Spring 2020

CHE 260-002: Fluid Flow

Ecevit Bilgili

ChE260 – Fluid Flow
Spring 2020
Otto H. York Department of Chemical and Materials Engineering
New Jersey Institute of Technology

Lectures: Tue. & Th., 10:00-11:20 AM, CKB 217
Instructor: Dr. Ecevit Bilgili, Associate Professor & Associate Chair for Undergraduate Study
Contact: 973.596.2998, bilgece@njit.edu
Office Hours: Wed. 08:45-10:00 AM & 4:30-5:45 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;0), 3 credits. 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 give a summary of the material and have been posted on the Canvas course 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. You are responsible for all the materials covered in the class, not just in the notes.

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 must 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 required to cover the most important subjects.

Assessment/Grading

Exam #1: 20%; Exam #2: 20%; Final Exam: 30%; Group Project: 15%, Quiz/HW: 15%

Quiz/HW Assignments: Quizzes will NOT be announced. A quiz has twice the weighting of a HW. Once assigned (announced in class and via Canvas), a HW is due the following week during class time, unless otherwise indicated. You can ask HW related questions as well as any questions regarding the class material and project 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 the 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 Canvas). 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 — Feb. 18; **Exam # 2** — Mar. 31, **Final Exam** — May 08-14, Day TBD by registrar
Project Report Due — Apr. 30 (Class Time)
Cancelled Lectures — Feb. 25 & 27 (FGBSIA Conference), Mar. 17 & 19 (Spring Recess)
Pre-set Make-up Lectures — Mar. 04, W, 2:30-3:50 & Mar. 13, F, 11:30-12:50, Place TBD
Make-up for snow-related cancellations will be held during common hours (Place TBD).
Common Hours — W 2:30-3:50 or F 11:30-12:50.
Last Day to Withdraw — Apr. 06 (M), no special permission to withdraw thereafter.
Tentative Review Session — May 07 (Th), 10:00-11:20 AM, Place TBD
Reading Days — May 06-07

Specific Goals for the Course

The student will be able to

1. define classes of fluids and bring examples of them
2. work with the units of fluid dynamics variables and convert between different unit systems
3. formulate and solve general fluid static/manometry problems using momentum balance
4. define viscosity, formulate and solve simple viscosity problems
5. classify different types of fluids based on their rheological behavior
6. explain laminar and turbulent flows and calculate Reynolds Number
7. formulate and solve overall mass and mechanical energy balance equations for selected fluid dynamic systems
8. formulate shell mass and momentum differential equations for the selected fluid dynamic system
9. solve the momentum differential equation mathematically
10. predict mechanical friction losses based on correlations for different components of pipe systems
11. formulate and solve overall mass and mechanical energy balance equations for flow in pipe systems
12. describe different types of fluid moving devices and their characteristics
13. size (design) a pump based on the use of overall mass and mechanical energy balance equations for flow in pipe systems
14. describe different types of flow measurement devices
15. formulate and solve overall mass and mechanical energy balance equations for different flow measurement devices
16. formulate and solve overall mass and mechanical energy balance equations for flow past immersed objects
17. formulate and solve overall mass and mechanical energy balance equations for flow in packed beds
18. solve equations numerically using appropriate software and writing appropriate code
19. write an effective 6-page report including figures and references, describe, analyze, and discuss a technology/process that had a major impact on society or at a global scale either positively or negatively or both, and speculate on ways that negative results might have been avoided, while clearly explaining how the impact specifically relates to the concepts/equations/approaches of fluid statics and fluid flow or rheology of the fluids, suspensions, etc. involved.

This course explicitly addresses the following student outcomes: 1, 3, 4, 7

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.

Contact Dean of Students and provide evidence for any extenuating circumstance regarding absence from an exam, while informing the instructor.

Policies, Rules, and Expectations during the Lectures/Course

- You are strongly recommended to attend ALL lectures. Sign attendance sheet at the beginning of the lecture; otherwise, consider yourself 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 has been a significant positive **correlation between absenteeism and non-satisfactory performance: W-F-D 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.
- As per ChE department policy, no internet-enabled devices including cell phone/laptop are allowed in class! 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 may come to the office hours individually or together with your study and project groups. 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 Canvas 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 Canvas 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 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 Canvas (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/Quizzes/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 must plan, study and do well in exams/HW/project if you want to get a good grade in this class. Instructor will NOT change letter grades to accommodate any special circumstances of students. 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. Group project is meant to give you the opportunity to raise your letter grade; use it well.
- 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.
- Use of cell phone, smart watch, laptop, or similar in the exams is considered "cheating".
- 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 Canvas titled "Professor, why do I lose points in exams?" before exams 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–Project

- Once assigned, HW is due the following week during class time, unless otherwise indicated. Due date is the last date of submission.
- 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 of HW 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.
- All information about **the Group Project was communicated in the "Project Description, Expectations, Deadlines, and Grading Rubric" document via Canvas. You must read this document ASAP**, follow the instructions therein, form a group, identify a project topic/title, note the deadlines, and visit the instructor during the office hours with your peer group.

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 identified in your Pre-Requisite Knowledge Quiz. 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 Canvas, and you must 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 Canvas webpage about the use of calculators, Matlab, and Excel. The instructor will demonstrate each tool with examples, but you must 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.