Fall 2021

PHEN 603-101: Pharmeceutical Unit Operations: Processing of Liquid and Dispersed-Phase Systems

Piero Armenante

Dr. P. M. Armenante
New Jersey Institute of Technology
August 26, 2021

Pharmaceutical Unit Operations: Processing of Liquid and Dispersed-Phase Systems – PhEn 603

Syllabus

Term: 2021 Fall Semester

NJIT Course Title: Pharmaceutical Unit Operations: Processing of Liquid and Dispersed-Phase Systems

NJIT Course Number: PhEn 603, Section 101

Course Day and Time: Monday, 6:00 – 8:50 p.m.

Classroom: Kupfrian Hall, Room 203

Course Instructor:
Piero M. Armenante, Ph.D.
Distinguished Professor of Chemical Engineering and Master Teacher
New Jersey Institute of Technology
Otto H. York Department of Chemical and Materials Engineering
Newark, NJ 07102

Office: YCEES Building - Room 120
Telephone: (973) 596-3548; **Mobile: (908) 347-8734** (**preferred**)
Fax: (973) 596-8436
E-Mail Address: piero.armenante@njit.edu

Availability of Instructor: In-person meetings: Monday, 5:00-6:00 pm; meeting room: 374 Tiernan Hall (office). Students can additionally e-mail me to set up appointments outside office hours, possibly to be conducted via WebEx online if needed.

Teaching Assistant (TA): TBA

TA's Office Hours: TBA

Computer Software Requirements and Access:

- NJIT e-mail account, including UCID and password, to access:
  - Canvas (https://canvas.njit.edu/)
  - WebEx (https://njit.webex.com/)
- Web browser (Chrome, Firefox, Safari, etc. - Internet Explorer is not recommended)
- Adobe Acrobat (freeware)
- Other common software to complete assignments (e.g., Microsoft Word, Microsoft Excel, etc.)

Course Notes, Textbooks, and Other Reference Material:

- **Course Lectures**: Armenante, P. M., 2021, *PhEn 603-Pharmaceutical Unit Operations: Processing of Liquid and Dispersed-Phase Systems Course Lectures.* The *Lectures* are videos containing course lectures identical in content and length to the face-to-face PhEn 603 lectures routinely offered at NJIT. The *Lectures* are available through Canvas and can be accessed as described below
- **Course Notes**: Armenante, P. M., 2021, *PhEn 603-Pharmaceutical Unit Operations: Processing of Liquid and Dispersed-Phase Systems: Course Notes*. The *Notes* are exact duplicates of the overheads used in the lectures. The *Notes* are also available through Canvas and can be accessed as described below.
- **Textbooks**: The following books are suggested but **not** required as textbooks:
  - McCabe, W. L., Smith, J. C. and Harriott, P., 2005, *Unit Operations of Chemical Engineering*, 7th Edition, McGraw-Hill, New York.
  - am Ende, M. T. and am Ende, D. J. (Eds.), 2019, *Chemical Engineering in the Pharmaceutical Industry, Drug Product Design, Development, and Modeling*, 2nd Edition, Hoboken, NJ, Wiley.
  - am Ende, D. J. and am Ende, M. T. (Eds.), 2019, *Chemical Engineering in the Pharmaceutical Industry, Active Pharmaceutical Ingredients*, 2nd Edition, Hoboken, NJ, Wiley.
- A list of additional reference books (not required) is attached.

Availability of Course Notes, Homework Assignments, Textbook, and References:

- Links to the *Course Lectures* are available to the students through Canvas. Students can access Canvas directly by going to https://canvas.njit.edu/ and following the instructions there. Once the appropriate course is selected, students will be able to watch streaming videos of the *Lectures* for that class period by clicking on the appropriate links
- The *Course Notes* can be downloaded from the NJIT website using Canvas, as described above. The *Course Notes* will be posted on the internet as PDF files
- The homework, homework solutions, and projects will be posted through Canvas as appropriate, depending on the material covered in that week (typically but not always on a weekly basis)
- Additional material (e.g., videos, reading material, etc.) will be posted through Canvas as appropriate
- If students experience problems and they are unable to log in or access the course material, they should contact the NJIT Helpdesk at 973-596-2900
- The textbook is available in the NJIT bookstore (973-596-3200; http://www.bkstr.com/njitstore/home) or from the publishers
- Most additional references (not required as textbooks) as well as the textbooks are available in most university libraries and have been being placed on reserve at the NJIT library.

WebEx Sessions:

- WebEx sessions are long distance conference calls, conducted via computer, that will enable students to meet (i.e., talk, show material, etc.) with the course instructor and the other students in the class
- WebEx sessions will be held as needed, either one-on-one or as a forum to discuss topics covered in class, address questions, review selected homework, clarify examples, etc.
- In order to use WebEx students should first visit http://webex.njit.edu, click on the "Participating in a WebEx Session" link, retrieve the PDF file with detailed instructions, and read it
- Remark: students do not need to open a WebEx account to attend a WebEx session

Course Prerequisites:

- **PhEn and ChE Students**: Currently, students are admitted to the PhEn program if they have baccalaureate degree in chemical engineering or equivalent with a minimum GPA of 3.0. This is a satisfactory prerequisite for this course. Students with undergraduate degrees in biology, chemistry, physics, and equivalent who are admitted to the PhEn program on condition that they additional take undergraduate courses, specified at the time of admission, must have taken and successfully completed those courses. *Students who do not have the necessary prerequisites should drop the course.* Additionally, PhEn 601 is recommended but not required as a prerequisite.

- **Non-PhEn and non-ChE Students**: Students with appropriate engineering backgrounds (e.g., BME, ME) can also take this course. Students with non-engineering background should have the *appropriate background* in math (up to differential equations), mass and energy balances, fluid flow, heat transfer, and mass transfer in order to be able to follow the course. Therefore, they should talk to Prof. Armenante to make sure that they are adequately prepared for this course before taking it. Additionally, PhEn 601 is recommended but not required as a prerequisite.

Course Objective: This course is one of the common core courses for the Pharmaceutical Engineering MS Degree Programs. The main objective of the course is to examine methodologies, both applied and fundamental, to analyze and scale up pharmaceutical manufacturing processes involving liquid and dispersed-phase systems, such as liquid and multiphase mixing, sterilization and sanitation, filtration, centrifugation and others. The emphasis is primarily on the engineering aspects of the pharmaceutical processes examined in the course.

Course Description: This course covers state-of-the-art pharmaceutical processing involving primarily liquid and dispersed-phase systems, identifying underlying chemical process engineering principles and providing quantitative approaches to drug product manufacturing process design and optimization.

Course Outline by Topic Areas: Chemical/pharmaceutical development activities; sterilization and sanitation processes, aseptic manufacturing; sedimentation; centrifugation; filtration; processing of liquid systems and dispersed-phase systems; liquid mixing and dispersion fundamentals; liquid mixing calculations; solid-liquid suspensions; equipment selection and scale-up for homogeneous and dispersed-phase systems.

Course Learning Outcomes: Upon successful completion of this course, students will be able to:
- Identify, categorize, and describe the most relevant industrial operations and equipment encountered in the pharmaceutical industry to process liquids and dispersed phase systems
- Construct and assemble mathematical models (typically based on mass, energy and momentum balances) best suited to analyze the performance of each process and equipment components
- Identify critical parameters for the operation of the process and its equipment, device experiments to extract them from lab/pilot scale equipment, and analyze the results to quantify them
- Select, preliminarily design, size, and scale-up equipment needed to achieve the desired process objectives
- Examine, assess, and compare different equipment and process alternatives to achieve optimal desired process objectives.

Course Requirements:
- Examinations: Two exams, i.e., a midterm exam and a final exam
- Homework: Assigned by the instructor at the end of each classes
- Quizzes: Possibly, several very short quizzes on homework just completed
- Projects: One, or possibly two, short projects will be assigned after the midterm exam (see below for details)

Grading Policy*:
- Midterm exam* 38%
- Final exam* 38%
- Homework.....12%
- Projects 12%

  Total 100%

(*) Students performing very poorly on the exams will **fail** the course *irrespective* of their performance in the homework and projects, as specified below.

Course Final Grade: a tentative guideline for the assignment of final grades is the following:

Cumulative Points	Overall Grade
85-90 to 100%	A
70-75 to 85-90%	B/B+
60 to 70-75%	C/C+
50 to 60%	"D"
0 to 50%	F

The grade of "D" is not assigned to students taking graduate courses. Students averaging a cumulative point score corresponding to a "D" in the above table could receive either a C or an F, depending on their overall performance.

Please remember that this is only a guideline designed to help the students understand how they are performing in the course. Dr. Armenante will feel free to change the grading scale (both ways) when assigning the final grades.

> **Important Remark**: Each exam (midterm and final) will be graded on a point scale from 0 to 100 (100 points in an exam=38% of the final grade; see above). However, **failing to achieve a combined average of at least 55/100 in the two exams** will imply **failing the course (F grade) *irrespective* of the points obtained through the homework and the projects.** In other words, students who perform extremely poorly in the exams will not be able to use the homework and the projects to pass the course. If this minimum requirement is satisfied, the final grade will be assigned based on the grading policy outlined above.

Exams:

- A calendar of exams is included in the Course Outline given below
- All exams are typically 3 hours long unless otherwise stated
- All exams are typically open-book and open-note. However, changes could be made and will be announced by the instructor prior to the exams
- No computers, telephones, i-Pads, etc. will be allowed during the exams
- Possible additional exam policy changes will be announced by the instructor prior to the exams
- The final exam will be on all material covered throughout the course (although the main emphasis of the exam will be on the material covered after the midterm exam);
- Make-up exams will only be given to students who cannot attend the regular exam time, *and only under documented and extraordinary circumstances*. In any case, no student will be allowed to take a make-up exam unless he/she has the prior consent of the instructor. *If a student will simply not come to an exam, the exam grade will automatically be zero.*
- Because of confidentiality issues, the Office of the **Dean of Students** now handles all issues related to **medical conditions** (including justification for postponing exams)

Homework:

- The homework will be posted on Canvas
- It will be assigned as appropriate (typically on a weekly basis), depending on the material covered in that week
- Students should turn in the homework by scanning it and attach it as a PDF file to an e-mail message addressed to the TA for the course
- The homework will not be returned to the students unless practical to do so
- No late homework will be accepted unless a valid reason is provided **in advance** (e.g., an upcoming business trip)
- Homework solutions will be posted on Canvas after the homework has been collected.

> ***Important Remark**: Previous experience has clearly shown that those students who do not work on the assigned problems (or at least seriously try to solve them) typically perform very poorly on the exams.*

Homework Grading: The homework will be graded by the TA on the basis of the effort that the student puts into using solving it using a simplified grading scale, i.e., 0 (no or minimal effort); 5 (intermediate effort); 10 (significant effort). Any questions regarding homework grades should be discussed with the instructor.

Projects: Every student will complete one, or possibly two, small projects, which will be assigned after the midterm exam and collected on the day of the final exam. The first project will consist of critically reviewing (critiquing) 2 papers published in scientific journals (as if the papers had been submitted for publication to the student). The papers will have to be related to each other and to be within the scope of the course. The students will be asked to write a short review of the papers. The student will have to justify whatever conclusions he/she may reach. The second project (if assigned) will consist of a small design problem for a case study assigned by the instructor. The problem will be open-ended to allow each student to come up with his/her own original design.

Class Attendance: As with all graduate courses at NJIT, attendance is not mandatory, but strongly recommended. Experience shows that students who do not regularly attend class typically perform poorly in the course. In addition, examples are worked out during the lectures. These examples are not in the *Course Notes*. Students are responsible for all material covered in class.

Time Commitment: Students are expected to allocate some three to six hours per week to study and work on the assignments for this course.

Code of Conduct and Academic Integrity: The NJIT University Code on Academic Integrity, found at http://www.njit.edu/doss/code-student-conduct-article-11-university-policy-academic-integrity/, will be followed. The Code is being upheld on all issues related to the course. Students are expected to be familiar with the code and conduct themselves accordingly. Academic integrity is fundamental to the activities and principles of a university. All members of the academic community must be confident that each person's work has been responsibly and honorably acquired, developed, and presented. Any effort to gain an advantage not given to all students is dishonest whether or not the effort is successful. The academic community regards breaches of the academic integrity rules as extremely serious matters. Sanctions for such a violation may include academic sanctions from the instructor, including failing the course for any violation, to disciplinary sanctions ranging from probation to expulsion. When in doubt about plagiarism, paraphrasing, quoting, collaboration, or any other form of cheating, consult the course instructor.

Plagiarism and Academic Integrity: The approved "University Code of Academic Integrity" is currently in effect for all courses. Should a student fail a course due to a violation of academic integrity, they will be assigned the grade of "XF" rather than the "F," and this designation will remain permanently on their transcript. All students are encouraged to look at the University Code of Academic Integrity and understand this document. Students are expected to uphold the integrity of this institution by reporting any violation of academic integrity to the Office of the Dean of Students. The identity of the student filing the report will be kept anonymous. NJIT will continue to educate top tier students that are academically sound and are self-disciplined to uphold expected standards of professional integrity. ***Academic dishonesty will not be tolerated.***

Students with Disabilities: NJIT adheres to Section 504 of the Rehabilitation Act (ADA) of 1990. Appropriate accommodations are provided at no cost to the student. Additional questions should be directed to the NJIT Office of Accessibility Resources and Services. For further information, students should visit https://www.njit.edu/studentsuccess/accessibility/.

Important Dates According to NJIT Calendar (Fall 2021):

September	1	Wednesday	First Day of Classes
September	4	Saturday	Saturday Classes Begin
September	6	Monday	Labor Day
September	8	Wednesday	Monday Classes Meet
September	**8**	**Wednesday**	**Last Day to Add/Drop a Class**
September	8	Wednesday	Last Day for 100% Refund, Full or Partial Withdrawal
September	9	Thursday	W Grades Posted for Course Withdrawals
September	15	Wednesday	Last Day for 90% Refund, Full or Partial Withdrawal - No Refund for Partial Withdrawal after this date
September	29	Wednesday	Last Day for 50% Refund, Full Withdrawal
October	20	Wednesday	Last Day for 25% Refund, Full Withdrawal
November	**10**	**Wednesday**	**Last Day to Withdraw from Classes**
November	25	Thursday	Thanksgiving Recess Begins
November	28	Sunday	Thanksgiving Recess Ends
December	10	Friday	Last Day of Classes
December	11	Saturday	Saturday Classes Meet
December	12	Sunday	Sunday Classes Meet
December	13	Monday	Reading Day 1
December	14	Tuesday	Reading Day 2
December	15	Wednesday	Final Exams Begin
December	21	Tuesday	Final Exams End
December	23	Thursday	Final Grades Due

Additional important dates are available at: http://www.njit.edu/registrar/calendars/.

Course Outline (Fall 2021)

Week	Date	Topic
1	September 8	Introduction Chemical/Pharmaceutical Development Activities Sterilization and sanitation processes
2	September 13	Sterilization and sanitation processes
3	September 20	Mathematical modeling of sterilization processes
4	September 27	Mathematical modeling of sterilization processes
5	October 4	Review of flow in confined systems
6	October 11	Filtration
7	October 18	Mathematical modeling of filtration processes
8	**October 25**	**Midterm Exam**
9	November 1	Mathematical modeling of filtration processes
10	November 8	Sedimentation
11	November 15	Sedimentation Centrifugation
12	November 22	Processing of liquid systems and dispersed-phase systems
13	November 29	Liquid mixing and dispersion fundamentals Liquid mixing calculations
14	December 6	Equipment selection and scale-up of equipment for dispersed-phase systems
15	**December 20**	**Final Exam**

Important: It is conceivable that some changes in the above outline will take place, depending on the overall performance of the class and the time actually required to cover the most important subjects of the course.

Additional References

- *The United States Pharmacopoeia & The National Formulary. The Official Compendia of Standards, USP 44–NF 39*, Pharmacopeial Convention Inc., 2021
- *ISPE Baseline Pharmaceutical Engineering Guides* (the following volumes are available from ISPE; www.ispe.org):
  - Water and Steam Systems
  - Commissioning and Qualification
  - Packaging and Warehousing
  - Bulk Pharmaceutical Chemicals
  - Oral Solid Dosage Forms
  - Sterile Manufacturing Facilities
  - Biotechnology
  - R&D Facilities
  - Oral Liquids and Aerosols
- am Ende, M. T. and am Ende, D. J. (Eds.), 2019, *Chemical Engineering in the Pharmaceutical Industry, Drug Product Design, Development, and Modeling*, 2nd Edition, Hoboken, NJ, Wiley.
- am Ende, D. J. and am Ende, M. T. (Eds.), 2019, *Chemical Engineering in the Pharmaceutical Industry, Active Pharmaceutical Ingredients*, 2nd Edition, Hoboken, NJ, Wiley.
- Michael Levin (ed.), *Pharmaceutical Process Scale-Up*, 3rd Ed., Informa Health Care, New York, 2011.
- Allen, L. V., Popovich, N. G., and Ansel, H. C., *Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems*, 9th Edition, Lippincott Williams & Wilkins Publishers, 2010. [Remark: this is the textbook used in PhEn 601].
- Hickey, A. J. and Ganderton, D., *Pharmaceutical Process Engineering*, Marcel Dekker, New York, 2001.
- Banker, G. S. and Rhodes, C. T., *Modern Pharmaceutics*, 3rd Edition, Marcel Dekker, New York, 1995.
- Lieberman, H. A., Rieger, M. M., and Banker, G. S. (eds.), *Pharmaceutical Dosage Forms: Dispersed Systems*, Vol. 1 (1996); Vol. 2 (1996), Vol. 3, (1998), Marcel Dekker, New York.
- Lieberman, H. A., Lachman, L. and Schwartz, J. B. (eds.), *Pharmaceutical Dosage Forms: Tablets*, Vol. 1 (1989); Vol. 2 (1990), Vol. 3 (1990), Marcel Dekker, New York.
- Avis. K. E. Lieberman, Lieberman, H. A., and Lachman, L. (eds.), *Pharmaceutical Dosage Forms: Parenteral Medications*, Vol. 1 (1991); Vol. 2 (1992), Vol. 3 (1993), Marcel Dekker, New York.
- Cole, G., *Pharmaceutical Production Facilities: Design and Applications*, 2nd Edition, Taylor & Francis, 1998.
- Avis, K. E. and Wu, V. L. (eds.), *Biotechnology and Biopharmaceutical Manufacturing, Processing, and Preservation* (Vol. 2), Interpharm Press, 1996.
- Armenante, P. M. and A. Kirpekar, "*Chapter 11: Sterilization in the Pharmaceutical and Biotechnology Industry,*" in *Handbook of Downstream Processing*, by E. Goldberg (editor), pp. 261-308, Chapman & Hall, New York, NY, 1997.
- Gennaro, A. R. (editor), *Remington: The Science and Practice of Pharmacy*, 20th Edition, Philadelphia College of Pharmacy and Science, 2000.
- Geankoplis, C. J., *Transport Processes and Unit Operations*, 4th Edition, 2003, Prentice Hall.
- McCabe, W. L., Smith, J. C. and Harriott, P., *Unit Operations of Chemical Engineering*, 7th Edition, 2005, McGraw-Hill.