Fluid Mechanics

SECTION I: Course Overview

Course Code: CHE350FCO
Subject Area(s): Engineering, Chemical Engineering
Prerequisites: Engineering Mathematics (differential and integral calculus; ordinary differential equations; elementary ideas in vectors like dot products, surface integrals, and volume integrals)
Language of Instruction: English
Total Contact Hours: 60
Recommended Credits: 4

COURSE DESCRIPTION

The overall aim of the course is to introduce students to the physical phenomena of fluid flow and the building of mathematical models of such phenomena. Initial classes are devoted to a comprehensive introduction to fluid mechanics while subsequent classes will focus on applications in chemical engineering. This course will discuss the principles of fluid mechanics as applied to engineering, including aspects such as fluid statics, pressure distribution, and buoyancy. The basic conservation laws of mass, momentum, and energy are analyzed in control volume and differential form. Students will gain an understanding of the Bernoulli equation, pipe flows, flow meters, pumps and compressors, irrotational flows, boundary layer theory, drag force on particles, non-Newtonian fluids. Further they will learn about fluidization, bubble mechanics, flow through porous media, packed beds and fluidized bed as well as filtration.

LEARNING OBJECTIVES

Upon successful completion of this course, you will be able to:

- Develop practical problem solving skills in fluid mechanics through applied mathematics
- Manage mathematical models and solve problems involving various fluid flow situation
- Identify, formulate, and solve engineering problems by using techniques, skills, and modern engineering tools necessary for engineering practice
- Define shear stress, shear rate, and absolute viscosity and identify common classes of fluids
- Write and apply macroscopic mass, energy, and momentum balances on chemical engineering flow processes and systems
- Use differential mass and momentum balance equations to understand pressure and velocity variations
- Use the Navier-Stokes equations and equation of continuity to evaluate shear stress profile, velocity profile, and friction factor for simple one-dimensional flows

- Use Bernoulli equation and macroscopic energy balance to evaluate frictional factor, pressure drop, and size in common fluid flow devices (e.g. pumps, piping, valves)
- Describe boundary layer development for flow over a flat plate, including velocity profile and boundary layer thickness as well as describe the phenomenon of pipe entrance length
- Apply the concept of drag coefficients to evaluate the drag force and settling velocity for spherical and non-spherical particles
- Compute the pressure drop through a packed bed and estimate the minimum fluidization velocity
- Understand the different physical behavior between Newtonian and Non-Newtonian fluids
- Develop an awareness of design criteria and relevant variables which are characteristic for engineering applications
- Analyze flow situations and use appropriate methods to obtain quantitative information for engineering applications.
- Develop creative thinking in solving engineering problems
- Improve competence in effective presentation of technical subjects using verbal, graphical, and written forms of communication

PREREQUISITES

Prior to enrollment, this course requires you to have completed course work related to Engineering Mathematics (differential and integral calculus; ordinary differential equations; elementary ideas in vectors like dot products, surface integrals, and volume integrals).

SECTION II: Instructor & Course Details

INSTRUCTOR DETAILS

Name: TBA
Contact Information: TBA
Term: SUMMER

ATTENDANCE POLICY

This class will meet 4 times weekly for 2 hour sessions. All students are expected to arrive on time and prepared for the day's class session.

CEA enforces a mandatory attendance policy. You are therefore expected to attend all regularly scheduled class sessions, including any field trips, site visits, guest lectures, etc. that are assigned by the instructor. The table below shows the number of class sessions you may miss before receiving a grade penalty.

ALLOWED ABSENCES – SUMMER TERM		
Courses Meeting X day(s) Per Week	**Allowed Absence(s)**	**Automatic Failing Grade at Xth Absence**
Courses meeting **4** day(s) per week	**1** Absence	**4th** Absence

For every additional absence beyond the allowed number, your final course grade will drop down to the subsequent letter grade (ex: A+ to A). As a student, you should understand that the grade penalties will apply

if you are marked absent due to tardiness or leaving class early. In the table below, you will find the grade penalty associated with each excessive absence up to and including automatic course failure.

ATTENDANCE DOCKING PENALTIES				
Absence	**1st**	**2nd**	**3rd**	**4th**
Penalty	**No Penalty**	**0.5 Grade Docked**	**1 Grade Docked**	**Automatic Failure**
HIGHEST POSSIBLE GRADE AFTER ATTENDANCE PENALTIES				
Grade	**A+**	**A**	**A-**	**F**

CEA does not distinguish between excused and unexcused absences. As such, no documentation is required for missing class. Similarly, excessive absences, and the grade penalty associated with each, will not be excused even if you are able to provide documentation that shows the absence was beyond your control. You should therefore only miss class when truly needed as illness or other unavoidable factors may force you to miss a class session later on in the term.

GRADING & ASSESSMENT

The instructor will assess your progress towards the above-listed learning objectives by using the forms of assessment below. Each of these assessments is weighted and will count towards your final grade. The following section (Assessment Overview) will provide further details for each.

Class Participation	**10%**
Homework	**30%**
Midterm Examination	**20%**
Final Examination	**40%**

The instructor will calculate your course grades using the CEA Grading Scale shown below. As a CEA student, you should understand that credit transfer decisions–including earned grades for courses taken abroad–are ultimately made by your home institution.

CEA GRADING SCALE			
Letter Grade	**Numerical Grade**	**Percentage Range**	**Quality Points**
A+	9.70 – 10.0	97.0 – 100%	4.00
A	9.40 – 9.69	94.0 – 96.9%	4.00
A-	9.00 – 9.39	90.0 – 93.9%	3.70
B+	8.70 – 8.99	87.0 – 89.9%	3.30
B	8.40 – 8.69	84.0 – 86.9%	3.00
B-	8.00 – 8.39	80.0 – 83.9%	2.70
C+	7.70 – 7.99	77.0 – 79.9%	2.30
C	7.40 – 7.69	74.0 – 76.9%	2.00
C-	7.00 – 7.39	70.0 – 73.9%	1.70

D	6.00 – 6.99	60.0 – 69.9%	1.00
F	0.00 – 5.99	0.00 – 59.9%	0.00
W	Withdrawal	N/A	0.00
INC	Incomplete	N/A	0.00

ASSESSMENT OVERVIEW

This section provides a brief description of each form of assessment listed above. Your course instructor will provide further details and instructions during class time.

Class Participation (10%): Student participation is mandatory for all courses taken at a CEA Study Center. The instructor will use the rubric below when determining your participation grade. All students should understand that attendance and punctuality are expected and will not count positively toward the participation grade.

CLASS PARTICIPATION GRADING RUBRIC	
Student Participation Level	**Grade**
You make major & original contributions that spark discussion, offering critical comments clearly based on readings, research, & theoretical course topics.	**A+** (10.0 – 9.70)
You make significant contributions that demonstrate insight as well as knowledge of required readings & independent research.	**A/A-** (9.69 – 9.00)
You participate voluntarily and make useful contributions that are usually based upon some reflection and familiarity with required readings.	**B+/B** (8.99 – 8.40)
You make voluntary but infrequent comments that generally reiterate the basic points of the required readings.	**B-/C+** (8.39 – 7.70)
You make limited comments only when prompted and do not initiate debate or show a clear awareness of the importance of the readings.	**C/C-** (7.69 – 7.00)
You very rarely make comments and resist engagement with the subject. You are not prepared for class and/or discussion of course readings.	**D** (6.99 – 6.00)
You make irrelevant and tangential comments disruptive to class discussion. You are consistently unprepared for class and/or discussion of the course readings.	**F** (5.99 – 0.00)

Homework (30%): During the course, three homework assignments will be given for different sets of topics. A maximum of 10% of the total score will be awarded for each completed homework assignment that is turned in on time

Midterm Examination (20%): The midterm exam consists of selected-response items covering course contents from the first half of the term.

Final Examination (40%): The final exam consists of selected-response items covering all course contents.

REQUIRED READINGS

Reading assignments for this course will come from the required text(s) and/or the selected reading(s) listed below. All required readings–whether assigned from the text or assigned as a selected reading–must be completed according to the due date assigned by the course instructor.

I. **REQUIRED TEXT(S)**: You may purchase the required text(s) prior to departure or upon program arrival. The required text(s) are listed below:

Wilkes, James O., (2006), *Fluid mechanics for chemical engineers*, 2nd ed., with microfluidics and CFD, Pearson Education, Inc.

RECOMMENDED READINGS

The recommended reading(s) and/or text(s) for this course are below. These recommended readings are not mandatory, but they will assist you with research and understanding course content.

R. B. Bird, W. L. Stewart and E. L. Lightfoot, *Transport Phenomena* (2nd edition), Wiley Singapore (2002).

M. M. Denn, *Process Fluid Mechanics*, Prentice Hall (1980).

ADDITIONAL RESOURCES

In order to ensure you success abroad, CEA has provided the academic resources listed below. In addition to these resources, each CEA Study Center provides students with a physical library and study areas for group work. The Academic Affairs Office at each CEA Study Center also compiles a bank of detailed information regarding libraries, documentation centers, research institutes, and archival materials located in the host city.

- **UNH Online Library**: As a CEA student, you will be given access to the online library of CEA's School of Record, the University of New Haven (UNH). You can use this online library to access databases and additional resources while performing research abroad. You may access the UNH online library here or through your MyCEA Account. You must comply with UNH Policies regarding library usage.

- **CEAClassroom – Moodle**: CEA instructors use Moodle, an interactive virtual learning environment. This web-based platform provides you with constant and direct access to the course syllabus, daily schedule of class lectures and assignments, non-textbook required readings, and additional resources. Moodle includes the normal array of forums, up-loadable and downloadable databases, wikis, and related academic support designed for helping you achieve the learning objectives listed in this syllabus. The ceaClassroom website is located here: https://www.ceaClassroom.com/

  During the first week of class, CEA academic staff and/or faculty will provide you with your Moodle credentials. They will also help you navigate through the many functions and resources Moodle provides. While you may print a hard copy version of the syllabus, you should always check Moodle for the most up-to-date information regarding this course. The instructor will use Moodle to make announcements and updates to the course and/or syllabus. It is your responsibility to ensure that you have access to all Moodle materials and that you monitor Moodle on a daily basis in case there are any changes made to course assignments or scheduling.

COURSE CALENDAR *Fluid Mechanics*			
SESSION	**TOPICS**	**ACTIVITY**	**READINGS & ASSIGNMENTS**
1	**Introduction to the course Overview of syllabus Classroom Policies**	Lecture & Discussion	
2-3	**Fluid Mechanics in Chemical Engineering, Stresses, Pressure, Velocity, Physical Properties—Density, Viscosity, & Surface Tension**	Lecture & Discussion	Wilkes, pp. 3-25
4-5	**General Conservation Laws, Mass, Energy Balance, Bernoulli's Equation**	Lecture & Discussion	Wilkes, pp. 55-77
6-7	**Momentum Balance, Pressure, Velocity, & Flow Rate Measurement**	Lecture & Discussion	Wilkes, pp. 78-96
8-9	**Models for Shear Stress, Piping & Pumping Problems, Flow in Noncircular Ducts**	Lecture & Discussion	Wilkes, pp. 129-155
10-11	**Compressible Gas Flow in Pipelines, Compressible Flow in Nozzles, Pumps & Compressors**	Lecture & Discussion	Wilkes, pp. 156-163; 188-193
12-13	**Drag Force on Solid Particles in Fluids Flow Through Packed Beds, Filtration**	Lecture & Discussion	Wilkes, pp. 194-214

14	**Fluidization, Cyclone Separators, & Sedimentation**	Lecture & Discussion	Wilkes, pp. 215-223
15	**MIDTERM EXAMINATION**		
16-17	**The Convective Derivative, Differential Mass Balance, Differential Momentum Balances, Newtonian Stress Components in Cartesian Coordinates**	Lecture & Discussion	Wilkes, pp. 266-285
18-19	**Rotational & Irrotational Flows, Steady Two-Dimensional Irrotational Flow, Examples of Planar Irrotational Flow**	Lecture & Discussion	Wilkes, pp. 356-378
20-21	**Uniform Streams & Point Sources, Doublets & Flow Past a Sphere, Single & Two-Phase Flow in Porous Media**	Lecture & Discussion	Wilkes, pp. 380-396
22-23	**Simplified Treatment of Laminar Flow Past a Flat Plate, Simplification of the Equations of Motion, Blasius Solution for Boundary-Layer Flow, Turbulent Boundary Layers**	Lecture & Discussion	Wilkes, pp. 414-432
24-25	**Boundary-Layer Separation, Polymer Processing, Thin Films and Surface Tension**	Lecture & Discussion	Wilkes, pp. 433-458
26-27	**Rise of Bubbles in Unconfined Liquids, Pressure Drop & Void Fraction in Horizontal Pipes, Two-Phase Flow in Vertical Pipes**	Lecture & Discussion	Wilkes, pp. 531-554
28-29	**Introduction to Fluidization, Bubble Mechanics, Classification of Non-Newtonian Fluids**	Lecture & Discussion	Wilkes, pp. 559-572; 591-594

The instructor reserves the right to make changes or modifications to this syllabus as needed

30	**FINAL EXAMINATION** **FINAL EXAM COVERS ALL MATERIAL IN THE COURSE**

SECTION III: CEA Academic Policies

The policies listed in this section outline general expectations for CEA students. You should carefully review these policies to ensure success in your courses and during your time abroad. Furthermore, as a participant in the CEA program, you are expected to review and understand all CEA Student Policies, including the academic policies outlined on our website. CEA reserves the right to change, update, revise, or amend existing policies and/or procedures at any time. For the most up to date policies, please review the policies on our website.

Class & Instructor Policies can be found here
General Academic Policies can be found here