ChE/EID 441 - Advanced Heat and Mass Transfer
Spring 2013
Department of Chemical Engineering
The Cooper Union for the Advancement of Science and Art

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Office Hours: Tues 4-5pm, Wed 11am-12pm, Thurs 11am-12pm, and by appointment

Textbook: "Analysis of Transport Phenomena" by Deen, Oxford, 2nd Ed. (2011)

Prerequisites: ChE/EID 440 - Advanced Fluid Mechanics

Catalog Description

ChE/EID 441 - Advanced Heat and Mass Transfer Introduction to the energy equation. Steady and transient heat transfer by conduction. Convective heat transfer. Energy transport in flowing media. Free convection. Conservation of species equation. Ficks law of binary diffusion. Mass transfer with simultaneous homogeneous or heterogeneous reaction. Multicomponent heat and mass transfer. Stefan-Maxwell equations for multicomponent diffusion. Simultaneous heat and mass transfer. Transport in electrolyte solutions. Special topics may include: membrane separation processes, drug delivery and controlled release, turbulent heat and mass transfer, boundary layer heat and mass transfer, and chemically reacting flows.

Course Introduction

In this course, we will continue our exploration of transport phenomena by developing the fundamental equations for energy and mass transfer. For both topics, we will consider steady and unsteady-state processes, as well as, processes driven by convection. We will extend the basic laws of energy and mass transfer to account for multicomponent systems and we will explore processes in which they occur simultaneously. Chemical reactions and thermodynamics will be considered to help model these systems. By the end of this course, you should have developed an appreciation, and a rigorous mathematical approach, for modeling and solving transport phenomena problems.

Grading Scheme

Graded Assignments – 20 %
Midterm Exam – 30 %
Final Exam – 30 %
Project/Presentation – 20 %

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

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.*

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 lecture!* Late assignments will only be accepted under extraordinary circumstances and might be penalized. Assignments will be typically due approximately *one week after they were assigned.* 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. 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 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* 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 persons 'work product' (ideas, words, equations, computer code, graphics, lab data, etc.) as one's own. Whether done intentionally 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 be not allowed, unless approved by the instructor. Some assignments might require the use of a computer (Microsoft Excel). In addition, for some assignments, computational software such as COMSOL and MATLAB might be required. Course materials will be posted on the The Cooper Union Moodle website (`http://moodle.cooper.edu/moodle/`). Lastly, students are expected to check their e-mail on a **daily** basis.

Course Outline

- Diffusive Fluxes and Material Properties (Constitutive Equations)
- Conservation Equations
- Diffusion/Reaction Systems (Nondimensionalization)
- Heat Transfer with and without Internal Generation (Perturbation Methods)
- Unsteady-state Diffusion in Semi-Infinite Media (Similarity Solutions)
- Unsteady-state Heat Transfer in Slabs (Sturm-Liouville Equations and Solution Techniques)
- Forced Convection Heat and Mass Transfer (The Graetz Problem)
- Transport in Buoyancy-Driven Flow (*tentative*)
- Multicomponent Heat and Mass Transfer
- Simultaneous Heat and Mass Transfer
- Transport in Electrolyte Solutions
- Special Topics: TBD

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.

Important Dates

Midterm Exam – March 13, 2013
Final Exam – May 2013
Project – May 2013

References

1. Transport Phenomena, Bird et al., Revised 2nd Ed., Wiley. (*Strongly recommended*)
2. Heat and Mass Transfer: Fundamentals & Applications, Çengel and Ghajar, 4th Ed. (2011)
3. Fundamentals of Heat and Mass Transfer, Incropera et al., 7th Ed., Wiley.
4. Fundamentals of Momentum, Heat and Mass Transfer, Welty et al., 5th Ed., Wiley.
5. An Introduction to Heat and Mass Transfer, S. Middleman, Wiley.
6. Applied Partial Differential Equations, Haberman, 4th Ed., Pearson, (2003)
7. Applied Mathematical Methods for Chemical Engineers, Loney, 2nd Ed., CRC Press
8. *Your favorite math handbook!*