Chemical Engineering Fluid Mechanics

University of Colorado – Department of Chemical Engineering
CHEN 3200 – Spring 2002

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Office Hours: Tuesday 3:30PM – 5:30 (Hrenya) and Wednesday 12PM-2 (TA)

TA's: Steven Dahl (steven.dahl@colorado.edu) will be responsible for grading weekly assignments and holding office hours (ECCH 175). If there are questions on course material, please contact Christine Hrenya or Steven Dahl via office hours, email, or individual appointment. You can also stop by my office without an appointment, but I may have to postpone if that time is inconvenient.

Text: Fox, R. W. and McDonald, A. T., Introduction to Fluid Mechanics, 5th edition, Wiley, New York, 1999.

Handouts: At the beginning of class, detailed handouts covering the day's material will be passed out to each student. These notes are a primary resource for course material. At the end of the semester, each student will be assessed copying charges for these handouts. Total cost per student is expected to be about $25.

Email: A course e-mail list has been established, and all students are required to subscribe. To do so, send an e-mail message to listproc@lists.colorado.edu with the following contents in the body of the message:

subscribe chen-3200 full-name-of-student

Although most course information will be transmitted during classtime, email will be used for various announcements regarding homework questions, feedback on exams, etc. Thus, students are expected to check their email on a regular and frequent basis.

Prereq: CHEN 2120 (or MCEN 2022), APPM 2350 (or APPM 2360), GEEN 1300 (or CSCI 1300)
Coreq: APPM 2360 (or APPM 2350, if APPM 2360 has been completed and APPM 2350 has not)

Learning Goals

The overall aims of this course is to (i) formulate chemical-engineering fluids problems in mathematical terms by employing the appropriate balances and/or correlations, (ii) to solve the resulting equations using an appropriate solution method, and (iii) to analyze experimental and theoretical results in both a qualitative and quantitative manner.

Learning Activities

Lectures – meet every Tuesday and Thursday at 8:00 – 9:15 AM in ECCR 105

Homework

- Weekly assignments will be handed out one week before the due date and are due at the beginning of class. The assignments will generally be due on Thursday. Late homeworks will not be accepted since the solutions will be posted in the glass cabinet (across the hall from ECCH 104) the day which the homeworks are due.
- Although the total points of various homework sets may vary, all will be normalized and weighted equally at the end of the course.
- Each student will hand in her/his own homework assignment. Discussion of homework problems with fellow students is allowed and encouraged; however, direct copying from *any* source is not permitted. If it is believed that a homework set has been graded unfairly, please resubmit within one week for re-grade of entire assignment.

Project

- A group project will be due during the final week of the semester. This project will be twofold in nature. First, the group will be asked to present an overview of a recent research project involving computational fluid dynamics. Second, the group will be responsible for developing a "review problem" for the final exam along with its solution; the topic for this problem will be assigned by the instructor. A compilation of these review problems will be available to all students prior to the final exam. Further details and guidelines on the project will be passed out during the semester.

Exams

- The exams will be given during a 2-hour period outside of the scheduled class time. All exams will be composed of two sections. The first section will be closed-book, and should take roughly 1/4 of the total exam time. The second portion of the exam will be open-everything (i.e., notes, homework, text)
- The exams will have problems similar to those on the homework assignments; therefore, students who have mastered the course material through the homework assignments will probably do quite well on the exams, and students who shortchange the homeworks with also come up short on the exams. The final exam will be comprehensive, covering the entire course material.
- No make-up exams will be given. If there is an extreme emergency, contact me *before* exam date for permission to be excused. If excused, the final exam grade will be used in place of the missed exam. If the final exam is excused, the grade on the previous exams will be averaged and used in place of the final exam. If more than one exam is missed, an incomplete/fail will be given for the course.
- Exam solutions will be posted in the glass cabinet after the exams are returned. If it is believed that an exam has been graded unfairly, please resubmit within one week for re-grade of entire exam.

Grading

Final course grades will *not* be curved. Instead, the grade will be determined based on the distribution and scale shown below, with plus and minus grades assigned for scores near the cutoffs. Class participation will also be factored into the final course grade for borderline cases.

Homework	25%	A	85-100
Project	10%	B	75-85
Exam 1	20%	C	65-75
Exam 2	20%	D	55-65
Final Exam	25%	F	0-55

Important Dates

February 27 (Wed)	Exam #1 (6:30-8:30 PM in ECCR 245)
March 26 and 28	Spring Break (no classes)
April 3 (Wed)	Exam #2 (6:30-8:30 PM in ECCR 245)
May 4 (Sat)	Final Exam (4:30-7:00 PM in ECCR 105)

Deadlines and Late Work

As a general rule, late work is not accepted. Assignments are due at the beginning of class, and are late if handed in after that time. Exceptions are made in the case of illness, only if proper documentation of the illness is provided. Arrangements should be made in advance in the case of trips out of town. Work will normally be due in advance of such trips.

Quality and Presentation of Written Work

Written work in this course must satisfy a quality standard. If it does not, it will be returned to the student ungraded and a zero grade will be recorded. Presentation must be neat and organized. Problem solutions involving derivations and calculations must include explanatory comments between steps and results must be set off clearly. The units must be clearly labeled. Homework assignment solutions must be on engineering paper if hand-written or on white paper if typed or computer-printed. Multiple pages must be stapled in the upper left corner. Take the time to make your work presentable!

Academic Ethics

If a student violates academic ethics in this course, the consequences will be an automatic F in the course, a letter of reprimand placed in the student's College file, and referral of the matter to the Committee on Undergraduate Academic Affairs for possible further action. The basic rule is that a student may not present as their own the work of another student nor allow their own work to be presented as the work of another student. In group work, all members are required to participate fully in the assignment.

Approach to Problem Solution

Chemical Engineering Fluid Mechanics
CHEN 3200 – Spring 2002

The following step-by-step approach to problem solution is highly recommended for all work in this course. As steps #1-6 are most important for the *learning* of the material, the majority of points will be placed on these steps.

1.) Restate, in a concise fashion, the information that is given in the problem statement. For quantities in which the nomenclature is not obvious, be sure to define accordingly.

2.) Draw a schematic diagram of the physical system under consideration. Label each of the quantities pertaining to the diagram, including distances, fluid properties, boundaries, etc. Also, define the coordinate direction.

3.) Identify what information needs to be found.

4.) List the appropriate mathematical relationships (force balance, momentum balance, ideal gas law, etc.) necessary to solve the problem.

5.) List all assumptions (steady-state, incompressible fluid, etc.) appropriate to problem.

6.) Solve the governing equations to completion (integration, solution of algebraic expressions, etc.) prior to the substitution of numerical values.

7.) Substitute known numerical values using a consistent set of units, and solve for the numerical quantity of interest. Make sure that the number of significant digits is consistent with the data, and draw a box around the final answer.

8.) Are the results reasonable (i.e., do they make physical sense)? Are the assumptions used in problem solution valid? If not, re-work problem without the invalid assumptions.

Tentative Course Schedule and Outline

Chemical Engineering Fluid Mechanics
CHEN 3200 – Spring 2002

Lecture #	Topic
1	Introduction to course
2-3	Basic concepts
4-6	**1. Fluid statics**
7-11	**2. Macroscopic (or integral) balances for fluids in motion**
12-16	**3. Microscopic (or differential) balances for fluids in motion**
17-18	**4. Dimensional analysis**
	5. Special Flow Systems
19-20	5.1 Incompressible, inviscid (or inertial) flows
21-23	5.2 Incompressible, viscous flows
	6. Special Topics
24	6.1 Comutational fluid dynamics (CFD)
25	6.2 Turbulence
26	6.3 Boundary-layer theory
27	6.4 Non-Newtonian fluids
28	Review (optimistic) or catch-up (pessimistic)
29-30	Project Presentations

Lecture	Date	Topic
1	Jan 15	**Introduction to Course** *Reading: pp. 1-12, 16-19*
2	Jan 17	**Basic Concepts I** *HW #1: 1.11 (no uncertaintly analysis), 1.20, 1.22, 1.30a*
3	Jan 22	**Basic Concepts II**
4	Jan 24	**1.1 Fluid Statics:** derivation of pressure-height relation; manometers *Reading: pp. 23-29, 36-38, 49-63* *HW #2: 2.27 (do not specify direction), 2.34 (assume linear vel. prof. in film), 3.13, 3.18, 3.20*
5	Jan 29	**1.2 Fluid Statics:** hydrostatic force on a submerged surface
6	Jan 31	**1.3 Fluid Statics:** buoyancy / stability **(TRAVEL: UF winter school)** *Reading: pp. 100-114 (not 4-1.4 and 4-1.5)* *HW #3: 3.5, 3.7, 3.40, 3.42, 3.50, 3.73 (find displacement volume instead of equil. position)*
7	Feb 5	**2.1 Integral Balances:** Reynolds Transport Theorem
8	Feb 7	**2.2 Integral Balances:** Mass Balance *Reading: pp. 114-133, 146-154* *HW #4: 4.19, 4.22, 4.33*
9	Feb 12	**2.2 & 2.3 Integral Balances:** Mass Balance & Linear Momentum Balance
10	Feb 14	**2.3 Integral Balances:** Linear Momentum Balance *Reading: pp. 207-221* *HW #5: 4.38, 4.41., 4.49, 4.57* **(midterm evaluations)**
11	Feb 19	**2.3 Integral Balances:** Linear Momentum Balance *(did not cover integral angular momentum balance in lieu of more linear momentum examples before exam – only two of these are contained on HW #5)*
12	Feb 21	**3. Differential Balances:** Basic Concepts – Kinematics *Reading: pp. 195-203* *No HW in lieu of exam next week…*
13	Feb 26	**3. Differential Balances:** Mass Balance
---	Feb 27	**EXAM 1 (evening)**
14	Feb 28	**CLASS CANCELLED (day after exam)** *Reading: pp. 221-231* *HW #6: 5.1, 5.5, 5.10, 5.16, 5.34, 5.43, 5.45, 5.47*
15	Mar 5	**3. Differential Balances:** Momentum Balance (Navier-Stokes derivation)
16	Mar 7	**3. Differential Balances:** Momentum Balance (use of Navier-Stokes) *Reading: pp. 241-247, 248-257* *HW #7: 5.81, 5.82, & extra problem (pipe flow)*
17	Mar 12	**4.1 Incompressible, Inviscid Flows:** Bernoulli equation derivation
18	Mar 14	**4.1 Incompressible, Inviscid Flows:** Bernoulli equation – demos & example problems *Reading: pp. ??* *HW #8: 6.30, 6.32, 6.35 (assume Vair outside tunnel ~0) 6.36, 6.41*
19	Mar 19	**4.1 Incompressible, Inviscid Flows:** Bernoulli vs. CV: critical assessment of assumptions
20	Mar 21	**4.1 Incompressible, Inviscid Flows:** Bernoulli: more examples!!! *Reading: pp.*
21	Apr 2	**Special Topic: Dimensionless Analysis**
---	Apr 3	**EXAM 2 (evening)**
22	Apr 4	**CLASS CANCELLED (day after exam)** *Reading: pp. 332-333, 354-381* *HW #9: 7.1, 7.6, 7.15, 7.34, 7.36, 7.46*
23	Apr 9	**Special Topic: Dimensional Analysis & Turbulence**

24	Apr 11	**4.2 Incompressible, viscous flows (Steve guest lecture)** *HW #10: 8.1, 8.4, 8.6, 8.74, 8.78, 8.80, 8.86, 8.89*
25	Apr 16	**4.2 Incompressible, viscous flows**: Head loss Demonstration & Contest
26	Apr 18	**FTEP Course Interview (Susan Avery)** *Reading: pp. 332-333* *HW #11: 8.100, 8.103, 8.105, 8.114, 8.118*
27	Apr 23	Flows over submerged objects **TRAVEL: MFDRC**
28	Apr 25	**Special Topic: CFD**
29	Apr 30	Project Presentations
30	May 2	Project Presentations
	May 4	**FINAL EXAM** (Saturday: 4:30-7:00 PM – ECCR 105)