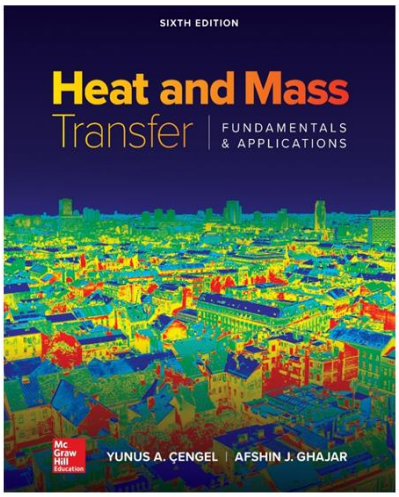
USC Viterbi School of Engineering



AME-431 Heat Transfer (Section 28906)

Term: Fall 2024 Units: 4.0

Course Syllabus (Rev 0)

Lecture: F 13:00-15:50
Location: GFS-118
Discussion: W 12:00-12:50
Location: GFS-106

Instructor: Dr. Leslie King
Office: OHE-430N
Office Hours: TBD
Contact Info:
LK lking@usc.edu (urgent : leslie.b.king@aero.org)

Teaching Assistants: Yi Wang
Office: VHE-202
Office Hours: TBD
Contact Info: ywang334@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 cooling, coffee makers, rocket plume, 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 once a week. 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 Sixth Edition;
Yunus A. Cengel and Afshin J. Ghajar; McGraw-Hill, 2020. Chapters 1-9, 11-13. ISBN: 978-0-07-339819-8

Course Notes

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

- Homework 200 (10 homeworks. approximately 1 per week, graded)
- Quiz 70 (2 per semester, 35 each)
- Midterm Exam 300 (2 per semester)
- Design Project 130 (1)
- Final Exam 300 (1)
- EES Problems 40 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

Exams and quizzes are open-book, open-note, open-personal electronic devices in airplane mode. Students can bring and use a hand calculator on quizzes and exams. Accessing internet is not allowed during any quiz or exam. Approximately 10 extra credit problems (4 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 code 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 Fridays)
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 to the assignment's specific folder on Blackboard**.
Late HW may be uploaded to the assignment folder or submitted electronically (as PDF file) via email to the instructor (if the folder is locked).
Late credit will be given for homework submitted up to the last day of class (Friday, December 1, 2023)

Additional Policies

- Design Projects (5-6 PowerPoint slides per design team) are due at 10:00 PM on Thursday, November 30 (approximately 13 hours before Friday lecture). ***No exceptions***.
- Students should inform the instructor 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 instructor. 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.

Support Systems

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) - (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention - (213) 821-4710
campussupport.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.
Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.
USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.
USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Week No.	Lecture No.	Day/Date	Cengel & Ghajar Reading	SUBJECT	Student Work Product	Cengel & Ghajar Homework Due Last Items Each Row (Red Text) are Extra Credit
1	1	Wed 8/28	1-1 to 1-9; 1-13 to 1-15	Introduction	<none>	
	2	Fri 8/30		Mechanisms of Heat Transfer, Solving Heat Transfer Problems		
2	3	Wed 9/4	2-2 to 2-6	Differential Equations		
	4	Fri 9/6		Boundary&Initial Conditions, Steady 1-D Conduction, Heat Generation	Homework #1	1-36, 1-47, 1-49, 1-79, 2-2, 2-18, 2-27, 1-110
3	5	Wed 9/11	2-7 to 3-4	Variable K		
	6	Fri 9/13		Thermal Networks	Homework #2	2-65, 2-77, 2-83, 2-90, 2-97, 2-110, 2-113, 2-137, 2-98
4	7	Wed 9/18	3-5 to 3-8	Insulation Critical Radius	**Quiz#1**	
	8	Fri 9/20		Cylinders, Spheres, Fins, Solving Conduction Problems	Homework #3	3-24, 3-31, 3-40, 3-46, 3-54, 3-77, 3-92, 3-97
5	9	Wed 9/25	4-1 to 4-4	Transient Conduction		
	10	Fri 9/27		Semi-Infinite Solid, Multidimensional Systems	Homework #4	3-104, 3-111, 3-115, 3-116, 3-128, 3-137, 3-153, 3-143
6	11	Wed 10/2	5-1 to 5-4	Numerical Methods		
	12	Fri 10/4		Finite Difference Conduction	**Midterm #1 (Ch. 1-3)**	
7	13	Wed 10/9	6-1 to 6-11	Convection Fundamentals		
	14	Fri 10/11			**Fall Recess**	
8	15	Wed 10/16	7-1 to 7-4	Conservation Equations		
	16	Fri 10/18		Flat Plate Convection, External Convection	Homework #5	4-4, 4-14, 4-30, 4-63, 4-85, 4-97, 4-117, 4-95
9	17	Wed 10/23	8-1 to 8-6	Internal Forced Convection	**Quiz#2**	
	18	Fri 10/25		Laminar, Turbulent Heat Transfer in Tubes	Homework #6	5-5, 5-65, 5-72, 5-76, 6-7, 6-13, 6-21, 6-33, 6-44, 6-79
10	19	Wed 10/30	9-2 to 9-6; 11-1 to 11-2	Solving Convection Problems		
	20	Fri 11/1		Natural Convection, Intro to Heat Exchangers	Homework #7	7-6, 7-14, 7-18, 7-38, 7-41, 7-67, 7-78, 7-97, 7-108, 7-79
11	21	Wed 11/6	11-3 to 12-2	LMTD and NTU Methods		
	22	Fri 11/8		Radiation Principles	Homework #8	8-7, 8-15, 8-23, 8-83, 8-93, 9-8, 9-27, 9-44, 9-55, 9-33
12	23	Wed 11/13	12-3 to 12-6	Radiation Intensity		
	24	Fri 11/15		Radiation Properties	Homework #9 **Midterm #2 (Ch. 5-8)**	11-9, 11-26, 11-53, 11-59, 11-86, 11-99, 11-123, 11-105
13	25	Wed 11/20	13-1 to 13-6	View Factors		
	26	Fri 11/22		Radiation Heat Transfer, Participating Medium		
14	27	Wed 11/27		**THANKSGIVING BREAK**		
	28	Fri 11/29				
15	29	Wed 12/4		Radiation Review		
	30	Fri 12/6		**DESIGN PROJECT PRESENTATIONS**	Homework #10	12-9, 12-27, 12-40, 12-46, 12-57, 13-16, 13-48, 13-91, 13-106, 13-111, 12-38
	optional	*Tue12/10*		*Optional Review Session (location tbd)*		
28906	(13:00 -15:50 Section)	Wed 12/18 11AM-1PM	Location: GFS-118	**FINAL EXAM (Chapters 1-9, 11-13)**		