NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

COURSE CONTENT

Academic Year	2023/2024	**Semester**	2
Course Coordinator	Dr. Mukta Bansal / Dr. Teoh Jia Heng		
Course Code	CH2151		
Course Title	Unit Operations: Fluid-Solid Separation		
Pre-requisites	Nil		
No of AUs	3		
Contact Hours	*26 hours lecture, 12 hours tutorial*		
Proposal Date	11th Feb 2020		

Course Aims

This course is designed for students with an engineering background to learn particle processing and the separation techniques used for pharmaceutical and biological industries. The course emphasizes the fundamental chemical engineering principles encountered in gas-solid/liquid-solid systems. The objective of the course is to provide you with a comprehensive and concise overview of different separation processes available for system involving solids and to develop independent problem-solving abilities.

Intended Learning Outcomes (ILO)

At the end of this course, you should be able to:

1. Interpret the need for fluid-solid and solid-solid separations
2. Apply fundamental chemical engineering principles such as heat/mass transfer behaviour and flows in unit operations involving fluid-solid and solid-solid separations
3. Identify, Formulate and Solve Engineering Problems

Course Content

1	Particle size analysis
2	Packed bed
3	Introduction to fluidized bed
4	Dense phase fluidization
5	Dilute phase fluidization
6	Gas-liquid-solid fluidized bed
7	Particle separations in fluidized bed
8	Introduction to crystallization process
9	Crystal science
10	Crystallization kinetics
11	Crystal growth and size distribution
12	Introduction to filtration process
13	Constant flow and constant pressure filtration
14	Drying

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team /Individual	Assessment rubrics
1. CA (50%) a. Quiz 1 (25%)	1, 2, 3	EAB SLO* a, b, c	25%	Individual	Appendix 1
b. Quiz 2 (25%)	1, 2, 3	EAB SLO* a, b, c	25%	Individual	Appendix 1
2. Final Examination (50%) (2hrs, open book)	1, 2, 3	EAB SLO* a, b, c	50%	Individual	Appendix 1
Total			100%		

Mapping of Course ILOs to EAB Graduate Attributes

Course Intended Learning Outcomes	Cat	EAB's 12 Graduate Attributes*											
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
CH2151	Core	●	◐	◐				○					
1. Interpret the need for fluid-solid and solid-solid separations													EAB SLO* a, b
2. Apply fundamental chemical engineering principles such as heat/mass transfer behaviour and flows in unit operations involving fluid-solid and solid-solid separations													EAB SLO* b, c
3. Identify, Formulate and Solve Engineering Problems													EAB SLO* b, c

Legend:
- ● Fully consistent (contributes to more than 75% of Intended Learning Outcomes)
- ◐ Partially consistent (contributes to about 50% of Intended Learning Outcomes)
- š Weakly consistent (contributes to about 25% of Intended Learning Outcomes)
- Blank Not related to Student Learning Outcomes

Formative feedback

Examination results;
Marker's report on overall examination performance will be uploaded to NTUlearn;
Quiz answers will be discussed in class

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lecture	Demonstrate how to carry out a procedure such as working through a problem, use incomplete handouts which enabling students participating in class.
Tutorial	12 classroom discussion sessions on tutorial questions and related topics

Reading and References

1) Liang-Shih Fan and Chao Zhu, **Principles of Gas-solid Flows**, Cambridge University Press 1998.
2) Seader and Henley, **Separation Process Principles**, 2nd Edition, Wiley, 2006.
3) Mullin, J.W. Oxford: Butterworth-Heinemann. **Crystallization**. 2001 [E-resource].
4) Jones, A.G. Oxford: Butterworth-Heinemann. **Crystallization Process Systems**. 2001 [E-resource].
5) Reynolds, Tom. D, **Unit Operations and Processes in Environmental Engineering**, (TD145.R465, 1982).
6) Christie J. Geankoplis, **Mass Transport Phenomena**, (QC175.2.G292, 1972).
7) Kirk, Raymond E., **Kirk-Othmer Encyclopedia of Chemical Technology**, 5th edition, Wiley, 2004 [E-resource].
8) Christie J. Geankoplis, **Transport Processes & Unit Operation**, 3rd edition, Prentice-Hall, 1993.
9) Warren L.McCabe, Julian C Smith, Peter Harriott, **Unit Operations of Chemical Engineering**, McGraw-Hill, 7th edition (TP155.7.M121 2005).
10) Martin Rhodes, **Introduction to Particle Technology**, 2nd edition, Wiley, 2008 (TP156.P3R477 2008).
11) Perry, Robert H., **Perry's Chemical Engineers' Handbook**, 8th Edition, McGraw-Hill, 2008 (TP155.C517 2008

Course Policies and Student Responsibilities

General: You are expected to complete all online activities and take all scheduled assignments and tests by due dates. You are expected to take responsibility to follow up with course notes, assignments and course related announcements. You are expected to participate in all tutorial discussions and activities.

Continuous assessments: You are required to attend all continuous assessments.
Absenteeism: Continuous assessments make up a significant portion of your course grade. Absence from continuous assessments without officially approved leave will result in no marks and affect students' overall course grade.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Mukta Bansal	N1.2-B2-28	6316 8775	mbansal@ntu.edu.sg
Teoh Jia Heng			jiaheng.teoh@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Particle size analysis	1	
2	Packed bed	2	
3	Introduction to fluidized bed	2, 3	
4	Dense phase fluidization	2, 3	
5	Dilute phase fluidization	1, 2	
6	Gas-liquid-solid fluidized bed	2, 3	
7	Particle separations in fluidized bed	1, 2, 3	
8	Introduction to crystallization process	1	
9	Crystal science	2	
10	Crystallization kinetics	2, 3	
11	Crystal growth and size distribution	2, 3	
12	Introduction to filtration process	1, 2	
13	Constant flow and constant pressure filtration	2, 3	
14	Drying	1, 2, 3	

Appendix 1: Assessment Criteria

Criteria	Unsatisfactory: <40%	Borderline: 40% to 49%	Satisfactory: 50% to 69%	Very good: 70% to 89%	Exemplary: >90 %
Interpretation	Interpretation of the problem is not clear	Interpretation of the problem and explanation of the proposed solution suggests minimal understanding of the basics	Interpretation of the problem and explanation of the proposed solution suggests that there is basic understanding	Interpretation of the problem and explanation of the proposed solution suggests that there is understanding of the Unit Operation	Interpretation of the problem and explanation of the proposed solution suggests a very clear understanding of the Unit Operation

Appendix 2: The EAB (Engineering Accreditation Board) Accreditation SLOs (Student Learning Outcomes)

a) **Engineering knowledge:** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems
b) **Problem Analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
c) **Design/development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d) **Investigation:** Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
e) **Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations
f) **The engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
g) **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.
h) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
i) **Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.
j) **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
k) **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
l) **Life-long Learning:** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change