Particle Technology

University of Colorado – Department of Chemical Engineering
CHEN 4650/5650 – Spring 2017

Instructor: Christine Hrenya

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Text: M. Rhodes, <u>Introduction to Particle Technology (Second Edition)</u>, Wiley, New York, 2008.

Supp: Course Packet for CHEN 4650/5650, available at CU bookstore.

Email: All students who are registered for the course are automatically subscribed to a course email list. 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.

Web site: A course website will be established through Desire2Learn. This web site will contain some basic information on the course, but is not intended to duplicate all announcements, deadlines, etc. communicated during class or via email.

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 4-5:15 PM in BIOT A104. As a courtesy to the instructors and your fellow classmates, all cell phones, text messaging devices, music players, etc. that can cause distractions during the lecture should be turned off. If you need to receive or make a communication during this time, please do so outside of the lecture room.

Homework
- Assignments will be handed out one week before the due date and are due at the beginning of class. Homeworks may consist of problem solving, reading of literature articles and/or (announced) follow-up quizzes on such reading assignments. Approximately 10 homework sets will be assigned during the semester. Late homeworks will not be accepted since the solutions will be posted on a course web site immediately following the class period in which they are due. Arrangements should be made in advance in the case of trips out of town. Work will normally be due in advance of such trips.

- Although the total points of various homework sets may vary, all will be normalized and weighted equally at the end of the course. At the end of the semester, the lowest homework grade will be dropped, and no exceptions will be made to drop additional homeworks.

- 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.

- On the front page of each homework set, the CU honor pledge should be written and signed by the student. The specific text for the pledge is "On my honor, as a University of Colorado at Boulder student, I have neither given nor received unauthorized assistance on this work."

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 light 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). Note that for "open" portion of the exam, electronic devices other than calculators are not allowed.

- The exams will have problems analogous (but different!) 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 emphasis of the final exam will be on new material covered since the previous exam (though some previously covered material may be integrated for areas in which new material builds on previous knowledge). For practice, exams from previous years will be posted to the course web site.

- 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 on the course web site immediately following the exam. If it is believed that an exam has been graded unfairly, please resubmit within one week for re-grade of entire exam.

Project
- All students will have a mid-semester, small-group project, which will be counted as a separate homework grade. Details and guidelines on the project will be passed out during the semester.

- *For students enrolled in CHEN 5650 only,* a final project will be due during the final week of the semester. 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%			
	Final Project	10%			
	Exam 1	20%			
	Exam 2	20%			
	Final Exam	25%			

Important Dates

Feb 20 (Mon)	Exam #1 (6-8:00 PM in BIOT A108)
Apr 10 (Mon)	Exam #2 (6-8:00 PM in BIOT A108)
Mar 28 (Tues)	Spring Break (no classes)
Mar 30 (Thurs)	Spring Break (no classes)
May 11 (Thurs)	Final Exam (1:30-4:00 PM in BIOT A104)

Quality and Presentation of Written Work

Written work in this course must satisfy a quality standard. If it does not, points may be deducted. 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, and the final solution should be boxed. 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 Honor Council 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.

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy of the institution. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at http://honorcode.colorado.edu.

Classroom Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the student code.

Disabilities

If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by email at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary Injuries guidelines under the Quick Links at the Disability Services website and discuss your needs with your professor.

Observance of Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, 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. See the campus policy regarding religious observances for full details.

Discrimination and Harassment

The University of Colorado Boulder (CU Boulder) is committed to maintaining a positive learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age,

disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website.

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).

Crowe, C., M. Sommerfeld, and Y. Tsuji, *Multiphase Flows with Droplets and Particles*, CRC Press, New York (1998).

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).

Kaye, B. H., *Powder Mixing*, Chapman & Hall, New York (1997).

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).

Yang, W.-C. (ed.), *Handbook of Fluidization and Fluid-Particle Systems*, Marcel Dekker, Inc., New York (2003).

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
CHEN 4650/5650 – Spring 2017

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
7-10	Fluidization
11-12	Pneumatic Transport
13-15	Storage and Flow from Hoppers
16-17	Mid-semester Project Presentations
18-27	Special Topics
	Modeling (continuum vs. discrete, kinetic-theory models, discrete-element simulations)
	Short-Range Forces
	Contact Mechanics
28-29	Graduate Student Project Presentations
30	Course Summary / Review