MANIPAL UNIVERSITY
JAIPUR

FACULTY OF ENGINEERING

SCHOOL OF CIVIL AND CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEEING

The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full-scale plant taking into account environmental concerns.

PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

Director, SCCE

HoD, Chem. Engg.

Program Articulation Matrix

	Subject Code	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
SEM III	BB0025	0	0	0	0	0	1	3	0	0	0	0	0	2	1	2
	MA2105	3	2	2	2	1	0	1	0	0	0	0	0	1	1	0
	CE2101	3	2	2	2	1	2	1	1	1	0	0	3	3	1	1
	CE2102	2	2	1	1	0	1	2	1	1	1	1	1	1	0	2
	CE2103	3	3	2	1	1	2	1	1	3	2	2	1	3	2	2
	CE2104	3	3	0	0	3	0	2	0	2	0	2	0	3	2	0
	CE2130	2	2	2	3	1	1	1	2	3	2	0	1	2	1	0
SEM IV	EO2001	0	2	2	3	2	1	2	0	2	0	2	3	0	0	0
	MA2208	3	2	2	2	1	0	1	1	0	0	2	0	1	1	0
	CE2201	2	3	1	2	1	2	2	0	2	2	1	2	2	3	1
	CE2202	3	2	1	2	2	2	1	0	0	1	1	0	2	1	0
	CE2203	2	1	2	1	1	0	1	1	1	0	0	1	2	1	1
	CE2230	2	2	2	3	1	1	1	2	3	2	0	1	3	0	0
SEM V	CE1505	3	3	0	1	2	2	0	0	3	1	0	1	3	2	1
	CE1506	3	2	3	1	1	2	1	0	1	0	1	2	3	1	2
	CE1507	2	3	1	2	1	2	2	1	2	2	1	2	2	3	1
	CE1553	2	2	1	1	2	1	2	1	0	0	0	0	2	1	3
	CE1554	0	3	1	1	3	2	3	1	1	1	0	1	0	0	3
	CE1531	0	2	2	3	1	1	1	2	3	2	0	1	2	1	0
	CE1532	3	3	3	1	3	1	1	0	2	2	0	1	2	1	2
SEM VI	CE1604	3	1	2	2	2	3	2	2	2	1	3	3	2	1	1
	CE1605	3	3	1	0	2	0	2	0	2	2	1	1	3	0	2
	CE1606	3	3	0	0	0	0	1	2	3	2	0	0	0	1	0
	PS1601	1	3	2	0	0	3	0	1	0	0	0	3	0	0	0

	CE1654	3	3	2	3	2	3	3	3	2	0	3	1	3	2	3
	CE1631	2	2	2	3	1	1	1	2	3	2	0	1	3	0	0
SEM VII	CE1705	3	3	3	2	2	3	3	0	2	2	2	2	3	3	3
	CE1706	3	3	1	0	3	0	2	3	2	1	3	0	3	3	2
	CE1707	2	1	1	1	0	1	0	0	1	0	0	1	2	0	0
	CE1708	0	2	1	1	0	0	0	2	1	2	3	0	1	2	0
	CE1754	3	3	3	3	0	2	3	3	1	2	2	2	3	3	3
	CE1731	2	2	2	3	1	1	1	2	3	2	0	1	2	1	2
	CE1732	2	2	2	3	1	1	1	2	3	2	0	1	3	1	1
SEM VIII	CE1803	3	2	0	0	2	0	0	1	2	0	1	1	1	3	1
	CE1804	2	2	1	0	2	0	0	0	1	1	1	1	1	1	1
	CE1833	1	2	2	3	1	1	1	2	3	2	0	1	2	0	0
TOTAL		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

A. Introduction: The course is offered to understand Moral Values and Ethics in personal as well as professional life. It is basic requirement of every human to be a good human being and a good citizen. It further imparts him basics of corporate governance so as to empower him to work technically and professionally in any organization with confidence and conviction and at the same time with honesty & integrity.

B. Course Objectives: At the end of the course, students will be able to

BB0025.1	Define the meaning and relevance of Value and Ethics and apply in personal & professional life.
BB0025.2	Describe the importance of three Gunas for self-development, lifelong learning & growth.
BB0025.3	Find issues and identify solutions related to Public & Private Governance systems.
BB0025.4	Explain the relevance of Company's Act 2013 with reference to corporate world.
BB0025.5	Explain the role and key objectives of organizational governance in relation to ethics and law.
BB0025.6	Demonstrate the social & environmental responsibilities of corporate for sustainability, harmony and growth.

C. Program Outcomes and Program Specific Outcomes

[PO.1]. Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives**.**

[PO.2]. Effective Communication: Speak, read, write and listen clearly in person and through electronic media in English and in one Indian language, and make meaning of the world by connecting people, ideas, books, media and technology.

[PO.3]. Social Interaction: Elicit views of others, mediate disagreements and help reach conclusions in group settings.

[PO.4]. Effective Citizenship: Demonstrate empathetic social concern and equity centered national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

[PO.5]. Ethics: Recognize different value systems including your own, understand the moral dimensions of your decisions, and accept responsibility for them.

[PO.6]. Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

[PO.7]. Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

[PSO.1]. Understanding Traditional and Contemporary Managerial Concepts and Models: Understanding in detail, the contents of various functional areas of Business & Management and the implications of psychological and behavioral aspects on the organizations.

[PSO.2]. Analyzing Business Environment: Identifying opportunities existing in the domestic and global business and economic environment and initiating systematic approach towards rational decision making.

[PSO.3]. Application of Business Concepts and Managerial Skills: Implementing conceptual knowledge in real business situations for ensuring business sustainability and growth.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Mid Sem Exam I	20
	Mid Sem Exam II	20
	In class Quizzes/ Assignments/ Students' Presentations	20
End Term Exam (Summative)	End Term Exam	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	

E. Syllabus:

Values: Relevance of Value Education in day-to-day life. Mantra for success - Value, Moral and Ethics. Determinants of human nature (Three Gunas) and its impact on human life.

Relevance of traits like Personality, Attitude, Behaviour, Ego, Character, introspection, Motivation, Leadership and 4 Qs with relevant Case Studies*.

Governance: Understanding of Public and Private sector Governance systems; Courts & CAG.

Public Sector Governance: Need, relevance, stakeholders.

Private Sector Governance: Proprietary, Partnership, Company (Pvt Ltd & Ltd), Company' Act 2013, Board of Directors; its Roles and Responsivities. Regulatory bodies; its role in ethical governance.

Projects on PPP mode-relevance & prospects.

CSR: Relationship with Society, Philanthropy and Business strategy, CSR Policy, Triple Bottom Line

F. Text / Reference Books:

1. Professional Module of ICSI.
2. Ghosh B.N., Business Ethics & Corporate Governance, McGraw Hill.
3. Mandal S.K., Ethics in Business & Corporate Governance, McGraw Hill .
4. Ray C.K., Corporate Governance, Value & Ethics, Vaya Education of India
5. Chatterjee Abha, Professional Ethics, Oxford Publications.

G. Lecture Plan:

Lec No	**Topics**	**Session Outcome**	**Mode of Delivery**	**Corresponding CO**	**Mode of Assessing the Outcome**
1	**Introduction: Values:** Meaning & Relevance of value education	To acquaint and clear teacher's expectations and understand student expectations. Basics of Value Education	Lecture	BB0025.1	In class Quiz Mid Term I End Term Exam
2	Success: Meaning in perspective of morals & ethics	To understand the concept of success achieved with or without morals / ethics/ values	Lecture, case study	BB0025.1	In class Quiz Mid Term I End Term Exam
3,4	Professional Ethics & ethical dilemmas	To understand the role of professional ethics in the life & deal with dilemmas	Lecture	BB0025.1	In class Quiz, assignment Mid Term I End Term Exam
5	Three Gunas and their relevance, Nature and kinds of value with examples	Understand basic traits in one's personality, its causes and relevance with value based living.	Lecture	BB0025.2	In Class Quiz, Mid Term I End Term
6,7	Relevance of traits of individual like Personality, Attitude, Behaviour	To acquaint & develop positive traits of personality in oneself	Short stories, Lecture	BB0025.2	Class Quiz assignment Mid Term I End Term
8.9	Ego, Character, introspection, Motivation	*To acquaint & develop positive traits of personality in oneself and understand negative traits*	Lecture Short stories	BB0025.2	In Class Quiz Mid Term I End Term
10,11	Leadership traits & 4Qs (PQ, IQ, EQ, SQ)	To realize importance of leadership and to imbibe in life	Lecture Short stories	BB0025.2	In Class Quiz assignment Mid Term I End Term
12,13	Governance & its relevance	To acquaint with the concept of Governance	Lecture	BB0025.3	In Class Quiz Mid Term II End Term
14	Public Sector Governance: Need, relevance, stakeholders	Understand various aspects of public sector governance	Lecture	BB0025.3	Class Quiz, Mid Term II End Term
15	Public Finance, Audit & Control	Understand basics of Public Finance, Check & balance	Lecture Case study	BB0025.3	Class Quiz, assignment Mid Term II End Term

16,17	Private Sector Governance, proprietary & partnership firms and corporate, PPP mode projects	Understand meaning of proprietary & partnership in a firm / company and perspective in PPP mode	Lecture Short stories	BB0025.3 & BB0025.4	Class Quiz Mid Term II End term
18, 19	Company' Act 2013: Roles & Responsibilities of Directors & regulatory authorities	Explain various Regulations and practices of Corporate Governance internationally & understand key role of directors	Lecture	BB0025.4	Class Quiz Mid Term II End Term
20,21	Role of Ethics in Governance	Recognize the necessity of ethics & transparency in Governance	Movie: Gandhi	BB0025.5	Class Quiz, assignment Mid Term II End Term
22,23	CSR: Relationship with Society, Philanthropy and Business strategy	To understand the relevance of giving back to society by a corporate & its importance in society	Lecture, case study	BB0025.6	Class Quiz, End Term
24	CSR Policy, Triple Bottom Line	Understand the concept of TBL in organizational frameworks	Lecture case study	BB0025.6	Class Quiz assignment End Term
25,26	Students' Presentation	Recall contents and their importance through case studies.	Flipped Class	ALL	Class Quiz End Term

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES							CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PSO 1	PSO 2	PSO 3
BB0025.1	Define the meaning and relevance of Value and Ethics and apply in personal & professional life.						1		2		
BB0025.2	Describe the importance of three Gunas for self-development, lifelong learning & growth.						1		2	1	1
BB0025.3	Find issues and identify solutions related to Public & Private Governance systems.						1	1		1	2
BB0025.4	Explain the relevance of Company's Act 2013 with reference to corporate world.						1		1	1	
BB0025.5	Explain the role and key objectives of organizational governance in relation to ethics and law.						1		2	1	
BB0025.6	Demonstrate the social & environmental responsibilities of corporate for sustainability, harmony and growth.						1	3			

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

A. Introduction: This course is offered by Department of Mathematics and Statistics. The use of Engineering Mathematics is indispensable in modern world. It is applicable to every discipline, be it physical sciences, engineering and technology. Much of the advanced research in electronics, electrical, computer science, industrial engineering, biology, genetics, and information science relies increasingly on use of mathematics tools. It is essential for the students to get acquainted with the subject of mathematics at an early stage. The present course has been designed to introduce the subject to undergraduate students in science and engineering. The course contains a good introduction to each topic and an advance treatment of theory at an understandable level to the students at this stage. Each concept has been explained through examples and application-oriented problems.

B. Course Outcomes: At the end of the course, students will be able to think logically.

[2105.1] Summarize the conceptual theory of Functions and understand about Fourier integral.

[2105.2] Explain the concept of Complex analysis and its applications in Engineering.

[2105.3] Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.

[2105.4] Solve heat equations using Gauss divergence theorem and method of separation of Variables

[2105.5] Solve wave equations using Gauss divergence theorem and method of separation of Variables

C. Program Outcomes and Program Specific Outcomes

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

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PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

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PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

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PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full-scale plant taking into account environmental concerns.

PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	**Description**	**Maximum Marks**
Internal Assessment (Summative)	Sessional Exam I **(Closed Book)**	20
	Sessional Exam II **(Closed Book)**	20
	Quizzes , Assignments & Presentation	20
End Term Exam (Summative)	End Term Exam **(Closed Book)**	40
	Total	100

E. Syllabus

Periodic Functions, odd and even functions, Euler's formulae. Half range expansions, Harmonic analysis. Fourier integrals & transforms, Parseval's identity.

Functions of complex variable. Analytic function, C-R equations, differentiation, Integration of complex function, Cauchy's integral formula. Taylor's and Laurent Series, Singular points, Residues, Cauchy's residue theorem. Conformal mappings, bilinear transformations.

Gradient, divergence and curl, their physical meaning and vector identities. Line, surface and volume integrals. Green's theorem, divergence and Stokes' theorem, applications. Formation, solutions of equations involving derivatives with respect to one variable only.

Solutions by indicated transformations and separation of Variables. Derivation of one dimensional wave equation (vibrating string) and its solution by using the method of separation of Variables. D'Alembert's solution of wave equation. Derivation of one dimensional heat equation using Gauss divergence theorem and solution of one dimensional heat equation. Solution by separation of variables.

F. Text Books:

1. Eewin Kreyszig, *Advanced Engineering Mathematics*, 7(e), John Wiley & Sons, Inc.1993.

2. B.S. Grewal, *Higher Engineering Mathematics*, 43(e), Khanna Publishers, 2014.

G. Reference Books:

1. R. Spiegel Murray, *Vector Analysis*, 2(e), Schaum Publishing Co., 2009.

3. B.V. Ramana, *Engineering Mathematics*, 2(e), Tata McGraw Hill Publishing Company limited, 2007.

H. Lecture Plan:

Lecture No.	Description of the Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of Assessing the Outcome
1	Introduction and Course Hand-out briefing	To acquaint and clear teachers expectations and understand student expectations	**Discussion**	**NA**	**NA**
2	Periodic Functions	Memorize the conceptual theory of Functions and understand about Fourier integral.	Lecture, Discussion & Examples	**2105.1**	Quizzes, assignments, Two Sessional, End Term Examination
3	odd and even functions	Memorize the conceptual theory of Functions and understand about Fourier integral.	Lecture, Discussion & Examples	**2105.1**	Quizzes, assignments, Two Sessional, End Term Examination
4	Euler's formulae	Memorize the conceptual theory of Functions and understand about Fourier integral.	Lecture, Discussion & Examples	**2105.1**	Quizzes, assignments, Two Sessional, End Term Examination
5	Half range expansions, Harmonic analysis.	Memorize the conceptual theory of Functions and understand about Fourier integral.	Problem solving	**2105.1**	Quizzes, assignments, Two Sessional, End Term Examination
6	Fourier integrals & transforms	Memorize the conceptual theory of Functions and understand about Fourier integral.	Lecture, Discussion & Examples	**2105.1**	Quizzes, assignments, Two Sessional, End Term Examination
7	Fourier integrals & transforms	Memorize the conceptual theory of Functions and understand about Fourier integral.	Lecture, Discussion & Examples	**2105.1**	Quizzes, assignments, Two Sessional, End Term Examination

8	Parseval's identity.	Memorize the conceptual theory of Functions and understand about Fourier integral.	Problem solving	**2105.1**	Quizzes, assignments, Two Sessional, End Term Examination
9	Functions of complex variable	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
10	Analytic function	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
11	C-R equations	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
12	Differentiation	Explain the concept of Complex analysis and its applications in Engineering.	Problem solving	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
13	Integration of complex function	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
14	Integration of complex function	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
15	Cauchy's integral formula	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
16	Taylor's and Laurent Series	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
17	Taylor's and Laurent Series	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
18	Singular points	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
19	Residues	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
20	Cauchy's residue theorem	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination

21	Conformal mappings	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
22	Bilinear transformations	Explain the concept of Complex analysis and its applications in Engineering.	Lecture, Discussion & Examples	**2105.2**	Quizzes, assignments, Two Sessional, End Term Examination
23	Gradient & Directional derivatives	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
24	Divergence & Curl	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
25	Line Integrals Identify	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
26	Surface Integrals	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
27	Volume Integrals	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
28	Green's Theorem and its application	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
29	Gauss's Theorem and its Applications	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
30	Stoke's Theorem and its Applications	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
31	Formation, solutions of equations involving derivatives with respect to one variable only	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination

32	Formation, solutions of equations involving derivatives with respect to one variable only	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	Lecture, Discussion & Examples	**2105.3**	Quizzes, assignments, Two Sessional, End Term Examination
33	Solutions by indicated transformations and separation of Variables.	Solve wave and heat equations using Gauss divergence theorem and method of separation of Variables	Lecture, Discussion & Examples	**2105.4**	Quizzes, assignments, Two Sessional, End Term Examination
34	Derivation of one dimensional heat equation using Gauss divergence theorem	Solve wave and heat equations using Gauss divergence theorem and method of separation of Variables	Lecture, Discussion & Examples	**2105.4**	Quizzes, assignments, Two Sessional, End Term Examination
35	Derivation of one dimensional heat equation using Gauss divergence theorem	Solve wave and heat equations using Gauss divergence theorem and method of separation of Variables	Lecture, Discussion & Examples	**2105.4**	Quizzes, assignments, Two Sessional, End Term Examination
36	Derivation of one dimensional wave equation (vibrating string) and its solution by using the method of separation of Variables.	Solve wave and heat equations using Gauss divergence theorem and method of separation of Variables	Lecture, Discussion & Examples	**2105.5**	Quizzes, assignments, Two Sessional, End Term Examination
37	Derivation of one dimensional wave equation (vibrating string) and its solution by using the method of separation of Variables.	Solve wave and heat equations using Gauss divergence theorem and method of separation of Variables	Lecture, Discussion & Examples	**2105.5**	Quizzes, assignments, Two Sessional, End Term Examination

Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
MA2105.1	Memorize the conceptual theory of Functions and understand about Fourier integral	3	1	1	1	1								1	1	
MA2105.2	Explain the concept of Complex analysis and its applications in Engineering.	3	2	1	1	1								1	1	
MA2105.3	Sketch the concept of Vector calculus to form and solve the equations involving derivatives with respect to one variable.	3	2	1	1	1								1	1	
MA2105.4	Solve heat equations using Gauss divergence theorem and method of separation of Variables	3	2	2	2	1		1						1	1	
MA2105.5	Solve wave using Gauss divergence theorem and method of separation of Variables	3	2	2	2	1		1						1	1	

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR
School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Hand-out
Chemical Process Calculations| CE 2101 | 4 Credits | 3 1 0 4
Session: Aug'20 – Dec'20 | Faculty: Dr. Harsh Pandey | Class: Core course

A. INTRODUCTION

This course on Chemical Process Calculations is a core course designed for the undergraduate students of Chemical Engineering. This course is intended to provide clear overview of field of chemical engineering and introduce the elementary principles involved in the analysis of chemical processes. It offers the fundamental knowledge required in solving the material and energy balances related to industrial problems and covers the concepts ranging from basic units and dimensions to simultaneous material and energy balances for reacting and non-reacting systems.

B. COURSE OUTCOME

At the end of the course, students will be able to

[CE 2101.1] Understand the fundamental concepts and calculations in chemical processes

[CE 2101.2] Develop the skills to perform mass balance calculations on existing systems

[CE 2101.3] Develop the skills to perform energy balance calculations

[CE 2101.4] Evaluate the bubble point and dew points of multicomponent mixtures

[CE 2101.5] Use the psychrometric charts to determine the properties of air required in solving vaporization and condensation problems

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full-scale plant taking into account environmental concerns.

PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	15
	Sessional Exam II (Open Book)	15
	In class Quizzes and Assignments , Activity feedbacks (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Homework/ Home Assignment/Quiz (Formative)	All assignments are to be solved and submitted, on/before deadline, on plain A4 size sheets only. Late submissions will not be entertained.	
Make up Assignments (Formative)	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture. However, you may contact the course coordinator for clarification of doubts, if any.	

E. SYLLABUS

Guidelines for Problem Solving; Review of Basic concepts – Process variables & properties, Degree of Freedom, **MATERIAL BALANCES**: Steady State Material Balances – in non-reacting systems and reacting system, Recycle & purge, elemental vs. species balance, combustion of fossil fuels. **MULTIPHASE EQULIBRIUM**: Single component and multicomponent phase equilibrium, Steady State Material balances in Multiphase systems. **ENERGY BALANCES**: Steady State Energy Balances – in non-reacting & reacting systems, De-Coupled & coupled mass & energy balances, Calculations for network of units with recycle & bypass, Process Flow sheeting with sequential modular calculations, Unsteady State Balances. **HUMIDIFICATION**: Terminology of humidity, Humidity charts, heating and cooling problems of moist air.

F. TEXT BOOKS

T1. David M. Himmelblau and James B.Riggs, Basic Principles and Calculations in Chemical Engineering, 8th ed., Pearsons, TN, 2015

G. REFERENCE BOOKS

R1. Richard M. Felder, Ronald W. Rousseau, Elementary Principles of Chemical processes, 3rd ed., Wiley, 2004

R2. B.I Bhatt and S.M Vora, Stoichiometry, 4th ed., Mc Graw Hill, 2004

H. LECTURE PLAN

LEC NO	TOPICS	SESSION OUTCOME	MODE OF DELIVERY	CORRESPONDING CO	MODE OF ASSESSING CO
1	Introduction to course and its significance	-	Lecture	-	
2,3	Dimensions and Units - Units and conversions and its significance, Fundamental and derived units, Conversion factors, Dimensional consistency	Fundamentals of units and conversions	Lecture	CE 2101.1	Mid Term I, Assignment / Quiz & End Term
4,5	Basic chemical calculations	Concept of mole unit and equivalent weight, Definitions and Calculations for density, specific gravity concentration, interconversion of mole fraction and mass fraction, Temperature and pressure	Lecture	CE 2101.1	Mid Term I, Assignment / Quiz & End Term
6, 7	Choosing a basis, Example problems	Choosing a basis	Lecture	CE 2101.1	Mid Term I, Assignment / Quiz & End Term
8,9	Material Balances without chemical reactions -	Concept of open vs closed systems, steady vs unsteady state systems Degrees of freedom	Lecture	CE 2101.2	Mid Term I, Assignment / Quiz & End Term
10,11	Material Balances without chemical reactions -	Material balance for single units	Lecture	CE 2101.2	Mid Term I, Assignment / Quiz & End Term
12-14	Material Balances without chemical reactions -	Material balance for single units involving unit operations such as mixers, dryers, evaporators, crystallizers, absorbers and strippers	Lecture	CE 2101.2	Mid Term I, Assignment / Quiz & End Term

15-17	Material Balances with chemical reactions -	Concept of limiting and excess reactants, Extent of reaction, Percentage conversion, yield, selectivity.	Lecture	CE 2101.2	Mid Term I, Assignment / Quiz & End Term
18	Material Balances with chemical reactions -	Material balances involving single and multiple reactions using atomic/elementary balances and molecular/species balances	Lecture	CE 2101.2	Mid Term II, Assignment / Quiz & End Term
19 - 22	Material Balances for multiple units –	Material balances with recycle, bypass and purge streams	Lecture	CE 2101.2	Mid Term II, Assignment / Quiz & End Term
22-25	Combustion calculations -	Problems on combustion of coal, calorific value of fuels, Air requirement and flue gas analysis	Lecture	CE 2101.2, CE 2101.3	Mid Term II, Assignment / Quiz & End Term
26-28	Ideal and Real Gases -	Concept of Ideal gas law and Henrys law. Real gas relationships and estimation of gas properties. Compressibility factor	Lecture	CE 2101.3	Mid Term II, Assignment / Quiz & End Term
29,30	Multiphase Equilibrium -	Vapour liquid equilibrium, dew point and bubble point calculations	Lecture	CE 2101.4	Mid Term II, Assignment / Quiz & End Term
31,32	Multiphase Equilibrium -	Use of Psychometric/humidity charts in problem solving	Lecture	CE 2101.4	Mid Term II, Assignment / Quiz & End Term
33,34	Energy Balances without reactions -	First law of thermodynamics, heat capacities of gases and gaseous mixtures, Sensible heat changes in liquids and gases.	Lecture	CE 2101.3	Assignment / Quiz & End Term
35,36	Energy Balances without reactions -	Enthalpy changes during phase transition	Lecture	CE 2101.3	Assignment / Quiz & End Term
37,38	Energy Balances with Chemical Reactions -	Heat of reaction, heat of formation, heat of combustion	Lecture	CE 2101.3	Assignment / Quiz & End Term
39,40	Energy Balances with Chemical Reactions -	enthalpy change associated with systems involving chemical reactions	Lecture	CE 2101.3	Assignment / Quiz & End Term
41,42	Humidity charts and their use	Humidity calculations	Lecture	CE 2101.5	Assignment / Quiz & End Term

I. COURSE ARTICULATION MATRIX (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE 2101.1	Understand the fundamental concepts and calculations in chemical processes	3	1	2		1	2		1				3	3	2	
CE 2101.2	Develop the skills to perform mass balance calculations on existing systems	3	2	2		1		1		1			3	3	2	1
CE 2101.3	Develop the skills to perform energy balance calculations	3	2	2		1		1		1			3	3	2	1
CE 2101.4	Evaluate the bubble point and dew points of multicomponent mixtures	3	2	2	2	1	1						1	1		1
CE 2101.5	Use the psychrometric charts to determine the properties of air required in solving vaporization and condensation problems	3	2	2	2		2	1					2	1		1

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Momentum Transfer Operations | CE 2102 | 4 Credits | 3 1 0 4

Session: July 20 – Dec 20 | Faculty: Dr. Anees Y. Khan | Class: Core Course

A. Introduction:

This course is one of the fundamental ground stones of Chemical Engineering. As a practicing chemical engineer you will have to deal with fluids that need to be transported from one part of the process plant to another. Therefore, in this course of momentum transfer you will be introduced to what a fluid is and how are they classified based on their flow properties. Following that you will study how to analyse a fluid in static state, kinematic state and dynamic state. This would include you getting to know different ways of measuring fluid flow and pumping of fluids. At the end of the course unit operations of agitation and mixing, flow through packing, filtration, fluidization and centrifugation will be introduced.

B. Course Outcomes:

At the end of the course, students will be able to

[CE2102.1] Classify fluids based on rheology and calculate as well as correlate different fluid properties.

[CE2102.2] Correlate the concept of pressure with its measurement and use this knowledge to evaluate and design fluid static equipment like storage tanks and decanters.

[CE2102.3] Assess and design fluid flow measurement equipment based on Bernoulli's equation applying them to different flow problems.

[CE2102.4] Design, evaluate and develop the skill to understand the characteristics of different types of pumps/Blowers.

[CE2102.5] Design different fluid-based unit operations like agitation and mixing, flow through packing, filtration, fluidization and centrifugation.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.
PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10. 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.
PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	In class Quizzes and Assignments.	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	No makeup for missed short quizzes or assignments or exam will be allowed, except in extenuating circumstances with prior permission of the instructor. The decision of the instructor in this regard will be final.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS

Review of Navier-Stokes' (NS) equations; non-dimensionalization of NS equations; introduction to turbulence; analogies; correlations for fluid flow; Short introduction to non-Newtonian flows, Engineering Bernoulli Equation; f vs. NRe charts; K factors and equivalent lengths for various fittings; hydraulic diameter; Head vs. Q plots of centrifugal pumps; NPSH, cavitation and priming; pipeline system design including pseudo-steady state approximation; flow measurements; compressors and blowers. Compressible flows in conduits. Mixing and Agitation: Power consumption; mixing times; scale-up, Characterization of solids; fundamentals of two-phase flow; flow through packed beds and in fluidized beds (pressure drops, loading and flooding); pneumatic and hydraulic transportation. Filtration, Centrifuges and cyclones.

F. TEXT BOOKS

T1. de Nerves, N., "Fluid Mechanics for Chemical Engineers", McGraw Hill International.

T2. McCabe, W.L., Smith, J.C., Harriott, P., "Unit operations of Chemical Engineering", McGraw Hill International.

G. REFERENCE BOOKS

R1. Foust, A.S., Wenzel, L.A., Clump, C.W., Maus, L., Andersen, L.B., "Principles of Unit Operations", John Wiley & Sons.

R2. Coulson, J.M., Richardson J.F, Backhurst, J.R., Harker, J.H., "Coulson and Richardson's Chemical Engineering Volume 1: Fluid Flow, Heat Transfer and Mass Transfer" Butterworth-Heinemann/Elsevier.

R3. Streeter, V.L., Wiley, B., "Fluid Mechanics", McGraw Hill International.

R4. Bansal, R.K., "A Textbook of Fluid Mechanics and Hydraulic Machine", Khanna Publications.

R5. Douglas, J.F., Gasiorek, J.M., Swaffield, J.A., "Fluid Mechanics", Pearson/Prentice Hall

R6. Bennett, C.O., Myers, J.E., "Momentum, Heat, and Mass Transfer", McGraw Hill International.

R7. Bird, R.B., Stewart, W.E., Lightfoot, E.N., "Transport Phenomena" John Wiley & Sons.

R8. Geankoplis, C.J., "Transport Processes and Separation Process Principles", Prentice Hall of India.

H. Lecture Plan

Lecture	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
1-3	**Introduction to fluid mechanics**	Introduction to Fluid Mechanics, Continuum Hypothesis, Properties of fluids	Lecture	2102.1	Mid Term I, Assignment & End Term
4-7	**Fluid statics**	Hydrostatics, Application of hydrostatics, Buoyancy, Barometers, Manometers, Gravity settling, Centrifugal decanters, Illustration by examples.	Lecture	2102.2	Mid Term I, Assignment & End Term
8-9	**Dimensional analysis**	Raleigh Method, Buckingham π theorem, Introduction of dimensionless numbers	Lecture	2102.1	Mid Term I, Assignment & End Term
10-11	**Introduction to Fluid Dynamics**	The General Balance Equations, Mass Balance, Flow lines, Velocity Distribution, Steady and Unsteady state balance (one dimensional),- illustration by examples	Lecture	2102.3	Mid Term I, Assignment & End Term
12	**Differential analysis of Fluid Flow**	Euler's equation, Navier Stokes Equation	Lecture	2102.3	Mid Term II, Assignment & End Term
13-17	**Energy Balance Equations for Fluid Flow**	Energy and its different forms, First Law of Thermodynamics, Mechanical Energy Equation (Bernoulli's Equation), Correction factors for Bernoulli's Equation, Head form of Bernoulli's Equation	Lecture	2102.3	Mid Term II, Assignment & End Term
18-21	**Flow though Pipes**	Reynold's Experiment, Reynold's number, Laminar and Turbulent flow, Boundary layer theory, Flow through pipes, Friction factor, Moody's diagram- illustration by examples	Lecture	2102.3	Mid Term II, Assignment & End Term
22-24	**Applications of Bernoulli's equation**	Sudden Expansion and Sudden Contraction, Torricelli's Equation, Pitot tube, Venturi meters, Orifice meters, Rotameter, Losses in pipe systems- illustration by examples	Lecture	2102.4	Mid Term II, Assignment & End Term
25-27	**Pumps and Compressors**	Introduction to positive displacement pumps, centrifugal pumps, NPSH, Cavitation, Reciprocating blowers, centrifugal blowers- illustration by examples	Lecture	2102.4	Mid Term II, Assignment & End Term

28-29	**Pipe Networks**	Design of pipe networks- illustration by examples	Lecture	2102.3	Mid Term II, Assignment & End Term
30-32	**Mixing and Agitation**	Need for agitation and mixing, Types of agitation, Vortex and Baffles, Impeller types, Dimensionless numbers related to mixing, Scale up of agitated vessels, Static mixers, Jet mixers	Lecture	2102.5	End Term
33-42	**Solid Liquid Flows**	Concept of Drag & Coefficient of Drag, Stagnation point, Flow through bed of solids, Motion of particles in fluids, Fluidization, Sedimentation, Filtration	Lecture	2102.5	End Term

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE2102.1	Classify fluids based on rheology and calculate as well as correlate different fluid properties.	3	3		1								2	1		2
CE2102.2	Correlate the concept of pressure with its measurement and use this knowledge to evaluate and design fluid static equipment of storage tanks and decanters.	3	3	1			1	2	1		1	1	2			
CE2102.3	Assess and design fluid flow measurement equipment based on Bernoulli's equation applying them to different flow problems.	3	3	2				1		1	1	1	2			
CE2102.4	Design, evaluate and develop the skill to understand the characteristics of different types of pumps/Blowers.	3	3	2				2		2	1	1	2	1		
CE2102.5	Design different fluid-based unit operations like agitation and mixing, flow through packing, filtration, fluidization and centrifugation.	3	3				1	3		2	1	2	2	2	1	

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Transport Phenomena | CE2104 | 4 Credits | 3 1 0 4

Session: Aug 20 – Nov 20 | Faculty: Dr Gaurav Kataria | Class: II Semester

A. Introduction: This course is an introductory course in Transport Phenomena whereby the student shall be exposed to the various major areas and their applications. The student shall be armed with the basic tools and understanding of the field. The 'premium' in this course shall be on 'thinking' rather than doing things 'mechanically' so that the student is able to apply the various concepts to different situations, other than the ones encountered during the course, as and when the need arises.

B. Course Outcomes: At the end of the course, students will be able to

[2104.1]. Identify transport properties and analyse the mechanisms of momentum, energy and mass transport.

[2104.2]. Develop the skills to select, locate and orient coordinate systems for transport phenomena problems.

[2104.3]. Generate the skills to formulate the differential forms of the equations of change for momentum, heat and mass transfer problems for steady-state and unsteady flows.

[2104.4]. Reduce and solve appropriate macroscopic balances for conservation of momentum, energy and mass

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.

The Graduates of Chemical Engineering from MUJ will have:

PO.1 **Engineering Knowledge:** A thorough knowledge of the basic science, engineering and mathematics and apply that to the underline practice of Chemical Engineering.

PO.2 **Problem Analysis:** Ability to apply these basic principles to solve real world problems in a broad range of career paths.

PO.3 **Project management and finance:** The skills of making smart decisions on process feasibility based in technical and economic evaluation.

PO.4 **Ethics**: The ability to appreciate the social, ethical, cultural, environmental and safety issues related to chemical engineering profession.

PO.5 **Conduct investigations of complex problems**: The ability to develop experimental procedure/protocol to test hypothesis and analysis meaningful interpretation of the generated data.

PO.6 **Environment and sustainability**: The skill to generate sustainable engineering solutions to societal and industrial problems.

PO.7 **Modern tool usage**: Proficiency to use computational tools for problem solving.

PO.8 **Communication**: ability to communicate effectively (technical and non-technical context) in written and oral form.

PO.9 **Design/development of solutions**: Skills to work effectively and professionally in multi-disciplinary groups to solve complex chemical engineering problems.

PO.10 **Individual and team work**: The ability to work effectively and professionally on projects both independently and as a part of a group/team.

PO.11 **Life-long learning**: The ability to be self-learners and lifelong learners.

PO.12 **The engineer and society**: The motivation to develop and lead entrepreneurial projects for societal benefit.

Degree Specific Outcomes for chemical engineering are as follows:

PSO.1 Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

POS.2 Process Intensification: graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3 Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	In class Quizzes and Assignments	30
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Homework/ Home & Class Assignment (Formative)	Home and class assignments are an integral part of this course – you can only learn by doing! Homework will be assigned in between the lectures along with the due date for handing it over. Assignments will also be given during lecture hours where students will be asked to solve open-ended problems/case studies within stipulated time. No late assignments handed after the due date shall be accepted under any circumstance. It is expected that the students shall work on the assignments independently and not 'copy' the solutions from each other. Students are encouraged to discuss problems with their instructor in lecture hours. Students are advised to meet the instructor in case of any difficulty related to assignments and course related matters.	

E. SYLLABUS

Momentum Transport- Viscosity and mechanisms of momentum transport, shell momentum balances and velocity distribution in laminar flow, the equations of change for isothermal systems, velocity distributions with more than one independent variable, velocity distribution in turbulent flow, interphase transport in isothermal systems, macroscopic balances for isothermal flow systems

Energy Transport- Thermal conductivity and mechanisms of energy transport, shell energy balances and temperature distributions in solids and laminar flow, the equations of change for nonisothermal systems, temperature distributions with more than one independent variable, temperature distribution in turbulent

flow, interphase transport in nonisothermal systems, macroscopic balances for nonisothermal systems, energy transport by radiation

Mass Transport- Diffusivity and mechanisms of mass transport, concentration distributions in solids and laminar flow, equations of change for multicomponent systems, interphase transport in nonisothermal mixtures, macroscopic balances for multicomponent systems.

F. TEXT BOOKS

T1. "Transport Phenomena" (Second Edition), R B Bird, W E Stewart, E E Lightfoot, John Wiley & Sons, (2007).

G. REFERENCE BOOKS

"Analysis of Transport Phenomena" (Second Edition), W M Deen, Oxford University Press, (2013).

"Transport Processes and Separation Process Principles: (includes Unit Operations)" (Forth Edition), C Geankoplis, Prentice Hall of India, (2004).

"Introduction to Transport Phenomena" W J Thompson, Prentice Hall, (1999).

H. Lecture Plan:

Lecture No.	Topics	Session Outcome	Mode of Delivery	Corresponding Course Outcome	Mode of Assessing the Outcome
1.	Introduction ; Newton's Law of Viscosity	Understand the role of viscosity in the momentum transfer.	Lecture	2104.1	Mid Term I End Term
2.	Non-Newtonian Fluids; Pressure-Temperature Dependence of Viscosity	Distinguishing the types of fluids based on viscosity.	Lecture	2104.1	Mid Term I End Term
3.	Shell Momentum Balances: Boundary Conditions; Flow of a Falling Film	Understand the use of shell momentum balance.	Lecture	2104.1/3	Mid Term I End Term
4.	Flow through a Circular Tube	Understand the use of shell momentum balance.	Lecture	2104.1/2/3	Mid Term I End Term
5.	Flow through an Annulus.	Understand the use of shell momentum balance.	Lecture	2104.1/2/3	Mid Term I End Term
6.	The Equation of Continuity; The Equation of Motion	Generalizing the shell momentum balance equations.	Lecture	2104.1/2/3	Mid Term I End Term
7.	Equations of Change in Curvilnear Coordinates; Uses of Equations of Change to set up Steady Flow Problems	Generalizing the shell momentum balance equations.	Lecture	2104.1/2/3	Mid Term I End Term
8.	Dimensional Analysis of the Equations of Change	Generalizing the shell momentum balance equations.	Lecture	2104.1/2/3	Mid Term I End Term
9.	Unsteady Viscous Flow	Understanding the unsteady flow problems.	Lecture	2104.1	Mid Term I End Term
10.	Fluctuations and Time-Smoothed Quantities; Time-Smoothing of the Equations of Change for an incompressible Fluid	Understanding the solution of unsteady flow problems.	Lecture	2104.2/3	Mid Term I End Term
11.	Definition of Friction Factors; Friction Factors for Flow in Tubes; Friction Factors for Flow Around Spheres	Understanding the role of friction factor in the transport phenomenon.	Lecture	2104.1	Mid Term I End Term
12.	The Macroscopic Mass Balance; The Macroscopic Momentum Balance	Distinguishing the macroscopic and microscopic problems.	Lecture	2104.1/3	Mid Term I End Term

13.	The Macroscopic Mechanical Energy Balances; Estimation of Friction Loss	Distinguishing the macroscopic and microscopic problems.	Lecture	2104.1/3/4	Mid Term I End Term
14.	Use of the Macroscopic Balance to set up Steady Flow Problems	Distinguishing the macroscopic and microscopic problems.	Lecture	2104.1/3/4	Mid Term I End Term
15.	Review Lecture		Lecture		Mid Term I End Term
MID-TERM I					
16.	Fourier's Law of Heat Conduction; Temperature and Pressure Dependence of Thermal Conductivity in Gases and Liquids	Understand the basic concept of heat transfer.	Lecture	2104.1	Mid Term II End Term
17.	Shell Energy Balances; Boundary Conditions; Heat Conduction with an Electrical Heat Source	Understand the use of shell energy balance.	Lecture	2104.1/3	Mid Term II End Term
18.	Heat Conduction with a Viscous Heat Source	Understand the use of shell energy balance.	Lecture	2104.1/3	Mid Term II End Term
19.	Heat Conduction through Composite Walls: Addition of Resistances	Understand the use of shell energy balance.	Lecture	2104.1/3	Mid Term II End Term
20.	Forced Convection; Free Convection	Distinguishing the solution of forced and free convection.	Lecture	2104.1/3	Mid Term II End Term
21.	The Equations of Energy; The Energy Equation in Curvilinear Coordinates	Generalizing the shell energy balance equations.	Lecture	2104.1/2/3	Mid Term II End Term
22.	Summary of the Equations of Change; Use of the Equations of Change to set up Steady Flow Heat Transfer Problems	Generalizing the shell energy balance equations.	Lecture	2104.1/2/3	Mid Term II End Term
23.	Dimensional Analysis of the Equations of Change	Generalizing the shell energy balance equations.	Lecture	2104.1/2/3	Mid Term II End Term
24.	Unsteady Heat Conduction in Solids	Understanding the unsteady heat flow problems.	Lecture	2104.1/3	Mid Term II End Term
25.	Definition of the Heat Transfer Coefficient; Heat Transfer Coefficients for Forced Convection in Tubes; Heat Transfer Coefficient for Forced	Understanding the common terms of heat transfer and their role in the chemical engineering applications.	Lecture	2104.1/3/4	Mid Term II End Term

	Convection around Submerged Objects				
26.	Heat Transfer Coefficients for Free Convection	Understanding the heat transfer concept in free convection.	Lecture	2104.1/3	Mid Term II End Term
27.	Spectrum of Electromagnetic Radiation; Absorption and Emission at Solid Surfaces; Planck's Law; Wien's Law; Stefan-Boltzmann Law	Understanding the basics of radiation heat transfer.	Lecture	2104.1	Mid Term II End Term
28.	Direct Radiation between Black Bodies in Vacuo at Different Temperatures	Understanding the basics of radiation heat transfer.	Lecture	2104.1/3	Mid Term II End Term
MID-TERM II					
29.	The Macroscopic Energy Balance; The Macroscopic Mechanical Energy Balance (Bernoulli Equation)	Distinguishing the macroscopic and microscopic heat problems.	Lecture	2104.1/3	End Term
30.	Summary of the Balances for Pure Fluids; Use of the Macroscopic Balances for Solving Steady-State Problems (458-460)	Distinguishing the macroscopic and microscopic heat problems.	Lecture	2104.1/2/3	End Term
31.	Definition of Concentrations, Velocities, and Mass Fluxes; Fick's Law of Diffusion; Temperature and Pressure Dependence of Mass Diffusivity	Defining basic terms of mass transfer in transport phenomenon.	Lecture	2104.1/3/4	End Term
32.	Shell Mass Balances; Boundary Conditions; Diffusion through a Stagnant Film	Understand the use of shell mass balance.	Lecture	2104.1/3	End Term
33.	Diffusion with Heterogeneous Chemical Reaction; Diffusion with Homogeneous Chemical Reaction	Understand the use of shell mass balance.	Lecture	2104.1/3	End Term
34.	Diffusion in to a Falling Liquid Film: Forced Convection Mass Transfer	Understand the use of shell mass balance.	Lecture	2104.1/3	End Term
35.	The Equations of Continuity for a Binary Mixture; The Equation of Continuity of A in Curvilinear	Generalizing the shell mass balance equations.	Lecture	2104.1/3	End Term

	Coordinates; The Multicomponent Equations of Change in Terms of Fluxes				
36.	Dimensional Analysis of the Equations of Change for a Binary Isothermal Fluid Mixture	Generalizing the shell mass balance equations.	Lecture	2104.1/2/4	End Term
37.	Definition of Binary Mass Transfer Coefficients in One Phase; Correlations of Binary Mass Transfer Coefficients in One Phase at Low Mass Transfer Rates	Understanding the binary mass transfer terms.	Lecture	2104.1	End Term
38.	Definition of the Transfer Coefficients for High Mass Transfer Rates	Understanding the high mass transfer concepts.	Lecture	2104.1/4	End Term
39.	The Macroscopic Mass / Momentum / Energy Balances for Multicomponent Systems; Use of Macroscopic Balances to Solve Steady State Problems	Distinguishing the macroscopic and microscopic mass transfer problems.	Lecture	2104.1/3	End Term
40.	Use of Macroscopic Balances to Solve Steady State Problems	Solving the macroscopic mass transfer problems.	Lecture	2104.1/3	End Term
END-TERM EXAMINATION					

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE2104.1	Identify transport properties and analyze the mechanisms of momentum, energy and mass transport.	3	3			1		1		2		1		3	1	
CE2104.2	Develop the skills to select, locate and orient coordinate systems for transport phenomena problems.	3	3					1		1		2		2	1	
CE2104.3	Generate the skills to formulate the differential forms of the equations of change for momentum, heat and mass transfer problems for steady-state and unsteady flows.	3	3			3		2		2		2		3	2	
CE2104.4	Reduce and solve appropriate macroscopic balances for conservation of momentum, energy and mass	3	2			1		1		1		2		1	2	

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Lab Hand-out

Transport Phenomena Lab-I | CE 2130 | 2 Credits | 0 0 4 2

Session: Aug 20 – Dec 20 | Faculty: Anees Y. Khan | Class: Laboratory

A. Introduction: This lab focusses on the experiments related to momentum transfer operations theory course, designed for undergraduate students of chemical engineering. Experiments shall be performed on equipment based on Bernoulli's principle, Reynolds setup, major and minor losses in pipe friction, agitators, pumps etc.

B. Course Outcomes: At the end of the course, students will be able to

[2130.1] Have a deep understanding of the fundamentals of fluid mechanics and their real life applications
[2130.2] Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning
[2130.3] Perform experimental investigations on different fluid mechanics set up's and gain competency in performing and analysing the data.
[2130.4] Assess the results obtained to that approximated by theories reported in literature
[2130.5] Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment

C. Program outcomes and program specific outcomes

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.
PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6. 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.
PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Conducting experiments and report	Viva + Safety	10+5
	Soft copy of reports + Excel sheets	5
	Pre-lab and Post Lab reports	50
End Term Exam	End Term Exam (Open Book)	30
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Labs	No make-up labs will be conducted in case of absence during the labs except in extenuating circumstances, with the prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Pre & Post Lab reports	Pre & Post lab reports must be submitted before the specified due date for handing it over. No late submissions after the due date shall be accepted under any circumstance. It is expected that the students shall work on the experiments independently and analyse their results on their own without 'copying' the solutions from each other.	

E. List of Experiments & their objectives

Sl. No.	Experimental set-up	Objective
1.	Rotameter	To study the flow measurements using rotameter – Calibration and discharge measurement using rotameter.
2.	Venturimeter	To study the flow measurements using venturimeter –To determine the coefficient of discharge through venturimeter
3.	Bernoulli's setup	To verify experimentally the validity of Bernoulli's Principle for fluid flow.
4.	Orifice meter	To study the flow measurement using orificemeter –To determine the coefficient of discharge through orificemeter
5.	Setup for Major losses (pipe)	To study the losses due to friction in pipes and determine the friction factor.
6.	Setup for Minor losses (pipe-fittings)	To determine the loss of head in the fittings at various water flow rates to measure the loss coefficient for the pipe fittings and to study losses due to fittings, sudden enlargements and contractions.

7.	Agitated vessels	To study the power consumption of a fluid in an agitated vessel with and without baffles and to Plot the power number vs Reynolds Number for the same.
8.	Reynold's setup	To study of flow behavior (laminar, transition and turbulent regime) using Reynold's Apparatus.
9.	Pitot tube	To find the point velocity at the center of the tube for different flowrates of water and calibrate the Pitot tube.
10.	Characteristics of a centrifugal pump	To study of centrifugal pump characteristics – Determining the relationship between the head discharge, speed, power and efficiency for a centrifugal pump at various rotation speeds and determining flow rate characteristics at the same speed

F. Text books

T1. de Nerves, N., "Fluid Mechanics for Chemical Engineers", McGraw Hill International.

T2. McCabe, W.L., Smith, J.C., Harriott, P., "Unit operations of Chemical Engineering", McGraw Hill International.

G. Experiment Plan:

Lab No.	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1	Rotameter	To study the flow measurements using rotameter – Calibration and discharge measurement using rotameter.	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam
2	Venturimeter	To study the flow measurements using venturimeter –To determine the coefficient of discharge through venturimeter	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam
3	Bernoulli's setup	To verify experimentally the validity of Bernoulli's Principle for fluid flow.	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;;	Report + Viva +End sem lab exam
4	Orifice meter	To study the flow measurement using orificemeter –To determine the coefficient of discharge through orificemeter	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam
5	Setup for Major losses (pipe)	To study the losses due to friction in pipes and determine the friction factor.	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam
6	Setup for Minor losses (pipe-fittings)	To determine the loss of head in the fittings at various water flow rates to measure the loss coefficient for the pipe fittings and to study losses due to fittings, sudden enlargements and contractions.	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam
7	Agitated vessels	To study the power consumption of a fluid in an agitated vessel with and	Lab	CO2130.1; CO2130.2;	Report + Viva +End

		without baffles and to Plot the power number vs Reynolds Number for the same.		CO2130.3; CO2130.4; CO2130.5;	sem lab exam
8	Reynold's setup	To study of flow behavior (laminar, transition and turbulent regime) using Reynold's Apparatus.	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam
9	Pitot tube	To find the point velocity at the center of the tube for different flowrates of water and calibrate the Pitot tube.	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam
10	Characteristics of a centrifugal pump	To study of centrifugal pump characteristics – Determining the relationship between the head discharge, speed, power and efficiency for a centrifugal pump at various rotation speeds and determining flow rate characteristics at the same speed	Lab	CO2130.1; CO2130.2; CO2130.3; CO2130.4; CO2130.5;	Report + Viva +End sem lab exam

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE2130.1	Have a deep understanding of the fundamentals of fluid mechanics and their real life applications	2	1	1	1	1										
CE2130.2	Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning			1			1		2	3			1			
CE2130.3	Perform experimental investigations on fluid mechanics equipment's and gain competency in performing and analysing the data		2	2	3	1			2		1					
CE2130.4	Assess the results obtained to that approximated by theories reported in literature			2	3	1			2		2					
CE2130.5	Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment				3	1		1	2	1	1		1			

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

School of Humanities and Social Sciences
Department of Economics
Course Handout

Economics | EO 2001 | 3 Credits | 3003

Session: Jan-21-June21 | Faculty: Dr. Thakur Dev Pandey | Class: B. Tech, Chemical Eng. | Semester IV

A. Introduction: This course is offered by Dept. of Economics to the Engineering departments, targeting students to give basic understanding in the concept of economics. It mainly deals with economic issues related to consumer behaviour, firms, industries and business organizations to make aware the students regarding economic environment. This course also discusses the preliminary concepts associated with macroeconomic variable like GDP inflation, balance of payments etc. It explores various possibilities emerging in an economy and the role of economic policy in this context

B. Course Outcomes: At the end of the course, students will be able to

[2001.1] Describe the basic principles of micro and macroeconomic analysis to relate with real world.
[2001.2] Interpret and illustrate decision making process in practical life and hence enhance employability.
[2001.3] Aware of the tools and techniques of economics for real world to prepare the budget.
[2001.4] Recognize the problems and give solutions which in turn will create employability.
[2001.5] Recall the assumptions that underpin the Micro/Macro model

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

[PO1]. **Engineering knowledge**: Apply the knowledge of mathematics, computer science, and communication engineering fundamentals to the solution of complex engineering problems.

[PO2]. **Problem analysis**: The sophisticated curriculum would enable a graduate to identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using basic principles of mathematics, computing techniques and communication engineering principles.

[PO3]. **Design/development of solutions**: Upon analysing, the B Tech CCE graduate should be able to devise solutions for complex engineering problems and design system components or processes that meet the specified requirements with appropriate consideration for law, safety, cultural & societal obligations with environmental considerations.

[PO4]. **Conduct investigations of complex problems**: To imbibe the inquisitive practices to have thrust for innovation and excellence that leads to use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

[PO5]. **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.

[PO6]. **The engineer and society**: The engineers are called society builders and transformers. B. Tech CCE graduate should be able to 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.

[PO7]. **Environment and sustainability**: The zero effect and zero defect is not just a slogan, it is to be practised in each action. Thus, a B Tech CCE should understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

[PO8]. **Ethics**: Protection of IPR, staying away from plagiarism are important. Student should be able to apply ethical principles and commit to professional ethics, responsibilities and norms of the engineering practice.

[PO9]. **Individual and team - work**: United we grow, divided we fall is a culture at MUJ. Thus, an outgoing student should be able to function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

[PO10]. **Communication**: Communicate effectively for all engineering processes & activities with the peer engineering team, community and with society at large. Clarity of thoughts, being able to comprehend and formulate effective reports and design documentation, make effective presentations, and give and receive clear instructions.

[PO11]. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in varied environments.

[PO12]. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

At the end of the B Tech program, the student:

[PSO1]. Should be able to clearly understand the basic principles, concepts and applications in the field of computer -based Communication/networking, information sharing, signal processing, web -based systems, smart devices and communication technology.

[PSO2]. Should be able to nail down the issues prevalent in the field of computer -based Engineering.

[PSO3]. Should be able to identify the existing open problems in the field of computing and propose the best possible solutions.

[PSO4]. Should be able to apply the contextual knowledge in the field of computer -based Communication Engineering to assess social, health, safety and cultural issues and endure the consequent responsibilities relevant to the professional engineering practice.

D. ASSESSMENT PLAN:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I	15
	Sessional Exam II	15
	Assignments , Activity, etc.	30
End Term Exam (Summative)	End Term Exam	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	

E. SYLLABUS

Introduction; Microeconomics: Consumer behaviour, cardinal and ordinal approaches of utility, law of diminishing marginal utility, theory of demand and supply, law of demand, exceptions to the law of demand, change in demand and change in quantity demanded,elasticity of demand and supply, consumer surplus and producer; Indifference curve, properties, consumer equilibrium, Price and income effect; **Production:** Law of production, production function, SR and LR production function, law of returns and returns to scale, Isoquant curve, characteristics, Iso-cost, producer's equilibrium; **Cost and revenue analysis:** Cost concepts, Opportunity cost, Incremental and sunk cost, Recurring and non-recurring cost, fixed and variable cost, short run and long- run cost and revenue curves**; Introduction to markets:** Characteristics and types, **Introduction to Macro Economics:** National Income, Monetary Policy, Fiscal Policy, Inflation and Business Cycle; **Economic decision making:** Cash flow and rate of return analysis, Pay - back period, Internal rate of return(IRR), Net present value(NPV), Time value of money.

F. TEXT- BOOKS

1. H.L Ahuja, *Macroeconomics Theory and Policy*, (20e) S. Chand Publication.
2. Peterson H C et.al., *Managerial Economics*, (9e), Pearson, 2012
3. P L Mehta, *Managerial Economics*, Sultan Chand & Sons, New Delhi, 2012.
4. G J Tuesen & H G Tuesen, *Engineering Economics*, PHI, New Delhi, 2008.
5. James L Riggs, David D Bedworth, Sabah U Randhawa, *Engineering Economics*, Tata - McGraw Hill, 2018.

G. LECTURE PLAN:

Lec. No	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of Assessing the Outcome
1	Overview of the course structure	To acquaint and clear the overview of the course	Lecture	NA	NA
2	Objective of the course	Discussion of the objective of the course for the engineers	Lecture	NA	NA
3,4	Introduction to Economics,	Describe the concept given by different economists, its scope, differences between micro and macro economics	Lecture	2001.1	Class Test Mid Term I
5,6,7,	Introduction to Consumer Behaviour, Cardinal approaches of utility	Describe the concept of cardinal approach of utility, Law of DMU and equi marginal utility	Lecture	2001.1	Class Test Mid Term I
8,9,10	Law of demand and supply, elasticity of demand and supply	Describe the concept of demand, supply, elasticity of demand and supply with examples, conceptual questions	Lecture	2001.1	Class Test Mid Term I
11	Revision of previous lectures	Recall all the concepts discussed in previous classes	Lecture	2001.5	Class Test Mid Term I End Term
12	Discussion of the topics related to assignment	Discussion about the assignment topics	Lecture, Activity		Home Assignment Mid Term 1 End term
14,15,16,17	Ordinal approaches of utility, Consumer surplus and producer's surplus	Recall of the differences between the concept of the cardinal approach and ordinal approach of utility , IC analysis, Consumers equilibrium, IE,SE,PE, Consumer and Producer surplus	Lecture	2001.5	Class Test Mid Term I End Term
17,18,19	Production, laws of production and return to scale	Discussion of the concept of production, recognize production function, producers equilibrium, RTS	Lecture	2001.4	Class Test Mid Term II End Term
20,21	Cost and revenue analysis	Discussion of the concept of different types of cost and cost function, recognize SR and LR cost curves, revenues	Lecture	2001.4	Class Test Mid Term II End Term
22,23	Types of Market Competition	Aware of market morphology with examples, Interpret the forms of market situations	Lecture	2001.3	Class Test Mid Term II End Term
24	Revision of previous lectures	Recall all the concepts discussed in previous classes	Lecture	2001.5	Class Test Mid Term II

					End Term
25	Discussion of the topics related to assignment	Recall the discussion about the assignment topics	Lecture, Activity	2001.5	Home Assignment Mid Term II End term
26	Macro Economics: National income and its concepts	Interpret and illustrate the concept of CB and various tools	Lecture	2001.2	Home Assignment Class Test End Term
27,28,29	Monetary and fiscal policies	Interpret and illustrate the concept of NI,GDP,GNI,PI etc., circular flow	Lecture	2001.2	Home Assignment Class Test End Term
30,31	Inflation	Concept of monetary and fiscal policies, Aware of its instruments, importance and limitations	Lecture	2001.3	Home Assignment Class Test End Term
32	Business Cycle	Concept of Business Cycles, Role of monetary and fiscal policy to counter business cycles	Lecture	2001.3	Home Assignment Class Test End Term
33, 34,35	Economic Decision Making	Cash flow and rate of return analysis, payback period, IRR, NPV and Time value of money	Lecture	2001.3	Home Assignment Class Test End Term
36	Revision of Previous Lectures	Recall the discussion about the assignment topics	Lecture	2001.5	End Term
37	Conclusion and Course Summarization	Recall all the concepts discussed in previous classes	Lecture	2001.5	End Term
38	Quiz-1	Microeconomics	Quiz	NA	Internal Assessment
39	Quiz-II	Macroeconomics	Quiz	NA	Internal Assessment

H. Course Articulation Matrix: (Mapping of COs with POs and PSOs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES			
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
EO 2001.1	Describe the basic principles of micro and macroeconomic analysis									1		2	2				
EO 2001.2	Interpret and illustrate decision making process in practical life and hence enhance employability						1			2			2				
EO 2001.3	Aware of the tools and techniques of economics for real world to prepare the budget									2		2	2				
EO 2001.4	Recognize the problems and give solutions which in turn will create employability									2		2	2				
EO 2001.5	Recall the assumptions that underpin the Micro/Macro model.									2			3				

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

Manipal University Jaipur
School of Civil and Chemical Engineering
Department of Mathematics & Statistics
Course Hand-out

Engineering Mathematics-IV | MA2208 | 3 Credits | 2 1 0 3
Session: Jan – May, 2021 | Faculty: Dr. Rishikesh Dutta Tiwary | Class: Chemical Eng. IV-Sem

A. Introduction: This course is offered by the Department of Mathematics & Statistics as a regular course will provide an overview of Operations Research (O.R.) from the perspective of an industrial engineer. A scientific approach to solving problems; it abstracts the essential elements of the problem into a *model*, which is then analyzed to yield an optimal solution for implementation. Also principles of probability and statistics, random variables and random functions will be discussed. Application to chemical engineering problems, including process design, process safety, heterogeneous materials and processes. In the second part the student will be acquainted with some Ordinary and Partial differential equation like Basic concepts, numerical solutions of boundary valued problems, Laplace and Poisson equations and heat and wave equations by explicit method, and fundamental knowledge from difference equations.

B. Course Outcomes: At the end of the course, students will be able to think logically.

[2208.1] Understand the mathematical tools that are needed to solve optimisation problems.

[2208.2] Express the concept of probability and its features with discrete and continuous random variables.

[2208.3] Understand the concept of Finite difference and classification of partial differential equation.

[2208.4] Solve the two dimensional Laplace and Poisson equations.

[2208.5] Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.

C. Program Outcomes and Program Specific Outcomes

PO1]. **Engineering knowledge**: Apply the knowledge of mathematics, computer science, and communication engineering fundamentals to the solution of complex engineering problems.

[PO2]. **Problem analysis**: The sophisticated curriculum would enable a graduate to identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using basic principles of mathematics, computing techniques and communication engineering principles.

[PO3]. **Design/development of solutions**: Upon analysing, the B Tech CCE graduate should be able to devise solutions for complex engineering problems and design system components or processes that meet the specified requirements with appropriate consideration for law, safety, cultural & societal obligations with environmental considerations.

[PO4]. **Conduct investigations of complex problems**: To imbibe the inquisitive practices to have thrust for innovation and excellence that leads to use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

[PO5]. **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.

[PO6]. **The engineer and society**: The engineers are called society builders and transformers. B. Tech CCE graduate should be able to 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.

[PO7]. **Environment and sustainability**: The zero effect and zero defect is not just a slogan, it is to be practised in each action. Thus, a B Tech CCE should understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

[PO8]. **Ethics**: Protection of IPR, staying away from plagiarism are important. Student should be able to apply ethical principles and commit to professional ethics, responsibilities and norms of the engineering practice.

[PO9]. **Individual and team - work**: United we grow, divided we fall is a culture at MUJ. Thus, an outgoing student should be able to function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

[PO10]. **Communication**: Communicate effectively for all engineering processes & activities with the peer engineering team, community and with society at large. Clarity of thoughts, being able to comprehend and formulate effective reports and design documentation, make effective presentations, and give and receive clear instructions.

[PO11]. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in varied environments.

[PO12]. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns

[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
	Sessional Exam I **(Closed Book)**	20

Internal Assessment (Summative)	Sessional Exam II **(Closed Book)**	20
	Quizzes , Assignments & Presentation	20
End Term Exam (Summative)	End Term Exam **(Closed Book)**	40
	Total	100

E. Syllabus

Prerequisites: - Differential calculus, Solution of Linear Differential equations, Collection, classification & representation of data, Permutations & combinations.

Syllabus: - Formation of Linear Programming problem, Graphical method, Simplex method, Penalty cost and two phase methods.

Finite sample spaces, conditional probability and independence, Bayes' theorem. One dimensional random variable, mean, variance, Chebyshev's inequality. Two and higher dimensional random variables, covariance, correlation coefficient, regression, least squares principles of curve fitting. Binomial, Poisson, uniform, normal, gamma, Chi-square and exponential.

Finite difference expressions for first and second order derivatives (ordinary and partial). Solution of BVP's in ODE. Classification of second order linear partial differential equations. Numerical solutions of two dimensional Laplace and Poisson equations by standard five point formula.

Solution of one dimensional heat and wave equations by explicit methods. Crank-Nicolson method. Finite element method, Introduction, simple applications.

Difference equations representing physical systems, the z transforms, properties of z transforms, initial and final value theorems, solution of difference equations by the method of z transforms, convolution theorem

F. Text Books:

1. Erwin Kreyszig, Advanced Engineering Mathematics, 7(e), John Wiley & Sons, Inc. 1993.

2. P.L. Meyer, Introduction to probability and Statistical applications, 2(e), American Publishing Co 1970. 3. A Taha Hamdy, Operation research, (7e), Inc. Pearson Education, 2002.

3. B.S. Grewal, Higher Engineering Mathematics, 43(e), Khanna Publishers, 2014.

4. S.S. Sastry, Introductory methods for Numerical Analysis, (5e), PHI Learning Private Limited, 2012.

G. Lecture Plan:

Lecture No.	Description of the Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of Assessing the Outcome
1	Introduction and Course Hand-out briefing	To acquaint and clear teachers expectations and understand student expectations	Discussion	**NA**	**NA**

2	Formation of Linear Programming problem	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
3	Formation of Linear Programming problem-Graphical method	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
4	Formation of Linear Programming problem-Graphical method	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
5	Formation of Linear Programming problem-Simplex method	Understand the techniques to form the LPP and its solution	Problem solving	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
6	Formation of Linear Programming problem-Simplex method	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
7	Formation of Linear Programming problem-Simplex method	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
8	Penalty Cost method	Understand the techniques to form the LPP and its solution	Problem solving	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
9	Penalty Cost method	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
10	Two phase method	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
11	Two phase method	Understand the techniques to form the LPP and its solution	Lecture, Discussion & Examples	**2208.1**	Quizzes, assignments, Two Sessional, End Term Examination
12	Finite sample spaces	Express the concept of probability and its features with discrete and continuous random variables.	Problem solving	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
13	conditional probability and independence	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
14	Bayes' theorem.	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
15	One dimensional random variable	Express the concept of probability and its features with discrete and continuous random variables	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
16	mean	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination

17	variance	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
18	Chebyshev's inequality	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
19	Two and higher dimensional random variables	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
20	covariance	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
21	correlation coefficient	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
22	regression	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
23	least squares principles of curve fitting	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
24	Binomial, Poisson	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
25	uniform, normal, gamma	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
26	Chi-square and exponential.	Express the concept of probability and its features with discrete and continuous random variables.	Lecture, Discussion & Examples	**2208.2**	Quizzes, assignments, Two Sessional, End Term Examination
27	Finite difference expressions for first and second order derivatives	Understand the concept of Finite difference and classification of partial differential equation.	Lecture, Discussion & Examples	**2208.3**	Quizzes, assignments, Two Sessional, End Term Examination
28	Solution of BVP's in ODE.	Understand the concept of Finite difference and classification of partial differential equation.	Lecture, Discussion & Examples	**2208.3**	Quizzes, assignments, Two Sessional, End Term Examination
29	Classification of second order linear partial differential equations.	Understand the concept of Finite difference and classification of partial differential equation.	Lecture, Discussion & Examples	**2208.3**	Quizzes, assignments, Two Sessional, End Term Examination
30	Numerical solutions of two dimensional Laplace and Poisson	Solve the two dimensional Laplace and Poisson equations.	Lecture, Discussion & Examples	**2208.4**	Quizzes, assignments, Two Sessional, End Term Examination

	equations by standard five point formula.				
31	Solution of one dimensional heat and wave equations by explicit methods.	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	Lecture, Discussion & Examples	**2208.5**	Quizzes, assignments, Two Sessional, End Term Examination
32	Crank-Nicolson method	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	Lecture, Discussion & Examples	**2208.5**	Quizzes, assignments, Two Sessional, End Term Examination
33	Finite element method	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	Lecture, Discussion & Examples	**2208.5**	Quizzes, assignments, Two Sessional, End Term Examination
34	Difference equations representing physical systems,	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	Lecture, Discussion & Examples	**2208.5**	Quizzes, assignments, Two Sessional, End Term Examination
35	the z transforms, properties of z transforms	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	Lecture, Discussion & Examples	**2208.5**	Quizzes, assignments, Two Sessional, End Term Examination
36	initial and final value theorems, solution of difference equations by the method of z transforms	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	Lecture, Discussion & Examples	**2208.5**	Quizzes, assignments, Two Sessional, End Term Examination
37	convolution theorem	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	Lecture, Discussion & Examples	**2208.5**	Quizzes, assignments, Two Sessional, End Term Examination

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
MA2208.1	Understand the mathematical tools that are needed to solve optimisation problems	3	1	1	1	1						2	1	1	1	
MA2208.2	Express the concept of probability and its features with discrete and continuous random variables.	3	2	1	1	1						1	1	1	1	
MA2208.3	Understand the concept of Finite difference and classification of partial differential equation.	3	2	1	1	1							1	1	1	
MA2208.4	Solve the two dimensional Laplace and Poisson equations.	3	2	2	2	1		1						1	1	
MA2208.5	Solve heat and wave equations by explicit method and solution of difference equation by the method of z-transforms.	3	2	2	2	1		1						1	1	

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Hand-out
Chemical Reaction Engineering I | CE 2201 | 4 Credits | 3 1 0 4
Session: Jan'21 – June'21 | Faculty: Nandana Chakinala | Class: B. Tech. (Chemical) IV Semester

A. Introduction: The aim of a chemical engineer is to conduct the chemical reactions at controlled conditions in such a manner so as to achieve maximum selectivity, yield and energy efficiency. This course on chemical reaction engineering combines the knowledge of chemical kinetics and thermodynamics that enables to decide upon the extent of reaction, rate of reaction, and process conditions. It introduces the basic concepts of reactor designing including elucidation of reaction rate and reaction mechanism, principles of chemical reactor design and analysis for homogeneous reactions, multiple reactors and their sequence, temperature and pressure effects, and selection of appropriate reactor and optimizing the reactor conditions.

B. Course Outcomes: At the end of the course, students will be able to:

[CE1506.1] Analyze and interpret the reaction systems and reaction kinetics

[CE1506.2] Analyze experimental kinetic data to determine reaction mechanisms

[CE1506.3] Design the ideal reactors (isothermal Batch, CSTR, and PFR)

[CE1506.4] Develop skills to choose the right reactor among single, multiple, recycle reactors

[CE1506.5] Understand and apply the concepts of heat capacity and heat of reaction in non-isothermal systems

C. Program Outcomes and Program Specific Outcomes

[PO.1]. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

[PO.2]. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

[PO.3]. 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 the public health and safety, and the cultural, societal, and environmental considerations.

[PO.4]. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

[PO.5]. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

[PO.6]. 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.
[PO.7]. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
[PO.8]. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
[PO.9]. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
[PO.10]. 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.
[PO.11]. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
[PO.12]. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

[PSO.2]. Process Intensification: graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	Quizzes/Home and Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have	

(Formative)	to study the topics that were covered during that particular lecture. However, you may contact the course coordinator for clarification of doubts, if any.

E. Syllabus

Kinetics of homogeneous chemical reactions, Rate expressions, Temperature dependence of rate Differential, integral, half-life and total pressure method theories, Elementary and Non elementary reaction kinetics - Pseudo, steady state hypothesis mechanism. Isothermal reactor design. Design of batch, semi-batch, CSTR's and PFR's. Multiple reactor systems, Reactors in series or/and parallel, CSTRs series Performance analysis, Batch, Semi-Batch, Continuous and Recycle reactors. Multiple reaction systems, Series and parallel reactions in flow reactors, Product distribution, Yield and selectivity. Maximizing the desired product in parallel reactions, Different reactors and schemes for minimizing the unwanted product, maximizing the desired product in series reactions.

F. Books

- Levenspiel, O., Chemical Reaction Engineering, 3rd ed., Wiley India Pvt Ltd
- Fogler, H. S., Elements of Chemical Reaction Engineering, 4th ed., Prentice-Hall of India, Delhi, 2003.

G. Reference Books

- Smith, J. M., Chemical Engineering Kinetics, 3rd ed., McGraw-Hill, 1981.
- Levenspiel, O., The Chemical Reactor Omnibook, OSU Bookstores, Corvallis Oregon, 1993.
- Froment, G. F., and Bischoff, K. B., Chemical Reactor Analysis and Design, 3rd ed., John Wiley and Sons, 2010.
- Richardson, J.F., and Peacock D.G., Coulson and Richardson's Chemical Engineering, vol. 3, 3rd ed., Asian Books Pvt. Ltd., New Delhi, 1998.

H. Lecture Plan

Lecture	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
1	Overview of Chemical Reaction Engineering	Acquainted with basic knowledge of chemical reactions	Lecture	2201.1	Mid Term I, Quiz/Assignment & End Term
2	Kinetics of homogeneous chemical reactions, reactor types, rate expressions, Concentration dependent term of a rate equation, kinetic models, testing and validation.	Understanding the fundamentals of chemical rate equations	Lecture	2201.1	Mid Term I, Quiz/Assignment & End Term
3	Temperature dependent term of rate equation and reaction mechanism	Understanding the fundamentals of chemical rate equations	Lecture	2201.1	Mid Term I, Quiz/Assignment & End Term

4	Temperature dependent term of rate equation and reaction mechanism	Understanding the fundamentals of chemical rate equations	Lecture	2201.1	Mid Term I, Quiz/Assignment & End Term
5	Interpretation of Batch reactor data: Constant volume batch reactor, Integral Method of data analysis: Irreversible unimolecular type I order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
6	Irreversible bimolecular type II order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
7	Irreversible trimolecular type III order reactions, empirical nth order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
8	Irreversible trimolecular type III order reactions, empirical nth order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
9	Zero-order reactions, Overall order by half-life and fractional-life method	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
10	Irreversible reaction in parallel, homogeneous catalyzed reactions, Autocatalytic reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
11	Irreversible reactions in series, first-order and second-order reversible reactions, reversible reactions in series	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term

12	Irreversible reactions in series, first-order and second-order reversible reactions, reversible reactions in series	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
13	Differential method of data analysis, varying volume batch reactor	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	2201.2	Mid Term I, Quiz/Assignment & End Term
14	Introduction to reactor design, ideal reactors for a single reactions, ideal batch reactor, space time and space velocity	Grasping the principles for solving chemical reactor design problems	Lecture	2201.3	Mid Term I, Quiz/Assignment & End Term
15	Review I		Lecture		Mid Term I, Quiz/Assignment & End Term
16	Steady-State Mixed flow reactor	Grasping the principles for solving chemical reactor design problems	Lecture	2201.3	Mid Term II, Quiz/Assignment & End Term
17	Steady-State Plug flow reactor	Grasping the principles for solving chemical reactor design problems	Lecture	2201.3	Mid Term II, Quiz/Assignment & End Term
18	Holding time and space time for flow reactors	Grasping the principles for solving chemical reactor design problems	Lecture	2201.3	Mid Term II, Quiz/Assignment & End Term
19	Design for single reactions, Size comparison of single reactors	Grasping the principles for solving chemical reactor design problems	Lecture	2201.3	Mid Term II, Quiz/Assignment & End Term
20	Multiple reactor systems, Plug flow reactor in series	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term

21	Mixed flow reactors in series	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
22	Recycle reactors	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
23	Autocatalytic reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
24	Design for parallel reactions: introduction to multiple reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
25	Quantitative treatment of product distribution and of reactor size	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
26	Quantitative treatment of product distribution and of reactor size	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
27	Multiple reactions: Irreversible first order reaction in series	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
28	First order followed by zero-order reaction, Zero-order followed by first order reaction	Developing the fundamental knowledge for solving complex	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term

		chemical reactor design problems			
29	Reversible reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
30	Irreversible series parallel reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Mid Term II, Quiz/Assignment & End Term
31	Review II		Lecture		Mid Term II, Quiz/Assignment & End Term
32	Temperature and Pressure Effects: Single reactions	Analyzing the effect of operating conditions on Reaction kinetics	Lecture	2201.5	Quiz/Assignment & End Term
33	Equilibrium constants from thermodynamics	Analyzing the effect of operating conditions on Reaction kinetics	Lecture	2201.5	Quiz/Assignment & End Term
34	Multiple reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Quiz/Assignment & End Term
35	Choosing the right kind of reactor	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	2201.4	Quiz/Assignment & End Term
36	Overall Review		Lecture		Quiz/Assignment & End Term

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[CE1506.1]	Analyze and interpret the reaction systems and reaction kinetics	2	3	1	1		1	1		1	1	1	2	1	1	
[CE1506.2]	Analyze experimental kinetic data to determine reaction mechanisms	2	2	1	2	1		1		1	2			2		1
[CE1506.3]	Design the ideal reactors (isothermal Batch, CSTR, and PFR)	2	3		2		1	1		1			2	1	2	
[CE1506.4]	Develop skills to choose the right reactor among single, multiple, recycle reactors	1	3	1			2	2		2	1		2	2	3	1
[CE1506.5]	Understand and apply the concepts of heat capacity and heat of reaction in non-isothermal systems	1	1	1		1	1	2		1		1		1	1	1

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Heat Transfer Operations| CE 2202 | 4 Credits | 3 1 0 4

Session: Feb 21 – May 21 | Faculty: Anees Y. Khan | Class: Core course

A. Introduction: This course on Heat Transfer Operations is designed for the undergraduate students of Chemical Engineering. In this course, an elementary knowledge of the heat transfer operations is taught. This is primarily developed for the UG students who need to understand the heat transfer mechanisms in fluids and solids and their applications in various heat transfer equipment in process industries.

B. Course Outcomes: At the end of the course, students will be able to

[2104.5]. Understand the basic concepts and laws of the three modes of heat transfer.

[2104.6]. Develop skills to identify, formulate and solve engineering problems involving conduction, convection and radiation heat transfer.

[2104.7]. Develop skills to identify, formulate and solve engineering problems involving boiling and condensation

[2104.8]. Design heat exchangers and perform basic calculations of common heat exchangers.

[2104.9]. Understand the concepts and able to solve evaporation problems.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.

The Graduates of Chemical Engineering from MUJ will have:

[PO.1]. A thorough knowledge of the basic science, engineering and mathematics and apply that to the underline practice of Chemical Engineering

[PO.2]. Ability to apply these basic principles to solve real world problems in a broad range of career paths

[PO.3]. The skills of making smart decisions on process feasibility based in technical and economic evaluation

[PO.4]. The ability to appreciate the social, ethical, cultural, environmental and safety issues related to chemical engineering profession

[PO.5]. The ability to develop experimental procedure/protocol to test hypothesis and analysis meaningful interpretation of the generated data

[PO.6]. The skill to generate sustainable engineering solutions to societal and industrial problems

[PO.7]. Proficiency to use computational tools for problem solving

[PO.8]. The ability to communicate effectively (technical and non-technical context) in written and oral form

[PO.9]. Skills to work effectively and professionally in multi-disciplinary groups

[PO.10]. The ability to work effectively and professionally on projects both independently and as a part of a group/team

[PO.11]. The ability to be self-learners and lifelong learners

[PO.12]. The motivation to develop and lead entrepreneurial projects for societal benefit

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

[PSO.2]. Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments

[PSO.3]. Students will be specialized in the areas of petroleum, energy and environment related fields

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	In class Quizzes and Assignments , Activity feedbacks (Accumulated and Averaged)	20
End Term Exam	End Term Exam (Open Book)	40
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments	No make-up for missed short quizzes/assignments or exam will be allowed except in extenuating circumstances, with prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Homework/ Home Assignment	Home works/assignments will be assigned in between the lectures along with the due date for handing it over. No late assignments handed after the due date shall be accepted under any circumstance. It is expected that the students shall work on the assignments independently and not 'copy' the solutions from each other.	

E. SYLLABUS

Introduction – Modes of heat transfer, heat transfer equipment. ***Conduction*** – Steady state conduction in one dimension, Fourier's law, Thermal conductivity, Steady state conduction of heat through composite solid, variable area and in bodies with heat sources. ***Convective heat transfer*** – Overall heat transfer coefficient, heat transfer between fluids separated by plane wall, cylindrical wall, thermal contact resistance, critical insulation thickness; Forced convection – Flow over flat plate, thermal boundary layer, flow across a cylinder, Dimensionless groups in heat transfer, correlations for heat transfer coefficient for both internal and external flows; Free convection – Heat transfer correlations, combined free and forced convection. ***Radiation heat transfer*** – Basic concepts, blackbody radiation, Laws related to radiation heat transfer, Grey body; Radiation intensity of black body, Radiation shield, View factor, combined radiation, conduction and convection. ***Heat transfer in boiling and condensation*** – Boiling phenomena and boiling curve, Mechanism of nucleate boiling, correlations for pool boiling, forced convection boiling; Condensation phenomena, condensation outside horizontal tube or tube bank, inside a horizontal tube, effect of non-condensable gases, drop wise condensation. ***Heat exchanger design*** – Double pipe heat exchanger design using Kern method, Shell and tube heat exchanger design using Kern method. Effectiveness NTU method of heat exchanger analysis. ***Evaporators*** –Principles of evaporation and evaporators – capacity & economy, boiling point rise.

F. TEXT BOOKS

1) Y.A. Cengel, Heat and Mass transfer: A Practical Approach, McGraw Hill, New York. 3rd edition, 2006.

2) D.Q. Kern, Process Heat Transfer, Mc Graw Hill, 1997.

3) J. P., Holman, Heat Transfer, McGraw Hill, New York.

4) W.L. McCabe, J.C. Smith, P. Harriot, Unit operations of Chemical engineering, 7th edition, Mc Graw Hill.

G. REFERENCE BOOKS

1) J.M. Coulson and J.F. Richardson, Chemical Engineering, Volume 1, 6th edition, Elsevier.

2) L. Bergman, Theodore, Adrienne S. Lavine, Incropera, Frank P, DeWitt, David P. "Introduction to Heat Transfer", 6th Edition.

3) J. R. Backhurst and J.H. Harker, Process plant design, Heinemann, London 1973.

4) A. J., Chapman, "Heat Transfer", Maxwell Macmillan, 1984.

H. Lecture Plan:

Lec. No.	Topics	Reference for students	Time (minutes)
1	Introduction to heat transfer	Chap 1, TB1	60
2	*Conduction* – Steady state conduction in one dimension, Fourier's law, Thermal conductivity	Chap 2, TB1	*60*
3-7	*Conduction* – Steady and unsteady state conduction of heat through composite solid, variable area and in bodies with heat sources.	Chap 3, TB1	*300*
8-10	*Convective heat transfer* – Overall heat transfer coefficient, heat transfer between fluids separated by plane wall, cylindrical wall, thermal contact resistance, critical insulation thickness	Chap 6, TB1	*180*
11-15	*Convective heat transfer* – Forced convection	Chap 7,8 TB1	*300*
16-19	*Convective heat transfer* - Free convection	Chap 9, TB1	*240*
20-25	*Radiation heat transfer*	Chap 12, 13, TB1	*360*
26-27	*Heat transfer in boiling*	Chap 10, TB1	*120*
28-30	*Heat transfer in condensation*	Chap 10, TB1	*180*
31-33	*Heat exchanger design* – Double pipe heat exchanger design using Kern method	Chap 6, TB2	*180*
34-40	*Heat exchanger design* – Shell and tube heat exchanger design using Kern method	Chap 7, TB2	*420*
41-43	Effectiveness - NTU method of heat exchanger analysis	Chap 10, TB3	180
44-48	*Evaporators*	Chap 16, TB4	*300*

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE 1407.1	Understand the basic concepts and laws of the three modes of heat transfer	3	2			1	1				1	1		2		
CE 1407.2	To identify, formulate and solve engineering problems involving conduction, convection and radiation heat transfer	2	2	1	1	1		1						2		
CE 1407.3	To identify, formulate and solve engineering problems involving boiling and condensation	2	2	1	1	1		1						2	1	
CE 1407.4	To design heat exchangers and perform basic calculations of common heat exchangers	2	2			1	1					1		2	1	
CE 1407.5	Understanding the concepts and able to solve evaporation problems	2	2			1	1					1		2	1	

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR
School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Handout
Mass Transfer I | CE2203| 4 Credits | 3 1 0 4
Session: February'21 – June'21 | Faculty: Dr. Gaurav Kataria| Class: B. Tech. (Chemical) IV Semester

A. INTRODUCTION

This course is offered by Department of Chemical Engineering as a core course. The course focuses on the fundamentals of molecular diffusion, convective mass transfer, and interphase mass transfer. It deals with the design of various mass transfer equipment related to absorption, stripping, adsorption, and humidification.

B. COURSE OUTCOMES

At the end of the course, students will be able to:

[CE1506.6] Understand the basics of diffusional mass transfer

[CE1506.7] Understand the concepts of interphase mass transfer and mass transfer coefficients

[CE1506.8] Understand the mechanism of various mass transfer operations such as absorption, stripping, adsorption, and humidification

[CE1506.9] Develop skills to perform design calculations involved in various mass transfer operations

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open/Closed Book)	20
	Sessional Exam II (Open/Closed Book)	20
	Quizzes and Home Assignments / Class Assignments (Accumulated and Averaged)	20
End Term Exam (Summative)	End Term Exam (Open/Closed Book)	40
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Assignments (Formative)	Assignments are an integral part of the course. Home assignments / Class assignments will be provided from time to time. No late submissions will be entertained. It is expected that the students will work on the assignments independently. If any assignment is found copied from any source, marks will be deducted for the same.	
Make up Assignments	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture(s). You may contact the course coordinator for clarification of doubts, if any.	

E. SYLLABUS

Introduction to mass transfer operations. Theory of interphase mass transfer, estimation of mass transfer coefficient, individual and overall mass transfer coefficients for gas-liquid and liquid-liquid operations. Gas Absorption, graphical calculation of number of theoretical stages for absorption and stripping column. Adsorption, adsorption isotherm, batch and continuous stage adsorption, design of adsorption column, and adsorption equipment. Vapor gas mixtures, terminology, Psychometric chart, Water cooling operations, Gas-Liquid contact operations, adiabatic operations, Types of equipment, Design calculations, Cooling towers, design of cooling towers, Recirculating Liquid-gas humidification cooling.

F. TEXT BOOKS

T1. Treybal, R. E., Mass Transfer Operations, 3rd ed., McGraw Hill, 2012.

T2. Seader, J. D. and Henley, E. J., Separation Process Principles, 2nd ed., Wiley, 2010.

G. REFERENCE BOOKS

R1. Geankoplis, C. J., Transport Processes and Unit Operations, 3rd ed., PHI, New Delhi, 2000.

R2. Foust, A.S., Wenzel, L.A., Clump, C.W., Naus, L., and Anderson, L.B., Principles of Unit operations, 2nd ed., John Wiley and Sons, 1980.

R3. McCabe and Smith, Unit Operations in Chemical Engineering, 5th ed., McGraw-Hill, NY, 1993

R4. Hill, G. B., Cooling towers principles and practice, BH, London, 1990.

R5. Sinnott, R. K., Coulson & Richardson's Chemical Engineering Design: Chemical Engineering Design: Vol. 6, 2006.

H. LECTURE PLAN

Lecture No.	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
1.	Introduction	Learn the mechanism and Classification of mass transfer operation	Lecture	CE1506.1	Assignment / quiz / Mid Term I
2.	Introduction	Gain knowledge about selection of separation method, methods of conducting mass transfer operations, Design principles	Lecture	CE1506.1	Assignment / quiz / Mid Term I
3.	Molecular diffusion in fluids	Learn the basics of steady state molecular diffusion in fluids at rest	Lecture	CE1506.1	Assignment / quiz / Mid Term I
4.	Molecular diffusion in fluids	Learn the basics of steady state molecular diffusion in fluids at rest and in laminar flow	Lecture	CE1506.1	Assignment / quiz / Mid Term I
5.	Molecular diffusion in fluids	Learn the basics of steady state molecular diffusion in fluids in laminar flow	Lecture	CE1506.1	Assignment / quiz / Mid Term I
6.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II

7.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II
8.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II
9.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II
10.	Interphase mass transfer	Learn the basics of Interphase mass transfer and equilibrium conditions	Lecture	CE1506.2	Assignment / quiz / Mid Term II
11.	Interphase mass transfer	Learn the basics of Interphase mass transfer and equilibrium conditions	Lecture	CE1506.2	Assignment / quiz / Mid Term II
12.	Interphase mass transfer	Learn the basics of Interphase mass transfer and equilibrium conditions	Lecture	CE1506.2	Assignment / quiz / Mid Term II
13.	Interphase mass transfer	Able to apply the material balances and calculate the number of stages	Lecture	CE1506.2	Assignment / quiz / Mid Term II
14.	Interphase mass transfer	Able to apply the material balances and calculate the number of stages	Lecture	CE1506.2	Assignment / quiz / Mid Term II
15.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
16.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
17.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
18.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
19.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
20.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
21.	Gas-Liquid Operations	Students will understand the basics of Humidification operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
22.	Gas-Liquid Operations	Students will understand the basics of Humidification operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
23.	Gas-Liquid Operations	Students will understand the basics of Humidification operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
24.	Gas-Liquid Operations	Gain knowledge about the types of Humidification equipment	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
25.	Gas-Liquid Operations	Be able to Design a cooling tower	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
26.	Gas-Liquid Operations	Be able to Design a cooling tower	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
27.	Gas-Liquid Operations	Be able to Design a cooling tower	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
28.	Gas-Liquid Operations	Able to learn the fundamentals of Gas absorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II

29.	Gas-Liquid Operations	Able to learn the fundamentals of Gas absorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
30.	Gas-Liquid Operations	Students will be introduced to gas absorption equipment	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
31.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
32.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
33.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
34.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
35.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
36.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
37.	Solid-Fluid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
38.	Solid-Fluid Operations	Understand the Fundamentals of Adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
39.	Solid-Fluid Operations	Understand the Fundamentals of Adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
40.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
41.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
42.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
43.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term

I. COURSE ARTICULATION MATRIX: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[CE1506.6]	Understand the basics of diffusional mass transfer	3	2					1		1			2	3		1
[CE1506.7]	Understand the concepts of interphase mass transfer and mass transfer coefficients	2	2		1			1					1	2	1	
[CE1506.8]	Understand the mechanism of various mass transfer operations such as absorption, stripping, adsorption, and humidification	2	2	1	2			1				1	2	2	1	2
[CE1506.9]	Develop skills to perform design calculations involved in various mass transfer operations	3	1	3		1			1				2	2	1	2

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Process Modelling and Simulation| CE1505 | 3 Credits | 3 0 0 3

Session: Aug 20 – Dec 20 | Faculty: Dr Gaurav Kataria| Class: B.Tech III Year

A. Introduction: This course is offered by Dept. of Chemical Engineering as a core course. This course focuses on the modelling and simulation of processes involved in chemical engineering operations. In this unit, the students will learn the fundamentals of process synthesis and design using mathematical modelling tools. By the end of this course, the students will have a clear understanding required for analysis of process engineering solutions of real world problems.

B. Course Outcomes: At the end of the course, students will be able to

[1505.1] Understand the basic principles of process modelling and simulation
[1505.2] Carry out the analysis of lumped and distributed models used in process intensive industries
[1505.3] Perform the validation, parametric estimation and optimization of a process model
[1505.5] Carry out the simulation for generation of material and energy balances for overall system

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO.1 **Engineering Knowledge:** A thorough knowledge of the basic science, engineering and mathematics and apply that to the underline practice of Chemical Engineering.
PO.2 **Problem Analysis:** Ability to apply these basic principles to solve real world problems in a broad range of career paths.
PO.3 **Project management and finance:** The skills of making smart decisions on process feasibility based in technical and economic evaluation.
PO.4 **Ethics**: The ability to appreciate the social, ethical, cultural, environmental and safety issues related to chemical engineering profession.
PO.5 **Conduct investigations of complex problems**: The ability to develop experimental procedure/protocol to test hypothesis and analysis meaningful interpretation of the generated data.
PO.6 **Environment and sustainability**: The skill to generate sustainable engineering solutions to societal and industrial problems.
PO.7 **Modern tool usage**: Proficiency to use computational tools for problem solving.
PO.8 **Communication**: ability to communicate effectively (technical and non-technical context) in written and oral form.
PO.9 **Design/development of solutions**: Skills to work effectively and professionally in multi-disciplinary groups to solve complex chemical engineering problems.
PO.10 **Individual and team work**: The ability to work effectively and professionally on projects both independently and as a part of a group/team.
PO.11 **Life-long learning**: The ability to be self-learners and lifelong learners.
PO.12 **The engineer and society**: The motivation to develop and lead entrepreneurial projects for societal benefit.

Degree Specific Outcomes for chemical engineering are as follows:

PSO.1 **Concept to Commissioning:** The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.
PSO.2 **Process Intensification:** Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
PSO.3 **Specialization:** students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	In class Quizzes, Assignments, Projects	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	No makeup assignments will be given.	
Projects	A project may be given to group of 2-3 students on a topic relevant to the industrial application of process modelling and simulation. The details of this component will be discussed during the lectures.	

E. SYLLABUS

Fundamentals and industrial applications of process Modeling and simulation, Macroscopic mass, energy and momentum balances, integration of fluid thermodynamics, chemical equilibrium, reaction kinetics and feed/ product property estimation in mathematical models. Steady state lumped systems, Modeling of chemical process equipment (reactors, distillation, absorption, extraction columns, evaporators, and heat exchangers). Modelling and simulation of complex industrial systems in petroleum, petrochemicals, polymer, basic chemical industries; Commercial steady state and dynamic simulators; Simulation of process flow sheets.

F. BOOKS

T1. Luyben, W. L., *Process Modeling, Simulation and Control for Chemical Engineers*, McGraw Hill, 1989.

T2. Ramirez, W.F., *Computational Methods for Process Simulation*, 2nd ed., Butterworth-Heinemann, 1997.

T3. Ingham, J., Dunn, I. J., Heinzle, E., Prenosil, J.E., Snape, J.B., *Chemical Engineering Dynamics: An Introduction to Modelling and Computer Simulation*, 3rd ed., Wiley-VCH Verlag GmbH & Co. KGaA, 2007.

T4. Holland, C. D., *Fundamentals and Modeling of Separation Processes*, Prentice Hall, 1975.

T5. Himmelblau, D. M., & Bischoff, K. B., *Process analysis and simulation: Deterministic systems*, John Wiley, New York, 1968.

G. Lecture Plan:

LEC NO	TOPICS	Session Outcome	Mode of Delivery	Corresponding Course Outcome	Mode of Assessing the Outcome
1	Modelling Overview and Industrial Applications of Process Modelling	Understanding the basic need of modelling and simulation in chemical engineering.	Lecture	CE1505.1	Mid Term I End Term
2	Modelling Process	Understanding the basic 7 step modeling process.	Lecture	CE1505.1	Mid Term I End Term
3	Process Model Characteristics and Introduction to Matlab	Understanding the use of MATLAB in the course.	Lecture	CE1505.4	Mid Term I End Term
4	System Definition; White, Black and Grey Box Models	Understanding the difference between white, black and grey box models.	Lecture	CE1505.1	Mid Term I End Term
5,6	Systematic Modelling Procedure	Applying 7 step modelling process in chemical engineering applications.	Lecture	CE1505.1	Mid Term I End Term
7	Introduction to Matlab Files	Understanding the use of MATLAB in the course.	Lecture	CE1505.4	Mid Term I End Term
8	Fundamental Concepts	Understanding the basic concepts used in the modeling of chemical engineering equipment's.	Lecture	CE1505.1	Mid Term I End Term
9,10,11	Conservation Equations	Understanding the basics of using mass, material and energy balance.	Lecture	CE1505.5	Mid Term I End Term
12,13	Constitutive Relations	Understanding the constitutive relations used in chemical engineering.	Lecture	CE1505.5	Mid Term I End Term
14	Matlab Applications	Apply MATLAB in the chemical engineering applications.	Lecture	CE1505.1/2	Mid Term I End Term
15	Introduction to Lumped Models	Understanding the concept of having variation of variable with time.	Lecture	CE1505.1/2	Mid Term I End Term
16	Solution of Ordinary Differential Equations	Use of Runge Kutta and other ODE solvers.	Lecture	CE1505.1/2	Mid Term I End Term
MID TERM I					
17	Matlab Applications	Use of Runge Kutta and other ODE solvers in MATLAB.	Lecture	CE1505.1/2	Mid Term II End Term
18	Introduction to Distributed Models	Understanding the concept of having variation of variable with time and space.	Lecture	CE1505.1/2	Mid Term II End Term
19	Initial and Boundary Conditions	Understanding the concept of using initial and boundary conditions.	Lecture	CE1505.1/2	Mid Term II End Term
20	Real Time Applications	Use the concepts for real applications of chemical engineering.	Lecture	CE1505.1/2	Mid Term II End Term

21	Partial Differential Equations Solving Methods	Understanding the concept of solving PDEs.	Lecture	CE1505.1/2	Mid Term II End Term
22	Finite Difference Approximation and Boundary Conditions Handling	Understanding the concept of solving PDEs.	Lecture	CE1505.1/2	Mid Term II End Term
23	Matlab Applications	Apply MATLAB to solve PDEs.	Lecture	CE1505.4	Mid Term II End Term
24,25	Model Validation and Verification, Model Calibration	Applying the simulation to validate and verify the model.	Lecture	CE1505.1/2	Mid Term II End Term
26	Model Optimization and Parameter Estimation	Applying the simulation to validate and verify the model.	Lecture	CE1505.1/2	Mid Term II End Term
27	Matlab Applications	Apply MATLAB in the chemical engineering applications	Lecture	CE1505.4	Mid Term II End Term
28,29	Process Synthesis and Design	Applying the simulation to provide the design of the equipment.	Lecture	CE1505.4	Mid Term II End Term
MID TERM II					
30	Aspen Hysys Introduction	Understanding the use of ASPEN in the course.	Lecture	CE1505.4	End Term
31	Convergence Methods	Understand the convergence and divergence of the solution.	Lecture	CE1505.1	End Term
32	Sequential Modular vs Equation Oriented Simulation	Understand the convergence and divergence of the solution.	Lecture	CE1505.1	End Term
33	Aspen Hysys Unit Models	Apply ASPEN in the chemical engineering applications	Lecture	CE1505.4	End Term
34	Reactor Design	Use the balances to design a reactor.	Lecture	CE1505.3/4/5	End Term
35	Thermodynamic Package Selection	Understand the uses of thermodynamic packages in the software's.	Lecture	CE1505.1	End Term
36	Package Selection Recommendations	Understand the uses of thermodynamic packages in the software's.	Lecture	CE1505.1	End Term
38	Types of Heat Exchanger	Use the balances to design a heat exchanger.	Lecture	CE1505.3/4/5	End Term
39	Heat Exchanger Balance	Use the balances to design a reactor.	Lecture	CE1505.3/4/5	End Term
40,41	Heat Exchanger Design	Use the balances to design a reactor.	Lecture	CE1505.3/4/5	End Term
42	Degree of Freedom Analysis, Control Synthesis using Industry Example	Understand the concept of DoF to assume the parameters constant for solving the model.	Lecture	CE1505.3/4/5	End Term
END TERM					

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE1505.1	Understand the basic principles of process modelling and simulation	2	1			2	2			3			1	2		
CE1505.2	Carry out the analysis of lumped and distributed models used in process intensive industries	3	3			2	1	3		3				2	2	1
CE1505.3	Perform the validation, parametric estimation and optimization of a process model	2	3		1	2		3		3				1	2	1
CE1505.4	Carry out the simulation for generation of material and energy balances for overall system	3	3			2		3		3	1			3	2	1

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR
School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Handout
Mass Transfer I | CE1506 | 3 Credits | 3 0 0 3
Session: Jul'20 – Dec'20 | Faculty: Dr. Manisha Sharma | Class: B. Tech. (Chemical)
V Semester

A. INTRODUCTION

This course is offered by Department of Chemical Engineering as a core course. The course focuses on the fundamentals of molecular diffusion, convective mass transfer, and interphase mass transfer. It deals with the design of various mass transfer equipment related to absorption, stripping, adsorption, and humidification.

B. COURSE OUTCOMES

At the end of the course, students will be able to:

[CE1506.10] Understand the basics of diffusional mass transfer

[CE1506.11] Understand the concepts of interphase mass transfer and mass transfer coefficients

[CE1506.12] Understand the mechanism of various mass transfer operations such as absorption, stripping, adsorption, and humidification

[CE1506.13] Develop skills to perform design calculations involved in various mass transfer operations

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	Quizzes and Home Assignments / Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Assignments (Formative)	Assignments are an integral part of the course. Home assignments / Class assignments will be provided from time to time. No late submissions will be entertained. It is expected that the students will work on the assignments independently. If any assignment is found copied from any source, marks will be deducted for the same.	
Make up Assignments	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture(s). You may contact the course coordinator for clarification of doubts, if any.	

E. SYLLABUS

Introduction to mass transfer operations. Theory of interphase mass transfer, estimation of mass transfer coefficient, individual and overall mass transfer coefficients for gas-liquid and liquid-liquid operations. Gas Absorption, graphical calculation of number of theoretical stages for absorption and stripping column. Adsorption, adsorption isotherm, batch and continuous stage adsorption, design of adsorption column, and adsorption equipment. Vapor gas mixtures, terminology, Psychometric chart, Water cooling operations, Gas-Liquid contact operations, adiabatic operations, Types of equipment, Design calculations, Cooling towers, design of cooling towers, Recirculating Liquid-gas humidification cooling.

F. TEXT BOOKS

T3. Treybal, R. E., Mass Transfer Operations, 3rd ed., McGraw Hill, 2012.

T4. Seader, J. D. and Henley, E. J., Separation Process Principles, 2nd ed., Wiley, 2010.

G. REFERENCE BOOKS

R6. Geankoplis, C. J., Transport Processes and Unit Operations, 3rd ed., PHI, New Delhi, 2000.

R7. Foust, A.S., Wenzel, L.A., Clump, C.W., Naus, L., and Anderson, L.B., Principles of Unit operations, 2nd ed., John Wiley and Sons, 1980.

R8. McCabe and Smith, Unit Operations in Chemical Engineering, 5th ed., McGraw-Hill, NY, 1993

R9. Hill, G. B., Cooling towers principles and practice, BH, London, 1990.

R10. Sinnott, R. K., Coulson & Richardson's Chemical Engineering Design: Chemical Engineering Design: Vol. 6, 2006.

H. LECTURE PLAN

Lecture No.	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
44.	Introduction	Learn the mechanism and Classification of mass transfer operation	Lecture	CE1506.1	Assignment / quiz / Mid Term I
45.	Introduction	Gain knowledge about selection of separation method, methods of conducting mass transfer operations, Design principles	Lecture	CE1506.1	Assignment / quiz / Mid Term I
46.	Molecular diffusion in fluids	Learn the basics of steady state molecular diffusion in fluids at rest	Lecture	CE1506.1	Assignment / quiz / Mid Term I
47.	Molecular diffusion in fluids	Learn the basics of steady state molecular diffusion in fluids at rest and in laminar flow	Lecture	CE1506.1	Assignment / quiz / Mid Term I
48.	Molecular diffusion in fluids	Learn the basics of steady state molecular diffusion in fluids in laminar flow	Lecture	CE1506.1	Assignment / quiz / Mid Term I
49.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II
50.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II
51.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II
52.	Mass Transfer coefficients	Gain knowledge about the significance of mass transfer coefficients and must be able to calculate the Mass Transfer Coefficients	Lecture	CE1506.2	Assignment / quiz / Mid Term II
53.	Interphase mass transfer	Learn the basics of Interphase mass transfer and equilibrium conditions	Lecture	CE1506.2	Assignment / quiz / Mid Term II
54.	Interphase mass transfer	Learn the basics of Interphase mass transfer and equilibrium conditions	Lecture	CE1506.2	Assignment / quiz / Mid Term II
55.	Interphase mass transfer	Learn the basics of Interphase mass transfer and equilibrium conditions	Lecture	CE1506.2	Assignment / quiz / Mid Term II
56.	Interphase mass transfer	Able to apply the material balances and calculate the number of stages	Lecture	CE1506.2	Assignment / quiz / Mid Term II
57.	Interphase mass transfer	Able to apply the material balances and calculate the number of stages	Lecture	CE1506.2	Assignment / quiz / Mid Term II
58.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II

59.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
60.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
61.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
62.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
63.	Gas-Liquid Operations	Students will be introduced to the equipment for Gas-Liquid Operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
64.	Gas-Liquid Operations	Students will understand the basics of Humidification operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
65.	Gas-Liquid Operations	Students will understand the basics of Humidification operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
66.	Gas-Liquid Operations	Students will understand the basics of Humidification operations	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
67.	Gas-Liquid Operations	Gain knowledge about the types of Humidification equipment	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
68.	Gas-Liquid Operations	Be able to Design a cooling tower	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
69.	Gas-Liquid Operations	Be able to Design a cooling tower	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
70.	Gas-Liquid Operations	Be able to Design a cooling tower	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
71.	Gas-Liquid Operations	Able to learn the fundamentals of Gas absorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
72.	Gas-Liquid Operations	Able to learn the fundamentals of Gas absorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
73.	Gas-Liquid Operations	Students will be introduced to gas absorption equipment	Lecture	CE1506.3 CE1506.4	Assignment / quiz / Mid Term II
74.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
75.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
76.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
77.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
78.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
79.	Gas-Liquid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
80.	Solid-Fluid Operations	Be able to Design Gas absorption towers	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
81.	Solid-Fluid Operations	Understand the Fundamentals of Adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
82.	Solid-Fluid Operations	Understand the Fundamentals of Adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
83.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
84.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
85.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term
86.	Solid-Fluid Operations	Be able to design equipment for adsorption	Lecture	CE1506.3 CE1506.4	Assignment / quiz / End Term

I. COURSE ARTICULATION MATRIX: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[CE1506.10]	Understand the basics of diffusional mass transfer	3	2					1		1			2	3		1
[CE1506.11]	Understand the concepts of interphase mass transfer and mass transfer coefficients	2	2		1			1					1	2	1	
[CE1506.12]	Understand the mechanism of various mass transfer operations such as absorption, stripping, adsorption, and humidification	2	2	1	2			1				1	2	2	1	2
[CE1506.13]	Develop skills to perform design calculations involved in various mass transfer operations	3	1	3		1	2		1	1		1	2	2	1	2

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

A. Introduction: The aim of a chemical engineer is to conduct the chemical reactions at controlled conditions in such a manner so as to achieve maximum selectivity, yield and energy efficiency. This course on chemical reaction engineering combines the knowledge of chemical kinetics and thermodynamics that enables to decide upon the extent of reaction, rate of reaction, and process conditions. It introduces the basic concepts of reactor designing including elucidation of reaction rate and reaction mechanism, principles of chemical reactor design and analysis for homogeneous reactions, multiple reactors and their sequence, temperature and pressure effects, and selection of appropriate reactor and optimizing the reactor conditions.

B. Course Outcomes: At the end of the course, students will be able to:

[1507.1] Analyze and interpret the reaction systems and reaction kinetics

[1507.2] Analyze experimental kinetic data to determine reaction mechanisms

[1507.3] Design the ideal reactors (isothermal Batch, CSTR, and PFR)

[1507.4] Develop skills to choose the right reactor among single, multiple, recycle reactors

[1507.5] Understand and apply the concepts of heat capacity and heat of reaction in non-isothermal systems

C. Program Outcomes and Program Specific Outcomes

[PO.1]. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

[PO.2]. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

[PO.3]. 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 the public health and safety, and the cultural, societal, and environmental considerations.

[PO.4]. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

[PO.5]. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

[PO.6]. 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.

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[PO.10]. 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.

[PO.11]. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

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[PSO.4]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

[PSO.5]. Process Intensification: graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.6]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	Quizzes/Home and Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture. However, you may contact the course coordinator for clarification of doubts, if any.	

E. Syllabus

Kinetics of homogeneous chemical reactions, Rate expressions, Temperature dependence of rate Differential, integral, half-life and total pressure method theories, Elementary and Non elementary reaction kinetics - Pseudo, steady state hypothesis mechanism. Isothermal reactor design. Design of batch, semi-batch, CSTR's and PFR's. Multiple reactor systems, Reactors in series or/and parallel, CSTRs series Performance analysis, Batch, Semi-Batch, Continuous and Recycle reactors. Multiple reaction systems, Series and parallel reactions in flow reactors, Product distribution, Yield and selectivity. Maximizing the desired product in parallel reactions, Different reactors and schemes for minimizing the unwanted product, maximizing the desired product in series reactions.

F. Books

T1. Levenspiel, O., Chemical Reaction Engineering, 3rd ed., Wiley India Pvt Ltd

T2. Fogler, H. S., Elements of Chemical Reaction Engineering, 4th ed., Prentice-Hall of India, Delhi, 2003.

G. Reference Books

R1. Smith, J. M., Chemical Engineering Kinetics, 3rd ed., McGraw-Hill, 1981.

R2. Levenspiel, O., The Chemical Reactor Omnibook, OSU Bookstores, Corvallis Oregon, 1993.

R3. Froment, G. F., and Bischoff, K. B., Chemical Reactor Analysis and Design, 3rd ed., John Wiley and Sons, 2010.

R4. Richardson, J.F., and Peacock D.G., Coulson and Richardson's Chemical Engineering, vol. 3, 3rd ed., Asian Books Pvt. Ltd., New Delhi, 1998.

H. Lecture Plan

Lecture	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
1	Overview of Chemical Reaction Engineering	Acquainted with basic knowledge of chemical reactions	Lecture	1507.1	Mid Term I, Quiz/Assignment & End Term
2	Kinetics of homogeneous chemical reactions, reactor types, rate expressions, Concentration dependent term of a rate equation, kinetic models, testing and validation.	Understanding the fundamentals of chemical rate equations	Lecture	1507.1	Mid Term I, Quiz/Assignment & End Term
3	Temperature dependent term of rate equation and reaction mechanism	Understanding the fundamentals of chemical rate equations	Lecture	1507.1	Mid Term I, Quiz/Assignment & End Term
4	Temperature dependent term of rate equation and reaction mechanism	Understanding the fundamentals of chemical rate equations	Lecture	1507.1	Mid Term I, Quiz/Assignment & End Term
5	Interpretation of Batch reactor data: Constant volume batch reactor, Integral Method of data analysis: Irreversible unimolecular type I order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
6	Irreversible bimolecular type II order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term

7	Irreversible trimolecular type III order reactions, empirical nth order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
8	Irreversible trimolecular type III order reactions, empirical nth order reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
9	Zero-order reactions, Overall order by half-life and fractional-life method	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
10	Irreversible reaction in parallel, homogeneous catalyzed reactions, Autocatalytic reactions	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
11	Irreversible reactions in series, first-order and second-order reversible reactions, reversible reactions in series	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
12	Irreversible reactions in series, first-order and second-order reversible reactions, reversible reactions in series	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
13	Differential method of data analysis, varying volume batch reactor	Acquiring the knowledge of methods for calculating reaction rate parameters	Lecture	1507.2	Mid Term I, Quiz/Assignment & End Term
14	Introduction to reactor design, ideal reactors for a single reactions, ideal batch reactor, space time and space velocity	Grasping the principles for solving chemical reactor design problems	Lecture	1507.3	Mid Term I, Quiz/Assignment & End Term
15	Review I		Lecture		Mid Term I, Quiz/Assignment & End Term

16	Steady-State Mixed flow reactor	Grasping the principles for solving chemical reactor design problems	Lecture	1507.3	Mid Term II, Quiz/Assignment & End Term
17	Steady-State Plug flow reactor	Grasping the principles for solving chemical reactor design problems	Lecture	1507.3	Mid Term II, Quiz/Assignment & End Term
18	Holding time and space time for flow reactors	Grasping the principles for solving chemical reactor design problems	Lecture	1507.3	Mid Term II, Quiz/Assignment & End Term
19	Design for single reactions, Size comparison of single reactors	Grasping the principles for solving chemical reactor design problems	Lecture	1507.3	Mid Term II, Quiz/Assignment & End Term
20	Multiple reactor systems, Plug flow reactor in series	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
21	Mixed flow reactors in series	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
22	Recycle reactors	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
23	Autocatalytic reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
24	Design for parallel reactions: introduction to multiple reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term

25	Quantitative treatment of product distribution and of reactor size	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
26	Quantitative treatment of product distribution and of reactor size	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
27	Multiple reactions: Irreversible first order reaction in series	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
28	First order followed by zero-order reaction, Zero-order followed by first order reaction	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
29	Reversible reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
30	Irreversible series parallel reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Mid Term II, Quiz/Assignment & End Term
31	Review II		Lecture		Mid Term II, Quiz/Assignment & End Term
32	Temperature and Pressure Effects: Single reactions	Analyzing the effect of operating conditions on Reaction kinetics	Lecture	1507.5	Quiz/Assignment & End Term
33	Equilibrium constants from thermodynamics	Analyzing the effect of operating conditions on Reaction kinetics	Lecture	1507.5	Quiz/Assignment & End Term

34	Multiple reactions	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Quiz/Assignment & End Term
35	Choosing the right kind of reactor	Developing the fundamental knowledge for solving complex chemical reactor design problems	Lecture	1507.4	Quiz/Assignment & End Term
36	Overall Review		Lecture		Quiz/Assignment & End Term

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[CE1507.1]	Analyze and interpret the reaction systems and reaction kinetics	2	3	1	1		1	1		1	1	1	2	1	1	
[CE1507.2]	Analyze experimental kinetic data to determine reaction mechanisms	2	2	1	2	1		1		1	2			2		1
[CE1507.3]	Design the ideal reactors (isothermal Batch, CSTR, and PFR)	2	3		2		1	1		1			2	1	2	
[CE1507.4]	Develop skills to choose the right reactor among single, multiple, recycle reactors	1	3	1			2	2		2	1		2	2	3	1
[CE1507.5]	Understand and apply the concepts of heat capacity and heat of reaction in non-isothermal systems	1	1	1		1	1	2		1		1		1	1	1

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Petroleum Production Technologies | CE 1553 | 3 Credits | 3 0 0 3

Session: Aug'20 – Dec'20 | Faculty: Abhishek Sharma | Class: B. Tech. (Chemical) V Semester

A. Introduction: The objective of the course is to provide a handy guideline to design, analyse and optimize petroleum production systems. The students are introduced to the concepts of petroleum production systems, properties of oil, gas and produced water and performance of oil & gas production wells as well as addressing production enhancement techniques such as matrix acidizing and hydraulic fracturing. They are also introduced to the concepts of midstream operations of natural gas processing like acid gas treatment, natural gas compression. This course also addresses designing acidizing jobs, tubing design and separation and dehydration systems.

B. Course Outcomes: At the end of the course, students will be able to

[CE 1553.1]. Understand the basic operations of an upstream & midstream petroleum production process
[CE 1553.2]. Estimate the properties of oil, natural gas and produced water using correlations
[CE 1553.3]. Evaluate the reservoir deliverability and well deliverability
[CE 1553.4]. Design acidizing jobs for enhanced oil production
[CE 1553.5]. Develop employability skills required for equipment design in upstream and midstream processes

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.
PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
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[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
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[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

E. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	In class Quizzes, Assignments, Projects, Case studies (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	No make-up for missed short quizzes/assignments or exam will be allowed except in extenuating circumstances, with prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Homework/ Home Assignment/ Project (Formative)	Home works will be assigned in between the lectures along with the due date for handing it over. No late assignments handed after the due date shall be accepted under any circumstance. It is expected that the students shall work on the assignments independently and not 'copy' the solutions from each other. Group projects are assigned which is assessed in the form of individual reports submitted.	

F. SYLLABUS

Introduction to Petroleum production technologies*:* Reservoir, well, separators, pumps and pipelines, compressors, safety controls, **Properties of crude oil, natural gas and produced water**: Review of gas properties, crude oil properties, produced water properties, **Petroleum production from**: *Under saturated oil reservoirs*- Transient flow, pseudo steady state flow, steady state well performance, horizontal well production, effect of water production, *Two-phase reservoirs*- Two phase flow, inflow performance relationship (IPR), Generalized VOGEL IPR, other approximations, *Natural gas reservoirs*- Gas well deliverability, approximations, transient flow, horizontal IPR, **Well bore and choke performance:** Single phase flow of incompressible and compressible, Multiphase flow, Flow through chokes-Single phase liquid flow and gas flow, **Artificial lift methods**: Sucker rod pumping, Gas lift, Plunger lift, Introduction to enhanced oil recovery, **Matrix acidizing:** Acid

rock interaction, Carbonate acidizing design, sandstone acidizing design, Hydraulic fracturing, **Midstream operations of natural gas processing:** Process modules, Processing objectives, effect of gas type in field processing, Phase separation, Gravity separators, Multistage separation, Centrifugal separators, Slug catchers, gas-liquid coalescers, Acid gas treatment, Batch processes, amine processes, carbonate washing and water washing, Methanol based process, other processes, process selection, Sulfur recovery process, **Natural gas compression:** Thermodynamics of gas compression, Liquefaction processes, types and selection of compressors, Compressor design, control and performance maps, **Equipment design and selection**: Well tubing, separation systems, transportation systems.

G. TEXT BOOKS

T1. B.Guo, W.C. Lyons, A. Ghalambor, Petroleum Production Engineering, 3rd ed., Gulf professional publishing, 2007.

H. REFERENCE BOOKS

R1. B.Guo, A. Ghalambor, Natural Gas Engineering Handbook, Gulf professional publishing, 2005.

R2. Dake L.P., Fundamentals of reservoir engineering, Elsevier, 1978.

R3. Smith H.C., Tracy G.W., Farrar R.L., Applied Reservoir Engineering, Vol I and II, OGCL, 1999.

R4. Economides, M.J., Daniel Hill, A., Economides, C.E., Petroleum Production Systems, Prentice Hall Inc., 1994.

R5. Abdel-Aal, H.K., Aggour, M., Fahim, M.A., Petroleum and Gas Field Processing, Marcel Dekker Inc., 2003.

Lecture Plan:

LEC NO	TOPICS	Session outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1-2	Introduction to Petroleum production technologies	Overview of Crude oil production	Lecture	CE 1553.1	Mid Term-1, End term
3-5	Properties of crude oil, natural gas and produced water	Estimation of the crude properties using empirical equations	Lecture	CE 1553.2	Mid Term-1, End term
6-10	Petroleum production from: Under saturated oil reservoirs, Two-phase reservoirs, Natural gas reservoirs	Prediction of IPR for different reservoirs	Lecture	CE 1553.3	Mid Term-1, End term, Assignment-1
11-14	Well bore and choke performance	Prediction of TPR and pressure drop	Lecture	CE 1553.3	Mid Term-2, End term, Assignment-2
5-9	Artificial lift methods	Acquaint with several lift methods	Lecture	CE 1553.3	Mid Term-2, End term
10-13	Matrix acidizing	Able to determine the amount of acid consumption	Lecture	CE 1553.4	Mid Term-2, End term
14	Hydraulic fracturing	Overview of the concept	Lecture	CE 1553.4	Mid Term-2, End term, Assignment-3
15-19	Midstream operations of natural gas processing	Familiarize with mid-stream operations and phase separation	Lecture	CE 1553.5	End term
20-23	Phase separation		Lecture	CE 1553.5	End term, Assignment-4
24-29	Acid gas treatment	Able to design separation systems	Lecture	CE 1553.5	End term
30-32	Natural gas compression	Built understanding for gas compression systems	Lecture	CE 1553.5	End term
33 - 36	Equipment design and selection	Able to design tubing, separation systems and transportation systems	Lecture	CE 1553.5	End term

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE1553.1	Understand the basic operations of an upstream & midstream petroleum production process	2	1		1									1		3
CE1553.2	Estimate the properties of oil, natural gas and produced water using correlations	2	1		1	2								1		3
CE1553.3	Evaluate the reservoir deliverability and well deliverability	2	1		1	2								1		3
CE1553.4	Design acidizing jobs for enhanced oil production		1	1	1	2	1	2	1					2	1	3
CE1553.5	Develop employability skills required for equipment design in upstream and midstream processes		2	1	1	2	1	1	1					2	1	3

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Conventional and Non-Conventional Energy Resources | CE 1554 | 3 Credits | 3 0 0 3

Session: Aug 20 – Dec 20 | Faculty: Anand G. Chakinala | Class: B. Tech III Year

A. Introduction: This course focuses on the generation of available and derived forms of energy for different industrial applications. In this course, the students will learn about both conventional and non-conventional energy resources such as coal, natural gas, oil, biomass, hydro, wind and solar. By the end of this course, the students will have a better understanding of energy harnessing methods from different sources around the world.

B. Course Outcomes: At the end of the course, students will be able to

[CE1554.1] List and explain the main sources of energy and their primary applications.
[CE1554.2] Describe the challenges and problems associated with the use of various energy resources, including fossil fuels, with regard to future supply and the environment.
[CE1554.3] Develop the skills to explain the principles and outline the technologies to deliver useable energy from conventional and non-conventional energy resources.
[CE1554.4] Identify issues facing the non-conventional energy industries.
[CE1554.5] Identify planning and environmental issues related to non-conventional energy systems.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO.1 **Engineering Knowledge:** A thorough knowledge of the basic science, engineering and mathematics and apply that to the underline practice of Chemical Engineering.
PO.2 **Problem Analysis:** Ability to apply these basic principles to solve real world problems in a broad range of career paths.
PO.3 **Project management and finance:** The skills of making smart decisions on process feasibility based in technical and economic evaluation.
PO.4 **Ethics**: The ability to appreciate the social, ethical, cultural, environmental and safety issues related to chemical engineering profession.
PO.5 **Conduct investigations of complex problems**: The ability to develop experimental procedure/protocol to test hypothesis and analysis meaningful interpretation of the generated data.
PO.6 **Environment and sustainability**: The skill to generate sustainable engineering solutions to societal and industrial problems.
PO.7 **Modern tool usage**: Proficiency to use computational tools for problem solving.
PO.8 **Communication**: ability to communicate effectively (technical and non-technical context) in written and oral form.
PO.9 **Design/development of solutions**: Skills to work effectively and professionally in multi-disciplinary groups to solve complex chemical engineering problems.
PO.10 **Individual and team work**: The ability to work effectively and professionally on projects both independently and as a part of a group/team.
PO.11 **Life-long learning**: The ability to be self-learners and lifelong learners.
PO.12 **The engineer and society**: The motivation to develop and lead entrepreneurial projects for societal benefit.

Degree Specific Outcomes for chemical engineering are as follows:

PSO.1 **Concept to Commissioning:** The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

PSO.2 **Process Intensification:** Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3 **Specialization:** students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	In class Quizzes, Assignments AND Projects (Accumulated and Averaged)	15+15
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	No makeup assignments will be given.	
Projects	Each group of 2-3 students will submit a project on a topic relevant to relevant to conventional and non-conventional energy production techniques. The details of this component will be discussed during the lectures.	

E. SYLLABUS

Introduction of coal, natural gas and oil as sources of energy. Application of coal in industries. In situ Coal Gasification. Oil and Gas from condensate and oilfields. Scope of Oil and Natural gas industry. Concepts of thermodynamics and system energy in Natural Gas Engineering. Physical properties of natural gas and the associated hydrocarbon liquids. Reservoir aspects of natural gas and oil. Conversion of coal and gas to liquid. Introduction to world energy scenario, Renewable energy resources, Radiation, Solar Geometry, radiation models; Solar Thermal, Optical efficiency, thermal efficiency, concentrators, testing procedures, introduction to thermal systems (flat plate collector), Biomass, Biomass resources, wood composition, biogas, biodiesel, ethanol; Wind, types of wind machines, Hydro resources, types of hydro turbine, small hydro systems; Other systems, Geothermal, wave energy, ocean energy.

F. BOOKS

Reference Books:

R1. Probstein, R. F., and Hicks, R. E., Synthetic Fuels, Dover Publications, 2013.
R2. S. Rao and B.B. Parulekar, Energy technology, Khanna Publishers, 2017.
R3. P.C. Jain, Engineering Chemistry, Dhanpat Rai Publishing Company, 2018.
R4. D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, 1987.
R5. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, 1986.
R6. Sukhatme, S. P., Solar Energy - Principles of Thermal Collection and Storage, 3rd ed., Tata McGraw-Hill, 1996.
R7. Duffie, J. A., and Beckman, W. A., Solar Engineering of Thermal Processes, 4th ed., John Wiley, 2013.
R8. Goswami, D. Y., Kreith, F., and Kreider, J. F., Principles of Solar Engineering, Taylor and Francis, 2000.
R9. Green, Solar Cells, Prentice-Hall, Englewood Cliffs, 1982.

G. Lecture Plan:

Class Number	Topics	Session Outcome	Mode of Delivery	Corresponding Course Outcome	Mode of Assessing the Outcome
1	Introduction to World Energy Resources	List and explain the main sources of energy and their primary applications	Lecture and interaction	1554.1	Quiz
2	Introduction of coal, natural gas and oil as sources of energy. Application of coal in industries	List and explain the main sources of energy and their primary applications	Lecture and interaction	1554.1 1554.2	
3	Oil and Gas from condensate and oilfields. Scope of Oil and Natural gas industry.	Describe the challenges and problems associated with the use of various energy resources, including fossil fuels, with regard to future supply and the environment.	Lecture and interaction	1554.1 1554.2	Quiz 1st Sessional ET Exam Home Assignment
4	Concepts of thermodynamics and system energy in Natural Gas Engineering.				
5-6	Physical properties of natural gas and the associated hydrocarbon liquids. Reservoir aspects of natural gas and oil. Conversion of coal and gas to liquid.				
7-12	Oil and Natural Gas Production Techniques		Lecture and interaction	1554.1 1554.2	1st Sessional ET Exam Home Assignment Quiz Project
13-20	Nuclear Processes, Nuclear decay, Nuclear fuel processing, Life cycle of nuclear fuel, Nuclear reactor types and applications.	Explain the principles and outline the technologies to deliver useable energy from conventional and non-conventional energy resources.			
	Hydroelectric power: Design considerations for a hydroelectric power plant, classification of hydroelectric power plants, flow duration and power duration curve, Selection of turbine, power load factor.	Identify issues facing the non-conventional energy industries. Identify planning and environmental issues related to non-conventional energy systems.	Lecture and interaction	1554.1 1554.2 1554.3 1554.4	
First sessional exam					
21-23	Biomass, Biomass resources, wood composition, biogas, biodiesel, ethanol.	Identify planning and environmental issues related to non-conventional energy systems.	Lecture and interaction	1554.3 1554.4 1554.5	Quiz II Sessional ET Exam Home Assignment Project
24-26	Wind, types of wind machines, Energy generation from wind.	Identify planning and environmental issues related to non-conventional energy systems.	Lecture and interaction	1554.3 1554.4 1554.5	
27-28	Introduction to world energy scenario, Renewable energy resources, Radiation, Solar Geometry, radiation models	Identify planning and environmental issues related to non-conventional energy systems.	Lecture and interaction	1554.3 1554.4 1554.5	
29-30	Solar Thermal, Optical efficiency, thermal efficiency, concentrators, testing procedures,	Identify planning and environmental issues related to non-conventional energy systems.	Lecture and interaction	1554.3 1554.4 1554.5	

30-32	Introduction to solar thermal systems (flat plate collector).	List and explain the main sources of energy and their primary applications	Lecture and interaction	1554.3 1554.4 1554.5	ET Exam Home Assignment Quiz Project
33-40	Other non-conventional energy sources such as Geothermal, wave energy, ocean energy.	List and explain the main sources of energy and their primary applications Identify planning and environmental issues related to non-conventional energy systems.	Lecture and interaction		

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[1554.1]	List and explain the main sources of energy and their primary applications.			1			1	1								3
[1554.2]	Describe the challenges and problems associated with the use of various energy resources, including fossil fuels, regarding future supply and the environment.			1			2	3			1					3
[1554.3]	Explain the principles and outline the technologies to deliver useable energy from conventional and non-conventional energy resources.			1			2	2								3
[1554.4]	Identify issues facing the non-conventional energy industries.		3		1				1	1						3
[1554.5]	Identify planning and environmental issues related to non-conventional energy systems.					3	1	1					1			3

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Lab Hand-out

Transport Phenomena Lab-I | CE 1531 | 2 Credits | 0 0 4 2

Session: Aug 20 – Dec 20 | Faculty: Anees Y. Khan | Class: Laboratory

A. Introduction: This lab focusses on the experiments related to momentum transfer operations theory course, designed for undergraduate students of chemical engineering. Experiments shall be performed on equipment based on Bernoulli's principle, Reynolds setup, major and minor losses in pipe friction, agitators, pumps etc.

B. Course Outcomes: At the end of the course, students will be able to

[1531.1] Have a deep understanding of the fundamentals of fluid mechanics and their real life applications
[1531.2] Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning
[1531.3] Perform experimental investigations on different fluid mechanics set up's and gain competency in performing and analysing the data.
[1531.4] Assess the results obtained to that approximated by theories reported in literature
[1531.5] Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment

C. Program outcomes and program specific outcomes

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.
PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6. 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.
PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.
PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Conducting experiments and report	Viva + Safety	10+5
	Soft copy of reports + Excel sheets	5
	Pre-lab and Post Lab reports	50
End Term Exam	End Term Exam (Open Book)	30
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Labs	No make-up labs will be conducted in case of absence during the labs except in extenuating circumstances, with the prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Pre & Post Lab reports	Pre & Post lab reports must be submitted before the specified due date for handing it over. No late submissions after the due date shall be accepted under any circumstance. It is expected that the students shall work on the experiments independently and analyse their results on their own without 'copying' the solutions from each other.	

E. List of Experiments & their objectives

Sl. No.	Experimental set-up	Objective
11.	Rotameter	To study the flow measurements using rotameter – Calibration and discharge measurement using rotameter.
12.	Venturimeter	To study the flow measurements using venturimeter –To determine the coefficient of discharge through venturimeter
13.	Bernoulli's setup	To verify experimentally the validity of Bernoulli's Principle for fluid flow.
14.	Orifice meter	To study the flow measurement using orificemeter –To determine the coefficient of discharge through orificemeter
15.	Setup for Major losses (pipe)	To study the losses due to friction in pipes and determine the friction factor.
16.	Setup for Minor losses (pipe-fittings)	To determine the loss of head in the fittings at various water flow rates to measure the loss coefficient for the pipe fittings and to study losses due to fittings, sudden enlargements and contractions.

17.	Agitated vessels	To study the power consumption of a fluid in an agitated vessel with and without baffles and to Plot the power number vs Reynolds Number for the same.
18.	Reynold's setup	To study of flow behavior (laminar, transition and turbulent regime) using Reynold's Apparatus.
19.	Pitot tube	To find the point velocity at the center of the tube for different flowrates of water and calibrate the Pitot tube.
20.	Characteristics of a centrifugal pump	To study of centrifugal pump characteristics – Determining the relationship between the head discharge, speed, power and efficiency for a centrifugal pump at various rotation speeds and determining flow rate characteristics at the same speed

F. Text books

T1. de Nerves, N., "Fluid Mechanics for Chemical Engineers", McGraw Hill International.

T2. McCabe, W.L., Smith, J.C., Harriott, P., "Unit operations of Chemical Engineering", McGraw Hill International.

G. Experiment Plan:

LEC NO	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1	Rotameter	To study the flow measurements using rotameter – Calibration and discharge measurement using rotameter.	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam
2	Venturimeter	To study the flow measurements using venturimeter –To determine the coefficient of discharge through venturimeter	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam
3	Bernoulli's setup	To verify experimentally the validity of Bernoulli's Principle for fluid flow.	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;;	Report + Viva +End sem lab exam
4	Orifice meter	To study the flow measurement using orificemeter –To determine the coefficient of discharge through orificemeter	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam
5	Setup for Major losses (pipe)	To study the losses due to friction in pipes and determine the friction factor.	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam
6	Setup for Minor losses (pipe-fittings)	To determine the loss of head in the fittings at various water flow rates to measure the loss coefficient for the pipe fittings and to study losses due to fittings, sudden enlargements and contractions.	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam
7	Agitated vessels	To study the power consumption of a fluid in an agitated vessel with and without baffles and to Plot the	Lab	CO1531.1; CO1531.2;	Report + Viva +End

		power number vs Reynolds Number for the same.		CO1531.3; CO1531.4; CO1531.5;	sem lab exam
8	Reynold's setup	To study of flow behavior (laminar, transition and turbulent regime) using Reynold's Apparatus.	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam
9	Pitot tube	To find the point velocity at the center of the tube for different flowrates of water and calibrate the Pitot tube.	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam
10	Characteristics of a centrifugal pump	To study of centrifugal pump characteristics – Determining the relationship between the head discharge, speed, power and efficiency for a centrifugal pump at various rotation speeds and determining flow rate characteristics at the same speed	Lab	CO1531.1; CO1531.2; CO1531.3; CO1531.4; CO1531.5;	Report + Viva +End sem lab exam

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE1531.1	Have a deep understanding of the fundamentals of fluid mechanics and their real life applications	2	1	1	1	1										
CE1531.2	Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning			1			1		2	3			1			
CE1531.3	Perform experimental investigations on fluid mechanics equipment's and gain competency in performing and analysing the data		2	2	3	1			2		1					
CE1531.4	Assess the results obtained to that approximated by theories reported in literature			2	3	1			2		2					
CE1531.5	Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment				3	1		1	2	1	1		1			

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Handout
Process Modeling and Simulation Lab | CE1532 | 2 Credits | 0 0 4 2
Session: Aug'20 – Dec'20 | Faculty: Dr. Manisha Sharma | Class: B. Tech. (Chemical) V Semester

A. Introduction: The course focuses on the modeling and simulation of processes involved in chemical engineering industries. It deals with the development of mathematical modeling, parametric estimation and application of numerical methods to solve chemical engineering problems. In this unit, the students will learn the fundamentals of process synthesis and design using mathematical modeling tools. By the end of this course, the students will have a clear understanding required for analysis of process engineering solutions of real world problems.

B. Course Outcomes: At the end of the course, students will be able to:

[CE1532.1]	Understand the basic concepts of MATLAB and ASPEN HYSYS
[CE1532.2]	Develop and simulate the MATLAB codes for the mathematical models of various chemical process / equipment
[CE1532.3]	Perform the validation, parametric estimation and optimization of a process model
[CE1532.4]	Develop employability skills to generate the process flowsheet using different unit operations in a process simulator

C. Program Outcomes

[PO.1]. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

[PO.2]. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

[PO.3]. **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 the public health and safety, and the cultural, societal, and environmental considerations.

[PO.4]. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

[PO.5]. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

[PO.6]. **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.

[PO.7]. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

[PO.8]. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

[PO.9]. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

[PO.10]. **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.

[PO.11]. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

[PO.12]. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Lab Reports / Projects (Accumulated and Averaged) (Lab reports will not be accepted after the due date of submission)	70
End Term Exam (Summative)	End Term Exam (Practical Exam)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Students who miss a lab will not be provided with any sort of makeup assignment or make up lab. You may contact the course coordinator for clarification of doubts, if any.	

Zero tolerance on academic dishonesty

E. Course Contents

MATLAB as well as process simulation packages such as ASPEN HYSYS will be utilized to simulation the model equations and develop the process flowsheet for the given chemical process. Slight modifications may be made as the course progresses. Practice as much you can. You can only then get proficient in MATLAB coding. You aim should be to learn, understand and master the course. Try to develop the code by yourself. If you face any challenge or difficulty, then contact the course coordinator.

Lab No.	Topic	Session Outcome	Mode of Delivery	Corresponding CO	Mode of Assessing CO
87.	Introduction to MATLAB	Understand the basic concepts of MATLAB	Hands-on practice in lab	CE1532.1	Lab reports / End Term Exam
88.	Non-Linear Algebraic Equations	Understand the techniques to solve non-linear algebraic equations in MATLAB	Hands-on practice in lab	CE1532.1 CE1532.2	Lab reports / End Term Exam
89.	Ordinary Differential Equations (ODE)	Understand the techniques to solve ODEs in MATLAB	Hands-on practice in lab	CE1532.1 CE1532.2	Lab reports / End Term Exam
90.	Differential Algebraic Equations (DAE) - I	Understand the techniques to solve DAEs in MATLAB	Hands-on practice in lab	CE1532.1 CE1532.2	Lab reports / End Term Exam
91.	Differential Algebraic Equations (DAE) - II	Develop MATLAB codes to solve DAEs for a chemical process / equipment	Hands-on practice in lab	CE1532.1 CE1532.2	Lab reports / End Term Exam
92.	Partial Differential Equations (PDE)	Understand the techniques to solve PDEs in MATLAB	Hands-on practice in lab	CE1532.1 CE1532.2	Lab reports / End Term Exam
93.	Introduction to Aspen HYSYS	Understand the basic concepts of HYSYS	Hands-on practice in lab	CE1532.1	Lab reports / End Term Exam
94.	Process Simulation Case Study I	Generate Process flowsheet using different unit operations in a process simulator for an industrial process	Hands-on practice in lab	CE1532.1 CE1532.3 CE1532.4	Lab reports / End Term Exam
95.	Process Simulation Case Study II	Generate Process flowsheet using different unit operations in a process simulator	Hands-on practice in lab	CE1532.1 CE1532.3 CE1532.4	Lab reports / End Term Exam

		for an industrial process			
96.	Process Simulation Case Study III	Generate Process flowsheet using different unit operations in a process simulator for an industrial process	Hands-on practice in lab	CE1532.1 CE1532.3 CE1532.4	Lab reports / End Term Exam
97.	Process Simulation Case Study IV	Generate Process flowsheet using different unit operations in a process simulator for an industrial process	Hands-on practice in lab	CE1532.1 CE1532.3 CE1532.4	Lab reports / End Term Exam
End – Sem Exam					

F. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[CE1532.1]	Understand the basic concepts of MATLAB and ASPEN HYSYS	2	1	3		3		1		2	1		1	1		1
[CE1532.2]	Develop and simulate the MATLAB codes for the mathematical models of various chemical process / equipment	3	2	3	1	3				2	1		1	2		1
[CE1532.3]	Perform the validation, parametric estimation and optimization of a process model	3	2	3	1	3	1			2	1		1	1	1	1
[CE1532.4]	Develop employability skills to generate the process flowsheet using different unit operations in a process simulator	2	3	3		3	1			2	2		1	2		2

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Lab Hand-out (Transport Phenomena -II)

Heat Transfer Operation Lab | CE 1631/CE 2230 | 2 Credits | 0 0 4 2

Session: Jan 21 – May 21 | Faculty: Nandana Chakinala | Class: Laboratory

A. Introduction: This Transport Phenomena Lab – II is related to Heat Transfer Operations that is designed for the undergraduate students of Chemical Engineering. This lab introduces the experiments related to different Heat Transfer mode of operations such as conduction, convection and radiation that are earlier covered in the theory course.

B. Course Outcomes: At the end of the course, students will be able to

[CE 1553.6]. To have a deep understanding of the fundamentals of heat transfer operations and its real life applications

[CE 1553.7]. Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning

[CE 1553.8]. Perform experimental investigations on different heat transfer equipment's and gain competency in performing and analysing the data.

[CE 1553.9]. Assess the results obtained to that approximated by theories reported in literature

[CE 1553.10]. Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment

C. Program outcomes and program specific outcomes

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10. 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.
PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Conducting experiments and report	Viva & Safety	15
	Soft copy of reports + Excel calculations	5
	Pre-lab and Post Lab reports	50
End Term Exam	End Term Exam (Open Book)	30
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Labs	No make-up labs will be conducted in case of absence during the labs except in extenuating circumstances, with the prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Pre & Post Lab reports	Pre & Post lab reports must be submitted before the specified due date for handing it over. No late submissions after the due date shall be accepted under any circumstance. It is expected that the students shall work on the experiments independently and analyse their results on their own without 'copying' the solutions from each other.	

E. List of Experiments & their objectives

Sl. No.	Experimental set-up	Objective
21.	Thermal conductivity of liquids	To determine thermal conductivity of liquids and to gain insights related to thermal conductivity measurement techniques
22.	Heat transfer in agitated vessel under unsteady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation and to develop insights in determining heating/cooling time
23.	Heat transfer in agitated vessel under steady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation at different flowrates and to study the effect of agitation speed on heat transfer coefficient
24.	Shell and tube heat transfer coefficient	To determine overall heat transfer coefficient and understand the significance of LMTD. Evaluate model parameters and study the effect of change in flow rate on U and h_i.
25.	Plate type heat exchanger	To determine overall heat transfer coefficient and understand the significance of LMTD. Evaluate model parameters and get introduced to compact heat exchangers.
26.	Cross flow heat exchanger	To study the heat transfer rate and to determine the overall heat transfer coefficient and understand the significance of LMTD at different flow rates.
27.	Heat transfer in fluidized bed	To determine the overall heat transfer coefficient and to study the relationship between heat transfer coefficient and porosity
28.	Single effect evaporator	To study the material and energy balances and to estimate the overall heat transfer coefficient, economy and capacity of evaporator
29.	Two phase heat transfer unit	To plot the heat flux & temperature difference between metal and liquid and determine the boiling regime
30.	Drop wise and film wise condensation	To determine the heat transfer coefficient of two types drop wise and film wise of condensation
31.	Unsteady state heat transfer unit	To determining heat transfer coefficient and to calculate Biot number, Fourier number
32.	Vertical and horizontal condenser	To determine the overall heat transfer coefficient and film coefficient for vertical and horizontal condenser
33.	Stefan Boltzmann set-up	To determine Stefan Boltzmann constant and study the effect of hemisphere temperature on it

F. Text books

1) Perry's Chemical Engineering Handbook

2) D.Q. Kern, Process Heat Transfer, Mc Graw Hill, 1997.

3) W.L. McCabe, J.C. Smith, P. Harriot, Unit operations of Chemical engineering, 7th edition, Mc Graw Hill.

4) A.S. Foust, L.A. Wenzel, C.W. Clump, L. Maus, L.B. Andersen, Principles of Unit Operations, 2nd edition, Wiley India.

Experiment Plan:

LEC NO	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1	Thermal conductivity of liquids	To determine thermal conductivity of liquids and to gain insights related to thermal conductivity measurement techniques	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam

2	Heat transfer in agitated vessel under unsteady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation and to develop insights in determining heating/cooling time	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
3	Heat transfer in agitated vessel under steady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation at different flowrates and to study the effect of agitation speed on heat transfer coefficient	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
4	Shell and tube heat transfer coefficient	To determine overall heat transfer coefficient and understand the significance of LMTD. Evaluate model parameters and study the effect of change in flow rate on U and h_i.	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
5	Plate type heat exchanger	To determine overall heat transfer coefficient and understand the significance of LMTD. Evaluate model parameters and get introduced to compact heat exchangers.	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
6	Cross flow heat exchanger	To study the heat transfer rate and to determine the overall heat transfer coefficient and understand the significance of LMTD at different flow rates.	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
7	Heat transfer in fluidized bed	To determine the overall heat transfer coefficient and to study the relationship between heat transfer coefficient and porosity	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
8	Single effect evaporator	To study the material and energy balances and to estimate the overall heat transfer coefficient, economy and capacity of evaporator	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
9	Two phase heat transfer unit	To plot the heat flux & temperature difference between metal and liquid and findout the boiling regime	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam

10	Drop wise and film wise condensation	To determine the heat transfer coefficient of two types drop wise and film wise of condensation	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
11	Unsteady state heat transfer unit	To determining heat transfer coefficient and to calculate Biot number, Fourier number	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
12	Vertical and horizontal condenser	To determine the overall heat transfer coefficient and film coefficient for vertical and horizontal condenser	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
13	Stefan Boltzmann set-up	To determine Stefan Boltzmann constant and study the effect of hemisphere temperature on it	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam

G. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1	PO12	*PSO1*	*PSO2*	*PSO3*
CE1631.1	To have a deep understanding of the fundamentals of heat transfer operations and its real life applications	2	1	1	1	1								3		
CE1631.2	Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning			1			1		2	3			1	3		
CE1631.3	Perform experimental investigations on different heat transfer equipment's and gain competency in performing and analysing the data		2	2	3	1			2		1			3		
CE1631.4	Assess the results obtained to that approximated by theories reported in literature			2	3	1			2		2			3		
CE1631.5	Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment				3	1		1	2	1	1		1	3		

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Process Safety Analysis | CE 1604/1601 | 3/4 Credits | 3/3 0/1 0/0 3/4

Session: February 21 – June 21 | Faculty: Dr. Harsh Pandey | Class: VI Semester

A. COURSE SUMMARY: This material on Process Safety Analysis is designed for the undergraduate students of Chemical Engineering. This course introduces the basic concepts relating to chemical hazards, risk, and ethics. The interaction and trade-offs of these concepts are stressed in order to establish approaches to the proper selection and evaluation of processes and their implementation into small and large scale plants/laboratories. Quantitative analyses of chemical releases and dispersion using thermodynamic, transport, and reaction/reactor considerations are used to develop an appreciation for and understanding of chemical incidents and the possible consequences to plant facilities, workers, and the general public. Examples of problems that may arise due to inadequate process design, improper process modification, and disregard for ethical decision making are discussed using numerous case studies.

B. COURSE OUTCOMES: By the end of the course, students will be able to

[2230.1]. Develop safety culture
[2230.2]. Evaluate effect of toxicants and other hazards
[2230.3]. Quantitatively analyse release and dispersion rates of liquid and vapors
[2230.4]. Analyse fire and explosion hazards
[2230.5]. Integrate safety concepts and ethics into chemical process design
[2230.6]. Perform hazard identification, risk assessment, enhancing employability.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Graduate attributes in the B.Tech. Course in Chemical Engineering include:

[PO.13]. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems

[PO.14]. **Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences

[PO.15]. **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 the public health and safety, and the cultural, societal, and environmental considerations

[PO.16]. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

[PO.17]. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations

[PO.18]. **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

[PO.19]. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development

[PO.20]. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practices

[PO.21]. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings

[PO.22]. **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

[PO.23]. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments

[PO.24]. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes for chemical engineering are as follows:

[PSO.7]. **Concept to Commissioning:** The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

[PSO.8]. **Process Intensification:** graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.9]. **Specialization:** Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN:

Criteria	Description	Maximum Marks
Internal Assessment	Sessional Exam I (Open/Closed Book)	20
	Sessional Exam II (Open/Closed Book)	20
	In class Quizzes, Assignments, Projects, Case Studies (Accumulated and Averaged)	30
End Term Exam	End Term Exam (Open Book)	30
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments	No make-up for missed short quizzes/assignments or exam will be allowed except in extenuating circumstances, with prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Homework/ Home Assignment/ Project	Home works will be assigned in between the lectures along with the due date for handing it over. No late assignments handed after the due date shall be accepted under any circumstance. It is expected that the students shall work on the assignments independently and not 'copy' the solutions from each other. A case study is given which is assessed in form of individual reports submitted.	

Lectures	Content	Session Outcome	Mode of Delivery	CO Tracking	Assessment
1	Introduction to Safety	To introduce chemical process safety to the students	Lecture, Interaction	CE1604.1	NA
2-4	Toxicology	Introducing concepts related to toxicity and exposure to the students	Interaction, Discussion	CE1604.2	Assignment
5-7	Industrial Hygiene	Introduces industrial hygiene and best practices to the students	Interaction, Discussion	CE1604.2, CE1604.5	Assignment
8-10	Source Models	This key concept for understanding release of hazardous materials is introduced	Interaction, Discussion	CE1604.2, CE1604.3	Assignment
11	Flashing liquids, Liquid pool evaporation or boiling	Students learn about these fire and explosion hazards	Interaction, Discussion	CE1604.4	Assignment
12	Pre-Sessional Review	Review of Syllabus Covered	Discussion	CE1604.1, CE1604.2, CE1604.3, CE1604.4	NA
FIRST SESSIONAL EXAM					
13-16	Toxic Release and dispersion models	This key concept for understanding release and spreading of hazardous materials is introduced	Interaction, Discussion	CE1604.2, CE1604.3	Assignment
17-20	Fires	Students learn about these fire and explosion hazards	Interaction, Discussion	CE1604.4	Assignment
21-23	Explosions	Students learn about these fire and explosion hazards	Interaction, Discussion	CE1604.4	Assignment
24-27	Inerting, Static electricity, Explosion proof equipment and instruments, Sprinkler systems	Students learn about preventing and minimizing damage from fire and explosion hazards	Interaction, Discussion	CE1604.4	Assignment
28	Relief concepts, Location of reliefs, Relief scenarios	Students learn about preventing and minimizing damage from fire and explosion, toxicity, and other hazards	Interaction, Discussion	CE1604.1, CE1604.2, CE1604.3, CE1604.4, CE1604.5	Assignment
29	Relief systems for flares, scrubbers, condensers, knock out drum	Students learn about preventing and minimizing damage from fire and explosion, toxicity, and other hazards	Interaction, Discussion	CE1604.1, CE1604.2, CE1604.3, CE1604.4, CE1604.5	Assignment
30-34	Relief sizing	Students learn about preventing and minimizing damage from fire and explosion, toxicity, and other hazards	Interaction, Discussion	CE1604.1, CE1604.2, CE1604.3, CE1604.4, CE1604.5	Assignment
35	Pre-Sessional Review	Review of Syllabus Covered	Discussion	CE1604.1, CE1604.2, CE1604.3, CE1604.4, CE1604.5	NA
SECOND SESSIONAL EXAM					
36-39	Hazard Identification and Risk Assessment	Students learn about the formal approaches to Hazard Identification and Risk Assessment standardized by Industry	Interaction, Discussion	CE1604.6	NA

40-42	Accident investigations	Students learn about some major industrial disasters, what went wrong, and the lessons learnt from them	Discussion, Class Participation	CE1604.1, CE1604.2, CE1604.3, CE1604.4, CE1604.5, CE1604.6	Miniproject Report
END TERM EXAM					

E. SYLLABUS:

Introduction – Accident and loss statistics, inherent safety, safety culture, ethics; **Toxicology**- How toxicants enter and are eliminated from biological organisms, Toxicological studies, Dose vs response, Relative toxicity, threshold limit values; **Industrial Hygiene:** Government regulations, Identification, Evaluation of exposures to volatile toxicants, dusts, noise, toxic vapors, Control; **Source Models:** Flow of liquid through hole, hole in a tank, pipes; Flow of vapor through holes, gases through pipes; Flashing liquids, Liquid pool evaporation or boiling, Toxic Release and dispersion models; **Fires and explosion:** Fire triangle, fire vs explosion, Flammability characteristics of liquid and vapors, TNT equivalency, energy of chemical and mechanical explosions, vapor cloud explosions, BLEVE, Inerting, Static electricity, Explosion proof equipment and instruments, Sprinkler systems; **Relief systems:** Relief concepts, Location of reliefs, Relief scenarios, Relief systems for flares, scrubbers, condensers, knock out drum; **Relief sizing:** Spring operated for liquid/vapor/gas service, Rupture disk relief for liquid/vapor/gas, reliefs for thermal expansion of process fluids; **Hazard Identification:** Surveys, HAZOP, safety reviews **Risk assessment:** Probability theory, event trees, fault trees, QRA, LOPA, **Accident investigations**

F. TEXT BOOKS:

T1. Crowl, D.A., Louvar, J.F., Chemical Process Safety, Pearson, 3rd edition, 2015.

G. REFERENCE BOOKS:

R1. Center for Chemical Process Safety (CCPS), Introduction to process safety for undergraduates and engineers, Wiley, 1st Edition, 2016.

R2. Sanders, R. E., Chemical Process Safety, Elsevier, 3rd edition, 2006.

R3. Klein, J.A., Vaughen, B.K., Process Safety: Key concepts and practical approaches, CRC press, 1st edition, 2017.

H. COURSE ARTICULATION MATRIX (Mapping of COs with POs):

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO 3*
CE 1604.1	Develop safety culture				3									2		1
CE 1604.2	Evaluate effect of toxicants and other hazards	1			2			1						2		
CE 1604.3	Quantitatively analyse release and dispersion rates of liquid and vapors	1			2			2						2	1	
CE 1604.4	Analyse fire and explosion hazards	1			2			2						2		1
CE 1604.5	Integrate safety concepts and ethics into chemical process design			1	2									2		1
CE 1604.6	Perform hazard identification, risk assessment, enhancing employability.			2										2		1

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR
School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Handout
Mass Transfer II | CE1605 | 3 Credits | 3 0 0 3
Session: Jan'21 – May'21 | Faculty: Dr. Manisha Sharma | Class: B. Tech. (Chemical) VI Semester

A. INTRODUCTION

This course on Mass Transfer II is a core course designed for the undergraduate students of Chemical Engineering. This course continues further on the concepts learned in Mass Transfer-I which describes interphase mass transfer involved in design of separation systems. It covers the concepts of vapour-liquid, liquid-liquid, solid-liquid equilibrium involved in mass transfer operations with emphasis on design and performance calculations of rate based and equilibrium-based separations. Separation processes covered in detail in this course are distillation, extraction, leaching and drying.

B. COURSE OUTCOMES

At the end of the course, students will be able to:

[1605.1]	Interpret the equilibrium data required in design of separation processes
[1605.2]	Illustrate the mass transfer fundamentals involved in design calculations
[1605.3]	Use the design methods for solving problems related to mass transfer operations in industries
[1605.4]	Perform process design calculations of various mass transfer equipment such as distillation columns, extraction columns and dryers enhancing employability

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	Quizzes and Home Assignments / Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Assignments (Formative)	Assignments are an integral part of the course. Home assignments / Class assignments will be provided from time to time. No late submissions will be entertained. It is expected that the students will work on the assignments independently. If any assignment is found copied from any source, marks will be deducted for the same.	
Make up Assignments	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture(s).	

	You may contact the course coordinator for clarification of doubts, if any.

E. SYLLABUS

Distillation, concept of vapour liquid equilibrium, Raoult's law, deviations from ideal law, azeotropic distillation and steam distillation. Enthalpy concentration diagrams, binary and multi component systems, dew and bubble point calculations, flash vaporization, simple distillation, binary component distillation, Ponchan Savarit method: minimum reflux ratio, optimum reflux ratio- total reflux ratio, partial condenser, total condenser, McCabe Thiele method: concept of q line, optimum reflux ratio- total reflux ratio, partial condenser, total condenser. Multi component distillation: azeotropic, extractive, molecular distillation. Liquid-Liquid Extraction: liquid-liquid-equilibria, ternary systems triangular and rectangular coordinates-choice of solvent-single stage and multi stage cross current, equipment's such as mixer settler, packed and tray towers. Leaching, Drying and design criteria, Design of rotary dryers.

F. TEXT BOOKS

R11. Treybal R. E, Mass Transfer Operations, 3rd ed., McGraw Hill, 2012

G. REFERENCE BOOKS

R1. Seader, J.D., Henley, E.J., Roper D.K., "Separation Process Principles," 3rd ed., (International Edition), John Wiley & Sons.

R2. McCabe and Smith, Unit Operations in Chemical Engineering, 5th ed., McGraw-Hill.

R3. Coulson, J.M., Richardson, J.F., Chemical Engineering Volume-2, 5th ed., Butterworth-Heinemann.

R4. Geankoplis, C. J., Transport Processes and Unit Operations, 3rd ed., PHI, New Delhi.

R5. Robert H. Perry and Don W. Green, Perry's Chemical Engineers hand book, 8th ed., McGraw Hill.

R6. King, C. J., Separation Processes, 2nd ed., Tata McGraw Hill, New Delhi.

H. LECTURE PLAN

Lecture No.	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
1.	Introduction	Understand the basics of Mass Transfer Operations	Lecture	-	Assignment / quiz / Mid Term I
2.	Introduction	Understand the basics of Mass Transfer Operations	Lecture	-	Assignment / quiz / Mid Term I
3.	Distillation	Vapor liquid equilibrium, concept of relative volatility	Lecture	CE1605.1	Assignment / quiz / Mid Term I
4.	Distillation	Effect of P and T on equilibrium data, P-x-y and T-x-y diagrams, y vs x diagrams	Lecture	CE1605.1	Assignment / quiz / Mid Term I
5.	Distillation	Ideal Solutions, Raoult's law, Deviations from ideality, Maximum and minimum boiling azeotrope	Lecture	CE1605.1	Assignment / quiz / Mid Term I

6.	Distillation	Bubble and dew point calculations	Lecture	CE1605.1	Assignment / quiz / Mid Term I
7.	Distillation	Bubble and dew point calculations	Lecture	CE1605.1	Assignment / quiz / Mid Term I
8.	Distillation	Enthalpy concentration diagrams	Lecture	CE1605.1	Assignment / quiz / Mid Term I
9.	Distillation	Single stage flash distillation	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term I
10.	Distillation	Steam distillation	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term I
11.	Distillation	Simple distillation binary and multicomponent mixtures	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term I
12.	Distillation	Continuous rectification of binary systems	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term I
13.	Distillation	Determination of number of stages by Ponchon Savarit method, case study	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term I
14.	Distillation	Determination of number of stages by Ponchon Savarit method, case study	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term I
15.	Distillation	Determination of number of stages by Ponchon Savarit method, case study	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term I
16.	Distillation	Determination of number of stages by Mc-Cabe Thiele method, Case study	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
17.	Distillation	Determination of number of stages by Mc-Cabe Thiele method, Case study	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
18.	Distillation	Partial and total condenser, Concept of minimum, total and optimum reflux ratio	Lecture	CE1605.2; CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
19.	Distillation	Partial and total condenser, Concept of minimum, total and optimum reflux ratio	Lecture	CE1605.2; CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
20.	Distillation	Partial and total condenser, Concept of minimum, total and optimum reflux ratio	Lecture	CE1605.2; CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
21.	Distillation	Use of open steam	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term II
22.	Distillation	Azeotropic distillation, extractive distillation	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term II
23.	Distillation	Concept of multi-component distillation	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term II
24.	Extraction	Liquid-Liquid equilibrium, Choice of solvent	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term II

25.	Extraction	Ternary diagrams	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term II
26.	Extraction	Design calculations for miscible solvents (co-current and counter current)	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
27.	Extraction	Design calculations for miscible solvents (co-current and counter current)	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
28.	Extraction	Design calculations for miscible solvents (co-current and counter current)	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
29.	Extraction	Design calculations for immiscible solvents (co-current and counter current)	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
30.	Extraction	Design calculations for immiscible solvents (co-current and counter current)	Lecture	CE1605.3; CE1605.4	Assignment / quiz / Mid Term II
31.	Extraction	Types of extractors	Lecture	CE1605.1; CE1605.2	Assignment / quiz / Mid Term II
32.	Leaching	Solid liquid equilibrium	Lecture	CE1605.1; CE1605.2	Assignment / quiz / End Term
33.	Leaching	Leaching equipment	Lecture	CE1605.1; CE1605.2	Assignment / quiz / End Term
34.	Leaching	Single and multistage operation	Lecture	CE1605.3; CE1605.4	Assignment / quiz / End Term
35.	Leaching	Single and multistage operation	Lecture	CE1605.3; CE1605.4	Assignment / quiz / End Term
36.	Leaching	Single and multistage operation	Lecture	CE1605.3; CE1605.4	Assignment / quiz / End Term
37.	Drying	Equilibrium relationship and hysteresis, types of moisture	Lecture	CE1605.1; CE1605.2	Assignment / quiz / End Term
38.	Drying	Mechanism of drying, rate of drying	Lecture	CE1605.1; CE1605.2	Assignment / quiz / End Term
39.	Drying	Drying equipment	Lecture	CE1605.1; CE1605.2	Assignment / quiz / End Term
40.	Drying	Drying equipment	Lecture	CE1605.1; CE1605.2	Assignment / quiz / End Term
41.	Drying	Design of Batch, continuous dryers	Lecture	CE1605.3; CE1605.4	Assignment / quiz / End Term
42.	Drying	Design of Batch, continuous dryers	Lecture	CE1605.3; CE1605.4	Assignment / quiz / End Term
43.	Drying	Cross-circulation drying, Freeze drying	Lecture	CE1605.3; CE1605.4	Assignment / quiz / End Term
44.	Drying	Cross-circulation drying, Freeze drying	Lecture	CE1605.3; CE1605.4	Assignment / quiz / End Term

I. COURSE ARTICULATION MATRIX: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[1605.1]	Interpret the equilibrium data required in design of separation processes	3	3					2				1		3		2
[1605.2]	Illustrate the mass transfer fundamentals involved in design calculations	3	1					2			1		1	3		2
[1605.3]	Use the design methods for solving problems related to mass transfer operations in industries	3	3			2		2		2		1		3		2
[1605.4]	Perform process design calculations of various mass transfer equipment such as distillation columns, extraction columns and dryers enhancing employability	3	3	1		2		2		2	2	1		3		2

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Chemical Reaction Engineering II| CE 1606 | 3 Credits | 3 0 0 3

Session: Jan' 21 – May' 21 | Faculty: Dr Abhishek Sharma| Class: B. Tech. (Chemical) VI Semester

A. Introduction: This course is offered by Dept. of Chemical Engineering as a core course. This course focuses on the design of chemical reacting systems. In this unit, the students will learn the basics of non-ideal reactors, heterogeneously reacting systems and application of real reactors available in process plants and industries. By the end of this course, the students will have a clear understanding required for troubleshooting the design related problems of chemical reactors in real world.

B. Course Outcomes: At the end of the course, students will be able to

[CE1606.1] Understand the fundamentals of Residence Time Distribution in chemical reactors

[CE1606.2] Utilize different Flow Models to understand non-ideal reactor behaviour

[CE1606.3] Analyze the heterogeneous and solid catalysed reactions for industrial applications

[CE1606.4] Develop employability skills to evaluate the performance of different industrial reactors such as packed bed, fluidized bed, and three phase reactors

[CE1606.5] Develop skills to apply the detailed kinetics for design of fluid-fluid and fluid-particle systems

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO.1 **Engineering Knowledge:** A thorough knowledge of the basic science, engineering and mathematics and apply that to the underline practice of Chemical Engineering.

PO.2 **Problem Analysis:** Ability to apply these basic principles to solve real world problems in a broad range of career paths.

PO.3 **Project management and finance:** The skills of making smart decisions on process feasibility based in technical and economic evaluation.

PO.4 **Ethics**: The ability to appreciate the social, ethical, cultural, environmental and safety issues related to chemical engineering profession.

PO.5 **Conduct investigations of complex problems**: The ability to develop experimental procedure/protocol to test hypothesis and analysis meaningful interpretation of the generated data.

PO.6 **Environment and sustainability**: The skill to generate sustainable engineering solutions to societal and industrial problems.

PO.7 **Modern tool usage**: Proficiency to use computational tools for problem solving.

PO.8 **Communication**: ability to communicate effectively (technical and non-technical context) in written and oral form.

PO.9 **Design/development of solutions**: Skills to work effectively and professionally in multi-disciplinary groups to solve complex chemical engineering problems.

PO.10 **Individual and team work**: The ability to work effectively and professionally on projects both independently and as a part of a group/team.

PO.11 **Life-long learning**: The ability to be self-learners and lifelong learners.

PO.12 **The engineer and society**: The motivation to develop and lead entrepreneurial projects for societal benefit.

Degree Specific Outcomes for chemical engineering are as follows:

PSO.1 **Concept to Commissioning:** The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant.

PSO.2 **Process Intensification:** Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3 **Specialization:** students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	In class Quizzes, Assignments, Mini-Project (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	No makeup assignments will be given.	
Projects	Each group of 2-3 students will submit a project on a topic relevant to the design of chemical reactors applicable in process plants. The details of this component will be discussed during the lectures.	

E. SYLLABUS

Isothermal non-ideal flow reactors, RTD in chemical reactors, distribution functions. Conversion in non-ideal flow reactors, Single and multi-parameter models for non-ideal flow, Concepts of mixing, Micro and macro mixing. Heterogeneous reactions, Rate equation for heterogeneous systems, Contacting patterns for two phase systems, Fluid particle non-catalytic reactions, Different models, Derivation of rate equations, Application to design Fluid-fluid non- catalytic reactions. Introduction to Slurry, Trickle bed reactors, and Fluidized bed reactors.

F. BOOKS

Fogler, H. S., Elements of Chemical Reaction Engineering, 4th ed., Prentice-Hall of India, Delhi, 2003.

Levenspiel, O., Chemical Reaction Engineering, 3rd ed., Wiley India Pvt Ltd., 2010.

Smith, J. M., Chemical Engineering Kinetics, 3rd ed., McGraw-Hill, 1981.

Carberry, J. J., Catalytic Reaction Engineering, McGraw-Hill, 1976.

Levenspiel, O., The Chemical Reactor Omnibook, OSU Bookstores, Corvallis Oregon, 1993.

Froment, G. F., and Bischoff, K. B., Chemical Reactor Analysis and Design, 3rd ed., John Wiley and Sons, 2010.

Lecture Plan:

Lec No	Topics	Session Outcomes	Model of Delivery	Corresponding CO	Mode of assessing the outcome
1,2	Revision of Chemical Reaction Engineering-I	Revise the fundamentals with applications taught in Chemical Reaction Engineering I Course	Lecture	NA	NA
3	RTD Concept	Introducing the concept of Residence Time Distribution	Lecture	1606.1	Mid-Term I End Term Assignment/Quiz/Mini Project
4	Age Distribution of Fluid	Introducing the experimental methods for calculating age distribution of fluids	Lecture	1606.1	Mid-Term I End Term Assignment/Quiz/Mini Project
5	Step and Pulse Experiments, Convolution Integral	Explaining the applied methods for mean residence time and exit age distribution (E) calculation	Lecture	1606.1	Mid-Term I End Term Assignment/Quiz/Mini Project
6	Non Ideal Reactor Conversion	Calculating the conversion in non-ideal flow reactors	Lecture	1606.1	Mid-Term I End Term Assignment/Quiz/Mini Project
7,8	Non Ideal Flow Models-Compartment Model	Explaining the fundamentals of compartment model for E calculations	Lecture	1606.2	Mid-Term I End Term Assignment/Quiz/Mini Project
9,10	Non Ideal Flow Models-Dispersion Model	Explaining the fundamentals of dispersion model for E calculations	Lecture	1606.2	Mid-Term I End Term Assignment/Quiz/Mini Project
11,12	Non Ideal Flow Models-Tank In Series Model	Explaining the fundamentals of tank in series model for E calculations	Lecture	1606.2	Mid-Term I End Term Assignment/Quiz/Mini Project
13,14	Non Ideal Flow Models-Pure Convective Model	Explaining the fundamentals of pure convective model for E calculations	Lecture	1606.2	Mid-Term I End Term Assignment/Quiz/Mini Project
15	Mixing Concepts	Introducing the concepts of degree of segregation and earliness of mixing in RTD calculation	Lecture	1606.2	Mid-Term I End Term Assignment/Quiz/Mini Project
16,17	Heterogeneous Reactions-Introduction	Introducing the heterogeneous chemical engineering systems	Lecture	1606.3	Mid-Term II End Term Assignment/Quiz/Mini Project
18,19,20	Solid Catalysed Reactions	Explaining the mechanism of heterogeneous	Lecture	1606.3	Mid-Term II End Term

		reactions in presence of solid catalysts and evaluating the performance of different flow reactors			Assignment/Quiz/Mini Project
21,22	Packed Bed Catalytic Reactors	Describing the basics of packed bed reactors with performance evaluation for different design considerations	Lecture	1606.4	Mid-Term II End Term Assignment/Quiz/Mini Project
23,24,25	Fluidized Bed Catalytic Reactors	Explaining the behaviour and performance of fluidized bed reactors using different hydrodynamic models	Lecture	1606.4	Mid-Term II End Term Assignment/Quiz/Mini Project
26,27	Catalyst Deactivation	Explaining the catalyst decay mechanism and its effect on reactor performance	Lecture	1606.4	Mid-Term II End Term Assignment/Quiz/Mini Project
28,29,30	Three Phase Reactors	Describing the fundamentals of three phase reactors with their performance evaluation	Lecture	1606.4	Mid-Term II End Term Assignment/Quiz/Mini Project
31,32,33	Fluid-Fluid Reactions: Kinetics and Design	Explaining the factors involved in kinetic estimation and designing of fluid-fluid reactions	Lecture	1606.5	End Term Assignment/Quiz/Mini Project
34,35,36	Fluid-Particle Reactions: Kinetics and Design	Explaining the factors involved in kinetic estimation and designing of fluid-particle reactions	Lecture	1606.5	End Term Assignment/Quiz/Mini Project

G. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE 1606.1	Understand the fundamentals of Residence Time Distribution in chemical reactors	3	3					1	2	3	2				1	
CE 1606.2	Utilize different Flow Models to understand non-ideal reactor behaviour	3	3					1	2	3	2				1	
CE 1606.3	Analyze the heterogeneous and solid catalysed reactions for industrial applications	3	3					1	2	3	2				1	
CE 1606.4	Develop employability skills to evaluate the performance of different industrial reactors such as packed bed, fluidized bed, and three phase reactors	3	3					1	2	3	2				1	
CE 1606.5	Develop skills to apply the detailed kinetics for design of fluid-fluid and fluid-particle systems	3	3					1	2	3	2				1	

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Industrial Psychology | PS 1601 | 3 Credits | 3 0 0 3

Session: Jan 21 – May 21 | Faculty: Dr. Suyesha Singh | Semester: VI

A. Introduction: This course is offered by Department of Psychology as an elective course. Industrial Psychology is concerned with the study of human behaviour in those aspects of life that are related to the production, distribution and use of the goods and services in our civilization. "Workplace psychology "refers to the practice of applying psychological principles and practices to a work environment in order to solve problems and make improvements.

B. Course Objectives: At the end of the course, students will be able to:

[PS1601.1] Explain the nature, scope and methods of Industrial Psychology.

[PS1601.2] Comprehend principles and techniques of employee Selection and recruitment.

[PS1601.3] Acquire Skills required for conducting effective training and development in industrial setup

[PS1601.4] Understand the process of Job Performance Evaluation and Appraisal

[PS1601.5] Evaluate the implications of Physical working conditions, Work Schedules, Accidents and safety in work place

[PS1601.6] Acquire skills and learn techniques to maintain work-life balance and manage work stress, motivation, job satisfaction, job involvement

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B. Tech. in Chemical Engineering are as follows.

The Graduates of Chemical Engineering from MUJ will have:

PO.1 A thorough knowledge of the basic science, engineering and mathematics and apply that to the underline practice of Chemical Engineering

PO.2 Ability to apply these basic principles to solve real world problems in a broad range of career paths

PO.3 The skills of making smart decisions on process feasibility based in technical and economic evaluation

PO.4 The ability to appreciate the social, ethical, cultural, environmental and safety issues related to chemical engineering profession

PO.5 The ability to develop experimental procedure/protocol to test hypothesis and analysis meaningful interpretation of the generated data

PO.6 The skill to generate sustainable engineering solutions to societal and industrial problems

PO.7 Proficiency to use computational tools for problem solving

PO.8 The ability to communicate effectively (technical and non-technical context) in written and oral form
PO.9 Skills to work effectively and professionally in multi-disciplinary groups
PO.10 The ability to work effectively and professionally on projects both independently and as a part of a group/team
PO.11 The ability to be self-learners and lifelong learners
PO.12 The motivation to develop and lead entrepreneurial projects for societal benefit

Degree Specific Outcomes for Chemical Engineering are as follows:

PSO.1 The graduates will possess a working knowledge of fundamental principles such as basic chemistry, material and energy balances, physical and chemical equilibria, transport and rate processes, separation processes, chemical process control, reaction engineering
POS.2 The graduates will be able to design sustainable chemical processes including techno-economic feasibility of the process
PSO.3 The graduates will minor in either Petroleum Engineering or Energy and Environment depending on their choice of interest
PSO.4 The graduates will have an aptitude for learning new innovative technologies in chemical and allied fields of chemical engineering or peruse advanced studies

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	In class Quizzes and Assignments , Activity feedbacks (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Students who misses a class will have to report to the teacher about the absence. A makeup assignment on the topic taught on the day of absence will be given which has to be submitted within a week from the date of absence. No extensions will be given on this. The attendance for that particular day of absence will be marked blank, so that the student is not accounted for absence. These assignments are limited to a maximum of 5 throughout the entire semester.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS

Introduction to Industrial & Organizational Psychology (I/O): Nature, scope and methods of study; Challenges for I/O psychology, problems for I/O psychologists; Human engineering. **Employee Selection and recruitment:** Principles and techniques. **Training & development:** Principles and techniques. **Job Performance Evaluation and Appraisal:** Meaning and nature, techniques. **Working conditions:** Physical working conditions, Work Schedules; Accidents and safety in work place. **Motivation and Work:** Theories of motivation, job satisfaction, job involvement. **Work stress and management:** Nature and meaning, sources, individual differences, consequences of job stress; Stress management techniques.

F. TEXT BOOKS

- Schultz, S.E & Schultz, D.P., Psychology and Work Today: An introduction to Industrial and Organisational Psychology. Pearson, 2014.
- Landy, F.L. & Conte, J.M.2nd Edition, Work in the 21st Century: An Introduction to Industrial and Organizational Psychology**.** Wiley India Private Limited,2009.

G. REFERENCE BOOKS

- Blum, M.L. & Naylor, J.C., Industrial psychology: Its theoretical and social foundations. New Delhi: CBS Publishers & Distributors, 2002.
- Riggio, R.R., Introduction to Industrial and Organizational Psychology. Routledge
- APA Handbook of industrial and organizational psychology-volumes: I, II& III, New York: American Psychological Association, 2011.

H. Lecture Plan:

Lec No.	Topics	Session Objective	Mode of Delivery	Corresponding CO	Mode of Assessing the Outcome
1	Introduction and Course Hand-out briefing	To acquaint and clear teachers expectations and understand student expectations	Lecture		NA
2	Introduction to Industrial & Organizational Psychology (I/O)	Define industrial psychology and its goals	Lecture	PS1601.1	Written test, First Sessional and end Sem Exam
4-5	Nature, scope and methods of study	understand various research method used in industrial psychology and scope of the field	Lecture	PS1601.1	
6	Challenges for I/O psychology, problems for I/O	Discuss challenges and problems of an Industrial Psychologist	Lecture	PS1601.1	Class test, First Sessional and end Sem Exam

	psychologists; Human engineering.				
7-8	Employee Selection and recruitment: Principles and techniques.	Understand the principles and process of employee selection	Lecture	PS1601.2	Class test, First Sessional and end Sem Exam
9-10	psychological testing and assessment for employee selection & Job analysis	Explain role of psychological test in employee selection	Lecture	PS1601.2	Class test, First Sessional and end Sem Exam
11	Test of Unit I and Unit II	Nature, scope, goals, methods of industrial psychology. Principles and practices in employee selection and recruitment.			Class test, First Sessional and end Sem Exam
12	Meaning and need of training in an organization	Discuss the importance training and development in an organization	Lecture	PS1601.3	Class test, First Sessional and end Sem Exam
13-15	Steps of Training design	Design and execute a training and development programme	Experiential learning based on group activity	PS1601.3	First Sessional and end Sem Exam
16	Techniques for Training	Apply various techniques of training as part of group task/activity	Group activity	PS1601.3	Class test, First Sessional and end Sem Exam
17	Evaluation of Training Program	Critically evaluate the importance and implications of training programme	Lecture	PS1601.3	Class test, First Sessional and end Sem Exam
18	Case Study				
19-21	Meaning and importance of Job performance evaluation	Discuss the importance and implications of Job performance evaluation	Lecture	PS1601.4	Class test, Second Sessional and end Sem Exam
22-23	Sources of Job performance evaluation	Identify sources of Job Performance evaluation	Lecture	PS1601.4	Class test, Second Sessional and end Sem Exam

24-25	Appraisal rating systems and non-rating evaluation methods	Differentiate between rating and non-rating evaluation methods	Lecture	PS1601.4	Class test, Second Sessional and end Sem Exam
26	Case study				
27	Meaning of working condition	Discuss the major physical conditions that affects the employee health	Lecture	PS1601.5	Class test, Second Sessional and end Sem Exam
28	Concept and types of Work Schedules	Explain how work schedules can affect employee health and well-being.	Lecture	PS1601.5	Class test, Second Sessional and end Sem Exam
29-30	Occupational Health and Safety	Describe the causes of accident and steps that can be taken to prevent them.	Lecture	PS1601.5	Class test, Second Sessional and end Sem Exam
31	Meaning of motivation and factor effecting motivation of employee	Discuss the term motivation and its factor effecting motivation of employee	Flipped classroom	PS1601.6	Home Assignments, Second Sessional and end Sem Exam
32-33	Theories of motivation	Discuss various theory of motivation	Lecture	PS1601.6	Class test, Second Sessional and end Sem Exam
34-35	Job satisfaction and job involvement	Understand the concept of job satisfaction and its relationship with employee growth	Lecture	PS1601.6	Class test Second Sessional and end Sem Exam
36-37	Nature and meaning of stress.	Discuss and describe work related stress and its consequences.	Lecture	PS1601.7	Class test Second Sessional and end Sem Exam
38-40	Consequences of job stress; Stress management techniques	Learn skills and strategies to manage work related stress and maintain work-life balance.	Lecture	PS1601.7	Class test Second Sessional and end Sem Exam
41	Case study				

I. Course Articulation Matrix: (Mapping of COs with POs and PSOs)

CO	Statement	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES			
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
[PS1601.1]	Explain the nature, scope and methods of Industrial Psychology			2													
[PS1601.2]	Comprehend principles and techniques of employee Selection and recruitment	1		2													
[PS1601.3]	Acquire Skills required for conducting effective training and development in industrial setup																
[PS1601.4]	Understand the process of Job Performance Evaluation and Appraisal			2								1					
[PS1601.5]	Evaluate the implications of Physical working conditions, Work Schedules, Accidents and safety in work place						3										
[PS1601.6]	Critically evaluate and apply the theories of motivation, job satisfaction, job involvement												3				
[PS1601.7]	Acquire skills and learn techniques to maintain work-life balance and manage work stress		2						1								

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Petroleum Refining Technology| CE 1653 | 3 Credits | 3 0 0 3

Session: Feb 21 – May 21 | Faculty: Dr. Anand G. Chakinala | Class: Elective course

A. Introduction: Petroleum refining technology is a program elective course offered by chemical engineering department targeting students who wish to acquire enough background to pursue his/her specific area of interest in detail. This course presents the basic concepts of petroleum refining technology in a systematic manner and make the students appreciate the major refining processes. It trains the student to make complete material and energy balances around the major refinery units.

B. Course Outcomes: At the end of the course, students will be able to

[1654.1]. Describe major refinery operations and its significance

[1654.2]. Interpret and illustrate the effect of operating parameters on performance of refinery operations

[1654.3]. Perform material and energy balances around the major refinery units

[1654.4]. Recognize and calculate the properties and specifications of crude and petroleum products

[1654.5]. Assess the importance of safety and pollution considerations in refineries which enhances additional skills required for the employability

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	In class Quizzes and Assignments , Activity feedbacks (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	No make-up for missed quizzes/assignments shall be allowed except in emergency situations with prior permission of the instructor.	
Homework/ Home Assignment/ Quiz (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded. Un-announced quizzes will be part of the lecture/tutorial.	

E. SYLLABUS

Petroleum resources, petroleum industry in India. Composition and classification of petroleum crude, ASTM, TBP and FEV distillation. Refinery flowsheet-overview, Properties and specifications of petroleum products – LPG, Gasoline, naphtha, kerosene, diesel oil,

lubricating oil, wax etc. Crude distillation-Atmospheric and Vacuum, Design and operation of topping and vacuum distillation units. Tube still furnaces. Solvent extraction processes for lubricating oil base stocks and for aromatics from naphtha and kerosene, solvent dewaxing. Thermal and catalytic cracking, vis-breaking and coking processes, reforming, hydro processing, alkylation, polymerization and isomerization, Utilities-Hydrogen production, Product blending, Sulphur recovery. Economics, Safety and pollution considerations in refineries.

F. TEXT BOOKS

1) J.H. Gary, G.E. Handwerk and M.J. Kaiser, Petroleum Refining – Technology and Economics, 5th ed., CRC Press, New York, 2007

G. REFERENCE BOOKS

1) Nelson, W. L., Petroleum Refinery Engineering, 4th ed., McGraw Hill, 1987
2) Rao, B.K.B., Modern Petroleum Refining Processes, Oxford, IBH, 2008
3) Watkins, R.N. Petroleum Refinery Distillation, 2nd ed., Gulf Publishing, Houston, TX, 1979
4) API Petroleum Refining Handbook, 1989
5) R.J. Hengstebeck, Petroleum Processing, Mc Graw Hill, New York
6) J.G Speight, The Chemistry and Technology of Petroleum, 3rd ed., Marcel-Dekker, 1999

Lecture Plan:

LEC NO	TOPICS	Session Outcome	Mode of Delivery	Corresponding Course Outcome	Mode of Assessing the Outcome
1	Introduction to conventional crude oil resources, oil wells, world-wide oil distribution, oil usage	*Basic introduction about the crude production and its distribution across the globe*	Lecture	CO 1	NA
2	*Refinery process flowsheet* – Major operations	*To acquaint with overall refinery processes and to To estimate the properties*	*Lecture*	CO 1, CO 2	NA
3	*Refinery products* - Physical and Chemical properties		*Lecture*	CO 1, CO 2	NA
4	*Refinery feedstocks* - Crude oil properties and crude oil classification		*Lecture*	CO 1, CO 2	NA
5	*Crude distillation* – TBP and gravity mid percent curves		*Lecture + Problem solving*	CO 2, CO 3, CO 4	*Assignment-1*
6	*Crude distillation* – Property prediction and its hierarchy		*Lecture + Problem solving*	CO 2, CO 3, CO 4	NA
7-8	*Crude distillation* – Atmospheric and Vacuum distillation, Typical boiling range cut fractions		*Lecture*	CO 2, CO 3	NA

9	*Coking* – Types, Properties and uses of petroleum coke	*To familiarize with the processes (Coking and thermal processes) for upgrading the heavier crudes (Bottom of the barrel)*	*Lecture*	CO 2, CO 3, CO 4	*Assignment-2*
10,11	*Coking* – Delayed coking, Flexi coking and Fluid coking		*Lecture*	CO 2, CO 3	NA
12	*Coking* – Material balance delayed coker		*Lecture + Problem solving*	CO 3	*1st Sessional ET Exam*
13,14	*Fluid Catalytic Cracking* – Process, New designs of FCC-Regenerator system		*Lecture + Problem solving*	CO 2, CO 3	NA
15-17	*Fluid Catalytic Cracking* – Cracking reactions, Process variables, Yield estimation, Case-study		*Lecture + Problem solving*	CO 2, CO 3, CO 4	*Assignment-3*
18, 19	*Catalytic Reforming and Isomerization* – Process, Reactions, Reactor design	*To know the processes involved in refining for enhancing the yield of lighter products (gasoline) as well as minimizing the environmental concerns (S)*	*Lecture + Problem solving*	CO 2, CO 3, CO 4	NA
20	*Catalytic Reforming and Isomerization* – Isomerization Yields, Capital and Operating costs, case study		*Lecture + Problem solving*		*Assignment - 4*
21, 22	*Hydrotreating* – Process Variables, Reactions and material balance Case study		*Lecture + Problem solving*		*Assignment - 5*
23	*Catalytic Hydrocracking* – Process, Process Variables		*Lecture*		NA
24	*Catalytic Hydrocracking* – Hydrocracking yields, Material balance case study		*Lecture + Problem solving*		*Assignment – 6* *2nd Sessional ET Exam*
25, 26	*Alkylation and Polymerization* – Feedstocks, Types of Process, Comparison of processes	*To understand the importance of alkylation & polymerization processing in refining*	*Lecture*	CO 2, CO 3, CO 4	NA
27, 28	*Alkylation and Polymerization* –Process variables, Reactions, Yields		*Lecture*		NA
29	*Supporting processes* – Hydrogen production, Gas processing	*To know other supporting processes involved in the production of hydrocarbon fuels but serve in supporting roles.*	*Lecture*	CO 2 CO 3	NA
30	*Supporting processes* – Acid gas removal, Sulfur recovery processes		*Lecture*		NA
31, 32	*Product Blending* – Blending for Octane number, Blending for	*To have an idea of blending intermediate streams to produce a*	*Lecture*	CO 4	NA

	Reid Vapour Pressure, Blending for other properties	*variety of onspec products maximizing the profits while increasing operating flexibility*			
33	*Product Blending* – Case studies		*Lecture*		NA
34	*Lubricating oil blending stocks* – Propane deasphalting	*To have an understanding of how lubes are produced in refinery operations.*	*Lecture*	CO 4	NA
35	*Lubricating oil blending stocks* – Viscosity index improvement and solvent extraction		*Lecture*		NA
36	*Lubricating oil blending stocks* – Dewaxing		*Lecture*		NA
37,38	Economic Evaluation in refineries	*To have the knowledge of estimating profitability criterion of a proposed investment and evaluate alternatives*	*Lecture*	CO 4	NA
39,40	Safety and Pollution considerations in refineries		*Lecture*	CO 5	NA

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CE 1651.1	Describe major refinery operations and its significance	2	2		1				2	3		2		1		3
CE 1651.2	Interpret and illustrate the effect of operating parameters on performance of refinery operations	2	2		1			2	1	1				2		3
CE 1651.3	Perform material and energy balances around the major refinery units	2	2				2							2		3
CE 1651.4	Recognize and calculate the properties and specifications of crude and petroleum products	2	2											2		3
CE 1651.5	Assess the importance of safety and pollution considerations in refineries	2	2		3		2		2	3		2		3		3

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Environmental Systems Engineering | CE 1654 | 3 Credits | 3 0 0 3

Session: February 21 – June 21 | Faculty: Dr. Harsh Pandey | Class: VI Semester

A. COURSE SUMMARY: This course is designed to bring together and integrate in a single text the more general subject matter of the three principal areas of environmental engineering-air, water and solid-waste management. In this course, students will be introduced with a unique approach to the overall concept of environmental engineering, an approach that emphasizes the relationship between the principles observed in natural purification processes and those employed in engineered processes.

B. COURSE OUTCOMES: By the end of the course, students will be able to

[1654.1]. Develop skills to define, analyse and quantify the environmental quality in describing physical, chemical, mathematical and biological principles.

[1654.2]. Understand the processes by which the environment assimilates waste material/pollution from human activities and industries.

[1654.3]. Have a clear understanding of engineering principles and practices involved in the design and operation of conventional environmental engineering works.

[1654.4]. Develop skills to acquire the fundamental knowledge of different treatment technologies to curb environmental pollution-air, water and solid-wastes.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Graduate attributes in the B.Tech. Course in Chemical Engineering include:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.
PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
Program Specific Outcomes for chemical engineering are as follows:
[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open/Closed Book)	20
	Sessional Exam II (Open/Closed Book)	20
	Quizzes, Assignments and Mini-projects (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of **75% Attendance** is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Homework/ Home & Class Assignment (Formative)	Home works will be assigned in between the lectures along with the due date for handing it over. No late assignments handed after the due date shall be accepted under any circumstances. Assignments will also be given during lecture hours. Students will be given open-ended problems/case-studies as a part of assignments. It is expected that the students shall work on the assignments independently and not 'copy' the solutions from each other. Students are encouraged to discuss problems with their instructor in lecture hours. Students are advised to meet the instructor in case of any difficulty related to assignments and course related matters.	

E. SYLLABUS:

Air Pollution- fundamentals and standards, effects, origins, fate of pollutants, greenhouse effect, acid rain, ozone, dispersion of pollutants, control of stationary and mobile sources.

Solid Wastes- sources, management, processing, and disposal, Waste to Energy

Hazardous Wastes- definition & classification, sources, management, The resource conservation and recovery act (RCRA), the federal hazardous and solid waste amendments (HSWA), the comprehensive environmental response, compensation, and liability act (CERCLA) and the superfund amendments and reauthorization act (SARA)- What are these? Treatment technologies and disposal.

Water Pollution- water chemistry and water quality, water quality standards, treatment systems: coagulation and flocculation; sedimentation and filtration; disinfection, adsorption; membrane processes, Wastewater Characteristics- water quality, constituents, biochemical oxygen demand, dissolved oxygen sag curve, Analysis and Selection of Wastewater Flowrates and Constituents Loadings, standards, onsite, preliminary, primary, secondary and tertiary treatments, Treatment techniques – Physical unit operations; biological processes; chemical unit processes; sludge and biosolids treatment reuse and disposal. **Water Reuse**

F. TEXT BOOKS:

T1. Davis and Cornwell, Introduction to Environmental Engineering, 5th edition, McGraw-Hill, 2014.

T2. Metcalf and Eddy, Wastewater Engineering: Treatment and Reuse, 4th edition, McGraw-Hill, 2002.

G. REFERENCE BOOKS:

R1. Masters, Gilbert. M., Ela, Wendell. P., *Introduction to Environmental Engineering and Science*, Pearson Education, Inc., 2015.

R2. Peavy, H. S., Rowe, D. R., Tchobanoglous, G., *Environmental Engineering*, McGraw Hill, 2013.

R3. Bhatia, S.C., *Environmental Pollution and Control in Chemical Process Industries*, Khanna Publishers, Delhi, 2001.

R4. Perkins, Henry. C., *Air Pollution*, McGraw Hill, 1974.

H. LECTURE PLAN:

Lectures	Content	Session Outcome	Mode of Delivery	CO tracking	Assessment
1-2	Introduction to Environmental System Engineering.	Basic understanding of Environmental acts and rules	Lecture and interaction	1654.1	In Class Quiz
3-4	Air Pollution – fundamentals and standards	Define, analyse and quantify the environmental quality in describing physical, chemical, mathematical and biological principles. Acquire the fundamental knowledge of different treatment technologies to curb environmental pollution-air, water and solid-wastes	Lecture and interaction	1654.1 1654.2 1654.3 1654.4	
5-6	Air Pollution –effects, origins, fate of pollutants		Lecture and interaction		
7-8	Air Pollution – greenhouse effect, acid rain, ozone		Lecture and interaction		
9-10	Air Pollution – dispersion of pollutants		Lecture and interaction		1st Sessional

					Home Assignment
11-13	Air Pollution – control of stationary and mobile sources		Lecture and interaction		1st Sessional ET Exam
14-15	Solid Wastes – sources, management	Understand the processes by which the environment assimilates waste material/pollution from human activities and industries	Lecture and interaction	1654.1 1654.2	Home Assignment
16-18	Solid Wastes – processing, and disposal		Lecture and interaction		
First sessional exam					
19	Waste to Energy		Lecture and interaction		
20	Hazardous Wastes– definition & classification, sources, management		Lecture and interaction		
21	RCRA, HSWA, CERCLA and SARA- What are these?		Lecture and interaction		
22-24	Hazardous Wastes– treatment technologies and disposal		Lecture and interaction		I1 Sessional Home Assignment
25	Water Pollution – water chemistry and water quality	Acquire the fundamental knowledge of different treatment technologies to curb environmental pollution-air, water and solid-wastes	Lecture and interaction	1654.1 1654.2 1654.3 1654.4	
26	Water Pollution – water quality standards, treatment systems		Lecture and interaction		
27	Water Pollution – treatment system: coagulation and flocculation		Lecture and interaction		
28-29	Water Pollution – treatment system: sedimentation and filtration		Lecture and interaction		
30-32	Water Pollution – treatment system: disinfection, adsorption		Lecture and interaction		II Sessional ET Exam Home Assignment

33	Water Pollution – treatment system: membrane processes		Lecture and interaction		
34	Wastewater Characteristics- water quality, constituents		Lecture and interaction		
35	Wastewater – biochemical oxygen demand		Lecture and interaction		II Sessional
	Wastewater – dissolved oxygen sag curve		Lecture and interaction		ET Exam Home Assignment
Second sessional exam					
36-37	Analysis and Selection of Wastewater Flowrates and Constituents Loadings	Have a clear understanding of engineering principles and practices involved in the design and operation of conventional environmental engineering works.	Lecture and interaction	1654.3	
38	Wastewater – standards, onsite, preliminary, primary, secondary and tertiary treatments				ET Exam Home Assignment
39-45	Wastewater treatment techniques – biological processes (selected)		Lecture and interaction	1654.3 1654.4	
46-48	Wastewater treatment techniques – chemical unit processes (selected)		Lecture and interaction	1654.3 1654.4	
49-50	Wastewater – sludge and biosolids treatment reuse and disposal		Lecture and interaction	1654.3 1654.4	ET Exam Home Assignment
End Term exams					

I. COURSE ARTICULATION MATRIX (Mapping of COs with POs):

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE 1654.1	Define, analyse and quantify the environmental quality in describing physical, chemical, mathematical and biological principles	3	3	0	2	1	3	3	3	0	0	2	0	1	1	3
CE 1654.2	Understand the processes by which the environment assimilates waste material/pollution from human activities and industries	2	2	0	0	0	2	2	2	0	0	1	0	2	1	0
CE 1654.3	Have a clear understanding of engineering principles and practices involved in the design and operation of conventional environmental engineering works	3	3	2	3	2	2	3	3	2	0	3	0	3	2	3
CE 1654.4	Acquire the fundamental knowledge of different treatment technologies to curb environmental pollution-air, water and solid-wastes	2	2	2	3	2	2	3	3	2	0	2	1	2	1	3

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Lab Hand-out (Transport Phenomena -II)

Heat Transfer Operation Lab | CE 1631/CE 2230 | 2 Credits | 0 0 4 2

Session: Jan 21 – May 21 | Faculty: Nandana Chakinala | Class: Laboratory

A. Introduction: This Transport Phenomena Lab – II is related to Heat Transfer Operations that is designed for the undergraduate students of Chemical Engineering. This lab introduces the experiments related to different Heat Transfer mode of operations such as conduction, convection and radiation that are earlier covered in the theory course.

B. Course Outcomes: At the end of the course, students will be able to

[2230.1]. To have a deep understanding of the fundamentals of heat transfer operations and its real life applications

[2230.2]. Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning

[2230.3]. Perform experimental investigations on different heat transfer equipment's and gain competency in performing and analysing the data.

[2230.4]. Assess the results obtained to that approximated by theories reported in literature

[2230.5]. Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment

C. Program outcomes and program specific outcomes

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

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[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Conducting experiments and report	Viva & Safety	15
	Soft copy of reports + Excel calculations	5
	Pre-lab and Post Lab reports	50
End Term Exam	End Term Exam (Open Book)	30
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Labs	No make-up labs will be conducted in case of absence during the labs except in extenuating circumstances, with the prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Pre & Post Lab reports	Pre & Post lab reports must be submitted before the specified due date for handing it over. No late submissions after the due date shall be accepted under any circumstance. It is expected that the students shall work on the experiments independently and analyse their results on their own without 'copying' the solutions from each other.	

E. List of Experiments & their objectives

Sl. No.	Experimental set-up	Objective
34.	Thermal conductivity of liquids	To determine thermal conductivity of liquids and to gain insights related to thermal conductivity measurement techniques
35.	Heat transfer in agitated vessel under unsteady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation and to develop insights in determining heating/cooling time
36.	Heat transfer in agitated vessel under steady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation at different flowrates and to study the effect of agitation speed on heat transfer coefficient
37.	Shell and tube heat transfer coefficient	To determine overall heat transfer coefficient and understand the significance of LMTD. Evaluate model parameters and study the effect of change in flow rate on U and h_i.

38.	Plate type heat exchanger	To determine overall heat transfer coefficient and understand the significance of LMTD. Evaluate model parameters and get introduced to compact heat exchangers.
39.	Cross flow heat exchanger	To study the heat transfer rate and to determine the overall heat transfer coefficient and understand the significance of LMTD at different flow rates.
40.	Heat transfer in fluidized bed	To determine the overall heat transfer coefficient and to study the relationship between heat transfer coefficient and porosity
41.	Single effect evaporator	To study the material and energy balances and to estimate the overall heat transfer coefficient, economy and capacity of evaporator
42.	Two phase heat transfer unit	To plot the heat flux & temperature difference between metal and liquid and determine the boiling regime
43.	Drop wise and film wise condensation	To determine the heat transfer coefficient of two types drop wise and film wise of condensation
44.	Unsteady state heat transfer unit	To determining heat transfer coefficient and to calculate Biot number, Fourier number
45.	Vertical and horizontal condenser	To determine the overall heat transfer coefficient and film coefficient for vertical and horizontal condenser
46.	Stefan Boltzmann set-up	To determine Stefan Boltzmann constant and study the effect of hemisphere temperature on it

F. Text books

5) Perry's Chemical Engineering Handbook

6) D.Q. Kern, Process Heat Transfer, Mc Graw Hill, 1997.

7) W.L. McCabe, J.C. Smith, P. Harriot, Unit operations of Chemical engineering, 7th edition, Mc Graw Hill.

8) A.S. Foust, L.A. Wenzel, C.W. Clump, L. Maus, L.B. Andersen, Principles of Unit Operations, 2nd edition, Wiley India.

Experiment Plan:

LEC NO	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1	Thermal conductivity of liquids	To determine thermal conductivity of liquids and to gain insights related to thermal conductivity measurement techniques	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
2	Heat transfer in agitated vessel under unsteady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation and to develop insights in determining heating/cooling time	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
3	Heat transfer in agitated vessel under steady state	To determine the coil side overall heat transfer coefficient for constant speeds of agitation at different flowrates and to study the effect of agitation speed on heat transfer coefficient	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
4	Shell and tube heat transfer coefficient	To determine overall heat transfer coefficient and understand the significance	Lab	CO1631.1; CO1631.2;	Report + Viva +End

		of LMTD. Evaluate model parameters and study the effect of change in flow rate on U and h_i.		CO1631.3; CO1631.4; CO1631.5;	sem lab exam
5	Plate type heat exchanger	To determine overall heat transfer coefficient and understand the significance of LMTD. Evaluate model parameters and get introduced to compact heat exchangers.	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
6	Cross flow heat exchanger	To study the heat transfer rate and to determine the overall heat transfer coefficient and understand the significance of LMTD at different flow rates.	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
7	Heat transfer in fluidized bed	To determine the overall heat transfer coefficient and to study the relationship between heat transfer coefficient and porosity	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
8	Single effect evaporator	To study the material and energy balances and to estimate the overall heat transfer coefficient, economy and capacity of evaporator	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
9	Two phase heat transfer unit	To plot the heat flux & temperature difference between metal and liquid and findout the boiling regime	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
10	Drop wise and film wise condensation	To determine the heat transfer coefficient of two types drop wise and film wise of condensation	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
11	Unsteady state heat transfer unit	To determining heat transfer coefficient and to calculate Biot number, Fourier number	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
12	Vertical and horizontal condenser	To determine the overall heat transfer coefficient and film coefficient for vertical and horizontal condenser	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam
13	Stefan Boltzmann set-up	To determine Stefan Boltzmann constant and study the effect of hemisphere temperature on it	Lab	CO1631.1; CO1631.2; CO1631.3; CO1631.4; CO1631.5;	Report + Viva +End sem lab exam

G. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
[2230.1].	To have a deep understanding of the fundamentals of heat transfer operations and its real life applications	2	1	1	1	1								3		
[2230.2].	Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning			1			1		2	3			1	3		
[2230.3].	Perform experimental investigations on different heat transfer equipment's and gain competency in performing and analysing the data		2	2	3	1			2		1			3		
[2230.4].	Assess the results obtained to that approximated by theories reported in literature			2	3	1			2		2			3		
[2230.5].	Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment				3	1		1	2	1	1		1	3		

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Process Plant Design | CE 1705 | 3 Credits | 3 0 0 3

Session: Aug – Dec 2020 | Faculty: Nandana Chakinala | Class: VII Semester

A. Introduction: This course on Process Plant Design is a core course designed for the undergraduate students of chemical engineering. This course provides the student an insight into various aspects of process design by coupling chemical engineering principles to the principles of economics. It covers in detail the preliminary process synthesis, developing base case design and use of heuristics for choosing the best from various process alternatives.

B. Course Outcomes: At the end of the course, students will be able to

[CE1705.1] Understand concepts of process design and economics.

[CE1705.2] Analyse, synthesize and design processes for manufacturing products commercially.

[CE1705.3] Develop skills in designing equipment optimally based on economics and process considerations.

[CE1705.4] Use excel/ commercial flow sheeting software (if available) to perform material, energy balance of complete process flowsheet and design major equipment for enhancing employability in industries/consultancy firms.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.
The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. 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.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1 Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

POS.2 Process Intensification: graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3 Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	In class Quizzes, Assignments & Project	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	No make-up for missed quizzes/assignments shall be allowed except in emergency situations with prior permission of the instructor.	
Home and Class Assignments and Project (Formative)	Home and Class assignments are integral part of this course. Mainly design oriented problems will be assigned along with the due date for handing it over. Projects shall be assigned at the beginning of the semester. Students are expected to work in groups. A detail project report and viva voce are part of the grading process for Mini project	

E. SYLLABUS

Process Design and Development- The hierarchy of chemical process design, General design considerations, the nature of process synthesis & analysis, engineering economics, economic decision making

Developing a conceptual design and finding the best flowsheet- input information: batch vs continuous input-output structure flowsheet, recycle structure of flowsheet, separation system, heat exchanger networks, cost diagram and quick screening of process alternatives

Plant Design- Process design development and general design considerations

Process Economics- Economic feasibility of project using order-of-magnitude cost estimates, plant and equipment cost estimation, product cost estimation

Design Tools and Application- preliminary process optimization, Application of Aspen Plus in different processes.

F. TEXT BOOKS

T1 James M. Douglas, "Conceptual Design of Chemical Processes", McGraw Hill, New York, International Edition (1988).

T2 Robin Smith, "Chemical Process Design", International Editions, McGraw Hill, Singapore (2000).

T3 Max S. Peters, Klaus D. Timmerhaus and Ronald E. West, "Plant Design and Economics for Chemical Engineers", McGraw Hill India, 5th Edition, (2011).

G. REFERENCE BOOKS

R1 Warren D. Seider, J. D. Seader, and Daniel R. Lewin, "Product & Process Design Principles: Synthesis, Analysis, and Evaluation", Wiley-India Edition, India, 2nd Edition (2004).

R2 Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz, and Debangsu Bhattacharyya, "Analysis, Synthesis, and Design of Chemical Processes", International Edition, Pearson Education International, New Jersey (2012).

R3 Dale F. Rudd, and Charles C. Watson, "Strategy of Process Engineering", John Wiley & Sons, New York (1968).

H. TUTORIALS

Short quizzes will be conducted during lecture hour. No late-comers will be allowed to take the quiz, MAKE SURE YOU ARE ON TIME! No make-up for missed short quizzes will be allowed. Problem discussion and solution shall also be a part of the tutorials.

I. HOME/CLASS ASSIGNMENTS AND PROJECT

Home assignment is an integral part of this course. No late assignments/projects handed after the due date shall be accepted under any circumstance. It is expected that the students shall work on the assignments independently and not 'copy' the solutions from each other.

Conceptual design oriented problem/case study will be given as mini project. Students need to make use of Excel/ Aspen Plus (if available)/ HYSYS (if available) to generate the process flow diagram and design the major equipments in the process flow sheet. Students need to submit a project report detailing the study carried out, by the last instruction day.

J. NOTICES

All notices concerning this course will be mailed to students. Students are responsible for regularly checking their group email ID.

K. LECTURE PLAN

Lecture No.	Topics to be covered	Session Outcome	Mode of Delivery	Corresponding CO	Mode of Assessing CO
1-2	Introduction to Process Design Decisions: Process Synthesis and Analysis.	To acquaint basic knowledge of synthesis and analysis	Lecture	1705.1	Quiz
3-5	Nature of Process Synthesis and Analysis: Creative aspects, Hierarchical approach to conceptual design, HDA Process. Preliminary Process Synthesis with examples.	To acquaint the basic steps of designing a process with few case studies	Lecture	1705.1	Quiz, Mid Term I, End Term
6-8	Conceptual Design of Chemical Processes: Flowsheet synthesis, Design aspects of Batch vs. Continuous, input/output structure of flowsheet, recycle structure of flowsheet	To perform material balances required in synthesizing a process flow sheet	Lecture	1705.2	Mid Term I, Quiz, End Term
9-11	Flowsheet Synthesis	Hands on calculation for synthesizing a process flow sheet	Tutorial	1705.2	Mid Term I, Assignment, End Term, Mini project

12-14	Basic principles of reactor design, Reactor non ideality, residence time distributions, types of reactors and selection criteria	To assess the reactor performance using design equations	Flipped Class	1705.3	Mid term I, Assignment and End term
15-16	Reactor design and cost estimation	Hands on calculations for reactor design	Tutorial	1705.3	Mid term I, Assignment and End term, Mini Project
17	Application of excel/commercial flow sheeting software (if available) for process design	To generate process flow diagram in excel/ commercial flow sheeting software (if available)	Flipped Classroom & Activity	1705.4	Mini Project
18-20	Introduction, types of separations, criteria for selection of separation processes	To acquaint the basic knowledge of industrial separation processes	Lecture & Flipped Class	1705.1	Quiz
21-24	Design of Separation processes: Guidelines, design of distillation columns, energy integration of distillation columns, Tutorials on design of absorption column and distillation columns	To perform design calculations of the conventional separation units	Lecture & Tutorial	1705.3	Mid Term II, Quiz and Assignment, End Term, Mini Project
25-29	Process Heat integration: Concepts and basic principles of heat integration, Identification of area and cost targets, Pinch technology for heat exchanger network design	To synthesize the maximum energy recovery design of a given process	Lecture & Case study	1705.3	Mid Term II, Assignment & End term
30-33	Economic Decision making: Case study of gas absorber	To apply the concepts of process design in a case study & design absorber-stripper flowsheet	Lecture & case study	1705.2	Mid Term II & End Term
34-36	Cost Diagram & quick screening of process alternatives: General concepts and principles, Lumped cost diagram and cost allocation diagram, Case study of HDA	To acquaint the basic knowledge of process economics concepts	Lecture	1705.1	Quiz & End Term
36-38	Chemical Project economics: Selection of project site, project cost estimation, cost model and depreciation, time value of	To investigate the profitability of a chemical project	Lecture & Tutorial	1705.1	Assignment, Project & End term

	money, measures of profitability, project evaluation, tutorial				

L. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE 1705.1	Understand concepts of process design and economics	3	3	3	2	2	3	2					2	3	3	1
CE 1705.2	Analyse, synthesise and design processes for manufacturing products commercially	3	3	3	2	1	2	3		2	2	2	2	3	3	2
CE 1705.3	Develop skills in designing equipment optimally based on economics and process considerations	2	2	2	2	2	2	3		2	2	2	2	3	3	2
CE 1705.4	Use excel/ commercial flow sheeting software(if available) to perform material, energy balance of complete process flowsheet and design major equipment for enhancing employability in industries/consultancy firms.	1	2	1	1	1	2	3			2	2		3	3	3

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Hand-out
Chemical Process Industries | CE 1706 | 3 Credits | 3 0 0 3
Session: Aug-Dec, 2020 | Faculty: Dr. Harsh Pandey | Class: Core Course

A. **Introduction:** This course is offered by Dept. of Chemical Engineering as a core course. This course will cover the manufacturing of various chemicals and industrial gases related to chemical industry, which is an integral part of chemical sciences and engineering. Every chemical engineer should have knowledge on this content. It mainly covers the synthesis, industrial manufacture, process flow diagrams, properties and uses of various chemicals and industrial gases.

B. **Course Outcomes:** At the end of the course, students will be able to

[CE1706.1]. Identify different types of chemical process industries classified as inorganic, organic and natural product industries and their applications.

[CE 1706.2]. Recall various unit operation techniques and their use to synthesize a particular chemical.

[CE 1706.3]. Understand the process flow diagram and various process parameters for the manufacture of various inorganic, organic and natural chemicals.

[CE 1706.4]. Recognize and solve engineering problems during production, while also developing entrepreneurship skills along relevant lines.

[CE 1706.5]. Interpret and illustrate the material balance involved in process synthesis.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.

The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. **Assessment Plan:**

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Close Book)	20
	Sessional Exam II (Close Book)	20
	In class Quizzes, Assignments, Presentation and Mini project	30
End Term Exam (Summative)	End Term Exam (Close Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Student who misses a class will have to report to the teacher about the absence. A makeup assignment on the topic taught on the day of absence will be given which has to be submitted within a week from the date of absence. No extensions will be given on this. The attendance for that particular day of absence will be marked blank, so that the student is not accounted for absence. These assignments are limited to a maximum of 5 throughout the entire semester.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS

Overview of typical chemical processes, unit operations and unit processes, Indian chemical process industries scenario. Study aspects of chemical process industries - raw materials, consumption pattern, chemical reactions, process and block flow diagram, applications and major engineering issues. Uses of industries for Water conditioning and environmental protection.

F. TEXT BOOKS

T1. "*Dryden's Outlines of Chemical Technology – for the 21st Century (3rd Edition)*", M Gopala Rao and Marshall Sitting, East-West Press, New Delhi (India), 1997.

T2. "*Shreve's Chemical Process Industries (5th Edition)*", George T Austin, Tata McGraw-Hill Companies Inc, New York, 2012.

G. REFERENCE BOOKS

R1. *"Unit processes in organic synthesis (5th ed)*", Groggins P H, Mcgraw-Hill, 2004.

H. Lecture Plan:

Lecture	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
1	**Introduction to chemical industries – Facts and figures**	Introduction to chemical industries.	Lecture	1706.1	Mid Term I, Assignment & End Term
2	**Unit operations and unit process concepts**	Introduce concepts of UOPs.	Lecture	1706.2	Mid Term I, Assignment & End Term
3, 4, 5, 6	**Sulfur and Sulfuric acid**	Mining of sulfur, Manufacture of sulfuric acid by contact and DCDA process, its applications, Engineering problems	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term I, Assignment & End Term
7, 8, 9, 10, 11	**Fuels and Industrial gases**	Gases like producer gas, water gas, coke oven gas, natural gas, synthesis gas, hydrogen and acetylene. Different types of gasifiers	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term I, Assignment & End Term
12, 13, 14, 15, 16, 17	**Fertilizer Industry**	Overview of fertilizer, major components of fertilizers. Nitrogen fertilizers – ammonia, nitric acid, urea, ammonium nitrate. Phosphate fertilizers – phosphoric acid, single and triple superphosphate, ammonium phosphate	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term II, Assignment & End Term
18,19	**Cement Industry**	History and overview, scenario in India Portland cement and quick lime	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term II, Assignment & End Term
20, 21	**Chlor-alkali industry**	Manufacturing of soda ash, caustic soda and chlorine by methods of production	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term II, Assignment & End Term
22, 23	**Pulp and Paper Industry**	Kraft process and paper making process	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term II, Assignment & End Term
24, 25, 26, 27, 28, 29,	**SYNTHETIC ORGANIC**	Few selected chemicals from C1, C2, C3 and C4 compounds (***power point presentations by students***)	Student In-Class Presentations	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term II, Assignment

30, 31, 32, 33	**CHEMICAL INDUSTRIES**				& End Term
34	**Pyrolysis and Cracking**	Pyrolysis and Cracking	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	Mid Term II, Assignment & End Term
35, 36	**Carbohydrates and fermentation industries**	Manufacturing of sugar or sucrose, ethanol production by fermentation	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	End Term
37, 38	**Edible and essential oils**	Extraction of vegetable oils, hydrogenation of oils	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	End Term
39, 40, 41, 42	**Soaps, Detergents and Glycerine**	Manufacturing of soaps, detergents and glycerine	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	End Term
43, 44	**Water conditioning and environmental protection**	Water conditioning and environmental protection	Lecture	1706.1, 1706.2, 1706.3, 1706.4, 1706.5	End Term

I. COURSE ARTICULATION MATRIX (Matching COs with POs):

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE1706.1	Identify different types of chemical process industries classified as inorganic, organic and natural product industries and their applications	2	3			2			2	1	1	1		1	1	1
CE1706.2	Recall various unit operation techniques and their use to synthesize a particular chemical	3	2	1		1		2	2	2		3		1	2	1
CE1706.3	Understand the process flow diagram and various process parameters for the manufacture of various inorganic, organic and natural chemicals	3	3			3		2	3	2	1	2		3	3	2
CE1706.4	Recognize and solve engineering problems during production, while also developing entrepreneurship skills along relevant lines.	3	2			2		2	1	1		2		2	3	2
CE1706.5	Interpret and illustrate the material balance involved in process synthesis	3	3	1					2			2		3	2	1

1- Low Correlation, 2- Moderate Correlation, 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR
School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Handout
Process Dynamic and Control | CE1707 | 4 Credits | 3 0 2 4
Session: Jul'20 – Dec'20 | Faculty: Dr. Manisha Sharma | Class: B. Tech. (Chemical)
VII Semester

A. INTRODUCTION

This course is offered by Department of Chemical Engineering as a core course. This course introduces the behavior and control of dynamic chemical process systems. Subject covers modeling the static and dynamic behavior of processes; control strategies; design of feedback, feedforward, and other control structures; and applications to process equipment.

B. COURSE OUTCOMES

At the end of the course, students will be able to:

[CE1707.1] Demonstrate the fundamentals of process dynamics and control

[CE1707.2] Develop skills to identify, formulate, and solve linear chemical process dynamics problems

[CE1707.3] Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.

[CE1707.4] Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

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Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

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PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open / Closed Book)	20
	Sessional Exam II (Open / Closed Book)	20
	Quizzes and Home Assignments / Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open / Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Assignments (Formative)	Assignments are an integral part of the course. Home assignments / Class assignments will be provided from time to time. No late submissions will be entertained. It is expected that the students will work on the assignments independently. If any assignment is found copied from any source, marks will be deducted for the same.	
Make up Assignments	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture(s). You may contact the course coordinator for clarification of doubts, if any.	

E. SYLLABUS

Introduction to process control, Laplace transforms. Linear Open-Loop Systems, First-Order Systems: Transfer function, transient response (step response, impulse response, and sinusoidal response), and response of first-order systems in series: non-interacting systems and interacting systems. Second-Order Systems: Transfer function, step response, impulse response, sinusoidal response, transportation lag. Linear Closed-Loop Systems. Control system: Components of a control system, block diagram, negative feedback and positive feedback, servo problem and

regulator problem. Controller and final control element: Mechanism of control valve and controller, transfer functions (P, PI, PD, PID), Example of a chemical-reactor control system.

F. TEXT BOOKS

T1. Coughnowr, D. R., Process System Analysis and Control, 3rd ed., McGraw Hill Inc, 2013.

G. REFERENCE BOOKS

R1. Stephanopoulos, G., Chemical Process Control: An Introduction to Theory & Practice, Prentice -Hall of India Pvt. Ltd., New Delhi, 1993.

R2. Mellichamp, D. A., Seborg, D., and Edgar, T.F., Process Dynamics and Control, John Wiley and Sons, 2010.

H. LECTURE PLAN

Lecture No.	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
1.	Introductory concepts	Demonstrate the fundamentals of process dynamics and control	Lecture	CE1707.1	Assignment / quiz / Mid Term I
2.	Introductory concepts	Demonstrate the fundamentals of process dynamics and control	Lecture	CE1707.1	Assignment / quiz / Mid Term I
3.	The Laplace Transforms	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
4.	The Laplace Transforms	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
5.	The Laplace Transforms	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
6.	Inversion by partial fractions	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
7.	Inversion by partial fractions	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
8.	Inversion by partial fractions	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
9.	Properties of Transforms	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
10.	Properties of Transforms	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
11.	Properties of Transforms	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I

12.	Linear open loop systems: Response of first order systems	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
13.	Linear open loop systems: Response of first order systems	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
14.	Linear open loop systems: Response of first order systems	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
15.	Linear open loop systems: Response of first order systems	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
16.	Physical examples of first order system	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
17.	Physical examples of first order system	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term I
18.	Response of first order systems in series.	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term II
19.	Response of first order systems in series.	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term II
20.	Higher order systems: Second order and Transportation lag	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term II
21.	Higher order systems: Second order and Transportation lag	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term II
22.	Higher order systems: Second order and Transportation lag	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term II
23.	Higher order systems: Second order and Transportation lag	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term II
24.	Higher order systems: Second order and Transportation lag	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.1 CE1707.2	Assignment / quiz / Mid Term II
25.	Linear Closed Loop Systems: The Control Systems	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
26.	Linear Closed Loop Systems: The Control Systems	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II

27.	Linear Closed Loop Systems: The Control Systems	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
28.	Linear Closed Loop Systems: Controllers and final control elements	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
29.	Linear Closed Loop Systems: Controllers and final control elements	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
30.	Linear Closed Loop Systems: Controllers and final control elements	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
31.	Block diagram of a Chemical Reactor Control System	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
32.	Block diagram of a Chemical Reactor Control System	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
33.	Block diagram of a Chemical Reactor Control System	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
34.	Closed loop transfer functions	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
35.	Closed loop transfer functions	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
36.	Transient response of Simple Control Systems	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
37.	Transient response of Simple Control Systems	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
38.	Transient response of Simple Control Systems	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
39.	Transient response of Simple Control Systems	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / Mid Term II
40.	Stability	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / End Term
41.	Stability	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / End Term
42.	Root Locus	Design a analyze a feedback control schemes for a given	Lecture	CE1707.2 CE1707.3	Assignment / quiz / End Term

		process and analyze stability of transfer functions.			
43.	Root Locus	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / End Term
44.	Root Locus	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions.	Lecture	CE1707.2 CE1707.3	Assignment / quiz / End Term
45.	Frequency Response	Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems	Lecture	CE1707.4	Assignment / quiz / End Term
46.	Frequency Response	Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems	Lecture	CE1707.4	Assignment / quiz / End Term
47.	Frequency Response	Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems	Lecture	CE1707.4	Assignment / quiz / End Term
48.	Frequency Response	Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems	Lecture	CE1707.4	Assignment / quiz / End Term
49.	Frequency Response	Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems	Lecture	CE1707.4	Assignment / quiz / End Term
50.	Frequency Response	Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems	Lecture	CE1707.4	Assignment / quiz / End Term

I. COURSE ARTICULATION MATRIX: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[CE1707.1]	Demonstrate the fundamentals of process dynamics and control	2														
[CE1707.2]	Develop skills to identify, formulate, and solve linear chemical process dynamics problems	3	2	1									1	2		
[CE1707.3]	Design a analyze a feedback control schemes for a given process and analyze stability of transfer functions	3	2	2	1		1			1			1	3		
[CE1707.4]	Develop skills to design PID controllers and conduct the frequency analysis of closed loop systems	3		2	1	3	1	1		1				3		

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

A. Introduction: The business of business is making money – regardless of area and scale!

Economic evaluation of investment alternatives that maximize profits is a major goal of any corporate manager – or, even an individual. This requires familiarity with economic evaluation and investment decision methods to provide a sound quantitative basis to scrutinize choose the best among alternative engineering projects and general investment opportunities.

Economic feasibility is a pre-requisite for investing in any engineering or non-engineering investment opportunity.

Project Management

Managing projects for on – time completion is very necessary to avoid cost – overruns. Network techniques, such as CPM / PERT / others, are used to aid in planning, scheduling, monitoring and control of activities that are related to each other, and required, for completion of any project (engineering and non-engineering).

Hence, the methods discussed in this course are equally valid for use by

- Engineers
- Business Managers
- Bankers
- Accountants
- Individuals
- Others

B. Course Outcomes: At the end of the course, students will be able to:

CE1708.1 Present and discuss the 'Economic Evaluation' fundamentals and Project Management techniques (Gantt Chart / Networks (CPM / PERT / Others).
CE1708.2 'Arm' the student with the methodology to evaluate project investment alternatives.
CE1708.3 Develop the employability skills to manage projects and identify bottlenecks for better scheduling and control.
CE1708.4 Develop employment / entrepreneurship skills for economic evaluation and investment decision methods / project management techniques.

C. Program Outcomes

Graduate attributes in the B.Tech. Course in Chemical Engineering include:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.
PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6. 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.
PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10. 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.
PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Closed Book)	20
	Sessional Exam II (Closed Book)	20
	Quizzes and Home/Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture. However, you may contact the course coordinator for clarification of doubts, if any.	

E. Syllabus

Cash Flow Concepts, Present Future and Annual Values, Net Present Value, Present value Ratio, Rate of Return, Breakeven, Depreciation and taxes, Project Definition, Project network, scheduling resource and cost, Managing project risk, Project progress, performance measurement, and evaluation.

F. Text Books

T1. "Economic Evaluation and Investment Decision Methods (14th Edition)", Franklin J Stermole and Johm M Stermole, Investment Evaluation Corporation, Golden,CO (USA), 2014.

T2. "Operations Research: An Introduction", Hamdy A Taha, Prentice Hall, 1997.

G. Reference Books

R1. Peters M. S., Timmerhaus K. D., and West R. E., Plant Design and Economics for Chemical Engineers, McGraw Hill Higher Education, 5th Edition, 2003.

H. Lecture Plan:

Lecture No.	Topics	Session Outcome	Mode of Delivery	Corresponding Course Outcome	Mode of Assessing the Outcome
41.	Introduction – Making Decisions / Concept of Interest / Minimum Rate of Return / Investment Analysis (1-13)	Understanding the basics of subject that why are they studying this in engineering.	Lecture	1708.1	Mid Term I End Term
42.	Compound Interest Formulae and Equivalence Applications (15-41)	Understanding the interest scenario in industries.	Lecture	1708.1	Mid Term I End Term
43.	Compound Interest Formulae and Equivalent Applications (42-52)	Understanding the interest scenario in industries.	Lecture	1708.1	Mid Term I End Term
44.	Present Worth / Annual Worth / Future Worth / ROR / Break-Even Analysis (64-91)	Relating the time with money	Lecture	1708.2/4	Mid Term I End Term
45.	Present Worth / Annual Worth / Future Worth / ROR / Break-Even Analysis (91-120)	Relating the time with money	Lecture	1708.2/4	Mid Term I End Term
46.	Present Worth / Annual Worth / Future Worth / ROR / Break-Even Analysis (120-157)	Relating the time with money	Lecture	1708.2/4	Mid Term I End Term
47.	Incremental Cost Analysis Methods – Mutually Exclusive Investment Analysis by ROR / Unequal Life Projects / NPV / Future Worth of Cash Flows (183-200)	Understanding how to compare the positive ROR alternative with the negative or infinite ROR alternative.	Lecture	1708.2/4	Mid Term I End Term
48.	Incremental Cost Analysis Methods – Mutually Exclusive Investment Analysis by ROR / Unequal Life Projects / NPV / Future	Understanding how to compare the positive ROR alternative with the negative or infinite ROR alternative.	Lecture	1708.2/4	Mid Term I End Term

	Worth of Cash Flows (201-220)				
49.	Incremental Cost Analysis Methods – Mutually Exclusive Investment Analysis by ROR / Unequal Life Projects / NPV / Future Worth of Cash Flows (220- 256)	Understanding how to compare the positive ROR alternative with the negative or infinite ROR alternative.	Lecture	1708.2/4	Mid Term I End Term
50.	Incremental Cost Analysis Methods – Mutually Exclusive Investment Analysis by ROR / Unequal Life Projects / NPV / Future Worth of Cash Flows (Handout)	Understanding how to compare the positive ROR alternative with the negative or infinite ROR alternative.	Lecture	1708.2/4	Mid Term I End Term
51.	Production Cost Variations / Break-Even Analysis / Min Cost/Max Profit Analysis (64 + Handout)	Understanding the concept of variable cost and fixed cost.	Lecture	1708.2/4	Mid Term I End Term
52.	Production Cost Variations / Break-Even Analysis / Min Cost/Max Profit Analysis (Handout)	Understanding the concept of variable cost and fixed cost	Lecture	1708.2/4	Mid Term I End Term
53.	Sensitivity Analysis / Inflation / Risk Analysis (276-306)	Understanding the sensitivity of the parameters relating to production and marketing.	Lecture	1708.2/4	Mid Term I End Term
54.	Sensitivity Analysis / Inflation / Risk Analysis (313-327)	Understanding the sensitivity of the parameters relating to production and marketing.	Lecture	1708.2/4	Mid Term I End Term
55.	Sensitivity Analysis / Inflation / Risk Analysis (327-351)	Understanding the sensitivity of the parameters relating to production and marketing.	Lecture	1708.2/4	Mid Term I End Term
56.	Review Lecture	Reviewing all the syllabus that has been completed.	Lecture		Mid Term I End Term
MID-TERM I					
57.	Depreciation / Depletion / Amortization (359-366)	Understand the concept of decreasing value of tangible/non tangible things.	Lecture	1708.2	Mid Term II End Term
58.	Depreciation / Depletion / Amortization (366-384)	Understand the concept of decreasing value of	Lecture	1708.2	Mid Term II

		tangible/non tangible things.			End Term
59.	Depreciation / Depletion / Amortization (384-403)	Understand the concept of decreasing value of tangible/non tangible things.	Lecture	1708.2	Mid Term II End Term
60.	Income Tax, Cash Flow, and Discounted Cash Flow Rate of Return (415-435)	Understanding what to include or exclude from the income to save income tax.	Lecture	1708.2/4	Mid Term II End Term
61.	Income Tax, Cash Flow, and Discounted Cash Flow Rate of Return (435-470)	Understanding what to include or exclude from the income to save income tax.	Lecture	1708.2/4	Mid Term II End Term
62.	After-Tax Investment Decision Methods and Applications (487-521)	Understand how to estimate the after tax or actual ROR.	Lecture	1708.2/4	Mid Term II End Term
63.	After-Tax Investment Decision Methods and Applications (521-548)	Understand how to estimate the after tax or actual ROR.	Lecture	1708.2/4	Mid Term II End Term
64.	Replacement Analysis (567-593)	Understand the alternatives of replacing the machinery or other things.	Lecture	1708.2/4	Mid Term II End Term
65.	Replacement Analysis (594-605)	Understand the alternatives of replacing the machinery or other things.	Lecture	1708.2/4	Mid Term II End Term
66.	Leverage Concepts: Evaluations Involving Borrowed Money (616-639)	Compare the alternatives of taking leverage of paying at one go.	Lecture	1708.2/4	Mid Term II End Term
67.	Leverage Concepts: Evaluations Involving Borrowed Money (639-647)	Compare the alternatives of taking leverage of paying at one go.	Lecture	1708.2/4	Mid Term II End Term
68.	Review Lecture	Reviewing all the syllabus that has been completed after Mid Term I.	Lecture		Mid Term II End Term
MID-TERM II					
69.	Introduction to Project Management and Control	Understand the necessity to study project management in chemical engineering.	Lecture	1708.1/3	End Term

70.	Gantt Chart	Understanding how to schedule the project	Lecture	1708.1/3	End Term
71.	Introduction to Networks – Terminology (Handout)	Understanding how to distinguish critical and non critical activities.	Lecture	1708.1/3	End Term
72.	Critical Path Method (CPM) (278-288 + Handout)	Understand how to evaluate the critical path which will not to be violated.	Lecture	1708.1/3	End Term
73.	Project Evaluation and Review Technique (PERT) (288-290 + Handout)	If the project is working on probabilistic timeline than understanding how to evaluate the probability that project will complete in the pre described time.	Lecture	1708.1/3	End Term
74.	PERT (Handout)	If the project is working on probabilistic timeline than understanding how to evaluate the probability that project will complete in the pre described time.	Lecture	1708.1/3	End Term
75.	Other Topics in Networks – Shortest Route Problem	If the project is working on probabilistic timeline than understanding how to evaluate the probability that project will complete in the pre described time.	Lecture	1708.1/3	End Term
76.	Review	Reviewing all the syllabus that has been completed.	Lecture		End Term
END-TERM EXAMINATION					

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE1708.1	Present and discuss the 'Economic Evaluation' fundamentals and Project Management techniques (Gantt Chart / Networks (CPM / PERT / Others).		1		1				1	1	2	3		1	2	
CE1708.2	'Arm' the student with the methodology to evaluate project investment alternatives.		2	1	1				2	1	2	3		1	2	
CE1708.3	Develop the employability skills to manage projects and identify bottlenecks for better scheduling and control.		2	1	1				2	1	2	3		1	2	
CE1708.4	Develop employment / entrepreneurship skills for economic evaluation and investment decision methods / project management techniques.		2	1	1				2	1	2	3		1	2	

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Energy and Process Integration | CE1754 | 3 Credits | 3 0 0 3

Session: July 20 – Dec 20 | Faculty: Dr. Anees Y. Khan | Class: Programme Elective

A. Introduction:

"Together we all win". Integration is the process of keeping 'all together' in an optimized way. Chemical process needs to be integrated in an optimized way so that the whole process requires minimum energy as well as the cost. Therefore, we have to familiar with the fundamental concepts related to process integration, pinch technology, heat exchanger network and energy targeting. These are the mostly talked (hot topics) terms used by a chemical industry because chemical industries are very energy intensive process.

Hence, the contents discussed in this course will be very useful for a chemical engineer working in process & plant design as well as research & development. Basically, it will be an excellent subject to learn for a core engineer.

B. Course Outcomes:

At the end of the course, students will be able to

[CE1754.1]. Understand the fundamentals of process integration and pinch technology.

[CE 1754.2]. Do pinch analysis for heat exchanger networks and mass exchanger networks.

[CE 1754.3]. Identify the energy target, unit target, area target, cost target and super-targeting for a heat exchanger network (HEN).

[CE 1754.4]. Recognize maximum energy recovery (MER) network using pinch design method (PDM).

[CE 1754.5]. Conduct the process optimization of energy and resource analysis using network evolution and evaluation.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.

The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open Book)	20
	Sessional Exam II (Open Book)	20
	In class Quizzes and Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Open Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Assignments (Formative)	Students who misses a class will have to report to the teacher about the absence. A makeup assignment on the topic taught on the day of absence will be given which has to be submitted within a week from the date of absence. No extensions will be given on this. The attendance for that particular day of absence will be marked blank, so that the student is not accounted for absence. These assignments are limited to a maximum of 5 throughout the entire semester.	
Homework/ Home Assignment/ Activity Assignment (Formative)	There are situations where a student may have to work in home, especially before a flipped classroom. Although these works are not graded with marks. However, a student is expected to participate and perform these assignments with full zeal since the activity/ flipped classroom participation by a student will be assessed and marks will be awarded.	

E. SYLLABUS

Introduction – Energy Targeting and the Pinch Principle, Problem Table, Cascade Diagram, Composite / Grand Composite Curves, Pinch Point, Utility Pinch; Maximum Energy Recovery Network – Pinch Design Method, Grid\Diagram, Stream Splitting / Matching; Evolution / Evaluation of Networks – Euler's Principle, Identification and Breaking of Loops Using Paths; Capital Cost targeting, Continuous Targeting – Area / Cost Targeting, Vertical Heat Transfer, Threshold Problem, Super targeting; Distillation Column Targeting Principles, Grand Column Composite Curves, Column Composite Curves, Evaluation of Energy Saving Options; Introduction to Heat and Power Systems.

F. TEXT BOOKS

T1. Shenoy, U.V., *Heat exchanger network synthesis: Process optimization by energy and resource analysis*, Gulf publishing, 1995.

G. REFERENCE BOOKS

R1. Douglas, James. M., *Conceptual design of chemical processes*, McGraw-Hill Inc, 1988.

R2. Seider, W. D., Seader, J. D., Lewin, D. R., Widagdo, S., *Product and process design principles: synthesis, analysis and evaluation (3rd Ed)*, John Wiley & Sons, Singapore, 2010.

R3. Kemp, I. C., *Pinch analysis and process integration: A user guide on process integration for the efficient use of energy*, Butterworth Heinemann, 2006.

R4. Klemes, J. J., Varbanov, P. S., Alwi S. R. W. W., and Manan, Z. A., *Process Integration and Intensification: Saving Energy, Water and Resources*, De Gruyter, 2014.

H. Lecture Plan:

LEC NO	TOPICS	Session outcome	Mode of delivery	Corresponding CO	Mode of assessing CO
1	Introduction and course hand-out briefing	Acquainted with basics of Energy and Process Integration	Lecture	1754.1	Mid Term I, Quiz/Assignment/Project & End Term
2	Process integration, methods and area of application, history and few examples from nature	Acquainted with basics of Energy and Process Integration	Lecture	1754.1	Mid Term I, Quiz/Assignment/Project & End Term
3	Fundamentals concepts related to heat integration (process design hierarchy, onion diagram), energy losses by various industries, The role of thermodynamics in process design	Acquainted with basics of Energy and Process Integration	Lecture	1754.1	Mid Term I, Quiz/Assignment/Project & End Term
4	Key concepts of process integration and pinch analysis and its significance, Composite curves (basic concepts of heat exchange and temp–enthalpy diagram)	Understanding the fundamentals of Energy Exchange in processes	Lecture	1754.2	Process Mid Term I, Quiz/Assignment/Project & End Term
5	Hot and cold composite curves and their allowability of shifting vertically/horizontally	Understanding the fundamentals of Energy Exchange in processes	Lecture	1754.2	Process Mid Term I, Quiz/Assignment/Project & End Term
6	Network grid representation	Understanding the fundamentals of Energy Exchange in processes	Lecture	1754.2	Process Mid Term I, Quiz/Assignment/Project & End Term
7	Temperature intervals and heat cascade diagram	Understanding the fundamentals of Energy Exchange in processes	Lecture	1754.2	Process Mid Term I, Quiz/Assignment/Project & End Term
8, 9, 10	Energy targeting procedure (problem table algorithm, pinch point and minimum utility requirements)	Understanding the fundamentals of Energy Exchange in processes	Lecture	1754.2	Process Mid Term I, Quiz/Assignment/Project & End Term
11	Basic pinch design method (understanding the pinch design feasibility and important design criteria), maximum energy recovery (MER) network	Acquiring the Design knowledge of HEN in Process	Lecture	1754.3	Mid Term I, Quiz/Assignment/Project & End Term
12, 13, 14	Case study – MER network drawing (split and without split network), stream split algorithm	Acquiring the Design knowledge of HEN in Process	Lecture	1754.3	Mid Term I, Quiz/Assignment/Project & End Term

15, 16	Concept of balanced composite curves	Acquiring the Design knowledge of HEN in Process	Lecture	1754.3	Mid Term II, Quiz/Assignment/Project & End Term
17	Concept of grand composite curves and use of multiple utilities	Acquiring the Design knowledge of HEN in Process	Lecture	1754.3	Mid Term II, Quiz/Assignment/Project & End Term
18	Concept of vertical heat transfer and Spaghetti network	Acquiring the Design knowledge of HEN in Process	Lecture	1754.3	Mid Term II, Quiz/Assignment/Project & End Term
19	Case Study – number of units targeting	Acquiring the Design knowledge of HEN in Process	Lecture	1754.3	Mid Term II, Quiz/Assignment/Project & End Term
20	Euler's network and graph theory for number of units and loop finding. Concept of loops and paths.	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
21, 22	Identification of loops, elimination of loop	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
23	Checking ΔTmin violation and restoration by path relaxation	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
24, 25	Network evolution and evaluation and final MER design after path relaxation	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
26	Case Study – shell targeting	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
27	Case Study – cost targeting (operating cost, capital cost and total annual cost)	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
28	Effect of ΔTmin and supertargeting	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
29	Fundamentals of threshold problems and pseudo pinch problems	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
30	Case study – threshold problem	Grasping the basics of advanced HEN	Lecture	1754.4	Mid Term II, Quiz/Assignment/Project & End term
31	Continuous targeting and determination of significant curve shift	Developing the knowledge of solving HEN problems in Industries	Lecture	1754.5	Quiz/Assignment/Project & End Term
32	Case study – continuous determination of energy and unit targets	Developing the knowledge of solving HEN problems in Industries	Lecture	1754.5	Quiz/Assignment/Project & End Term
33	Topology trap	Developing the knowledge of solving HEN problems in Industries	Lecture	1754.5	Quiz/Assignment/Project & End Term
34	Fast matching algorithm for threshold problem	Developing the knowledge of solving HEN problems in Industries	Lecture	1754.5	Quiz/Assignment/Project & End Term

35	Retrofitting of final network	Developing the knowledge of solving HEN problems in Industries	Lecture	1754.5	Quiz/Assignment/Project & End Term
36	Multiple utilities and pinches (concept of HP, MP and LP steams)	Developing the knowledge of solving HEN problems in Industries	Lecture	1754.5	Quiz/Assignment/Project & End Term

I. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE1754.1	Understand the fundamentals of process integration and pinch technology	2	2	1			2	3	1		1			1	2	3
CE1754.2	Do pinch analysis for heat exchanger network and mass exchanger network	3	3	3	3		2	3	1	1	2		1	2	3	3
CE1754.3	Identify the energy target, unit target, area target, cost target and supertargeting for a heat exchanger network	3	3	3	3		1	3	1	1	2	2	1	3	3	3
CE1754.4	Recognize maximum energy recovery (MER) network using pinch design method	2	3	3	3		2	2			2	2	1	2	2	3
CE1754.5	Conduct the process optimization of energy and resource analysis using network evolution and evaluation	2	3	3	3		2	3		1	2	2	2	2	3	3

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Lab Hand-out (Transport Phenomena -III)

Mass Transfer Operation Lab | CE 1731 | 2 Credits | 0 0 4 2

Session: Jul 20 – Nov 20 | Faculty: Dr. Harsh Pandey | Class: Laboratory

A. Introduction: This Transport Phenomena Lab – III is related to Mass Transfer Operations that is designed for the undergraduate students of Chemical Engineering. This lab introduces the experiments related to different Mass Transfer operations which are earlier covered in the theory course.

B. Course Outcomes: At the end of the course, students will be able to

[CE1731.1] To have a deep understanding of the fundamentals of mass transfer operations and its real-life applications including employability skills
[CE1731.2] Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning
[CE1731.3] Perform experimental investigations on different mass transfer equipment and gain competency in performing and analysing the data.
[CE1731.4] Assess the results obtained to that approximated by theories reported in literature
[CE1731.5] Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment

C. Program outcomes and program specific outcomes

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.
PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6. 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.
PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.
PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Conducting experiments and report	Viva + Safety	10+5
	Soft copy of reports + Excel sheets	5
	Pre-lab and Post Lab reports	50
End Term Exam	End Term Exam (Open Book)	30
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Labs	No make-up labs will be conducted in case of absence during the labs except in extenuating circumstances, with the prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Pre & Post Lab reports	Pre & Post lab reports must be submitted before the specified due date for handing it over. No late submissions after the due date shall be accepted under any circumstance. It is expected that the students shall work on the experiments independently and analyse their results on their own without 'copying' the solutions from each other.	

E. List of Experiments & their objectives

Sl. No.	Experimental set-up	Objective
1.	Humidification in wetted wall column	To determine the gas film coefficient / overall mass transfer coefficient in a wetted wall column for air-water system.
2.	Sieve Plate Distillation column	To study the distillation in a sieve plate distillation column. Calculate theoretical number of plates, plate efficiency, perform material and energy balances, heat loss from column and analyze via McCabe-Thiele diagram.

3.	Packed Bed Distillation Column	To study the distillation in a packed bed distillation column. Calculate number of transfer units, perform material and energy balance, and calculate heat loss and HETP.
4.	Vapour-Liquid Equilibrium	To generate the vapour-liquid equilibrium data for various mixtures and test the data for thermodynamic consistency.
5.	Batch Crystallizer	To study the performance of a Batch Crystallizer. Determine the crystal yield and efficiency of crystallizer.
6.	Forced draft tray dryer	To study the drying characteristics of a solid under forced draft condition. To determine the rates of drying under different conditions of temperature and air flow. To calculate critical moisture content. To correlate the constant drying rate with air mass velocity.
7.	Mass transfer with and without chemical reaction	To calculate the mass transfer coefficient and enhancement factor. Expt: Dissolution of Benzoic acid in water. Expt: Dissolution of Benzoic acid with reaction in aqueous NaOH solution.
8.	Liquid-liquid extraction	To determine the equilibrium curve for the extraction of acetic acid from acetic acid-MIBK mixture using water as solvent, and to find extract and raffinate composition of the mixture.
9.	Absorption in wetted wall column	To determine the number of transfer units, height of transfer unit and overall mass transfer coefficient for CO_2 and NaOH system.

F. Text- / Reference- books:

9) D.W. Green Ed., Perry's Chemical Engineering Handbook, 9th Edition, Mc Graw Hill, 2018.

10) R.E. Treybal, Mass Transfer Operations, 3rd Edition, Mc Graw Hill, 2017.

11) W.L. McCabe, J.C. Smith, P. Harriot, Unit operations of Chemical engineering, 7th Edition, Mc Graw Hill, 2017.

12) A.S. Foust, L.A. Wenzel, C.W. Clump, L. Maus, L.B. Andersen, Principles of Unit Operations, 2nd Edition, Wiley India, 2008.

G. Experiment Plan:

Expt No.	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1	Humidification in wetted wall column	To determine the gas film coefficient / overall mass transfer coefficient in a wetted wall column for air-water system.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam
2	Sieve Plate Distillation column	To study the distillation in a sieve plate distillation column. Calculate theoretical number of plates, plate efficiency, perform material and energy balances, heat loss from column and analyze via McCabe-Thiele diagram.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam
3	Packed Bed Distillation Column	To study the distillation in a packed bed distillation column.	Lab	CO1731.1; CO1731.2;	Report + Viva +End

		Calculate number of transfer units, perform material and energy balance, and calculate heat loss and HETP.		CO1731.3; CO1731.4; CO1731.5;	sem lab exam
4	Vapour-Liquid Equilibrium	To generate the vapour-liquid equilibrium data for various mixtures and test the data for thermodynamic consistency.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam
5	Batch Crystallizer	To study the performance of a Batch Crystallizer. Determine the crystal yield and efficiency of crystallizer.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam
6	Forced draft tray dryer	To study the drying characteristics of a solid under forced draft condition. To determine the rates of drying under different conditions of temperature and air flow. To calculate critical moisture content. To correlate the constant drying rate with air mass velocity.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam
7	Mass transfer with and without chemical reaction	To calculate the mass transfer coefficient and enhancement factor. Expt: Dissolution of Benzoic acid in water. Expt: Dissolution of Benzoic acid with reaction in aqueous NaOH solution.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam
8	Liquid-liquid extraction	To determine the equilibrium curve for the extraction of acetic acid from acetic acid-MIBK mixture using water as solvent, and to find extract and raffinate composition of the mixture.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam
9	Absorption in wetted wall column	To determine the number of transfer units, height of transfer unit and overall mass transfer coefficient for CO2 and NaOH system.	Lab	CO1731.1; CO1731.2; CO1731.3; CO1731.4; CO1731.5;	Report + Viva +End sem lab exam

H. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE1731.1	To have a deep understanding of the fundamentals of mass transfer operations and its real life applications including employability skills	2	1	1	1	1								2		1
CE1731.2	Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning			1			1		2	3			1	1		1
CE1731.3	Perform experimental investigations on different mass transfer equipment's and gain competency in performing and analysing the data		2	2	3	1			2		1			2	1	1
CE1731.4	Assess the results obtained to that approximated by theories reported in literature			2	3	1			2		2			2	1	1
CE1731.5	Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment				3	1		1	2	1	1		1	2		2

I. Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Lab Hand-out

Chemical Reaction Engineering Lab | CE 1732 | 2 Credits | 0 0 4 2

Session: Aug 20 – Dec 20 | Faculty: Nandana Chakinala | Class: Laboratory

A. Introduction: This Chemical reaction Engineering lab focusses on the experiments related to chemical reaction engineering theory course, designed for undergraduate students of chemical engineering. Experiments shall be performed on ideal reactor configurations such as plug flow reactor, Continuous Stirred Tank Reactor (CSTR), batch reactor to study the kinetics of any reaction and Residence Time Distribution (RTD) studies.

B. Course Outcomes: At the end of the course, students will be able to

[CE1732.1] To have a deep understanding of the fundamentals of reaction engineering and its real life applications

[CE1732.2] Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning
[CE1732.3] Perform experimental investigations on different reaction engineering set up's and gain competency in performing and analysing the data.
[CE1732.4] Assess the results obtained to that approximated by theories reported in literature
[CE1732.5] Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment

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Program Outcomes for B.Tech. in chemical engineering are as follows.

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E. List of Experiments & their objectives

Sl. No.	Experimental set-up	Objective
47.	Plug Flow reactor	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in a plug flow reactor and to determine i) order of reaction ii) Rate constant k
48.	Series of CSTR's	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in series of three CSTRs and to evaluate the rate constant

49.	PFR and CSTR in series (Combination of reactors)	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in a series of PFR and CSTR and to draw performance chart for the reactor system and evaluate the rate constant
50.	Gas-Solid reaction	Study of non-catalytic gas solid reaction for combustion of dhoop stick and to record weight loss-time data and to find out suitable model for the reaction
51.	Characterization of an adsorbent/catalyst	Characterization of given sample of adsorbent/ catalyst and to determine its i)Bulk density ii)Pore volume iii)True density
52.	Trickle bed reactor	Study the hydrodynamic characteristics of trickle bed reactor and determine i) pressure drop ii) holdup.
53.	Photocatalytic reactor	Study the kinetics of photocatalytic degradation of dye and determine i) order of reaction ii) rate constant
54.	RTD in CSTR	Study of behavior of PFR by using pulse input of a tracer and determine i) mean residence time ii) Variance iii) Dispersion number and iv) Dispersion coefficient
55.	Batch reactor	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in a plug flow reactor and to determine i) order of reaction ii) Rate constant k and iii) Effect of temperature on k and determine activation energy
56.	RTD in PFR	Study of behavior of a CSTR in series by using pulse input of a tracer and determine i) Mean residence time ii) Variance iii) Dispersion number and iv) Dispersion coefficient

F. Text books

13) Octave Levenspiel, "Chemical Reaction Engineering", 3rd edition, John Wiley and Sons, 2007.

14) H. Scott Fogler, "Elements of chemical reaction engineering", 5th edition, Prentice hall international.

15) Perry's Chemical Engineering Handbook

16) J.M Smith, "Chemical Engineering Kinetics", Ms Graw Hill.

Experiment Plan:

LEC NO	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1	Plug Flow reactor	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in a plug flow reactor and to determine i) order of reaction ii) Rate constant k	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
2	Series of CSTR's	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in series of three CSTRs and to evaluate the rate constant	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
3	PFR and CSTR in series (Combination of reactors)	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in a series of PFR and CSTR and to draw performance chart for the reactor system and evaluate the rate constant	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;;	Report + Viva +End sem lab exam

4	Gas-Solid reaction	Study of non-catalytic gas solid reaction for combustion of dhoop stick and to record weight loss-time data and to find out suitable model for the reaction	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
5	Characterization of an adsorbent/catalyst	Characterization of given sample of adsorbent/ catalyst and to determine its i)Bulk density ii)Pore volume iii)True density	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
6	Trickle bed reactor	Study the hydrodynamic characteristics of trickle bed reactor and determine i) pressure drop ii) holdup.	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
7	Photocatalytic reactor	Study the kinetics of photocatalytic degradation of dye and determine i) order of reaction ii) rate constant	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
8	RTD in CSTR	Study of behavior of PFR by using pulse input of a tracer and determine i) mean residence time ii) Variance iii) Dispersion number and iv) Dispersion coefficient	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
9	Batch reactor	Study the kinetics of non-catalytic homogenous reaction between sodium hydroxide and ethyl acetate in a plug flow reactor and to determine i) order of reaction ii) Rate constant k and iii) Effect of temperature on k and determine activation energy	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam
10	RTD in PFR	Study of behavior of a CSTR in series by using pulse input of a tracer and determine i) Mean residence time ii) Variance iii) Dispersion number and iv) Dispersion coefficient	Lab	CO1732.1; CO1732.2; CO1732.3; CO1732.4; CO1732.5;	Report + Viva +End sem lab exam

G. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE1732.1	To have a deep understanding of the fundamentals of reaction engineering and its real life applications	2	1	1	1	1										
CE1732.2	Work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning			1			1		2	3			1			
CE1732.3	Perform experimental investigations on reaction engineering equipment's and gain competency in performing and analysing the data		2	2	3	1			2		1					
CE1732.4	Assess the results obtained to that approximated by theories reported in literature			2	3	1			2		2					
CE1732.5	Prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment				3	1		1	2	1	1		1			

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Course Hand-out

Industrial Training | CE 1781 | 2 Credits

Session: Aug – Dec 2020 | Faculty: Nandana Chakinala | Class: VII Semester

A. Introduction: The aim of the industrial training is to provide an exposure to 'real' working environment to help them prepare for their career. A student gains practical experience in his/her related field of engineering and can relate, apply the fundamentals learnt in theory courses at the institute. This industrial training is required for the partial fulfilment of the B. Tech. program in Chemical Engineering at Manipal University Jaipur. The training needs to be done after the completion of the third year when the student is expected to have knowledge about the basic chemical engineering subjects.

B. Course Outcomes: At the end of the course, students will be able to

[CE1781.1] Experience the real working environment and gain knowledge through hands-on observation.

[CE1781.2] Apply and integrate the classroom theory with workplace assignments

[CE1781.3] Interact with professionals and develop technical, communication skills both oral & written.

[CE1781.4] Write a technical report explaining the work and experience gained.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Program Outcomes for B.Tech. in chemical engineering are as follows.
The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. 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.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1 Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

POS.2 Process Intensification: graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3 Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. ASSESSMENT PLAN

The training is evaluated based on the following criteria:

- Seminar/Presentation 20%
- Report 50%
- Subject knowledge/Supervisor's feedback 30%

All the evaluation components will be evaluated by the course coordinator and the panel

Report must be submitted in the proper format. Date of submission shall be communicated in due course of time via email.

Tasks

1. Discuss with your supervisor at the industry regarding the project or assignment regularly.
2. Analyse the work environment.
3. Maintain a record of day-to-day activities performed at the industry and email it to the training coordinator.
4. Apply the concepts learnt to solve tasks assigned to you. In case if no task has been assigned, the student is expected to take up any problem statement (like material balance or energy balance or a review study) on his/her own.

Industrial training report

Students are required to submit neatly typed and bound training report. The report should contain information about working of the industry as also specific information of the work done by the student in the industry. The students are also required to attach the Certificate issued by the competent authority from the industry where he /she has undergone training mentioning the successful completion of the training. The industrial report is to be submitted within 15 days of commencement of the seventh semester in bound format and soft copy. The department will conduct presentation session for every student. An industrial training report should be well prepared and well documented in a professional manner. The template of the report shall be communicated to the students via email.

It should contain the following information:

- Length of training
- Preliminary information
- Technical report
- Conclusion (Should include the comments on the type and value of the experience gained and how it relates to your professional career)
- References

A copy of the report should be submitted to your supervisor at the industry (if required), another copy to the Department (through the course coordinator). Students should also retain a personal copy of the report.

Guidelines for Preparation of Industrial Training Report

Introduction

The purpose of the Industrial Training is to provide exposure for the students on practical engineering fields. The students will have better understanding of engineering practice (in general) and the problems frequently encountered. Since, this training is a part of the learning process, the knowledge and experience gained by the

student needs to be properly documented in the form of a report. A properly prepared report can facilitate the presentation of the practical experience in an orderly, precise and interesting manner.

Purpose of the Report

a) Put down in writing the record of the training experience i.e. personal performance reflection;

b) Implanting engineering expertise onto the students, that is, preparation of technical reports, communications, technical evaluation and design;

c) Train student in effective writing as a preparation for the Final Year Project.

Contents and Format of Report

The procedure for preparation of the report has to follow the format determined by the Faculty based on the guidelines below:

a) The report must be typewritten on white A4 size paper. Font-size of 12 points; Times New Roman must be used throughout the report, with line spacing of 1.5. The report must be properly bound with 'staple and tape binding'.

b) Front Cover Format Students are advised to use '310 gram Whiteart Card' in as the front cover.

c) Certificate From the industry/academic supervisor.

d) Acknowledgements

e) Abstract This section of the report should consist of brief description of the following:

i. Activities of the Organization

ii. Summary of the Report

f) Table of Contents This section of the report should consist of:

i. Titles

ii. Sub-titles

iii. Page numbers

iv. Every appendix must have a title and each page must be page numbered accordingly.

g) List of Figures All figures, and similar contents must be captioned and labeled. Every figure or table must be mentioned and discussed in the main text.

h) List of Tables All tables and similar contents must be captioned and labeled. Every figure or table must be mentioned and discussed in the main text.

i) Nomenclature If the report contains notations and symbols, the full definition must be given when each notation or symbol first appeared in the main text.

j) Background of Company/Organization Brief and concise description of the company/organization in which the student is undertaking the industrial training. The main items are:

i. History

ii. Structural organization of main activity

iii. Title and position of the officer in responsible

k) Summary of Duties This section should include the brief description of time, duration and types of duty carried out during the training. The description must follow the schedule of the training, that is, in chronological order. The days when the student is not on duty must be properly recorded with reasons given. Letter of permission must be attached in the appendix.

l) Working Experience In this section, the student must describe the experience gained according to titles considered appropriate. For example, the main items are: i. Projects carried out ii. Supervisory works iii. Problems encountered iv. Problems solved

m) Summary Student should provide an overall discussion in this section and arrive at a conclusion with regards to the industrial training undergone. Subjects that may be presented are: i. Types of experience gained ii. Problems iii. Views and recommendations

n) Technical Report

o) Conclusion

p) References Provided that there are important resources that are used as references while preparing the report, a complete list of the titles of references concern must be included.

Please follow a single style for all the references. All the references must be properly cited in the text.

q) Appendix Appendixes are additional information considered appropriate to support the main text. Suggested appendixes are:

i. Investigation/project report during the industrial training

ii. Technical drawings etc.

Every appendix must have a title and be mentioned in the main text where appropriate. All page numbers must for appendixes must be continual from the main text. DO NOT include irrelevant materials, e.g. brochures from the organizations, order forms, organization newsletters and similar materials.

E. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE 1781.1	Experience the real working environment and gain knowledge through hands-on observation	3	3	3	2	2	3	2					2	3	3	1
CE 1781.2	Integrate the classroom theory with workplace assignments	3	3	3	2	1	2	3		2	2	2	2	3	3	2
CE 1781.3	Interact with professionals and develop technical, communication skills both oral & written	2	2	2	2	2	2	3		2	2	2	2	3	3	2
CE 1781.4	Write a technical report explaining the work and experience gained	1	2	1	1	1	2	3			2	2		3	3	3

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Hand-out
Process Intensification | CE 1803/1801 | 3/4 Credits | 3/3 0/1 0/0 3/4
Session: February 21 – June 21| Faculty: Dr Gaurav Kataria| Class: VIII Semester

A. COURSE SUMMARY:

In the modern times, there has been a great focus on the optimal use of energy and cost to get better way of life. However, the chemical and process industry has a delayed response in incorporation of new technologies, because of the high risk involved. In the 1980's, Colin Ramshaw introduced to the world the idea of high gravity (HiGEE) based distillation and paved the way for what is today *Process Intensification*. This topic covers a wide range of unit operations and unit processes that have been reimagined to become highly optimized and efficient. The current course has been designed to introduce to the students the idea of process intensification and give them a feel of its application to unit operations and unit processes.

B. COURSE OUTCOME:

By the end of the course the students will be able to

CE1803.1 Describe the basic principles underlying process intensification.

CE1803.2 Describe with elaboration the design of different physical process intensification equipment.

CE1803.3 Assess the enhancement factors responsible for heat intensification in process industries and their applications.

CE1803.4 Develop skills to assess the design of intensified reactors for different types of reactions.

CE1803.5 Develop skills to assess the enhancement factors responsible for intensification of separation processes related to equipment design and application.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Graduate attributes in the B.Tech. Course in Chemical Engineering include:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.
PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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.

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

PSO.1. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.

PSO.2. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.

PSO.3. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Internal Assessment (Summative)	Sessional Exam I (Open/Closed Book)	20
	Sessional Exam II (Open/Closed Book)	20
	Quizzes and Home/Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100

Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.
Make up Assignments (Formative)	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture. However, you may contact the course coordinator for clarification of doubts, if any.

E. SYLLABUS:

Introduction to process intensification (PI): sustainability related issues in process industry; definitions of process intensification; fundamental principles and approaches of PI; design of a sustainable and inherent safer processing plants.

Mechanisms involved in PI: intensified heat transfer, intensified mass transfer, electrically enhanced processes, micro fluidics; compact and micro heat exchangers;

Reactors: Reactor engineering theory, spinning disc reactors, oscillatory baffled reactors, micro reactors, reactive separations, membrane reactors, supercritical operations, Field enhanced reactors, Rotating fluidized beds

Intensification and separation processes: Distillation (reactive, extractive), centrifuges, membranes, drying, precipitation and crystallization; Intensified mixers, PI case study.

F. TEXT BOOKS:

T1. Reay, D.A.; Ramshaw, C.; Harvey, A.P.; "*Process Intensification: engineering for efficiency, sustainability and flexibility*", 1ed, (IChemE) Butterworth Harriman, London, 2008.

T2. Stankiewicz, A.; Moulijn, J.A.; (Eds) "*Re-Engineering the Chemical Processing Plant: Process Intensification*," 1st ed., CRC Press, 2003.

G. REFERENCE BOOKS:

R1. Segovia-Hernandez, J.G.; Bonilla-Petriciolet, A.; (Eds) "*Process Intensification in Chemical Engineering Design Optimization and Control*", 1st ed., Springer, 2016.

R2. Keil, F.J.; (Ed) "*Modelling of Process Intensification*", 1st ed., Wiley International, 2007.

R3. Kiss, A.A; "*Process Intensification Technologies for Biodiesel Production*", 1st ed., Springer, 2014.

R4. Raghavan, K.V; Reddy, B.M.; (Eds) "*Industrial Catalysis and Separations Innovations for Process Intensification*", 1st ed, CRC Press/Apple Academic Press, 2015.

R5. Mothes, H.; "*Process Design Synthesis, Intensification and Integration of Chemical Processes*", 1st ed, Manufective, 2015.

H. LECTURE PLAN:

Lectures	Content	Session Outcome	Mode of Delivery	CO tracking	Assessment
1-3	Introduction to Process Intensification (PI)	Understand the basics and history of Process intensification, unit operation and unit processes, philosophy and opportunity of PI, classification of PI, sustainability of PI	Lecture	CE1803.1	Class Quiz
4-6	Physical methods for PI	Understand the use of Momentum transfer concepts Mixing and flow through packed bed, channel flow, and fluidization, static mixers, spinning disk, oscillatory baffled mixers in PI.	Lecture	CE1803.2 CE1803.5	Class Quiz, Case study essay, Mid Semester exams.
7-14	PI for heat transfer	Understand the use of Heat transfer operations, combined heat and fluid flow, intensification of heat flow, plate heat exchangers, spiral heat exchangers, plate and shell heat exchangers, plate fin heat exchangers, flat tube and fin heat exchangers, microchannel heat exchangers, Matrix heat exchangers, application of heat exchangers, nanofluids in PI.	Lecture	CE1803.2 CE1803.3 CE1803.5	Class quiz, Case study essay, mid semester exam and end semester exam
Mid Term I					
15-22	PI for separation processes	Understand the use of mass transfer concepts, nanofluids, divided walls columns, HiGee distillation, centrifuges, membranes, drying, crystallization, Soxhlet extraction, ultrasound mass transfer in PI.	Lecture	CE1803.5 CE1803.1	Class quiz, case study essay, mid and end semester exams
23-34	PI for reactions and reactors.	Understand the concept of mass transfer with chemical reactions, reactive distillation, reactive adsorption, reactive extraction, supercritical fluids, spinning reactors, ultrasound reactors, cavitation reactors, HEX reactors, Fluidized bed reactors, packed bed reactors, membrane reactors used to intensify the Processes in chemical engineering.	Lecture	CE1803.4 CE1803.5 CE1803.1	Class quiz, case study essay, mid and end semester exams
Mid Term II					
35-40	Application of PI	Follow the case studies of how PI can be applied for all different process industries.	Lecture	CE1803.2 CE 1803.3 CE1803.4 CE1803.5	Class quiz, case study essay, mid and end semester exams
End Term					

I. COURSE ARTICULATION MATRIX (Matching COs with POs):

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CE1803.1	Describe the basic principles underlying process intensification.	3	2			2			1	2		1		1	3	
CE1803.2	Describe with elaboration, design of different physical process intensification equipment.	1	2			1			1	2			1	1	3	
CE1803.3	Assess the enhancement factors responsible for heat intensification in process industries and their applications.	1	2			1			1	2			1		3	1
CE1803.4	Develop skills to assess the design of intensified reactors for different types of reactions.	1	2			1			1	2			1		3	1
CE1803.5	Develop skills to assess the enhancement factors responsible for intensification of separation processes related to equipment design and application.	1	2			1			1	2			1		3	1

1- Low Correlation, 2- Moderate Correlation, 3- High Correlation

MANIPAL UNIVERSITY JAIPUR
School of Civil and Chemical Engineering
Department of Chemical Engineering
Course Handout
Process Optimization | CE1804 | 3 Credits | 3 0 0 3
Session: Jan'21 – May'21 | Faculty: Dr. Manisha Sharma | Class: B. Tech. (Chemical)
VIII Semester

A. INTRODUCTION

Due to the increased cost of energy and stringent environmental regulations, the chemical industry has gone through several developments during the past few years. Optimization is one of the tools to address these issues. With an emphasis on problem formulation, this course introduces the students to the basic concepts of Optimization which has been applied in many fields of science, engineering, as well as business. The various techniques and tools used for optimization have also been discussed in this course.

B. COURSE OUTCOMES

At the end of the course, students will be able to:

[CE1506.14]	Develop a mathematical statement for the objective function and the equality and inequality constraints
[CE1506.15]	Implement the theory and applications of optimization techniques in a comprehensive manner for solving linear and non-linear, geometric, dynamic, integer and stochastic programming techniques
[CE1506.16]	Identify, formulate and solve a practical engineering problem of their interest by applying or modifying an optimization technique to enhance employability skills
[CE1506.17]	Use of commercial software to optimize chemical processes thereby enhancing their skills.

C. PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

The Graduates of Chemical Engineering from MUJ will have:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

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	Sessional Exam II (Closed Book)	20
	Quizzes and Home Assignments / Class Assignments (Accumulated and Averaged)	30
End Term Exam (Summative)	End Term Exam (Closed Book)	30
	Total	100
Attendance (Formative)	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Assignments (Formative)	Assignments are an integral part of the course. Home assignments / Class assignments will be provided from time to time. No late submissions will be entertained. It is expected that the students will work on the assignments independently. If any assignment is found copied from any source, marks will be deducted for the same.	
Make up Assignments	Students who miss a class will not be provided with any sort of makeup assignment or make up quiz. If you miss a lecture, you yourself have to study the topics that were covered during that particular lecture(s). You may contact the course coordinator for clarification of doubts, if any.	

E. SYLLABUS

Formulation of the objective function. Unconstrained single variable optimization: Newton, Quasi-Newton methods, polynomial approximation methods. Unconstrained multivariable optimization: Direct search method, conjugate search method, steepest descent method, conjugate gradient method, Newton's method. Linear Programming: Formulation of LP problem, graphical solution of LP problem, simplex method, duality in Linear Programming, two-phase method. Nonlinear programming with constraints: Necessary and sufficiency conditions for a local extremum, Quadratic programming, successive quadratic programming, Generalized reduced gradient (GRG) method. Use of MS-Excel and MATLAB for solving optimization problems. Introduction to global optimization techniques. Applications of optimization in Chemical Engineering.

F. TEXT BOOKS

T5. Edgar, T.F., Himmelblau, D. M., Ladson, L. S., Optimization of Chemical Process, 2nd ed., McGraw-Hill, 2001.

G. REFERENCE BOOKS

R12. Rao, S. S., Optimization Techniques, Wiley Eastern, New Delhi, 1985.

R13. Godfrey, C.O. and Babu, B.V., New Optimization Techniques in Engineering, Springer-Verlag, Germany, 2004.

R14. Beveridge, G. S. and Schechter, R. S., Optimization Theory and Practice, McGraw- Hill, New York, 1975.

R15. Reklaitis, G.V., Ravindran, A. and Ragsdell, K. M., Engineering Optimization-Methods and Applications, Wiley India Pvt Ltd., 2006.

H. LECTURE PLAN

Lecture No.	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode Of Assessing CO
98.	Introduction	Understand the nature and organization of optimization problems	Lecture	CE1804.1	Assignment / quiz / Mid Term I
99.	Problem formulation	Develop models for optimization	Lecture	CE1804.1	Assignment / quiz / Mid Term I
100.	Problem formulation	Formulate the objective function	Lecture	CE1804.1	Assignment / quiz / Mid Term I
101.	Optimization theory and methods	Learn the Basics concepts of Optimization	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
102.	Optimization theory and methods	Learn the Basics concepts of Optimization	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
103.	Optimization theory and methods	Learn the Basics concepts of Optimization	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
104.	Optimization theory and methods	To optimize unconstrained functions (one dimensional search)	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
105.	Optimization theory and methods	To optimize unconstrained functions (one dimensional search)	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I

106.	Optimization theory and methods	To optimize unconstrained Multivariable functions	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
107.	Optimization theory and methods	To optimize unconstrained Multivariable functions	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
108.	Optimization theory and methods	To optimize unconstrained Multivariable functions	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
109.	Optimization theory and methods	To optimize unconstrained Multivariable functions	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
110.	Optimization theory and methods	Understand the basics of Linear programming (LP) and its applications	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
111.	Optimization theory and methods	Understand the basics of Linear programming (LP) and its applications	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
112.	Optimization theory and methods	Understand the basics of Linear programming (LP) and its applications	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
113.	Optimization theory and methods	Understand the basics of Linear programming (LP) and its applications	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term I
114.	Optimization theory and methods	Understand the basics of Nonlinear programming (NLP) with constraints	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term II
115.	Optimization theory and methods	Understand the basics of Nonlinear programming (NLP) with constraints	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term II
116.	Optimization theory and methods	Understand the basics of Nonlinear programming (NLP) with constraints	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term II
117.	Optimization theory and methods	Understand the basics of Nonlinear programming (NLP) with constraints	Lecture	CE1804.1; CE1804.2	Assignment / quiz / Mid Term II
118.	Optimization theory and methods	Solution of global optimization problems with continuous and discrete variables	Lecture	CE1804.2	Assignment / quiz / Mid Term II
119.	Optimization theory and methods	Solution of global optimization problems with continuous and discrete variables	Lecture	CE1804.2	Assignment / quiz / Mid Term II
120.	Optimization theory and methods	Solution of global optimization problems with continuous and discrete variables	Lecture	CE1804.2	Assignment / quiz / Mid Term II
121.	Optimization theory and methods	Solution of global optimization problems with continuous and discrete variables	Lecture	CE1804.2	Assignment / quiz / Mid Term II
122.	Applications of optimization in Chemical Engineering	Optimization of Heat transfer and energy conservation problems	Lecture	CE1804.3	Assignment / quiz / Mid Term II
123.	Applications of optimization in Chemical Engineering	Optimization of Heat transfer and energy conservation problems	Lecture	CE1804.3	Assignment / quiz / Mid Term II
124.	Applications of optimization in Chemical Engineering	Optimization of Heat transfer and energy conservation problems	Lecture	CE1804.3	Assignment / quiz / Mid Term II
125.	Applications of optimization in Chemical Engineering	Optimization of Heat transfer and energy conservation problems	Lecture	CE1804.3	Assignment / quiz / Mid Term II

126.	Applications of optimization in Chemical Engineering	Optimization of Separation processes	Lecture	CE1804.3	Assignment / quiz / Mid Term II
127.	Applications of optimization in Chemical Engineering	Optimization of Separation processes	Lecture	CE1804.3	Assignment / quiz / Mid Term II
128.	Applications of optimization in Chemical Engineering	Optimization of Separation processes	Lecture	CE1804.3	Assignment / quiz / End Term
129.	Applications of optimization in Chemical Engineering	Optimization of Separation processes	Lecture	CE1804.3	Assignment / quiz / End Term
130.	Applications of optimization in Chemical Engineering	Optimization of Fluid flow systems	Lecture	CE1804.3	Assignment / quiz / End Term
131.	Applications of optimization in Chemical Engineering	Optimization of Fluid flow systems	Lecture	CE1804.3	Assignment / quiz / End Term
132.	Applications of optimization in Chemical Engineering	Optimization of Fluid flow systems	Lecture	CE1804.3	Assignment / quiz / End Term
133.	Applications of optimization in Chemical Engineering	Optimization of Fluid flow systems	Lecture	CE1804.3	Assignment / quiz / End Term
134.	Applications of optimization in Chemical Engineering	Optimization of Chemical reactor and its operation	Lecture	CE1804.3	Assignment / quiz / End Term
135.	Applications of optimization in Chemical Engineering	Optimization of Chemical reactor and its operation	Lecture	CE1804.3; CE1804.4	Assignment / quiz / End Term
136.	Applications of optimization in Chemical Engineering	Optimization of Chemical reactor and its operation	Lecture	CE1804.3; CE1804.4	Assignment / quiz / End Term
137.	Applications of optimization in Chemical Engineering	Optimization of Chemical reactor and its operation	Lecture	CE1804.3; CE1804.4	Assignment / quiz / End Term
138.	Applications of optimization in Chemical Engineering	Optimization in large-scale plant design and operations	Lecture	CE1804.3; CE1804.4	Assignment / quiz / End Term
139.	Applications of optimization in Chemical Engineering	Optimization in large-scale plant design and operations	Lecture	CE1804.3; CE1804.4	Assignment / quiz / End Term

I. COURSE ARTICULATION MATRIX: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
[CE1506.14	Develop a mathematical statement for the objective function and the equality and inequality constraints	3	3										1	2		
[CE1506.15	Implement the theory and applications of optimization techniques in a comprehensive manner for solving linear and non-linear, geometric, dynamic, integer and stochastic programming techniques	3	2				1					1	1			
[CE1506.16	Identify, formulate and solve a practical engineering problem of their interest by applying or modifying an optimization technique to enhance employability skills	3	2	1				1				1	1	2		2
[CE1506.17	Use of commercial software to optimize chemical processes thereby enhancing their skills.			1		3				2	1	1	1	2	1	1

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

MANIPAL UNIVERSITY JAIPUR

School of Civil and Chemical Engineering

Department of Chemical Engineering
Lab Hand-out

Process Control Lab | CE 1833 | 2 Credits | 0 0 4 2

Session: Feb 21 – May 21 | Faculty: Anees Y. Khan | Class: Laboratory

A. Introduction: This lab focusses on the experiments related to process dynamics and control theory course, designed for undergraduate students of chemical engineering. Experiments shall be performed on First order systems, second order systems, control valves, temperature, pressure, and level controls in CSTR and pilot scale distillation column.

B. Course Outcomes: At the end of the course, students will be able to

[1833.1] Have a deep understanding of the fundamentals of process control and its real-life applications
[1833.2] Have skills to work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning
[1833.3] Have skills to perform experimental investigations on different experimental set ups and gain competency in performing and analysing the data.
[1833.4] Have skills to assess the results obtained to that approximated by theories reported in literature
[1833.5] Have skills to prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment

C. Program outcomes and program specific outcomes

Program Outcomes for B.Tech. in chemical engineering are as follows.

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3. 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 the public health and safety, and the cultural, societal, and environmental considerations.
PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6. 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.
PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10. 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.
PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes for chemical engineering are as follows:

[PSO.1]. Concept to Commissioning: The students of the program would be able to envision, synthesize, demonstrate, and design any chemical processes right from conceiving the idea to commissioning of a full scale plant taking into account environmental concerns.
[PSO.2]. Process Intensification: Graduates would be equipped with the skills of assessing and finding cost effective innovations involving process intensification and integration for sustainable future developments.
[PSO.3]. Specialization: Students will be specialized in the areas of petroleum, energy and environment related fields.

D. Assessment Plan:

Criteria	Description	Maximum Marks
Conducting experiments and report	Viva + Safety	10+5
	Soft copy of reports + Excel sheets	5
	Pre-lab and Post Lab reports	50
End Term Exam	End Term Exam (Open Book)	30
	Total	100
Attendance	A minimum of 75% Attendance is required to be maintained by a student to be qualified for taking up the End Semester examination. The allowance of 25% includes all types of leaves including medical leaves.	
Make up Labs	No make-up labs will be conducted in case of absence during the labs except in extenuating circumstances, with the prior permission of the instructor(s), and the decision of the instructor(s) in this regard shall be final.	
Pre & Post Lab reports	Pre & Post lab reports must be submitted before the specified due date for handing it over. No late submissions after the due date shall be accepted under any circumstance. It is expected that the students shall work on the experiments independently and analyse their results on their own without 'copying' the solutions from each other.	

E. List of Experiments & their objectives

Sl. No.	Experimental set-up	Objective
57.	First order system	To study the dynamic response of first order system subjected to a step change
58.	Second order system	To study the dynamic response of a second order system subjected to a step change
59.	Interacting/non interacting tanks system	To study the dynamic response of two tank non-interacting system subjected to a step and impulse change

60.	Interacting/non interacting tanks system	To study the dynamic response of two tank interacting system subjected to a step and impulse change
61.	Control valve setup	To study the inherent characteristics of control valves
62.	Control valve setup	To study the hysteresis of control valves
63.	CSTR setup	To study the feedback pressure and temperature control in CSTR.
64.	Multivariable tank setup	To study the feedback level control of a single tank.
65.	Multivariable tank setup	To study the cascade control of liquid level in a tank in non-interacting tank system
66.	Pilot scale distillation column setup	To study the feedback control of feed level in the reboiler of a distillation column
67.	Pilot scale distillation column setup	To study the feedback control of top tray temperature of distillation column
68.	Pilot scale distillation column setup	To study the feedback control of liquid level in the reflux drum

F. Text books

17) Donald R. Coughnowr, " Process System Analysis and Control", 3rd ed., , McGraw-Hill Inc., 2013.

18) George Stephanopoulos, Chemical Process Control: An Introduction to Theory & Practice, Prentice -Hall of India Pvt. Ltd., New Delhi, 1993

19) Duncan A. Mellichamp, Dale Seborg, Thomas F. Edgar, Process Dynamics and Control, John Wiley & Sons Inc, 3rd ed., 2010

Experiment Plan:

LEC NO	Topics	Session Outcome	Mode of Delivery	Corresponding CO	Mode of assessing CO
1	First order system	To study the dynamic response of first order system subjected to a step change and estimate time constant.	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
2	Second order system	To study the dynamic response of a second order system subjected to a step change and estimate various parameters such as damping coefficient, rise time, period of oscillations etc	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
3	Two non-interacting tanks system	To study the dynamic response of two tank non-interacting system subjected to a step and impulse change and estimate the sluggishness of response with higher number of tanks	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
4	Two interacting tanks system	To study the dynamic response of two tank interacting system subjected to a step and	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4;	Report + Viva +End sem lab exam

		impulse change and estimate the sluggishness of response with higher number of tanks		CO1833.5;	
5	Control valve	To study the inherent characteristics of control valves such as linear, quick opening and equal % valve	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
6	Control valve	To study the hysteresis in different types of control valves such as linear, quick opening and equal % valves	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
7	Temperature and pressure control of CSTR	To study the feedback pressure and temperature control in CSTR and study the effect of controller parameters on response.	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
8	Feedback liquid level control	To study the feedback level control of a single tank and study the effect of controller parameters on response.	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
9	Cascade liquid level control	To study the cascade control of liquid level in a tank in non-interacting tank system and understand the role of master and slave controllers	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
10	Feed level control of distillation column	To study the feedback control of feed level in the reboiler of a distillation column and study the effect of controller parameters on response.	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
11	Temperature control of top tray of distillation column	To study the feedback control of top tray temperature of distillation column and study the effect of controller parameters on response.	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam
12	Liquid level control of reflux drum of distillation column	To study the feedback control of liquid level in the reflux drum and study the effect of controller parameters on response.	Lab	CO1833.1; CO1833.2; CO1833.3; CO1833.4; CO1833.5;	Report + Viva +End sem lab exam

G. Course Articulation Matrix: (Mapping of COs with POs)

CO	STATEMENT	CORRELATION WITH PROGRAM OUTCOMES												CORRELATION WITH PROGRAM SPECIFIC OUTCOMES		
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	*PSO1*	*PSO2*	*PSO3*
CE1833.1	Skills to have a deep understanding of the fundamentals of process control and its real-life applications	2	1	1	1	1										
CE1833.2	Skills to work collaboratively in a group to acquire "Hands on" laboratory experience and develop the skill of open-ended learning			1			1		2	3			1			
CE1833.3	Skills to perform experimental investigations on different experimental set ups and gain competency in performing and analysing the data		2	2	3	1			2		1					
CE1833.4	Skills to assess the results obtained to that approximated by theories reported in literature			2	3	1			2		2					
CE1833.5	Skills to prepare concise, well documented technical lab report that details the results, conclusions and errors associated with the experiment				3	1		1	2	1	1		1			

1-Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation