CHE 520 (4 Cr.) – Mass Transfer
Spring Quarter 2014
School of Chemical, Biological, and Environmental Engineering
Oregon State University
2014.06.20
COURSE SYLLABUS

Instructor:

Travis Walker
Email: travis.walker@oregonstate.edu
Phone: 541.737.7244
Office: Gleeson Hall 211
Office Hours: Wednesdays from 1300-1400 and by appointment

Dates: 2014.03.31-2014.06.06
Lectures: CRN 52577: MF 1400-1550
Classroom: Gleeson 100
Recitation: W 1400-1550
Classroom: Gleeson 100

Course Description: (CRN: 52577) CHE 520. MASS TRANSFER (4). Diffusion in gases, liquids, solids, membranes, and between phases. Effects of reactions on mass transfer. Mass transfer rates by convection and dispersion. Rates of dispersion. Rates of combined heat and mass transfer.

CHE 520 is the required mass transfer course for first-year graduate students in the OSU chemical engineering program. The course content focuses on the fundamentals of diffusion and mass transfer in fluid (gas and liquid) systems. About two-thirds of the course emphasizes diffusion, while the remainder of the course emphasizes convective mass transfer. Major lecture topics are detailed in the Lecture Outline (see page 5).

Students are expected to have completed some undergraduate coursework in the transport phenomena, including fluid flow (necessary) and heat transfer (desired). Students are also expected to be proficient in calculus and differential equations, particularly analytical solution of ordinary differential equations (e.g., MTH 256). Experience with analytical solution techniques for partial differential equations (e.g., CHE 525) is also recommended.

Website: `http://my.oregonstate.edu`
(Please make sure you have access to the My Oregon State website, since all course materials and announcements will be available there.)

Recommended Textbook:

Bird, R.B., Stewart, W.E., Lightfoot, E.N. *Transport Phenomena*, 2nd ed. John Wiley & Sons, New York (1999). ISBN 0-47011-539-4.

Other Textbooks:

Crank, J. *The Mathematics of Diffusion*, 2nd ed. Oxford University Press (1975). ISBN 0-19853-411-6.

Cussler, E.L. *Diffusion: Mass Transfer in Fluid Systems*, 3rd ed. Cambridge University Press (2009). ISBN 0-52187-121-2.

Greenberg, M.D. *Foundations of Applied Mathematics*. Dover (2013). ISBN 978-0486492797.

Happel, J., Brenner, H. *Low Reynolds Number Hydrodynamics*. Prentice-Hall, Englewood Cliffs, NJ (1965).

Hinch, E.J. *Perturbation Methods*. Cambridge University Press (2002). ISBN 0-521-37897-4.

Lamb, H. *Hydrodynamics*, 6th ed. Cambridge University Press (1932).

Leal, L.G. *Advanced Transport Phenomena: Fluid Mechanics and Convective Transport Processes*. Cambridge University Press (2010). ISBN 978-0521179089.

Incropera, F.P., DeWitt, D.P. *Fundamentals of Heat and Mass Transfer*, 5th ed. John Wiley, Hoboken, NJ (2007). ISBN 0-47145-728-0.

Kim, S., Karrila, S.J. *Microhydrodynamics: Principles and Selected Applications*. Buttersworth-Heinemann, Boston (1991).

Reid, R.C., Prausnitz, J.M., Poling, B.E. *The Properties of Gases and Liquids*, 4th ed. McGraw-Hill, New York (1987).

Slattery, J.C. *Advanced Transport Phenomena*. Cambridge University Press (1999). ISBN 978-0521635653.

Varma, A., Morbidelli, M. *Mathematical Methods in Chemical Engineering*. Oxford University Press (1997). ISBN 978-0-19509821-8.

Course Grading:

Homework	20%
Group Project	20%
Midterm Examination	30%
Final Examination	30%

Grade Policy: Homework received up to 24-hours late will receive 50% credit. Homework received beyond 24-hours late will receive 0% credit. Group work on homework is permitted, but each student must turn in his or her own individual assignment with a list of contributors.

Grading: If you determine that a regrade is necessary, the entire assignment will be regraded.

Final performance percentage will be assigned a minimum letter grade by the following scale (implying that the percentage requirements for a particular grade may be decreased at the instructors' sole discretion but will not be increased):

90-100	A
80-90	B
70-80	C
60-70	D
0-60	F

Course Overview & Objectives: By the end of the course, a student will be able to do the following:

- Develop a fundamental knowledge base for using vectors and tensors while being introduced to Einstein notation. Derive the conservation laws including the Reynolds transport equation, develop constitutive equations, and understand the boundary conditions necessary to solve transport systems.
- Estimate diffusion coefficients within a homogeneous gas phase, a homogeneous liquid phase, and within porous materials.
- For a diffusion based mass transfer process, simplify the differential forms of the flux equation and the mass conservation equation, and propose reasonable boundary conditions, based upon the system geometry and assumptions made regarding the behavior of the physical system. Develop and use integral expressions for steady-state diffusion processes based on consideration of the following limiting cases: one-dimensional diffusion flux with constant or changing flux area, zero or first-order chemical reaction.
- Experience the usefulness of dimensional analysis (Buckingham Π), similarity solutions, perturbation theory, and boundary layer theory. Use the error function and infinite-series solutions for solving unsteady-state molecular diffusion problems associated with semi-infinite and finite dimensional media.

Course Structure:

Communication:

The Blackboard announcement tab (CRN 53577) will be used to distribute information, while email to ONID addresses will be used for course communication. All scores will be posted in the Blackboard grade center.

Lectures:

Lectures will be used for the following:

- Content instruction,
- Project presentations,
- One midterm exam, and
- Exam feedback and questions.

Attendance in lectures is expected. You are expected to be punctual and to minimize disruptions. Cell-phones need to be off during class. Also, no use of laptops or other electronic devices for activity outside of its use in this class will be tolerated. If you miss a class, you are responsible for obtaining lecture notes from other students.

While the University is a place where the free exchange of ideas and concepts allows for debate and disagreement, all classroom behavior and discourse should reflect the values of respect and civility. Behaviors which are disruptive to the learning environment will not be tolerated. As your instructor, I am dedicated to establishing a learning environment that promotes diversity of race, culture, gender, sexual orientation, and physical disability. Anyone noticing discriminatory behavior, or who feels discriminated against, should bring it to the attention of the instructor or other University personnel as appropriate.

Recitations:

Recitations will be used for the following:

- Content instruction,
- Project presentations,
- Homework feedback and questions,
- Exam feedback and questions.

Recitations will not occur every week. Attendance in recitation is optional. If a lecture day is unavailable for a lecture, the recitation time period may be used to replace a lecture for those individuals that can attend.

Homework:

Homework will be due on Fridays at 1400. Homework will be assigned every other week. To increase efficiency in the grading process, homework will be graded in the following manner.

✓+	excellent
✓	satisfactory
✓-	unsatisfactory
0	not submitted

To aid in the understanding of the information, complete solutions will be posted to Blackboard following the submission of the homework. Inquiries will be directed to these solutions for comparison to the returned homework, while further discussion will be saved for office hours and recitations.

Group Project:

A course project will be completed by groups of one, two, or three (1, 2, 3) students depending on the number of students in the course. The project will be used as an overall assessment of the students' understanding of key concepts described throughout the course. The deliverable will consist of an oral presentation during Week 10 of the course. Further information will be distributed in a separate document entitled Project Description.

Exams:

Two exams will exist for this course: one in-class midterm during a lecture period and one take-home final during the last week of class. The tentative dates of the exams are the following:

- Midterm: Week 6, Monday, 2014.05.05 from 1400-1550 in class
- Final: Week 10, from Friday, 2014.05.30 to Friday, 2014.06.06 at 2000

During exams you may only use your copy of the required textbook and any materials provided during the course. You cannot "share" a textbook during an exam or use copies of pages from the book. Laptops, calculators, or phones are not allowed during exams.

Make-up exams will only be allowed in the case of documented emergencies or with prior authorization from the instructor. If you must miss one of the exams for an emergency situation, please let the instructor know as soon as possible (travis.walker@oregonstate.edu). You will not have an opportunity to make up the exam without an approved reason.

Classes:

March 31

April 07, 09, 11, 14, 21, 23, 28

May 02, 05, 07, 09, 12, 16, 19, 23, 30

June 02, 04, 06

No Classes: April 04[*], 18[†], 25[‡]; May 26[§]

Important Dates:

Add/Drop Deadline 2014.04.11
Midterm Exam 2014.05.05 1400-1550
Withdraw Deadline 2014.05.16
Final Exam .... 2014.05.30 – 2014.06.06 2000

Tentative Course Outline (2014.06.20):

Lecture Topic	Reading[¶]
0. Cartesian vectors and tensors & Einstein (indicial or index) notation	BSL App A V&M Ch 1.1-12
1. Conservation laws, constitutive equations, and boundary conditions HW Set #1 due 2014.04.21	LGL Ch 2
2. Diffusivity and the mechanisms of mass transport	BSL Ch 17
HW Set #2 due 2014.05.02	
Midterm Exam (Topics 0 & 2) on 2014.05.05	
3. Concentration distribution in solids and laminar flow	BSL Ch 18 ESGS M300 L1-4
HW Set #3 due 2014.05.16	
4. Equations of change for multicomponent systems	BSL Ch 19
HW Set #4 due 2014.05.30	
5. Perturbation theory and boundary layers	V&M Ch 9.1-6
Final Exam (Topics 1 – 6) due 2014.06.06	

[*] NSF Workshop
[†] Funeral
[‡] AIChE Regional Conference in Pullman, Washington
[§] Memorial Day
[¶] BSL: Bird, Stewart, & Lightfoot; LGL: Leal; V&M: Varma & Morbidelli

Tentative Lecture Outline (2014.06.20):

0. Cartesian vectors and tensors & Einstein (indicial or index) notation
    - 0.1. Basic Cartesian vectors and tensors – Einstein notation
    - 0.2. Cartesian tensors
    - 0.3. Differential and integral calculus of vectors and tensors
    - 0.4. Useful integral theorems
1. Conservation laws, constitutive equations, and boundary conditions
    - 1.1. Continuum approximation
    - 1.2. Conservation of mass – continuity equation
    - 1.3. Newton's law of mechanics
    - 1.4. Conservation of energy and entropy inequality
    - 1.5. Constitutive equations
    - 1.6. Fluid statics – stress tensor for a stationary fluid
    - 1.7. Constitutive equation for a flowing fluid – Newtonian fluid
    - 1.8. Equations of motion for a Newtonian fluid – Navier-Stokes equation
    - 1.9. Buckingham Π (dimensional analysis)
2. Diffusivity and the mechanisms of mass transport
    - 2.1. Fick's law of binary diffusion
    - 2.2. Temperature and pressure dependence of diffusivities
    - 2.3. Theory of diffusion in gases at low density
    - 2.4. Theory of diffusion in binary liquids
    - 2.5. Theory of diffusion in colloidal suspensions
    - 2.6. Theory of diffusion of polymers
    - 2.7. Mass and molar transport by convection
    - 2.8. Maxwell-Stefan equations for multicomponent diffusion in gases at low density
3. Concentration distribution in solids and laminar flow
    - 3.1. Shell mass balances; boundary conditions
    - 3.2. Diffusion through a stagnant gas film
    - 3.3. Diffusion with a heterogeneous chemical reaction
    - 3.4. Diffusion with a homogeneous chemical reaction
    - 3.5. Similarity solutions
    - 3.6. Diffusion into a falling liquid film (gas absorption)

   3.7. Diffusion into a falling liquid film (solid dissolution)
   3.8. Diffusion and chemical reaction inside a porous catalyst
   3.9. Diffusion in a three-component gas system

4. Equations of change for multicomponent systems
   4.1. The equations of continuity for a multicomponent mixture
   4.2. Summary of multicomponent equations of change
   4.3. Summary of multicomponent fluxes
   4.4. Use of the equation of change for mixtures
   4.5. Dimensional analysis of the equations of change for binary mixtures

5. Perturbation theory and boundary layers

OSU STATEMENTS:

From the Office of the Dean of Students (1995.12.13): Behaviors which are disruptive to the learning environment will not be tolerated, and will be referred to the Office of the Dean of Students for disciplinary action. Behaviors which create a hostile, offensive or intimidating environment based on gender, race, ethnicity, color, religion, age, disability, marital status or sexual orientation will be referred to the Affirmative Action Office.

Web link : `http://oregonstate.edu/admin/stucon/index.htm`

Statement Regarding Students with Disabilities Accommodations are collaborative efforts between students, faculty and Disability Access Services (DAS). Students with accommodations approved through DAS are responsible for contacting the faculty member in charge of the course prior to or during the first week of the term to discuss accommodations. Students who believe they are eligible for accommodations but who have not yet obtained approval through DAS should contact DAS immediately at 737-4098.

Web link: `http://ds.oregonstate.edu/prospective/`

Academic Honesty Any instances of dishonesty in academic work will be treated according to OSU Academic Regulations. The Statement of Expectations for Student Conduct is given in the OUS OAR #576-015-0020, accessible at the following link:

Web link: `http://oregonstate.edu/studentconduct/home/`.

The policy is stated below:

> Academic or Scholarly Dishonesty is defined as an act of deception in which a Student seeks to claim credit for the work or effort of another person, or uses unauthorized materials or fabricated information in any academic work or research, either through the Student's own efforts or the efforts of another.
>
> b) It includes:
>
> (i) CHEATING - use or attempted use of unauthorized materials, information or study aids, or an act of deceit by which a Student attempts to misrepresent mastery of academic effort or information. This includes but is not limited to unauthorized copying or collaboration on a test or assignment, using prohibited materials and texts, any misuse of an electronic device, or using any deceptive means to gain academic credit.
>
> (ii) FABRICATION - falsification or invention of any information including but not limited to falsifying research, inventing or exaggerating data, or listing incorrect or fictitious references.
>
> (iii) ASSISTING - helping another commit an act of academic dishonesty. This includes but is not limited to paying or bribing someone to acquire a test or assignment, changing someone's grades or academic records, taking a test/doing an assignment for someone else by any means, including misuse of an electronic device. It is a violation of Oregon state law to create and offer to sell part or all of an educational assignment to another person (ORS 165.114).
>
> (iv) TAMPERING - altering or interfering with evaluation instruments or documents.
>
> (v) PLAGIARISM - representing the words or ideas of another person or presenting someone else's words, ideas, artistry or data as one's own, or using one's own previously submitted work. Plagiarism includes but is not limited to copying another person's work (including unpublished material) without appropriate referencing, presenting someone else's opinions and theories as one's own, or working jointly on a project and then submitting it as one's own.

ACCESSING COE PROGRAMS AND DOCUMENTS:

1. **Verify that you have a valid OSU ONID and ENGR computing account.** More information on getting access to and using ENGR computing resources is available here:
   `http://engineering.oregonstate.edu/computing/gettingstarted/224`
   To create an ENGR computing account (if you have not done so already),

   (a) go to `https://secure.engr.oregonstate.edu:8000/teach.php`
   (b) select "Create a new account" at the bottom of the screen.
   (c) follow the prompts to create your ENGR account.

   It is strongly suggested that you immediately log in and verify that you can access the Web, printers, etc. from your ENGR account.
   If you are working from off-campus, you will need to access COE systems through the secure Virtual Private Network (VPN).
   For more information and to download software to set up the VPN, please visit `http://oregonstate.edu/helpdocs/network/vpn-campus-access`

2. **You must have a laptop computer with access to wireless networks and which is capable of running Microsoft Excel and MATLAB.** You will lose points for any lab section that you do not have a laptop with access to Excel and MATLAB.
   Access to a laptop computer is a requirement for students in the OSU College of Engineering (c.f., `http://engineering.oregonstate.edu/laptop-requirements`).
   For general information about OSU COE computing resources, visit `http://engineering.oregonstate.edu/computing/personal`.
   If you need help with your ENGR account, setting up your laptop, installing software, or access to the ENGR wireless network, please contact the COE Wireless Helpdesk. The Helpdesk is located in Dearborn 120A and is open from 9AM ? 11PM, 7 days a week. `http://engineering.oregonstate.edu/computing/personal/155`

3. **MATLAB may be downloaded and installed on your personal laptop free of charge from the ENGR website.** Carefully follow the directions given at the College of Engineering website: `http://engineering.oregonstate.edu/computing/personal/149` (Note that the 64-bit installer is larger and will run only on 64-bit PCs. The 32-bit version should run on any PC running Windows).
   If you install MATLAB locally, you will need to have access to the OSU VPN each time you run the program in order to obtain a license key. More information on VPN is available here: `http://oregonstate.edu/helpdocs/network/vpn-campus-access`

4. **Microsoft Office may be purchased from the campus book store for $99 with valid student ID.** Purchasing a copy of Microsoft Office to use throughout the several years that you work towards your degree is highly recommended.
   Although they perform similar functions and have similar interfaces, we will not use OpenOffice or other spreadsheet programs in this course. Microsoft Office is ubiquitous throughout the engineering workplace, and we hope to keep confusion to a minimum by using only one software package for this course. All files which are handed in must be fully compliant with Microsoft Office; incompatible files will be returned ungraded to the student.

5. **Accessing MATLAB and MS Office through Citrix/XenApp Web (no need to purchase Microsoft Office)** Both MATLAB and MS Office (including Excel) can be accessed remotely, at no cost, from COE servers using the Citrix or XenApp Web mechanisms. You will need to be on-campus, or have access to the COE VPN (see above), to access the OSU Citrix servers.
   Citrix and XenApp allow you to run a wide variety of software applications on your PC or Mac system, as well as some iOS, Android and Chrome-based devices. A convenient Web-based interface makes access to the applications simple, and can be accessed at `https://apps.engr.oregonstate.edu/Citrix/EngineeringWeb/`.
   You will need to install the Citrix Receiver software to use applications on the Citrix servers. Follow the directions at the site below to get started with Citrix: `http://engineering.oregonstate.edu/computing/citrix/`

If you need help with any of these steps, please contact the OSU College of Engineering Helpdesk: `http://engineering.oregonstate.edu/computing/policies/155` or `https://secure.engr.oregonstate.edu/forms/contact.php?to=support`