NATIONAL INSTITUTE OF TECHNOLOGY ANDHRA PRADESH

SCHEME OF INSTRUCTION AND SYLLABI

B.Tech. – Chemical Engineering

Effective from 2020-21

Contents

NATIONAL INSTITUTE OF TECHNOLOGY ANDHRA PRADESH

Vision of the Department of Chemical Engineering:

To offer academic and research programs that prepare students to address a global society's challenges and needs by solving complex problems associated with Chemical and Allied Engineering.

Mission of the Department of Chemical Engineering:

- **M 1.** To deliver high-quality technical education that enables the students to lead productive careers in the chemical and allied industries.
- **M 2.** To develop a state-of-the-art infrastructure that promotes internationally recognized research, creativity, and entrepreneurial culture.
- **M 3.** To offer credible solutions to problems prevalent in the Chemical and allied industries by building a robust interface.
- **M 4.** To make students contribute to the nation's sustainable development through leadership in professionalism, education, research, and public services.

Department of Chemical Engineering:

About the Department: The Department of Chemical Engineering at NIT Andhra Pradesh was established in 2015-16, with a mission to impart high-quality engineering education and mould the students to meet the ever-growing demand for technical human resources in Chemical Engineering.

The Department currently offers B.Tech. M.Tech. and Ph.D. programmes in Chemical Engineering. We have revised our academic curriculum to be in tune with the current developments in the field while retaining the core concepts from the discipline. In addition, faculty introduced new electives related to their research, and these are pretty well subscribed.

Our students are highly encouraged to participate in national and international conferences, seminars, workshops, and symposia. The last few years have seen a dramatic increase in industrial associations, research projects, publications, and faculty awards.

Programme Educational Objectives (PEOs) for the B.Tech. (Ch.E) Programme:

Within few years after the end of the B.Tech. in Chemical Engineering programme, graduates will be able to:

PEO1	Apply theoretical knowledge and experimental skills of basic sciences, mathematics and program core to address challenges faced in chemical engineering and allied areas.
PEO2	Execute chemical engineering projects to improve quality of life.
PEO3	Analyze issues related to safety, energy and environment
PEO4	Demonstrate effective communication, management and leadership skills.
PEO5	Carry out cradle to grave analysis of chemical processes

Programme Articulation Matrix (PEO vs. Mission) for the B.Tech. (Ch.E) Programme:

PEO\Mission	M1	M2	M3	M4
PEO1	3	3	-	3
PEO2	3	2	2	2
PEO3	3	2	-	3
PEO4	3	-	3	2
PEO5	3	-	2	3

S: Strong correlation, M: Medium correlation, L: Low correlation

Programme Outcomes (POs) for the B.Tech. (Ch.E) Programme:

At the end of any B.Tech. program in NIT Andhra Pradesh, graduates will be able to:

PO1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and chemical engineering to the solution of complex engineering problems.
PO2	Problem analysis: Identify, formulate, 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 chemical 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 chemical 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 chemical engineering practice.
PO7	Environment and sustainability: Understand the impact of the chemical 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.

Programme Specific Outcomes (PSO) for the B.Tech. (Ch.E) Programme:

At the end of the B.Tech. in Chemical Engineering programme, graduates will be able to:

PSO1	Apply the knowledge of unit operations and unit processes for designing a chemical plant.
PSO2	Analyze the processes & equipment using conservation and phenomenological laws, reaction kinetics, thermodynamics, process control, economics for sustainable environment
PSO3	Develop mathematical models& simulation tools to design and/or optimize Chemical Processes

Degree Requirements for B.Tech. (Ch.E) Programme

	Proposed Credits (New Regulation)
Basic Science Core (BSC)	**25 (15.43%)**
Engineering Science Core (ESC)	**14 (8.64%)**
Humanities and Social Science Core (HSC)	**06 (3.7%)**
Program Core Courses (PCC)	**67 (41.36%)**
Departmental Elective Courses (DEC)	**15 (9.26%)**
Open Elective Courses (OPC)	**09 (5.56%)**
Program Major Project (PRC)/Skill Development (SD)/Foreign Languages	**20 (12.34%)**
EAA: Games and Sports (MSC)	**2 (1.23%)**
MOOCs (MOE)	**4 (2.47%)**
Total	162

Choice Based Credit System: 25.30 %
NOTE: The minimum no. of credits required to award B.Tech. degree is 162 as per the proposed curriculum.

Credit Distribution in Each Semester

	I	II	III	IV	V	VI	VII	VIII	TOT	REQ
BSC	8	8	6	3	0	0	0	0	**25**	≥ 19
ESC	4	10	0	0	0	0	0	0	**14**	≥ 14
HSC	3	0	0	0	0	3	0	0	**6**	≥ 06
PCC	0	0	14	18	16	9	10	0	**67**	≥ 62
DEC	0	0	0	0	0	6	6	3	**15**	≥ 15
OPC	0	0	0	0	3	3	0	3	**9**	≥ 09
PRC/ SD	5	2	0	1	0	2	4	6	**20**	≥ 15
EAA (MSC)	1	1	0	0	0	0	0	0	**2**	≥ 2
MOOCS (MOE)	0	0	0	0	2	0	0	2	**4**	≥ 4
	21	**21**	**20**	**22**	**21**	**23**	**20**	**14**	**162**	

I Year B.Tech. Course Structure
(Common for all branches)

Physics Cycle							
S. No.	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MA101/ MA151	Differential and Integral Calculus / Matrices and Differential Equations	3	0	0	**03**	**BSC**
2	HS101	English for Technical Communication	2	0	2	**03**	**HSC**
3	PH101	Engineering Physics	3	0	0	**03**	**BSC**
4	EC101	Basic Electronics Engineering	2	0	0	**02**	**ESC**
5	CE102	Environmental Science and Engineering	2	0	0	**02**	**ESC**
6	CS101	Introduction to Algorithmic Thinking and Programming	3	0	0	**03**	**SD**
7	CS102	Introduction to Algorithmic Thinking and Programming Lab	0	1	2	**02**	**SD**
8	PH102	Engineering Physics Lab	0	1	2	**02**	**BSC**
9	EA101/ EA151	Physical Education/Health Education	0	0	3	**01**	**MSC**
		TOTAL	**15**	**2**	**9**	**21**	

Chemistry Cycle							
S. No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MA101/ MA151	Differential and Integral Calculus / Matrices and Differential Equations	3	0	0	**03**	**BSC**
2	ME102	Engineering Graphics with Computer Aided Drafting	0	1	2	**02**	**ESC**
3	CY101	Engineering Chemistry	3	0	0	**03**	**BSC**
4	EE101	Elements of Electrical Engineering	2	0	0	**02**	**ESC**
5	BT101	Biology for Engineers	2	0	0	**02**	**ESC**
6	ME101	Basics of Mechanical Engineering	2	0	0	**02**	**ESC**
7	CE101	Engineering Mechanics	2	0	0	**02**	**ESC**
8	ME103	Workshop Practice	0	1	2	**02**	**SD**
9	CY102	Engineering Chemistry Lab	0	1	2	**02**	**BSC**
10	EA101/ EA151	Physical Education/Health Education	0	0	3	**01**	**MSC**
		TOTAL	**14**	**3**	**9**	**21**	

Note:

BSC: Basic Science Core

ESC: Engineering Science Core

HSC: Humanities and Social Science Core

PCC: Program Core Courses

DEC: Departmental Elective Courses

OPC: Open Elective Courses

Program Major Project (PRC)/Skill Development (SD)/Foreign Languages

EAA (MSC): Games and Sports MOOCs (MOE)

Summer Internship – I#

II Year B.Tech. Chemical Engineering Course Structure

YEAR – II							
Semester – I							
S. No.	**Course Code**	**Course Name**	**L**	**T**	**P**	**C**	**Category Code**
01	MA202	Complex Variables and Transform Methods	3	0	0	03	BSC
02	CY201	Industrial Organic Chemistry	3	0	0	03	BSC
03	CH201	Chemical Process Calculations	3	1	0	04	PCC
04	CH202	Fluid Mechanics	3	1	0	04	PCC
05	CH203	Mechanical Operations	3	1	0	04	PCC
06	CH204	Fluid Mechanics Laboratory	0	0	2	01	PCC
07	CH205	Mechanical Operations Laboratory	0	0	2	01	PCC
		Total	**15**	**3**	**4**	**20**	
Semester – II							
01	MA251	Numerical and Statistical Methods	3	0	0	03	BSC
02	CH251	Heat Transfer	3	1	0	04	PCC
03	CH252	Chemical Engineering Thermodynamics – I	3	1	0	04	PCC
04	CH253	Chemical Reaction Engineering – I	3	1	0	04	PCC
05	CH254	Mass Transfer – I	3	1	0	04	PCC
06	CH255	Heat Transfer Laboratory	0	0	2	01	PCC
07	CH256	Chemical Reaction Engineering Laboratory	0	0	2	01	PCC
08	CH299	Mini Project – I (EPICS based)	0	0	2	01	SD
		Total	**15**	**4**	**6**	**22**	

Summer Internship – II#

III Year B.Tech. Chemical Engineering Course Structure

YEAR – III							
Semester – I							
S. No.	**Course Code**	**Course Name**	**L**	**T**	**P**	**C**	**Category Code**
01	CH301	Chemical Engineering Thermodynamics – II	3	0	0	03	PCC
02	CH302	Chemical Reaction Engineering – II	3	0	0	03	PCC
03	CH303	Mass Transfer – II	3	0	0	03	PCC
04	CH304	Transport Phenomena	3	1	0	04	PCC
05	CH305	Mass Transfer Laboratory	0	0	2	01	PCC
06	CH306	Computational Methods in Chemical Engineering Laboratory	0	1	2	02	PCC
07	CH340	Open Elective – 1 / Foreign Language	3	0	0	03	OPC/SD
08		MOOCS – 1	2	0	0	02	MOE
		Total	**17**	**2**	**4**	**21**	
Semester – II							
01	CH351	Process Dynamics and Control	3	1	0	04	PCC
02	CH352	Chemical Technology	3	1	0	04	PCC
03	CH36X	Department Elective – 1	3	0	0	03	DEC
04	CH37X	Department Elective – 2	3	0	0	03	DEC
05	SM355	Engineering Economics and Management	3	0	0	03	HSC
06	CH353	Process Control Laboratory	0	0	2	01	PCC
07	CH390	Open Elective – 2 / Foreign Language	3	0	0	03	OPC/SD
08	CH399	Mini Project - II	0	0	4	02	SD
		Total	**18**	**2**	**6**	**23**	

Summer Internship – III#

#: The student can do Summer Internship with duration of minimum 45 days at Institutes / Organizations / Industries and produce the certificate of completion and copy of internship report to the department.

It is optional only, Not Mandatory.

IV Year B.Tech. Chemical Engineering Course Structure

YEAR – IV							
Semester – I							
S. No.	**Course Code**	**Course Name**	**L**	**T**	**P**	**C**	**Category Code**
01	CH401	Industrial Safety and Hazard Mitigation	3	0	0	03	PCC
02	CH41X	Department Elective – 3	3	0	0	03	DEC
03	CH42X	Department Elective – 4	3	0	0	03	DEC
04	CH402	Process Engineering & Design*	2	1	0	03	PCC
05	CH403	Plant Design and Process Economics	2	0	0	02	PCC
06	CH404	Design and Simulation Laboratory	0	1	2	02	PCC
07	CH449	Project Work Part – A	0	0	8	04	PRC
			13	**2**	**10**	**20**	
Semester – II							
01	CH46X	Department Elective – 5	3	0	0	03	DEC
02	CH490	Open Elective – 3	3	0	0	03	OPC
03		MOOCS – 2	2	0	0	02	MOE
04	CH499	Project Work Part – B	0	0	12	06	PRC
			8	**0**	**12**	**14**	

* May be offered with the support of Industry.

POOL OF ELECTIVES

S. No.	Course Code	Course Name	L	T	P	C	Category Code
Department Elective – 1							
01	CH361	Computational Fluid Dynamics	3	0	0	3	DEC
02	CH362	Separation Processes	3	0	0	3	DEC
03	CH363	Bioprocess Engineering	3	0	0	3	DEC
04	CH364	Characterization of Materials	3	0	0	3	DEC
05	CH365	Water and Wastewater Treatment	3	0	0	3	DEC
06	CH366	Industrial Energy Systems	3	0	0	3	DEC
07	CH367	Fertilizer Technology	3	0	0	3	DEC
Department Elective – 2							
01	CH371	Design and Analysis of Experiments	3	0	0	3	DEC
02	CH372	Fluidization Engineering	3	0	0	3	DEC
03	CH373	Food Process Engineering	3	0	0	3	DEC
04	CH374	Science and Technology of Nanomaterials	3	0	0	3	DEC
05	CH375	Solid Waste and Hazard Management	3	0	0	3	DEC
06	CH376	Fuel Cell Technology	3	0	0	3	DEC
07	CH377	Catalysis	3	0	0	3	DEC
Department Elective – 3							
01	CH411	Process Modeling and Simulation	3	0	0	3	DEC
02	CH412	Multiphase Flow	3	0	0	3	DEC
03	CH413	Biochemical Engineering	3	0	0	3	DEC
04	CH414	Interfacial Science	3	0	0	3	DEC
05	CH415	Statistical Thermodynamics	3	0	0	3	DEC
07	CH416	Scale up Methods	3	0	0	3	DEC
Department Elective – 4							
01	CH421	Polymer Technology	3	0	0	3	DEC
02	CH422	Air Pollution Control	3	0	0	3	DEC
03	CH423	Energy Resources and Systems	3	0	0	3	DEC
04	CH424	Petroleum Refining Processes	3	0	0	3	DEC
05	CH425	Process Modelling and Analysis	3	0	0	3	DEC
06	CH426	Statistical Design of Experiments	3	0	0	3	DEC

Department Elective – 5							
01	CH461	Process and Product Design	3	0	0	3	DEC
02	CH462	Mathematical methods in Chemical Engineering	3	0	0	3	DEC
03	CH463	Membrane Technology	3	0	0	3	DEC
04	CH464	Optimization Techniques	3	0	0	3	DEC
05	CH465	Process Intensification	3	0	0	3	DEC
06	CH466	Soft Computing Techniques	3	0	0	3	DEC
07	CH467	Water and Air Quality Management	3	0	0	3	DEC
Open Electives (Not offered to Chemical Engineering Students)							
01	CH340	Paper Production Technology	3	0	0	3	OPC
02	CH390	Nanotechnology and Applications	3	0	0	3	OPC
03	CH490	Carbon Capture, Sequestration and Utilization	3	0	0	3	OPC

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I Year B.Tech. Course Structure
(**Common for All Branches)**

MA101	**Differential and Integral Calculus** I B.Tech. I Semester - all sections	**BSC**	**3-0-0**	**3 Credits**

Pre-requisites: None

Differential Calculus of functions of several variable: Review of Limit, continuity (sequential verification) and differentiability, Partial differentiation; Total differentiation; Euler's theorem and generalization; Change of variables- Jacobians; Maxima and minima of functions of several variables (2 and 3 variables); Lagrange's method of multipliers. (14)

Integral Calculus: Convergence of improper integrals; Beta and Gamma integrals; Differentiation under integral sign; Double and Triple integrals - computation of surface areas and volumes; change of variables in double and triple integrals. (14)

Vector Calculus: Scalar and vector fields; vector differentiation; level surfaces; directional derivative; gradient of a scalar field; divergence and curl of a vector field; Laplacian; Line and Surface integrals; Green's theorem in a plane; Stokes' theorem; Gauss Divergence theorem. (14)

Text Reference:

1. Joel R. Hass, Maurice D. Weir, George B. Thomas, Thomas' Calculus, 12th edition, Pearson , 2010.
2. Erwin Kreyszig, *"Advanced Engineering Mathematics"*, Eighth Edition, John Wiley and Sons, 2015
3. B. S. Grewal, *"Higher Engineering Mathematics"*, Khanna Publications, 2015
4. R. K. Jain and S. R. K. Iyengar, *"Advanced Engineering Mathematics"*, Fifth Edition, Narosa Publishing House, 2016.
5. T. M. Apostol, Calculus, Volumes 1 and 2 (2nd Edition), Wiley Eastern, 1980.

MA151	**Matrices and Differential Equations** I B.Tech. II Semester - all sections	BSC	3-0-0	3 Credits

Pre-requisites: Mathematics-I

Matrix Theory: Linear dependence and independence of vectors; Rank of a matrix; Consistency of the system of linear equations; Eigenvalues and eigenvectors of a matrix; Caley-Hamilton theorem and its applications; Reduction to diagonal form; Reduction of a quadratic form to canonical form - orthogonal transformation; Properties of complex matrices - Hermitian, skew-Hermitian and Unitary matrices

Ordinary Differential Equations of Higher Order : Higher order linear differential equations with constant coefficients - homogeneous and non-homogeneous; Euler and Cauchy's differential equations; Method of variation of parameters; System of linear differential equations; applications in physical problems - forced oscillations, electric circuits, etc

Laplace Transforms: Laplace transforms; inverse Laplace transforms; Properties of Laplace transforms; Laplace transforms of unit step function, impulse function, periodic function; Convolution theorem, Solving certain initial value problems, Solving system of linear differential equations, Finding responses of systems to various inputs viz. sinusoidal inputs acting over a time interval, rectangular waves, impulses etc.

Text Reference:

1. E. Kreyszig, Advanced Engineering Mathematics, Eighth Edition, John Wiley and Sons, 2015.
2. B. S. Grewal, Higher Engineering Mathematics, Khanna Publications, 2015.
3. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Fifth Edition, Narosa Publishing House, 2016.
4. G. Strang, Linear Algebra and Its Applications, 4th Edition, Brooks/Cole India, 2006.
5. T. M. Apostol, Calculus, Volume 2 (2nd Edition), Wiley Eastern, 1980.

HS101	English For Technical Communication	SD	2 – 0 – 2	3 Credits

Pre-requisites: None.

Detailed syllabus

Grammar Principles and Vocabulary Building: -Exposure to basics of grammar-tenses—active and passive voice- their usage-Concord -Error Detection-Idioms and Phrases-Phrasal verbs—their meanings and usage, Synonyms and antonyms

Developing paragraphs using mind mapping- Definition- structure- Types and Composition-unity of theme- coherence- organization patterns-essays and their structure-note-making

Letter Writing: Formal letters-- communicative purpose-strategy- letter format and mechanics- letters of request, complaint and invitation-writing emails
Reading Comprehension –skimming-scanning-intensive and extensive reading-reading to retrieve information ––techniques of comprehension -find clues to locate important points- answering objective type questions–inference, elimination

Delegation- steps involved in delegation-preparing delegation for a program
Preparing Questionnaire-Determine audience and content of each question-response structure-develop wording for each question-establish sequence of questions

Profiling Readers-Audience analysis- Identifying potential audience- Identifying primary, secondary, tertiary readers, and gatekeepers- Identifying the needs, values, and attitude of the readers
Resume Writing-Writing for Professional Networking-Academic writing-research proposals-Interpretation of Graphs.

Technical Report-Writing - kinds of reports-proposals, progress and final reports- their structure- features- process of writing a report-editing.

Language Laboratory
Introduction to basic phonetics: Vowels, Consonants, Diphthongs, phonetic symbols.
Listening: Challenges in listening, enhancing listening skills, listening activities.
Speaking:JAM using cue cards-role play-Group presentation-presentation with emphasis on body language- public speaking-extempore speech.
Group discussion: Dos and don’ts, intensive practice
Mock interview:Interview etiquette, common interview questions

Text Books:

1. Emden, Joan van. *Effective Communication for Science and Technology*. Macmillan Education UK, 2001.
2. Mohan, Krishna and Meera Banerji. *Developing Communication Skills*. Macmillan India Limited, 2000.

3. Murphy, Raymond. *Intermediate English Grammar*. Cambridge University Press, 2014.
4. Narayanaswami, V. R. *Strengthen Your Writing*. Orient Longman Private Limited, 2005.
5. Soundaraj, Francis. *Speaking and Writing for Effective Business Communication*. Macmillan Publishers India Limited, 2007.
6. Ur, Penny. *Discussions that Work*. Cambridge University Press, 1981.

Reference:

Aarts, Bas. *Oxford Modern English Grammar*. Oxford University Press, 2011.

Anderson, Marilyn, Pramod K. Nayar, and Madhucchanda Sen. *Critical Thinking, Academic Writing and Presentation Skills*. Pearson Education, 2008.

Blake,Gary.The Elements of Technical Writing. Pearson,2000

Brown, Carla L. *Essential Delegation Skills*. Routledge, 2017.

Busan, Tony. *Mind Map Mastery*. Walkins, 2018.

Carlisle, Joanne and Melinda S. Rice. *Improving Reading Comprehension Research-based Principles and Practices*. York Press, 2002.

Carter, Ronald and Michael McCarthy. *Cambridge Grammar of English: A Comprehensive Guide*. Cambridge University Press, 2006.

Carter, Ronald, Rebecca Hughes, and Michael McCarthy. *Exploring Grammar in Context: Upper-intermediate and Advanced.* Cambridge University Press, 2000.

Eastwood, John. *Oxford Guide to English Grammar*. Oxford University Press, 1994.

Harris, David.F. *Complete Guide to Writing Questionnaires.* I& M Press, 2014.

Hering, Lutz and Heike Hering. *How to Write Technical Reports: Understandable Structure, Good Design, Convincing Presentation*. Springer; 2010.

HuckinN.Thomas and Leslie A.Olsen*Technical Writing and Professional Communication for Non-native Speakers*. McGraw-Hill Education,1991.

Laplante, Phillip A*. Technical Writing: A Practical Guide for Engineers, Scientists, and Nontechnical Professionals.* CRC Press, 2018.

McQuail, Dennis. *Audience Analysis*. Sage, 1997

Ogden, Richard. *Introduction to English Phonetics*. Edinburgh University Press, 2017.

Parker, Glenn M. *Team Players and Teamwork: New Strategies for Developing Successful Collaboration*. Wiley, 2011.

Seely, John. *Oxford Guide to Effective Writing and Speaking: How to Communicate Clearly*. Oxford University Press: 2013.

PH101	Engineering Physics	BSC	3-0-0	3 Credits

Waves and Optics

Interference: Superposition principle, coherence of light, methods to produce coherent light: division of amplitude and wave front division, Young's double slit experiment: concept, working principle, and applications, Newton's ring: concept, working principle, and applications

Diffraction: Fraunhofer's single-slit diffraction, diffraction grating, and resolving power of a grating.

Polarization: Types of optical polarization, various methods to produce polarized light, working and applications of retarder plates, and half-shade polarimeter: construction and working principle.

Lasers and Optical Communication

LASER: Basic theory of LASER, Einstein's coefficients and their relations, concept of population inversion, components of lasers, modes of laser beam, construction and working principle of various types of lasers: Ruby, Helium-Neon, and semiconductor diode lasers.

Optical Fibre: Optical fibre and its working principle, total internal reflection, numerical aperture, modes of propagation, and classification of optical fibres.

Quantum Physics

Origin of quantum theory and related experiments: Black-Body radiation, photo-electric effect, and Compton effect. Heisenberg's uncertainty principle, de- Broglie's wave concept, phase and group velocities, wave function, and its properties, operators, Schrödinger's time-dependent and time-independent equations, particle in one-dimensional, infinite potential and finite potential wells, and quantum tunneling phenomena and their applications in alpha decay, and scanning tunneling microscopy (STM).

Magnetic, Superconducting and Dielectric Materials

Magnetic Materials: Introduction to Weiss theory of ferromagnetism, concepts of magnetic domains, Curie transition, hard and soft magnetic materials and their applications, magneto-resistance, GMR, and TMR.

Superconducting Materials: Introduction to superconductivity, Meissner effect, Type-I and Type-II superconductors and their applications.

Dielectric Materials: Introduction to dielectrics, dielectric constant, polarizability, frequency and temperature dependent polarization mechanism in dielectrics, dielectric loss, and applications.

Advanced Functional Materials & NDT

Smart Materials: Biomaterials, high-temperature materials and smart materials, applications of functional materials.

Nanomaterials: Introduction, classification, and properties of nanomaterials, various methods of synthesizing nanomaterials: top-down (ball milling) and bottom-up (sol-gel) approaches.

Photovoltaic Materials: Solar spectrum, photovoltaic effect, materials, structure and working principle, I-V characteristics, power conversion efficiency, quantum efficiency, emerging PV technologies, and applications.

NDT: Methods of non-destructive testing

References:

1. A Textbook of Engineering Physics, M. N. Avadhanulu, P. G. Kshirsagar, S. Chand and Company (2015).
2. Concepts of Modern Physics, Beiser A., Mc. Graw Hill Publishers (2003).
3. Optics, Ajoy Ghatak, Tata Mc Graw Hill (2012).
4. Materials Science and Engineering: An Introduction (Tenth edition), William D. Callister, John Wiley & Sons (2018).
5. Introduction to Solid State Physics, Charles Kittel, Wiley Publishers (2011).

EC101	Basic Electronics Engineering	ESC	2 – 0 – 0	2 Credits

Detailed Syllabus:

Introduction to electronics systems, diode circuit models and applications, Zener diode as regulator, photodiode.

Transistor and applications: Introduction to transistors, BJT Characteristics, biasing and applications. FET and MOSFET characteristics and applications.

Feedback in Electronic Systems: open loop and closed loop systems, Negative and positive Feedback, Principles of LC and RC oscillators.

Integrated Circuits: Operational amplifiers Characteristics and applications, linear operations using Op-amps.

Digital Circuits: Number systems and logic gates, Combinational Logic circuits, Sequential Circuits, Analog to Digital and Digital to Analog converters (ADC/DAC).

Laboratory measuring instruments: principles of digital multi-meters, Cathode ray oscilloscopes (CRO).

Reading:

1. Bhargava N. N., D C Kulshreshtha and S C Gupta, Basic Electronics & Linear Circuits, 2nd Edition, Tata McGraw Hill, 2013.
2. S. Sedra and K. C. Smith, Microelectronic Circuits, Oxford University Press, 6th Edition
3. Leach, Malvino, Saha, Digital Principles and Applications, McGraw Hill Education, 8th Edition
4. Boylestad, Robert L., Louis Nashelsky, Electronic Devices and Circuit, Pearson, 11th Edition
5. Helfrick and Cooper, ― Modern Electronic Instrumentation and Measurement Techniques‖ PHI, 2011
6. Neil Storey, Electronics A Systems Approach, 4th Edition, Pearson Education Publishing Company Pvt Ltd.

CE102	ENVIRONMENTAL SCIENCE AND ENGINEERING	ESC	2-0-0	2 Credits

Detailed Syllabus:

Introduction to Environmental Science: Environment and Societal Problems, Major Environmental Issues, Global Climate Change Agreements, Montreal, Kyoto Protocol & Paris Agreement, Basics of Environmental Impact Assessment, Principles of Sustainability, and related indices, Population Dynamics, Urbanization. Identification and Evaluation of Emerging Environmental Issues with Air, Water, Wastewater and Solid Wastes, Introduction to Environmental Forensics.

Water & Wastewater Treatment: Water Sources, constituents, potable water quality requirements (IS 10500), overview of water treatment, sources and types of pollutants, their effects, self-purification capacity of water bodies, principles of wastewater treatment, 5R Concept.

Air & Noise Pollution: Sources, classification and their effects, national ambient air quality standards (NAAQS), air quality index, dispersion of pollutants, control of air pollution, understanding and improving indoor air quality, sources of noise pollution, effects, quantification of noise pollution.

Solid Waste Management: Sources and characteristics of solid waste, effects, 3R concept, sustainable practices in waste management, CPHEEO guidelines for solid waste management, transition to zero waste lifestyle.

Reading:

1. G.B. Masters, Introduction to Environmental Engineering and Science, Pearson Education, 2013.
2. Gerard Kiely, Environmental Engineering, McGraw Hill Education Pvt Ltd, Special Indian Edition, 2007.
3. Benny Joseph, Environmental Science and Engineering, Tata McGraw-Hill, New Delhi, 2006.

References:

1. Peavy, H.S, Rowe, D.R., and G. Tchobanoglous (1985), Environmental Engineering, McGraw Hill Inc., New York
2. W P Cunningham, M A Cunningham, Principles of Environmental Science, Inquiry and Applications, Tata McGraw Hill, Eighth Edition, 2016.

CS101	Introduction to Algorithmic Thinking and Programming	SD	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Construct algorithms for solving problems that requires solutions involving searching, sorting, selection and / or a numerical method as a sub-routine.
CO2	Analyze the suitability of different algorithmic design paradigms for solving problems with an understanding of the time and space complexities incurred.
CO3	Construct algorithms for solving problems with an understanding of the internals of a computing system and its components like processor, memory and I/O sub-systems.
CO4	Construct efficient modular programs for implementing algorithms by leveraging suitable control structures.
CO5	Construct efficient programs by selecting and using suitable in-built Data Structures and programming language features available.

Course Articulation Matrix:

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	S	M	L									
CO2	S	M	L									
CO3	S	M	L		L							
CO4	S	M	L		S							
CO5	S	M	L		S							

S: Strong correlation, M: Medium correlation, L: Low correlation

Detailed Syllabus:

Fundamentals of Computers, Historical perspective, Early computers, Modern Computers, Hardware Components of a Computer, Data Representation in Computers, Introduction to Operating Systems, Software and Firmware, Problems, Flowcharts, Memory, Variables, Values, Instructions, Programs.

Problem solving techniques – Algorithmic approach, characteristics of algorithms, Problem solving strategies: Top-down approach, Bottom-up approach, Time and space complexities of algorithms, Algorithm Analysis.

Basic Syntax in Python, Data Types, Variables, Assignments, immutable variables, Types of Operators, Expressions, Comments, Boolean Logic, Logical Operators in Python.

Conditional statements - If-else, Loops - while, for, Lazy Evaluation

Inbuilt Data Structures and their operations in Python: List, Tuples and Dictionaries.

Fundamental Algorithms: Swapping variables, Problems involving summation of a series, Sine function computation, Base Conversion, generation of sequences like Fibonacci, Reversing the digits of an integer, Character to number conversion.

Factoring Methods: Finding the square root, Finding the smallest divisor of an integer, finding the greatest common divisor using Euclid's algorithm, Computing the prime factors of an integer, generating prime numbers, Raising a number to a large power, Computation of the nth Fibonacci number.

Functions – Modular programming and benefits, user defined functions, library functions, parameter passing, Formal and Actual arguments, named arguments return values, Recursion.

Sorting algorithms: Bubble, Selection and Insertion sorts, Search algorithms: Linear and binary search

String processing: Algorithms for implementing String functions like Strlen, Strcpy, StrRev, Strcmp, Searching for a keyword or pattern in a text.

File and Directory Handling: Reading and Writing to/from a file, Formatted File creation and operations.

Simple 2D Graphics, drawing 2D objects using Turtle Graphics.

Reading List:

1. Kenneth Lambert, Fundamentals of Python: First Programs, Cengage Learning, 2019
2. R.G. Dromey, how to solve it by Computer, Pearson, 2008.

CS102	Introduction to Algorithmic Thinking and Programming Lab	SD	0 – 1 – 2	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Construct, debug, test and run efficient programs by leveraging suitable flow of control constructs and syntactic units of the programming language.
CO2	Construct efficient programs by constructing and translating algorithms for solving problems using sorting, searching, selection and / or arithmetic computations.
CO3	Implement, refactor, test and debug functional programs in a shell-based run time environment.
CO4	Construct efficient programs by demonstrating problem-solving skills and out-of-the-box algorithmic thinking.

Course Articulation Matrix:

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	S	M	L		S				M			L
CO2	S	M	L		S				M			L
CO3	S	M	L		S				M			L
CO4	S	M	L		S				M			L

S: Strong correlation, M: Medium correlation, L: Low correlation

Detailed Syllabus:

List of Experiments:

1. Familiarization with Python installation, basic syntax and running scripts in the shell.
2. Programs on conditional control constructs.
3. Programs on iterative constructs. (While, do-while, for).
4. Programs using user defined functions and in-built function calls.
5. Programs related to Recursion.
6. Programs involving in-built data structures like List, Tuples and Dictionaries.

7. Programs related to String processing.
8. Programs related to Files and I/O.
9. Implementation of Factoring methods.
10. Programs that require sorting, searching and selection as sub-routines.
11. Problems involving simple 2D graphics.
12. Implementation of a capstone application to unify the concepts learnt in the course.

Reading List:

1. Kenneth Lambert, Fundamentals of Python: First Programs, Cengage Learning, 2019.
2. R.G. Dromey, how to solve it by Computer, Pearson, 2008.
3. The Python Tutorial, Available at: https://docs.python.org/3/tutorial/.

PH102	Engineering Physics Lab	BSC	0-0-2	2 Credits

List of experiments (any eight of the following):

S. No	Name of the experiment
1	Determination of Planck's constant using light emitting diode.
2	Determination of wavelength of monochromatic light in Newton's ring experiment.
3	Determination of the width of narrow slit by diffraction method.
4	Determination of wavelength of He-Ne laser using diffraction by a metal scale.
5	Determination of capacitance and time constant of a capacitor using R-C circuit.
6	Determination of wavelength of mercury spectrum by normal incidence method (diffraction grating).
7	Determination of specific rotation of an optically active material-using Laurent's half-shade polarimeter.
8	Determination of resonating frequency and bandwidth of an LCR circuit.
9	Determination of dielectric constant of various dielectric materials.
10	Studying B-H curve loop and permeability of magnetic materials.
11	Measuring spatial distribution of magnetic field between a pair of identical coils using Helmholtz coils.
12	Studying current-voltage characteristics of a photovoltaic material using solar cell.
13	Determination of numerical aperture of an optical fibre.
14	Determination of resistivities of various materials using four-probe method.

Exposure to virtual lab (any three of the following):

1. LCR – Series/Parallel
2. B-H Loop tracer
3. Planck's Constant
4. Numerical aperture of Optical Fiber
5. Newton's rings

Micro project:

This can be implemented in the subsequent semesters based on the facilities available. In the case of implementation, three or four experiments from the above listed eight experiments will be replaced with the project (~40 % of the experiments will be relaxed).

References:

1. *Physics Laboratory Manual*, School of Sciences (Physics), National Institute of Technology Andhra Pradesh (2020).
2. *Practical Physics (Electricity, Magnetism, and Electronics),* R. K. Shukla, A Srivastava, New age international publishers (2011).
3. *B.Sc. Practical Physics*, C. L. Arora, S. Chand & Co. Ltd. (2012).

EA101	Physical Education	MSC	0-0-3	1 Credit

Detailed Syllabus:

I. Introduction to Physical Education & EAA = Sports and Games

Meaning & Definition of Physical Education, Aims & Objectives of Physical Education, Importance of Physical Education

II. Physical Fitness & Wellness Lifestyle

Meaning & Importance of Physical Fitness, Components of Physical Fitness (Cardiovascular Endurance, Strength Endurance Muscular Endurance, Flexibility, Body Composition), Components of Motor Fitness (Agility, Balance, Power, Speed, Coordination), Development of Fitness Components

III. Training Methods in Physical Education

Circuit Training (Circuit Training), Continues Training (Endurance), Interval Training (Speed & Endurance), Fartlek Training (Speed Endurance), Weight Training (Maximum Strength), Plyometric Training (Power), Flexibility Training

IV. Test & Measurements

Measurements: Height, Weight, Age, Calculation of BMI, Motor Fitness and Physical Fitness Tests (Pre - Test & Post-Test), Cardiovascular Endurance - 9/12 Minute Run or Walk, Muscular Endurance – Sit Ups for abdominal strength, Strength Endurance – Flexed arm hang for girls / Pull ups for boys, (Speed – 50m Dash or 30mts Fly Start, Strength – Broad Jump, Vertical Jump for Lower Body, Medicine Ball Put for Shoulder Strength, Endurance - 800mts, Flexibility - Bend and Reach, Agility (Coordination)) – Shuttle Run and Box Run

V. Formal Activities

Calisthenics (free hand exercises), Dumbbells, Woops, Wands, Laziums (Rhythmic activities), Aerobic Dance and Marching

VI. Sports / Games

Following sub topics related to any one Game/Sport of choice of student out of: Athletics, Badminton, ball badminton, Kabaddi, Kho-Kho, Table Tennis, Yoga etc., Teaching & Coaching of the Game/Sport, Latest General Rules of the Game/Sport.

Specifications of Play Grounds and Related Sports Equipment

EA151	Health Education	MSC	0-0-3	1 Credit

Health Education & Personal Hygiene

Introduction & Meaning of Health Education, Definition of Health Education, Principles of Health Education, Importance of Health Education, Meaning of Personal Hygiene, Importance of Personal Hygiene, Personal cleanliness (teeth, ears, eyes, nose & throat, nails & fingers, skin, cloths, and hair).

Nutrition

Introduction of Nutrition, Balanced Diet, Daily Energy Requirements, Nutrient Balance, Nutritional Intake, Eating and Competition, Ideal Weight

First Aid & Injury Management

Introduction, Types and Principles of First Aid, Functions of First Aider, Reasons for Sports Injuries,The First Aid and Emergency Treatment in Various cases (drowning, dislocation & fractures, burns, electric shock, animal bite, snake bite, poison, etc.

Human Posture

Introduction, Meaning of Posture, types of Good Posture, causes of Poor Posture, preventive and Remedial Poor Posture, common Postural Deformities, Body Types, Advantages of Good Posture

Yoga

Introduction, Meaning & Importance of Yoga, Elements of Yoga, Introduction - Asanas, Pranayama, Meditation & Yogic Kriyas, Yoga for concentration & related Asanas (standing asanas, sitting asanas, supine and prone postures.), Relaxation Techniques for improving concentration – Yoga – nidra, Pranayama

Sports / Games

Following sub topics related to any one Game/Sport of choice of student out of: Athletics, Badminton, ball badminton, Kabaddi, Kho-Kho, Table Tennis, Yoga etc.,Teaching & Coaching of the Game/Sport., Latest General Rules of the Game/Sport, Specifications of Play Grounds and Related Sports Equipment.

ME102	Engineering Graphics with Computer Aided Drafting	ESC	2-0-0	2 Credits

Note: 50% of the Practice through manual drawing and 50% of the Practice through a Computer Aided Drafting Package.

Detailed Syllabus:

Introduction: Overview of the course, Lines Lettering and Dimensioning: Types of lines, Lettering, Dimensioning, Geometrical Construction of Polygons, Scales. Introduction to Computer Aided Drafting (CAD), DRAW tools, MODIFY tools, TEXT, DIMENSION, PROPERTIES, etc.

Orthographic Projection: Principles, of Orthographic projection, Four Systems of Orthographic Projections.

Projection of Points: Projections of points when they are situated in different quadrants.

Projections of Lines: Projections of a line parallel to one of the reference planes and inclined to the other, line inclined to both the reference planes, Traces.

Projections of Planes: Projections of a plane perpendicular to one of the reference planes and inclined to the other, Oblique planes.

Projections of Solids: Projections of solids whose axis is parallel to one of the reference planes and inclined to the other, axis inclined to both the planes.

Sections of Solids: Sectional planes, Sectional views - Prism, pyramid, cylinder and cone, true shape of the section.

Isometric Views: Isometric axis, Isometric Planes, Isometric View, Isometric projection, Isometric views - simple objects.

Reading:

1. N.D. Bhatt and V.M. Panchal, Engineering Graphics, Charotar Publishers, 2013.

2. Sham Tickoo, AutoCAD 2017 for Engineers & Designers, Dreamtech Press, 23 rd Edition, 2016.

CY101	Engineering Chemistry	BSC	3-0-0	3 Credits

Basic Organic Chemistry

Reaction intermediates: carbocations, carbanions, free radicals and carbenes. Classification of organic reactions, examples and their mechanisms: substitution, addition, elimination and rearrangement reactions. Reimer–Tiemann reaction, Kolbe-Schmidt reaction, Cannizzaro reaction. Pinacol-Pinacolone, Hofmann and Beckmann rearrangements. Diels-Alder reaction.

Spectroscopic Techniques for Chemical Analysis

Introduction of spectroscopy, Quantum aspects of electronic, vibrational and nuclear energy levels. UV-Visible spectroscopy: Principle, Instrumentation, Beer-Lambert's law, Effect of conjugation, Woodward-Fieser empirical rules for acyclic/cyclic dienes. IR spectroscopy: Principle, Factors that affect vibrational frequencies and functional group detection. Proton NMR spectroscopy: Principle, Instrumentation, Chemical equivalency, Chemical shift and spin-spin splitting. Applications of UV-Vis, IR and proton-NMR spectroscopy in determining the structure of small organic molecules.

Coordination Chemistry

Introduction of coordination chemistry, Valence bond (VB) theory and shapes of Inorganic Compounds, Spectrochemical series, Crystal Field theory (CFT): octahedral and tetrahedral complexes, Crystal field splitting energy (CFSE); Molecular Orbital (MO) Theory: Molecular orbital diagrams for octahedral complexes (strong and weak ligand fields).

Electrochemistry

Electrodes, Electrochemical Cells, Electrochemical series and Nernst equation; Conductometry and Potentiometry; Batteries: Types of batteries, Ni-Cd and Lithium (Li)-ion batteries; Fuel Cells: Hydrogen-Oxygen, Methanol-Oxygen fuel cells; Corrosion - Theories of corrosion, Wet corrosion, Types of wet corrosion, Factors affecting the rate of corrosion, Corrosion control methods: Sacrificial anode method and Impressed current method.

Engineering Materials and Applications

Polymers: Introduction, Types of polymerization, Functionality in polymers, Number and Weight average molecular weight, Polydispersity index, Biodegradable polymers; Conductive polymers: classification, examples and applications; Organic light emitting diode (OLED): structure, principle and applications; Optical fibres: principle and Applications.

Reference books:

1. Organic Chemistry, Clayden, Greaves, Warren and Wothers, Oxford University Press, 2014.
2. Organic Spectroscopy, William Kemp, 2nd edition, Macmillan publishers, 2019.
3. Advanced Inorganic Chemistry, F. Albert Cotton, Geoffrey Wilkinson, Carlos A. Murillo and Manfred Bochmann, 6th Edition, 1988.
4. Physical Chemistry, P. Atkins and Julio de Paula, 8th Edition, Freeman & Co. 2017.
5. A Textbook of Engineering Chemistry, Shashi Chawla, 2017.
6. Polymer Science and Technology, Premamoy Ghosh, 3rd edition, McGraw-Hill, 2010.

EE101	Elements of Electrical Engineering	ESC	2-0-0	2 Credits

Detailed Syllabus

Basic Concepts

Electric Charge, Current and Electromotive force, Potential and Potential Difference; Electrical Power and Energy; Ohm's Law, Resistance, Capacitance and Inductance, Series and Parallel Connection of Resistances and Capacitances, Kirchoff's Laws and Their Applications

AC Fundamentals:

Concept of Alternating Voltage and Current, RMS and Average Values, Single Phase and Three Phase Supply; 3-ph Star-Delta connections, Alternating Voltage applied to Pure Resistance, Inductance, Capacitance and their combinations, Concept of Power and Power Factor in AC Circuit.

Measuring Instruments:

Principle and Construction of Instruments used for Measuring Current, Voltage, Power and Energy, Methods and precautions in use of these.

Electromagnetic Induction:

Concept of Magnetic Field, Magnetic Flux, Reluctance, Magneto Motive Force (MMF), Permeability; Self and Mutual Induction, Basic Electromagnetic laws, various losses in magnetic circuits;

Electrical Machines:

Elementary concepts of an electrical machine, Basic principle of a motor and a generator, Classification of Electrical machines; Principles, Construction and Working of a machine; Starters: Need, Construction and Operation; Transformer: Classification, Principles, Construction and Working of a Transformer, Applications of Transformers;

Utilization of Electricity:

Utilization concepts of Electricity for electrolysis process, Electrochemical Cells & Batteries; Application of Electricity, Energy Conversation and Efficiency

Basic Troubleshooting:

Basic Testing and faults diagnosis in electrical systems, various tools and their applications, replacement of different passive components.

Electrical Safety:

Electrical Shock and Precautions against it, Treatment of Electric Shock; Concept of Fuses and Their Classification, Selection and Application; Concept of Earthing.

Reading:

1. Edward Hughes, Electrical & Electronic Technology, Pearson, 12 th Edition, 2016.

2. Vincent Del Toro, Electrical Engineering Fundamentals, Pearson, 2 nd Edition, 2015.

3. V N Mittle and Arvind Mittal, Basic Electrical Engineering, Tata McGraw Hill, 2nd Edition, 2005.

4. E. Openshaw Taylor, Utilization of Electrical Energy, Orient Longman, 2010.

5. B.L.Theraja , Fundamentals of Electrical Engineering and Electronics volume -I, S Chand & Company 2005.

6. Ashfaq Husain, Fundamentals of Electrical Engineering, Dhanpat Rai & Sons 4 th edition, 2010.

7. H.Partab: Art & Science of Utilization of Electric Energy, Dhanpat Rai & Sons, 1998.

8. Fundamentals of Electrical Circuits by Charles k.Alexander, Mattew N.O.Saidiku, Tata McGraw Hill company.

BT101	BIOLOGY FOR ENGINEERS	ESC	2-0-0	2 Credits

Pre-requisites: None

Detailed Syllabus:

Importance of biology to engineers, Molecules of life: Water and Carbon, Evolution and origin of life, Darwins theory, Diversity of life, Chemical basis of life, Nucleic acids, Amino acids and Proteins, Carbohydrates, Lipids and Membranes.

Cell structure and function:

Prokaryotic, Eukaryotic cell and Virus, Sub cellular organelles and their functions, Regulation of cellular metabolism: Cellular respiration and Fermentation, Photosynthesis, Cell division (differences between mitosis and meiosis), Mendel's Law and Patterns of inheritance.

Gene structure and expression

Difference between prokaryotic and eukaryotic gene structure, DNA replication, Transcription, RNA processing and Translation, Control of gene expression (lac operon).

Applications of Biology in Engineering

Genetic engineering (microbe, plant and animal cells for improvement), Industrial Biotechnology (Primary and Secondary metabolites), Environmental engineering, Biopharmaceuticals, Tissue engineering, Biomaterials, Stem cell engineering, Biosensors, Bioinformatics.

Reading:

1. Quillin, Allison Scott Freeman, Kim Quillin and Lizabeth Allison, Biological Science, Pearson Education India, 2016.

2. Reinhard Renneberg, Viola Berkling and Vanya Loroch, Biotechnology for Beginners, Academic Press, 2017.

ME101	Basics of Mechanical Engineering	ESC	2-0-0	2 Credits

Detailed Syllabus:

Evolution of Mechanical Engineering: Introduction, Definition and scope of Mechanical Engineering, relation of Mechanical Engineering with other Engineering Disciplines, Revolutionary Inventions in wheels, tools, windmills, steam engine, CNC machines, Rapid Prototyping, Air-conditioning and Refrigeration, History of Mechanics, Thermodynamics and Heat Transfer, Production and Industrial Engineering, Mechatronics.

Engineering Materials: Introduction to Engineering Materials, Classification and Properties, Alloys. Composites, Micro and Nano Materials.

Manufacturing Processes: Castings - Patterns & Moulding, Metal forming, Hot Working and Cold Working Extrusion, Drawing, Rolling, Forging. Welding - Arc Welding & Gas Welding, Soldering, Brazing. Introduction to Machining processes – Lathe, Milling, Shaping, Drilling, Grinding, Introduction to NC/CNC Machines, 3D Printing.

Power Transmission: Transmission of Power, Belt Drives, Gears and Gear Trains - Simple Problems, **Fasteners and Bearings:** Fasteners - Types and Applications, Bearings - Types and Selection,

Thermodynamics: Introduction to Energy Sources - Thermodynamics - System, State, Properties, Thermodynamic Equilibrium, Process & Cycle, Zeroth law of Thermodynamics, Work & Heat, First law - Cyclic process, Change of State, Cp, Cv, Limitations of First law, Thermal Reservoirs, Heat Engine, Heat Pump/Refrigerator, Efficiency/COP, Second law, PMM2, Carnot Cycle, Entropy - T-S and P-V diagrams.

Introduction to Steam Turbines and I.C. Engines: I.C. Engines: 2-Stroke & 4-Stroke Engines, P-v Diagram; S.I. Engine, C.I. Engine, Differences.

Introduction to Heat Transfer and Refrigeration: Vapor Compression Refrigeration Cycle - Refrigerants, Desirable Properties of Refrigerants. Modes of Heat Transfer, Thermal Resistance Concept, Composite Walls & Cylinders, and Overall Heat Transfer Coefficient – problems.

Reading:

1. Dixit, U.S., Hazarika, M. and Davim, J.P, A Brief History of Mechanical Engineering, Springer, 2017.
2. M.L. Mathur, F.S. Mehta and R.P. Tiwari, R.S. Vaishwnar, Elements of Mechanical Engineering, Jain Brothers, New Delhi, 2008.
3. Praveen Kumar, Basic Mechanical Engineering, Pearson Education, India, 2013.
4. P.N. Gupta, M.P. Poonia, Elements of Mechanical Engineering, Standard Publishers, 2004.
5. C.P. Gupta, Rajendra Prakash, Engineering Heat Transfer, NemChand Brothers, New Delhi, 1994.
6. B.S. Raghuvanshi, Workshop Technology, Vol. 1&2, Dhanpath Rai & Sons, New Delhi, 1989.

CE101	Engineering Mechanics	ESC	2-0-0	2 Credits

Prerequisites: None

Detailed syllabus:

Introduction - Specification of force vector, Formation of Force Vectors, Moment of Force – Cross product – Problems, Resultant of a general force system in space,

Equillibrium of force system- Degrees of freedom - Equilibrium Equations, Degree of Constraints – Free body diagrams.

Coplanar Force Systems - Introduction – Equilibrium equations – All systems, Problems

Coplanar Concurrent force system, Coplanar Parallel force system, Coplanar General force system – Point of action, Method of joints, Method of sections, Method of members.

Friction in rigid bodies- Friction – Coulombs laws of dry friction – Limiting friction, Problems on Wedge friction, Belt Friction-problems.

Centroid & Moment of Inertia - Centroid and M.I – Arial – Radius of Gyration, Parallel axis– Perpendicular axis theorem – Simple Problems.

Dynamics of Particles – Introduction to kinematics- Equations of rectilinear motion, D'Alembert's principle -Simple problems- Introduction to kinetics- Work and Energy.

Reading:

1. J.L.Meriam, L.G. Kraige, Engineering Mechanics, Statics, John Wiley &Sons,7th Edition, 2012.
2. A.K. Tayal, Engineering Mechanics, Umesh Publications, 14th Edition, 2010.
3. S S Bhavikatti and K G Rajashekarappa, Engineering Mechanics, New Age International Publication, 4th Edition.

Reference:

1. Dietmar Gross, Werner Hauger, Jorg Schroder, Wolfgang A. Wall, Nimal Rajapakse, Engineering Mechanics 1, Statics, Springer, 2nd Edition, 2013.

S. Timoshenko, D.H. Young, Pati Sukumar, J V Rao, Engineering Mechanics, Mc-Graw Hill, 5th Edition.

ME103	Workshop Practice	SD	0-1-2	2 Credits

Detailed Syllabus:

Fitting Shop: Preparation of T-Shape Work piece as per the given specifications, Preparation of U-Shape Work piece which contains: Filing, Sawing, Drilling, Grinding, and Practice marking operations.

Machine shop: Study of machine tools in particular Lathe machine (different parts, different operations, study of cutting tools), Demonstration of different operations on Lathe machine, Practice of Facing, Plane Turning, step turning, taper turning, knurling and parting and Study of Quick return mechanism of Shaping operation. Demonstration of the working of CNC and 3D Printing Machines.

Power Tools: Study of different hand operated power tools, uses and their demonstration and Practice of Power tools.

Carpentry: Study of Carpentry Tools, Equipment and different joints, Practice of Cross Half lap joint, half lap Dovetail joint and Mortise Tenon Joint.

Welding: Study of welding tools and welding equipment, Arc Welding Practice (Lap and Butt joint).

CY102	Engineering Chemistry Lab	BSC	0-0-2	2 Credits

List of experiments (any eight of the following):

Exp. No	Name of the experiment
1	Standardization of $KMnO_4$ solution
2	Determination of Iron in Haematite
3	Determination of Hardness of Water
4	Determination of available chlorine in bleaching powder and of iodine in Iodized salt
5	pH-metric titration of an acid vs a base
6	Conductometric titration of an acid vs a base
7	Potentiometric titration of Fe^{2+} against $K_2Cr_2O_7$
8	Colorimetric determination of Potassium Permanganate
9	Determination of rate of Corrosion of mild steel in acidic environment in the absence of presence of an inhibitor
10	Determination of Chlorophyll in Olive oil by using UV and Fluorescence spectroscopic techniques
11	Functional group analysis of organic compounds by using IR spectroscopic technique
12	Organic solvent evaporation by using rotary-evaporation technique

Virtual labs

1. Determination of unknown concentration of analyte by using the Beer-Lambert's law.
2. Identification of unknown components using spectroscopic techniques.
3. Nuclear magnetic resonance spectroscopy and evolution of simple ^1H NMR spectra of organic compounds
4. Study of kinetics of a reaction by using spectrophotometric methods.

Reference books:

1. Charles Corwin, Introductory Chemistry laboratory manual: Concepts and Critical Thinking, Pearson Education, 2012.
2. David Collins, Investigating Chemistry: Laboratory Manual, Freeman & Co., 1st Edition, 2006.

II Year B.Tech. Chemical Engineering Courses offered by Ch.ED

MA202	Complex Variables and Transform Methods	BSC	3 - 0 - 0	3 Credits

Pre-requisites: Differential & Integral Calculus (MA101), Matrices & Differential Equations (MA151).

Course Outcomes: At the end of the course, student will be able to:

CO1	Understand and use of complex variables and evaluation of real integrals
CO2	Obtain the Fourier series for a given function
CO3	Find the Fourier transform of a function and Z- transform of a sequence
CO4	Determine the solution of a PDE by variable separable method

Mapping of course outcomes with program outcomes

CO \ PO	1	2	3	4	5	6	7	8	9	10	11	12	PSO1	PSO2	PSO3
CO1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2

Detailed Syllabus:

Complex Variables: Analytic function - Cauchy Riemann equations - Harmonic functions - Conjugate functions - complex integration - line integrals in complex plane - Cauchy's theorem (simple proof only), Cauchy's integral formula - Taylor's and Laurent's series expansions - zeros and singularities - Residues - residue theorem, use of residue theorem to evaluate the real integrals without poles on the x-axis. (16)

Fourier Series: Expansion of a function in Fourier series for a given range - Half range sine and cosine expansions. (6)

Fourier Transforms: Fourier transformation and inverse transforms - sine, cosine transformations and inverse transforms - simple illustrations. (6)

Z-transforms: Z- transform and Inverse Z-transforms – Properties – convolution theorem- simple illustrations. (6)

Partial Differential Equations: Method of separation of variables - Solution of one dimensional wave equation, one dimensional heat conduction equation and two dimensional steady state heat conduction equation with illustrations. (8)

Text Books:

1. R.K. Jain and S.R.K. Iyengar, *Advanced Engineering Mathematics,* Narosa Publishing House, 5th edition, 2016.
2. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 8th edition, 2008.
3. B.S. Grewal, *Higher Engineering Mathematics*, Khanna Publications,44th edition, 2017.

Reference Books:

1. M. Spiegel, S. Lipschutz , J. Schiller, and D. Spellman, *Complex Variable (Schaum's Outlines)*, Revised 2nd edition, 2017.

CY201	Industrial Organic Chemistry	BSC	3 – 0 – 0	3 Credits

Pre-requisites: CY101-Chemistry
Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the reactivity of the intermediates, hydrocarbon chemistry, importance of functional group transformations.
CO2	Differentiate the structure and properties of biomolecules, polymers and heterocyclic compounds
CO3	Identify the role of chemical engineer in modern drug discovery programs
CO4	Separate the racemic mixtures using resolution methods.
CO5	Elucidate the structure of organic compounds (small molecules) using spectroscopic methods.

Course Articulation Matrix:

POCO	1	2	3	4	5	6	7	8	9	10	11	12	PSO1	PSO2	PSO3
CO1	3	3	2	1	2	1	1	1	1	1	-	2	3	2	1
CO2	3	3	2	1	2	1	1	1	1	1	-	2	3	2	1
CO3	1	2	1	2	2	3	3	2	1	1	1	2	2	1	1
CO4	2	2	2	1	3	1	1	1	1	1	-	2	3	2	1
CO5	2	2	2	1	3	1	1	1	1	1	-	2	3	2	1

Detailed Syllabus:

Reactivity of organic compounds: Generation and reactions of: carbenes, nitrenes and benzyne, reactions and properties of: alkane, alkene, alkyne, alkyl halides, alcohols, ethers, carbonyl compounds, carboxylic acids, nitro compounds and nitriles, functional group transformations. Chemistry of heterocyclic compounds: Preparation and properties of furan, pyrrole, thiophene, pyridine, indole, quinoline and isoquinoline.

2. Stereochemistry: Introduction to stereochemistry, isomerism, chirality, optical activity, D, L and R, S-nomenclature, enantiomers, diastereomers, meso compounds, conformational analysis of cyclohexane and its derivatives, racemization and resolution techniques.

3. Introduction to drug discovery: Synthesis of drugs (a) Antipyretics-Paracetamol, (b) Anti-inflammatory drugs-Ibuprofen, (c) Antibiotics-Penicillin, (d) Antimalarial drugs-Quinine, (e) Anticancer drugs and (f) Antihypertensive drugs.

4. Separation techniques for organic compounds: Chromatographic techniques: column chromatography, thin-layer chromatography, gas chromatography, size exclusion chromatography, Gel permeation chromatography and electrophoresis method.

5. Recent techniques in organic synthesis: Use of alternative reaction media (use of water, ionic liquids), alternative energy sources (microwave, sonication) for organic reactions, catalysis, homogeneous and heterogeneous catalysis, combinatorial chemistry.

Text Reference:

1. Francis A. Carey, Organic Chemistry, Tata McGraw Hill Publishing Company Limited, 5th Edition, 2007.
2. John A. Joule, Heterocyclic Chemistry, 5th Edition, 2010
3. E. Eliel, Stereochemistry of carbon compounds, John Wiley & Sons, Inc., 2009.
4. Mike Lancaster, Green Chemistry, Royal Society of Chemistry, 2002.
5. Clifton E. Meloan, Chemical Separations: Principles, Techniques and Experiments, Wiley-Interscience, 1999.

CH201	Chemical Process Calculations	PCC	3 – 1 – 0	4 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understanding of the material and energy balances (steady and unsteady states) of chemical processes
CO2	Perform material and energy balances on chemical processes/equipment without and with reactions.
CO3	Solve the problems involving recycle, purge and bypass in a process or unit
CO4	Understand the vapour-liquid equilibrium concepts and calculations
CO5	Learn to Draw the process flow diagram

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	-	3	-	2	-	-	-	-	-	-	-	3	2	3
CO2	3	-	3	-	3	-	-	-	-	-	-	-	3	3	3
CO3	3	-	3	-	3	-	-	-	-	-	-	-	3	2	3
CO4	3	1	3	-	2	-	-	-	-	-	-	-	2	3	2
CO5	2	2	3	1	1	-	-	-	-	-	-	-	3	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

Introduction to chemical engineering calculations: units and dimensions - conversion of units, fundamental concepts of stoichiometry.

Steady state material balance: material balances: basic material balance principles, material balance problems without and with chemical reactions (species and elemental balances, combustion of fuels, recycle, bypass and purge.

Ideal gas law, real gas relationships, vapour pressure, vapor-liquid equilibrium calculations, partial saturation & humidity, humidity chart, bubble point and dew point calculations.

Steady state energy balances: heat capacity, calculation of enthalpy changes, energy balances without chemical reactions, enthalpy changes of phase changes, heat of solution and mixing, energy balances accounting for chemical reactions - standard heat

of reaction, formation and combustion, Hess Law, effect of temperature, adiabatic flame temperature.
Flow sheeting (block diagram) and solutions to mass and energy balances of integrated process.
Unsteady state material and energy balances.

Readings:

1. Himmelblau. D.H and James B. Riggs, Basic Principles and Calculations in Chemical Engineering, 8th Edition, Prentice Hall, 2012.
2. Hougen. O.A., Watson. K.M. and Ragatz. R.A., Chemical Process Principles (Part-I): Material and Energy Balances, 2nd Edition, CBS Publishers, 2004.
3. Bhatt, B.I. and Thakore S.M., Stoichiometry, 5th Edition, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2010.

CH202	Fluid Mechanics	PCC	3 – 1 – 0	4 Credits

Pre-requisites: MA151-Matrices and Differential Equations, CE101-Engineering Mechanics.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the basic concepts of fluid mechanics and statics.
CO2	Solve problems related to conservation equations, dimensional analysis and equations of motion.
CO3	Analyse the motion of fluid flow in laminar and turbulent conditions.
CO4	Enunciate the flow through fluidized beds and pipes and its transportation.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	2	-	-	-	-	-	-	-	-	3	1	1
CO2	3	2	1	3	-	-	-	-	-	-	-	-	3	2	2
CO3	3	3	1	3	-	-	-	-	-	-	-	-	3	1	1
CO4	3	2	1	2	-	-	-	-	-	-	-	-	3	1	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

Introduction and Fundamental Concepts: Definitions of stress and fluid, Distinction between a solid and a fluid, Fluid properties, Unit systems.

Fluid Statics: Nature of Fluids, Forces on Fluid Elements, Normal Stresses in a Stationary Fluid, Fundamental Equation of Fluid Statics, Pressure Measurement, Buoyancy.

Kinematics of Fluid: Scalar and Vector Fields, Flow Field and Description of Fluid Motion, Existence of Flow.

Conservation Equations and Analysis of Finite Control Volumes: System, The Continuity Equation, Conservation of Momentum: Momentum Theorem, Analysis of Finite Control Volumes, Euler's Equation: The Equation of Motion for an Ideal Flow, Conservation of Energy.

Applications of Equations of Motion and Mechanical Energy: Bernoulli's Equation in Irrotational Flow, Steady Flow Along Curved Streamlines, Measurement of Flow Rate Through Pipe, Flow Through Orifices and Mouthpieces.

Principles of Physical Similarity and Dimensional Analysis: Concept and Types of Physical Similarity, The Application of Dynamic Similarity, Dimensional Analysis.

Viscous Incompressible Flows: Navier-Stokes Equations, Low Reynolds Number Flow.

Laminar Boundary Layers: Boundary Layer Equations, Blasius Flow Over a Flat Plate, Wall Shear and Boundary Layer Thickness, Momentum-Integral Equations for Boundary Layer, Separation of Boundary Layer.

Turbulent Flow: Characteristics of Turbulent Flow, Laminar-Turbulent Transition, Mean Motion and Fluctuations, Universal Velocity Distribution Law, Skin Friction Coefficient for Boundary Layers on a Flat Plate.

Applications of Viscous Flows Through Pipes: Concept of Friction Factor in a Pipe Flow, Variation of Friction Factor, Concept of Flow Potential and Flow Resistance, Flow through Branched Pipes, Losses in Pipe Bends, Losses in Pipe Fittings.

Flow Past Immersed Bodies: Friction in flow through beds of solids, Motion of particles through fluids, Fluidization.

Transportation of fluids: Positive displacement pumps and centrifugal pumps, fans, blowers, and compressors.

Readings:

1. McCabe W. L., Jullian Smith C. and Peter Harriott - Unit Operations of Chemical Engineering, McGraw-Hill international edition, 7th Edition, 2005.
2. Coulson J.M, Richardson. J.F, Chemical Engineering Volume I and II, Elsevier India, 5th Edition, 2006.
3. De Nevers N H- Fluid Mechanics for Chemical Engineers, McGraw Hill, NY, 3rd Edition, 2004.
4. Wilkes James O., Fluid Mechanics for Chemical Engineers, Prentice Hall, 3rd Edition, 2017.
5. Som S. K., Biswas G., Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw-Hill Education, 2nd Edition, 2003.

CH203	Mechanical Operations	PCC	3 – 1 – 0	4 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the role of mechanical unit operations in chemical industries
CO2	Select suitable size reduction equipment based on performance and power requirement.
CO3	Analyze particle size distribution of solids and solid conveying methods
CO4	Evaluate solid-fluid separation equipment.
CO5	Determine the power required for agitation, blending and mixing

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	-	-	-	-	-	-	-	-	-	3	1	1
CO2	1	1	3	2	-	-	-	-	-	-	-	-	3	2	-
CO3	2	2	3	2	-	-	-	-	-	-	-	-	2	2	-
CO4	3	2	2	2	-	1	2	-	-	-	-	-	2	3	1
CO5	2	2	1	2	-	1	-	-	-	-	-	-	2	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

Introduction: Unit operations and their role in chemical industries; Types of mechanical operations.

Properties and handling of particulate solids: Characterization of solid particles, Properties of masses of particles, Storage of solids, mixing of solids.

Handling of solids, Bulk solids, Conveyers-Belt conveyors, Screw conveyor, Chain and Flight conveyors, Bucket Elevators, Pneumatic conveyors.

Size reduction, Mechanism of Size reduction, Crushing Efficiency, Energy and power requirement, crushing laws, Size reduction equipments.

Screening: Screening equipment, Screen analysis, Standard screens, Capacity and effectiveness of screen, Ideal and actual screens, Screening Equipment.

Classification of solid particles, Liquid clarification, Magnetic Separation, Floatation, Sedimentation, Cyclone Separator.

Filtration: Cake filters, Centrifugal filters, Filter media, Principles of cake filtration, Washing filter cakes. Clarifying filters, Liquid clarification, Principles of clarification. Cross flow filtration, Types of membranes, Permeate flux for ultrafiltration, Concentration polarization, Applications of ultrafiltration, Diafiltration, Microfiltration.

Agitation and mixing of liquids: Agitated vessels, Blending and mixing, Suspension of solid particles, Dispersion operations, Agitator selection and scaleup, Power Number, Mixing Index.

Readings:

1. McCabe W. L., Jullian Smith C. and Peter Harriott - Unit Operations of Chemical Engineering, 7th Edition, McGraw-Hill international Edition, 2005.
2. Coulson J.M., Richardson J.F, Chemical Engineering, Vol. II, 4th Edition, Elsevier India, 2006.
3. Alan S. Foust, Leonard A. Wenzel, Curtis W. Clump, Louis Maus, L. Bryce Andersen, Principles of Unit Operations, Wiley, 2nd Edition, 2008.
4. Walter L. Badger, Julius T. Banchero, Introduction to Chemical Engineering, Tata McGraw Hill Edition, 2001.
5. Christie John Geankoplis, Transport Processes and Separation Process Principles (Includes Unit Operations), Prentice Hall India Learning Private Limited, 4th Edition, 2004.

CH204	Fluid Mechanics Laboratory	PCC	0 – 0 – 2	1 Credit

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determine properties of fluid and flow.
CO2	Apply Bernoulli's theorem and Stokes law to fluid and fluid-solid systems.
CO3	Determine the characteristics of various flow meters.
CO4	Determine the characteristics of packed and fluidized beds and centrifugal pump.
CO5	Calculate pressure drop across pipes, valves and fittings.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	-	3	-	-	-	-	2	3	2	-	3	2	1
CO2	3	1	-	3	-	-	-	-	2	3	2	-	3	2	1
CO3	3	1	-	3	-	-	-	-	2	3	2	-	3	2	1
CO4	3	1	-	3	-	-	-	-	2	3	2	-	3	2	1
CO5	3	1	-	3	-	-	-		-2	3	2	-	3	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus (List of Experiments)

1. Determination of viscosity on laminar and turbulent flow.
2. Distinguish between laminar and turbulent flow using Reynolds Experiment.
3. Verification of Bernoulli's theorem experimentally.
4. Determination of losses in pipes.
5. Determination of drag coefficient.
6. Study the characteristics of a packed bed.

7 Measurement of point velocity and determination of velocity profile using pitot tube.

8. Determination of discharge coefficients of orifice and venturi meters.
9. Study the characteristics of fluidized bed.
10. Flow through an open channel by weirs and notches
11. Determination of pressure drop in flow through non-circular pipes.
12. Flow through nozzles.
13. Study the characteristics of a centrifugal pump.

Readings:

1. Laboratory Manuals.
2. McCabe W. L., Jullian Smith C. and Peter Harriott - Unit operations of Chemical Engineering,7th Edition, McGraw-Hill International Edition, 2005.
3. Coulson J.M and Richardson. J.F, Chemical Engineering Volume I and II, 5th Edition, Elsevier India, 2006.
4. De Nevers N H- Fluid Mechanics for Chemical Engineers,3rd Edition, McGraw Hill, NY, 2004.

CH205	Mechanical Operations Laboratory	PCC	0 – 0 – 2	1 Credit

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Select suitable methods for size reduction of minerals or other intermediates
CO2	Calculate the reduction ratio and product crushing efficiency of ball mill
CO3	Evaluate suitable mechanical separations of powders, solid-liquid and solid-gas mixtures
CO4	Calculate the filtration area, cake resistance and membrane resistance of filter
CO5	Acquaint with theories of sedimentation and to study settling characteristics of batch settling

Course Articulation Matrix

	PO 1	P O2	P O3	P O4	P O5	P O6	P O7	P O8	P O9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	2	3	-	-	-	-	-	-	-	-	-	1	3	3
CO2	2	3	2	-	-	-	-	-	-	-	-	-	3	1	3
CO3	3	2	3	2	1	-	-	-	-	-	-	-	3	2	3
CO4	2	1	2	1	-	-	-	-	-	-	-	-	2	1	3
CO5	3	2	3	1	-	1	-	-	-	-	-	-	3	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

List of experiments:

1. Measurement of particle size distribution by sieve analysis.
2. Measurement of effectiveness of vibrating screen.
3. Measurement of crushing efficiency of Jaw crusher.
4. Finding the critical speed and crushing efficiency of Ball Mill.
5. Study the operation of Sigma Mixer
6. Study of constant pressure filtration and washing of cake in a plate and frame filter press
7. Operation of a Cyclone separator.
8. Study the batch Sedimentation Process.

Readings: Lab manuals

MA251	Numerical and Statistical Methods	BSC	3– 0 – 0	3 Credits

Pre-requisites: Differential & Integral Calculus (MA101), Matrices & Differential Equations (MA151).

Course Outcomes: At the end of the course, student will be able to:

CO1	Interpret an experimental data using interpolation / curve fitting
CO2	Solve numerically algebraic/transcendental and ordinary differential equations
CO3	Provides a solid foundation about the concept of probability and its features
CO4	Provide the idea of important results used in statistical Inference

Mapping of course outcomes with program outcomes

POCO	1	2	3	4	5	6	7	8	9	10	11	12	PSO1	PSO2	PSO3
CO1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2

Numerical Methods:
Curve fitting by the method of least squares. Fitting of (i) Straight line (ii) Second degree parabola (iii) Exponential curves - Gauss-Seidal iteration method to solve a system of equations -Numerical solution of algebraic and transcendental equations by Regula-Falsi method and Newton-Raphson's method - Lagrange interpolation, Forward and backward differences, Newton's forward and backward interpolation formulae - Numerical differentiation with forward and backward differences - Numerical Integration with Trapezoidal rule, Simpson's 1/3 rule and Simpson's 3/8 rule - Taylor series method, Euler's method, modified Euler's method, 4th order Runge-Kutta method for solving first order ordinary differential equations. (21)

Probability and Statistics: Random variables, discrete and continuous random variables, Mean and variance of Binomial, Poisson and Normal distributions and applications. Testing of Hypothesis – Null and alternate hypothesis, level of significance and critical region - Z-test for single mean and difference of means, single proportion and difference of proportions - t-test for single mean and difference of means - F-test for comparison of variances, Chi-square test for goodness of fit - Karl Pearson coefficient of correlation, lines of regression and examples. (21)

Text books:

1. M. K. Jain, S. R. K.Iyengar and R. K. Jain, *Numerical methods for Scientific and Engineering Computation*, New Age International Publications, 2008.
2. S. C. Gupta and V. K. Kapoor, *Fundamentals of Mathematical Statistics*, S.Chand & Co, 2006.
3. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 8th Edition, 2008.
4. B. S. Grewal, *Higher Engineering Mathematics*, Khanna Publications, 2009.

CH251	Heat Transfer	PCC	3 – 1 – 0	4 Credits

Pre-requisites: CH201 Chemical Process Calculations, CH202 Fluid and Particle Mechanics.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the modes of heat transfer.
CO2	Calculate heat transfer coefficients for forced and natural convection.
CO3	Perform heat transfer calculations involving phase changes.
CO4	Analyze the heat exchanger performance for co-current and counter-current flows.
CO5	Design double pipe and shell & tube heat exchangers.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2
CO2	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2
CO3	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2
CO4	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2
CO5	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

Introduction: Modes of heat transfer, material properties of importance in heat transfer.

Heat Transfer by Conduction in Solids & Principles of heat flow in fluids: Steady state heat conduction; Conduction through bodies in series; unsteady state heat conduction; Concept of heat transfer coefficient; Individual and overall heat transfer coefficient; Concept of fins; Critical insulation thickness.

Heat Transfer to fluids without phase change: Principle of convection; Concept of Boundary layers; Heat transfer by forced convection in laminar flow; Turbulent flow and transition region; Heat transfer to liquid metals; Forced convection on outside tubes; Natural convection; Momentum and heat transfer analogies.

Heat Transfer to fluids with phase change: Heat transfer from condensing vapors; Heat transfer to boiling liquids.

Radiation Heat Transfer: Concepts of radiation; Laws of radiation; Radiation between black surfaces; Interchange factor; Exchange of energy between parallel planes and concentric cylinders/spheres.

Heat Exchange equipment: Heat Exchangers; Condensers and Boilers; Shell and Tube Heat Exchangers; Other types of Heat Exchangers; Preliminary Design of Heat Exchangers; Effectiveness-NTU Method.

Evaporation: Basics of evaporation; Performance of tubular evaporators; Capacity & Economy; Multiple effect evaporator; Principles of Crystallization; Crystallization equipment; single and multiple effect evaporators.

Readings:

1. McCabe W.L., Smith J.C., Harriott P., Unit Operations of Chemical Engineering, 7th Edition, McGraw Hill, 2005.
2. Holman J. P, Heat Transfer, 10th Edition, McGraw Hill, New York, 2010.
3. Ozisik N, Heat Transfer: A Basic Approach, Vol. 1, McGraw Hill, 1985.
4. Cengel Y. A, Heat Transfer: A Practical Approach, 2nd Edition, McGraw Hill, 2003.
5. Kern D. Q., Process Heat Transfer, Tata McGraw Hill Education Pvt. Ltd., 2001.
6. Serth R.W, Process Heat Transfer: Principles, Applications and Rules of Thumb, 2nd Edition, Academic Press, 2014.
7. Frank P. Incropera, Theodore L. Bergman, David P. DeWitt, Bergmann, Adrienne S. Lavine, Fundamentals of Heat and Mass Transfer, John Wiley & Sons, 7th Edition, 2013.

CH252	Chemical Engineering Thermodynamics - I	PCC	3 – 1 – 0	4 Credits

Pre-requisites: ME101 Basic Mechanical Engineering

Course Outcomes: At the end of the course, the student will be able to:

CO1	Provide a fundamental overview of the thermodynamic laws and its application
CO2	Compute the properties of ideal and real gas mixtures.
CO3	Evaluate the efficiency of expansion and compression flow processes.
CO4	Estimate heat and work requirements for industrial processes.
CO5	Analyze refrigeration and liquefaction processes.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	-	-	-	-	-	-	-	-	-	1	3	3
CO2	3	2	3	2	1	-	-	-	-	-	-	-	3	2	3
CO3	2	1	2	1	-	-	-	-	-	-	-	-	2	1	3
CO4	3	2	3	1	-	1	-	-	-	-	-	-	3	1	2
CO5	2	2	3	1	1	-	-	-	-	-	-	-	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

Definitions and fundamental concepts, property, Energy, Work, Zeroth law of thermodynamics, First Law: energy balance in open, closed, and isolated systems; Steady state and transient processes; Heat effects – sensible, temperature dependence, latent heat, heat of reaction, heat of formation, heat of combustion, temperature dependence of heat of reaction.

Second law: Statements of the Second Law, Heat Engines, Thermodynamic Temperature Scales, Entropy, Entropy Changes of an Ideal Gas, Mathematical Statement of the Second Law, reversible and irreversible processes; Entropy balance for open, closed, and isolated systems; Third law: molecular basis for zero entropy at zero temperature.

Properties of pure fluids: phase diagrams, equations of state, compressibility factor, generalized correlations, residual properties, equations of state for liquids; Ideal gas and real fluids: cubic equations; departure functions; Relationship among thermodynamic

functions: fundamental relationships between thermodynamic properties; Maxwell's equations; Thermodynamic property calculations.
Thermodynamics of fluid flow and devices: expansion and compression of fluids; turbines, tubes, throttling, nozzles, pumps; Thermodynamics of energy conversion: power production (e.g. Carnot cycle; Rankine cycle, internal combustion engine; diesel engine); Refrigeration and liquefaction: Carnot and actual cycles; vapor compression and absorption; refrigerants; liquefaction of gases. Refrigeration and Liquefaction: Carnot Refrigerator, Vapor-Compression Cycle, Choice of Refrigerant, Absorption Refrigeration, Heat Pump, Liquefaction Processes.

Readings:

1. Smith J. M, H. C. Van Ness and M. M. Abbott, Introduction to Chemical Engineering Thermodynamics, McGraw-Hill, 7th Edition, 2004.
2. S.I. Sandler, Chemical, Biochemical and Engineering Thermodynamics, 4th Edn, Wiley India, 2006.
3. K. V. Narayanan, Chemical Engineering Thermodynamics, Prentice Hall of India Pvt. Ltd., 2009.
4. Milo D. Koretsky, Engineering and Chemical Thermodynamics, Wiley, 2009.

CH253	Chemical Reaction Engineering - I	PCC	3 – 1 – 0	4 Credits

Pre-requisites: CH201-Chemical Process Calculations

Course Outcomes: At the end of the course, the student will be able to:

CO1	Derive the rate law for non-elementary chemical reactions.
CO2	Determine the kinetics of chemical reaction using integral, differential and fractional life methods.
CO3	Design reactors for homogenous reactions under isothermal and non-isothermal conditions.
CO4	Select optimal sequence in multiple reactor systems
CO5	Analyze the performance of non-ideal reactors

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	-	-	-	-	-	-	-	-	3	2	1
CO2	3	2	1	1	-	-	-	-	-	-	-	-	3	2	1
CO3	3	3	2	1	-	-	-	-	-	-	-	-	3	2	2
CO4	3	3	2	1	-	-	-	-	-	-	-	-	3	2	3
CO5	3	3	2	1	-	-	-	-	-	-	-	-	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

Kinetics of Homogeneous Reactions: Concentration-dependent term of a rate equation, Temperature-dependent term of a rate equation, Searching for a mechanism, Predictability of reaction rate from theory.

Conversion and Reactor Sizing: Definition of conversion, Batch reactor design equations, Design equations for flow reactors, Applications of the design equations for continuous-flow reactors, Reactors in series.

Analysis of Rate Data: The Algorithm for data analysis, Interpretation of batch reactor data, Method of initial rates, Method of half-lives.

Isothermal Reactor Design: Mole balances in terms of conversion, Design of continuous stirred tank reactors (CSTRs), Tubular reactors, Mole balances written in terms of concentration and molar flow rate, Mole balances on CSTRs, PFRs, and batch reactors, Recycle reactor.

Non-Isothermal Reactor design: Energy balances, Adiabatic tubular reactor design.
RTD for Chemical Reactors: General Characteristics, Measurement of the RTD, Characteristics of the RTD, RTD in ideal reactors, Diagnostics and troubleshooting, Reactor modelling using the RTD, Zero-parameter models, RTD and multiple reactions.
Analysis of non-ideal reactors: One- parameter models, Two-parameter models, Tanks-in-Series (T-I-S) Model, Dispersion model, modelling real reactors with combinations of ideal reactors, Other models of non-ideal reactors using CSTRs and PFRs.

Readings:

1.Levenspiel O., Chemical Reaction Engineering, 3rd Edition, Wiley, 2019.
2. Fogler S.H., Elements of chemical reaction engineering. Prentice Hall, 6th Edition, 2020.
3. Ronald W. Missen, Charles A. Mims, Bradley A. Saville, Introduction to Chemical Reaction Engineering & Kinetics, Wiley, 1998.
4. E. Bruce Nauman, Chemical Reactor Design, Optimization and Scaleup, Wiley, 2nd Edition, 2008.
5. Mark E. Davis & Robert J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill, 2002.
6. Martin Schmal, Chemical Reaction Engineering: Essentials, Exercises and Examples, CRC Press, 2014
7. S. Suresh and S. Sundaramoorthy, Green Chemical Engineering: An introduction to Catalysis, Kinetics, and Chemical Processes, CRC Press, 2015.

CH254	MASS TRANSFER – I	PCC	3 – 1 – 0	4 Credits

Pre-requisites: CH201-Chemical Process Calculations, CH202- Fluid Mechanics

Course Outcomes: At the end of the course, the student will be able to:

CO1	Learn the concept of diffusion in gas, liquid & solid.
CO2	Understand the basics of interphase mass transfer.
CO3	Design equipment for gas-liquid mass transfer operations
CO4	Analyze different mass transfer operations such as absorption and Adsorption.
CO5	Calculate rate of mass transfer in humidification.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	2	2	-	-	-	-	-	-	2	2	2	1
CO2	3	3	2	2	2	-	-	-	-	-	-	2	2	2	2
CO3	3	3	2	2	2	-	-	-	-	-	-	2	2	2	2
CO4	3	3	3	2	2	2	-	-	-	-	-	2	3	2	2
CO5	3	3	3	2	2	2	-	-	-	-	-	2	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus

Introduction: Unit operations with mass transfer phenomena, Introduction to solute transport.

Fundamentals of mass transfer: Definition, Molecular and eddy diffusion, Ficks law, Diffusion in gaseous mixtures, liquid mixtures and solids, Types of solid diffusion, Pseudo steady state diffusion, measurement and calculation of diffusivities. Ordinary diffusion in multicomponent gaseous mixtures. Unsteady state Diffusion.

Inter-Phase Mass Transfer: Equilibria, Mass transfer coefficients- Individual and overall with relations, Theories of mass transfer, Analogies between momentum, heat and mass transfer to predict mass transfer coefficients.

Absorption: Solubility, theory of gas absorption, Design of absorption towers, Concept of Equilibrium and operating lines. Mass Transfer Equipments - Batch and continuous Stage wise contactors and Differential contactors, Concept of HTU and NTU, Tower packings

and packing characteristics, non-isothermal absorbers, absorption with chemical reactions.
Adsorption: Adsorption equilibria, Batch and continuous adsorption, Selection of adsorbent, Specific surface area of an adsorbent, Adsorption Dynamics, Thermal regeneration of adsorbents, Pressure swing adsorption.
Humidification Operations: Terminology and definitions, Psychrometric charts, Adiabatic operation, Equipment & components, non-adiabatic operation, Design of cooling tower.

Reading:

1. Treybal R.E., Mass Transfer Operations, 3rd Edition, McGraw Hill, 1981.
2. Geankoplis C.J., Transport processes and Separation Process Principles, 4th Edition, Prentice-Hall India, 2003.
3. Binay K. Dutta, Principles of Mass Transfer and Separation Processes, 2nd Edition, Prentice- Hall India, 2007.
4. E. L. Cussler, Diffusion – Mass transfer in fluid systems, 3rd Edition, Cambridge University Press, 2009.
5. KV Narayanan and B Lakshmikutty, Mass Transfer – Theory and Applications, CBS Publishers & Distributors Pvt. Ltd., 2014.
6. Ernest J. Henley, J.D. Seader, D. Keith Roper, Separation Process Principles, Wiley, 3rd Edition, 2011.

CH255	Heat Transfer Laboratory	PCC	0 – 0 – 2	1 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determine thermal conductivity of solids and fluids
CO2	Calculate efficiency of fins
CO3	Verify Newton's law of cooling of hot objects
CO4	Determine efficiency of Double Pipe and Shell & Tube Heat exchangers
CO5	Analyze condensation and boiling phenomena

Course Articulation Matrix

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	1	2	1	-	-	1	-	-	-	-	-	2	3	1
CO2	2	1	2	1	-	-	1	-	-	-	-	-	2	3	1
CO3	2	1	2	1	-	-	1	-	-	-	-	-	2	3	1
CO4	2	1	2	1	-	-	1	-	-	-	-	-	2	3	1
CO5	2	1	2	1	-	-	1	-	-	-	-	-	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

List of experiments:

1. Temperature Measuring Devices.
2. Determination of overall and individual plate thermal conductivity for a composite wall.
3. Heat Transfer from a Pin Fin by Natural & Forced Convection.
4. Heat Transfer in Natural Convection.
5. Determination of overall heat transfer coefficient of a shell and tube heat exchanger.
6. Determination of overall heat transfer coefficient of a double pipe heat exchanger.
7. Determination of radiation emissivity of a test plate.
8. Boiling Experimental Setup/Heat Flux.
9. Determination of characteristics of drop-wise and film-wise condensation.

Readings: Lab manuals

CH256	Chemical Reaction Engineering Laboratory	PCC	0 – 0 – 2	1 Credit

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determine the kinetics and temperature dependency of a reaction in a batch reactor, semi-batch reactor, CSTR, PFR and packed bed reactor.
CO2	Evaluate the performance of reactors through RTD studies
CO3	Compare the performance of single reactor with combination of reactors
CO4	Determine the kinetics of polymerization reaction

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	-	2	-	-	-	-	2	3	1	-	3	2	1
CO2	3	1	-	2	-	-	-	-	2	3	1	-	3	2	1
CO3	3	1	-	2	-	-	-	-	2	3	1	-	3	2	1
CO4	3	1	-	2	-	-	-	-	2	3	1	-	3	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus

1. Determination of rate constant and temperature dependency of a reaction in an isothermal batch reactor.
2. Determination of rate constant and temperature dependency of a reaction in an isothermal CSTR.
3. Determine the concentration dependency of a reaction in a semi-batch reactor (SBR).
4. Determine the concentration dependency of a reaction in a PFR.
5. Determination of rate constant in a combined reactor (PFR followed by CSTR).
6. Determination of rate constant in a Cascade CSTR (or CSTRs in series).
7. Determination of rate constant in a packed bed reactor.
8. Determination of the kinetics of polymerization reaction in a batch reactor.
9. Determination of RTD characteristics of a batch reactor.
10. Determination of RTD characteristics of a CSTR.
11. Determination of RTD characteristics of a PFR.
12. Comparison of performances of batch reactor, PFR, CSTR and packed bed reactor using chemical reactor trainer.

Readings:

1. Laboratory Manuals.
2. Levenspiel O., Chemical reaction engineering, 3rd Edition, Wiley, 2019.
3. Fogler S.H.. Elements of chemical reaction engineering. Prentice Hall, 6th Edition, 2020.

III Year B.Tech. Chemical Engineering Courses offered by Ch.ED

CH301	Chemical Engineering Thermodynamics – II	PCC	3 – 0 – 0	3 Credits

Pre-requisites: CH252-Chemical Engineering Thermodynamics – I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Calculate heat effects involved in industrial chemical processes
CO2	Determine thermodynamic properties of gaseous mixtures and solutions
CO3	Estimate Bubble-P & T, Dew-P & T for binary and multi-component systems
CO4	Calculate vapor-liquid equilibrium (VLE) composition for ideal and non-ideal systems
CO5	Determine equilibrium constant and composition of product mixture for single and multiple reactions

Course Articulation Matrix

	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
CO1	3	3	3	3	-	-	3	-	-	-	-	-	2	3	1
CO2	3	3	3	3	-	-	3	-	-	-	-	-	1	2	2
CO3	3	3	3	3	-	-	3	-	-	-	-	-	1	2	2
CO4	3	3	3	3	-	-	1	1	-	-	-	-	2	2	2
CO5	3	3	3	3	-	-	-	-	-		-	-	1	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus:

Heat Effects: Sensible Heat Effects, Temperature Dependency of Heat Capacity, Latent Heat of Pure Substance, Standard Heats of Reaction, Formation and Combustion, Heat Effects of Industrial Reactions.

Solution Thermodynamics: Fundamental Property Relation, Chemical Potential, Partial Properties, The Ideal Gas Mixture Model, Fugacity and Fugacity Coefficient, The Ideal Solution Model, Excess Properties.

Applications of Solution Thermodynamics: Liquid Phase Properties from VLE Data, Activity Coefficient, Excess Gibbs Energy, Models for The Excess Gibbs Energy, Property Changes of Mixing, Heat Effects of Mixing Process.

VLE at Low to Moderate Pressures: The Nature of Equilibrium, Criteria of Equilibrium, The Phase Rule, Duhem's Theorem, Raoult's Law, Henry's Law, Modified Raoults's Law, Dew Point and Bubble Point Calculations, Relative Volatility, Flash Calculations.

Stability of Thermodynamic Systems; Liquid-Liquid Equilibria; Vapor-Liquid-Liquid Equilibrium; Solid-Liquid Equilibria; Solid-Gas Equilibria.

Thermodynamic Properties and VLE from Equations of State.

Chemical Reaction Equilibria: The Reaction Coordinate, Equilibrium Criteria to Chemical Reactions, Gibbs Free Energy Change, Equilibrium Constant, Effect of Temperature on Equilibrium Constant, Evaluation of Equilibrium Constants, Relation of Equilibrium Constant to Composition, Equilibrium Conversions for Single Reactions, Phase Rule and Duhem's Theorem for Reacting Systems, Multi-Reaction Equilibria.

Reading List:

1. J.M. Smith, Van Ness H.C and Abbott M.M., Introduction to Chemical Engineering Thermodynamics,
   7thEdition, McGraw Hill International, 2004.
2. Y.V.C. Rao, Chemical Engineering Thermodynamics, 7thEdition. Universities Press, 1997.
3. K. V. Narayanan, Chemical Engineering Thermodynamics, Prentice Hall of India Pvt. Ltd., 2009.
4. J. M. Prausnitz, Molecular Thermodynamics of Fluid-Phase Equilibria, 3rdEdition. Pearson Education., 1998.

CH302	Chemical Reaction Engineering – II	PCC	3 – 0 – 0	3 Credits

Pre-requisites: CH253-Chemical Reaction Engineering-I, CH254-Mass Transfer-I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Derive the rate law for gas-phase reactions catalyzed by solids.
CO2	Analyze the effect of velocity, particle size and fluid properties on rate of reactionscontrolled by mass transfer
CO3	Design packed bed reactor in the absence and presence of mass transfer effects
CO4	Determine internal and overall effectiveness factors and estimate the Diffusion-and Reaction limited regimes
CO5	Design reactors for fluid-fluid reactions

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	-	1	-	-	-	-	-	-	-	3	2	1
CO2	2	2	3	-	-	-	-	-	-	-	-	-	3	3	1
CO3	3	2	2	-	-	-	-	-	-	-	-	-	3	2	1
CO4	3	2	2	1	1	-	-	-	-	-	-	-	2	1	1
CO5	2	2	3	1	1	-	-	-	-	-	-	-	3	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Catalysis and Catalytic Reactors: Catalysts, Steps in a Catalytic Reaction, Synthesizing a Rate Law, Mechanism, and Rate-Limiting Step, Heterogeneous Data Analysis for Reactor Design, Catalyst Deactivation.

External Diffusion Effects on Heterogeneous Reactions: Diffusion Fundamentals, Binary Diffusion, External Resistance to Mass Transfer, Parameter Sensitivity, Shrinking Core Model.

Diffusion and Reaction: Diffusion and Reaction in Spherical Catalyst Pellets, Internal Effectiveness Factor, Falsified Kinetics, Overall Effectiveness Factor, Estimation of Diffusion-and Reaction-Limited Regimes, Mass Transfer and Reaction in a Packed Bed, Determination of Limiting Situations from Reaction Data, Multiphase Reactors, Fluidized Bed Reactors.

Non-catalytic systems: Fluid-Fluid reactions: Kinetics, Fluid-Fluid Reactors: Design.

Reading List:

1. H. Scott Fogler, Elements of Chemical Reaction Engineering, Pearson India Education Services PrivateLimited,4thEdition,2015.
2. O. Levenspiel, Chemical Reaction Engineering, Wiley India,3rdEdition,2006.
3. J.M. Smith, Chemical Engineering Kinetics, 3rdEdition, McGrawHill,1981.
4. T.J.Carberry, Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976.

CH303	Mass Transfer - II	PCC	3 – 0 – 0	3 Credits

Pre-requisites:

CH252-Heat Transfer, CH253-Mass Transfer-I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyse VLE, LLE, and SLE data
CO2	Select a suitable mass transfer operation for a given separation
CO3	Determine number of stages in distillation, extraction and adsorption operations
CO4	Estimate the height of packed column in distillation, extraction and adsorption operations
CO5	Calculate drying rates and moisture content for batch and continuous drying operations

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2	-	-	-	-	-	-	2	2	2	1
CO2	3	2	2	2	2	-	-	-	-	-	-	2	2	2	1
CO3	3	2	3	2	2	-	-	-	-	-	-	2	3	2	1
CO4	3	2	3	2	2	-	-	-	-	-	-	2	3	2	1
CO5	3	2	2	2	2	-	-	-	-	-	-	2	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Distillation: Vapor-Liquid Equilibria, Single Stage Operation - Flash Vaporization, Differential or Simple Distillation, Continuous Rectification - Binary Systems, Multistage Tray Towers: Ponchon Savarit Method, McCabe-Thiele Method. Steam Distillation, Continuous Contact Equipment (Packed Towers), Multicomponent Systems, Extractive Distillation, Azeotropic Distillation, Hybrid Distillation.

Liquid-Liquid Extraction: Liquid-Liquid Equilibria, Extraction Equipments, Stage-Wise Contact, Design of Stage Type Extractors and Differential (Continuous Contact) Extractors: Immiscible and Partially Miscible Systems.

Drying: Equilibrium, Drying Operations - Batch Drying, Mechanism of Batch Drying and Continuous Drying, Drying Equipment.

Ion – Exchange Processes: Principles, Techniques and Applications.

Leaching: Methods of Operation and Equipment, Unsteady State and Steady State Operation

Reading List:

1. R.E. Treybal, Mass Transfer Operations, McGraw Hill, 3rd Edition, 1981.
2. C.J. Geankoplis, Transport processes and Separation Process Principles, Prentice-Hall India, 4th Edition, 2003.
3. B. K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice-Hall India, 2nd Edition, 2007.
4. K.V. Narayanan, and Lakshmikutty, B., Mass Transfer – Theory and Applications, CBS Publishers & Distributors Pvt. ltd., 2014.
5. J.D. Seader and E.J. Henley, Separation Process Principles with application using process simulators, John Wiley & Sons, NY, 4th Edition, 2016.

CH304	Transport Phenomena	PCC	3 – 1 – 0	4 Credits

Pre-requisites:

CH202-Fluid and particle mechanics, CH252-Heat Transfer, CH253-Mass Transfer-I, CH254-Chemical Reaction Engineering-I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the transport properties of solids, liquids and gases.
CO2	Formulate a mathematical representation of flow / heat / mass transfer phenomena.
CO3	Solve flow/heat/mass transfer problems either individually or coupled for simple geometries analytically.
CO4	Identify the similarities among the correlations for flow, heat and mass transfer at interfaces.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	2	1	2	-	1	-	1	-	-	2	1	3	1
CO2	3	2	2	2	1	-	1	-	1	1	-	2	2	3	2
CO3	3	3	3	2	1	-	1	-	1	1	-	2	2	3	2
CO4	3	2	2	2	1	-	1	-	1	1	-	2	2	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction of Momentum transport: Convective Momentum Flux, Molecular Momentum Flux, Total Momentum Flux. Shell Momentum Balance and velocity profile in Laminar Flow: Momentum Balance formulation, Flow of a falling film, Flow through circular tube, Flow through Annulus, Flow of Two Adjacent Immiscible Fluids, Flow in a Cone and Plate Viscometer. The Equations of Change for Isothermal Systems: The Equation of Continuity, The Equation of Motion, The Equation of Change for Mechanical Energy, The Equation of Change for Angular Momentum, Common Simplifications of the Equation of Motion, The Equations of Change and Solving Steady-State Problems with Variables.

Velocity Distributions in Turbulent Flow: Comparisons of Laminar and Turbulent Flows, Time smoothed Equations of Change for Incompressible Fluids, The Time-Smoothed Velocity Profile Near a Wall, Empirical Expressions for the Turbulent Momentum Flux.

Interphase Transport in Isothermal Systems: Definition of Friction Factors, Friction Factors for Flow in Tubes, Friction Factors for Flow Around Spheres, Friction Factors for Packed Columns.

Introduction of Energy Transport: Convective Energy-Flux Vector, Conductive Heat-Flux Vector—Fourier's Law, Work-Flux Vector, Total Energy-Flux Vector.

Shell Energy Balances and Temperature Distributions in Solids and Laminar Flow: Shell Energy Balances, Heat Conduction in a Steam Pipe, Heat Conduction Through Composite Walls, Electrical Energy Conversion in a Wire,Chemical Energy Conversion in a Reactor, Mechanical Energy Conversion by Viscous Dissipation, Forced Convection, Free Convection, Macroscopic Balances for Nonisothermal Systems.

Mechanisms of Mass Transport: Species Concentrations, Convective Mass and Molar Flux Vectors, Diffusive Mass and Molar Flux Vectors—Fick's Law, Total Mass and Molar Flux Vectors.

Shell Mass Balances and Concentration Distributions in Solids and in Laminar Flow: Diffusion of Gases Through Solids, Diffusion Away from a Slightly Soluble Sphere, Diffusion with a Homogeneous Chemical Reaction, Diffusion with a Heterogeneous Chemical Reaction, Diffusion Through a Stagnant Gas Film, The Equations of Change for Binary Mixtures, Concentration Distributions in Turbulent Flow.

Reading List:

1. R.B. Bird, W.E. Stewart and E.N. Light Foot, Transport Phenomena, John Wiley &Sons, 2ndEdition, 2007.
2. C.J. Geankoplis, Transport Processes and Separation Process Principles, 4th Edition, Prentice Hall Inc., 2009.
3. R. Bodh, Introduction to Transport Phenomena: Momentum, Heat, and Mass, Prentice Hall India Learning Private Limited, 2012.
4. S.K. Thamida, Transport Phenomena: Chemical Processes, Studium Press (India) Pvt. Ltd. 2016.

CH305	Mass Transfer Lab	PCC	0 – 0 – 2	1 Credits

Pre-requisites: CH253-Mass Transfer-I, CH303 Mass Transfer - II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determine separation performance of batch distillation, steam distillation, sieve plate and packed bed distillation
CO2	Determine the efficiency of liquid-liquid extraction
CO3	Determine the critical moisture content in drying
CO4	Determine the effect of mass transfer with and without chemical reaction
CO5	Estimate the diffusion coefficient of vapour in gas
CO6	Determine the performance of gas-liquid and liquid-solid operations

Course Articulation Matrix:

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	2	2	1	1	1	2	1	-	-	-	2	1	2	3	-
CO2	2	2	2	1	1	2	1	-	-	-	2	1	2	3	-
CO3	3	2	2	2	1	2	1	-	-	-	2	1	2	3	-
CO4	2	2	2	1	2	2	1	-	-	-	2	1	2	3	-
CO5	2	2	3	1	1	2	1	-	-	-	2	1	2	2	-
CO6	2	2	2	2	1	2	1	-	-	-	2	1	2	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

1. Determine the diffusivity of a vapor in air.
2. Solid in air diffusion apparatus
3. Absorption studies in packed bed
4. Adsorption studies in a packed bed for a solid liquid system
5. Study the operation of sieve plate distillation column: verify the Rayleigh equation
6. Study the operation of a packed bed distillation column
7. Calculate the vaporizing efficiency using stem distillation column
8. Study the performance of a Rotary Disc Liquid-Liquid Extraction Column
9. Liquid-liquid extraction studeis in a packed bed

10. Solid liquid extraction operation in a packed bed extraction unit
11. Mass transfer with & without chemical reaction (solid-liquid system)

Reading List:

1. Lab Manuals.

CH306	Computational Methods in Chemical Engineering	PCC	0-1-2	2 Credits

Pre-Requisites: MA251-Mathematics-IV

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determine roots of algebraic equations, solution of simultaneous equations, and ordinary differential equations
CO2	Solve problems using regression analysis, interpolation, extrapolation and numerical differentiation and numerical integration
CO3	Solve problems involving material and energy balances, fluid flow operations, heat and mass transfer, evaporation, thermodynamics and mechanical operations.
CO4	Solve initial value problems, boundary value problems, & Initial and boundary value problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	1	2	-	-	1	2	2	1	2	1	2	2
CO2	3	3	1	1	2	-	-	1	2	2	1	2	1	2	2
CO3	3	3	3	2	3	-	-	1	2	2	1	2	2	2	2
CO4	3	3	1	2	3	-	-	1	2	2	1	2	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

List of Experiments:

Numerical Methods: Roots of algebraic equations and solution of simultaneous equations, Regression analysis,
Interpolation and Extrapolation, Differentiation and Numerical Integration, Solution of ordinary differential equations, Initial and Boundary Value Problems.
Applications of Numerical Methods to Chemical Engineering Problems: Material and Energy Balance, Fluid flow

operations, Heat transfer, Mass Transfer, Thermodynamics, Mechanical operations, Prediction of properties.

Reading List:

1. C. Alkis, M. Navid, Numerical Methods for Chemical Engineers with MATLAB Applications, Prentice Hall,1999.
2. S.K. Niket, Computational Techniques for Process Simulation and Analysis using MATLAB, Taylor & Francis, CRC press, 2018.
3. Lab manuals.

CH351	Process Dynamics and Control	PCC	3 – 1 – 0	4 Credits

Pre-requisites: MA201-Mathematics-III

Course Outcomes: At the end of the course, the student will be able to:

CO1	Evaluate the dynamic behavior of processes
CO2	Analyze stability of feedback control system
CO3	Design PID controllers
CO4	Determine frequency response for controllers and processes
CO5	Apply advanced control schemes for processes
CO6	Identify the characteristics of control valves

Course Articulation Matrix:

	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
CO1	3	3	3	3	3	-	-	-	-	-	-	1	2	3	3
CO2	3	3	3	2	3	-	-	-	-	-	-	1	2	3	3
CO3	3	2	3	3	3	-	-	-	-	-	1	1	2	3	3
CO4	3	3	2	3	3	-	-	-	-	-	-	1	1	3	3
CO5	3	3	3	3	3	-	-	-	-	-	1	1	2	3	3
CO6	3	3	3	2	3	-	-	-	-	-	-	1	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed syllabus:

Introduction to process control. Laplace transforms. Response of first order systems: Transfer Function, Transient Response, Forcing Functions and Responses. Examples of first and second order systems. Linearization, Transportation Lag.

State space models: linear and nonlinear models. Linearization. Components of a control system, Development of Block Diagrams, Controllers and Final Control Elements. Closed loop Transfer functions: Standard Block-Diagram Symbols, Transfer Functions for Single-Loop Systems and Multi-loop Systems. Transient response of simple control systems: Servo Problem, Regulatory Problem.

Controllers: Proportional, Proportional-Integral, PID Controllers. Ziegler-Nichols and Cohen-Coon Controller Settings. Model based controller design methods: direct synthesis method and IMC method.

Stability: Routh Test and Root Locus Techniques.

Introduction to frequency Response: Substitution Rule, Bode Diagrams. Control system design based on frequency response: Bode and Nyquist Stability Criterion, Gain and Phase Margins.

Advanced Control Strategies: Cascade Control, Feed-forward Control, Ratio Control, Dead-Time Compensation (Smith Predictor), Split Range Control.

Control Valves: Types of Control Vales, Valve Sizing, Valve Characteristics, Valve Positioner.

Reading List:

1. D.R. Coughanowr, Process System analysis and Control, McGraw Hill, 3rd Edition,2012.
2. D.Seborg, T. E. Edgar, D.A. Millichamp. and F. Doyle, Process Dynamics and Control, John Wiley & Sons, 3rd Edition, 2010.
3. G. Stephanopolis , Chemical Process Control, Prentice Hall India,2008.
4. B. Wayne Bequette, Process Control: Modeling, Design and Simulation, Prentice Hall India Learning Private Limited,2003.
5. J.A. Romagnoli, and A. Palazoglu, Introduction to Process Control, CRC Press, 2nd Edition, 2012.
6. J.P. Corriou, Process Control: Theory and Applications, Springer, 2nd Edition,2018.
7. K. Krishnaswamy, Process Control, New age publishers,2009.

CH352	Chemical Technology	PCC	3 – 1 – 0	4 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Selection of a process for manufacture of chemicals
CO2	Draw process flow diagrams
CO3	Identify the engineering problems in chemical processes
CO4	Understand chemical reactions and their mechanism involved.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	1	3	1	2	3	3	-	-	-	-	-	3	2	-
CO2	2	2	2	2	2	-	-	-	-	-	-	-	3	2	-
CO3	3	3	2	1	2	-	-	-	-	-	-	-	3	2	-
CO4	2	2	2	2	-	-	-	-	-	-	-	-	3	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Chemical industries-facts and figures, Unit operation and unit process concepts, Chemical processing and role of chemical engineers.

Chloro-Alkali Industries: Soda ash, Solvay process, Dual process, Natural soda ash from deposits, Chlorine Caustic soda, Electrolytic process.

Phosphorus Industries: Phosphoric acid, Wet process, Electric furnace process, Calcium phosphate, Ammonium phosphates, Nitrophosphates, Sodium phosphate.

Nitrogen Industries: Ammonia, Nitric acid, Urea from ammonium carbonate, Ammonium nitrate.

Sulfur and Sulfuric Acid Industries: Elemental sulfur mining by Frasch process, Sulfur production by oxidation-reduction of H2S, Sulfur and sulfur dioxide from pyrites, Sulfuric acid. Contact process, Chamber process.

Soap and Detergents: Batch saponification production, Continuous hydrolysis and saponification process, Sulfated fatty alcohols, Alkyl-aryl sulfonates.

Sugar and Starch Industries: Sucrose, Extraction of sugar cane to produce crystalline white sugar, Extraction of sugar cane to produce sugar, Starch production from maize, Production of dextrin by starch hydrolysis in a fluidized bed.

Pulp and Paper Industries: Sulfate pulp process, Chemical recovery from sulfate pulp digestion liquor, Types of paper products, Raw materials, Methods of production, Role of additives.

Plastic Industries: Polymerization fundamentals, Polymer manufacturing processes, Ethenic polymer processes, Polycondensation processes, Polyurethanes. Rubber: Elastomer polymerization processes, Rubber polymers, Butadiene-Styrene copolymer, Polymer oils and rubbers based on silicon.

Cement Industries: Classification- based on source of cement, based on broad sense cement, based on the application, appearance and constituent of cement. Manufacturing methods- Wet method, Dry method.

Pharmaceutical industries: Classification of drugs, Sources of raw materials, Penicillin

Reading List:

1. G. T. Austin, Shreve's Chemical Process Industries - International Student Edition, McGraw Hill Inc., 5th Edition, 1998.
2. M. Sittig and Gopala M. Rao, Dryden's Outlines of Chemical Technology for the 21st Century, 3rd Edition, WEP East West Press, 2010.
3. B.K. Sharma, Industrial chemistry, 15th edition, Goel Publishing House (Krishna Prakashan Media P. LTD.- Meerut), 2016.
4. A. James and R. Kent Hand Book of Industrial Chemistry, Springer Science+Business Media, LLC, 9th Edition, Volume-1, 2013.
5. J. Andreas and P. Wasserscheid, Chemical Technology, Wiley-VCH, 2013. 6. Smith W. and Chapman R., Chemical Process Industries, Vol 1 & 2, CBS Publishers, 1st Edition, 2016.

SM355	Engineering Economics and Management	HSC	3 – 0 – 0	3 Credits

Course outcomes: At the end of the course, the student will be able to:

CO1	Evaluate the economics of the management, operation, and growth and profitability of engineering firms and analyze operations of markets under varying competitive conditions
CO2	Analyze cost/revenue data and carry out economic analyses in the decision-making process to justify existing/finding alternative projects on an economic basis
CO3	Produce a constructive assessment of a social problem by drawing the importance of environmental responsibility and demonstrate knowledge of global factors influencing business and ethical issues.
CO4	Apply models to describe economic phenomena; analyze and make predictions about the impact of government intervention and subsequent changing market conditions on consumer-producer relationship

Detailed syllabus

General Foundations of Economics: Forms of organizations-Objectives of firms-Opportunity Principle-Discounting-Production possibility frontier-Central problems of an economy- Two sector, Three sector, and Four sector circular flow of income-Demand Analysis-Individual, Market and Firm demand- Determinants of demand and supply- Shifts and changes in demand and supply- Market equilibrium, Shortages versus surpluses- Elasticity of demand and business decision making.

Production functions in the short and long run-Cost concepts- Short run and long run costs-economies and diseconomies of scale--Product markets- Market structure-Competitive market-Imperfect competition (Monopoly, Monopolistic competition and Oligopoly) Price discrimination- Game Theory--Maximin, Minimax, Saddle point, Nash Equilibrium, Prisoners' Dilemma- Monetary system-Indian stock market- Development Banks-NBFIs- role of Reserve Bank of India, Money Market, Capital market; NIFTY, SENSEX.

Brief introduction to data analytics as a tool in terms of understanding the markets, performances of indexes, performance of various sectoral indexes.

Introduction to Management Theory and Functional Areas-Marketing-HR and Finance-Financial Mangement-Financial Statements-Profit and Loss Statements-Fund Flow Statement-Balance Sheets-Ratio Analysis-Investment and Financial Decision—Inventory Management-Functions and Objectives of Inventory Management—Decision Models-Break even analysis-Economic Order Quantity (EOQ)-Model Sensitivity Analysis of EOQ model

Reference:

1. K. E. Case, R. C. Fair and S. Oster, *Principles of Economics*. Prentice Hall, 10th ed., 2011. Maheswari,Anil.*Data Analytics*.Mc Graw Hill, 2017
2. N. G. Mankiw,*Principles of Microeconomics*. Cengage Publications,7th ed.,2014.
3. P.A. Samuelson and W.D Nordhaus. *Economics*. Tata Mcgraw Hill, 19th Ed., 2017
4. R.S. Pindyck, D.L. Rubinfield and P.L. Mehta,*Microeconomics*,Pearson Education, 9th

Edition, 2018
5. R.W.Griffin, *Management,Principles and Practices*. Cengage India,11th ed.,2017.
6. S. B. Gupta. *Monetary Economics: Institutions, Theory & Policy*,New Delhi: S. Chand & Company Ltd., 2013.

CH353	Process Control Laboratory	PCC	0 – 0 – 2	1 Credits

Pre-requisites: CH254 Process Instrumentation, CH401 Process Dynamics and Control.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Calculate the characteristics of control valves
CO2	Determine the dynamics of level and temperature measurement process
CO3	Determine the dynamics of two capacity liquid level process without interaction and with interaction, U-tube manometer
CO4	Determine the performance of controllers for a flow process, pressure process, level process, temperature process.
CO5	Evaluate the performance of cascade control

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	-	-	3	-	3	-	-	3	-	3	-	-	-	-
CO2	2	-	-	2	-	3	-	-	3	-	3	-	-	-	-
CO3	2	-	-	1	-	3	-	-	3	-	3	-	-	-	-
CO4	2	-	-	2	-	3	-	-	3	-	3	-	-	-	-
CO5	3	-	-	-	-	3	-	-	3	-	3	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

List of experiments:

1. Control valve characteristics
2. Dynamics of Interacting process
3. Dynamics of Non-interacting process
4. Dynamics of Temperature measurement process
5. Flapper nozzle system
6. Dynamics of Cascade control system
7. Characteristics of I &P converters
8. Dynamics of Level measurement system
9. Dynamics of First and second order process
10. Design of controllers and simulation using MATLAB

Reading List:

1. Lab Manuals.
2. W. Richard Stevens, UNIX Network Programming, Volume 2, Second Edition: Interprocess Communications, Prentice Hall, 1999
3. W. Richard Stevens, Stephen Rago, Advanced Programming in the UNIX Environment, Pearson Education, Second Edition.

IV Year B.Tech. Chemical Engineering Courses offered by Ch.ED

CH401	Industrial Safety and Hazard Mitigation	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze the effects of release of toxic substances.
CO2	Select the methods of prevention of fires and explosions
CO3	Identify the hazards and preventive measures.
CO4	Assess the risks using fault tree diagram.

Course Articulation Matrix

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO2	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO3	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO4	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Detailed Syllabus:

Introduction and Industrial Hygiene: Safety Programs, Engineering Ethics, Accident and Loss Statistics, Acceptable Risk, Public Perceptions, Nature of the Accident Process, Inherent Safety, Anticipation and Identification, Hygiene Evaluation, Hygiene Control.

Fires and Explosions and Concepts to Prevent Fires and Explosions: Fire Triangle, Distinction between Fires and Explosions, Flammability Characteristics of Liquids and Vapors, Limiting Oxygen Concentration and Inerting, Flammability Diagram, Inerting, Controlling Static Electricity, Explosion-Proof Equipment and Instruments, Ventilation, Sprinkler Systems.

Introduction to Reliefs: Relief Concepts, Location of Reliefs, Relief Types, Relief Scenarios, Data for Sizing Reliefs, Relief Systems.

Hazards Identification: Process Hazards Checklists, Hazards Surveys, Hazards and Operability Studies, Safety Reviews.

Safety Procedures and Designs: Process Safety Hierarchy, Managing Safety, Best Practices, Procedures—Operating, Procedures—Permits, Procedures—Safety Reviews and Accident Investigations, Designs for Process Safety.

Readings:

1. D.A. Crowl and J.F. Louvar, Chemical Process Safety (Fundamentals with Applications), Prentice Hall, 3rd Edition, 2011.
2. John Metcalf Coulson, John Francis Richardson, R.K. Sinnott, Coulson & Richardson's Chemical Engineering, Vol. 6, Butterworth-Heinemann, 1999.
3. Ralph King, Safety in the Process Industries, Butterworth-Heinemann, 1990.
4. K. S. N. Raju, Chemical process Industry Safety, Tata McGraw-Hill Education, 2014. 5. F.P. Lees, Loss Prevention in Process Industries, Elsevier, 1996.

CH402	Process Engineering & Design*	PCC	2 – 1– 0	3 Credits

*** Open Book Exam**

Pre-requisites: CH202-Fluid and Particle Mechanics; CH251-Heat Transfer; CH302-Chemical Reaction Engineering-II; CH303-Mass Transfer-II

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

CO1	Evaluate the process design considerations of separation columns and heat transfer equipment
CO2	Draw process flow diagrams and process instrumentation diagrams
CO3	Apply mechanical design concepts to process equipment
CO4	Design heat exchangers, evaporators, absorbers, distillation columns, reactors

Course Articulation Matrix:

	PO1	PO 2	P O3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	-	2	-	-	1	-	-	-	-	-	2	3	3	-	1
CO2	-	2	-	-	1	-	-	-	-	-	-	-	3	-	1
CO3	2	-	3	3	2	2	-	-	-	-	-		3	-	1
CO4	2	-	3	3	2	3	-	-	-	-	-	-	3	-	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to process design of Separation columns (Distillation, Absorption, and Extraction): Design variables, general design considerations, process design methods, Column sizing, Plate and packed column hydraulics design.

Process design of heat-transfer equipment: Types of heat exchanger, Process design of shell and tube heat exchanger, Condenser, and reboilers.

Drawing: Drawing of process equipment symbols for fluid handling, heat transfer, mass transfer, and mechanical operations Detailed drawing of equipment, Drawing of process flow diagram, Piping and instrumentation diagram (P&ID), Vessel and piping layout isometrics.

Mechanical Design of Process Equipment: Introduction to mechanical aspects of chemical equipment design, Design Preliminaries, Design of cylindrical and spherical vessels under internal pressure, external pressure and combined loading, Design of heads and closers, Design of tall vessels. Design of a heat exchanger, Design of an absorber, Design of a distillation column, Design of evaporator, Design of condenser, Design of a chemical reactor.

Readings:

1. R.K. Sinnott, Coulson & Richardson's Chemical Engineering, Volume 06, Elsevier, 3rd Edition, 2005.
2. Robert E. Treybal, Mass Transfer Operations, McGraw Hill Education, 3rd Edition, 1980.
3. Donald Q. Kern, Process Heat Transfer, Tata McGraw-Hill Education, Indian Edition, 1st Edition, 2017.
4. Bhattacharya B.C., Introduction to Chemical Equipment Design- Mechanical Aspects, CBS Publishers and Distributors, 2008.

CH403	Plant Design and Process Economics	PCC	2 – 0– 0	2 Credits

Pre-requisites: CH304-Elements of Transport Phenomena

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

CO1	Analyze alternative processes and equipment for manufacturing a product.
CO2	Determine costs involved in process plants.
CO3	Perform economic analysis and optimum design of processes.
CO4	Evaluate project profitability.

Course Articulation Matrix:

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	1	3	2	-	-	2	2	-	2	3	3	-	2	3	-
CO2	2	-	-	2	2	-	-	-	2	2	3	-	1	3	-
CO3	3	2	2		2	-	-	-	2	2	3	-	-	3	3
CO4	2	3	3	1	2	-	-	-	2	3	3	-	-	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Chemical Engineering plant design, Overall design consideration, Practical considerations in design, engineering ethics in design.

General Design Considerations: Health and Safety hazards, Loss prevention, Environmental Protection, Plant Location, Plant Layout, Plant Operation and Control.

Process Design Development: Development of design database, Process creation, Process design criteria, Process Flow Diagram (PFD), Equipment design specifications.

Flow sheet synthesis and development: General procedure, Process information, Functions diagram, Flow sheet synthesis, Software use in process design.

Cost and asset accounting: General accounting procedure, Balance sheet and Income statements.

Analysis of Cost Estimation: Cash flow for industrial operations, Factors affecting investment and production costs, Capital investments, Fixed capital and working capital, Estimation of capital investment, Cost indices, Estimation of total cost, Gross profit, Net profit and cash flow, Cost scaling factors, Net present value analysis.

Interest and Insurance: Interest, Simple Interest, Compound Interest, Nominal and effective interest rates, Continuous interest, Costs of Capital, Time value of money, Annuity, Cash flow patterns, Income Taxes, Present Worth, Future Worth, Taxes and Insurance.

Depreciation: Depreciable investments, Methods for calculating Depreciation.

Profitability Analysis: Profitability standards, Costs of capital, Minimum acceptable rate of return, Methods of calculating profitability, Rate of return on investment, Payback period, Net return, discounted cash flow rate of return, Net present worth, Pay-out period, Alternative investments, Replacements.

Optimum design and design strategy: Defining the optimization problem, Selecting an objective function, Structural optimization, parametric optimization, Variable screening and selection, Optimization Applications. Design Report.

Readings:

1. Peters M.S., K.D. Timmerhaus and R.E. West, Plant Design and Economics for Chemical Engineers, McGraw Hill, 5th Edition, 2011.
2. Turton R., R.C. Baile, W.B. Whiting, J. A. Shaeiwitz. Analysis, Synthesis and Design of Chemical Processes, PHI, New Delhi, 3rd Edition, 2011.
3. Seider W.D., J.D. Seader, D.R. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, Wiley, 2nd Edition, 2004.
4. R. Panneerselvam, Engineering Economics, Prentice Hall India, 2013.

CH404	Design and Simulation Laboratory	PCC	0 – 1– 2	2 Credits

Pre-requisites: None

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

CO1	Carry out thermodynamic property estimations using Aspen
CO2	Simulate Mixer, splitter, pumps, compressors and flash units
CO3	Apply sensitivity, design specification and case study tools in Aspen
CO4	Design heat exchangers, reactors and distillation columns
CO5	Optimize process flow sheets using sequential modular and equation oriented approaches.

Course Articulation Matrix

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	3	3	3	3	3	-	-	-	-	-	-	3	3	3
CO2	3	3	3	3	3	1	-	-	-	-	-	-	3	3	3
CO3	3	3	3	3	3	3	-	-	-	-	-	-	3	3	3
CO4	3	3	3	3	3	2	-	-	-	-	-	-	3	3	3
CO5	3	3	3	3	3	2	-	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Solve the following steady state simulation exercises using Aspen:

1. Physical property estimations.
2. Simulation of individual units like, mixers, splitters, heat exchangers, flash columns and reactors.
3. Design and rating of heat exchangers.
4. Design and rating of distillation columns.
5. Mass and Energy balances.
6. Handling user specifications on output streams – Sensitivity and design Spec tools.
7. Simulation of a flow sheet.
8. Simulation exercises using calculator block.
9. Optimization Exercises.
10. Simulation using equation oriented approach.

Readings:

1. A.K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall India, 3rd Edition, 2018.
2. Lab manuals / Exercise sheets.

CH411	Process Modeling and Simulation	DEC	3 – 0 – 0	3 Credits

Pre-requisites: Transport Phenomena (CH304), Chemical Engineering Thermodynamics - II (CH301), Chemical Reaction Engineering – I (CH253)

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

CO1	To analyze physical and chemical phenomena involved in various Chemical process.
CO2	To develop mathematical models for various chemical processes.
CO3	Use various simulation approaches.
CO4	Simulate a process using process simulators (ASPEN PLUS/ ASPEN HYSYS)

Course Articulation Matrix:

	PO1	PO2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	3	2	2	1	-	-	-	-	-	-	-	3	3	3
CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
CO3	3	3	2	2	1	-	-	-	-	-	-	-	3	3	3
CO4	3	2	2	2	1	-	-	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables, Review of numerical techniques, Model simulation.

Fundamental Laws: Equations of continuity, energy, momentum, and state, Transport properties, Equilibrium and chemical kinetics, Review of thermodynamic correlations for the estimation of physical properties like phase equilibria, bubble and dew points.

Modeling of Specific Systems: Constant and variable holdup CSTRs under isothermal and non-isothermal conditions, Stability analysis, Gas phase pressurized CSTR, Two phase CSTR, Non-isothermal PFR, Batch and semi-batch reactors, Heat conduction in a bar, Laminar flow of Newtonian fluid in a pipe, Gravity flow tank, Single component vaporizer, Multi-component flash drum, Absorption column, Ideal binary distillation column and nonideal multi-component distillation column, Batch distillation with holdup etc.

Simulation: Simulation of the models, Sequential modular approach, Equation oriented approach, Partitioning and tearing, Introduction and use of process simulation software (Aspen Plus/ Aspen HYSYS) for flow sheet simulation.

Readings:

1. Amiya K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall India, 2nd Edition, 2011.
2. B. A. Finlayson, Introduction to Chemical Engineering Computing, Wiley India Edition, 2010.
3. W. L. Luyben, Process Modeling, Simulation, and Control for Chemical Engineering, McGraw-Hill (1998).

Elective Courses offered by Chemical Engineering Department

CH361	Computational Fluid Dynamics	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to

CO1	Derive governing equations of fluid flow and heat transfer and classify them
CO2	Discretize the equations using Finite difference and volume formulation
CO3	Solve the discretized equations using different techniques
CO4	Implement pressure velocity coupling algorithms
CO5	Understand grid generation techniques

Course Articulation Matrix

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO 1	3	2	2	2	3	-	-	-	2	2	-	1	-	1	3
CO 2	3	2	2	2	3	-	-	-	2	2	-	1	-	1	3
CO 3	3	2	2	2	3	-	-	-	2	2	-	1	-	1	3
CO 4	3	2	2	2	3	-	-	-	2	2	-	1	-	1	3
CO 5	3	2	2	2	3	-	-	-	2	2	-	1	-	1	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction – CFD approach, Need for CFD.

Governing equations of fluid flow and heat transfer - Laws of conservation: Mass – Momentum - Energy, Initial and boundary conditions - Conservative form – Differential and Integral forms of general transport equations – Classification of physical behaviours – Classification of fluid flow equations.

Discretization of equations – Finite difference / volume methods – 1D, 2D and 3D Diffusion problems - Convection and diffusion problems - Properties of discretization schemes- Central, upwind, hybrid and higher order differencing schemes.

Solution methods of discretized equations- Tridiagonal matrix algorithm (TDMA)- Application of TDMA for 2D and 3D problems – Iterative methods – Multigrid techniques.

Pressure – velocity coupling algorithms in steady flows – Staggered grid – SIMPLE, SIMPLEC and PISO - Unsteady flows- Explicit scheme, Crank Nicholson scheme, fully implicit scheme Turbulence modelling - Prantl mixing length mode - One equation model, k - ε model, RSM equation model - Applications.

Structured and unstructured grids – Grid generation methods

Reading:

1. H. K. Versteeg, W. Malalasekera, An Introduction to Computational Fluid Dynamics - The finite volume method, Pearson Education Limited,2nd Edition, 2007.
2. T. J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2nd Edition, 2010
3. C. Hirch, Numerical Computation of internal and external flows, Wiley, 2nd Edition, 2007.
4. J. D. Anderson Jr., Computational Fluid Dynamics - The basics with Applications, McGraw Hill, 1995.
5. Sreenivas Jayanti, Computational Fluid Dynamics for Engineers and Scientists, Springer, 2018.

CH362	Separation Processes	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Knowledge of various chemical engineering modern separation techniques in various processes
CO2	Ability to analyze and design novel membranes for intended application
CO3	Ability to analyze and design pervaporation, chromatography and dialysis based separation processes
CO4	Ability to analyze the separation system for multi-component mixtures
CO5	Ability to select and design separation system for the effective solution of intended problem

Course Articulation Matrix

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO 1	1	1	3	1	2	3	3	-	-	-	-	-	3	2	-
CO 2	2	2	2	2	2	-	-	-	-	-	-	-	3	2	-
CO 3	3	3	2	1	2	-	-	-	-	-	-	-	3	2	-
CO 4	2	2	2	2	-	-	-	-	-	-	-	-	3	2	-
CO 5	2	2	2	2									3	2	

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Absorptive separations, review of fundamentals, mathematical modeling of column factors, pressure swing adsorption, ion-exchange, affinity chromatography, gradient chromatography & counter current separations etc.

Membrane separation processes, classification, structure & characteristics of membranes, thermodynamic considerations, mass transfer considerations, design of R.O.U.F, per-evaporation, gaseous separations.

Surfactant based separations, fundamentals of surfactants at surfaces & in solutions, liquid membrane permeation, foam separations, micellar separations, external field induced separations electric & magnetic field separations, centrifugal separations.

Super critical fluid extraction, physicochemical principles, thermodynamics, process synthesis and energy analysis, separation by thermal diffusion and electrophoresis.

Reading:

1. P. C. Wankat, Large Scale Adsorption Chromatography, CRC press, 1986.

2. R. W. Rousseu,, Handbook of Separation Process Technology, John Wiley & Sons, 1987.

3. S. Sourirajan and T. Matsura, Reverse Osmosis and Ultra Filtration Process Principle, NRC publication Ottawa, 1985.

4. T. A. Hatton, Surfactant Based Separation Process, Vol.23, 1989.

5. M. A. Mchugh, and V. J. Krukonis, Supercritical Fluid Extraction, Butterworth, 1985.

CH363	Bioprocess Engineering	DEC	3– 0 – 0	3 Credits

Pre-requisite: Knowledge in Biochemical Engineering and Reaction Engineering.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Get knowledge on fermentation processes and its characteristics
CO2	Understand the concepts of enzyme kinetics.
CO3	Define stoichiometry of the fermentation process
CO4	Understand the working principle of bioreactor and product recovery operations and its monitoring instruments

Course Articulation Matrix

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO 1	3	3	2	1	-	1	2	1	-	-	-	-	3	3	1
CO 2	3	3	2	1	-	1	2	1	-	-	-	-	3	3	1
CO 3	3	3	2	1	-	1	2	1	-	-	-	-	3	3	1
CO 4	3	3	2	1	-	1	2	1	-	-	-	-	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Fermentation Processes General Requirements of Fermentation Processes- An Overview of Aerobic and Anaerobic Fermentation Processes and Their Application in Industry - Medium Requirements for Fermentation Processes - Examples of Simple and Complex Media Design and Usage of Commercial Media for Industrial Fermentation. Sterilization: Thermal Death Kinetics of Micro-Organisms - Batch and Continuous Heat-Sterilization of Liquid Media filter Sterilization of Liquid Media and Air.

Enzyme Technology, Microbial Metabolism: Enzymes: Classification and Properties-Applied Enzyme Catalysis - Kinetics of Enzyme Catalytic Reactions-Metabolic Pathways - Protein Synthesis in Cells.

Stoichiometry and Kinetics of Substrate Utilization and Biomass and Product Formation: Stoichiometry of Microbial Growth, Substrate Utilization and Product Formation-Batch and Continuous Culture, Fed Batch Culture.

Bioreactor and Product Recovery Operations: Operating Considerations for Bioreactors for Suspension and Immobilized Cultures, Selection, Scale-Up, Operation of Bioreactors-Mass Transfer in Heterogeneous Biochemical Reaction Systems; Oxygen Transfer in Submerged Fermentation Processes; Oxygen Uptake Rates and Determination of Oxygen Transfer Rates and Coefficients; Role of Aeration and Agitation in Oxygen Transfer. Heat Transfer Processes in Biological Systems. Recovery and Purification of Products.

Introduction to Instrumentation and Process Control in Bioprocesses: Measurement of Physical and Chemical Parameters in Bioreactors- Monitoring and Control of Dissolved Oxygen, pH, Impeller Speed and Temperature in a Stirred Tank Fermenter.

Reading:

1. M.L. Shuler and F. Kargi, Bio-process Engineering, 2nd Edition, Prentice Hall of India, New Delhi. 2002.

2. J.E. Bailey and D.F. Ollis, Biochemical Engineering Fundamentals, 2nd Edn., McGraw Hill, Publishing Co. New York, 1985.

3. P. Stanbury A. Whitakar and S.J.Hall, Principles of Fermentation Technology, 2ndEdn., Elsevier-Pergamon Press, 1995.

4. J.M. Lee, Biochemical engineering, Prentice Hall, 1992.

CH364	Characterization of Materials	DEC	3 – 0 – 0	3 Credits

Pre-requisite: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Exposed to impart the knowledge of experimental methods for characterization of various synthesized materials.
CO2	Expected to be conversant with various characterization techniques.
CO3	Competent to carry out experiments to find out the structural, thermal, chemical and mechanical properties of materials of concern.
CO4	Analyze various characteristics of materials and its suitability in desired applications.

Course Articulation Matrix

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO 1	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO 2	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO 3	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO 4	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Materials characterization: importance and applications; principles of X-ray diffraction (XRD) methods.

Microscopy techniques: optical and electrons (SEM and TEM) microscopy; Introduction to spectroscopy (UV-vis, IR and Raman).

Thermal stability analysis: thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). Mechanical property characterization: principles and characterization of tensile, compressive, hardness, fatigue, and fracture toughness properties.

Principles of characterization of other materials properties: BET surface area; chemisorption; particle size; zeta potential; rheology; and interfacial tension.

Reading:

1. Y. Leng, Materials Characterization: Introduction to microscopic and spectroscopic methods, 1st Ed., John Wiley & Sons, 2008.

2. A.W. Adamson and A.P. Gast, Physical Chemistry of Surfaces, John Wiley, New York, 1997.

3. D. G. Baird and D. I. Collias, Polymer Processing Principles and Design, Butterworth Heinemann, Massachusetts, 1995.

4. A.J. Milling, Surface Characterization Methods: Principles, techniques, and applications, Marcel Dekker, 1999.

5. G. Ertl, H. Knozinger and J. Weitkamp, Handbook of Heterogeneous Catalysis, Vol. 2, Wiley VCH, 1997. 6. W.D. Callister (Jr.), Material Science and Engineering: An introduction, 8th Ed., John Wiley & Sons, 2010.

CH365	Water and Wastewater Treatment	DEC	3 – 0 – 0	3 Credits

Pre-requisite: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Describe different methods for wastewater treatment and environmental effects of wastewater.
CO2	Know the five stages of wastewater treatment and alternative strategies for providing these levels of treatment.
CO3	Impart knowledge on the various advances in waste water treatment process across the industries.
CO4	Analyze the various waste water treatment processes and operations, and optimization.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO2	3	1	3	3	1	-	-	-	-	-	-	-	-	2	1
CO3	3	1	3	3	1	-	-	-	-	-	-	-	-	2	1
CO4	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: An Overview of Water and Waste-Water Treatment, Need for Waste Water Treatment: Water Scenario - Escalating Demand – Pollution of Existing Sources. Waste Water Sources – Industrial, Agricultural & Domestic. Assessment of Waste Water Composition – General Characteristics – TSS, TDS, BOD, COD, pH – Specific Characteristics – Analysis for Various Ionic Species, Heavy Metals and Other Identified Pollutants.

Regulations for Treatment – ALARA Concept – Pollution Control Board Regulations.

Conventional Treatment of Waste Water: Primary – Secondary - Aim of The Treatment. Particulate Removal (Primary) - Screens – Filters – Rapid & Gravity Filters. Secondary Treatment - Aerobic Treatment; Suspended Growth Aerobic Treatment Processes, Activated Sludge Process and Its Modifications. Attached Growth Aerobic Processes, Tricking Filters and Rotating Biological Contactors, Membrane Biological Reactor. Anaerobic Treatment- Suspended Growth, Attached Growth, Fluidized Bed and Sludge Blanket Systems, Nitrification, Denitrification, Phosphorus Removal. Sludge Treatment -Thickening; Digestion; Dewatering; Sludge Drying;

Composting, Low Cost Wastewater Systems Ponds and Lagoons; Wetlands and Root-Zone Systems. (Qualitative Treatment Only)

Chemically Induced Mechanical Operations – Coagulation – Clarifiers – Oxygenation – Precipitation – Adsorption – Ion Exchange and Membrane Processes. Removal of Trace Level Pollutants – Disinfection Using Chlorine – UV – UF.

Sequencing of Unit Operations - Processes– Operational Aspects Including Batch and Continuous Systems. Volume Reduction – Concept of Water Recovery and Recycle.

Reading:

1. G. Tchobanoglous and Metcalf & Eddy, “Wastewater Engineering Treatment and Reuse”, 4th Edn., Tata McGraw-Hill Publishing Company, New Delhi, 2003.

2. S.J. Arceivala, Waste Water Treatment for Pollution Control, Tata McGraw Hill, 1998.

3. W.W. Eckenfelder, “Industrial Water Pollution Control”, 3rd edition., McGraw Hill, Boston, MA, 2000.

4. E.F. Eldridge, “Industrial Waste Treatment Practice”, McGraw-Hill Book Company, Inc., New York, NY, 1942.

5. C.P.L. Grady,, G. T. Daigger, and H. C. Lim., “Biological Wastewater Treatment”, 2nd edition., Rev. and Expanded, Marceldekker, New York, 1999

CH366	Industrial Energy Systems	DEC	3 – 0 – 0	3 Credits

Pre-requisite: Knowledge in thermodynamics, heat transfer and heat exchanger process design.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the different technologies and heat distribution configurations for various industrial systems.
CO2	Optimize the process parameters and investment cost using process integration methods.
CO3	Understand the design a heat exchanger network for maximum heat recovery for a given process.
CO4	Identify opportunities for integration of high-efficiency energy conversion technologies and energy-intensive thermal separation operations (distillation, evaporation) at an industrial process site.
CO5	Identify the cost-optimal mix of technologies for an industrial process heat demand.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	-	-	3	-	-	3	3	-	-	1	2	1	1	-	-
CO2	1	1	2	1	1	3	3	-	-	1	2	1	1	2	2
CO3	1	1	2	1	1	3	3	-	-	1	2	1	1	2	-
CO4	2	3	2	1	1	3	3	-	-	1	2	1	1	2	2
CO5	-	-	3	1	1	3	3	-	-	1	2	1	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to Industrial Process Energy Systems: Concepts, Heat Balances, Heat Distribution Systems; Local Heating Vs Central Heating Systems; Illustrating Example from The Pulping Industry.

Energy Conversion Technologies in Industrial Energy Systems: Overview of Technologies and Engineering Thermodynamics for Process Utility Boilers, Heat Pumps, Steam Turbine Combined Heat and Power (CHP) And Gas Turbine CHP. Energy Conversion Performance of Such Systems for Given Energy Conversion Process Parameters, And Given Industrial Process Heat Load Characteristics.

Process Integration: Basics of Process Integration Methodologies with Emphasis On Pinch Analysis (Pinch Temperature, Minimum Process Heating and Cooling Requirements, Composite Curves and Grand Composite Curves, Targeting for Minimum Number of Heat Exchanger Units, And Heat Exchanger Surface Area Costs). Design of Heat Exchanger Networks for Maximum Heat Recovery. Process Integration Principles for Energy-Intensive Thermal Separation Operations (Distillation, Evaporation). Energy Efficiency and Economic Performance Evaluation of Process Integration Measures. Process Integration Methodologies for Retrofit Applications in Existing Industrial Energy Systems.

Economics of Energy Conversion in Industrial Energy Systems: Characteristics of Heat Pumps and Combined Heat and Power (CHP) Units (Performance, Investment Costs). Influence of Operating Conditions On Performance. Optimization of Size and Various Design Parameters Based On Process Integration Principles. Methodology for Identifying the Cost-Optimal Mix of Technologies for Satisfying a Process Heat Demand, Accounting for Heat Load Variation Over the Course of the Year. Greenhouse Gas Emissions Consequences of Energy Efficiency Measures in Industry. Greenhouse Gas Emissions from Industrial Energy Systems. Optimization of Industrial Energy Systems Considering Future Costs Associated with Greenhouse Gas Emissions.

Reading:

1. D.W. Linnhoff et al., User Guide on Process Integration for the efficient use of Energy, Institution of Chemical Engineers, U.K., 1994.

2. R. E. Putman, Industrial Energy Systems: Analysis, Optimization, and Control, ASME Press, 2004.

3. A. Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill New Delhi, 1977.

4. F.M. Vanek, L.D. Albright, L.T. Angenent, Energy Systems Engineering: Evaluation and Implementation, 2nd Edition, Mc-Graw Hill, 2012.

CH367	Fertilizer Technology	DEC	3 – 0 – 0	3 Credits

Pre-requisite: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Classify fertilizers
CO2	Explain manufacturing processes for production of fertilizers
CO3	Identify the effect of technologies on the health, safety and environment.
CO4	Explain the mechanism of chemical reactions

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO2	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO3	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO4	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Elements required for plants growth, Classification of fertilizers, Compound, Complex and bulk blended fertilizers. N-P-K values and calculations.

Nitrogenous Fertilizers: Manufacturing Processes for Ammonia, Manufacture of ammonium sulphate, ammonium chloride, Ammonium phosphate, Ammonium nitrate, nitric acid, Urea etc. Economics and other strategies, Material of construction and corrosion problem. Phosphatic fertilizers: Calculation of percentage tricalcium phosphate of lime in phosphatic rock: Manufacture of triple super phosphate and single super phosphate, Nitro phosphate, Sodium phosphate, phosphoric acid and other phosphatic fertilizers.

Potash Fertilizers: Manufacture of potash fertilizers like potassium sulphate, potassium chloride. Complex Fertilizers: Processes for nitro-phosphates and complex NPK fertilizers liquid fertilizers.

Reading:

1. Sittig M and Gopala Rao M., Dryden's Outlines of Chemical Technology for the 21st Century, WEP East West Press, 3rd Edition, 2010.
2. Austin G T., Shreve's Chemical Process Industries, McGraw Hill Book Company, New Delhi, 5th Edition, 1986.

3. Handbook on Fertilizer Technology, Fertilizer Association of India, JNU, New Delhi, 2nd
4. Edition, 1977.
5. Shukla S D and Pandey G N, A Text Book of Chemical Technology, Vol I & II, Vikas
6. Publishing House Pvt. Ltd., New Delhi, 2000.
7. Eugene Perry, Fertilizers: Science and Technology, Callisto Reference Publisher, 2018.
8. A.K. Kolay, Manures and Fertilizers, Atlantic, 2008.

CH371	Design And Analysis of Experiments	DEC	3 – 0 – 0	3 Credits

Pre-requisite: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Plan experiments according to a proper and correct design plan
CO2	Analyze and evaluate experimental results (statistically), according to chosen experimental design (ANOVA, regression models).
CO3	Use fundamentals such as hypothesis testing, degrees of freedom, ANOVA, fractional design and other design methods/techniques and so on.
CO4	Know the fundamentals of multivariate analysis and chemometric methods (PCA and PLS) with simple applications.

Course Articulation Matrix

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	1	-	-	-	-	-	-	-	3	3	3
CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
CO3	3	3	2	2	1	-	-	-	-	-	-	-	3	3	3
CO4	3	2	2	2	1	-	-	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to Probability, Probability Laws, Bayes theorem. Probability Distributions, Parameters and Statistics. Normal and T-Distributions, Central Limit Theorem, Random Sampling and Declaration of Independence Significance Tests.

Randomization and Blocking with Paired Comparisons Significance Tests and Confidence Interval for Means, Variances, Proportions and Frequencies.

Analysis of Variance, Experiments to Compare K-Treatment Means, Two-Way Factorial Designs, Blocking, Yate's Algorithm.

Fractional Factorial Designs at Two Levels, Concept of Design Resolution, Simple Modeling with Least Squares (Regression Analysis), Matrix Versions of Normal Equations.

Mechanistic Model Building, Empirical and Mechanistic Models, Model Building Process, Model Testing with Diagnostic Parameters.

Reading:

1. D.C. Montgomery, Design and Analysis of Experiments, Wiley, 8 th Edition, 2012.
2. Z.R. Lazic, Design of Experiments in Chemical Engineering: A Practical Guide, Jhon Wiley &Sons Inc, 2004.
3. Statistics for experimenters by G.E.P. Box, William G. Hunter and J.S. Hunter, John Wiley & Sons.
4. R.L. Mason, R.F. Gunst, J.L. Hess, Statistical Design and Analysis of Experiments: With Applications to Engineering and Science, Jhon Wiley &Sons Inc.2nd ed., 2003.

CH372	Fluidization Engineering	DEC	3 – 0 – 0	3 Credits

Pre-requisite: Basic knowledge in Transfer operations.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Evaluate the fluidization behavior
CO2	Estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for fluidized beds
CO3	Develop model equations for fluidized beds
CO4	Design gas solid fluidized bed reactors

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	-	-	1	-	-	-	-	-	-	-	3	-	-
CO2	3	3	2	2	1	-	-	-	-	-	-	-	3	3	-
CO3	3	3	2	3	3	-	-	-	-	-	-	-	3	3	-
CO4	3	3	3	3	3	-	-	-	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Applications of Fluidized Beds: Introduction, Industrial Application of Fluidized Beds, Physical Operations and Reactions.

Fluidization and Analysis of Different Phases: Gross Behavior of Fluidized Beds. Bubbles in Dense Beds. The Emulsion Phase in Dense Bubbling Beds. Flow Pattern of Gas Through Fluidized Beds.

Heat and Mass Transfer in Fluidized Bed Systems: Mass and Heat Transfer Between Fluid and Solid. Gas Conversion in Bubbling Beds. Heat Transfer Between Fluidized Bed and Surfaces.

Elutriation and Entrainment: TD and Also Distribution of Solid in A Fluidized Bed. Circulation Systems.

Design of Fluidized Bed Systems: Design of Fluidization Columns for Physical Operations, Catalytic and Non- Catalytic Reactions, Three Phase Fluidization.

Reading:

1. D. Kunii and O. Levenspiel, Fluidization Engg., 2nd Ed., Butterworth Heinemann, 1991.
2. J. F. Davidson and Harrison, Fluidization, 10th Ed, Academic Press, London, 1994.
3. R. Jackson, The Dynamics of Fluidized Particles, Cambridge University Press, New York, 2000.
4. L.S. Fan, and C. Zhu, Principles of Gas-Solid Flows, Cambridge University Press, New York, 1998.
5. L.G. Gibilaro, Fluidization Dynamics, 1st Edition, Butterworth-Heinemann, 2001.

CH373	Food Process Engineering	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Explain techniques in food processing
CO2	Design process equipment to achieve the desired quality of food
CO3	Develop novel food processes that have a minimal effect on food quality
CO4	Select control strategies to maintain food quality

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	-	-	-	-	3	-	-	-	-	-	3	2	-
CO2	1	3	2	3	-	-	3	-	-	-	-	-	3	3	-
CO3	1	3	2	2	-	-	3	-	-	-	-	-	3	3	-
CO4	1	3	-	3	-	1	3	-	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: General Aspects of Food Industry, World Food Demand and Indian Scenario, Constituents of Food, Quality and Nutritive Aspects, Product and Process Development, Engineering Challenges in the Food Processing Industry. Basic Principles: Properties of Foods and Processing Theory, Heat Transfer, Effect of Heat On Microorganisms, Basic Food Biochemistry and Microbiology: Food Constituents; Food Fortification, Water Activity, Effects of Processing On Sensory Characteristics of Foods, Effects of Processing On Nutritional Properties, Food Safety, Good Manufacturing Practice and Quality Process Control in Food Processing. Ambient Temperature Processing: Raw Material Preparation, Size Reduction, Mixing and Forming, Separation and Concentration of Food Components, Centrifugation, Membrane Concentration, Fermentation and Enzyme Technology, Irradiation, Effect On Micro-Organisms, Processing Using Electric Fields, High Hydrostatic Pressure, Light or Ultrasound. Heat Processing Using Steam, Water and Air: Blanching, Pasteurisation, Heat Sterilization, Evaporation and Distillation, Extrusion, Dehydration, Baking and Roasting.

Heat Processing by Direct and Radiated Energy: Dielectric Heating, Ohmic Heating, Infrared Heating, Gamma Irradiation. Post Processing Applications Packaging: Coating or Enrobing, Theory and Types of Packaging Materials, Printing, Interactions Between Packaging and Foods, Environmental Considerations.

Reading:

1. Fellows P., Food Processing Technology: Principles and Practice, Woodhead Publishing, 4th Edition, 2016.
2. Toledo R, Fundamentals of Food Process Engineering, Springer, 3rd Edition, 2010.
3. Singh R.P. & Heldman D.R., Introduction to Food Engineering, Academic Press, 3rd Edition, 2001.

CH374	Science And Technology of Nanomaterials	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the properties of nanomaterials and their applications
CO2	Apply chemical engineering principles to nanoparticles production and scale-up
CO3	Understanding about carbon allotropes, quantum dots, clays.
CO4	Analyze the nanomaterials characterization techniques.
CO5	State the applications of nanotechnology in catalysis, electronics and chemical industries.

Course Articulation Matrix:

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PS O1**	**PS O2**	**PS O3**
CO 1	3	1	1	1	-	-	-	-	-	-	-	-	1	1	1
CO 2	3	2	2	1	-	-	-	-	-	-	-	-	3	2	1
CO 3	3	3	1	1	-	-	-	-	-	-	-	-	2	-	-
CO 4	2	1	1	1	-	-	-	-	-	-	-	-	1	-	-
CO 5	1	-	1	-	-	-	2	-	-	-	-	-	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to Nanotechnology: Introduction to Nanotechnology and Materials, Nanomaterials, Introduction to Nanosizes and Properties Comparison with The Bulk Materials, Classification of Nanomaterials (Shape, Size, Morphology, Origin Etc.)

Preparation Techniques of Nanomaterials: Top Down Approach, Grinding, Planetary Milling and Comparison of Particles, Bottom Up Approach, Wet Chemical Synthesis Methods, Microemulsion Approach, Co-Precipitation, Hydrothermal, Colloidal Nanoparticles Production, Sol Gel Methods, Sonochemical Approach, Microwave and Atomization, Lithography, Electrospinning, Sputtering, Arc Discharge Method, Laser Ablation, Drying, Gas Phase Production Methods: Chemical Vapour

Depositions. Template (Hard & Soft) Based Nanomaterials, Biosynthesis of Nanomaterials, Electro and Electro Less Deposition Techniques.

Characterization of Nanomaterials: XRD, DLS, Microscopy (SEM, TEM Etc.), Spectroscopy (UV, FTIR & Raman)

Kinetics at Nanoscale: Nucleation and Growth of Particles, Issues of Aggregation of Particles, Oswald Ripening, Stearic Hindrance, Layers of Surface Charges, Zeta Potential and pH.

Representative Nanomaterials: Carbon Allotropes (Graphene, CNT, CNF, Fullerene etc.), Clays, Quantum Dots, Wells and Wires, Bio Materials (Cellulose Nanocrystals (CNC), Bio Nanofibers)

Applications: Nanomaterials and Catalysis, Nanocomposites, Semiconductors, Nanosensors, Nanomedicine

Reading:

1. Kulkarni Sulabha K., Nanotechnology: Principles and Practices, Capital Publishing Company, 2007.
2. Gabor L. Hornyak., Harry F. Tibbals, Joydeep Dutta, John J. Moore, Introduction to

Nanoscience and Nanotechnology, CRC Press, 2009.

3. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005.
4. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009.
5. Davies, J.H. The Physics of Low Dimensional Semiconductors: An Introduction, Cambridge
6. University Press, 1998.
7. Viswanathan B. Nano Materials, Alpha Science2009.
8. Pradeep. T. Nano - The essentials understanding nanoscience and nanotechnology, The McGraw Hill, 2007.

CH375	Solid Waste and Hazard Management	DEC	3 – 0 – 0	3 Credits

Pre-requisite: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the concept of solid waste management.
CO2	Recognize the various classifications of solid waste and characteristics of solid waste.
CO3	Identify the methods of collection of solid waste.
CO4	Evaluate the method of management of solid waste.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	-	1	1	3	-	-	-	-	-	2	3	-	3
CO2	3	2	-	1	1	2	-	-	-	-	-	2	3	-	3
CO3	3	2	-	1	1	2	1	-	-	1	-	-	3	-	3
CO4	3	2	2	1	2	-	2	3	-	2	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Municipal Solid Waste Management: Legal and Organizational Foundation: Definition of Solid Waste – Waste Generation Technological Society – Major Legislation, Monitoring Responsibilities, Sources and Types of Solid Waste – Sampling and Characterization – Determination of Composition of MSW – Storage and Handling of Solid Waste – Future Changes in Waste Composition.

Collection and Transport of Solid Waste: Collection of Solid Waste: Type of Waste Collection Systems, Analysis of Collection System – Alternative Techniques for Collection System. Separation and Processing and Transformation of Solid Waste: Unit Operations User for Separation and Processing, Materials Recovery Facilities, Waste Transformation Through Combustion and Aerobic Composting, Anaerobic Methods for Materials Recovery and Treatment – Energy Recovery – Incinerators Transfer and Transport: Need for Transfer Operation, Transport Means and Methods, Transfer Station Types and Design Requirements.

Landfills: Site Selection, Design and Operation, Drainage and Leachate Collection Systems – Requirements and Technical Solution, Designated Waste Landfill Remediation – Integrated Waste Management Facilities. Hazardous Waste Management: Definition and Identification of Hazardous Wastes-Sources and Characteristics – Hazardous Wastes in Municipal Waste – Hazardous Waste Regulations – Minimization of Hazardous Waste-Compatibility, Handling and

Storage of Hazardous Waste-Collection and Transport, e-waste - Sources, Collection, Treatment and Reuse Management.

Hazardous Waste Treatment and Design: Hazardous Waste Treatment Technologies - Design and Operation of Facilities for Physical, Chemical and Thermal Treatment of Hazardous Waste – Solidification, Chemical Fixation and Encapsulation, Incineration. Hazardous Waste Landfills: Site Selection, Design and Operation – Remediation of Hazardous Waste Disposal Sites.

Reading:

1. G. Tchobanoglous, H. Theisen, and S. Vigil, Integrated Solid Waste Management: Engineering Principles and Management Issue, McGraw-Hill Publication, 1993.
2. C. A. Wentz, Hazardous Waste Management, McGraw Hill Publication, 1995.

CH376	FUEL CELL TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand fuel cell fundamentals.
CO2	Analyze the performance of fuel cell systems.
CO3	Demonstrate the operation of fuel cell stack and fuel cell system.
CO4	Apply the modeling techniques for fuel cell systems

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO2	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO3	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO4	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Overview of Fuel Cells: What Is a Fuel Cell, Brief History, Classification, How Does It Work, Why Do We Need Fuel Cells, Fuel Cell Basic Chemistry and Thermodynamics, Heat of Reaction, Theoretical electrical Work and Potential, Theoretical Fuel Cell Efficiency.

Fuels for Fuel Cells: Hydrogen, Hydrocarbon Fuels, Effect of Impurities Such as CO, S and Others.

Fuel Cell Electrochemistry: Electrode Kinetics, Types of Voltage Losses, Polarization Curve, Fuel Cell Efficiency, Tafel Equation, Exchange Currents.

Fuel Cell Process Design: Main PEM Fuel Cell Components, Materials, Properties and Processes: Membrane, Electrode, Gas Diffusion Layer, Bi-Polar Plates, Fuel Cell Operating Conditions: Pressure, Temperature, Flow Rates, Humidity.

Main Components of Solid-Oxide Fuel Cells, Cell Stack and Designs, Electrode Polarization, Testing of Electrodes, Cells and Short Stacks, Cell, Stack and System Modeling.

Fuel Processing: Direct and In-Direct Internal Reforming, Reformation of Hydrocarbons by Steam, CO_2 and Partial Oxidation, Direct Electro-Catalytic Oxidation of Hydrocarbons, Carbon Decomposition, Sulphur Tolerance and Removal, Using Renewable Fuels for SOFCs.

Reading:

1. Hoogers G, Fuel Cell Technology Hand Book, CRC Press, 2003.
2. O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, 2006.
3. F. Barbir, PEM Fuel Cells: Theory and Practice, Elsevier/Academic Press, 2nd Edition, 2013.
4. Subhash C. Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications.
5. Larminie J, Dicks A, Fuel Cell Systems Explained, 2nd Edition, John Wiley, New York, 2003.

CH377	CATALYSIS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: CH302-Chemical Reaction Engineering-II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the basic concepts of catalysis
CO2	Analyze the role of heat and mass transfer in the catalytic reactor design
CO3	Describe the methods of preparation and characterization of catalysts
CO4	Distinguish the performance of catalytic reactors
CO5	Identify the role of catalysts in the environmental protection

Course Articulation Matrix

	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
CO1	3	3	2	1	-	-	-	-	-	-	-	-	3	2	1
CO2	2	3	2	1	-	-	-	-	-	-	-	-	3	1	1
CO3	2	1	2	1	-	-	-	-	-	-	-	-	1	1	1
CO4	2	3	1	1	-	-	-	-	-	-	-	-	1	1	1
CO5	-	-	-	-	-	-	3	-	-	-	-	-	1	1	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Basic Concepts in Heterogeneous Catalysis and Green Chemistry. Catalyst Preparation and Characterization, Optimal Distribution of Catalyst in A Pellet. Surface Reactivity and Kinetics of Reaction On Surfaces, Poisoning and Regeneration.

Heat and Mass Transfer and Its Role in Heterogeneous Catalysis. Calculations of Effective Diffusivity and Thermal Conductivity of Porous Catalysts.

Industrially Important Catalysts and Processes Such as Oxidation, Processing of Petroleum and Hydrocarbons, Synthesis Gas and Related Processes, Environmental Catalysis. Zeolite Catalysts, Preparation, Characterization and Applications.

Commercial Catalytic Reactors (Adiabatic, Fluidized Bed, Trickle Bed, Slurry Etc.). Selection, Design and Preparation of Catalysts.

Reading:

1. John Meurig Thomas, W. J. Thomas, Principles and Practice of Heterogeneous Catalysis, Wiley VCH; 2nd Edition, 2014.
2. James John Carberry, Chemical and Catalytic Reaction Engineering, Dover Publications, INC, 2001.
3. L. K. Doraiswamy, M. M. Sharma, Heterogeneous Reactions: Fluid-fluid-solid Reactions, Wiley, 1984.
4. B. Viswanathan, S. Sivasanker, and A.V. Ramaswamy, Catalysis: Principles and Applications, Narosa Publishing House, 2002.
5. B. Viswanathan, S. Kannan, R.C. Deka, Catalysts and Surfaces: Characterization Techniques, Alpha Science International, 2010.

CH412	Multiphase Flow	DEC	3 – 0 –0	3 Credits

Pre-requisites: None

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

CO1	Understand the fundamentals of multi-phase flow
CO2	Analyze multi-phase flow with inertia effects
CO3	Analyze flow regimes with appropriate models
CO4	Measure parameters in multi-phase flow

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	1	1	1	-	-	-	-	-	-	-	1	2	3
CO2	2	3	1	1	1	-	-	-	-	-	-	-	1	2	3
CO3	2	3	1	1	1	-	-	-	-	-	-	-	1	2	3
CO4	2	3	1	1	1	-	-	-	-	-	-	-	1	2	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to multiphase flow, types and applications, Common terminologies, flow patterns and flow pattern maps.

One dimensional steady homogenous flow, Concept of choking and critical flow phenomena, one dimensional steady separated flow model, Phases are considered together but their velocities differ, Phases are considered separately, flow with phase change, Flow in which inertia effects dominate, energy equations,

The separated flow model for stratified and annular flow, General theory of drift flux model, Application of drift flux model to bubbly and slug flow.

Hydrodynamics of solid-liquid and gas-solid flow, Principles of hydraulic and pneumatic transportation.

Introduction to three phase flow, Measurement techniques for multiphase flow. Flow regime identification, pressure drop, void fraction and flow rate measurement.

Readings:

1. C. E. Brennen, Fundamentals of Multiphase Flow, Cambridge University Press, New York, 2005.
2. M. E. Weber, R. Clift, J. R. Grace, Bubbles, Drops, and Particles, Dover Books, New York, NY. 2013.
3. V. P. Carey, Liquid-Vapor Phase-Change Phenomena, Hemisphere Pub. Corp. 1992.

CH413	Biochemical Engineering	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand cell and enzyme kinetics
CO2	Discuss methods of immobilization.
CO3	Calculate volume of a bioreactor
CO4	State sterilization methods
CO5	Select downstream process to separate the products

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	1	-	-	1	2	1	-	-	-	3	3	-
CO2	3	3	2	1	-	-	1	2	1	-	-	-	3	3	-
CO3	3	3	2	1	-	-	1	2	1	-	-	-	3	3	-
CO4	3	3	2	1	-	-	1	2	1	-	-	-	3	3	-
CO5	3	3	2	1	-	-	1	2	1	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Biotechnology, Biochemical Engineering, Biological Process, Definition of Fermentation.

Enzyme Kinetics: Introduction, Simple Enzyme Kinetics, Enzyme Reactor with Simple Kinetics, Inhibition of Enzyme Reactions, and Other Influences on Enzyme Activity.

Immobilized Enzyme: Immobilization techniques and effect of mass transfer resistance. Industrial application of enzymes: Carbohydrates, starch conversion and cellulose conversion. Cell Cultivation: Microbial cell cultivation, animal cell cultivation, plant cell cultivation, cell growth measurement and cell immobilization.

Cell Kinetics and Fermenter Design: Introduction, growth cycle for batch cultivation, stirred tank fermenters, multiple fermenters connected series, cell recycling, alternate fermenters and structured model.

Sterilization: Sterilization methods, thermal death kinetics, design criterion, batch sterilization, continuous sterilization and air sterilization

Agitation and Aeration: Introduction, basic mass transfer concepts, correlation for mass transfer co-efficient, measurement of interfacial area, correlations for ‘a’ and D32, gas-holdup, power consumption, determination of oxygen absorption rate, correlation for k_{La}, scale-up and shear sensitivity.

Downstream Processing: introduction, solid-liquid separation, cell rupture, recovery and purification.

Readings:

1. James M. Lee, Biochemical Engineering, Prentice Hall, 1992.
2. James E. Bailey and David F. Ollis, Biochemical Engineering Fundamentals, McGraw Hill International, 2nd Edition, 1986.
3. Michael L. Shuler and Fikret Kargi, Bioprocess Engineering – Basic Concepts, Prentice Hall of India, 2nd Edition, 2002.

CH414	Interfacial Science	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the interfacial phenomena occurring at macro scale and quantify the effect owing to interfacial properties.
CO2	Analyze ab-initio calculations for inter-colloidal forces
CO3	Identify equipment and sensors for characterizing various interfaces.
CO4	Design processes that utilize interfacial phenomena to achieve a desired effect.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	-	-	-	-	-	-	-	-	-	-	-
CO2	3	3	1	1	-	-	-	-	-	-	-	-	-	-	-
CO3	1	3	1	1	-	-	-	-	-	-	-	-	-	-	-
CO4	3	3	3	3	-	-	-	-	-	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to types of interfaces: The importance of interfaces, Surfaces and interfaces, Stable interfaces.

Capillarity and surface tension: Surface tension and work, Measurement of surface tension, The Laplace equation, The Kelvin equation, The surface tension of pure liquids.

Adsorption and thermodynamics of surfaces: Introduction, Models of the interface, Adsorption, Thermodynamic properties of interfaces, Surface excess quantities, Measurement of Adsorption, Adsorption form solution, Kinetics of Adsorption.

Surfactants & Micelles, Films and foams: Introduction, Application of surfactants, Adsorption of surfactants, Micelles, films and foams, Aerosols.

Monolayers formation: Introduction, Formation of floating monolayers, Surface pressure-area relationships, Deposition of Langmuir Blodgett (LB) films, The study of film structure, the structure and properties of floating monolayers, Interactions in monolayers, the structures of LB films, characterization and application.

The liquid-liquid interface: Emulsions, Colloids, Membranes: Introduction, Emulsions, Emulsion stability and selection of the emulsion, Micro-emulsion, Emulsion polymerization, Liquid-liquid extraction, Membranes.

The liquid-solid interface: Introduction, Colloidal dispersions, The properties of colloidal dispersions, Coagulation of lyophobic colloids by electrolytes, solvent effects in colloidal interactions, Nanoparticles.

Readings:

1. Geoffrey Barnes and Ian Gentle, Interfacial Science: An Introduction, Oxford University Press, 2nd Edition, 2011.
2. Jacob N. Israelachvili, Intermolecular and Surface Forces, Academic Press, 3rd Edition, 201.
3. Paul C. Hiemenz and Raj Rajagopalan, Principles of Colloids and Surface Chemistry, Taylor and Francis, 3rd Edition, 1997.

CH415	Statistical Thermodynamics	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the molecular level properties influencing the macroscopic thermodynamic properties
CO2	Develop models for simulating real gases, liquids and solids using ensemble methods to estimate thermodynamic properties
CO3	Design molecular level architecture to enhance macroscopic properties
CO4	Estimate macroscopic properties based on molecular level interactions.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO2	2	2	2	2	3	-	-	-	1	-	-	2	1	3	2
CO3	1	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO4	1	2	1	2	2	2	2	-	1	-	-	2	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Basics of Statistical Thermodynamics: The Statistical Foundation of Classical Thermodynamics, Classification Scheme for Statistical Thermodynamics, Importance of Statistical Thermodynamics.

Ensembles: Ensembles and Postulates, Canonical Ensemble, Canonical Ensemble and Thermodynamics, Grand Canonical Ensemble, Micro Canonical Ensemble, Thermodynamic Equivalence of Ensembles.

Evaluation of Probabilities: Probability- Definitions and Basic Concepts, Permutations and Combinations, Distribution Functions: Discrete and Continuous, Binomial Distribution, Poisson distribution, Gaussian Distribution, Combinatorial Analysis for Statistical Thermodynamics. Criteria for Equilibrium: Equilibrium Principles, States of Equilibrium: Neutral, Metastable, and Unstable equilibrium, Maximizing Multiplicity.

Model for Mono-atomic Ideal Gas and Polyatomic Ideal Gases: Energy Levels and Canonical Ensemble, Partition Function, Thermodynamic Functions for Mono-atomic Ideal Gases, Grand Ensemble, Internal Degrees of Freedom, Independence of Degrees of Freedom, Potential Energy Surface, Vibration, Rotation, Thermodynamic Functions for Poly-atomic Ideal Gases, Hindered Internal Rotation in Ethane, Hindered Translation on a Surface.

Einstein's and Debye's Model of the Solid, Simple Liquids, Phase Equilibrium, Models for Multi Component Systems: Ideal Lattice Gas, Lattice Gas with Interactions, Solutions

(Bragg-William Model and Regular Solutions, Quasi-Chemical Model), Chemical Equilibrium.

Readings:

1. Leonard K. Nash, Elements of Statistical Thermodynamics, Dover Publications, 2nd Edition, 2006.
2. Normand M. Laurendeau, Statistical Thermodynamics: Fundamentals and Applications, Cambridge University Press, 2005.
3. Stanley I. Sandler, An Introduction to Applied Statistical Thermodynamics, John Wiley & Sons, 2010.
4. Herbert B. Callen, Thermodynamics and Introduction to Thermo-statistics, Wiley, 2nd Edition, 1985.

CH416	Scale Up Methods	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand principles of scale up
CO2	Apply dimensional analysis technique for scale up problems.
CO3	Carry out scale up of mixers, heat exchangers and chemical reactors
CO4	Scale up distillation columns and packed towers.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO2	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO3	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO4	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Principals of Similarity, Pilot Plants & Models: Introduction to scale-up methods, pilot plants, models and principles of similarity, Industrial applications.

Dimensional Analysis and Scale-Up Criterion: Dimensional analysis, regime concept, similarity criterion and scale up methods used in chemical engineering, experimental techniques for scaleup.

Scale-Up of Mixing and Heat Transfer Equipment: Typical problems in scale up of mixing equipment and heat transfer equipment.

Scale-Up of Chemical Reactors: Kinetics, reactor development & scale-up techniques for chemical reactors.

Scale-Up of Distillation Column & Packed Towers: Scale-up of distillation columns and packed towers for continuous and batch processes.

Readings:

1. Marko Zlokamik, Scale-up in Chemical Engineering, Wiley-VCH, 2nd Ed, 2006.
2. Johnstone, Thring, Pilot Plants Models and Scale-up methods in Chemical Engineering, McGraw Hill, New York, 1962.
3. Hoyle W, Pilot Plants and Scale-Up, Royal Society of Chemistry, 1999.
4. Bruce Nauman E, Chemical Reactor Design, Optimization and Scale-up, McGraw Hill Handbooks, New York, 2002.

CH421	Polymer Technology	DEC	3 – 0– 0	3 Credits

Pre-requisites: None

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

CO1	Understand thermodynamics of polymer structures
CO2	Select polymerization reactor for a polymer product.
CO3	Characterize polymers.
CO4	State polymer additives, blends and composites, polymer processing (fundamentals and techniques)

Course Articulation Matrix:

	PO 1	PO 2	P O3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO2	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO3	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO4	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction and Classification of Polymers. Thermosets, Factors influencing the polymer properties, Monomers used for polymer synthesis, synthesis procedure for monomers Styrene, ethylene, Vinyl monomers etc., Thermoplastics, Linear Branch, Cross Linked Polymers, Ewart Kinetics for emulsion polymerization.

Addition polymers – kinetics, synthesis and reactions, Condensation polymers, Kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits

Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, Smith Ewart Kinetics for emulsion polymerization, Kinetics of free radical polymerization, Chain transfer agents, Kinetics of Step growth polymerization, Ziegler Natta polymerization Processes, Differentiation based on kinetics of Anionic and cationic polymers.

Polymerization reactors types and mode of operation, Polymerization reactor design, control of polymerization, Post polymerization unit operations and unit processes.

High Performance and Specialty Polymers, Polymer additives, compounding. Fillers, plasticizers, lubricants, colorants, UV stabilizers, fire retardants and antioxidants.

Impact, flexural tensile testing methods of polymers, Mechanical Properties of Polymers, Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers.

Polymer processing: Extrusion process, Twin and Single Screw extrusion, Blow moulding, injection moulding, Wet and Dry spinning processes, thermoset moulding. Processing of polymer nanocomposites.
Manufacturing of polymers: flow-sheet diagrams, properties & applications of PE, PP, PS, Polyesters, Nylons, ABS and PC.

Readings:

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, 2000.
2. Premamoy Ghosh, Polymer Science and Technology, Tata McGraw Hill Publishing Company, New Delhi, 3rd Edition, 2010.
3. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.
4. George Odian, Principles of Polymerization, John Wiley & Sons, Inc., 2004.

CH422	Air Pollution Control	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze the effects of pollutants on the environment.
CO2	Understand meteorological aspects of air pollution
CO3	Understand air pollution control methods
CO4	Design unit operations for pollution control.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO2	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO3	1	3	-	1	-	-	3	-	-	-	-	-	-	-	-
CO4	1	3	3	3	-	-	3	-	-	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Biosphere, Hydrological cycle, Nutrient cycle, Consequences of population growth, Pollution of air, Water and soil.

Air pollution sources & effects: Classification and properties of air pollutants, Emission sources, Behavior and fate of air pollutants, Effect of air pollution.

Meteorological aspects of air pollutant dispersion: Temperature lapse rates and stability, Wind velocity and turbulence, Plume behavior, Dispersion of air pollutants, Estimation of plume rise.

Air pollution sampling and measurement: Types of pollutant sampling and measurement, Ambient air sampling, Stack sampling, Analysis of air pollutants.

Air pollution control methods & equipment: Control methods, Source correction methods, Cleaning of gaseous effluents, Particulate emission control, Selection of a particulate collector, Control of gaseous emissions, Design methods for control equipment.

Control of specific gaseous pollutants: Control of sulphur dioxide emissions, Control of nitrogen oxides, Carbon monoxide control, Control of hydrocarbons and mobile sources.

Readings:

1. C.S. Rao, Environmental Pollution Control Engineering, Wiley Eastern Limited, India, 1993.
2. Noel de Nevers, Air Pollution and Control Engineering, McGraw Hill, 2000.
3. M.N. Rao and Rao H.V.N - Air Pollution, Tata – McGraw Hill Publishing Ltd., 1993.
4.

CH423	Energy Resources and Systems	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the basic sources of energy
CO2	Understand Conversion routes of energy
CO3	Understand energy Management
CO4	Develop and solve energy balance equation for industry

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	1	1	1	-	-	-	-	-	-	-	2	2	2
CO2	1	1	-	-	-	-	-	-	-	-	-	-	2	2	2
CO3	2	2		3	3	-	-	-	-		-	-	2	2	2
CO4	2	3	3	2	3	-	-	-	-	-	-	-	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Energy and Development, Units and Measurements, Conventional and Non-Conventional Sources of Energy, Fossil and Mineral Energy Resources, Details of Coal, Peat, Oil, Natural Gas and Nuclear Resources, Recovery of Fossil Fuels, Classification and Characterization of Fossil fuels, Basic of Solar, Wind, Bio, Hydro, Tidal, Ocean Thermal and other Renewable Energy Sources, Impact of Energy on Environment, Flow of Energy in Ecological System, Environmental Degradation due to energy, Control of Pollution from Energy.

Energy, Conversion routes, Direct and indirect way of Energy Conversion, Principles of heat and mass transfer, Thermodynamics, Fluid statics and dynamics, Electricity generation, distribution and use, Basic of Solar Thermal Conversion, Technology of Selective Coating, Fundamentals of Flat Plate Collector and Evacuated Collector, Basic of Wind Energy Conversion, Wind machine, Wind electric generator, Wind pump.

Energy Management and Audit, Basics of Energy Demand and Supply, Principles of Economic analysis in the Energy Management and Audit Programme, Supply side and demand side energy management, Boilers and Firing System, Steam, Condensation Systems, Energy Conservation and Management in power plant, Energy conservation in Buildings, Heating, Ventilation and Air Conditioning System

Material and energy balance in the industries, Products and the process, industrial demand and supply networking, Optimization techniques, efficiency analysis, methods,

Energy monitoring and ongoing information dissertation in terms of energy consumption, production and cumulative sum of differences.
Basic concept of power plants, types of power plants, thermal power stations, various components of thermal power stations, power plant cycles, fuel handling, combustion, waste disposal methodologies, economizers, turbo alternators, heat balance and efficiencies.

Readings:

1. Tushar K. Ghosh, Mark A. Prelas, Energy Resources and Systems, Springer, 2011.
2. Nikolai V. Khartchenko, Vadym M. Kharchenko, Advanced Energy Systems, CRC Press, 2nd Edition, 2013.
3. P. Venkataseshaiah and K.V. Sharma, Energy Management and Conservation, Wiley, 2020.

CH424	Petroleum Refining Processes	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Characterize the petroleum and petroleum products
CO2	Identify the methods involved in crude pre-processing
CO3	Design the fractionating column for crude
CO4	Differentiate the treatment techniques involved in post processing of crude
CO5	Apply the process flow technologies for crude conversion to fuels

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	-	-	2	3	3	-	-	-	-	-	3	3	3
CO2	1	3	-	-	-	-	3	-	-	-	-	-	3	3	3
CO3	3	3	-	-	3	1	3	-	-	-	-	-	3	3	3
CO4	3	3	-	-	-	1	3	-	-	-	-	-	3	3	3
CO5	3	3	-	-	-	-	3	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Origin, formation and composition of petroleum: Origin and formation of petroleum, Reserves and deposits of world, Petro Glimpses and petroleum industry in India, Composition of petroleum. Petroleum processing data: Evaluation of Petroleum, Thermal properties of petroleum fractions, important products-properties and test methods.

Fractionation of petroleum: Dehydration and desalting of crudes, heating of crudes, Distillation of petroleum, blending of gasoline.

Treatment techniques: Fractions-Impurities, Gasoline treatment, Treatment of kerosene, Treatment of lubes, Wax and purification.

Thermal and catalytic processes: Cracking, Catalytic cracking, Catalytic reforming-introduction and theory, Naphtha cracking, Coking, Hydrogen processes, Alkylation, Isomerization processes, Polymer gasoline.

Readings:

1. B.K. Bhaskara Rao, Modern Petroleum Refining Processes, 4th Edition, Oxford& IBH Publishing Co. Pvt. Ltd., 2008.
2. J.G. Speight, and B. Ozum, Petroleum Refining Processes, Marcel Dekker, 2002.
3. Mohamed A. Fahim, Taher A. Al-Sahhaf, Amal Elkilani, Fundamentals of Petroleum Refining, Elsevier Science, 2010.
4. R. A. Meyers, Hand Book of Petroleum Refining Processes, McGraw Hill, 3rd Edition, 2003.

CH425	Process Modelling and Analysis	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand model building techniques
CO2	Develop first principles, grey box and empirical models for systems
CO3	Develop mathematical models for engineering processes
CO4	Model discrete time systems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	1	-	-	-	-	-	-	-	3	3	3
CO2	3	3	3	3	2	-	-	-	-	-	-	-	3	3	3
CO3	3	3	2	2	1	-	-	-	-	-	-	-	3	3	3
CO4	3	2	2	2	1	-	-	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to modelling, a systematic approach to model building, classification of models.

Development of steady state and dynamic lumped and distributed parameter models based on conservation principles. The transport phenomena models: Momentum, energy and mass transport models. Analysis of ill-conditioned systems.

Classification of systems, system's abstraction and modelling, types of systems and examples, system variables, input-output system description, system response, analysis of system behavior, linear system, superposition principle, linearization, non-linear system analysis, system performance and performance targets.

Development of grey box models. Empirical model building. Statistical model calibration and validation. Population balance models. Examples.

Mathematical model development for electromagnetic forces in high field magnet coils, free and forced vibration of an automobile, cantilever beam subjected to an end load. Mathematical model development for different chemical engineering processes – distillation columns, reactors, heat exchangers.

Discrete systems: difference equations, state-transition diagrams, cohort simulation of Markov models, random processes, descriptive statistics, hypothesis testing, probabilistic distributions, pseudo-random numbers, Monte Carlo methods, numerical simulation of continuous-time dynamics, discrete-event systems, cellular automata, Moore machines, real-world system examples: Mechanical, Electrical, Electro-Mechanical, Chemical Systems.

Readings:

1. Amiya K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall, 2nd Edition, 2011.
2. K. M. Hangos and I. T. Cameron, Process Modelling and Model Analysis, Academic Press, 2001.
3. M. Chidambaram, Mathematical Modelling and Simulation in Chemical Engineering, Cambridge University Press, 2018.
4. Jim Caldwell, Douglas K. S. Ng, Mathematical Modelling: Case Studies, Kluwer Academic Publishers, 2004.

CH426	Statistical Design of Experiments	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Plan experiments for a critical comparison of outputs
CO2	Include statistical approach to propose hypothesis from experimental data
CO3	Implement factorial and randomized sampling from experiments
CO4	Estimate parameters by multi-dimensional optimization

Course Articulation Matrix:

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	-	-	-	-	-	-	-	2	2	3
CO2	3	3	3	3	2	-	-	-	-	-	-	-	2	2	3
CO3	3	3	3	3	2	-	-	-	-	-	-	-	2	2	3
CO4	3	3	3	3	2	-	-	-	-	-	-	-	2	2	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Strategy of experimentation, basic principles, guidelines for designing experiments. Simple Comparative Experiments: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means: Hypothesis testing, Choice of samples size, Confidence intervals, Randomized and paired comparison design.

Experiments with Single Factor: An example, The analysis of variance, Analysis of the fixed effect model, Model adequacy checking, Practical interpretation of results, Sample computer output, Determining sample size, Discovering dispersion effect, The regression approach to the analysis of variance, Non-parametric methods in the analysis of variance, Problems.

Design of Experiments: Introduction, Basic principles: Randomization, Replication, Blocking, Degrees of freedom, Confounding, Design resolution, Metrology considerations for industrial designed experiments, Selection of quality characteristics for industrial experiments. Parameter Estimation.

Response Surface Methods: Introduction, The methods of steepest ascent, Analysis of a second order response surface, Experimental designs for fitting response surfaces:

Designs for fitting the first-order model, Designs for fitting the second-order model, Blocking in response surface designs, Computer-generated (Optimal) designs, Mixture experiments, Evolutionary operation, Robust design, Problems.
Design and Analysis: Introduction, Preliminary examination of subject of research, Screening experiments: Preliminary ranking of the factors, active screening experiment-method of random balance, active screening experiment Plackett-Burman designs, Completely randomized block design, Latin squares, Graeco-Latin Square, Youden's Squares, Basic experiment-mathematical modeling, Statistical Analysis, Experimental optimization of research subject: Problem of optimization, Gradient optimization methods, Non-gradient methods of optimization, Simplex sum rotatable design, Canonical analysis of the response surface, Examples of complex optimizations.

Readings:

1. Lazic Z. R., Design of Experiments in Chemical Engineering, A Practical Guide, Wiley, 2005.
2. Antony J., Design of Experiments for Engineers and Scientists, Butterworth Heinemann, 2004.
3. Montgomery D. C., Design and Analysis of Experiments, Wiley, 5th Edition, 2010.
4. Doebelin E. O., Engineering Experimentation: Planning, Execution, Reporting, McGraw-Hill, 1995.

CH461	Process and Product Design	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand Chemical product design principles
CO2	Select processes and flowsheets
CO3	Assess energy requirements and safety/sustainability indicators of processes
CO4	Execute computer aided molecular and mixture design
CO5	Design chemical devices

Course Articulation Matrix:

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	2	2	1	2	-	-	-	-	-	-	-	1	1	2
CO2	3	3	3	2	1	-	-	-	-	-	-	-	2	2	2
CO3	2	3	3	2	1	2	2	-	-	-	-	-	3	3	3
CO4	3	3	3	2	3	-	-	-	-	-	-	-	2	3	3
CO5	3	3	3	2	1	-	-	-	-	-	-	-	2	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to Chemical Product Design: Introduction, The Diversity of Chemical Products, The Chain of Chemical Products, Companies Engaging in Production of Chemical Products, B2B and B2C Chemical Products, Market Sectors and Classes of Chemical Products, Product Design and Development, Tasks and Phases in Product Design and Development Project Management, Market Study, Product Design, Feasibility Study, Prototyping.

Introduction to Process Design : Objectives, Introduction, Information Gathering, Environmental and Safety Data, Chemical Prices, Experiments, Preliminary Process Synthesis, Chemical State, Process Operations, Synthesis Steps, Continuous or Batch Processing, Next Process Design Tasks, Flowsheet Mass Balances, Process Stream Conditions, Flowsheet Material and Energy Balances, Equipment Sizing and Costing, Economic Evaluation, Heat and Mass Integration, Environment, Sustainability, and

Safety, Controllability Assessment, Optimization, Preliminary Flowsheet Mass Balances, Flow Diagrams.
Design Literature, Stimulating Innovation, Energy, Environment, Sustainability, Safety, Engineering Ethics : Objectives, Design Literature, Information Resources, General Search Engines and Information Resources, Stimulating Invention and Innovation, Energy Sources - Coal, Oil, and Natural Gas, Shale Oil, Shale Gas, Hydrogen, Hydrogen Production, Fuel Cell Energy Source, Hydrogen Adsorption, Biofuels, Solar Collectors, Wind Farms, Hydraulic Power, Geothermal Power, Nuclear Power, Selection of Energy. Sources in Design, Environmental Protection, Environmental Issues, Environmental Factors in Product and Process Design, Sustainability—Key Issues, Sustainability Indicators, Life-Cycle Analysis, Safety Considerations, Safety Issues, Design Approaches Toward Safe Chemical Plants, Engineering Ethics.
Molecular and mixture design: Framework for Computer-Aided Molecular-Mixture Design, Molecular Structure Representation, Generation of Molecule-Mixture Candidates, Mathematical Formulations of Molecular and/or Mixture Design Problems, Solution Approaches, Case Studies - Refrigerant Design, Large Molecule (Surfactant) Design, Active Ingredient Design/Selection, Polymer Design, Dichloromethane (DCM) Replacement in Organic Synthesis, Azeotrope Formation, Solvent Substitution, Mixture Design.
Design of Chemical Devices, Functional Products, and Formulated Products: Objectives, Design of Chemical Devices and Functional Products, The Use of Models in Design of Devices and Functional Products, Design of Formulated Products, Design of Processes for B2C Products.

Readings:

1. Warren D. Seider, Daniel R. Lewin, J. D. Seader, S. Widagdo, R. Gani, K.A. Ming Ng, Product and Process design principles, Synthesis, Analysis and Evaluation, Wiley,4th Edition,1999.
2. E. L. Cussler and G. D. Moggridge, Chemical Product Design (Cambridge Series in Chemical Engineering), Cambridge University Press, 2nd Edition, 2011.

CH462	Mathematical Methods in Chemical Engineering	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand vector space and its application in chemical Engineering
CO2	Application of linear equations in chemical Engineering
CO3	Understand initial value problems and its application
CO4	Understand the solution procedure of homogeneous PDE
CO5	Understand the solution procedure of homogeneous non homogeneous PDE

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	-	-	3	-	-	-	-	-	-	2	3	3
CO2	3	1	1	-	-	3	-	-	-	-	-	-	2	3	3
CO3	3	1	1	-	-	3	-	-	-	-	-	-	2	3	3
CO4	3	3	3	--	-	3	-	-	-	-	-	-	2	3	3
CO5	3	3	3	-	-	3	-	-	-	-	-	-	2	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Vectors: Linear combination of vectors, dependent/independent vectors; Orthogonal and orthonormal vectors; Gram-Schmidt Orthogonalization; Examples.

Contraction Mapping: Examples Onto, into, one to one function, Definition; Applications in Chemical Engineering; Examples, Matrix, determinants and properties.

Introduction of vector space: Metric, Norm, Inner Product space; completeness of space.

Eigen value Problem: Various theorems; Solution of a set of algebraic equations; Solution of a set of ordinary differential equations; Solution of a set of non-homogeneous first order ordinary differential equations (ivps).

Applications of eigenvalue problems: Stability analysis; Bifurcation theory; Examples Partial Differential equations: Classification of equations; Boundary conditions; Principle of Linear superposition.

Special odes and Adjoint operators: Properties of adjoint operator; Theorem for eigenvalues and eigenfunctions. Solution of linear, homogeneous pdes by separation of variables: Cartesian coordinate system &

Different classes of pdes; Cylindrical coordinate system; Spherical Coordinate system, Solution of non-homogeneous pdes by Green's theorem, Solution of pdes by Similarity solution method, Solution of pdes by Integral method, Solution of pdes by Laplace transformation, Solution of pdes by Fourier transformation.

Readings:

1. S. Pushpavanam, Mathematical methods in chemical engineering. Taylor & Francis, 1st edition (2007).
2. B.K. Dutta, Mathematical Methods in Chemical and Biological Engineering. CRC Press; 1st edition (2016)
3. N.W. Loney, Applied mathematical methods for chemical engineers. CRC Press; 3rd edition (2015).

CH463	Membrane Technology	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Acquire in-depth knowledge in the areas of membrane separation mechanisms, transport models, membrane permeability computations, membrane types and modules, membrane contactors / reactors and applications.
CO2	Develop skills in applying transport models for the calculation of membrane permeability, flux, and the extent of separation for various membrane separation systems
CO3	Be able to determine the types of experimental data needed for the calculation of membrane permeability parameters.
CO4	To be able to calculate membrane process performance and analyze membrane separation characteristics
CO5	Be able to select membrane processes for solving separation problems

Course Articulation Matrix:

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	2	2	-	-	2	3	-	-	-	-	-	3	2	2
CO2	3	2	2	-	-	2	3	-	-	-	-	-	3	2	2
CO3	3	2	2	-	-	2	3	-	-	-	-	-	3	2	2
CO4	3	2	2	-	-	2	3	-	-	-	-	-	3	2	2
CO5	3	2	2	-	-	2	3	-	-	-	-	-	2	2	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Overview of Membrane Science and Technology: Historical Development of Membranes, Types of Membranes, Membrane Processes.

Membrane Transport Theory: The Solution-Diffusion Model, Structure-Permeability Relationships in Solution-Diffusion Membranes, Pore-Flow Membranes.

Membranes and Modules: Isotropic Membranes, Anisotropic Membranes, Inorganic Membranes, Liquid Membranes, Hollow Fiber Membranes, Membrane Modules.

Concentration Polarization and Fouling: Concentration Polarization in Liquid Separation Processes, Gel Layer Model, Osmotic Pressure Model, Boundary Layer Resistance

Model, Concentration Polarization in Gas Separation Processes, Membrane Fouling, Fouling Control.

Membrane Processes: Theory, System Design, Applications and Economics: Membrane Processes: Theory, System Design, Applications and Economics, Reverse Osmosis, Pressure-Retarded Osmosis and Nanofiltration, Ultrafiltration, Microfiltration, Gas Separation, Pervaporation, Ion Exchange Membrane Processes like Electrodialysis, Fuel Cell Membranes, Membranes in Chlor-Alkali Processes, Membrane Contactors 3 Membrane Separation Fundamentals and Applications Dr. Andre R. Da Costa Membrane Distillation, Membrane Reactors and Membrane Bioreactors, Carrier Facilitated Transport, Submerged Membranes, Medical Applications of Membranes

Readings:

1. O.V. Nakagawal, O. Yoshihito, Membrane Science and Technology, Marcel Dekker, 1992.
2. C.J. King, Separation Processes, Tata Mc Graw Hill Co. Ltd., 1982.
3. R.E. Lacey, S. Looeb, Industrial Processing with membrane, Wiley Inter-Science New York,1972.

CH464	Optimization Techniques	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Formulate and solve linear Programming Problems
CO2	Determine the optimum solution to constrained and unconstrained
CO3	Apply dynamic programming principle to Linear programming problems.
CO4	Determine the integer solutions to Linear Programming Problems.

Course Articulation Matrix:

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	3	1	1	2	-	-	-	-	-	-	-	-	-	3
CO2	3	3	1	1	2	-	-	-	-	-	-	-	-	-	3
CO3	3	3	1	1	2	-	-	-	-	-	-	-	-	-	3
CO4	3	3	1	1	2	-	-	-	-	-	-	-	-	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Linear Programming: Introduction and formulation of models, Convexity, Simplex method, Big-M method, Two-phase method, Degeneracy, non-existent and unbounded solutions, revised simplex method, duality in LPP, dual simplex method, sensitivity analysis, transportation and assignment problems, traveling salesman problem.

Nonlinear Programming: Introduction and formulation of models, Classical optimization methods, equality and inequality constraints, Lagrange multipliers and Kuhn-Tucker conditions, quadratic forms, quadratic programming problem, Wolfe's method.

Dynamic Programming: Principle of optimality, recursive relations, solution of LPP

Integer Linear Programming: Gomory's cutting plane method, Branch and bound algorithm, Knapsack problem, linear 0-1 problem.

Readings:

1. Kanti Swarup, Man Mohan and P.K. Gupta, Introduction to Operations Research, S. Chand & Co., 2006.
2. J.C.Pant, Introduction to Operations Research, Jain Brothers, New Delhi, 2008.
3. N.S. Kambo, Mathematical Programming Techniques, East-West Pub., Delhi, 1991.

CH465	Process Intensification	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the scope for process intensification in chemical processes.
CO2	Implement methodologies for process intensification
CO3	Understand scale up issues in the chemical process.
CO4	Solve process challenges using intensification technologies

Course Articulation Matrix:

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	2	2	2	2	-	-	-	-	-	-	-	2	3	1
CO2	3	2	2	1	1	-	-	-	-	-	-	-	1	2	3
CO3	2	1	3	1	1	-	-	-	-	-	-	-	2	3	1
CO4	3	3	2	2	1	-	-	-	-	-	-	-	2	1	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, Process Intensifying Equipment, Process intensification toolbox, Techniques for PI application.

Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Implementation of Microreaction Technology, from basic Properties to Technical Design Rules, Inherent Process Restrictions in Miniaturized Devices and Their Potential Solutions, Microfabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes.

Scales of mixing, Flow patterns in reactors, mixing in stirred tanks: Scale up of mixing, Heat transfer. Mixing in intensified equipment, Chemical Processing in High-Gravity Fields Atomizer Ultrasound Atomization, Nebulizers, High intensity inline MIXERS reactors Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers, Design Principles of static Mixers Applications of static mixers, Higee reactors.

Combined chemical reactor heat exchangers and reactor separators: Principles of operation, Applications, Reactive absorption, Reactive distillation, Applications of RD Processes, Fundamentals of Process Modelling, Reactive Extraction Case Studies: Absorption of NOx Coke Gas Purification.

Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluent heat exchangers, Integrated heat exchangers in separation processes, Design of compact heat exchanger - example.

Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation Reactors, Flow over a rotating surface, Hydrodynamic cavitation applications, Cavitation reactor design, Nusselt-flow model and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sono-crystallization, Reactive separations, Super critical fluids

Readings:

1. Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.
3. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013.
4. Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.), Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.

CH466	Soft Computing Techniques	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the concept of neural networks
CO2	Use neural networks to control the process plants
CO3	Develop fuzzy logic based controllers for different processes
CO4	Combine fuzzy logic with neural networks for plant control

Course Articulation Matrix:

	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO2	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO3	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO4	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to Neural Networks: Artificial Neural Networks: Basic properties of Neurons, Neuron Models, and Feed forward networks. Computational complexity of ANNs.

Neural Networks Based Control: ANN based control: Introduction: Representation and identification, modeling the plant, control structures - supervised control, Model reference control, Internal model control, Predictive control: Examples - Inferential estimation of viscosity an chemical process, Auto - tuning feedback control, industrial distillation tower.

Introduction to Fuzzy Logic: Fuzzy Controllers: Preliminaries - Fuzzy sets and Basic notions -Fuzzy relation calculations - Fuzzy members - Indices of Fuzziness - comparison of Fuzzy quantities - Methods of determination of membership functions.

Fuzzy Logic Based Control: Fuzzy Controllers: Preliminaries - Fuzzy sets in commercial products - basic construction of fuzzy controller - Analysis of static properties of fuzzy controller - Analysis of dynamic properties of fuzzy controller - simulation studies - case studies - fuzzy control for smart cars.

Neuro - Fuzzy and Fuzzy - Neural Controllers: Neuro fuzzy systems: A unified approximate reasoning approach - Construction of role bases by self-learning: System structure and learning. Introduction to Genetic algorithms. Controller design using genetic algorithms.

Readings:

1. Bose and Liang, Artificial Neural Networks, Tata McGraw Hill, 1996
2. Huaguang Zhang, Derong Liu, Fuzzy Modeling and Fuzzy Control, Birkhauser Publishers, 2006.
3. Kosco B, Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence, Prentice Hall of India, 1992.
4. S.N. Sivanandam, S.N. Deepa, Principles of Soft Computing, John Wiley & Sons, 2007.

CH467	Water and Air Quality Management	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	To understand the various forms of water pollutants and their effects on human and environment
CO2	To know the various methods of controlling water pollutants
CO3	To understand the various forms of air pollutants and their effects on human and environment
CO4	To know the various methods of controlling air pollutants

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	-	1	1	3	-	-	-	-	-	2	3	-	3
CO2	3	2	-	1	1	2	-	-	-	-	-	2	3	-	3
CO3	3	2	-	1	1	2	1	-	-	1	-	-	3	-	3
CO4	3	2	2	1	2	-	2	3	-	2	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Water Demand and Quality: Historical introduction to the water and wastewater environment; water quality standards and parameters; assessment of water quality; types of water demand; estimating quantity of water; forecasting population, design period and factors affecting it. Collection and Conveyance of Water: Selecting source(s), various kinds of intake; design of intake structure; design of pumping main; economic sizing of pumping mains. Water Treatment Processes: Clarification - principles of sedimentation; types of settling; discrete particle settling; design of primary sedimentation tank; flocculent type; design of secondary settling tank. Coagulation and flocculation - purpose and action of coagulants. Filtration - theory of granular media filtration; types of filters; slow sand filter and rapid sand filter; mechanism of filtration; modes of operation and operational problems; negative head and air binding phenomena; dual and multimedia filtration. Disinfection - chlorine dioxide; chloramines; ozonation; UV radiation; chlorination. Treatment of groundwater - iron and manganese removal; fluoride removal. Water Distribution Systems: Methods of distribution; design of water distribution systems.

Air pollution-sources, effects on human, vegetation, environment, air pollutants. Indoor pollution. Meteorology, factors affecting dispersion of pollutants, Plume behaviour. Modelling of air pollutants, Dispersion modelling. Monitoring of pollutants-Particulate and gaseous, Control of air pollutants-Methods for particulate and gaseous pollutants, Air quality legislations

Readings:

1. Nathanson, J.A., Basic Environmental Technology, Prentice Hall of India, New Delhi, 2002.
2. Masters, G.M., Introduction to Environmental Engineering and Science, Prentice Hall, India, 1995.
3. Peavy, H.S., Rowe, D.R., and Tchobanoglous, G., Environmental Engineering, McGraw Hill, Singapore, 1985.
4. Gray, N.F., Water Technology – An Introduction for Environmental Scientists and Engineers, Elsevier, A division of Reed Elsevier India Private Limited, New Delhi, 2006
5. C.S.Rao, “Environmental Pollution Control Engineering”, New Age International Pub., 2006
6. M.N. Rao & H.V.N Rao, Air Pollution, Tata McGraw Hill Co. Ltd, Delhi, 1990.
7. Peavy H S, Rowe, D.R. Tchobanaglous “Environmental Engineering” McGraw Hill Education, 1985

Service Courses offered by Ch.ED to Other Departments

OPEN ELECTIVES COURSES (OPC)

CH340	Paper Production Technology	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Explain process for manufacturing paper
CO2	Identify harmful impacts of paper and pulp industries on environment.
CO3	Describe mechanical-chemical pulping processes
CO4	Distinguish methods for pulp treatment.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	-	-	-	-	3	-	-	-	-	-	1	3	1
CO2	1	3	-	-	2	-	3	-	-	-	-	-	1	3	1
CO3	1	3	-	-	-	-	3	-	-	-	-	-	1	3	1
CO4	1	3	-	-	2	-	3	-	-	-	-	-	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction and Paper Making Raw Materials: History of Paper Making, Paper Making Raw Materials: Wood Anatomy and Chemistry, Wood Chip Preparation and Handling at The Pulp Mill, Solid Wood Measurement, Properties of Selected Wood Species.

Pulping Processes and Pulp Treatment: Introduction to Pulping, Mechanical Pulping, Chemical Pulping, Semi-Chemical Pulping, Soda Pulping, Kraft Pulping, Sulfite Pulping, Other Pulping Methods, Bleaching Mechanical Pulps, Measurement of Lignin Content, Bleaching Chemical Pulps, Chemical Recovery, Refining, Pulp Characterization.

Paper Making Equipment and Process: Fiber Preparation and Approach, Raw Materials, Functional Additives, Control Additives, Wet End Chemistry, Paper Manufacture, Paper Machine, Headbox, Fourdrinier Wet End, Twin Wire Formers, Cylinder Machine, Press Section, Dryer Section, Post Drying Operations, Coating.

Environmental Protection: Water Pollution, Water Quality Tests, Aqueous Effluent Treatments, Air Pollution, Air Quality Tests and Control, Solid Waste Disposal.

Properties of Paper: General Grades of Paper, Structure, Mechanical and Chemical Properties, Basic Optical Tests of Paper.

Readings:

1. J. P. Casey, Pulp and Paper: Chemistry and Chemical Technology, Volumes 1 & 2, Wiley
   Inter science, 3rd Edition, 1980.
2. G. A. Smook, Handbook for Pulp and Paper Technologists, Angus Wilde Publ, Inc, 3rd Edition, 2002.
3. Christopher J. Biermann, Handbook of Pulping and Paper Making, Academic Press, 1996.
4. Monika EK, Goran Gellerstedt, Gunnar Henrikson, Pulping Chemistry and Technology, Walter De Gruyter & Co, 2009.
5. George T. Austin, Shreve's Chemical Process Industries, McGraw Hill Education, 5th Edition, 2017.

CH390	Nanotechnology and Applications	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the properties of nanomaterials
CO2	Synthesize nanoparticles
CO3	Characterize nanomaterials
CO4	Scale up the production of nanoparticles
CO5	Evaluate safety and health related issues of nanoparticles

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	-	-	-	-	-	-	-	-	1	1	1
CO2	3	2	2	1	-	-	-	-	-	-	-	-	3	2	1
CO3	3	3	1	1	-	-	-	-	-	-	-	-	2	-	-
CO4	2	1	1	1	-	-	-	-	-	-	-	-	1	-	-
CO5	1	-	1	-	-	-	2	-	-	-	-	1	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction to Nanotechnology: Introduction to Nanotechnology and Materials, Nanomaterials, Introduction to Nanosizes and Properties Comparison with The Bulk Materials, Different Shapes and Sizes and Morphology.

Fabrication of Nanomaterials: Top Down Approach Grinding, Planetary Milling and Comparison of Particles, Bottom Up Approach, Wet Chemical Synthesis Methods, Microemulsion Approach, Colloidal Nanoparticles Production, Sol Gel Methods, Sonochemical Approach, Microwave and Atomization, Gas Phase Production Methods: Chemical Vapour Depositions.

Kinetics at Nanoscale: Nucleation and Growth of Particles, Issues of Aggregation of Particles, Oswald Ripening, Stearic Hindrance, Layers of Surface Charges, Zeta Potential and pH.

Carbon Nanomaterials: Synthesis of Carbon Bucky-Balls, List of Stable Carbon Allotropes Extended, Fullerenes, Metallofullerenes, Solid C60, Bucky Onions, Nanotubes, Nanocones.

Quantum Mechanics: Quantum Dots and Its Importance, Pauli Exclusion Principle, Schrödinger's Equation, Application of Quantum Dots: Quantum Well, Wire, Dot, Characteristics of Quantum Dots, Synthesis of Quantum Dots Semi-Conductor Quantum Dots

Nanomaterials Characterization: Fractionation Principles of Particle Size Measurements, Particle Size and Its Distribution, XRD, Zeta Potential, Electronic Band Structure Electron Statistics Application: Optical Transitions in Solids, Photonic Crystals, Microscopies SEM, TEM, Atomic Forced Microscopy, Scanning and Tunneling Microscopy.

Applications: Self-Assembly and Molecular Manufacturing, Surfactant Based System Colloidal System Applications, Functional Materials Applications, Commercial Processes of Synthesis of Nanomaterials.

Nano-inorganic Materials of $CaCO_3$ Synthesis, Hybrid Waste Water Treatments Systems, Electronic Nanodevices,

Nanobiology: Biological Synthesis of Nanoparticles and Applications in Drug Delivery, Nanocontainers and Responsive Release of Active Agents, Layer by Layer Assembly for Nanospheres, Safety and Health Issues of Nano Materials, Environmental Impacts, Case Study for Environmental and Societal Impacts.

Readings:

1. Kulkarni Sulabha K, Nanotechnology: Principles and Practices, Capital Publishing Company, 2007.
2. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009.
3. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005.
4. Gabor L. Hornyak, H. F. Tibbals, Joydeep Dutta, John J. Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2008.
5. Davies, J.H., The Physics of Low Dimensional Semiconductors: An Introduction, Cambridge University Press, 1998.

CH490	Carbon Capture, Sequestration and Utilization	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the necessity of CO_2 capture, storage and utilization.
CO2	Distinguish the CO_2 capture techniques.
CO3	Evaluate CO_2 Storage and sequestration methods.
CO4	Assess Environmental impact of CO_2 capture and utilization.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO2	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO3	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO4	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:
Introduction: Global status of CO_2 emission trends, Policy and Regulatory interventions in abatement of carbon footprint, carbon capture, storage and utilization (CCS&U).
CO_2 capture technologies from power plants: Post-combustion capture, Pre-combustion capture, Oxy-fuel combustion, chemical looping combustion, calcium looping combustion.
CO_2 capture agents and processes: Capture processes, CO2 capture agents, adsorption, ionic liquids, metal organic frameworks
CO_2 storage and sequestration: Geological sequestration methods, Biomimetic carbon sequestration.
CO_2 Utilization: CO_2 derived fuels for energy storage, polymers from CO_2, CO_2 based solvents.
CO_2 to oxygenated organics, Conversion into higher carbon fuels, High temperature catalysis.
Environmental assessment of CO_2 capture and utilization: Need for assessment, Green chemistry and environmental assessment tools, Life cycle assessment (LCA), ISO standardization of LCA, Method of conducting an LCA for CO_2 capture and Utilization.

Readings:
1. Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Carbon dioxide utilization: Closing the Carbon Cycle, Elsevier, 2015.

2. Goel M, Sudhakar M, Shahi RV, Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry, TERI, Energy and Resources Institute, 2015.
3. Amitava Bandyopadhyay, Carbon Capture and Storage, CO2 Management Technologies, CRC Press, 2014.
4. Fennell P, Anthony B, Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO2) Capture, Woodhead Publishing Series in Energy: No. 82, 2015.
5. Mercedes Maroto-Valer M, Developments in Innovation in Carbon Dioxide Capture and Storage Technology: Carbon Dioxide Storage and Utilization, Vol 2, Woodhead Publishing Series in Energy, 2014.