CBE 611 (3 Cr.) – Chemical Engineering Transport Phenomena

Spring Semester 2020
Department of Chemical and Biological Engineering
South Dakota School of Mines & Technology
2020.02.20

COURSE SYLLABUS

Instructor: Travis Walker
Email: travis.walker@sdsmt.edu
Phone: 605.394.2543
Office: CBEC 3310
Office Hours: T 1000-1100 (CBEC 3310) and by appointment

Graduate Teaching Assistant: Şebnem Özbek
Email: sebnem.ozbek@mines.sdsmt.edu
Office Hours: MF 0900-1000 (CBEC 221), T 0900-1000 (CBEC 3304), and by appointment

Dates: 2020.01.13-05.08
Lectures: TR 1100-1230
Classroom: CBEC 3305

Course Description: CBE 611 Chemical Engineering Transport Phenomena
Credits: (3-0) 3
Conservation equations governing diffusive and convective transport of momentum, thermal energy and chemical species will be explored within chemical engineering applications. Topics may include: fundamentals of fluid mechanics, unidirectional flow, creeping flow, laminar flow at high Reynolds number, flow in confined geometries, boundary layer flow, and creeping flow; combined heat and mass transfer; heat and mass transport coupled with chemical reactions and phase change; diffusive fluxes in solids, liquids and gases and between phases; scaling and approximation techniques; forced-convection heat and mass transfer in confined and unconfined flows; and dispersion rates.
Prerequisites: MATH 321 or equivalent.
CRN: 19588

Course Website:
`https://webpages.sdsmt.edu/~twalker/secure/teaching/2020/1/cbe611.html`

Required Textbook:

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

Recommended Textbook:

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

Other Textbooks:

M. Abramowitz, I.A. Stegun. *Handbook of Mathematical Functions: with Formulas, Graphs, and Mathematical Tables.* Dover (1965). Web Link.
G.K. Batchelor, *An Introduction to Fluid Dynamics.* Cambridge University Press (2000).
J.C. Berg, *An Introduction to Interfaces and Colloids: The Bridge to Nanoscience.* World Scientific (2009).
W.E. Boyce, R.C. DiPrima. *Elementary Differential Equations and Boundary Value Problems.* Wiley (2009).
P-G. de Gennes, F. Brochard-Wyar, D. Quere. *Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves.* Springer (2004).
M.D. Graham, *Microhydrodynamics, Brownian Motion, and Complex Fluids.* Cambridge University Press (2018).
M.D. Greenberg, *Foundations of Applied Mathematics*. Dover (2013).
J. Happel, H. Brenner, *Low Reynolds Number Hydrodynamics*. Prentice-Hall, Englewood Cliffs, NJ (1965).
E.J. Hinch, *Perturbation Methods*. Cambridge University Press (2002).
H. Lamb, *Hydrodynamics*, 6th ed. Cambridge University Press (1932).
S. Kim, S.J. Karrila, *Microhydrodynamics: Principles and Selected Applications*. Buttersworth-Heinemann, Boston (1991).
J.C. Slattery, *Advanced Transport Phenomena*. Cambridge University Press (1999).
A. Varma, M. Morbidelli, *Mathematical Methods in Chemical Engineering*. Oxford University Press (1997).

Course Grading:

Homework	20%
Midterm Examination I	25%
Midterm Examination II	25%
Final Examination	30%

Grade Policy: Work received up to 24 hours late will receive 50% credit. Work received beyond 24 hours late will receive 0% credit. Group work on homework is permitted, but each student must submit 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 instructor's sole discretion but will not be increased):

90-100	A
80-90	B
70-80	C
60-70	D
00-60	F

Course Objectives and Rationale: The overall objective of this course is to introduce you to analytic techniques that may be used to solve a variety of chemical engineering problems.

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

- Derive the conservation laws including the Reynolds transport equation, develop constitutive equations, and understand the boundary conditions necessary to solve transport systems.
- Experience the usefulness of dimensional analysis (Buckingham Π), similarity solutions, perturbation theory, boundary layer theory, and stability theory.
- Obtain a fundamental understanding of unidirectional and one-dimensional flow, asymptotic approximations, thin-gap (lubrication) approximations, and creeping flow.

Course Structure:

Communication:

The course website will be used to distribute information, while email to MINES addresses will be used for course communication. I do my best to answer emails as promptly as possible, but I reserve the right to have 24 hours to answer all email inquires. Under certain circumstances this timeline could be longer.

Lectures:

Lectures will be used for the following:

- content instruction,
- homework feedback and questions, and
- examination feedback and questions.

Attendance in lectures is expected. You are expected to be punctual and to minimize disruptions. Cellular devices 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 Institution 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 that 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 institutional personnel as appropriate.

Recitations:

Recitations will be used for the following:

- content instruction,
- homework feedback and questions, and
- examination 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:

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 the course website 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.

Examinations:

Two examinations will exist in this course: two regular examinations and one final examination during finals week. The tentative dates of the examinations are the following:

- Midterm Examination I: 2020.01.31-2020.02.11
  - Distributed Week 03, Friday, 2020.01.31
  - Due Week 05, Tuesday, 2020.02.11 in class
- Midterm Examination II: 2020.02.28-2020.03.17
  - Distributed Week 06, Friday, 2019.02.28
  - Due Week 08, Friday, 2020.03.17 by 1700 MST
- Final Examination: 2020.04.24-2020.05.08
  - Distributed Week 14, Friday, 2020.04.24
  - Due Finals Week Friday, 2019.05.03 by 1700 MST

Unless otherwise stated, during examinations you may only use your copy of the required textbook and any materials provided during the course. You cannot "share" a textbook during an examination or use copies of pages from the book. You may write notes in your textbook about topics that are covered in class but not included in the textbook. Laptops,

calculators, or phones are not allowed during examinations.

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

Tentative Dates:

- **Classes:**
  January 14, 16, 21, 23, 28, 30
  February 11, 13, 18, 20
  March 17, 19, 24, 26, 31
  April 02, 07, 09, 14, 16, 21, 23, 28, 30
- **No Classes:**
  February 04, 06 (GRC)
  February 25, 27 (ADP) – Recorded Lecturers!
  March 03, 05 (ADP)
  March 10, 12 (Spring Break)

Important Dates:

Add/Drop	2020.01.22
Midterm Examination I	2020.01.31-2020.02.11
Midterm Examination II	2020.02.28-2020.03.17
Withdraw	2020.04.02
Final Examination	2020.04.24-2020.05.08

Tentative Course Outline (2020.02.20): This tentative list is subject to change depending on class needs. All topics in the chapters may not be covered, and some topics may be covered to a greater depth than others. Additional reading material might be provided as well.

Topic	**Reading***
Basic principles: conservation laws, constitutive equations, boundary conditions	LGL Ch 02
Unidirectional and one-dimensional transport problems	LGL Ch 03
Midterm Examination I	
Introduction to asymptotic approximations and perturbation theory	LGL Ch 04 EJH Ch 01
Thin-gap approximation – Lubrication problems	LGL Ch 05 (& 06)
Midterm Examination II	
Creeping flow – 2D, axisymmetric, and 3D problems	LGL Ch (07 &) 08
Convection effects	LGL Ch 09
Laminar boundary-layer theory	LGL Ch 10
Final Examination	

*BSL: Bird, Stewart, Lightfoot; LGL: Leal; EJH: E. John Hinch; V&M: Varma & Morbidelli

Academic Integrity: Students are expected to abide by the SDSM&T policies of academic integrity (with regard to cheating, plagiarism, etc.), as outlined in the Course Catalog.

ADA Statement: *SD Mines strives to ensure that physical resources, as well as information and communication technologies, are accessible to users in order to provide equal access to all. If you encounter any accessibility issues, you are encouraged to immediately contact the instructor of the course and the Title IX and Disability Coordinator, Ms. Amanda Lopez at disabilityservices@sdsmt.edu or 605.394.2533. Students with special needs or requiring special accommodations should also contact the instructor and the Title IX and Disability Coordinator. More information can be found at* `https://www.sdsmt.edu/Campus-Life/Student-Support/Disability-Services/`.

Freedom in Learning Statement: Freedom in learning. *Under Board of Regents and University policy student academic performance may be evaluated solely on an academic basis, not on opinions or conduct in matters unrelated to academic standards. Students should be free to take reasoned exception to the data or views offered in any course of study and to reserve judgment about matters of opinion, but they are responsible for learning the content of any course of study for which they are enrolled. Students who believe that an academic evaluation reflects prejudiced or capricious consideration of student opinions or conduct unrelated to academic standards should contact the Provost and Vice President for Academic Affairs to initiate a review of the evaluation.*

Additional Support

- The Student Success Center is a hub for learning support, resources, and help in identifying sources of assistance or support on campus. Go to `http://www.sdsmt.edu/Academics/Student-Success-Center/` for more information or stop by the office in the Surbeck Center to visit with Lisa Carlson (Lisa.Carlson@sdsmt.edu). The phone number is 605.394.5261.
- Student Resource List:
  `http://www.sdsmt.edu/Campus-Life/Student-Resources/Student-Resources-List/`
- Information about how to use or access ITS resources (e.g., computer, Internet, email):
  `http://www.sdsmt.edu/Campus-Services/ITS/How-Do-I/`
- Title IX of the Educational Amendments Act of 1972 is the federal law prohibiting discrimination based on sex under any education program and/or activity operated by an institution receiving and/or benefiting from federal financial assistance. Behaviors that can be considered "sexual discrimination" include sexual assault, sexual harassment, stalking, relationship abuse (dating violence and domestic violence), sexual misconduct, and gender discrimination. You are encouraged to report these behaviors. Reporting: SD Mines can better support students in trouble if we know about what is happening. Reporting also helps us to identify patterns that might arise – for example, if more than one complainant reports having been assaulted or harassed by the same individual.
  SD Mines is committed to providing a safe and positive learning experience. To report a violation of sexual misconduct or gender discrimination, please contact the Title IX Coordinator at 605.394.1203. Please note that as your professor, I am required to report any incidences to the Title IX Coordinator. Confidential support for students is available by contacting the Student Counseling Center at 605.394.1924.