ChE141 - Heat and Mass Transfer
Spring 2013
Department of Chemical Engineering
The Cooper Union for the Advancement of Science and Art

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Textbook: "Heat and Mass Transfer: Fundamentals & Applications," Çengel and Ghajar, 4th Ed. (2011)

Prerequisite: ESC140 - Fluid Mechanics and Flow Systems

Catalog Description

ChE141 - Heat and Mass Transfer Introduction to heat and mass transfer. Steady-state and unsteady-state heat transfer. Steady-state and unsteady-state mass transfer. Interphase transport and transfer coefficients. Convective heat and mass transfer. Internal and external forced convection. Heat transfer equipment. Natural convection. Boiling and condensation. Radiation heat transfer.

Course Introduction

In this course, we will build upon our knowledge of fluid mechanics and thermodynamics to learn the principles of heat and mass transfer. Although the principles of heat and mass transfer have widespread usage in the chemical process industry, these principles are also applied in the food science, pharmaceutical, and other industries. First, we will begin by learning the three principle modes and mechanisms of heat transfer. After developing a strong understanding of how heat and energy are transported, we will consider mass transfer as an analogous transport process by which matter and material are transported by diffusion. We will then consider how both energy and mass are transported by convection and the analogies and relationships between convective momentum, heat, and mass transfer. Finally, we will apply all of these principles to the design of heat transfer equipment, particularly heat exchangers. To accomplish this, we will learn process simulation software to aid us in heat exchanger design.

Grading Scheme

Problem Sets (Homework) – 10%
COMSOL Project #1 – 10%
COMSOL Project #2 – 15%
Exams (3) – 45% (15% each)
Heat Exchanger Design Project – 20%

The grading scheme may be modified based on the assignments given throughout the semester. Students will always be notified of any changes and will have an opportunity to discuss them.

Final Course Grade Scheme

From the Cooper Union Course Catalog:

A - superior and comprehensive grasp of the course principles
B - good degree of familiarity with the course principles
C - average knowledge of the course principles and fair performance
D - minimum workable knowledge of the course principles
F - unsatisfactory understanding of the course principles

Final letter grades will be determined based on the above grading scheme and definitions of the final course grade scheme. Curving is at the discretion of the instructor. For those students whose weighted average is in a *gray area* between two letter grades, the following factors will influence your grade: (a) class attendance and participation in class, and (b) whether your performance has been improving or declining during the course period.

Important Advice

To be successful in this course, you must be able to

- *describe* the mechanisms of heat and mass transfer occurring in a system or process
- *develop a fundamental understanding of the physics* behind transport phenomena (momentum, heat, and mass transport) occurring in a particular system or process
- *derive, select, and apply* the basic conservation and/or rate equations for modeling a particular system or process
- *translate a verbal or written transport phenomena or unit operation problem into a mathematical model* by drawing a diagram of the system or process, identifying input-output streams, generation-consumption terms, accumulation terms, applying relevant conservation and/or rate equations, and solving the mathematical model
- *use knowledge of calculus and differential equations* to solve the model analytically
- *acquire and develop skills* to use software packages to numerically solve mathematical models via computational methods
- *apply* the principles of transport phenomena to the design of heat transfer equipment (e.g. heat exchangers), particularly by using process simulation software

Policies

1. **Class Attendance:** Students must attend all classes. Absences from class will inhibit your ability to fully participate in class discussions and can therefore affect your grade. Please come to class *on time*. Tardiness to class is very disruptive to the instructor and students and will not be tolerated. Under no circumstances should you distract other students and the lecturer. Students are expected to behave, communicate, and interact with the instructor and peers with respect and dignity as a *candidate, professional chemical engineer.* Students are expected to print out and bring the lecture notes to all class meetings.

2. **Assignments:** Assignments are due on the date assigned and will be collected or discussed at the *beginning* of class. This also implies that *the assignment is due whether or not you show up to class!* Late assignments will only be accepted under extraordinary circumstances and might be penalized. Only select assignments (info blind to students) will be collected/graded. Assignments will be typically due *at the next class meeting.* Students are expected to work on all assignments (including computer assignments) independently. Problem Sets must be written *legibly in an organized, structured fashion* and should be completed on 8.5" by 11" paper. Since only certain problems will be collected, each problem should be started on a new page with your name written on the top. Instead of stapling the problems together, use a paper clip. Although problem sets may be handwritten, all projects *must be typeset.* All projects must be submitted both in hardcopy form and uploaded onto Moodle (including computer files). You are allowed to *dispute your assignment/project scores and request a "re-grade"* within 24 hours.

3. **Exams:** The formats for the exams will be announced prior to their administration. However, exams will most likely be *closed book and closed notes.* Cell phones and other electronic devices (except calculators) are **not** permitted during exams. Make-up exams will only be given under extraordinary circumstances (e.g. major close-family emergency, serious accident or acute medical problem) and at the sole discretion of the instructor. It is the student's responsibility to inform the instructor of any conflicts ASAP. On all exams, you have to *write legibly in an organized, structured fashion* and *show all work.* You are allowed to *dispute your exam scores and request a "re-grade"* within 24 hours. Please note that this means your exam score can go up *or down. No extra credit* will be allowed under any circumstances (there is no need to ask).

4. **Plagiarism:** Plagiarism will **not** be tolerated. According to the Cooper Union Course Catalog, "plagiarism is the presentation of another person's 'work product' (ideas, words, equations, computer code, graphics, lab data, etc.) as one's own. Whether done intention ally or unintentionally, plagiarism will not be tolerated in the School of Engineering." Please refer to the Cooper Union Course Catalog for more information.

5. **Technology:** Students are expected to bring a calculator to all classes (including for exams). The use of laptop computers during class will not be allowed unless approved by the instructor. Course materials will be posted on The Cooper Union Moodle website (`http://moodle.cooper.edu/moodle/`). Although tutorials and workshops will be given, since many assignments will require the use of software packages, students are expected to practice and develop their skills using the software *outside of class.* Lastly, students are expected to check their e-mail on a **daily** basis.

Course Objectives

1. To understand the basic principles and modes of heat transfer (conduction, convection, and radiation).
2. To understand the basic principles and modes of mass transfer (diffusion and convection).
3. To model and solve engineering heat and mass transfer problems using analytical and numerical mathematical techniques.
4. To understand and utilize the analogies between momentum, heat, and mass transfer, particularly when applied to convective transport processes.
5. To apply the principles of heat transfer to the design of heat transfer process equipment (heat exchangers, condensers, boilers).
6. To use process simulators and other software for the design of heat transfer process equipment.

ABET Course Student Outcomes

Upon completion of this course, the student should achieve the following outcomes:

- an ability to apply knowledge of mathematics, science, and engineering [a]
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability [c]
- an ability to identify, formulate, and solve engineering problems [e]
- an ability to communicate effectively [g]
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context [h]
- a recognition of the need for, and an ability to engage in life-long learning [i]
- a knowledge of contemporary issues [j]
- an ability to use the techniques, skills, and modern engineering tools necessary for chemical engineering practice [k]

Important Dates

Exam # 1 – February 2013
Exam # 2 – March/April 2013
Exam # 3 – May 2013 (Final Exam Week)
Heat Exchanger Design Project – May 2013
Spring Break! – March 16-24, 2013

Course Outline

- Introduction to Heat and Mass Transfer
- Heat Conduction/Diffusion Equation
- Steady-state Heat Transfer
- Transient (Unsteady-state) Heat Transfer
- Steady-state Mass Transfer and Diffusion
- Transient (Unsteady-State) Mass Transfer (with Biological Applications)
- Introduction to Convective Transport
- External Forced Convection
- Internal Forced Convection
- Heat Transfer Equipment (Heat Exchangers)
- Natural (Free) Convection (*tentative*)
- Boiling and Condensation (*tentative*)
- Radiation Heat Transfer (*tentative*)

The contents and order of the course are tentative and subject to revision. The amount of time devoted to each topic will vary as the semester progresses.

References

1. A Heat Transfer Textbook, Lienhard and Lienhard, 4th Ed., Dover. (*Recommended*)
2. Fundamentals of Heat and Mass Transfer, Incropera et al., 7th Ed., Wiley.
3. Transport Phenomena, Bird et al., 2nd Ed., Wiley. (*Recommended*)
4. Fundamentals of Momentum, Heat and Mass Transfer, Welty et al., 5th Ed., Wiley.
5. Engineering Heat Transfer, W. Janna, 3rd Ed., Wiley.
6. Unit Operations of Chemical Engineering, McCabe et al., 7th Ed., McGraw-Hill.
7. Process Heat Transfer, R. Serth, Academic Press.
8. Process Heat Transfer, D.Q. Kern, McGraw-Hill.
9. An Introduction to Heat and Mass Transfer, S. Middleman, Wiley.
10. Basic Heat and Mass Transfer, A.F. Wills, 2nd Ed., Prentice-Hall.
11. Handbook of Heat Transfer, Rohsenow et al., 3rd Ed., McGraw-Hill.