CM 3120: Transport/Unit Operations 2
Spring 2021

Instructor:
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Course Description and Timing: Transient heat transfer and mass transfer fundamentals with applications to chemical engineering unit operations. Topics include applying the species A microscopic mass balance, Fick's Law of diffusion, and mass transfer coefficients. Applications include absorption, distillation, extraction, adsorption, and membrane separations.

- MW 9am – lectures
- F 9am – Problem sessions; Unit operations lectures

Prerequisites: CM3110, CM2120, plus differential equations. All the prerequisites to these classes are also prerequisites to this class.

This course will make intensive use of all of your math background (units, algebra, calculus, differential equations, vectors, partial derivatives, boundary conditions), your physics background (Newton's laws, forces, problem solving, sig figs), and your chemical engineering background (macroscopic mass and energy balances, heat exchangers, friction in flow, pumps, introductory unit operations and staged operations). For a handy sheet of commonly used integrals, see the supplemental handouts link (http://www.chem.mtu.edu/~fmorriso/cm310/2014CommonIntegrals.pdf) and the recommended readings list (http://pages.mtu.edu/~fmorriso/cm310/reading_assignments.html).

Office Hours: Dr. Morrison's Zoom student office hours are posted on the web (http://www.chem.mtu.edu/~fmorriso/office_hours.html); other times by arrangement - request by email.

Course Learning Objectives (What is the course about? How is it relevant to your interests?)

Upon successful completion of CM3120, students will be able to

1. Model the unsteady flow of heat
2. Solve unsteady state heat-transfer modeling equations;
3. Model and solve for the motion of independent species in a mixture;
4. Apply the solutions above to engineering problems to describe or predict real system behavior (data correlations); and
5. Apply the models and model solutions to chemical engineering unit operations to predict how unit operations function and to enable troubleshooting.

Textbooks and Resources

Required:

Christie J. Geankoplis, *Transport Processes and Unit Operations*, 4th Edition, Prentice Hall, New York (2003). This text is available **free** in electronic form through the Michigan Tech Library's Safari O'Reilly's Learning Platform for Higher Education, (https://learning.oreilly.com/library/view/transport-processes-and/013101367X/?ar). You can sign in with your Tech email, and if you confirm the reply email, your account will store your highlights and notes. If you prefer to use the book anonymously, you can create a dummy account (mickeymouse@mtu.edu) which will work for a few days and then go dead, but you can create it again. You cannot save your highlights and notes when working under a pseudonym.

I have several copies of Geankoplis that I can loan on a first-come, first served basis (please email).

I strongly recommend that you print and use the unit conversion and physical property sheet I have prepared (http://pages.mtu.edu/~fmorriso/cm310/convert.pdf).

Supplemental:

Richard Felder and Ronald Rousseau, *Elementary Principles of Chemical Processes*, 3rd Edition, Wiley, New York, 2005. (If there is one book you do not sell back to the book store, make it this one; see also my summary notes on the energy balance information from CM2110/CM2120 (http://www.chem.mtu.edu/~fmorriso/cm310/Energy_Balance_Notes_2008.pdf).

Perry's Handbook of Chemical Engineering, 8th Edition (McGraw-Hill Professional, New York, 2007). Note that if you join the AIChE (at the national level) you receive access to the online Perry's free. See the AIChE officers for more information.

Additional Resources:

Bird, R. B., W. E. Stewart, and E. N. Lightfoot, *Transport Phenomena*, 2nd edition, Wiley, NY, 2002. Widely known as "BSL," the first edition of this book came out in 1960 (the red book) and the second edition 42 years later, a testimony to the enduring value of this resource. BSL was an early textbook in the engineering science curricula in chemical engineering programs (it has its own Wikipedia page).

Faith A. Morrison, *An Introduction to Fluid Mechanics*, Cambridge University Press, New York (2013).

Learning Plan

The learning objectives for this course (see above) are written at a very high level and are designed to let you know what the course is about and how it is relevant to your interests. To actually get through the course learning objectives we need a plan, and so here is my learning plan for this course.

To help you achieve the planned course learning objectives, I have: 1) chosen topics; 2) suggested readings; 3) provided lectures (synchronously recorded on Zoom; additional material on YouTube at

DrMorrisonMTU); 4) assigned problems; 5) produced *Study Guides*; 6) scheduled sessions for problem solving and learning about unit operations; and 7) structured a grading system. The details of the plan are given below. I have:

1) Chosen topics and divided these into four modules, each with its own learning objectives.

Module 1: Introduction and Prerequisite material
Module 2: Unsteady Heat Transfer
Module 3: Diffusion and Mass Transfer I
Module 4: Diffusion and Mass Transfer II

2) Suggested Readings

Reading recommendations, including on prerequisite materials, are provided on the course website. Readings of two types are assigned: basic and stretch. Stretch readings are provided for students who aspire to top comprehension and top class performance.

3) Prepared lectures

PDFs of the Monday/Wednesday lecture slides are posted on the class website. Attendance is not mandatory; the lectures are a resource for you to use to help you to achieve the course learning objectives.

Our TA will present four lectures on unit operations: distillation, gas absorption, membrane separation, and liquid-liquid extraction (see the syllabus link, second page for the schedule). Completed worksheets related to these lectures will be submitted as discussed in the section on grading.

4) Assigned Problems

Assigned homework problems are posted on the course website. *Answers* to assigned problems are provided on the website; *solutions* to assigned problems are not provided on the website, but we will devote many of our Friday class sections to problem solving, and this can include the assigned problems, as desired. Note that worked examples (examples) in the recommended texts are also opportunities to work out a problem and to compare to the published solution.

5) Produced Study Guides

The learning objectives for each module are given to you in the form of Study Guides. The four Module Study Guides tell you, directly, what types of problems/exercises you need to be able to do in order to reach the learning objectives. Some of the learning objectives in the Study Guides are identified as *stretch*. Stretch objectives are provided for students who aspire to top comprehension and top class-performance. A fifth "Study Guide" consists of the objectives listed in the worksheets associated with the four Friday unit operations lectures. The Study Guide Project is described in the section on grading.

6) Scheduled sessions for problem solving

Most Fridays at 9am I will be on Zoom coordinating problem sessions based on the Study Guides. These sessions will be interactive; the sessions will be recorded and posted. The hand notes from these sessions and from the MW lectures will also be posted.

7) Structured a grading system

There will be three exams plus a final exam. There will be a semester-long project linked to the Study Guides; this will include four Unit Operations worksheets.

Exams

The exams will be closed book, closed notes, closed internet (your own work; honor pledge required), with two 8.5 by 11 sheets, both sides, allowed for formulas (may be computer printed; I will ask you to upload your exam sheets to Canvas along with your worked exam). Exams will include instructor-produced handout tables and formula sheets as well; these will be available before the exam and I recommend that you print them off and use them as you work practice problems.

An exam may include any topic covered in the course up to the class period indicated in the syllabus for that exam (see the syllabus for coverage). Prerequisite material may appear on any of the exams. The exams from 2019 and the first half of 2020 (and solutions) are posted on the class website. Exams 1-3 are designed to be 90 minutes long (excluding uploading time), although I will allow 135 minutes for you to work the exam and upload the exam and your study sheets. The exam will include an honors pledge; I will rely on your honesty and your pledge that you will follow the integrity rules of this course. You may take the exam during any 135 minute period between 7am and 11:59pm on the day indicated below.

Exam 1 (week 2):	Wednesday	20 January 2021
Exam 2 (week 8):	Wednesday	3 March 2021
Exam 3 (week 11):	Wednesday	31 March 2021
Study Guide Project (week 14):	Final deadline: Friday 23 April 2021	
Final exam (week 15):	As scheduled by the registrar; 3 hours and 15 minutes. The final exam schedule for all classes can be viewed at: http://www.mtu.edu/registrar/ at the end of the 6th week of the semester.	

Study Guide Project

This is a semester-long project that is composed of five submissions, one associated with each of the four modules and an additional submission associated with the unit operations objectives discussed in the Friday sessions. The details of this project are given in a separate handout; some brief information is given here.

Module Study Guides

Each submission is comprised of a cover memo organizing attached material that represents evidence of your efforts to learn the skills and knowledge outlined on the Study Guides. The problem solutions submitted as part of the Study Guide Project will not be graded in detail; the course credit for the Study Guide Project will be apportioned based on assessment of your engagement with the Study Guide process. If you are giving it a serious try, you are meeting my expectations for the Study Guide project.

Unit Operations Worksheets

The four Unit Operations Worksheets together comprise a fifth "Study Guide." Worksheet submissions are scheduled for throughout the semester on Canvas but will be accepted up to Friday of week 14. l

Course Grades

1. First exam: 20% (lectures 1-2; Study Guide 1)
2. Second exam: 20%; (lectures 3-8, Study Guide 2)
3. Third exam: 20%; (lectures 9-14, Study Guide 3)
4. Final exam: 25%; (lectures 1-22, Study Guide 4)
5. Study Guide Project: 20%; (Modules 1-4, UO Worksheets SG)

Scale: 90-105 %A; 86-89 AB; 80-85 B; 76-79 BC; 70-75 C; 66-69 CD; 60-65 D; Less than 60% F

Students who have registered their need for accommodations with the Dean of Students (Disability Services) will be accommodated as requested. University policy requires 5-day advance notice of a request for accommodation.

Make-up exams will not be given except under extraordinary circumstances and when appropriate documentation is provided (medical, for example). Check the exam schedule and your final exam schedule early and report any conflicts as soon as possible.

No cell phone use or internet use of any sort allowed during exams.

Tips for better exam performance

The problems on the exams are not directly modeled on the homework problems, but the homework problems are designed to employ the same problem-solving skills as will be needed to do well on the exam. Your aim is meant to be to develop those problem-solving skills and critical thinking skills (to learn to formulate the right questions; this guides you to solving real problems). One of these skills is to read the problem carefully and to determine how to frame the solution to the problem (trouble shooting). Significant figures are important on anything that is submitted in this course or shared with an instructor or colleague; using significant figures properly demonstrates that you understand the meaning of your numbers.

Tips for better course performance

Readings, problems, and objectives of two types are assigned: *basic* and *stretch*. Stretch activities are provided for students who aspire to top comprehension and top class performance. Your best preparation for the exams is to attend class sessions, do the readings, do the assigned problems, engage seriously with the Study Guides, and see the professor or Learning Center with questions you have on the homework assignments and class sessions. Starting the problem (setting it up) is typically the hardest part of a transport/unit operations modeling problem. Simply reading over solutions is not good preparation for actually carrying out a calculation yourself.

Study Groups

You are encouraged to work together in study groups to trade ideas on how to solve problems and to help to teach each other the subject. The students who have done best in my classes in the past formed a study group (4-8 students) and met regularly to work on the homework. They came to instructor student office hours regularly with any questions they could not resolve themselves. During this pandemic year it will be more difficult to arrange study groups, but I encourage you to be creative. You may use Zoom, texting, Facetime/WhatsApp, socially distanced meetings. Please follow the guidance on health measures so that you remain healthy. I will give you a chance to set up a study group using a Google form.

CM Learning Center

The Chemical Engineering Learning Center is in ChemSci room 310. The CMLC is staffed Monday through Thursday 6-8pm for the weeks that classes are in session. Direct questions on the CMLC to Dr. Tim Eisele at tceisele@mtu.edu.

Cheating

Your integrity is your most important asset. Cheating of any form will not be tolerated. All exam work must be your own and all exam rules must be followed (see exam rules above); what you submit for your projects must follow the rules of the project (see separate handout). Submitting for credit a solution that is not your own, without attribution, is plagiarism and is considered cheating. If you use any solutions from the literature (the internet, a book, a friend), you must cite the source with a formal reference. Using someone else's work without attribution is considered cheating.

Any student found to be cheating would be reported to the Dean of Students. The punishment for plagiarism ranges from an F in the course to expulsion.

University Policies

The Michigan Tech University Senate Policy states that this course syllabus must provide information on university policies, including those related to academic integrity, disability services and institutional equity. Since policies and web links to these policies could change over time, we have been encouraged to include the following web link to provide up-to-date information: http://www.mtu.edu/ctl/instructional-resources/syllabus/policies.html.

Program Assessment:

Student work products (exams, essays, projects, etc.) may be used for the purposes of university, program, or course assessment. All work used for assessment purposes will not include any individual student identification.

Educational Objectives and Student Outcomes for the Department of Chemical Engineering

Michigan Tech Chemical Engineering ABET link:
https://www.mtu.edu/chemical/undergraduate/accreditation/

Educational Objectives

Michigan Tech Chemical Engineering alumni:

1. are successful early and have sustained success in their professional careers;
2. are valued for their hands-on engineering ability and safety culture;
3. have effectively communicated their technical knowledge via publications, reports, the Internet, and other media;
4. are providing service to society;
5. are earning or have earned advanced degrees or have participated in continuing education; and
6. have achieved leadership positions in their chosen professions.

Student Outcomes for the Department of Chemical Engineering

Graduates will have the following:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. 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
3. an ability to communicate effectively with a range of audiences
4. 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
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Program Criteria for the Department of Chemical Engineering

The curriculum provides a thorough grounding in the basic sciences including chemistry and physics, with some content at an advanced level. The curriculum includes the engineering application of these basic sciences to the design, analysis, and control of chemical and physical processes, including the hazards associated with these processes.