

## **Fluid and Solid Operations**

ECH 3203 Section 21BB

**Class Periods:** Lecture: MWF, Period 5 (11:45AM–12:35 PM)

Discussion Section: R, Period 4 (10:40–11:30 AM)

**Location:** Lecture: FLG 0270; Discussion: FLG 0260

**Academic Term:** Fall 2016

### ***Instructor***

Mark E. Orazem

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Office Hours: W 2-4 PM, Room 327 Chemical Engineering Building

### ***Teaching Assistant***

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Arthur R. Dizon

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Office Hours R 2-4 PM, ChESC Atrium

### ***Course Description***

3 credit hours. Characteristics of laminar and turbulent flow, mechanical energy balance, flow through packed beds and fluidization of solids, design of pumping systems and piping networks and metering of fluids.

### ***Course Pre-Requisites / Co-Requisites***

COT 3502 and ECH 3264

### ***Course Objectives***

Upon completion of this course, a student should be able to:

- Identify process variables and conduct a dimensional analysis.
- Apply shell balance approach to set up mass and momentum balances.
- Evaluate the operation of process involving a flow through pipes (pressure drop, frictional loss, flow rate).
- Design a pipe network for a specific process.
- Estimate the drag force on an object immersed in a fluid flow.
- Evaluate the operation of packed beds, fluidized beds, and filters for specific fluids.
- Select and evaluate the performance of pumps.
- Work ethically with other students, engaging in discussions and working independently as appropriate.

Specific topics covered will include:

- Unit systems.
- Dimensional analysis.
- Thermo-physical properties.
- Hydrostatic equilibrium, barometric equation, manometer, buoyancy force.
- Integral mass and momentum balances.
- Potential flow, Bernoulli's equation, and friction factors.
- Laminar and turbulent flows.
- Pipe network.
- Pumps and flow meters.
- Flow of compressible fluids (adiabatic and isothermal flows).
- Stokes' law, drag coefficient, settling velocity.
- Flow through porous media, Darcy's law.
- Packed bed, fluidized bed.
- Operations involving particulates (filtration, mixing, gas cleaning).

## **Materials and Supply Fees**

None.

## **Relation to Program Outcomes (ABET)**

<i>Subject</i>	<i>Objectives</i>
Unit systems and conversion between units	a
Scalings and dimensional analysis	a
Hydrostatic equilibrium, Barometric equation, Manometer, Buoyancy force	b
Mass & momentum balances	b, c
Mechanical energy balance, Bernoulli's equation	c, d
Laminar and turbulent flows	c, d
Friction factor, losses by fittings, contraction and expansion	c, d
Pipe network	c, d
Pumps and flow meters	d, f, g
Flow of compressible fluids (adiabatic and isothermal flows)	b
Stokes' law, drag coefficient	e, f
Settling/rising velocity	e
Flow through porous media, Darcy's law	e, f
Packed bed, fluidized bed	f
Filtration	f, g
Gas cleaning	e, f

ABET Program Outcomes:

- (a) Apply knowledge of mathematics, science, and engineering
- (b) Design and conduct experiments, as well as analyze and interpret data
- (c) Design a system, component, or process to meet desired needs
- (d) Function on multi-disciplinary teams
- (e) Identify, formulate, and solve engineering problems
- (f) Understand professional and ethical responsibilities
- (g) Communicate effectively
- (h) Understand the impact of engineering solutions in a global and societal context
- (i) Recognize the need for, and engage in life-long learning
- (j) Understand contemporary engineering issues
- (k) Use the techniques, skills, and modern engineering tools necessary for engineering practice

## **Required Textbooks and Software**

C. J. Geankoplis, Transport Processes and Separation Process Principles (Includes Unit Operations), 4th edition, Prentice Hall, Englewood Cliffs, N. J., 2003.

Note: Some exams will be open-book, and use of computers and phones will be prohibited. Thus, a paper copy of the book will be required.

## **Recommended Materials**

R. B. Bird, W. E. Stewart, and E. H. Lightfoot, Transport Phenomena, Wiley, Hoboken, NJ, 1960.

R. B. Bird, W. E. Stewart, and E. H. Lightfoot, Transport Phenomena, 2nd edition, Hoboken, NJ, 2006.

W. L. McCabe, J. C. Smith, and P. Harriott, Unit Operations of Chemical Engineering, 7th Edition, McGraw-Hill, Inc., New York, New York, 2004.

R. H. Perry and D. W. Green, editors, Perry's Chemical Engineers' Handbook, 8th edition, McGraw Hill, New York, 2007.

D. R. Lide, Jr., editor, CRC Handbook of Chemistry and Physics, 96th edition, CRC Press, Cleveland Ohio, 2015-2016.

## **Course Schedule**

The tentative schedule for exams and materials covered is attached.

**ECH 3203: Fluid and Solid Operations**

**Mark E. Orazem, Fall 2016**

### ***Attendance Policy, Class Expectations, and Make-Up Policy***

Attendance is required. Attendance records will be used to guide determination of final grades. Cell phones and other distractions may not be used in class. Excused absences must be consistent with university policies in the undergraduate catalog (<https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>) and require appropriate documentation.

### ***Evaluation of Grades***

Grades are based on exams, completion of homework assignments, attendance, and participation in the class.

Homework and quizzes		10%
Mid-term exams	(2)	50%
Final exam		40%

### ***Grading Policy***

Grades for this class are curved at the discretion of the instructor. Attendance and class participation will be considered.

Please note: A score of C or better required before continuing in the Chemical Engineering program. By University of Florida policy, a C- will not be a qualifying grade for critical tracking courses. In order to graduate, students must have an overall GPA and an upper-division GPA of 2.0 or better (C or better). Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit: <https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>.

### ***Relevant Aspects of the Chemical Engineering Policy on Exams***

- a) All exams will include the honor pledge and students must sign their name by the pledge.
- b) All students must leave backpacks, bags, etc., in the front of the classroom as they enter.
- c) Students are asked not to bring cell phones in the exam. In case they do, they have to place the cell phones in the front of the classroom. The department and proctors have no responsibility in case of theft (cell phones should not be brought). A cell phone discovered on a student's person may result in a zero grade for the exam. If a student is expecting an important call, he or she must discuss this with the proctors before starting the exam.
- d) Students are required to remove their hats during the exam and place them in the front of the classroom.
- e) In open book exams no printed material other than the textbook is allowed. A solution manual or printouts from solution manuals will result in a zero grade for the exam and additional harsher penalties.
- f) Any talking between students is strictly prohibited and will result in a zero grade for the exam.
- g) Students may not leave the room before turning in the exam.

### ***Students Requiring Accommodations***

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, <https://www.dso.ufl.edu/drc>) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

### ***Course Evaluation***

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at <https://evaluations.ufl.edu/evals>. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at <https://evaluations.ufl.edu/results/>.

### ***University Honesty Policy***

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### ***Software Use***

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### ***Student Privacy***

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <http://registrar.ufl.edu/catalog0910/policies/regulationferpa.html>

## ***Campus Resources***

### ***Health and Wellness***

#### **U Matter, We Care:**

If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) or 352 392-1575 so that a team member can reach out to the student.

**Counseling and Wellness Center:** <http://www.counseling.ufl.edu/cwc>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

#### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

### ***Academic Resources***

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu).  
<https://lss.at.ufl.edu/help.shtml>.

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.ufl.edu/>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.  
<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.  
<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus:** [https://www.dso.ufl.edu/documents/UF\\_Complaints\\_policy.pdf](https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf).

**On-Line Students Complaints:** <http://www.distance.ufl.edu/student-complaint-process>.

## Tentative Schedule (updated August 19, 2016)

Date	Topics Covered
Aug. 22, 2016	Introduction. Context. Expectations.
Aug. 24, 2016	Fundamental and derived units. American Engineering, and SI systems of units.
Aug. 25, 2016	Discussion Section: Pressure in psi. (bring your calculator)
Aug. 26, 2016	Fluid Statics.
Aug. 29, 2016	Shell momentum balance and velocity profile in laminar flow. <sup>1</sup>
Aug. 31, 2016	Viscosity of fluids. Non-Newtonian fluids.
Sep. 1, 2016	Discussion Section: Applications.
Sep. 2, 2016	Applications. Homework #1 due.
Sep. 5, 2016	Holiday <sup>2</sup>
Sep. 7, 2016	Applications.
Sep. 8, 2016	Discussion Section: Homework #1
Sep. 9, 2016	Generalized equations of continuity and motion. Homework #2 due.
Sep. 12, 2016	
Sep. 14, 2016	Applications.
Sep. 15, 2016	Discussion Section: Homework #2
Sep. 16, 2016	Applications. Homework #3 due.
Sep. 19, 2016	Types of Fluid Flow and Reynolds Number. Dimensional analysis in momentum transfer.
Sep. 21, 2016	Turbulence.
Sep. 22, 2016	Discussion Section: Homework #3 / Exam 1.
Sep. 23, 2016	Exam 1.
Sep. 26, 2016	Overall mass, energy, and momentum balances. Bernoulli equation. Design equations for laminar and turbulent flow in pipes.
Sep. 28, 2016	University of Florida Career Showcase – class not held
Sep. 29, 2016	Discussion Section:
Sep. 30, 2016	Video: FLUID MECHANICS OF DRAG: 1. Some Curious Experiments. Homework #4 due.
Oct. 3, 2016	Video: FLUID MECHANICS OF DRAG: 2. Fundamental Concepts.
Oct. 5, 2016	Video: FLUID MECHANICS OF DRAG: 3. The Laws of Drag in Fluids of High and Low Viscosity.
Oct. 6, 2016	Discussion Section: Homework #4
Oct. 7, 2016	Video: FLUID MECHANICS OF DRAG: 4. How to Reduce Drag. Homework #5 due.
Oct. 10, 2016	Measurement of flow of fluids.
Oct. 12, 2016	Flow past immersed objects.
Oct. 13, 2016	Discussion Section: Homework #5
Oct. 14, 2016	Homecoming. Holiday.
Oct. 17, 2016	Boundary-layer flow. Homework #6 due.
Oct. 19, 2016	
Oct. 20, 2016	Discussion Section: Homework #6
Oct. 21, 2016	Homework #7 due.
Oct. 24, 2016	Compressible flow of gases.
Oct. 26, 2016	
Oct. 27, 2016	Discussion Section: Homework #7 / Exam 2
Oct. 28, 2016	Exam 2.
Oct. 31, 2016	Pumps and gas-moving equipment.
Nov. 2, 2016	Flow in packed and fluidized beds.
Nov. 3, 2016	Discussion Section:
Nov. 4, 2016	Mechanical-Physical Separation Processes. Filtration. Homework #8 due.
Nov. 7, 2016	

<sup>1</sup> Color indicates that Prof. Orazem will be traveling. Arthur Dizon will serve as guest lecturer.

<sup>2</sup> Color indicates school holiday.

Nov. 9, 2016	
Nov. 10, 2016	Discussion Section: Homework #8
Nov. 11, 2016	Holiday
Nov. 14, 2016	Homework #9 due.
Nov. 16, 2016	
Nov. 17, 2016	Discussion Section: Homework #9
Nov. 18, 2016	Homework #10 due.
Nov. 21, 2016	Settling and Sedimentation.
Nov. 23, 2016	Holiday
Nov. 24, 2016	Holiday
Nov. 25, 2016	Holiday
Nov. 28, 2016	Fluid-particle flow. Dr. Yu Guo, guest lecturer
Nov. 30, 2016	Fluid-particle flow. Dr. Yu Guo, guest lecturer
Dec. 1, 2016	Discussion Section: Homework #10
Dec. 2, 2016	Expression. Homework #11 due.
Dec. 5, 2016	
Dec. 7, 2016	Review.
<b>Dec. 14, 2016</b>	<b>Comprehensive Final Exam (3:00-5:00 PM)</b>