New Jersey Institute of Technology
Otto H. York Department of Chemical Engineering

Course: PhEn 606 Pharmaceutical Unit Operations: Solids Processing (3 credits)

Instructor: Dr. Boris Khusid
Professor, Otto H. York Department of Chemical, Biological & Pharmaceutical Engineering
FMH 215, Tel: 973-596-3316, Fax: 973-596-8436, E-mail: khusid@adm.njit.edu
http://chemicaleng.njit.edu/people/khusid.php

Course description: The course focuses on fundamentals of particulate processing, such as the particle characterization, blending, milling, granulation, tableting, and coating. The emphasis is on the application of macro- and micro-scale models of granular materials to quantify and scale up manufacturing pharmaceutical processes.

The course combines lectures, problem-solving, and project assignment to provide students with
- Fundamentals of particulate processing in pharmaceutical technology
- Societal and economic impacts of pharmaceutical powder technologies
- Ability to communicate effectively the acquired knowledge in written & verbal form

The course objectives
- Identify the fundamental macro- and micro-scale phenomena underlying particulate processing
- Introduce the basic operating principles of solids processing units
- Apply basic concepts to analyze and scale up manufacturing pharmaceutical processes

Course outline
- Introduction - Pharmaceutical Powder Technology
  - Main Challenges of Pharmaceutical Technologies
  - FDA Process Analytical Technology Initiative

- Particle & Granule Micrometrics
  - Particle Size Characterization
  - Static and Dynamic Powder Sampling
  - Particle Size Measurement
  - Characterization of the Powder Bed Density, Porosity, Permeability, and Surface Area

- Continuum Mechanics of Particulate Solids
  - Flow of Powders
    - Flow of Granular Materials
    - Mohr’s Circle for Normal and Shear Stresses
    - The Mohr-Coulomb Failure Criterion
    - Active and Passive Rankine States
    - Angle of Repose
    - The Effective Wall Yield Locus
    - Shear Testing Equipment
    - Cohesionless and Cohesive Materials
    - Stress-Strain Diagram
    - Jenike’s Method for Flow of Cohesive Powders
    - Mass Flow Rate of Free-Flowing Materials
    - Discharge Devices
    - Janssen’s Analysis of Stresses and Forces in Silos

- Powder Basic Methods of Tablet Manufacturing
| Compaction | Diagram of Forces in a Punch-Die Assembly  
|            | Characterization of Powder Compressibility  
|            | Densification Behavior of Soft Powders  
|            | Work Involved in Compression of Powders  
|            | Optimization of Force-Displacement Diagram  
|            | Mechanical Tests of Formed Compacts  
|            | Indentation Hardness  
| • Micromechanics of Particulate Solids |  
| Interparticle Forces | Dry Vs. Wet Granular Materials  
|                      | Van der Waals Intermolecular Forces  
|                      | Interaction of Elastically and Plastically Deformed Spherical Particles  
|                      | Adhesion Model for Particle Friction  
|                      | Types of Electrostatic Forces  
|                      | Two Spheres Joined by a Liquid Bridge  
|                      | Liquid Bridge Between a Cone and a Plane  
|                      | Viscous Force Between Two Colliding Spheres  
|                      | Impact and Rebound of Particles  
|                      | Classification of Interparticle Forces  
|                      | Particle Assembly Elasticity  
| Wet and Dry Granulation | Wetting and Nucleation  
|                        | Drop Controlled Regime  
|                        | Granule Consolidation and Growth  
|                        | Characteristic Dimensionless Parameters  
|                        | Operating Regime Map  
|                        | Breakage of Wet and Dried Granules  
|                        | Measurements of Fracture Properties  
|                        | High and Low Shear Mixer Granulators  
|                        | Scale-Up, Endpoint Determination and Control  
|                        | Fluid Bed Granulation  
|                        | Geldart’s Diagram of Fluidization Behavior  
|                        | Scale-up and Granulation Endpoint  
|                        | Dry Granulation  
|                        | Roller Compaction  
|                        | Pressure Distribution Between Rolls  
| Mixing of Granular Materials | Mixing and Segregation  
|                                | Characterization of Powder Mixture  
|                                | Mixing Mechanisms  
|                                | Powder Mixers  
| Particle Size Reduction | Mechanisms of Size Reduction  
|                            | Properties Affecting Size Reduction  
|                            | Classification of Mills  
|                            | Low- and High-Energy Mills  

Tentative weekly listing of topics (15-week schedule)

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Subtopic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Particle &amp; Granule Micrometrics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Continuum Mechanics of Particulate Solids</td>
<td></td>
</tr>
<tr>
<td>3, 4</td>
<td></td>
<td>Flow of Powders</td>
</tr>
<tr>
<td>4, 5</td>
<td></td>
<td>Powder Compaction</td>
</tr>
<tr>
<td>6</td>
<td>Midterm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Micromechanics of Particulate Solids</td>
<td></td>
</tr>
<tr>
<td>7, 8</td>
<td></td>
<td>Interparticle Forces</td>
</tr>
<tr>
<td>9, 10</td>
<td></td>
<td>Wet and Dry Granulation</td>
</tr>
<tr>
<td>11, 12</td>
<td></td>
<td>Mixing of Granular Materials</td>
</tr>
<tr>
<td>13</td>
<td>Project Presentations</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Final Exam</td>
<td></td>
</tr>
</tbody>
</table>

**Midterm and final exam**

- There will be a midterm exam. Exact date of the midterm exam will be announced a week before.
- There will be a final exam during Finals’ week, covering all of the course materials.
- The midterm and final exams must be completed individually, in accordance with the NJIT Honor Code.
- Each problem will be graded independently.

A missed midterm exam will be averaged into the final grade as zero, unless an excuse is obtained in advance. Excuses are granted only for very serious circumstances attested to by the NJIT administration, verifiable and significant medical problems, religious holidays, and also serious personal situations, such as deaths in the family. A student who has been excused will be required to take a makeup exam.

**Project assignment**

Students will work as a team by cooperating in a group to carry out a short research project on specific applications of solids processing and prepare a written report and a verbal presentation at the seminar. Topics for research projects may include but are not limited to:

- Particle size analysis and control for process quality
- Powder processing equipment
- Pharmaceutical powder mixing, compaction, fluidization
- Pharmaceutical powder testing
- Pharmaceutical powder blends
- Properties of pharmaceutical powders (adhesion, wetting, flowability, etc) and their effects on powder processing
- Powder coating for pharmaceutical applications

**Project grading**

Evaluation of an the written report and oral presentation will be based on

- Mastery of the subject
- Quality of the write-up
- Presentation of the subject matter
- Quality of visuals
- Capture of the audience's attention
Assessment criteria and grading

This course has been designed so that lectures, problem-solving, project assignment, and laboratory work are integral and essential parts of the learning process. Final grades will be determined from scores as follows:

- Project 40%
- Homework 15%
- Midterm exam 15%
- Final exam 30%

The final grade will be assigned on the basis of “a curve”.

Course Materials

Lecture notes, relevant publications and websites:

- Pharmaceutical Online http://www.pharmaceuticalonline.com
- FDA Process Analytical Technology (PAT) Initiative http://www.fda.gov/aboutfda/centersoffices/officeofmedicalproductsandtobacco/cder/ucm088828.htm
- R. Weinkektor, H. Gericke Mixing of Solids, Particle Technology Series, Volume 12, Springer 2000
- R. Xu, Particle Characterization: Light Scattering Methods, Particle Technology Series, Volume 13, Springer, 2002

Accommodations due to disability

If you need accommodations due to a disability please contact Chantonette Lyles, Associate Director of Disability Support Services, Fenster Hall Room 260 to discuss your specific needs. A Letter of Accommodation Eligibility from the Disability Support Services office authorizing your accommodations will be required.