CHBE 424 - Transport Phenomena II: Heat & Mass Transfer

Department of Chemical and Biomolecular Engineering
University of Maryland
Spring 2019

COURSE INFORMATION

Pre-requisites:	Pre-requisite: CHBE422, Co-requisite: CHBE302		
Lectures:	Tuesday & Thursday	2:00 to 3:15 pm	ChE 2110
Discussion:	Friday	11:00 to 11:50 am	ChE 2110

Instructor: Dr. Deborah S. Goldberg
Office: ChE 1223D
Email: dsgold@umd.edu
Phone: 301-405-5575
Website: dsgoldberg.weebly.com

Course Description (from testudo): Principles of mass and heat transfer as applied to model development and process design. Species continuity equation with application to diffusion, and convection in laminar flow. Macroscopic balances and mass transfer coefficients with application to turbulent flow. Microscopic equation of energy with application to heat conduction, and convection in laminar flow. Macroscopic energy balance and heat transfer coefficients with application to turbulent flow. Heat exchanger design.

Teaching Team:

Leah Borden (TA)	Email: lkborden@umd.edu
Andre Chen (UTF)	Email: andrec279@gmail.com
Jack Perry (UTF)	Email: jperry18@terpmail.umd.edu

LEARNING RESOURCES

Office Hours: (also available by appointment):

Tuesday	12:00- 1:00 pm	Dr. Goldberg	Room ChE 1223D
Wednesday	2:00-3:00 pm	Leah Borden	Room CHM 0124
Thursday	12:30 pm – 1:30 pm	Andre Chen	Room AJC 2134
Thursday	3:30 pm - 4:30 pm	Jack Perry	Room ChE 2118

424 Learning Community:

Tuesday	3:30 pm -4:30 pm	Dr. Goldberg	Room ChE 2118

Textbook:
Material for this course will be drawn from two different textbooks. Custom e-text and hardcopy text versions are available for purchase. Source textbooks are also listed below. The custom text contains only the chapters needed for CHBE424 and represents considerable cost-savings compared to the full textbook.

A binder-ready version can be purchased from the University of Maryland bookstore:
Heat and Mass Transfer in Chemical & Biomolecular Engineering, ISBN: 9781119503385

An e-text version is available through VitalSource:
Heat and Mass Transfer in Chemical & Biomolecular Engineering, ISBN: 9781119503958
https://www.vitalsource.com/custom/9781119503958

Students may also opt to purchase the full textbooks:
Bird, R.B., **Introductory Transport Phenomena**, John Wiley & Sons, 2014.
Hardcover: ISBN: 978-1-118-77552-3
E-text: ISBN: 978-1-118-95372-3

Welty, J. **Fundamentals of Momentum, Heat, and Mass Transfer, Revised 6th Ed.,** John Wiley & Sons, 2015
Hardcover: ISBN: 978-1-118-94746-3
E-text: ISBN : 978-1-119-03439-1

Textbooks are available in both in hardcover and e-text versions. Since students are not permitted to use the textbook on quizzes or exams, either format is acceptable.

Supplemental Material: Will be posted to course website as needed.

COURSE OBJECTIVES & PERFORMANCE CRITERIA

Objectives:
1. To teach students the basic principles of heat and mass transfer, and to develop within them the ability to apply these principles to a variety of contemporary problems in chemical & biomolecular engineering research and practice.
2. To teach students to develop and assess mathematical models which describe a variety of transport phenomena, and to apply these models to the design of heat and mass transfer devices and processes.
3. To expose students to a variety of approaches for solving heat and mass transfer problems, and to develop within them the ability to select the most appropriate approach for solving the problem at hand.
4. To teach students to design various heat and mass exchange networks at various process time and size scales.
5. To develop a student's ability to become self-sufficient, and to think and work independently.

Performance Criteria:

1. Students will demonstrate an understanding of the principles of conservation of mass, momentum and energy, by applying them to a spectrum of heat and mass transfer problems. These can range from straight forward extensions of classroom and textbook material, to problems not previously considered.
2. Students will demonstrate an ability to physically visualize heat and mass transfer problems, to make rational assumptions on which to base a model, and to apply basic mathematical skills and transport phenomena principles to develop models for a variety of processes. These can range from straight forward extensions of classroom and textbook problems to those not previously considered. Students will demonstrate that they can apply generic models to the design of a variety of heat and mass transfer devices and processes, and that they can critically assess the validity of their results.
3. Students will demonstrate that they can rationally choose among a variety of approaches and modeling techniques to solve heat and mass transfer problems.
4. Students will demonstrate familiarity with the spectrum of transport behavior that can occur in pipes, conduits, tanks and other contactors, as well as in the environment, the human body and in biomedical devices. They will further demonstrate that they can apply models developed in class, the textbook and homework exercises to the design of these systems.
5. Students will demonstrate that they can work independently on homework and exam problems, and that they can use a variety of resources and tools from this course, previous courses and life experience to solve problems.

COURSE EXPECTATIONS

Faculty Expectations of Students:

- Review prerequisite course materials.
- Complete out of class assignments on time.
- Come to class prepared (having read the assigned textbook material) and on time.
- Participate in the classroom by asking and responding to questions and engaging in group activities.
- Get help and feedback from the instructor and teaching assistants, as needed.
- Treat instructor, teaching assistants and fellow students professionally, and with respect.
- Follow the university code and departmental policy on Academic Integrity.
- Write out and sign the University of Maryland Honor Pledge on all assignments and examinations, as well as abide by its principles.

Student Expectations of Faculty:

- Provide written documentation and dialog on what is expected of students, course objectives and content, and performance criteria and evaluation procedures.
- Hold advertised office hours and be available at other times, by appointment.
- Put course material in context by relating it to life experiences, career related problems and applications, contemporary issues in engineering research and practice, and the content of other courses.
- Respect students and be receptive to their questions and opinions.
- Treat students fairly and equitably.
- Come to class prepared and on time.
- Return graded material in a timely fashion.
- Set examinations appropriately for the material being tested.
- Provide continual feedback on student performance.

COURSE POLICIES

This course will adhere to university policies relevant to Undergraduate Courses are found here: http://ugst.umd.edu/courserelatedpolicies.html

In addition, links to full policies on excused absences and academic dishonesty can be found below. Students are expected to read and understand these policies.

Documented excused absences are required to make up any quiz or examination.

Excused Absence Policy:
http://www.president.umd.edu/sites/president.umd.edu/files/documents/policies/V-1.00G.pdf

Academic Integrity Policy:
http://www.president.umd.edu/sites/president.umd.edu/files/documents/policies/III-100A.pdf

COURSE FUNDAMENTALS

Course website
The course website is on ELMS: https://myelms.umd.edu/login. The course website will be used for posting course material, announcements, and grades. Ensure the email address you have associated with ELMS is current, as course information will be communicated through the ELMS messaging system. If you are having difficulty with ELMS/Canvas, do not contact the instructor for technical support. The University has professional 24-hour support for students: (877) 399 – 4090

Lecture
Lectures will typically be given by the instructor, though occasionally another qualified person may substitute or a recording may be posted on ELMS. Lectures will be the primary means to deliver new information. Lectures will include active participation to enhance learning.

Discussion
The discussion period is an opportunity to strengthen your understanding of course material. Discussion sections will include a review of the most important concepts from the week and a new example problem. Quizzes will also be given during certain discussion periods (see schedule). Select discussion sections will be used as lecture periods (see schedule).

424 Learning Community
After lecture on Tuesdays, 424 learning community will provide students with the space and time to work on the week's homework assignment peers. Dr. Goldberg will be available to answer questions and facilitate group problem solving.

Communication with the Instructor
Email is the best way to reach the instructor outside of office hours. A reply to email can be expected within two business days. Email should be used to notify the instructor of planned and/or excused absences and can be used to ask clarifying questions on assignments. **Any in depth questions on course material or homework assignments and any questions regarding student progress or grades should be addressed in person.**

Classroom Environment

Students are expected to contribute to a classroom environment that is conducive to learning. As such, please observe the following during class:

- Interact with all instructors and classmates in a respectful and professional manner. Behaviors and remarks perceived to constitute teasing or harassment will not be tolerated.
- Keep talking to a minimum outside of organized group activities. It is difficult for others to listen if there is background conversation taking place. If there is a question, please ask.
- Refrain from using electronic devices. The only electronic devices that you should need to use are calculators. E-mailing, texting, tweeting, and consuming any form of digital media can be distracting to your fellow students. Please leave the classroom if you need to use a device (in emergencies only).

Path to Success/ Expected Time Commitment:

Traditionally, students are expected to devote 2-3 hours of time per week outside of class per credit hour—6-9 hours per week for a 3 credit class. As a challenging upper level chemical engineering class, you should plan to spend approximately 9 hours per week on CHBE424. **The only way to succeed in this class is to put in the time to review notes, work through homework problems (independently first) and think critically about the course material.** If you are overcommitted and do not have sufficient time to spend on the course, you will likely earn a lower grade than you desire.

Resources Available:

If you are struggling to understand and keep up with course material GET HELP EARLY. Because of the cumulative nature of the material and the strong parallels between heat and mass transfer, falling behind can make it almost impossible to catch up. Many resources are available for extra help including:

- Instructor Office hours
- TA/UTF Office hours
- 424 Learning Community
- LearnChemE and other online videos
- Peer study groups

In addition, the campus's **Learning Assistance Services** offers guidance on building good study habits, time management skills, exam preparation, etc.
https://counseling.umd.edu/las/

Finally, the **Counseling Service** in the Counseling Center provides free and confidential therapy to help UMD students manage personal, social, and academic challenges.
https://www.counseling.umd.edu/cs/

Arrangements for Students with Disabilities

The University is legally obligated to provide appropriate accommodations for students with disabilities. Please contact Disability Support Service (DSS) Office (301) 314 – 7682 or Dissup@umd.edu or visit their website: http://www.counseling.umd.edu/DSS/
If you have an accommodation letter from DSS indicating that you have a disability which requires academic accommodations, please present it by the end of the schedule adjustment period (February 6, 2018) so we can discuss the accommodations that you might need in this class.

University Closures or Delays

If class is affected by a University closure or delay, the instructor will email the class concerning the impact to the missed class meeting and will distribute an updated course schedule.

Copyright Statement

All materials presented or provided in class and on the course website (e.g., lectures, handouts, videos, slides) are copyright protected. Students may not copy, record, or distribute these materials without the instructor's permission.

EVALUATION

Grading Policy

There will be a total of 1000 points from during the semester. Details on each item follow.

Homework:	10% (Highest 10 @ 10 points each)
Quizzes:	12% (Highest 4 @ 30 points each)
Reflections:	3% (3 @ 10 points each)
Exams:	45% (2 @ 225 points each)
Final Exam:	30% (300 points)

Grading Scale

This course will use a +/- grading system with letter grades equivalent to the following point values:
895-1000 points (90-100%): A-/A/A+; 795-894 points (80-89%): B-/B/B+; 695-794 point (70-79%): C-/C/C+; 595-694 points (60-69%): D-/D/D+; <595 points (<60%) = F
The instructor shall reserve the right to lower the cut-off points at the end of the semester.

Homework Assignments

Eleven homework exercises will be assigned during the semester. Only the highest ten scores will be counted towards the final grade. Assignments will be posted to Canvas on Fridays and due the following Friday. Homework is due at the beginning of discussion period (11:00 am on Fridays). **Late homework will not be accepted except in the case of a university excused absence**.

Homework will be completed in teams of 2-3. You will get to choose your own team and these teams will be used for the duration of the semester. You should work with your teammate on the homework, but you are expected to write up and turn in your own solutions. Only one solution per team will be graded.

Note that while you are you are encouraged to discuss your homework with classmates even beyond your teammate, you must turn in (and understand) your own solutions. Turning in solutions that are not your own is a violation of department and university academic integrity policies, and violations will be referred to the Honor Council. Additionally, you are not permitted to view homework solutions from the web or from other students who took this course previously (e.g., homework from previous students). Note that any version of the solution manual that is posted online has been posted illegally and that the solution manual contains frequent errors in solutions.

Follow these guidelines for homework assignments:

- Include a cover page with your name, UID, date, course number, assignment number and signed honor pledge.
- Write on only one side of the page and include your name and page number on each page.
- Remove "fringe" from notebook paper and staple the pages together.
- Write out a reasonable amount of step-by-step work to make the problem solving process clear, including but not limited to listing knowns, assumptions, diagrams, etc. Graders are not obligated to giving full credit if large gaps are present and the thought process is not clear. In addition, homework should be neatly written or typed. If it is illegible, it will not be graded.

Reading Assignments

Reading assignments will be posted on ELMS prior to each lecture. The course will not follow the order of the text, and you will only be responsible for the assigned material. Reading the textbook before class will make lecture much more valuable. On occasion, additional references may be provided.

Quizzes

Five short (20 minute) quizzes will be given in discussion section. Only the highest four quiz scores will be counted towards the final grade. Quiz dates are given on the tentative schedule, but are subject to change if inclement weather closures disrupt the course schedule. Quiz problems will be based on (but not identical to) homework problems assigned since the last quiz. Quizzes are closed book and closed notes. Relevant equations will be provided. Department calculators will be provided if calculations are required. You may also use your own scientific calculator up to TI-36x Pro. In order to receive full credit, students must show all work.

Students will have the opportunity to make up a missed quiz in case of an excused absence (with appropriate documentation). Note that a self-signed sick not is not acceptable for a missed quiz. Students must contact the instructor within 2 business days of the absence to schedule the makeup unless there are extenuating circumstances. For planned absences (ie interview, religious holiday), students should contact the instructor prior to the missed quiz. Students may also elect to use their "drop" for a missed quiz.

Exams

There will be two in-class exams (75 min) and one comprehensive final exam (2 hrs). Exams must be promptly turned in at the end of each class/exam period. For each exam, you may prepare and use one 8½ in. x 11 in. sheet for reference (one side only for semester exams, two sides for the final exam). This reference sheet must be turned in along with your exam and will be returned to you after the exam is graded. Department calculators will be provided if calculations are required. You may also use your own scientific calculator up to TI-36x Pro. No unauthorized materials or tools may be visible during exams, and students must stop working on the exam promptly when informed the exam is over; violation of these policies is a violation of the Code of Academic Integrity.

Exam Dates are as follows. Exam dates are subject to change due to inclement weather. Material covered on the exam will be confirmed 1 week prior to the exam. The exam may be moved to a different room or split into multiple rooms. This will be communicated at least 1 week prior to the exam.

Exam 1: Thursday, March 7, 2-3:15 pm
Exam 2: Thursday, April 18, 2-3:15 pm
Final Exam: Monday, May 20, 10:30 am- 12:30 pm

Re-grade Requests

Any questions (or complaints) regarding grading of homework, quizzes or exams must be brought up within one week of the graded item being returned. Requests for reconsideration after this time will not be accepted. Questions (or complaints) regarding homework should be directed to the teaching assistant, quizzes to the undergraduate teaching fellows and those regarding exams should be directed to the instructor. Homework or quiz regrades should be submitted via email with a picture of the item of concern. Exam regrades should be submitted on paper with a written note explaining the regrade request stapled to the exam.

TOPICS & TENTATIVE COURSE OUTLINE

	Class Type	Date	Topic	Reference	HW Assigned	HW Due	Quiz
L1	Tu Lecture	1/29/2019	Mechanisms of Transport, Energy Flux equations	Notes, B Ch 9			
L2	Th Lecture	1/31/2019	Shell energy balance for conduction: slab, cylinder	Notes, B Ch 2			
L3	Fr Discussion	2/1/2019	Special Lecture: Fluid dynamics review	B Ch 9	HW1	R1	
L4	Tu Lecture	2/5/2019	Shell energy balances for conduction: composite, overal HT coefficient	B Ch 10			
L5	Th Lecture	2/7/2019	Shell energy balances: active learning	B Ch 10			
D1	Fr Discussion	2/8/2019	Discussion: Review Key Lecture concepts + new example problem		HW2	HW1	
L6	Tu Lecture	2/12/2019	Shell energy balances for conduction: energy source, cooling fin	B Ch 10			
L7	Th Lecture	2/14/2019	Cooling fin, Diffeq of thermal energy	W Ch 16/ B Ch 11			
D2	Fr Discussion	2/15/2019	Discussion: Review Key Lecture concepts + Quiz		HW3	HW2	Q1 (HW 1,2)
L8	Tu Lecture	2/19/2019	Quasi Steady State heat transfer	Notes			
L9	Th Lecture	2/21/2019	Unsteady heat transfer (Bi zero and infinity)	W Ch 18			
D3	Fr Discussion	2/22/2019	Discussion: Review Key Lecture concepts + new example problem		HW4	HW3	
L10	Tu Lecture	2/26/2019	Unsteady heat transfer (Bi intermediate and semi infinite wall)	W Ch 18			
L11	Th Lecture	2/28/2019	Unsteady heat transfer (multiple directions) + Review	W Ch 18			
D4	Fr Discussion	3/1/2019	Discussion: Review Key Lecture concepts + Quiz			HW 4	Q2 (HW 3,4)
L12	Tu Lecture	3/5/2019	Mechanisms of Mass Transport and Fick's Law	B Ch 17			
	Th Lecture	3/7/2019	Exam 1				
L13	Fr Discussion	3/8/2019	Special Lecture: Shell balances for mass diffusion & boundary conditions	B Ch 18	HW5		
L14	Tu Lecture	3/12/2019	Shell mass balances: reactions	B Ch 18			
L15	Th Lecture	3/14/2019	Return and review exam 1, problems with convection & eq. relationships	B Ch 18			
D5	Fr Discussion	3/15/2019	Discussion: Review Key Lecture concepts + new example problem		HW6	HW5, R2	
	Spring Break	3/19/2019	Spring Break				
	Spring Break	3/21/2019	Spring Break				
	Spring Break	3/22/2019	Spring Break				
L16	Tu Lecture	3/26/2019	Differential Equations of Mass Transfer, Quasi SS Mass Transfer	W Ch 25, Notes			
L17	Th Lecture	3/28/2019	Quasi Steady State Mass Transfer	Notes			
D6	Fr Discussion	3/29/2019	Discussion: Review Key Lecture concepts + Quiz		HW7	HW6	Q3 (HW 5,6)
L18	Tu Lecture	4/2/2019	Quasi SS MT, Unsteady mass transfer	Notes, W Ch 27			
L19	Th Lecture	4/4/2019	Unsteady mass transfer	W Ch 27			
D7	Fr Discussion	4/5/2019	Discussion: Review Key Lecture concepts + new example problem		HW8	HW7	
L20	Tu Lecture	4/9/2019	Unsteady Mass transfer	W Ch 27			
	Th Lecture	4/11/2019	Exam 2 review/ Snow day backup				
D8	Fr Discussion	4/12/2019	Discussion: Review Key Lecture concepts + Quiz			HW8	Q4 (HW 7,8)
L21	Tu Lecture	4/16/2019	Convective Heat Transfer	W Ch 19			
L22	Th Lecture	4/18/2019	Exam 2				
L23	Fr Discussion	4/19/2019	Special Lecture: Convective Heat Transfer	W Ch 19	HW9		
L24	Tu Lecture	4/23/2019	Convective Heat Transfer Correlations	W Ch 20			
L25	Th Lecture	4/25/2019	Return and Review exam 2, convective heat transfer correlations	W Ch 20			
D9	Fr Discussion	4/26/2019	Discussion: Review Key Lecture concepts + new example problem		HW10	HW9	
L26	Tu Lecture	4/30/2019	Heat Exchangers	W Ch 22			
L27	Th Lecture	5/2/2019	Heat Exchangers, Convective mass transfer	W Ch 22, 28			
D10	Fr Discussion	5/3/2019	Discussion: Review Key Lecture concepts + Quiz		HW11	HW10	Q5 (HW 9,10)
L28	Tu Lecture	5/7/2019	Convective MT correlations	W Ch 30			
L29	Th Lecture	5/9/2019	Convective MT correlations	W Ch 30			
D11	Fr Discussion	5/10/2019	Discussion: Review Key Lecture concepts + new example problem			HW11	
L30	Tu Lecture	5/14/2019	Final lecture	Notes			
	FINAL EXAM	5/20/2019	FINAL EXAM 10:30 am - 12:30 pm				