 29, 33, 39, 45, 49a-b, 51



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	Finals week	Exam #3 Module 4 – Module 5		
15	Quiz 10	<u>Module 5</u> : <i>Lesson 15</i> – Radiation exchange between surfaces: view factors, radiation exchange between black surfaces (space resistance), radiation exchange between gray surfaces (surface resistance), multimode heat transfer.	Ch. 13.1 - 13.4	Ch. 13: 2, 3, 11, 14, 20, 26, 48, 52, 61, 68, 72, 73

Policies and Resources

Notice of Video Recording: Video and audio recordings of some office hours sessions will take place. The video and audio recording are used for educational use/purposes and may be made available to all students presently enrolled in the class. For purposes where the recordings will be used in future class session/lectures, the videos will adequately remove any type of student identifying information.

Disability Statement. Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. Student Disability Resources (SDR) Web site provides contact information for every Penn State campus: http://equity.psu.edu/sdr/disability-coordinator. For further information, please visit Student Disability Resources Web site: http://equity.psu.edu/sdr. In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: http://equity.psu.edu/sdr/guidelines. If the documentation supports your request for reasonable accommodations, your campus's disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. You must follow this process for every semester that you request accommodations.

Counseling & Psychological Services (CAPS) Statement. Students with academic concerns related to this course should contact the instructor in person or via email. Students also may occasionally have personal issues that arise in the course of pursuing higher education or that may interfere with their academic performance. If you find yourself facing problems affecting your coursework, you are encouraged to talk with an instructor and to seek confidential assistance at the Penn State Counseling and Psychological Services (CAPS) Center at (814) 863-0395. Visit their website for more information http://studentaffairs.psu.edu/counseling/. In addition, crisis intervention is always available 24/7 from Centre County CAN HELP (1-800-643-5432), or contact University Police at (814) 863-1111.

Academic Integrity Statement. This course adheres to University Senate Policy 49-20: "Academic integrity is the pursuit of scholarly activity in an open, honest, and responsible manner, serving as a basic guiding principle for all academic activity. Academic integrity includes a commitment not to engage in or tolerate acts of falsification, misrepresentation or deception. Such acts of dishonesty violate the fundamental ethical principles of the University community and compromise the worth of work completed by others." Unless explicitly directed otherwise by the instructor, all assignments are expected to be the student's own original work completed individually without collaboration. Violations of this code of conduct will result in reduced grades and can be reported to the College or University for further action.

Statement of Nondiscrimination. The Pennsylvania State University is committed to the policy that all persons shall have equal access to programs, facilities, admission, and employment without regard to personal characteristics not related to ability, performance, or qualifications as determined by University policy or by state of federal authorities. The Pennsylvania State University does not discriminate against any person because of age, ancestry, color, disability or handicap, national origin, race, religious creed, sex, sexual orientation, or veteran status.

Direct all inquiries regarding the nondiscrimination policy to: Affirmative Action Director The Pennsylvania State University 201 Willard Building University Park, PA 16802-2801 Telephone: (814) 863-0471 U.Ed.OVP98-4