Particle Technology

University of Colorado – Department of Chemical Engineering
CHEN 4838/5838 – Fall 2002

Instructor: Christine Hrenya
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Office Hours: Monday 4:30 – 6:00 PM and Wednesday 3:30 – 5:00 PM (Hrenya office)

TA's: Brent Rice (randall.rice@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 Brent Rice 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: M. Rhodes, Introduction to Particle Technology, Wiley, New York, 1998.

Handouts: This course will utilize a large number of handouts, to be distributed during the class period. 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-5838 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 3200 (Fluid Mechanics) and APPM 2360 (Differential Equations)

Learning Goals

The overall aims of this course is to (i) identify the important physical mechanisms occurring in processes involving particles, (ii) formulate and solve mathematical descriptions of such processes, (iii) analyze experimental and theoretical results in both a qualitative and quantitative manner, (iv) apply this knowledge to the design of particulate systems, and (v) be able to convey the breadth and depth of natural and industrial applications involving particulates.

Learning Activities

Lectures – meet every Tuesday and Thursday at 12:30 – 1:45 PM in ECCR 155

Homework

- Assignments will be handed out one week before the due date and are due at the beginning of class. Approximately 10 homework sets will be assigned during the semester. 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.

Laboratory Experiments

- During the course of the semester, small groups of students will each conduct 2-3 laboratory experiments. Since a separate laboratory section is not scheduled as part of the course, a lecture period will be cancelled in lieu of the required experiment, and the experiment will be performed by consecutive groups of students on that day. A sign-up sheet of available times to perform the experiment will be passed out ahead of time for scheduling purposes.

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, though the emphasis will be on new material covered since the previous exam.
- No make-up exams will be given. If there is an extreme emergency, contact me *before* exam 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.

Project

- *For graduate students only*, a group project will be due during the final week of the semester. The project will be centered around an open-ended question related to particle technology. Topics can be chosen from a list provided by the instructor or generated by group members and approved by the instructor. Only one group is allowed per topic. Both a written report and oral presentation will be required. Further details and guidelines on the project will be passed out during the semester.

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.

For undergraduate students:	Homework	35%	A	85-100
	Exam 1	20%	B	75-85
	Exam 2	20%	C	65-75
	Final Exam	25%	D	55-65
			F	0-55
For graduate students:	Homework	25%		
	Project	10%		
	Exam 1	20%		
	Exam 2	20%		
	Final Exam	25%		

Important Dates

October 8 (Tues)	Exam #1 (6:30-8:30 PM in ECCR 1B55)
October 10 (Thurs)	Fall Break (no classes)
Nov 12 (Tues)	Exam #2 (6:30-8:30 PM in ECCR 1B55)
November 28 (Thurs)	Thanksgiving Break (no classes)
December 13 (Fri)	Final Exam (1:30 – 4:00 PM in ECCR 155)

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. 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 file, and referral of the matter to the Committee on Undergraduate Academic Affairs or the Graduate School for possible further action. The basic rule is that a student may not present as their own the work of another student (or another source), 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.

Disabilities

Students with disabilities who qualify for academic accommodations must provide a letter from Disability Services (DS) and discuss specific needs with the professor, preferably during the first two weeks of class. DS determines accommodations based on documented disabilities (303-492-8671, Willard 322).

Observance of Religious Holidays

If course attendance or an exam date conflicts with the observance of a religious holiday, the student must notify the instructor at least two weeks in advance so that appropriate accommodations can be made.

Classroom Behavior

The University policy for classroom behavior is located at http://www.colorado.edu/policies/index.html. All students are required to read this document.

References

A list of useful references is given below. I have a copy of each of these books, and will lend them out for several hours upon request.

Bird, R. B., W. E. Stewart and E. N. Lightfoot, *Transport Phenomena,* John Wiley & Sons, Inc., New York (2002).

Clift, R., J. R. Grace and M. E. Weber, *Bubbles, Drops, and Particles,* Academic Press, New York (1978).

Chaouki, J., F. Larachi and M. P. Dudukovic (eds.), *Non-invasive Monitoring of Multiphase Flows*, Elsevier, New York, (1997).

Chapman, S. and T. G. Cowling, *The Mathematical Theory of Non-Uniform Gases,* Cambridge University Press, Cambridge (1970).

Fan, L.-S. and C. Zhu, *Principles of Gas-Solid Flows,* Cambridge University Press, New York (1998).

Gidaspow, D., *Multiphase Flow and Fluidization,* Academic Press, San Diego (1994).

Grace, J. R., A. A. Avidan and T. M. Knowlton (eds.), *Circulating Fluidized Beds*, Blackie Academic & Professional, New York, (1997).

Israelachvili, J., *Intermolecular and Surface Forces,* Academic Press, New York (1992).

Jackson, R., *The Dynamics of Fluidized Particles,* Cambridge University Press, New York (2000).

Johnson, K. L., *Contact Mechanics,* Cambridge University Press, New York (1985).

Kunii, D. and O. Levenspiel, *Fluidization Engineering,* Butterworth-Heinemann, Boston (1991).

Roco, M. C. (eds.), *Particulate Two-Phase Flow*, Butterworth-Heinemann, Boston, (1993).

Seville, J. P. K., U. Tuzun and R. Clift, *Processing of Particulate Solids,* Blackie Academic & Professional, New York (1997).

References on Aerosols (not covered in class)

Friedlander, S. K., *Smoke, Dust, and Haze,* Oxford University Press, New York (2000).

Hinds, W. C., *Aerosol Technology,* John Wiley & Sons, New York (1982).

Seinfeld, J. H., *Atmospheric Chemistry and Physics of Air Pollution,* John Wiley & Sons, New York (1986).

Tentative Course Schedule and Outline

Particle Technology
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Lecture #	Topic
1	Introduction to course
2	Basic concepts
3	Single particle in fluid
4	Multi-particle systems
5-6	Particle characterization
7	Packed bed flow
7-9, 13-14	Fluidization
10-12	Storage and flow of powders
15-16	Mixing and segregation
17-18	Pneumatic transport
19	Granulation
20-28	Special Topics
	Applications in pharmaceutical biotechnology
	Contact Mechanics
	Modeling (continuum vs. discrete, kinetic-theory models, discrete-element simulations)
29-30	Project Presentations