Chemical Engineering 356
Transport Phenomena I (Fluid Mechanics)
Spring 2010

Instructor: I.C. Schneider, 3053 Sweeney Hall, (515) 294-0450, ians@iastate.edu

Lecture: MWF 11:00-11:50, Sweeney Hall 1134

Office Hours: (tentatively) WR 1:00-3:00

Prerequisites: ChE 210 (mass and energy balances), Phys 221 (force balances), credit or enrollment in Math 267 (vectors and differential equations)

Text and Materials: Denn, *Process Fluid Mechanics*, Prentice-Hall (1980) and McCabe, Smith and Harriot, *Unit Operations of Chemical Engineering*, Seventh Edition, McGraw-Hill (2005). A good supplementary text is Bird, Stewart and Lightfoot, *Transport Phenomena*, Second Edition, Wiley (2002).

Course Description: This course is the first of three courses in the chemical engineering curriculum that deals exclusively with transport phenomena. What are transport phenomena? These are physical mechanisms by which momentum, heat and mass are transported from one point in space to another point in space over a given time period. These physical mechanisms can be caste into mathematical models that can be used to predict the behavior of transport phenomena in different situations. Chemical engineers use these mathematical models to both design and guide the operation of chemical processes. This class specifically deals with momentum (mass x velocity) transport and is focused on how momentum is transported within fluids (liquids and gases) and how forces are exerted at fluid-solid interfaces. Thus, momentum transport is also referred to as fluid mechanics in the chemical engineering curriculum. Fluid mechanics builds on your understanding of force balances from physics and mass and energy balances from ChE 210. The class is roughly broken up into two sections: macroscopic balances and microscopic balances. Macroscopic balances, in general, allow one to determine pressure drops in systems where detailed information on the fluid velocity is not needed. Microscopic balances, in general, allow one to determine the spatially-dependent fluid velocities that are important in understanding heat and mass transport rates in specific systems. This is the first chemical engineering course in which you will get to flex your mathematical muscles. However, the course is designed so that the more challenging mathematical problems are gradually presented addressed in the second half of the class.

Grading:

Exam I	15%
Exam II	15%
Exam III	15%
Home Problems	20%
Design Project	15%
Final Exam	20%

If you feel that the grade you received for homework or an exam was incorrect or unfair, submit to me a typed document outlining the reason why you think the grade to be incorrect or unfair. I will evaluate the request and regrade the entire homework or exam, not just the section in question.

Homework: Weekly homework will consist of one individual problem and several group problems. The groups will consist of 3 or 4 members and only one copy of the group problem solutions is to be submitted. The solutions should include the name of all of those members that contributed substantially to the solutions. Those that did not contribute and do not have their name on the group homework will be assigned a zero. Also, group evaluations will be given after each test and these evaluations will affect the group portion of your homework grade. Groups are intended to facilitate learning, not hinder it. You are not a company, so delegation of problems is not constructive and everyone is expected to contribute equally to the homework even though one copy is submitted. You are free to consult members of your homework group, the text, class notes, or me without reference, any other source needs to be referenced. After each test the class may vote on whether groups should be changed. Homework will be assigned on Monday and will be due on Friday at the beginning of class. Late homework will not be accepted unless there is a good reason and I approve of it before the homework is due. Handing in virtual copies of solutions of the same homework problems from previous course offerings or from other students or groups is plagiarism and is not permitted.

Exams: Exams will be closed book. I will only answer questions about the exams during the class hour, so that everyone has the benefit of hearing them. I will provide reference materials that you will need in order to solve the exam problems. Makeup exams will not be given, except for illnesses on the day of the exam.

Design Problem: There will be a design problem due at the end of the semester and the problem will be solved in groups of three. Specific information on the design project will be given midway through the semester.

Expectations and Academic Honesty: I expect you to show up and show up on time to class and remain in class until dismissed. Any absences from class should be brought to my attention at least one day before, barring family emergencies or illnesses. Please turn off your cell phones before class and cell phone use during class is not tolerated. With the prevalence of H1N1 flu this season, if you are running a fever and are knowingly sick, do not come to class. A doctor's note is not required, but please let me know.

Both the University and Departmental Student Handbooks and the University Catalog contain policy statements with which you should be familiar. The simplest statement of what is there is that anything you turn in under your name is to be your work and not that of others. If others have contributed (knowingly or unknowingly) they need to be referenced.

Course Objectives:

1. Learn how to formulate and solve hydrostatics problems.

2. Develop an understanding of the anomalous behavior of non-Newtonian fluids such as paint, blood, polymers and suspensions.

3. Estimate drag forces on falling or submerged objects.

4. Learn how to predict the relationships between flow rate, pressure changes, pipe diameter and length, and fluid properties for simple and complex pipe networks.

5. Learn how to determine the flow-pressure relations for flow through packed beds.

6. Gain some physical understanding of turbulence and how it affects drag forces and pressure changes.

7. Learn how to apply conservation of mass, momentum, and energy to finite control volumes.

8. Learn how to apply the principles of conservation of mass and momentum to differential control volumes to derive differential equations describing fluid motion.

9. Learn how to properly select boundary conditions to solve the differential equations of motion.

10. Learn how to reduce the generalized equations of motion in various coordinate systems to describe a specific problem.

11. Describe boundary layers and develop methods to calculate the velocity profiles and shear stresses in them.

Course Outline:

Date	Topic	Readings	Problems
Jan 11	Policies, Objectives, Introduction, Fluid Statics	D1, M2	
13	Fluid Statics	M2	
15	Newtonian Fluids	D2	
18	***Martin Luther King, Jr. Day***		
20	Non-Newtonian Fluids, Flow Past Objects	D2	HW 1
22	Flow Past Objects, more Fluid Statics	D4	
25	Flow in Pipes (hydraulic diameter)	D3	HW 2
27	Flow in Pipes (roughness)	D3	
29	Flow in Packed Beds	D4	HW 3
Feb 1	Flow in Packed Beds	D4	
3	Review for Exam I		HW 3.5
5	**Exam I**		
8	Macro. Bal. Derivations (eng. and mass)	D5	
10	Applications (eng. and mass)	D6	
12	Applications (eng. and mass)	D6	
15	Applications (open channel flow)	D6	HW 4
17	Macro. Bal. Derivations (Mom.), Applications (mom. and mass)	D6	
19	Applications (mom., eng. and mass)	D6	HW 5
22	Transient Problems, Compressible Flow	D6, M6	
24	Flow Meters	M8	
26	Reviewed Sprayer HW problem		HW 6
Mar 1	Review for Exam II		
3	Flow Meter Demonstration		HW 6.5
5	**Exam II**		
8	Pumps	M8	
10	Microscopic Balances (mass)	D7	
12	Microscopic Balances (vector, tensor, shell balance)	D8	HW 7
15	***Spring Break***		
17	***Spring Break***		
19	***Spring Break***		
22	Applications (shell balance)	D8	
24	**Design Problem**		
26	Applications (shell balance)	D8	
29	Applications (shell balance)	D8	HW 8
31	Microscopic Balances (Navier-Stokes)	D7	
Apr 2	Applications (Navier-Stokes)	D8	HW 9
5	Creeping Flow	D12	
7	Creeping Flow	D12	
9	Stream Function/Vorticity/Potential Function	D14	HW 10
11	Boundary Layers	D15	
14	Boundary Layers	D15	
16	Turbulence	D16	
	VEISHEA		
19	Review for Exam III		
21	**Exam III**		
23	Viscoelasticity	D19	
26	Review for Final Exam		Design Problem
28	Review for Final Exam		
30	Review for Final Exam		
May 4	**Final Exam (tentative)**	Tue., 9:45 -11:45 a.m	