ChE260 – Fluid Flow
Fall 2018
Otto H. York Department of Chemical and Materials Engineering
New Jersey Institute of Technology

Lectures: Tue. & Th., 10:00-11:20 AM, KUPF (Kupfrian Hall) 202
Instructor: Dr. Ecevit Bilgili, Associate Professor & Associate Chair for Undergraduate Study
Contact: 973.596.2998, bilgece@njit.edu
Office Hours: Wed. 08:30-10:00 AM & 5:00-6:00 PM in **Tiernan Hall 373**. Instructor is available for questions at other times via e-mail. Only for personal matters, an appointment must be made a week in advance for a face-to-face meeting, which depends on instructor's limited availability.
Teaching Assistant/Contact: Will be announced during the first week of classes

Course Description and Requirements

ChE260 – Fluid Flow (3-0-3) This course considers the principles of molecular and turbulent transport of momentum, particularly as they apply to pressure drop calculations in piping systems, packed columns, and other flow devices. Flow around submerged objects is also considered.

Prerequisites/Corequisites by Course: ChE 230 (prerequisite), as well as ChE 240 and Math 222 (corequisites). The student must satisfy the pre/corequisites for each course before registering. Please consult with your undergraduate adviser if you have any questions.

Prerequisites/Corequisites by Topic: Calculus (prerequisite), Material Balances (prerequisite), Thermodynamics (prerequisite), Energy Balances (corequisite), Differential equations (corequisite).

Course Objectives

1. Provide students with the knowledge and fundamentals of fluid mechanics as well as the tools/skills needed to design complex flow systems, including packed and fluidized beds
2. Develop mathematical representations (models) of physical phenomena and apply these models to solve engineering problems in fluid mechanics
3. Provide exposure to other engineering topics such as process safety, energy conservation, and pollution prevention in designing fluid flow systems

Learning Materials/Tools

Textbooks: Required: Geankoplis, C. J., "Transport Processes and Separation Process Principles," 4th Edition, Prentice Hall, Upper Saddle River, NJ, 2003. This book is available at NJIT's bookstore.
Strongly Recommended: Schaum's Mathematical Handbook of Formulas and Tables, M.R. Spiegel (with J. Liu), 2nd Ed., McGraw-Hill. Newer editions/other co-authors are all acceptable.

Other Learning Material: The class notes and PowerPoint presentations give a summary of the material, and have been posted on the Moodle webpage. Please print them and bring them along with your book and calculator before coming to each lecture. You will take additional notes on them during the lectures.

Required Software: MS Office, Matlab, Adobe Reader. All software can be downloaded from NJIT IST webpage. Student Mall labs and CME department PC lab have the software.

Calculator: A high-end calculator TI-83, TI-84, or TI-84-SE is required. In general, all students are asked to refer to user manual and web resources for their calculators. The instructor will give support for the above models only. You may use other calculator models, but the instructor will only direct you to online resources and you have to learn how to use them on your own.

Course Outline

Week	Topic
1	Introduction, Fluids, Fluid Statics, Pressure, Differential (Shell) Momentum Balance on Static Fluids, Manometry, Head
2	Molecular Transport, Newton's Law of Viscosity, Shear Viscosity, Non-Newtonian Fluids, Gradients, Introduction to Laminar and Turbulent Flow, Reynolds Number
3–4	Macroscopic Mass–Energy Balances, Continuity Equation, Mechanical Energy Balance, Bernoulli equation, Friction Losses in Mechanical Energy Balance **Exam #1**
5	Momentum Balance in Cylindrical Shell, Hagen-Poiseulle Equation, Momentum Balance in Falling Film, Navier-Stokes Equation, Velocity Distribution in Laminar and Turbulent Flow, Entry Length
6–8	Design Equations for Laminar and Turbulent Flow in Pipes, Friction Factor, Mechanical Energy Losses in Pipes and Fittings **Exam #2**
9	Pumps and Compressors
10	Measurement of Flow, Venturi, Orifices, Pitot Tube
11	Macroscopic Momentum Balance, Forces on Pipes
12	Flow Past Immersed Objects
13	Flow in Packed Beds **Final Exam**

Important: It is conceivable that slight changes in the above outline will take place, depending on the overall performance of the class and on the time actually required to cover the most important subjects.

Assessment/Grading

Quiz/HW — 15%, Exam #1 — 25%; Exam #2 — 25%; Final Exam — 35%

Quiz/HW Assignments: Quizzes will NOT be announced. Once assigned, a HW is due the following week during class time, unless otherwise indicated. You can ask HW related questions as well as other questions/inquiries during the office hours or by sending e-mails.

Your performance will be evaluated on an absolute scale and not relative to the performance of other students in class. Final letter grades will be awarded based on your weighted average score (see weighting above) and a table of average score–letter grade categories (to be posted on Moodle). Attendance may affect your final grade, as described under Policies/Norms.

Important Dates (*Please mark on your calendar, see Timetable document for details***)**

Exam # 1 — Oct. 02; **Exam # 2** — Nov. 01, **Final Exam** — Dec. 15-21, Day TBD by registrar
Cancelled Lectures — Oct. 30 (AIChE Mtg.), Nov. 22 (Thanksgiving Recess)
Set Make-up Lectures — Oct. 15 and Oct. 22 (Mon: 4:00–5:20 PM, Room TBD)
Other make-up lectures for cancellations due to unforeseen circumstances (Any Monday, Common Hours, 4:00-5:20 PM, Room TBD).
Last Day to Withdraw — Nov. 12 (M), no special permission to withdraw thereafter.
Tentative Review Session: Dec. 13 (Th), regular classroom/class time
Reading Days — Dec. 13-14

Course Objectives - ChE 260 Fluid Flow

Obj. 1: Provide students with the knowledge to understand the basic principles of fluid mechanics and the tools needed to design complex flow systems, including piping systems, packed and fluidized beds
Obj. 2: Teach students how to develop mathematical representations (models) of physical phenomena and apply these models to solve engineering problems in fluid mechanics
Obj. 3: Make students aware of the importance of energy conservation in designing fluid flow systems

Strategies and Actions	Student Learning Outcomes	Outcomes	Prog. Obj.	Assess. Methods /Metric*
Introduce basic definitions and properties of fluids and variables used in their study	Students are familiar with field variables of fluid dynamics and can correctly work with their units	a, e (1)	1	EX, HW, SCE, R
Derive and apply overall momentum balance equation to solve fluid static/manometry problems	Students learn to develop correct momentum balance for fluid static problems of various complexity and solve equations for pressure	a, e (1)	1	EX, HW, SCE, R
Introduce basic rheological properties of fluids and solve simple problems based on Newton's Law of Viscosity	Students are familiar with many different types of fluids based on their rheological classification and can calculate shear rate/stress stress	a, e (1)	1	EX, HW, SCE, R
Derive and apply overall mass energy/mechanical energy balance equations to solve fluid dynamic problems	Students can formulate and solve overall balance eqns. for various fluid flow systems and account for frictional losses and haft work	a, e (1)	1	EX, HW, SCE, R
Introduce shell balances; momentum transfer by bulk flow; velocity–shear stress profiles in laminar flow	Students learn to derive and solve the differential eqns. of motion, apply boundary conditions and determine velocity–shear stress	a, e (1)	1	EX, HW, SCE, R, TP
Introduce fanning friction factor and mechanical friction losses based on correlations for different components of piping	Students can calculate the friction losses for all components of pipe systems and/or for more complex arrangements	a, e, k (1)	1	EX, HW, SCE, R
Apply the overall (macroscopic) equations of conservation of mass, momentum and energy; mechanical energy balances to piping systems with fitting	Students learn to calculate mass and volumetric flow rates, design of complex piping systems including losses due to bends and fittings, expansions and contractions	a, e, k (1)	1	EX, HW, SCE, R
Introduce pumps and flow meters and derive appropriate design equations	Students learn how to design pumps and blowers	a, c, e, k (1,2)	1	EX, HW, SCE, R
Develop appropriate balance equations to predict flow past immersed objects	Students can calculate drag coefficient and are capable of formulating/solving overall momentum balance equation for flows past immersed objects	a, e (1)	1	EX, HW, SCE, R, TP
Develop appropriate balance equations to predict flow through beds of materials	Students can formulate/solve overall momentum balance equation for flows in packed beds	a, e (1)	1	EX, HW, SCE, R
Introduce Matlab and calculator to solve problems numerically	Students use Matlab/calculator for numerical solutions of fluid flow problems effectively	a, e, k (1)	1	EX, HW, SCE, R, TP

*EX: exams, HW: homework, SCE: student course evaluations, R: rubrics, TP: term project

Policies, Norms, and Expectations

Academic integrity/honesty is of paramount importance. The NJIT Honor Code will be upheld. Violations will be brought to the immediate attention of the Dean of Students.

If you need accommodations due to a disability, please contact Chantonette Lyles, Associate Director of The Office of Accessibility Resources and Services, Fenster Hall Room 260 to discuss your specific needs. A Letter of Accommodation Eligibility from The Office of Accessibility Resources and Services authorizing your accommodations will be required.

Rules and Expectations during the Lectures/Course

- You are strongly recommended to attend ALL lectures. Attendance sheet must be signed at the beginning of the lecture; otherwise, considered absent. Since the lectures cover many abstract/complex concepts and calculations, even missing a single lecture would cause you to spend enormous time to recover. In this course, there is a significant **correlation between absenteeism and non-satisfactory performance (W, F grades).**
- Please come to the class before the lecture starts or at least ON TIME. Under no circumstances, you should distract your peers and the instructor.
- You are responsible for all information given in lectures (oral, written or handouts, posted notes), whether you are present or not during the lectures.
- No cell phone/laptop use, no video/audio recording, and no eating any time during the lecture. Laptops will only be used when instructed so for few lectures (to be announced).
- Make sure to pair with other students to join in-class group activities (few minutes each). You are expected to participate when asked by the instructor.
- You are expected to behave, communicate, and interact with the instructor and peers with respect and dignity as a candidate, professional chemical engineer.
- **Expectations:** ATTEND all lectures, ASK questions, PARTICIPATE in group activities, SHOW UP during official office hours, DO homework, REVIEW/WORK ON/SOLVE the material of the previous lecture before next class. You are expected to READ the class/posted notes and covered sections of Geankoplis, BRING the printed notes to class along with the calculator, and TAKE additional notes on them during the lectures.
- For success, you have to WORK OUT all derivations and examples in the notes/in-class examples on your own after each lecture. In case of questions, please see the instructor during Office Hours or raise questions in the class. Do not delay this to the exam week.

Rules, Policies and Expectations about Course Materials, E-mails & Office Hours

- The instructor highly encourages all students to show up during the official office hours. You must make your best attempt to meet the instructor during these hours.
- Course notes, HW assignment, HW solutions, etc. have been (will be) posted on the Moodle course webpage. Critical announcements will be made through that system as well. You are required to visit the website on a daily basis to get recent homework assignments/solutions and other relevant announcements. You are expected to bring the relevant notes, the book, and calculator to the class and to take additional supplementary notes in the class.
- E-mail is usually intended for quick questions, not for asking about the whole solution of complex problems. You are first encouraged to check Moodle for information. Then, you should discuss the problems among your peers or study group. In the end, you are welcome to use the Office Hours fully. It is best for students to meet the instructor during the Office Hours and use e-mail for clarifying questions preferably.
- The instructor reserves the right not to respond to all e-mails. Improperly written e-mails with lax attitude will not be replied. If e-mailed questions require more than 5-10 min to

respond, students may be asked to meet the instructor during the office hours. Sometimes, instructor will share student questions with the whole class, keeping the anonymity of the student intact. This will help all class to benefit from such inquiries.

- Instructor-originated information is communicated via e-mail or posted on Moodle (check daily). **You are recommended to print and/or store all e-mails sent by the instructor in a separate folder.**

Policies and Expectations about Exams/Grades

- A letter grade is based on the weighted average score and a table of average score-letter grade categories. Letter grade will be assigned automatically by an Excel code (no emotions attached). The assigned letter grade is FINAL without subject to negotiation!
- You have to plan, study and do well in exams/HW if you want to get a good grade in this class. Instructor will NOT change letter grades to accommodate any special circumstances. The student will get the letter grade he/she deserves.
- You can dispute the exam scores within a week following the announcement of the score. You cannot dispute your prior exams or HWs after one week or at the end of the semester! After first review of the dispute, if the score is not modified, but the student is unconvinced and asks for an additional review, then he/she assumes the possibility of instructor reviewing the whole exam paper and removing points as well as giving points.
- You may be asked to return your graded exam papers within a week for the sake of a department-wide course assessment initiative.
- No extra credit will be allowed (no need to ask) under any circumstances.
- Exams are open notes and open books. You are required to bring notes, the required textbook, any other books on Fluid Mechanics, a Mathematics Handbook and/or comprehensive Advanced Mathematics/Diff. Eqs. Book(s), Math Review Document, and a high-end calculator.
- No cell phones (to be turned off), Ipads, laptops, etc. can be used during the exam.
- You have to write legibly while showing all work; otherwise, loss of points is likely. If two solutions are given for a problem including the correct and incorrect ones, you may be assigned 0 points. You are required to erase or cross out the incorrect solution.
- Students get 0 for no-show to exams. Make-up exams (no make-up quizzes) may only be given under extreme circumstances (e.g., major close-family emergency, serious accident or acute medical problem) at the sole discretion of the instructor. Students bear the responsibility of due proof and documentation to the Dean of Students. It is the student's responsibility to inform the instructor and Dean of Students ASAP.
- Read the Study Guide to be posted before each exam and attend the Review Session (if there is one). Some exam questions can be of multiple-choice type or of assay type requiring verbal explanations, while most others will be derivation type with symbolic manipulation and pure calculation type requiring calculators.
- Show all work, otherwise no partial credit means you cannot simply skip fundamental equations and important intermediate steps during a calculation/derivation. You may lose significant points even if the final answer is correct.
- Read the posting in Moodle titled "Professor, why do I lose points in exams?" before exams so as to learn about potential sources of errors/mistakes students commonly make and how to avoid them.
- There will be no tolerance for unit conversion mistakes; you will lose significant points.

Policies and Expectations about Homework

- Once assigned, HW is due the following week during class time, unless otherwise indicated. Due date is the last date of submission. You may submit HW in an earlier

lecture if you expect that you are unable to attend the lecture in which the HW is due.

- Solved problem sets have already been posted. You are strongly recommended to go over these solved problems as they will help you to solve HW problems that will be posted during the semester and prepare you for the Quiz/Exam. You are allowed to discuss HW problems with peer students, but cannot copy/use their solution directly.
- Late assignments will get 0 independent of the circumstances. Electronic submission will receive 0 score. Make sure you submit the HW at the beginning of the lecture. If you come late to class, do NOT attempt to submit the HW and interrupt the lecture, rather submit HW at the end of the lecture outside the classroom or more preferably put your HW in my mailbox at the CME office by 11:45 AM of the due date. The instructor will NOT collect/grade HW after this cutoff time (no need to submit); students will automatically get 0 for the late HW, and late HW paper will be discarded (if submitted).
- Homework and exam papers must be written legibly in an organized, structured fashion. You are responsible for potential loss of points due to sloppy, unclear, or illegible work on the papers.

Expectations for the Use of Mathematics, Calculators, and Excel/Matlab

- Mathematics is the language of engineers and the course will rely on some background in Calculus and Differential Equations. You are required to read the "Math Review" document and improve on the gap areas. Keep a Math Handbook such as Schaum's Mathematical Handbook handy for study and exams. While going through the course material and solving quantitative and theoretical problems, try to relate to the math in the "Math Review" and Math Handbook.
- In exams, you are required to use high-end calculators for solution of a non-linear equation, linear regression, and spread-sheet calculations. There are examples that make use of TI-83-83-84+SE calculators in the course material. The instructor also provides resources in Moodle, and you have to consult with the user manual and web sources of your specific calculator model.
- You will lose significant points if you are unable to solve a first-order ordinary differential equation (ODE), linear homogeneous second-order ODE with constant coefficients, integrate/differentiate a function analytically, and use your calculators for the aforementioned tasks. So, please consider these math-based expectations seriously.
- Toward obtaining analytical solutions, you should consult with your Math Handbook, Math Review Document, Calculus Textbook, and a Differential Equations Textbook. For numerical problems, you will use your calculator and Excel/Matlab.
- You are recommended to use online resources as well as documents posted on the course Moodle page about the use of calculators, Matlab, and Excel. The instructor will demonstrate each tool with examples, but you have to learn the basics on your own.

Reference Books

- Bird, R. B., Stewart, W. E., and Lightfoot, E. N., "*Transport Phenomena*," 2nd Edition, John Wiley & Sons, New York, 2001.
- Brodkey, R. S., and Hershey, H. C., "*Transport Phenomena—A Unified Approach*," McGraw-Hill, New York, 1988.
- Denn, M. M. "*Process Fluid Mechanics*," Prentice Hall, Englewood Cliffs, NJ, 1980.
- Felder, R.M. and Rousseau, R.W., "*Elementary Principles of Chemical Processes*,"2nd Ed., Wiley.
- McCabe, W.L., Smith, J.C., and Harriott, P., "*Unit Operations of Chemical Engineering*," McGraw-Hill.
- Middleman, S., "An Introduction to Fluid Dynamics," John Wiley & Sons, New York,1998.