# Sample Syllabus

**ME 410 Heat Transfer - Spring Semester 2021**
**Professor Stefan T. Thynell**
**Sect. 2: MWF 12:20-1:10pm via Canvas and Pre-recorded Lectures**

**TEXT:** T.L. Bergman, A.S. Lavine, *Fundamentals of Heat and Mass Transfer*, 8h Ed., Wiley, 2017; or, F.P. Incropera, D.P. DeWitt, T.L. Bergman & A.S. Lavine, *Fundamentals of Heat and Mass Transfer*, 7th Ed., Wiley, 2011 (suggested problems are different between the two editions)

**Prerequisites:** AERSP308, AERSP311, C E 360, or M E 320; MATH 220 or NUC E 309; MATH 251

| Date | Period | Topic | Text | Suggested Problems |
|---|---|---|---|---|
| 1/20 | 1 | Introduction | 1.1-1.2.3 | 1: 5, 7, 9 |
| 1/22 | 2 | Conservation of Energy | 1.3-1.7 | 1: 14, 15, 21 |
| 1/25 | 3 | Heat Diffusion-Mathematical Model – HW 1 | 2.1-2.5 | 2: 6, 8, 22, 24 |
| 1/27 | 4 | 1-D Conduction: Plane Wall | 3.1-3.2 | 3: 3a, 5a-b, 11 |
| 1/29 | 5 | 1-D Conduction: Radial System | 3.3-3.4 | 3:39,44,46a-c,47,51,54,57 |
| 2/1 | 6 | Conduction w/Internal Heat Generation – HW 2 | 3.5 | 3: 66, 67, 85, 86 |
| 2/3 | 7 | 1-D Conduction: Extended Surfaces | 3.6 | 3: 89, 92, 93 ,97 |
| 2/5 | 8 | 1-D Conduction: Extended Surfaces, cont. | 3.6 | 3: 99, 102, 103 |
| 2/8 | 9 | Practice Session – HW 3 | | |
| 2/8 | --- | **Evening Exam 1** (Cover Chapters 1-3), Online, 8:15-10:00pm | | |
| 2/9 | | Wellness Day - No Office Hours | | |
| 2/10 | 10 | 2-D Conduction, Finite Difference Methods | 4.1-4.2,4.4 | 4: 33, 34, 35 |
| 2/12 | 11 | Finite-Difference Methods, cont. | 4.4-4.6 | 4: 42, 46, 50 |
| 2/15 | 12 | Finite-Difference Methods, cont. – HW 4 | | 4: 52, 56 |
| 2/17 | 13 | Transient Conduction | 5.1-5.3 | 5: 6, 7, 9, 11, 13 |
| 2/19 | 14 | Spatial Effects and One-term Solution | 5.4-5.6 | 5: 39, 48a, 53, 59 |
| 2/22 | 15 | Semi-Infinite & Multi-Dimensional Effects – HW 5 | 5.7 | 5: 67, 73 |
| 2/24 | 16 | Finite-Difference Methods | 5.10 | 5: 87, 88, 89 |
| 2/26 | 17 | Introduction to Convection | 6.1-6.3 | 6: 5, 9, 11 |
| 3/1 | 18 | Conservation Equations - Boundary Layer – HW 6 | 6.4 | 6: 15, 16 |
| 3/3 | 19 | Similarity Solutions | 6.5-6.6 | 6: 24, 25, 31 |
| 3/5 | 20 | BL Analogies, Turbulence Correlations | 6.7-6.8 | 6: 36, 39 |
| 3/8 | 21 | Practice Session – HW 7 | | |
| 3/9 | --- | **Evening Exam 2** (Cover Chapters 4-6), Online, 8:15-10:00pm | | |
| 3/10 | 22 | Convection - External Flow | 7.1-7.3 | 7: 2a-c, 4, 7, 10, 19, 24 |
| 3/11 | | Wellness Day – No Office Hours | | |
| 3/12 | 23 | Cross Flow over a Cylinder/Sphere | 7.4-7.5 | 7: 35, 36, 42, 55, 56 |
| 3/15 | 24 | Convection - Internal Flows – HW 8 | 8.1-8.2 | 8: 5a, 7, 8 |
| 3/17 | 25 | Energy Balance | 8.3 | 8: 13, 14, 15 |
| 3/19 | 26 | Correlations | 8.4-8.6 | 8: 21, 25, 27, 49 |
| 3/22 | 27 | Free Convection - Governing Equations – HW 9 | 9.1-9.3 | 9: 7, 10, 12a-c, 16 |
| 3/24 | 28 | Laminar/Turbulent Flow: External Surfaces | 9.4-9.5 | 9: 22a, 39, 43 |
| 3/26 | 29 | Correlations for Enclosures | 9.6, 9.8 | 9: 78, 79 |
| 3/29 | 30 | Practice Session – HW 10 | | |
| 3/30 | --- | **Evening Exam 3** (Cover Chapters 7-9), Online, 8:15-10:00pm | | |
| 3/31 | 31 | Heat Exchangers – Introduction | 11.1-11.2 | 11: 2a-b, 5, 8 |
| 4/2 | 32 | LMTD Heat Exchanger Analysis | 11.3 | 11: 7, 12, 15 |
| 4/5 | 33 | NTU-ε Heat Exchanger Analysis | 11.4-11.5 | 11: 25, 30a-c, 38 |
| 4/7 | --- | Wellness Day – No Class and No Office Hours | | |
| 4/9 | 34 | Radiation - Concepts and Intensity – HW 11 | 12.1-12.3 | 12: 6a-b, 7, 9, 10, 13a |
| 4/12 | 35 | Radiation - Concepts and Intensity, cont. | 12.1-12.3 | 12: 14, 16 |
| 4/14 | 36 | Blackbody Radiation - Surface Characteristics | 12.4-12.5 | 12: 28, 29, 34, 38 |
| 4/16 | 37 | Kirchhoff's Law and Gray Body Radiation | 12.6-12.9 | 12: 49a-b, 56, 59 |
| 4/19 | 38 | Practice Session – HW 12 | | |
| 4/20 | --- | **Evening Exam 4** (Cover Chapters 11-12), Online, 8:15-10:00pm | | |
| 4/21 | 39 | View Factor | 13.1-13.2 | 13: 1, 3, 6, 8, 9 |
| 4/23 | 40 | Radiation Heat Transfer in Enclosures | 13.3 | 13: 14, 15, 17, 31 |
| 4/26 | 42 | Radiation H.T. in Enclosures, cont. – HW 13 | 13.3 | 13: 33, 34, 38, 42 |
| 4/28 | 43 | Radiation H.T. in Enclosures, cont. | 13.3 | 13: 48, 49, 50, 57 |
| 4/30 | 44 | Practice Session – HW 14 | | |
| **5/xx** | | **FINAL EXAM –** | | |

## GRADING

| | | | Guaranteed Cutoffs for Letter Grades | |
|---|---|---|---|---|
| Homework (12 of 14) | 10% | | $A^-$ | 90 |
| Exams (equal weight) | 75% | | $B^-$ | 80 |
| Final Exam | 15% | | C | 70 |
| | | | D | 60 |
| | | | F | <60 |

## EVALUATION and ACADEMIC INTEGRITY

**Homework:** Approximately 14 HWs will be assigned and due on dates indicated. Each will contain one or more problems (most likely not from the text) representative of the material covered in the previous lectures. It is expected that you solve these problems on your own; copying of problem solutions may lead to disciplinary action and obviously no credit will be given. **NO LATE HOMEWORK WILL BE ACCEPTED**. Two HWs are dropped, so students can deal with weddings, job interviews, trips, etc. These HWs are to be uploaded on Canvas.

**Exams:** Four evening exams (8:15-10:00 p.m.) and a comprehensive final exam will be given. The evening exams should be doable in 1 hour. Then I give 30 minutes extra time for checking your work and 15 minutes for uploading exam on Canvas. Exams are open book/notes, material from our Canvas web page, and a crib sheet will be handed out prior to the exam.

**ABSENCE FROM AN EXAM:** Makeup exams will be given only under extremely unusual circumstances. A written request for a makeup exam must be sent to me by email one week (or earlier) in order to be excused. It is possible that the makeup exam is oral. In addition, you must apply to the Registrar for a conflict final exam.

**GRADE APPEAL:** Within one week after returning a graded exam, you may appeal the grading by briefly describing the points of disagreement and then submit the exam to me as as an attachment in an email message.

**CHEATING ON EXAMS:** Students caught cheating will be dealt with according to University Policy.

## LECTURE FORMAT

Recordings of my lecture will be uploaded to Canvas when completed, usually in the morning prior to the afternoon's lecture. Then, I shall send a link to that lecture in an announcement from Canvas. You then choose to play the lecture at your convenience.

## CLASS PARTICIPATION

It is required that you listen and play the recordings of all lectures. I shall be available in the chat room on Canvas during the regular lecture time for questions, and during "office hours". You can also listen to the lecture at any time if you wish. Otherwise, please send me an email with your question.

## LATE DROP – April 19th Deadline

As a reminder, you may drop a course (late drop) up to April 19th. However, a WP (passing), WF (failing) or a WN (no grade) symbol will be entered on your academic record. Whether you obtain a WP, WF or WN will depend on your performance; usually, a 70% average on the quizzes, homework and the Exams is sufficient to obtain a WP.

## DEFERRED GRADES

My concurrence of a deferred grade is given only if you cannot complete the course within the prescribed time for "reasons beyond your control". Consult policy 48-40 in "Policies and Rules for Students 2020-21" for further information.

## OFFICE HOURS

Prof. Thynell: M&F 1:10-2:00 pm, via Chat Room on Canvas. I will also be available on Canvas during the regular class period. I'll also schedule a few ZOOM sessions. You can also send an email to me at other times, as I will not check on Canvas at other times (Thynell@psu.edu).

Teaching assistant: Mr. Changik Cho, cmc7589@psu.edu Monday: 4:00-5:00pm & Friday: 3:00-4:00pm chat room on Canvas or Zoom.

**SYLLABUS VERSION**: Jan. 2, 2021

## DISABILITY SERVICES AND ACCESS

In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: http://equity.psu.edu/student-disability-resources/applying-for-services. For further information, please visit the Student Disability Resources Web site (http://equity.psu.edu/sdr/).

## COUNSELING AND PSYCHOLOGICAL SERVICES (CAPS)

Many students at Penn State face personal challenges or have psychological needs that may interfere with their academic progress, social development, or emotional wellbeing. The university offers a variety of confidential services to help you through difficult times, including individual and group counseling, crisis intervention, consultations, online chats, and mental health screenings. These services are provided by staff who welcome all students and embrace a philosophy respectful of clients' cultural and religious backgrounds, and sensitive to differences in race, ability, gender identity and sexual orientation.

Counseling and Psychological Services at University Park (CAPS)
(http://studentaffairs.psu.edu/counseling/): 814-863-0395

Counseling and Psychological Services at Commonwealth Campuses
(https://senate.psu.edu/faculty/counseling-services-at-commonwealth-campuses/)

Penn State Crisis Line (24 hours/7 days/week): 877-229-6400
Crisis Text Line (24 hours/7 days/week): Text LIONS to 741741

## EDUCATIONAL EQUITY/REPORT BIAS

Consistent with University Policy AD29, students who believe they have experienced or observed a hate crime, an act of intolerance, discrimination, or harassment that occurs at Penn State are urged to report these incidents as outlined on the University's Report Bias webpage (http://equity.psu.edu/reportbias/).

## GENERAL ACADEMIC INTEGRITY STATEMENT

Academic integrity is the pursuit of scholarly activity in an open, honest and responsible manner. Academic integrity is a basic guiding principle for all academic activity at The Pennsylvania State University, and all members of the University community are expected to act in accordance with this principle. Consistent with this expectation, the University's Code of Conduct states that all students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts.

Academic integrity includes a commitment by all members of the University community not to engage in or tolerate acts of falsification, misrepresentation or deception. Such acts of dishonesty violate the fundamental ethical principles of the University community and compromise the worth of work completed by others.

## WELLNESS DAYS

Tuesday, February 9, Thursday, March 11 and Wednesday, April 7 have been designated as Wellness Days. No class meeting or office hours will be held for those days, and no assignments will be due on those days. Students are encouraged to use those days to focus on their physical and mental health. Please see wellnessdays.psu.edu for university sponsored events focusing on wellness that may be of interest to you.

# ME 410 HEAT TRANSFER

## Course Objectives: (Mapping to Program Outcomes shown in brackets)

A. Develop both qualitative and quantitative understanding of the three modes of heat transfer. [1b]
B. Make appropriate approximations, develop and apply simplified model equations for specific applications. [2b]
C. Apply mathematical and numerical methods to solve heat transfer problems. [1c, 1d, 1f, 5e]
D. Understand the role of and use dimensionless parameters in heat transfer analysis. [2b]
E. Design thermal systems for engineering applications. [2c, 2e, 5b]
F. Advance proficiency in professional communications and interactions. [3f]

## Course Outcomes: (Mapping to Course Objectives shown in brackets)

1. Sketch and interpret temperature distributions and heat flux distributions for mathematical models of heat conduction with planar and radial geometries, including heat generation. [A]
2. Derive fundamental differential thermal energy equations and develop mathematical models for thermal/fluid systems, including:
   a. Lumped capacitance for unsteady heat transfer
   b. 1D unsteady heat conduction equation with heat generation
   c. Quasi 1D heat conduction for extended surfaces (fins), including variable cross-sectional areas
   d. Mean axial temperature variation for internal flows with uniform surface temperature or uniform wall heat flux. [B]
3. Apply ODE solution methods to solve the differential heat transfer equations for applications including:
   a. Lumped capacitance for unsteady heat transfer
   b. Steady 1D planar and radial conduction with heat generation
   c. Quasi 1D fins with variable cross-sectional area
   d. Internal flows with uniform surface temperature or uniform wall heat flux. [C]
4. Apply existing PDE solutions to analyze 1D and quasi 1D unsteady heat conduction systems. [C]
5. From an energy balance, derive the finite difference equations for conduction with surface convection. Describe numerical solution methods used to solve the finite difference equations. [B]
6. For convective heat transfer over a flat plate with uniform surface or uniform wall heat flux, sketch and interpret:
   a. Hydrodynamic and thermal boundary layer thicknesses
   b. Hydrodynamic and thermal boundary layer profiles
   c. Local skin friction and local heat transfer coefficient as a function of distance from the leading edge. [A]
7. Sketch and interpret hydrodynamic and thermal profiles for internal flows with uniform surface or uniform wall heat flux. [A]
8. Develop and apply conduction and convection thermal circuits. [B]
9. Choose and apply appropriate dimensionless correlations for external and internal flows to solve convection heat transfer problems. [D]
10. Understand and apply the Reynolds Analogy for convection heat transfer. [B]
11. Analyze thermal sensors such as hot wires and thermocouples. [E]
12. Define and properly apply in an energy balance the following terms: emission, radiosity, irradiation, net radiation heat flux, emissivity, absorptivity, reflectivity, and transmissivity. [A]
13. Understand the spectral characteristics of radiation heat transfer including black and gray surfaces. [A]
14. Develop thermal circuit diagrams for radiation analysis and determine surface temperatures for two and three surface geometries including reradiating surface and radiation shield. [B]
15. Set up and solve combined conduction, convection, and radiation heat transfer problems. [B & C]
16. Apply fundamental heat transfer principles to perform heat exchanger design and performance calculations. [E]
17. Make effective use of spreadsheets as an analysis tool. [C]
18. Demonstrate the ability to solve problems in a clear step-by-step manner and follow policies and instructions as outlined in the syllabus and other course materials. [F]
19. Demonstrate professionalism in interactions with colleagues, faculty, and staff. [F]