Stevens Institute of Technology
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Syllabus

Course Number: ChE 621: Pharmaceutical Mixing

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Overview

This course will provide a fundamental understanding, and the application of emerging and current approaches to fluid mixing in the pharmaceutical and fine chemical industries. The course will focus on mixing methods to enhance pharmaceutical processes and bioreactor design by beginning with the fundamentals of mixing and progressing to more specific pharmaceutical applications. A successful student will grasp the importance of mixing and understand that perfect mixing is rarely achieved. This course will provide "tricks of the trade" and practical guidelines to optimize all facets of mixing as they pertain to the pharmaceutical and other industries. The mixing applications are intended to be as realistic as they can be.

This course is not Fluid Dynamics and the math is on the light side. Although the title of the course is Pharmaceutical Mixing anyone interested in mixing will benefit from this course as all of the basics are covered. If anyone is interested in other mixing applications, the student should make the professor aware of that and special accommodations can be made.

Cross-listed with.

Prerequisites

Are you a problem solver? Got a knack for thinking things through? Can you reason with logic? If yes, you've got what it takes for this course.

- Even though this is a graduate course, a high school senior should be able to manage the math.
- You should be comfortable creating your own Excel spreadsheets.
- You should also be a thinker and not a memorizer. There are no tests or quizzes that require memorizing. Einstein did not memorize, he knew where to look up information. So should you!
- You should feel comfortable being an engineer and applying engineering concepts or just plain common sense. If you can think practical, this course should be fun.
- Chemists, biologists, and pharmacists that are comfortable around machines and the design of machines should have no difficulties with this class, either.
- You should be comfortable with the notion of self discipline. As an internet based course, you need to find time to read the material and do the assignments. The exams stretch over a week and you need to know how to budget your time – just like in real life.

Cross-listed with.

Learning Goals

After taking this course, the student will be able to:

- Appreciate that there is no such thing as *perfect mixing*.
- Appreciate that there is no one mixer that is good for *all* mixing applications. There is an impeller spectrum to match the application spectrum.
- Understand the tradeoffs of impeller shear and flow required for successful processes.
- Understand that *scaling up* often starts with *scaling down*. Big mistakes can be avoided if laboratory experimentation is done with scaling up in mind.
- Understand that viscous fluids are usually not Newtonian and how to obtain the proper rheological information to use a mixer efficiently.
- Predict the energy dissipation of impellers to the fluid and use that information for designing, troubleshooting, and scaling up processes.
- Understand how to *size* a mixer for blending, solids suspension, liquid-liquid dispersions, and gas-liquid applications with an emphasis on pharmaceutically relevant processes.
- Be able to design a crystallizer, fermenter, hydrogenator, and a bio-reactor using Excel.

Pedagogy

This is an internet based course on mixing. This course should reflect the real world as much as possible.

- Students should read the PowerPoint presentation for each week including the required reading. These will be available each Monday morning at 7 AM (EST). Most of the PowerPoint presentations are about 70 pages long.
- Students are encouraged to use the *Discussion Forum* to post questions and comments that would benefit everyone. This is the internet version of raising your hand. Since class participation is part of your grade, you should take advantage of this. Students should use *Email*, if they don't want to share their question and answer with the others.
- There will be weekly quizzes. These will be generally multiple choice and true-false questions. You will have 3 chances to do each quiz. The best grade counts. They are open book. Unlike last semester, this time the answers will only be available after you submit your final version. There will also be questions requiring you to do some calculations and those require Excel.
- There will be two exams – the mid-term and the final. Each one will be open 1 full week and is open book. You are also encouraged to work with another student, but there is neither credit nor tolerance for copy and paste submissions. Please do your own work. These exams have a small multiple-choice component, but the majority of the test will require Excel and calculations. The exams should take 4-6 hours. If you wait until the exam to read the lecture it will take much longer.
- Students are highly encouraged to question the professor through email or via the *Discussion Forum* on anything not clear. Remarks such as, "I did not understand the question" are not acceptable. In the real world, as an engineer, you can't wait till a deadline to announce you did not understand. How long do you think you would keep your job if you did that?
- If you have SKYPE we can chat that way.
- Students will have access to the professor through the Stevens weblink. It is encouraged to bring any first hand mixing problems to the Professor's attention to be worked on as an example of process optimization.

Required Text(s)

"Handbook of Industrial Mixing – Science and Practice", edited by E. Paul et al., Wiley-Interscience, 2004, ISBN 0-471-26919-0

Useful additional materials if you can get your hands on these books. They are no longer in print, but may be in your library.

- "Biochemical Engineering", 2nd. Ed., S. Aiba et al, Academic Press, 1973, ISBN 0-12-045052-6
- "Fluid Mixing Technology", J. Oldshue, McGraw Hill, 1983, ISBN 0-07-047685-3
- "Mischen und Ruehren – Grundlagen und moderne Verfahren", (in German), Wiley-VCH, 2002, ISBN 3-527-30577-7
- Mixing – Principles and Applications", S. Nagata, Halsted Press, 1975, ISBN 0-470-62863-4

Required Readings

The majority of the required reading comes from the course's PowerPoint presentations released each week. Readings from the required book will be assigned for each week and will mainly enhance the presentation, but will also contain many formulae required to solve problems. The readings will be listed at the appropriate spot in the lecture materials and/or found on the course website. Optional reading will be also announced for those that would like to learn more about mixing and to get another view point.

Assignments

The course will emphasize an understanding of the often overlooked importance of mixing for the success of just about everything man-made. Mixing is not an exact science. Give an assignment to 5 mixing experts and you will most likely get 5 different answers and they may all work. As such, there is no single correct answer, but there may be only one optimum solution. Your first and most important assignment is to keep an open mind, ask questions, and bring examples or questions that we can work on.

1. Internet Class Participation - To enhance the learning experience, all students are expected to participate in the class *Discussion Forum* by responding to the posting by the professor and exchange ideas of postings by other students.
2. Quizzes and homework should be completed by the required date and submitted via Email (Excel submissions) and using the Assignment Forum (multiple choice and true-false questions) to the professor.
3. There will be open book mid-term and final exams that can be done at your convenience during an entire week. These can be considered as mini-projects. These tests will test how well you can design agitated reactors.
4. Team presentation - There will not be any team presentations for this course. You are on your own!

The assignments and their weights are as shown below:

1.	Class Participation - Discussion Forum	5%
2.	Homework and Quizzes	20%
3.	Mid-term	25%
4.	Project	15%
5.	Final exam	35%
	TOTAL	**100%**

For 3 credits.

Please note that assignments in this class may be submitted to www.turnitin.com, a web-based anti-plagiarism system, for an evaluation of their originality. Based on the fact that mixing discussions are hard to find in published form, the chance of plagiarism is probably very low. Be original! If two questions are answered identically then copying will be expected and will reduce the grade for both. Remember, 5 mixing experts will most likely get you 5 different answers that work. Copying is discouraged.

Course Schedule (Sample)

Week 1 is orientation week and also the release of the first lesson. During this week, I will try and contact you to discuss any concerns or questions you may have. Please introduce yourself to me.

Week	Subject	Assignment Due
Orientation	Mixing Basics – Part 1	Examples of processes that require mixing, Components of a mixer, Mixers of all sizes and shapes – Glass lined, metal, magnetic, Vessels of all sizes and shapes, Process application classifications, Why agitated vessels?, Aseptic - Sterilized
1	Mixing Basics – Parts 2 & 3	2. Three basic flow patterns, Baffled?, Determination of flow, Determination of power, Determination of shear, What does the process need? 3. Dimensionless numbers, Viscosity, Rheology, Caverns, Deadzones
2	Low viscosity single-phase blending	Impeller types, Mixing time correlations, Improving mixing, Mixing in the lab, Shake flasks, Continuous mixing, Relevant process examples
3	High viscosity single-phase blending	Impeller types, Mixing time correlations, Non-Newtonian considerations, Relevant process examples & thickeners, Requirements
4	Liquid-solid mixing	Suspending solids, Floating solids, Wetting out solids, Mass transfer and reactions, Dissolving, Crystallization, Catalysis
5	Heat Transfer and Review	Review of the basics, single phase mixing and solids suspension. Opportunity for discussion on a mixing project from your own experience. Discussion about crystallizers. We shall have designed a crystallizer by this week using Excel. Preparation for the mid-term.
6	Mid-Term Exam	Exam will be available at the beginning of the week and you have 1 full week to complete it. Open book. Emphasis is on thoroughness. Back-up any ideas or concepts with copies of the material you referenced. Answers should be in Windows Office 2003 compatible format. I prefer Excel sheets to show your work and comments.
7	Liquid-liquid mixing and separation	Dispersing liquids, Droplet sizes, Emulsions, Mass transfer, Purification through phase separations
8	Gas-liquid mixing – Parts 1 & 2	1. Dispersing gasses, Flooding characteristics, Gas hold-up 2. Mass transfer
9	Gas-liquid mixing – Parts 3 & 4	3. Reactor/Impeller designs, Fermenter designs, Hydrogenator design, 4. Up-pumping Technology
10	Scale-up of fluid mixing	Think full-scale and scale down, Problems with lab testing, Problems with full scale testing, Size matters, “Fear of Shear”, Mixing suppliers
11	More mixing concepts	Process intensification with agitation, emulsifiers - **This is your project**
12	Solids-solids mixing	Introduction, concept, uses
13	Review	Review of the entire course and multi-phase mixing. By this point you should have already designed a fermenter and hydrogenator using Excel.
14	Final exam	Exam will be available at the beginning of the week and you have 1 full week to complete it. Open book. Emphasis is on thoroughness. Back-up any ideas or concepts with copies of the material you. Answers should be in Windows Office 2003 compatible format. I prefer Excel sheets to show your work and comments.