ME 505 - INTERMEDIATE HEAT TRANSFER
SPRING 2017

Tuesday & Thursday, 12:00 – 1:15 PM, Wang 2599
Course Webpage: https://mycourses.purdue.edu/
Discussion Webpage: https://piazza.com/purdue/spring2017/me505/home

Instructor Information
Amy Marconnet
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(please include ME 505 in subject line)
Webpage: https://engineering.purdue.edu/MTEC/
Office Hours:
Mondays 5:30 – 7:00 pm (WebEx)
Thursdays 2:00 – 3:30 pm in ME 2151
or by appointment.

T.A.
Yuqiang Zeng
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Office Hours:
Fridays 3:30 – 4:30 pm in ME 2206
Fridays 5:00 – 6:00 pm (WebEx)
Or by appointment

Course Description

ME 505 is a dual-level course in heat and mass transfer that may be taken for graduate credit or as an undergraduate elective. The prerequisite for this course is ME 315 or an equivalent undergraduate course in heat transfer. As in ME 315, there is a balanced coverage of the three basic transport modes: diffusion, convection, and radiation. However, these topics are treated in greater depth, and students leave ME 505 with a better appreciation of the underlying fundamentals and with improved analytical skills. The specific objectives of the course are:

- To enhance the understanding of heat and mass transfer processes and their relevance to industrial problems
- To strengthen analytical skills and the ability to cope with complex problems
- To provide experience in treating multimode heat and mass transfer effects and in solving realistic engineering problems

Scope of the Course

Heat and mass transfer by diffusion in one-dimensional, two-dimensional, transient, periodic, and phase change systems. Convective heat transfer for external and internal flows. Similarity and integral solution methods. Heat, mass, and momentum analogies. Turbulence. Buoyancy driven flows. Convection with phase change. Radiation exchange between surfaces and radiation transfer in absorbing-emitting media. Multimode heat transfer problems.

A note on the Mathematics background expected for this course: You will be well served to review Taylor's series expansions, solution of simple ODEs, simple integration and differentiation, integration by parts, and trigonometric and hyperbolic functions in preparation for this course.

Text book

Fundamentals of Heat and Mass Transfer, 7th Edition, by Incorpera, DeWitt, Bergman, and Lavine, Wiley (2011)

This required textbook will serve as a good first resource for information. However, you are expected to refer to a variety of sources for information as indicated by the instructor. See pages 6-7 of the syllabus for additional suggested readings.

Virtual Office Hours

Professor Marconnet and Yuqiang Zeng will hold virtual office hours through WebEx.

Who:	Prof. Marconnet	Yuqiang Zeng
When:	Mondays from 5:30 – 7 pm	Fridays from 5 – 6 pm
Site:	https://purdue.webex.com/	https://purdue-student.webex.com/
Meeting number:	648 984 166	732 124 711
Password:	Fourier	Fourier

- You will need to use the WebEx website or App to connect to office hours. If using a computer, it must have a microphone and speakers for audio communications.
- Be prepared to email or post diagrams/equations/pictures of your current progress and/or questions.
- Students who post their questions to Piazza (see below) and/or email to instructors prior to office hours will have priority.
- Additionally, the TA will be available for phone, WebEx/skype, and/or email consultations for the online students.

Piazza Discussion Board

Piazza is an online forum that we will use in ME505. All students should sign up for Piazza (https://piazza.com/school-search). It is important that you use your Purdue email to sign up for Piazza as it allows the instructors and TAs to see which students are asking questions. Prior to sending an email to a TA or the instructor, please check Piazza to see if your question has already been answered. Be sure to use tags and folder for your questions. This will allow both your classmates as well as TAs to quickly find questions/answers.

Punctuality

Please arrive a few minutes prior to the class start time. Be seated and prepared to participate before the class begins. If you are late, be very quiet as you enter and find a seat quickly and quietly. Remember, homework is due at the beginning of class and no late homework wil be accepted.

Grading

The course grade will be based on homework, term project, and examinations according to the following tentative distribution:

- Homework 30%
- Midterm Exam 20%
- Final Exam 30%
- Term Project 20%

<u>Homework</u>
Homework assignments will be given on a regular basis. All assignments will be due by the beginning of the class on the due date (*i.e.* noon on the due date). **No late homework will be accepted.**

- <u>On campus students must turn hard copies of the homeworks in at class</u>.
- <u>EPE students should submit through Blackboard</u>.

If the website is not accessible on the due date, homework may be emailed to the instructor and TA. The subject line should read "ME505-Homework #-Your Name"

<u>Term Project</u>
The objective of this group project is to practice how to apply heat and mass transfer knowledge we discussed in the class to real-world applications. The process can be related to your research project or industrial experience. It can also be any natural process encountered in your daily life. You can also perform literature review to postulate an engineering process or product of your interest. The only constraints are the process should include at least two transport phenomena (conduction, convection, mass diffusion, radiation). If you haven't had a solid undergraduate foundation in radiation, remember that radiation will not be introduced in detail until week 12 of the course. Please also remember that this work should be done for this course - not recycled from past work and, while it can be related to your current job/research area, it should not be something you would normally be expected to complete as part of your employment, RA, or independent study position.

The project consists of following steps.

1. <u>Initial Team Formation (Due 2/2)</u>: For the project, you should form a team of **two**. Use Piazza to find a teammate and share project ideas. By class on 2/2, use Blackboard to submit your list of team members and a very short description of your idea. Students who have not formed teams by 2/2 should submit their interests via the same form and will be assigned to teams by the instructor and will submit their idea as the project proposal slide.
2. <u>Project Proposal (Due 2/9)</u>: One slide proposal postulating or identifying the process or product where at least than two transport phenomena occur.
3. <u>Project Report:</u> Report describing the analysis including the formulation and solution of relevant governing equations, boundary or initial conditions, necessary constitutive equations.
    a. <u>Rough draft (Due 3/23)</u>: Focused on the introduction, literature review, and preliminary analysis (plan and preliminary results).
    b. <u>Final Report (Due 4/27)</u>: Complete report including all sections.

<u>Academic Integrity</u>
All submitted **homework** must be the result of an individual's personal effort. Students may collaborate on concepts and discuss ideas and approaches, but all submitted homework must be your own. Any violations of this policy breach the standard of academic integrity that is vital to the mission of the university.

The **project** will be completed in teams of two. All team members are equally responsible for ensuring that all segments of their report are free from plagiarism. Note that plagiarism is "copying or imitating the language, ideas, and thoughts of another author and passing off the same as one's original work" (Barnhart, 1968) and is a violation of academic integrity. As an example, copying and pasting sections of articles together does not constitute a literature review. You must summarize relevant sources in your own words and give credit to the original authors with proper citations.

Emergency Procedure

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. Information about changes will be available via: Blackboard web page, e-mail inquiries to: amarconn@purdue.edu, and phone: 765-494-5626.

Students with Disability

If you are a student who requires accommodations in compliance with the ADA (Americans with Disabilities Act), please consult with the instructor.

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Tentative Schedule (subject to change)

Week Number	Dates	Topic(s)	Textbook Reading
1	1/10, 1/12	General Review, Conduction Intro	Chapter 1-2
2	1/17, 1/19	1D Steady State Conduction & Extended Surfaces	Chapter 3
3	1/24, 1/26	Extended Surfaces; Transient Conduction	Section 3.6; Chpater 5
4	1/31, **2/2**	Transient Conduction; Multi-Dimensional Conduction	Chapter 5; Chapter 4
5	2/7, **2/9**	Multi-Dimensional Conduction; Numerical Methods	Chapter 4; Grad Texts
6	2/14, 2/16	Numerical Methods; Solid-Liquid Phase Change	Section 4.5 & 5.10; Grad Texts
7	2/21, 2/23	Introduction to Convection, Conservation Equations	Chapter 6
8	2/28, 3/2	External Flow	Chapter 7
9	3/7, **3/9**	Internal Flow, **Midterm Exam**	
SB	**Spring Break (3/13-3/17)**		--
10	3/21, **3/23**	Internal Flow; Turbulence;	Chapter 8
11	3/38, 3/30	Natural Convection; Boiling & Condensation	Chapters 9 - 10
12	4/4, 4/6	Radiation Concepts	Chapter 12
13	4/11, 4/13	Radiation Exchange; Participating Media	Section 13.1-13.3; 13.6
14	4/18, 4/20	Mulit-Mode Heat Transfer	Section 13.4
15	4/25, **4/27**	Course Review	--
F	**Final Exam (TBD)**		--

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List of References

This extensive list of references is provided as a source of information, and not all the books in this list are needed for this course. Those with an asterisk are the most relevant for this course.

Off campus user library access info: https://www.lib.purdue.edu/help/access

General
*Nellis and Klein, Heat Transfer (2009).
Introductory text including examples with Matlab, Maple, and EES.

Lienhard IV and Lienhard V, A Heat Transfer Textbook (2012).
Free introductory heat transfer text available free online at http://web.mit.edu/lienhard/www/ahtt.html

Wong, K.-F. V., Intermediate Heat Transfer (2003).
Graduate heat transfer text available free online at http://www.crcnetbase.com/isbn/9780203912720

Bird, R.B. Stewart, W.E. and E.N. Lightfoot, *Transport Phenomena*, John Wiley (1960).
A comprehensive treatment of momentum, heat and mass transfer and a classic. Extensive treatment of conservation equations.

Eckert, E.R.G. and R.M. Drake, Jr., *Analysis of Heat and Mass Transfer*, McGraw-Hill (1972).
Comprehensive treatment of heat transfer by conduction, convection and radiation. Considers some interesting special cases.

Conduction/Diffusion
*Ozisik, M.N., *Heat Conduction*, John Wiley (1984).
Extensive discussion of analytical methods suitable for conduction problems. Many applications to different geometries and thermal conditions.

Arpaci, V.S., *Conduction Heat Transfer*, Addison-Wesley (1966).

Carslaw, H.S. and J.C. Jaeger, *Conduction of Heat in Solids*, Oxford University Press (1959).
For many years, the definitive work on conduction heat transfer analysis. Mathematical developments terse, but results presented for many geometries and conditions.

Convection
Arpaci, V.S. and P.S. Larsen, *Convection Heat Transfer*, Prentice-Hall (1984).
Covers a wide variety of topics. Many good examples.

Bejan, A., *Convection Heat Transfer*, John Wiley (1984).
Emphasis on appropriate scaling parameters and natural convection.

*Kays, W.M. and M.E. Crawford, *Convective Heat and Mass Transfer*, McGraw-Hill (1993).
Excellent treatment of laminar and turbulent single phase forced convection.

Radiation
Siegel, R. and J.R. Howell, *Thermal Radiation Heat Transfer*, Hemisphere (1992).
A very detailed and excellent treatment of radiation – a classic.

Brewster, M.Q., *Thermal Radiative Transfer & Properties*, John Wiley (1992).
A comprehensive and readable treatment of radiative heat transfer.

*Modest, M. F., *Radiative Heat Transfer*, Mc-Graw Hill (1993).
Radiation heat transfer text available free online at
http://www.sciencedirect.com/science/book/9780123869449

Bohren, C.F, and Hufman, D.R., 1984, *Absorption and Scattering of Light by Small Particles*, John Wiley & Sons.

Chandrasekhar, S., 1950, *Radiative Transfer*, Oxford University Press (Clarendon), London and New York; also 1960 Dover, New York.

Dewitt, D.P., and Nutter, G.D., 1988, *Theory and Practice of Radiation thermometry*, Wiley and Sons, New York.
Van de Hulst, H.C., 1981, *Light Scattering by Small Particles*, Dover.

Special Topics

Abramowitz, M. and Stegun, I. A., *Handbook of Mathematical Functions*, NBS, 1964.
Encyclopedic reference for mathematical functions.

*E. Kreyszig, *Advanced Engineering Mathematics*, Wiley, 1988.
Excellent general reference for most mathematical analysis methods.

Carey, V.P., Liquid-Vapor Phase-Change Phenomena, Hemisphere (1992).
Good treatment of boiling and condensation.

Minkowycz, W.J., Sparrow, E.M., Schneider, G.E., Pletcher, P.H. (Eds.), *Handbook of Numerical Heat Transfer*, John Wiley (1998).
Reference source for numerical method

Press, W.H., Flannery, B.P., Teukolsky, S.A. and Vetterling, W.T., *Numerical Recipes*, Cambridge (1989).
Self-explanatory name – useful book.

Topic By Topic Listing of Texts

	Incropera & Dewitt (7th ed)	Lienhard & Lienhard (3rd ed)	Wong (2003)	Carslaw & Jaeger (2nd ed)	Kays & Crawford (2005)	Modest (1993)
	-	*Available Online*	*Available Online*	-	-	*Available Online*
General Review	1.1 - 1.7	Ch 1	Ch1	-	-	-
Conduction Equations	2.1-2.5, 3.1-3.5	Ch 2, Ch 4	Ch 2, Ch 3	Ch 1	-	-
Extended Surfaces	3.6	4.5	3.12	-	-	-
Transient Conduction	5.1-5.9	5.1-5.6, 5.8	4.7	throughout text	-	-
2D Conduction	4.1-4.3, 4S.1	5.7-5.8	Ch 4		-	-
Separation of Variables	4.2, 5S.2	4.2,5.3	Ch 4	Ch. 5-9	-	-
Superposition	-	5.8	4.4		-	-
Laplace Transform	-	-		2.2, Ch 12	-	-
Numerical Methods	4.4-4.5,4S.2,5.10	-	Ch 5	-	-	-
Solid-Liquid Phase Change	-	-		Ch. 11, Ch. 15	-	-
Convection Principles	6.1-6.8	Ch 6	Ch 6	-	Ch 1-2	-
Conservation Equations	6S.1	6.1-6.3	Ch 6	-	Ch 4	-
Nondimensionalization	-	-	-	-	-	-
Heat-Mass Analogy	6.7	6.3	-	-	Ch 19-20	-
External Flow	7.1-7.9	6.2-6.8, 7.6-7.7	Ch 7	-	Ch 5- 6, Ch 9-12	-
Similarity and Integral Solutions	7.2,9.3	6.2	Ch 7, 9.2-9.4	-	Ch 5	-
Internal flow	8.1-8.10	7.1-7.5	Ch 8	-	Ch 7-8, Ch 13-14	-
Turbulence	7.2.2-7.2.3,8.5	6.7-6.8	-	-	Ch 11-14	-
Free Convection	9.1-9.11	Ch 8	Ch 9	-	Ch 17	-
Boiling and Condensation	10.1-10.12	Ch 9	-	-	-	-
Radiation Principles	12.1-12.10,13.5-13.7	10.1	Ch 12	-	-	Ch 1, Ch 3
Black-Body Radiation	12.4	10.1		-	-	1.1
View Factor	13.1	10.3	12.2-12.7	-	-	Ch 4
Radiation Exchange between Surfaces	13.2-13.3	10.1-10.4	Ch 12	-	-	Ch 5 (Ch 6 & 7)
Radiation Transfer in Enclosure	13.3	10.4	Ch 13	-	-	throughout Ch 5
Method of Radiosity	13.3	10.4	-	-	-	5.4
Multimode Heat Transfer	13.4	-	Ch 14	-	-	Ch 9 (advanced)