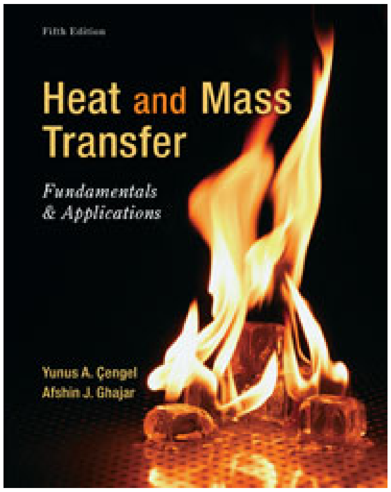
USC Viterbi School of Engineering

AME-331 Heat Transfer (Section 28762)

Term: Spring 2016 Units: 3.0

Course Syllabus (Rev 0) - new revision after 1/1/16



Lecture: **Tu/Th 09:30-10:50**
Location: **KAP 144**
Discussion (optional):
T.B.D.
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Instructors: Dr. Leslie King, Dr. Rick Martin
Office: VHE-M22
Office Hours:
LK Th 8:15-9:15AM, 12:45-1:45PM
RM Tu 8:15-9:15AM, 12:45-1:45PM
Contact Info:
LK lking@usc.edu (urgent : leslie.b.king@aero.org)
RM richarjm@usc.edu (urgent : rmartin@martinthermal.com)

Teaching Assistant(s):
Office: VHE-202
Office Hours: **TA#1: TBD** **TA#2: TBD**
Contact Info: **@usc.edu, @usc.edu**

Catalog Description General principles underlying heat transfer by conduction, convection, and radiation; steady and transient conditions; heat exchangers. Prerequisite: AME 310. Co-requisite: AME 309.

Instructors' Description This course is a one-semester introduction to heat transfer for mechanical and aerospace engineering students and others who need a solid understanding of the subject. For students intending to specialize in the thermosciences, advanced courses in convection, radiation, mass transfer, boiling/condensation, combustion, heat exchangers, and computational methods are encouraged. To emphasize the practical aspects of the subject, the lectures will contain "real world" applications of heat transfer in the engineering profession. Topics may include: utility boilers, industrial freezers, computer chip cooling, coffee makers, camp fires, thermal oxidizers, rotary kilns, temperature sensors, space shuttle tiles, and burn injuries.

Recommended Preparation The course material presented assumes the student has attained competency in physics, chemistry, calculus (including an introductory course in differential equations), engineering thermodynamics, and fluid mechanics. The format will be lectures plus optional discussion sections. There is no lab.

Prerequisite(s): AME 310 **Co-Requisite (s):** AME 309 **Concurrent Enrollment:** none

Required Textbook
Heat and Mass Transfer – Fundamentals and Applications Fifth Edition (with "ConnectPlus" Access Card); Yunus A. Cengel and Afshin J. Ghajar; McGraw-Hill, 2015. Chapters 1-9, 11-13. ISBN: 978-1-25-927990-4

Course Notes

Co-Instructors: Drs. Martin and King will lecture and provide office hours as a "team". Students must sit for quizzes and exams during the section in which they are enrolled. Students enrolled in Section 28761 will have their work evaluated primarily by Dr. Martin. Students enrolled in section 28762 will have their work evaluated primarily by Dr. King.

Grading: Students earn points (1000 possible) by successfully completing the following assignments:

- Homework 240 (approximately 1 per week, graded)
- Pop Quiz 100 (4 per semester, 25 each)
- Midterm Exam 300 (2 per semester, 150 each)
- Design Project 60 (1)
- Final Exam 300 (1)
- EES Problems 60 extra credit (Cengel textbook, approximately 1 per HW assignment)

Final grades are based on absolute scores and calibrated against a normal distribution to ensure fairest treatment for each student. See course schedule for reading and homework assignments.

A (920+), A- (880+)	(mastered essentially all the material)
B+ (850+), B (820+), B- (780+)	(mastered the majority of the material)
C+ (750+), C (720+), C- (680+)	(understood a moderate amount of the material)
D+ (650+), D (600+)	(only grasped minimum content; consider re-taking course)
F (599 and below)	(failed to grasp the material; must re-take course)

Technological Proficiency and Hardware/Software Required

Because exams and quizzes are open-book, open-note but closed-smartphone, closed-laptop, students are expected to bring and use a **hand calculator** on quizzes and exams. Accessing computers/internet (including eBook version of textbook) is not allowed during any quiz or exam. Approximately 12 extra credit problems (~5 points each) will require use of a mathematical software application (e.g, EES, Matlab, Mathcad, or Excel) to obtain the final solution. Students are expected to provide their own software and submit printouts with their HW assignment(s). For Chapter 5, an Excel spreadsheet tool will be provided on Blackboard, but students may elect to perform the calculations with a different numerical application.

Homework Submission Policy

See Class Schedule (posted on Blackboard) for assigned problems and due dates. (HW is due most Thursdays)

HW is LATE if not received by instructor at the end of class (no grace period provided).

- 25% penalty if 1 to 24 hours late
- 50% penalty if 25 to 48 hours late
- 75% penalty if 49 or more hours late

Solutions are posted on Blackboard after 2nd day

Regular HW must be submitted as hardcopy, in class. Never leave hard copy in instructor office! It may get lost and it will always be marked 3 days late.

Late HW may be submitted electronically (as PDF file) via email to both instructors (with email datestamp). Late credit will be given for homework submitted up to the last day of class (Thursday, April 28, 2016)

Additional Policies

- Design Projects (2 PowerPoint slides per design team) are due at 10:00 PM on Wednesday, April 27 (approximately 12 hours before the 9:30AM Thursday lecture). No exceptions.
- Students should inform both instructors in advance if they are unable able to sit for a quiz or exam due to illness or unavoidable schedule conflict. Permission to sit for a make-up exam is solely at the discretion of the instructors. Students must take the final exam on the assigned date – no exceptions.

Learning Objectives

Students should be able to demonstrate their understanding of each concept, law, or method enumerated below on one (or more) of the following assignment/exam types: HW, Quiz, MT, Final, or Project:

1. Week #1
   a. 1st & 2nd Law
   b. Temperature as Driving Force for Heat Transfer
   c. Heat Flux
   d. Properties of Solids (e.g., ρ, c_p, k)
   e. Fourier's Law
   f. Newton's Law of Cooling
   g. Properties of fluids and flows (e.g., V, μ, ρ, h)
   h. Stefan Boltzmann Law
   i. Radiative Properties of Surfaces (e.g., ε, F_{12})
2. Week #2
   a. 1-D Energy Equation for Conduction
   b. Conduction in Plane Wall
   c. Heat Generation
   d. Heat Storage
   e. Differential Formulation of First Law (x,y,z)
   f. Boundary Conditions for Differential Equations.
3. Week #3
   a. Poisson Eq., Laplace Eq., Diffusion Eq.
   b. Cylindrical, Spherical Coordinate Systems
   c. Six Types of Boundary Conditions
   d. Formulating/Solving Conduction Problems
   e. Mathematics of Heat Generation
4. Week #4
   a. Heat Generation Problem Solutions
   b. Mathematicas of Variable Thermal Conductivity
   c. Electric Circuit Analogy
   d. Thermal Resistance Network
   e. Sum of Resistances
   f. Overall Heat Transfer Coeff
   g. Thermal Contact Resistance
5. Week #5
   a. 1-D Conduction/Convection Systems
   b. Fin Equation
   c. Fin Efficiency, Effectiveness
   d. Shape Factor for 2D Conduction
   e. 2D Conductdion (Separation of Variables)
6. Week #6
   a. Lumped capacitance - Biot No.
   b. Distributed capacitance - Fourier No.
   c. Heisler charts
7. Week #7
   a. Transient Q, Semi-Infinite Solids
   b. Self-similarity method
   c. Error function, Complementary Error function
   d. Finite Difference Method for 1D Geometries
   e. Finite Difference Method for 2D Geometries
   f. Finite Diff Method for 1st 2nd Derivatives
   g. Source Terms, Transients, Boundary Conditions
8. Week #8
   a. Mass, Momentum, Energy Conservation
   b. Fluid Properties
   c. Boundary Layer Thickness
   d. Blasius vs Cubic Solution for Velocity Profile in BL
   e. Thermal BL
9. Week #9
   a. Prandtl Number and Thermal BL
   b. Reynolds-Colburn Analogy
   c. External BL (Drag, Wake)
   d. Film Temperature
   e. Heat transfer coefficient
   f. Stanton, Nusselt Numbers
   g. Cylinders, spheres (McAdams, Churchill, etc.)
   h. Drag coefficient
10. Week #10
    a. Laminar Tube Flow - Velocity Profile
    b. Laminar Tube Flow - Entry Length, Graetz Number
    c. Fully Developed Laminar Tube Flow
    d. Friction Factor, Nusselt Number
    e. Bulk and Bulk-Mean Temperatures
    f. Hydraulic Diameter
    g. Boundary Conditions - Constant T, Constant q"
    h. Log Mean Temperature Difference
    i. Turbulent Q (Dittus-Boelter, Petukhov)
    j. Moody Chart for friction factor
11. Week #11
    a. Natural Convection, Buoyancy Forces
    b. Volume Coefficient of Expansion
    c. Momentum Equation
12. Week #12
    a. Grashof Number, Rayleigh Number
    b. Other geometries (inclined plate, cylinders)
    c. Thermal, Momemtum BL
    d. Overall Heat Transfer Coefficient
    e. LMTD Method for Heat Exchangers
    f. Fouling
13. Week #13
    a. Parallel, Counterflow, Crossflow, Mixed, Unmixed
    b. Effectiveness-NTU method for Heat Exchangers
    c. Cmin, Cmax, NTU
    d. Radiation Fundamentals, Planck's Law
    e. Wien's Displacement Law
    f. Gray bodies, Emissivity, Absorptivity
14. Week #14
    a. Intensity, Steradians
    b. Radiant Exchange Equation
    c. View Factor derivation
    d. View Factor algebra
    e. Radiosity, Irradiation
    f. Thermal Radiation Resistance Networks
15. Week #15
    a. Radiation Shields
    b. Thermocouple Error
    c. Solar Radiation

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu or to the *Department of Public Safety* http://capsnet.usc.edu/department/department-public-safety/online-forms/contact-us. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage http://sarc.usc.edu describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* *http://emergency.usc.edu* will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.

Week No.	Lecture No.	Day/Date	Cengel Reading	SUBJECT	Student Work Product	Cengel Homework Due
1	1	Tue 1/12	1-1 to 1-5	Introduction		
	2	Th 1/14	1-6 to 1-8	Heat Transfer Mechanisms	Homework #1	tbd
2	3	Tue 1/19	1-9 to 1-11	Solving Heat Transfer Problems		
	4	Th 1/21	2-1 to 2-2	Diff. Equations & Conduction	Homework #2	tbd
3	5	Tue 1/26	2-3 to 2-4	Boundary & Initial Conditions		
	6	Th 1/28	2-5	Steady 1-D Conduction	Homework #3	tbd
4	7	Tue 2/24	2-6 to 2-7	Heat Generation, Variable k		
	8	Th 2/4	3-1 to 3-4	Thermal Networks	Homework #4	tbd
5	9	Tue 2/9	3-5 to 3-6	Cylinders, Spheres, Fins		
	10	Th 2/11	3-7 to 3-8	Solving Conduction Problems	Homework #5	tbd
6	11	Tue 2/16	4-1 to 4-2	Transient Conduction		
	12	Th 2/18		**MIDTERM #1 (Chapters 1 to 3)**		**No HW Due**
7	13	Tue 2/23	4-3 to 4-4; 5-1 to 5-2	Semi-Inf. Solid; Num. Methods		
	14	Th 2/25	5-3 to 5-4	Finite Difference Conduction	Homework #6	tbd
8	15	Tue 3/1	6-1 to 6-6	Convection Fundamentals		
	16	Th 3/3	6-7 to 6-11	Momentum and Heat Equations	Homework #7	tbd
9	17	Tue 3/8	7-1 to 7-2	Flat Plate Convection		
	18	Th 3/10	7-3 to 7-4	External Convection	Homework #8	tbd
		Tue 3/15			**SPRING BREAK**	
		Th 3/17			**SPRING BREAK**	
10	19	Tue 3/22	8-1 to 8-4	Internal Forced Convection		
	20	Th 3/24	8-5 to 8-6	Laminar, Turbulent Heat in Tubes	Homework #9	tbd
11	21	Tue 3/29	9-2 to 9-2	Solving Convection Problems		
	22	Th 3/31		**MIDTERM #2 (Chapters 4 to 7)**		**No HW Due**
12	23	Tue 4/5	9-3, 9-5 to 9-6	Natural Convection		
	24	Th 4/7	11-1 to 11-4	Intro to Heat Exchangers	Homework #10	tbd
13	25	Tue 4/12	11-5 to 11-6	LMTD and NTU Methods		
	26	Th 4/14	12-1 to 12-3	Radiation Principles	Homework #11	tbd
14	27	Tue 4/19	12-4 to 12-6	Radiation Properties		
	28	Th 4/21	13-1 to 13-3	View Factors		
15	29	Tue 4/26	13-4 to 13-6	Solving Radiation Problems	Homework #12	tbd
	30	Th 4/28	--	Design Project - Presentations	**DESIGN PROJECT PRESENTATIONS**	Pop Quizzes (total 4 over 15 weeks) during regular lectures
	31	*Tue 5/3*	*10:00AM - 11:00AM*	*Optional Review Session (location tbd)*		
28762	(09:30 - 10:50 Section)	Tue 5/10 8AM-10AM	Location: tbd	**FINAL EXAM (Chapters 8-9, 11-13, ...selections from 1-7)**		
28761	(11:00 - 12:20 Section)	Tue 5/10 11AM-1PM	Location: tbd	**FINAL EXAM (Chapters 8-9, 11-13, ...selections from 1-7)**		