AME-331 Heat Transfer (Section 28735)
Term:  Fall 2020  Units:  3.0
Course Syllabus (Rev 1)

Lecture:  F 13:00-15:50
Location:  On-line
Discussion (optional):
   Mondays  TBD
   Thursdays  TBD

Instructor:  Dr. Leslie King
Office:  VHE-418
Office Hours:
   F 12:00-1:00PM & 4:00-5:00PM

Contact Info:
   LK  lking@usc.edu  (urgent:  leslie.b.king@aero.org)

Teaching Assistant:  Ashkan Movaghar
Office:
Office Hours:  M 4:00 – 7:00pm; Th 4:00 – 6:00pm
Contact Info:  movaghar@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, ordinary 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; Yunus A. Cengel and Afshin J.
Students MUST purchase a hardcopy of the textbook. eBook version is optional as a supplement, but not in
lieu of hard copy. eBook is NOT permitted for exams or quizzes. Paper printout from the eBook may be
used as substitute for hardcover. (Publisher may require an extra fee for printing from eBook.)
Course Notes
Grading: Students earn points (1000 possible) by successfully completing the following assignments:

- Homework 240 (approximately 1 per week, graded)
- Quizzes 120 (4 per semester, 30 each)
- Midterm Exam 320 (2 per semester)
- Final Exam 320 (1)
- EES Problems 36 extra credit (Cengel textbook, 1 per HW assignment)
- Poll Everywhere 30 extra credit (smartphone quizzes during lectures)

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+) (mastered the majority of the material)
C+ (750+), C (720+) (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 (3 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 XC 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 as hardcopy, in class or electronically (as PDF) if student cannot attend 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 via email (with email datestamp).

Late credit will be given for homework submitted up to the last day of class (Friday, November 13, 2020)

Additional Policies
- Students should inform the instructor in advance if they are unable 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., \( \rho, c, p, k \))
   e. Fourier’s Law
   f. Newton’s Law of Cooling
   g. Properties of fluids and flows (e.g., \( V, \mu, \rho, h \))
   h. Stefan Boltzmann Law
   i. Radiative Properties of Surfaces (e.g., \( e, F_{12} \))

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)

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. Mathematics 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 Conduction (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, Momentum 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.
<table>
<thead>
<tr>
<th>Week No.</th>
<th>Lecture No.</th>
<th>Day/Date</th>
<th>Cengel Reading</th>
<th>SUBJECT</th>
<th>Student Work Product</th>
<th>Cengel Homework Due</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Fri 8/21</td>
<td>1-1 to 1-11, 2-1 to 2-4</td>
<td>Introduction, Mechanisms of Heat Transfer, Conduction, Differential Eqs, Boundary/Initial Conditions</td>
<td>Homework #1</td>
<td>1-1, 1-6, 1-11, 1-13, 1-23, 1-115</td>
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<td>3</td>
<td>3</td>
<td>Fri 9/4</td>
<td>3-1 to 3-5</td>
<td>Plane Walls, Contact Resistance, Resistance Networks</td>
<td>Homework #3 and Quiz #1</td>
<td>2-5, 2-7, 2-20, 2-30, 2-44, 2-50, 2-120</td>
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<td>4</td>
<td>4</td>
<td>Fri 9/11</td>
<td>3-6; 3-8</td>
<td>Finned Surfaces, Shape Factors</td>
<td>Homework #4</td>
<td>2-57, 2-66, 2-88, 2-91, 2-106, 2-108, 2-112, 2-89</td>
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<td>5</td>
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<td>Fri 9/18</td>
<td>4-1 to 4-3</td>
<td>Lumped Capacitance, Heisler Charts, Semi-Infinite Solids</td>
<td>Homework #5 and Quiz #2</td>
<td>3-9, 3-17, 3-28, 3-48, 3-72, 3-111, 3-122, 3-123</td>
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<td>6</td>
<td>6</td>
<td>Fri 9/25</td>
<td>4-4; 5-1 to 5-4</td>
<td>Transient Superposition, Finite Difference Method</td>
<td>Homework #6 Midterm #1 (Ch. 1-3)</td>
<td>3-139, 4-1, 4-28, 4-41, 4-50, 4-89, 4-116, 5-8, 4-118</td>
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<td>7</td>
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<td>Fri 10/2</td>
<td>6-1 to 6-11</td>
<td>Convection Fundamentals, Conservation Equations</td>
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<td>8</td>
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<td>Fri 10/9</td>
<td>7-1 to 7-4</td>
<td>External Forced Convection, Flat Plates, Cylinders, Spheres</td>
<td>Homework #7 and Quiz #3</td>
<td>5-27, 5-59, 5-73, 6-3, 6-5, 6-6, 6-33, 5-66</td>
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<td>9</td>
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<td>Fri 10/16</td>
<td>8-1 to 8-5</td>
<td>Internal Forced Convection, Fully Developed Flow, Laminar Flow</td>
<td>Homework #8</td>
<td>6-10, 6-16, 6-34, 6-59, 6-77, 6-90, 6-94, 6-72</td>
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<td>10</td>
<td>10</td>
<td>Fri 10/23</td>
<td>8-6; 9-1 to 9-3</td>
<td>Turbulent Flow in Tubes, Natural Convection</td>
<td>Homework #9</td>
<td>7-4, 7-14, 7-18, 7-38, 7-45, 7-67, 7-69, 7-46</td>
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<td>11</td>
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<td>Fri 10/30</td>
<td>11-1 to 11-5</td>
<td>Heat Exchangers, Log Mean Temp Diff, Effectiveness-NTU</td>
<td>Homework #10 Midterm #2 (Ch. 4-7)</td>
<td>8-4, 8-38, 8-41, 8-89, 9-7, 9-12, 9-36, 9-41, 8-90</td>
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<td>12</td>
<td>12</td>
<td>Fri 11/6</td>
<td>12-1 to 12-5; 13-1 to 13-2</td>
<td>Blackbody Radiation, Intensity, Emissivity, View Factor</td>
<td>Homework #11 and Quiz #4</td>
<td>11-1, 11-7, 11-20, 11-48, 11-63, 11-97, 11-114, 11-55</td>
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Optional Review Session (location TBD)

Location: Zoom

FINAL EXAM (Chapters 2-9, 11-13)