MAE 423 - HEAT TRANSFER

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Office hours: MF 10-11:50am in-person or Zoom
TA Office Hours: TR 1-2pm in-person 748

Lecture: MWF 9:00 AM – 9:50 PM Room ESB G39 or on Ecampus Collaborate Blackboard Collaborate Link will be on Ecampus. Lectures will be live and recorded on Collaborate and can be access after lecture on Collaborate.

Text: Introduction to Heat Transfer, Incropera F.P., DeWitt, D.P., Bergman T.L. and Lavine, A.S., John Wiley & Sons

You can purchase a back-edition of either Introduction to Heat and Mass Transfer or Introduction to Heat Transfer. Just make sure it was written by Incropera and DeWitt.

References: Basic Heat & Mass Transfer, A.F. Mills, Prentice Hall, 1999
Principals or Heat Transfer, Kreith, Manglik and Bohn, Cengage, 2011

Pre-requisites: MATH 261 with a grade of C- or better and MAE 320 and (MAE 331 or MAE335).

Required Software: Matlab, Solidworks (Download and Install)
Students need to download and install on personal machines or use computers on campus. 2nd Floor ESB computer lab or ESB756 MAE computer lab. ESB756 is available to use unless there is a lab scheduled in the classroom.

Course Objectives: The objective of this course is to provide students with the necessary knowledge of the three modes of heat transfer – conduction, convection and radiation. The course will focus on one-, two-, three-dimensional steady state conduction, transient conduction, free and forced convection, radiation, heat exchangers, heat and mass transfer, and design of thermal systems. Student Learning Outcomes of this undergraduate course:

Student Learning Outcomes:

SLO 1: Be able to calculate the heat transfer through conduction, convection and radiation, or their combination.
SLO 2: Master the applications of empirical equations in finding the convection heat transfer coefficient associated with both forced and free convection.
SLO 3: Be able to calculate the impact of insulation on reducing energy consumption, and maintaining room temperature to improve the public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

SLO 4: Capable of identifying the inappropriate design associated with heat transfer, and its impact in global, economic, environmental, and social contexts.

Course Learning Outcomes: This course supports the following ABET Learning Outcomes (ALO) and Student Learning Outcomes (SLO):

	Description	ALO	SLO
1.	An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	2	3
2.	An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	4	4

Grading:

Exam #1 …..…….....	20%
Exam #2 …..…….....	20%
Final Exam …….....	30%
HT Design Project .....…….....……..	15%
Homework .....…….....……	15%

(Final Exam will be comprehensive)

A final letter grade will be assigned on the following basis:

90 - 100	A
80 - 89	B
70 - 79	C
60 - 69	D
Below 59	F

Class Rules:

1. Professional Conduct: A professional attitude is expected from all students in class. Respect for diverse opinions and perspectives is essential. Harassment or discrimination of any kind will not be tolerated.

2. Academic Integrity: Plagiarism, cheating, or any form of academic dishonesty will not be tolerated. Any violations will result in disciplinary action, which may include a failing grade for the assignment or the course.

3. Class Participation: Active participation is encouraged. Disruptive behavior, including side conversations, will not be tolerated and may result in removal from the class.

4. Homework Submission: All homework assignments must be submitted on eCampus by the due date. You have unlimited submission attempts until the deadline. Ensure your PDF file is not corrupt before submitting; a corrupt file will be considered a non-submission. PDF format is required, and the maximum upload size is 15MB.

5. Homework Format: All homework assignments must adhere to the template provided on eCampus. Work must be completed on engineering paper or white paper with an engineering grid, which is available as a template on eCampus.

6. Make-Up Exams: Make-up exams are strongly discouraged and will only be allowed in cases of excused absence or illness. Make-up exams will be scheduled at the instructor's convenience.

7. Assignment Standards: Assignments, exams, and projects must be complete, neat, and legible. Unreadable work will receive a zero. Corrupt files will also receive a zero. All assignments must be submitted on eCampus; submissions via email will not be accepted.

8. Late Submissions: No late homework assignments will be accepted. eCampus submission links will close promptly at the specified due dates and times. If you are involved in a student organization or fall ill, you must notify me before the due date to arrange an alternative submission.

9. Exam Etiquette: Hats must be removed during exams. Book bags should be zipped and placed under your chair.

10. Exam Format: All exams will be in person unless otherwise specified by the instructor.

11. Technology Use: Laptops and tablets may be used for note-taking and class-related activities only. Any misuse, such as browsing unrelated websites or using social media, will result in the loss of this privilege.

12. Communication: All course-related communication should be done through the official university email or the course platform (eCampus). Check your email regularly for updates.

13. Office Hours: Office hours are an opportunity for you to ask questions and seek help. Please attend during the designated times or make an appointment if necessary. Be prepared with specific questions or topics.

14. Group Work: If group work is assigned, all members are expected to contribute equally. Any issues with group dynamics should be reported to the instructor as soon as they arise.

Academic Integrity: The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, instructors will enforce rigorous standards of academic integrity in all aspects and assignments of their courses. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the WVU Academic Standards Policy (http://catalog.wvu.edu/undergraduate/coursecreditstermsclassification/). Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an

attempt at academic dishonesty, please see your instructor before the assignment is due to discuss the matter. In addition, The Statler Policy of Academic Integrity will be used to address instances of academic dishonesty according to the following table:

STATLER POLICY OF ACADEMIC INTEGRITY
(Approved by the Statler College Academic Standards Committee, 28 March 2019)

Case	Violation	Penalty
1	Cheating or plagiarism on minor course element (e.g. quiz, weekly lab report, homework as specified in the syllabus).	Report of academic dishonesty. Grade of zero on the entire minor course element. Possible one-letter reduction in final grade.
2	Cheating or plagiarism on a major course element (e.g. exam, project).	Report of academic dishonesty. Grade of zero on the entire major course element. Possible additional one-letter reduction in final grade. Possible UF † recommendation. Possible exclusion from further participation in class.
3	Collusion on major course element.	Report of academic dishonesty. Exclusion from further participation in class. Failure of the course. Recommendation for UF †.
4	Other (document alteration, tampering with records, etc.).	Report of academic dishonesty. Grade of zero on the entire major course element. Possible additional one-letter reduction in final grade. Possible failure in the course. Possible exclusion from further participation in the class. Possible UF † recommendation.

* Dismissal from the Statler College is permanent for Academic Integrity violations. Student conduct violations can be considered dismissal. † UF– Unforgivable F Grade, cannot be replace under D-F repeat policy. π Separable sanctions (e.g. dismissal from Statler College, suspension, or expulsion from WVU) will be recommended for aggravated or second Academic Integrity offenses. § Warning letters may be issued from the Statler College or the WVU Office of Student Conduct.
Sanctions will be assessed at the instructor and at the college/university levels. Additional sanctions may be assigned at the level of the instructor, college, and/or university.
Statler Policy on Smart Devices: The use of programmable calculators or smart devices (including smart-phones, smart watches, tablets, cameras, wearable devices, etc.) is prohibited unless specifically indicated by the instructor.

Inclusive Statement: The West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with the Office of Accessibility Services (293-6700). For more information on West Virginia University's Diversity, Equity, and Inclusion initiatives.

Adverse Weather Statement: In the event of inclement or threatening weather, everyone should use his or her best judgment regarding travel to and from campus. Safety should be the main concern. If you cannot get to class because of adverse weather conditions, you should contact your instructor as soon as possible. Similarly, if I am unable to reach the class location, I will notify you of any cancellation or change as soon as possible, to prevent students from embarking on any unnecessary travel. If you cannot get to class because of weather conditions, instructors will make allowances relative to required attendance policies, as well as any scheduled exams, or other assessments.

Fundamentals of Engineering (FE) Exam: I strongly encourage all students to sign up and take the FE exam this semester. You will be excused from homework assignment (not exams) due the week before when you take FE exam. Please send me an email notifying me when you are taking the exam.

PLANNED COURSE CONTENT

1. Introduction to Heat Transfer

A. Modes of Heat Transfer

1. Conduction
2. Convection
3. Radiation

B. Fundamental Mechanisms of Heat Transfer

2. Conduction

A. Fourier's Law of Heat Conduction

1. Definitions: Thermal Conductivity, Thermal Diffusivity
2. Applications to a Steady One-Dimensional Slab and Hollow Cylinder
3. Electrical Analogy

B. Heat Conduction Equation

1. Derivation in Cartesian Coordinates

C. Steady One-Dimensional Heat Conduction Equation

1. Heat Conduction Across:
    - Plane Slab, Cylindrical Shell, Spherical Shell - Governing Equations, Boundary Conditions, Temperature Profiles, Heat Loss
2. Thermal Contact Resistance

3. Composite Slabs and Shells
4. Heat Conduction with Internal Heat Generation - Slab, Cylinder

D. Fins (Steady, One-Dimensional Heat Conduction)

1. Constant Area Rectangular Fin
2. Pin Fin
3. Three Cases: Short Fin, Infinitely Long Fin, and Insulated Fin
4. Fin Efficiency, Fin Resistance, Total Surface Efficiency

E. Multi-Dimensional Steady Heat Conduction

1. Review of the Three-Dimensional Heat Conduction Equation
2. Boundary Conditions and Initial Conditions
3. Solution to a Two-Dimensional Heat Conduction Equation (Including Handouts on Separation of Variables)
4. Conduction Shape Factors
5. Numerical Analysis - Finite Difference Methods (Discretization)

F. Transient Conduction

1. Review of the Three-Dimensional Heat Conduction Equation
2. Semi-Infinite Slab
3. Numerical Analysis - Finite Difference Methods (Explicit and Implicit Methods, Discretization Schemes)

3. Convection

A. Introduction

1. Types of Convection: Forced and Natural; Internal and External; Laminar and Turbulent; Fully Developed Flow and Entrance Effects

B. Boundary Layers

1. Basic Concepts: Thermal and Hydrodynamic Boundary Layers
2. Boundary Layer Equation and Boundary Conditions

C. Fundamentals of Convection

1. Dimensional Analysis
2. Internal Flows
    - Determination of Mixed Mean Temperatures (Inlet/Outlet)

3. Corrections for Variable Property Effects

D. Forced Convection (Internal Flows)

1. Tubes and Ducts (Circular)
2. Entrance Effects
3. Ducts (Various Cross-Sections)
    - Correlations for Internal Duct Flows for Laminar and Turbulent Flows (for Various Prandtl Number Fluids)

E. Forced Convection (External Laminar and Turbulent Flows)

1. Flow Over:
    - Flat Plate
    - Circular Cylinder
    - Sphere

F. Convection Analysis

1. Derivation of the Continuity, Momentum, and Energy Equations
2. Boundary Layer Equations (Laminar) and an Introduction to the Turbulent Boundary Layer Equation

G. Natural Convection (Laminar and Turbulent)

1. Heated and Cooled Surfaces
2. Inclined Surfaces

H. Boiling and Condensation

1. Boiling Modes
2. Pool Boiling Correlations

4. Heat Exchangers

A. Introduction

1. Types of Heat Exchangers
2. Configurations
3. Temperature Profiles

B. Heat Exchanger Concepts

1. Overall Heat Transfer Coefficient
2. Log Mean Temperature Difference (LMTD)

C. Heat Exchanger Design Approach

1. LMTD Factor Approach
2. Effectiveness-NTU Approach

5. Radiation

A. Introduction to Radiation Physics

1. Electromagnetic Spectrum
2. Planck's Blackbody Spectral Energy Distribution
3. Wien's Displacement Law
4. Stefan-Boltzmann Law

B. Radiation Exchange Between Surfaces

1. Exchange Between Black Bodies
2. Shape Factors
3. Electrical Network Analogy (Black Bodies)
4. Exchange Between Diffuse Gray Surfaces