SEMESTER-I								
S. No.	**Course Code**	**Name of Course**	**Cat.**	**L**	**T**	**P**	**Credits**	**Contact Hours**
01	XXXX	Physics/ Chemistry	EE	2	1	2	4	5
02	XXXX	Mathematics-I	EE	3	1	0	4	4
03	XXXX	English Language & Technical Communication / Introduction to Artificial Intelligence and Machine Learning	HSS/EE	2	0	2	3	4
04	CHN11101	Chemical Process Principles Core Engineering Essential Course-I (Flexible L-T-P)	CEE	3	0	0	3	3
05	CHN11102/CHN12400	Engineering Thermodynamics Core Engineering Essential Course-I (Flexible L-T-P)	CEE	2	1	0	3	3
06	XXXX	Engineering Graphics / Workshop and manufacturing Processes	EE	1	0	2	2	3
07	IDN11600/IDN12600	Environment and Climate Change	EE	2	0	0	0	2
08	XXXX	Extra Academic Activity-A / Extra Academic Activity-B	EAA	--	--	4	2	4**
Total							21	24+4**

Theory Courses = 6, Lab = 03, EAA = 1

SEMESTER-II								
S. No.	**Course Code**	**Name of Course**	**Cat.**	**L**	**T**	**P**	**Credits**	**Contact Hours**
01	XXXX	Physics / Chemistry	EE	2	1	2	4	5
02	XXXX	Mathematics-II	EE	3	1	0	4	4
03	XXXX	Introduction to Artificial Intelligence and Machine Learning / English Language & Technical Communication	EE	2	0	2	3	4
04	XXXX	Material Science and Engineering (to be taken up by Applied Mechanics) Core Engineering Supporting Course-I (Flexible L-T-P)	CES	3	0	0	3	3
05	XXXX	Fluid Flow Operations (to be taken up by Applied Mechanics) Core Engineering Essential Course-III (Flexible L-T-P)	CEE	3	0	2	4	5
06	XXXX	Engineering Graphics / Workshop and manufacturing processes	EE	1	0	2	2	3
07	XXXX	Extra Academic Activity-B / Extra Academic Activity-A	EAA	--	--	4	2	4**
Total							22	24+4**

Theory Course = 6, Lab = 04, EAA = 1

SEMESTER-I

COURSE CODE	XXXX
COURSE TITLE	Engineering Physics-III
NUMBER OF CREDITS	4
L: T: P	2: 1: 2

COURSE LEARNING OBJECTIVES

- PH11101.1: The course provides basics of concepts related to thermodynamics which are required for Civil Engineering, Chemical Engineering, and Biotechnology students to understand various reaction mechanism.
- PH11101.2: The crystal structure and their electronic and magnetic properties are introduced in the course. The contents will help students to understand usage of various materials in applications like chemical/gas/bio sensors, biotechnological, drug-delivery etc.
- PH11101.3: The course introduces students about applications of ultrasonics for the students of Civil Engineering, Chemical Engineering, and Biotechnology. Further, the applications of ultrasonics will provide understanding of building acoustics.

COURSE CONTENT

UNIT-1

Thermodynamics: Concept of heat. Laws of thermodynamics. Entropy. adiabatic isothermal and isobaric process. Carnot cycle and its efficiency. Refrigerator. Clausius Clapeyron's equation. latent heat. specific heat of solids and gases. thermal conductivity. Maxwell's equations.

UNIT-2

Solid State Physics: Crystal structure. Space lattice. Unit cell. Miller indices. Interplaner spacing. Characteristic and Continuous. X-ray spectra. Mosley's law. X-ray diffraction and Bragg's law.

UNIT-3

Diamagnetism. Paramagnetism. Ferromagnetism. Hysteresis curve. Curie-Weiss Law.

UNIT- 4

Semiconductors: intrinsic and extrinsic semiconductors, p-type and n-type semiconductors, p-n junction.

UNIT- 5

Acoustics: Production and detection of ultrasonic waves. Velocity of ultrasonics in liquids and gases. Applications of ultrasonic waves. Acoustics of buildings. Reverberation. Absorption coefficient. Sabines's formula for reverberation time.

LAB COMPONENTS

List of Experiments

1. To measure height of a building using Sextant.
2. To measure Coefficient of thermal conductivity of rubber by Lee's disc method.

3. To study variation of magnetic field along the axis of a current carrying coil.
4. Magnetic field distribution due to Helmholtz coil setup.
5. To determine resistivity by four probe method.
6. To study variation of magnetic field along axis of Helmholtz coil.
7. To measure surface tension using the “break-away” method.
8. To determine specific heat of copper, lead and glass.

TEXT BOOKS / REFERENCE BOOKS:

1. M. W. Zemansky, Richard Dittman, Heat and Thermodynamics, McGraw-Hill.
2. Brij Lal and Subramaniam, Heat Thermodynamics & Statistical Physics, S. Chand.
3. Charles Kittel, Introduction to Solid State Physics, Wiley India Edition.
4. B. Ghosh, Principles of Acoustics, Sreedhar Publishers.

COURSE CODE	MA-Il 01
COURSE TITLE	MATHEMATICS-I
NUMBER OF CREDITS	4
L: T: P	3: 1: 0

COURSE CONTENT

UNIT l: Continuity' and Differentiability **[5L]**

Limit and Continuity ($\epsilon - \delta$ definition of one variable), Rolle's Theorem, Mean Value Theorems, Limit and Continuity ($\epsilon - \delta$ definition for several variables) and Differentiability for several variables.

Unit 2: Partial Derivatives and Taylors Theorem **[5L]**

Partial derivatives, Euler's theorem, Implicit function, Change of variables, Jacobian,Taylor's theorem for functions of several variables, Extrema of functions of several variables, Lagrange method of undetermined multipliers.

UNIT 3: Integral Calculus **[7L]**

Multiple integrals (Double & Triple Integral), Change of order of integration, Area of bounded region, Arc length of curve, Volume and Surface area of solid of revolution, Multiple integral by change of variables, Dirichlet integrals, Moment of inertia, Center of gravity.

UNIT 4: Beta and Gamma Functions **[5L]**

Improper integrals, Convergence of improper integral, Beta function, Gamma function, Improper integrals involving a parameter.

UNIT 5: Vector Calculus **[8L]**

Gradient, Directional derivatives, Divergence and Curl, Line integral, Green's theorem, Surface and volume integrals, Gauss theorem, Stoke's theorems and their Applications.

UNIT 6: Ordinary Differential Equation **[10L]**

Existence and uniqueness of solutions of first order ODE, Exact differential equation, Solution of linear differential equation, Higher order linear differential equation, Solutions of homogeneous and non-homogeneous ODE (CF+PI), Variation of parameters, Method of undetermined coefficients.

TEXT BOOKS / REFERENCE BOOKS:

1. R. K Jain and S.R. K lyengar, Advanced Engineering Mathematics, Narosa Pub.House

2. Erwin Rreyszig, Advanced Engineering Mathematics, John Wiley & Sons, INC.

3. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers.

COURSE CODE	XXXX
COURSE TITLE	English Language & Technical Communication
NUMBER OF CREDITS	3
L: T: P	2: 0: 2

COURSE LEARNING OBJECTIVES

- The objective of this course is to develop essential language skills required for independent and effective communication for academic and social needs in the under-graduate engineering students.
- Understand the process and aspects of professional/technical communication in an international context.
- Develop a comprehensive understanding of the extensive vocabulary and usage in formal English language.
- Develop the competency for oral communication in everyday formal situations.
- Use the skills and sub-skills of reading and listening.
- Understand and practice the principles and conventions related to formal writing.

COURSE CONTENT

UNIT - 1 **[6L]**

Introduction to Technical Communication: Introduction- Definition of Communication, LSRW Skills, Good and Effective Communication, Process of Communication, Purpose of Professional/Technical Communication, Different Forms of Communication-Verbal and Non-verbal Communication, Organizational Communication and Barriers.

UNIT - 2 **[6L]**

Oral Communication: Common Everyday Situations- Conversations and Dialogues, Communication at Work Place, Professional Presentations- Key Principles in Making Effective Professional Presentations, Structuring a Professional Presentation, Common tools/aids in Presentation.

UNIT - 3 **[6L]**

Interviews and Group Discussion: Interviews: Types, preparation and strategies, positive grooming, frequently asked questions, verbal and non-verbal aspects.
Group Discussion: Introduction, types, techniques, Dos and Don'ts in a GD.

UNIT - 4 **[8L]**

Writing Skills - I: Basic Writing Skills- Effective Sentences: Role of Acceptability, Appropriateness, Brevity & Clarity in Writing, Cohesion & Coherence in Writing; Words and Style used for Formal and Informal Communication; Converting Informal Language to Formal.

UNIT - 5 **[10L]**

Writing Skills – II: Writing for Electronic Media-Letters, E-mails, Blogs, Cover letter, Resume Writing, Nuances of Technical Writing, Technical Reports, Plagiarism- how to avoid

plagiarism.

LAB COMPONENTS

List of Exercises:

1. **Grammar and Vocabulary:** Words Similar in Pronunciation- Homonyms and Homophones, Idioms, One Word Substitution, Foreign Expressions; Articles, Prepositions, Subject- Verb Agreement; Sentence Structure, Sentence types, Importance of Proper Punctuation.
   Activity: Various activities based on grammar and vocabulary.

2. **Phonetics:** Introduction to phonetics with the help of IPA/RP (Received pronunciation). Neutralization of mother tongue influence and conversation practice.
   Activity: Speaking / Vocabulary Drill: With special focus on intonation & common errors in pronunciation.

3. **Listening / Reading Comprehension:** Passage Comprehension- Skimming, Scanning Techniques, Note Making, Note Taking and Summarizing; Analytical and Critical Reading Practice, SQ3R Reading Method. Listening for Gist, Listening for Specific Information, listening to understand the attitude etc.
   Activity: Listening/ Reading Comprehension Exercises.

4. **Extempore/ Public Speaking:** The art of public speaking, techniques, strategies and methods.
   Activity: Delivering short prepared/impromptu speeches.

5. **Group Discussion**: Analysis of sample GDs.
   Activity: Topic based/ Case basedGDs based on current topics.

6. **Presentation Skills:** Analysis of Sample Presentations.
   Activity: Preparing a professional presentation on a topic and delivering it before the audience.

7. **Interviews:** Analysis of Sample Interviews
   Activity: Preparing resume, cover letter, mock interviews.

TEXT BOOKS / REFERENCE BOOKS:

1. Hancock, M. (2009). *English Pronunciation in Use*. Cambridge: Cambridge University Press.

2. Garner, Bryan A. (2013). *HBR Guide to Better Business Writing*, Boston: Harvard Business Review Press
3. Rizvi, M.A. (2005). *Effective Technical Communication*, Tata McGraw-Hill, New Delhi.
4. Raman, M and Sangeetha Sharma. (2015). *Technical Communication: Principles and Practice*, OUP.
5. Sharma, S and Binod Mishra. (2009). *Communication Skills for Engineers and Scientists (6th Ed.)*, Prentice Hall.
6. Wood, F.T. (2007). *Remedial English Grammar*, Macmillan.
7. Swan, M. (1995). Practical English Usage. Oxford: OUP.
8. Mohanraj, J. (2015). *Let Us Hear Them Speak*. New Delhi: Sage Texts.
9. Jones, D. (2012) *English Pronunciation Dictionary (18th ed)*. New Delhi: Cambridge Univ. Press.
10. Bansal, R.K and J.B Harrison. (2013). *Spoken English: A Manual of Speech and Phonetics*. New Delhi: Orient Blackswan
11. Seely, J (2005). The Oxford Guide to Effective Writing and Speaking. OUP.

COURSE CODE	CHN11101
COURSE TITLE	Chemical Process Principles
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES

- The capability to convert units and dimensions and also modify equations from system to another.
- The capability to apply the laws of physics and chemistry in solving process industry related applications.
- The proficiency to integrate the data and formulate the mass and energy balance problems.
- The capability to use mathematical knowledge for solving mass and energy balance problems with and without chemical reactions.

COURSE CONTENT

UNIT - 1 **[2L]**

Introduction to Chemical Engineering: History, importance of chemical engineering, role of chemical engineers, problems and challenges towards sustainability.

UNIT - 2 **[4L]**

Stoichiometry: Introduction - Units and Dimensions, conversions, Stoichiometric principles, composition relations, density and specific gravity.

UNIT - 3 **[4L]**

Ideal Gases and Vapor Pressure: Behaviour of Ideal gases, kinetic theory of gases, application of ideal gas law, gaseous mixtures, volume changes with change in composition. Vapour pressure- effect of Temperature on vapour pressure, vapour pressure plots, vapour pressure of immiscible liquids solutions.

UNIT - 4 **[4L]**

Humidity and Solubility: Humidity, saturation, vaporization, condensation, wet and dry bulb thermometry, Solubility and Crystallisation, Dissolution, solubility of gases.

UNIT - 5 **[8L]**

Material Balance: Material Balance in unit operations, material balance without chemical reaction, material balance involving chemical reaction, combustion of solids, liquids, and gaseous fuels, recycling operations, bypassing operations, purging operations. Unsteady state problems.

UNIT - 6 **[8L]**

Energy Balance: Thermophysics, components of energy balance equations, heat capacity of gases, liquids, and solids, estimation of heat of fusion, heat of vaporization, thermo-chemistry, Hess's law of constant heat summation, heat of reaction, effect of temperature on standard heat of reaction, calculation of theoretical flame temperature and actual flame temperature.

TEXT BOOKS / REFERENCE BOOKS:

1. Basic Principles and Calculations in Chemical Engineering, Himmelblau, 8th Edn.Prentice Hall of India Ltd, India.
2. Elementary Principles of Chemical Processes,Richard M. Felder, Ronald W. Rousseau, Lisa G. Bullard, Wiley,India.
3. Chemical Process Principles, O. A Hougen, K. M. Watson and R. A. Ragatz, CBS Publishers and Distributors, New Delhi.
4. Stoichiometry, B. I. Bhatt, Tata McGraw Hill Publishers Ltd., New Delhi.

COURSE CODE	CHN11102
COURSE TITLE	Engineering Thermodynamics
NUMBER OF CREDITS	3
L: T: P	2: 1: 0

COURSE LEARNING OBJECTIVES

- To understand the basic concepts of thermodynamics.
- To learn about first law of thermodynamics and its application in open and closed systems, steady and unsteady processes.
- To understand the second law of thermodynamics and concept of entropy and exergy.
- To study gas, vapor power cycles, and refrigeration cycles.

COURSE CONTENT

UNIT-1 **[7L]**

Basic concepts, Properties of pure substances and Work & heat: Introduction, thermodynamic systems, properties & state, process & cycle, force, energy, pressure, specific volume, zeroth law, Phase equilibrium, independent properties, equations of state, compressibility factor, tables of thermodynamic properties & their use. Definition of work and its identification, work done at the moving boundary, Concept of heat, comparison of heat and work.

UNIT-2 **[7L]**

First law for open and closed systems: First law for a cycle as well as for a change of state. Internal energy, enthalpy and Specific heats, Conservation of mass in control volume, steady state process, transient processes.

UNIT-3 **[8L]**

Second Law of Thermodynamics and Entropy: Need for the second law, heat engine, heat pump, refrigerator, Carnot cycle, Kelvin-Planck & Clausius statements, the ideal gas Carnot Cycle, Concept of entropy, entropy of a pure substance, entropy change of a reversible & irreversible process, principle of increase of entropy.

UNIT- 4 **[8L]**

Entropy analysis for control volume and exergy: Second law for control volume, Steady state & Transient processes. Efficiency, available energy, reversible work & irreversibility for open and closed systems, second law efficiency.

TEXT BOOKS / REFERENCE BOOKS:

1. Thermodynamics: An Engineering Approach, Cengel Y.A., Boles M.A., McGraw Hill Education; 8th ed. 2017.
2. Introduction to Chemical Engineering Thermodynamics, Smith, Van Ness & Abbot, McGraw Hill Education 7th ed. 2015.
3. Fundamentals of Thermodynamics, Sonntag R.E., Borgnakke C., John Wiley & Sons, 10th ed. 2019.

COURSE CODE	XXXX
COURSE TITLE	Engineering Graphics
NUMBER OF CREDITS	2
L: T: P	1: 0: 2

COURSE LEARNING OBJECTIVES

- Understand the importance and principles of engineering drawing by hand practice and using computer aided drafting software.
- Understand the isometric and orthographic projections of different objects.
- Create assembly drawing of simple machine components.

COURSE CONTENT

UNIT-1 **[2L+2P]**

Introduction to engineering drawing and its importance in real life design and manufacturing Standards in drawing practice viz. types of lines, lettering, dimensioning, scales etc.

UNIT-2 **[4L+8P]**

Introduction to isometric and orthographic projection. Orthographic projection of points, projection of lines, projection of planes, orthographic views of solids sketching of the same for conceptualization.

UNIT-3 **[2L+6P]**

Introduction to computer aided drafting software and hands on practice of orthographic views of solid objects.

UNIT- 4 **[2L+4P]**

Sectional views of solid objects and hands on practice of sectional views of solid objects using computer aided drafting software.

UNIT- 5 **[1L+2P]**

Introduction to temporary fasteners (e.g. screwed fasteners, keys, cotters etc.) Details of screwed fasteners (e.g. bolt, nut, stud, screw etc), terminology of threads, types (e.g. V, square, acme, single/multi start, left/right handed etc). Assembly drawing of nut-bolt using computer aided drafting software.

TEXT BOOKS / REFERENCE BOOKS:

1. Jolhe D. A.,Engineering Drawing, Tata McGraw Hill Education
2. Basant Agrawal, C. M. Agrawal, Engineering Drawing, Tata McGraw Hill Education.
3. K L Narayana, P. Kannaiah, K. Venketa Reddy, Machine Drawing, New Age International publishers.

4. Ajeet Singh, Machine Drawing includes AutoCAD, Tata McGraw Hill Publishing Company Ltd.
5. Bhatt ND, Elementary Engineering Drawing, Charotar Publishing.

COURSE CODE	XXXX
COURSE TITLE	Workshop and Manufacturing Practices
NUMBER OF CREDITS	2
L: T: P	1: 0: 2

COURSE LEARNING OBJECTIVES

- .Students will be able to understand the importance of manufacturing which comprises materials, processes and systems
- Students will be able to understand the metal casting, metal working process and able to perform casting of metals, forging and sheet metal operations through practical classes.
- Students will be able to understand the machining operations, permanent joining processes. They will be able to perform machining operations on Lathe machine and joining through arc and gas welding processes.
- Students will be able to learn and perform operations related to carpentry, fitting, plastic molding, and Computer Numerical Control (CNC) machines.

COURSE CONTENT

UNIT-1 **[4L]**

Concept of Manufacturing: Manufacturing definition; Role of materials, processes and systems in manufacturing; Classification and brief introduction of engineering materials such as metals & alloys, Classification and brief introduction of manufacturing processes.

UNIT-2 **[3L]**

Sand Casting Process of Metals: Elements of Green Sand Mould, Pattern design and making, Method of Preparation of Green Sand Mould; Casting Defects.

UNIT-3 **[2L]**

Metalworking Processes: Classification of Metalworking Processes-brief introduction of bulk and sheet metal processes, Hot Vs Cold Working; Hot and Cold Rolling; Types of Rolling Mills, Forging, Extrusion, Drawing.

UNIT- 4 **[3L]**

Machining Processes: Classification of machining processes & machine tools; Construction, Specification, and operations on Lathe Machine and Drilling machine.

UNIT- 5 **[2L]**

Fabrication Processes: Classification of Welding Operations, Types of Joints & Welding Positions; Brief description of Arc, Resistance and Gas welding techniques. Brazing and Soldering**.**

LAB COMPONENTS

List of Practical:

1. **Safety in Workshop (Demonstration):** Safety precautions and utilization of hand tools and machines of different shops with safe working habits. Introduction to measuring equipments and gauges of different shops.

2. **Carpentry:** Study of wood works, types of hand tools and machine. Making of one job involving wood work joint.

3. **Fitting:** Study of different fits and hand tools. Making of one job involving fitting to size, male-female fitting with drilling and tapping.

4. **Welding:** Study of electric arc welding and gas welding, tools, types of weld joints and safety precaution during welding. Making of one joint using electric and gas welding. Students will be introduced to brazing and soldering (demonstration).

5. **Sheet Metal Work:** Study of different hand tools, machine and sheet metal joints. Making of one utility job in sheet metal.

6. **Foundry:** Principles of molding, methods, core & core boxes, preparation of sand mould of given pattern and casting (demonstration).

7. **Black Smithy:** Introduction to hot working and Study of forging hand tools, furnace and machine. Making a job on hot upset forging.

8. **Machining:** Study of lathe machine, cutting tools and turning related operations. Making of one job on lathe machine including facing, step and taper turning, threading operations.

9. **Plastic Processing:** Introduction to plastics and different plastic molding techniques. Study of injection molding process with demonstration.

10. **Computer Numerical Control (CNC):** Introduction to automation & CNC, Assembly of models of CNC, CNC wood router, engraving and exposure to part programming. Preparation of part program for simple profiles. Making a job on CNC (Demonstration).

11. **Mini Project:** Team activity – Fabrication of prototype model based on above practical.

TEXT BOOKS / REFERENCE BOOKS:

1. Mikell P. Groover, Principles of Modern Manufacturing: Materials, Processes and Systems, John Wiley.
2. 1. S. K. Hajra Choudhury, A. K. Hajra Choudhury and N. Roy, Elements of Workshop Technology (Volume 1: Manufacturing Processes, Volume 2: Machine Tools), Media Promoters & Publishers Pvt Ltd., 2010.
3. Serope Kalpakjian and Steven R. Schmid, Manufacturing Engineering and Technology, Pearson, 2013.
4. Erik Oberg, Franklin D. Jones, Holbrook L. Horton, Henry H. Ryffel, and Christopher J. McCauley Laura Brengelman, Machinery's Handbook, Industrial Press, Inc., 2020.
5. HMT, Mechatronics, McGraw Hill Education, 2017.
6. Manufacturing Processes I, https://nptel.ac.in/courses/112107144.
7. Fundamentals of manufacturing processes, Swayam Course.

COURSE CODE	XXXXX
COURSE TITLE	Introduction to Environment and Climate Change
NUMBER OF CREDITS	2
L: T: P	1: 1: 0

Course Learning Objective:

This course enables the students to become conversant with the structural and functional attributes of ecosystem and environment. Moreover, the students will understand the impact of climate change and pollution on its resources including biodiversity.

COURSE CONTENT

UNIT-1 **[7L]**

Introduction to environmental science. Ecology, biodiversity and conservation. Biomagnification and Biotransformation. Bioremediation and phytoremediation. Biosorption and bioaccumulation. Biological wastewater treatment. Bioenergy. Need for public awareness.

UNIT-2 **[7L]**

Environmental pollution: sources, causes and effects. Environmental monitoring (EMP) and EIA. Control/ mitigation measure for water, soil and air pollution. Solid waste management. Sustainable development goals (SDG). Environmental laws/ Acts.

UNIT-3 **[6L]**

Current environmental issues of major concerns - acid rain, ozone layer depletion, global warming and climate change. Carbon ecology footprint and reduction. Case studies highlighting the impacts on society. Technological intervention.

TEXT BOOKS / REFERENCE BOOKS:

1. 1. A Basic Course in Environmental Studies. Deswal & Deswal. Pub. Dhanpat Rai & Sons. 2013
2. 2. Environmental Studies. E. Bharucha. Pub. University Press. 2018
3. 3. Environmental Engineering. Peavy et.al. Pub. McGraw Hill. 2013
4. 4. A Text Book of Environmental Engg. Venugpal Rao. Pub. PHI learning. 2012

SEMESTER-II

COURSE CODE	XXXX
COURSE TITLE	Mathematics - II
NUMBER OF CREDITS	4
L: T: P	3: 1: 0

COURSE CONTENT

UNIT – 1 **[7L]**

Linear Algebra and Matrices: Vector spaces, Subspaces, Linear dependence and independence, Basis and dimension, Dimension theorem. Linear Transformation, Rank–Nulity Theorem (Statement only), Computation of Rank and nullity of Linear Transformation, Eigenvalues and Eigenvectors, Cayley-Hamilton theorem, Application of Eigen Values and Eigen Vectors, Diagonalization.

UNIT – 2 **[7L]**

Laplace Transform: Laplace transformation and its properties, Unit – step, Impulse and Periodic functions, Error Function. Inverse Laplace Transform, Convolution Theorem, Evaluation of Integral by Laplace Transform, Application of Laplace transform to solution of ODE & PDE.

UNIT - 3 **[7L]**

Fourier Series & Fourier Transform: Fourier series, Convergence of Fourier Series, Half range series. Fourier Integral, Fourier sine and Cosine Integral, Complex form of Fourier Integral. Fourier Transform, Fourier Sine and Cosine Transform, Finite sine and cosine transform, Convolution theorem, Application of Fourier Transform to boundary value problems.

UNIT – 4 **[7L]**

Partial Differential Equation: First order PDE, Formation of PDE, Classification of solution: Complete, General and Particular solution, Lagrange's linear PDE, Non-Linear First Order PDE, Some Standard form -I, II, III, IV. Charpit's method. Higher Order Homogeneous linear PDE with constant coefficients, C. F. & P.I, Non-homogeneous PDE with constant coefficients, C. F. & P. I.

UNIT – 5 **[6L]**

Application of Partial Differential Equation: Classification of Linear PDE of second order: Elliptic, Parabolic and Hyperbolic, Solution of separation of variables. Interior and Exterior BVP: Heat and Wave equation, Laplace Equation.

UNIT – 6 **[6L]**

Probability: Discrete and Continuous Random Variables, Probability distributions of random variable, Mathematical Expectation, Descriptive Statistics-Mean, Median, Mode and standard deviation, Probability distributions: Binomial and Poisson Distributions, Normal Distribution.

TEXT BOOKS / REFERENCE BOOKS:

1. R.K. Jain & S.R.K. Iyenger, Advanced Engineering Mathematics, 5th edition, 2016, Narosa Pub.
2. B.S. Grewal, Higher Engineering Mathematics, 44nd edition, 2018, Khanna Publishers.
3. S. C. Gupta & V. K. Kapoor, Probability and Statistics, 12th edition, 2020, S Chand Publication.
4. Erwin Kreyszig, Advanced Engineering Mathematics, 10th Edition, 2015, John Wiley & Sons.
5. Qazi Zameeruddin & Surjeet Singh, Modern Algebra, 9th edition 2021, S Chand Publication
6. Online Source: NPTEL.

COURSE CODE	XXXX
COURSE TITLE	English Language & Technical Communication
NUMBER OF CREDITS	3
L: T: P	2: 0: 2

COURSE LEARNING OBJECTIVES

- The objective of this course is to develop essential language skills required for independent and effective communication for academic and social needs in the under-graduate engineering students.
- Understand the process and aspects of professional/technical communication in an international context.
- Develop a comprehensive understanding of the extensive vocabulary and usage in formal English language.
- Develop the competency for oral communication in everyday formal situations.
- Use the skills and sub-skills of reading and listening.
- Understand and practice the principles and conventions related to formal writing.

COURSE CONTENT

UNIT - 1 **[6L]**

Introduction to Technical Communication: Introduction- Definition of Communication, LSRW Skills, Good and Effective Communication, Process of Communication, Purpose of Professional/Technical Communication, Different Forms of Communication-Verbal and Non-verbal Communication, Organizational Communication and Barriers.

UNIT - 2 **[6L]**

Oral Communication: Common Everyday Situations- Conversations and Dialogues, Communication at Work Place, Professional Presentations- Key Principles in Making Effective Professional Presentations, Structuring a Professional Presentation, Common tools/aids in Presentation.

UNIT - 3 **[6L]**

Interviews and Group Discussion: Interviews: Types, preparation and strategies, positive grooming, frequently asked questions, verbal and non-verbal aspects.
Group Discussion: Introduction, types, techniques, Dos and Don'ts in a GD.

UNIT - 4 **[8L]**

Writing Skills - I: Basic Writing Skills- Effective Sentences: Role of Acceptability, Appropriateness, Brevity & Clarity in Writing, Cohesion & Coherence in Writing; Words and Style used for Formal and Informal Communication; Converting Informal Language to Formal.

UNIT - 5 **[10L]**

Writing Skills – II: Writing for Electronic Media-Letters, E-mails, Blogs, Cover letter,

Resume Writing, Nuances of Technical Writing, Technical Reports, Plagiarism- how to avoid plagiarism.

LAB COMPONENTS

List of Exercises:

8. **Grammar and Vocabulary:** Words Similar in Pronunciation- Homonyms and Homophones, Idioms, One Word Substitution, Foreign Expressions; Articles, Prepositions, Subject- Verb Agreement; Sentence Structure, Sentence types, Importance of Proper Punctuation.
   Activity: Various activities based on grammar and vocabulary.

9. **Phonetics:** Introduction to phonetics with the help of IPA/RP (Received pronunciation). Neutralization of mother tongue influence and conversation practice.
   Activity: Speaking / Vocabulary Drill: With special focus on intonation & common errors in pronunciation.

10. **Listening / Reading Comprehension:** Passage Comprehension- Skimming, Scanning Techniques, Note Making, Note Taking and Summarizing; Analytical and Critical Reading Practice, SQ3R Reading Method. Listening for Gist, Listening for Specific Information, listening to understand the attitude etc.
    Activity: Listening/ Reading Comprehension Exercises.

11. **Extempore/ Public Speaking:** The art of public speaking, techniques, strategies and methods.
    Activity: Delivering short prepared/impromptu speeches.

12. **Group Discussion**: Analysis of sample GDs.
    Activity: Topic based/ Case basedGDs based on current topics.

13. **Presentation Skills:** Analysis of Sample Presentations.
    Activity: Preparing a professional presentation on a topic and delivering it before the audience.

14. **Interviews:** Analysis of Sample Interviews
    Activity: Preparing resume, cover letter, mock interviews.

TEXT BOOKS / REFERENCE BOOKS:

12. Hancock, M. (2009). *English Pronunciation in Use*. Cambridge: Cambridge University Press.

13. Garner, Bryan A. (2013). *HBR Guide to Better Business Writing*, Boston: Harvard Business Review Press
14. Rizvi, M.A. (2005). *Effective Technical Communication*, Tata McGraw-Hill, New Delhi.
15. Raman, M and Sangeetha Sharma. (2015). *Technical Communication: Principles and Practice*, OUP.
16. Sharma, S and Binod Mishra. (2009). *Communication Skills for Engineers and Scientists (6th Ed.)*, Prentice Hall.
17. Wood, F.T. (2007). *Remedial English Grammar*, Macmillan.
18. Swan, M. (1995). Practical English Usage. Oxford: OUP.
19. Mohanraj, J. (2015). *Let Us Hear Them Speak*. New Delhi: Sage Texts.
20. Jones, D. (2012) *English Pronunciation Dictionary (18th ed)*. New Delhi: Cambridge Univ. Press.
21. Bansal, R.K and J.B Harrison. (2013). *Spoken English: A Manual of Speech and Phonetics*. New Delhi: Orient Blackswan
22. Seely, J (2005). The Oxford Guide to Effective Writing and Speaking. OUP.

COURSE CODE	XXXX
COURSE TITLE	Material Science and Engineering
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES

To impart knowledge about

- materials and structures.
- Properties of materials for variety of applications.
- Tailoring of different properties for different applications.

COURSE CONTENT

UNIT-1 **[5L]**

Introduction: Historical perspective of Materials Science; Structure and properties relationship of Engineering Materials; Classification of materials; Introduction to Ceramics, Composites Materials: Processing and Applications; Advanced Materials.

UNIT-2 **[7L]**

Structure of Solids and Characterization of Materials: Introduction to crystal structures and systems; Metallic structures; Ceramic crystal structures; Crystallographic directions and planes, Miller indices, Density computations, Crystallography, Diffraction methods, Metallography, Introduction to Electron microscopy and Thermal characterization techniques**.** .

UNIT-3 **[3L]**

Imperfections in Crystals: Types of imperfections, Dislocations, Surface and Bulk defects .

UNIT- 4 **[3L]**

Diffusion: Diffusion mechanisms, steady and non-steady state diffusion, Factors that influence diffusion, Laws of diffusion, Applications of Diffusion.

UNIT- 5 **[5L]**

Phase Diagrams and Phase Transformations: Unary, Binary, Equilibrium phase diagrams, Eutectic, Eutectoid, Peritectic and peritectoid reactions, Transformation rate effects and TTT diagrams. Microstructure and property changes in iron-carbon system, Iron-Carbon (Fe-C or Fe-Fe3C) Diagram.

UNIT - 6 **[10L]**

Mechanical Behaviour of Materials: Elastic and Plastic properties, Fatigue, Fracture, Creep.

UNIT - 7 **[7L]**

Thermal, Electrical, Magnetic, Optical Properties: Thermal behaviour of Materials; Electrical conduction, Semi conductivity, Super conductivity, Dielectric behaviour,

Ferroelectricity, Piezoelectricity, Magnetic behaviour of Materials; Optical properties of materials and their applications.

TEXT BOOKS / REFERENCE BOOKS:

1. "Materials Science and Engineering: An Introduction" by William D. Callister Jr., David G. Rethwisch.
2. "Materials Science and Engineering: A First Course" by Raghavan V.
3. "Mechanical Metallurgy" by George E. Dieter.
4. "Elements of materials science and engineering" by Lawrence H. Van Vlack..

COURSE CODE	XXXX
COURSE TITLE	Fluid Flow Operations
NUMBER OF CREDITS	4
L: T: P	3: 0: 2

COURSE LEARNING OBJECTIVE:
To understand basic concepts of fluid flow and its application to chemical process industries including pipe flow and fluid machinery

COURSE CONTENT

UNIT – 1:

INTRODUCTION TO FLUID MECHANICS

Physical properties of fluids, Rheology of fluids, Hydrostatic pressure on plane and curved surfaces, centre of pressure, Kinematics of Fluid flow: Types of fluid flows, Description of motion, continuity equation, stream function and velocity potential, applications of potential flow.

UNIT – 2:

DYNAMICS OF FLUID FLOW AND DIMENSIONAL ANALYSIS:

Euler's Equation of motion, Bernoulli's equation and its applications, Reynolds transport theorem, Momentum equation (Navier-Stokes equation). Dimensional Analysis and similarity, Buckingham's Pi theorem, Important dimensionless numbers and their physical significance.

UNIT – 3:

LAMINAR AND TURBULENT FLOWS:

Stokes law, Terminal Velocity, Free and hindered settling of particles, Criterion for settling regime. Equation of motion for laminar flow through pipes, isotropic and homogenous turbulence, scale and intensity of turbulence, eddy viscosity, Prandtl's mixing length theory, velocity distribution in turbulent flow over smooth and rough surfaces, minor losses, pipe in series and parallel.

UNIT – 4:

BOUNDARY LAYER:

Displacement, momentum and energy thickness, boundary layer over a flat plate, Prandtl boundary layer equation, laminar and turbulent boundary layer, application of momentum equation, separation and its control, drag and lift, drag on a sphere, 2D cylinder and aerofoil, Magnus effect.

UNIT – 5:

FLOW MEASURING DEVICES AND FLUID MACHINERY

Pitot tube, Orifice, Venturi, Nozzle and Bend meter, Rotameter, Turbine flowmeter, Vortex shedding flowmeter, Magnetic flowmeter, Doppler ultrasonic flowmeter. Pumps: Centrifugal Pumps, Specific speed, Priming, Characteristic curves, Cavitation, Reciprocating pumps, Comparison between Centrifugal and Reciprocating pumps. Compressors: working, classifications and applications.

LAB COMPONENT

List of Experiments

1. To verify the momentum equation using the experimental set-up on diffusion of submerged air jet.
2. To study the boundary layer velocity profile over a flat plate and to determine the boundary layer thickness.
3. To study the transition from laminar to turbulent flow and to determine the lower critical Reynolds number.
4. To study the variation of friction factor 'f' for turbulent flow in commercial pipes.
5. To calibrate an orifice meter, venturimeter, and bend meter and study the variation of the co-efficient of discharge with the Reynolds number.
6. To study the impact of jets in a flat plate.
7. To study performance of two Centrifugal pumps connected in series and parallel.
8. To study performance of a Reciprocating pump.

REFERENCE BOOKS

1. Fox, R.W., McDonald, A.T., "Introduction to Fluid Mechanics", Wiley India.
2. F. M. White, "Fluid Mechanics," McGraw- Hill, India.
3. Som, S.K., Biswas G, and Chakraborty, S., "Introduction of Fluid Mechanics & Fluid Machines", TMH, New Delhi.
4. Shames, I.H., Mechanics of Fluids, McGraw Hill, International Students Edition.
5. Jagdish Lal, Fluid Mechanics, Metropolitan Book Company Ltd., Delhi.
6. Singh, S. Experiments in Fluid Mechanics, PHI Learning, New Delhi.
7. Prakash, M. N. S., Experiments in Hydraulics and Hydraulic Machines: Theory and Procedures, PHI Learning, New Delhi.
8. Majumdar, B., Fluid Mechanics with Laboratory Manual, PHI Learning, New Delhi.
9. "Instrumentation, Measurements & Experiments Fluids", E. Rathakrishnan, CRC Press, NY, 2007.
10. "Low-Speed Wind Tunnel Testing", A. Pope and J.J. Harper, John Wiley & Sons Inc., NY, 1966.
11. "Experimental Methods for Engineers", J.P. Holman, McGraw-Hill Inc., NY, 2001.
12. "Design & Analysis of Experiments", D.C. Montgomery, Wiley, 7th ed., 2009.

SEMESTER-III								
S. No.	**Course Code**	**Name of Course**	**Cat.**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	CHN13103	Chemical Engineering Thermodynamics	CEE	3	1	0	4	4
2	CHN13104	Heat Transfer Operations	CEE	3	1	2	5	5
3	CHN13105	Fluid Particle Mechanics and Mechanical Operations	CEE	3	1	2	5	5
4	XXXX	Numerical Methods and Statistical Techniques (To be taught by Maths Deptt)	CEE	2	1	0	3	3
5	XXXX	Management Concepts and Applications	HSS	3	0	0	3	3
6	XXXX	Sports/NCC/NSS/Music/Yoga/Dance/Arts	EAA	0	0	2	2	2**
Total							**22**	**20+2****

SEMESTER-IV								
S. No.	**Course Code**	**Name of Course**	**Cat.**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	CHN14106	Environmental Pollution Monitoring and Control	CEE	3	1	2	5	6
2	CHN14107	Mass Transfer Operations -I	CEE	3	1	2	5	6
3	CHN14108	Chemical Reaction Engineering-I	CEE	3	1	2	5	6
4	CHN14109	Process Dynamics & Control	CEE	3	1	2	5	6
5	XXXX	Business Economics (or from pool of courses to be offered by HSS)	HSS	3	0	0	3	3
6	XXXX	Sports/NCC/NSS/ Music/Yoga/Dance/Arts	EAA	0	0	2	2	2**
Total							**25**	**27+2****

SEMESTER-III

COURSE CODE	CHN13103
COURSE NAME	Chemical Engineering Thermodynamics
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES:

- The objective is to enable understanding of thermodynamic principles from a chemical engineering viewpoint i.e., to determine states of phase and chemical equilibrium necessary for the design of separations processes and chemical reactors.

COURSE CONTENT

UNIT – 1 **[8L]**

Fundamentals and Law of Thermodynamics: Terminologies of thermo-dynamics, variables and quantities of thermodynamics, Point and path properties, heat and work, reversible and irreversible processes, phase rule, First law and internal energy, statements of first law for the non-flow and flow systems, enthalpy and heat capacity limitations of the first law, Statements of the second law of thermodynamics, available and unavailable energies, entropy function, applications of the second law, Zeroth law of thermodynamics.

UNIT – 2 **[6L]**

Refrigeration and Liquefaction: The Carnot refrigerator, vapor-compression cycle, choice of refrigerant, absorption refrigeration cycle, heat pump, liquefaction processes, applications of refrigeration and liquefaction processes.

UNIT – 3 **[8L]**

Thermodynamic Properties of Real Gases: The PVT behavior of fluids, laws of corresponding states and equation of states approaches to the PVT relationships of non-ideal gas problems, compressibility factors, generalized equations of state, property estimation via generalized equation of state, fugacity and fugacity coefficients of real gases.

UNIT – 4 **[10L]**

Thermodynamics of Solutions: Fundamental Property relation, Maxwell equation and consistency tests, The Chemical potential and phase equilibria, Partial molar quantities, Gibbs-Duhem Equation, Criteria for thermodynamic equilibrium, Phase equilibrium criteria, Ideal Solutions and Ideal Gas Mixtures, Concept of Fugacity and Fugacity coefficient, Fugacity and Activity Coefficient Models, Non-ideal solutions, Residual and excess properties, Solid-liquid equilibrium, solubility of gases in liquids, Liquid-liquid equilibrium.

UNIT – 5 **[8L]**

Chemical Reaction Equilibrium: The reaction Coordinate, Application of equilibrium criteria to chemical reactions, the standard Gibbs free energy change and the equilibrium constant, Effect of temperature on equilibrium constant, Evaluation of equilibrium constants, Relation of equilibrium constants to composition, Heat effects, industrial reactions (NH_3 synthesis etc.), free energy calculations, Homogeneous and heterogeneous reaction systems,

multiple reactions, partially miscible and immiscible systems, Azeotropes, retrograde condensation, thermodynamic diagrams, Multi reaction Equilibria.

TEXT BOOKS / REFERENCE BOOKS:

1. J. M. Smith and Van Ness, "Introduction to Chemical Engineering Thermodynamics", 6th edition, McGraw Hill, New York.
2. Rao. Y.V.C. “Chemical Engineering Thermodynamics,” Universities Press.
3. K.V. Narayanan, “A text book of Chemical Engineering Thermodynamics", PHI Learning Private Limited, New Delhi.
4. B.F. Dodge, "Chemical Engineering Thermodynamics", McGraw Hill, New York.
5. S.I. Sandler, “Chemical and Engineering Thermodynamics, Wiley.
6. M.D. Koretsky, Engineering and Chemical Thermodynamics, 2nd edition, Wiley.

COURSE CODE	CHN13104
COURSE NAME	Heat Transfer Operations
NUMBER OF CREDITS	5
(L: T: P)	3: 1: 2

COURSE LEARNING OBJECTIVES:

- To study the fundamental concepts of heat transfer viz., conduction, convection, radiation, boiling, and condensation.
- To use these fundamentals in typical engineering applications (Heat exchanger and Evaporator) and current research.

COURSE CONTENT

UNIT-1 **[5L]**

Introduction to Heat Transfer: Concept of the mechanism of heat flow: conduction, convection, and radiation; effect of temperature on thermal conductivity of materials; introduction to combined heat transfer mechanism.

UNIT-2 **[5L]**

Conduction: Steady state conduction through plane and composite walls general heat conduction equation, concepts of thermal diffusivity and equivalent thermal conductivity. Variable thermal conductivity, Radial Heat conduction through thick cylindrical and spherical vessels, the concept of critical thickness, extended surfaces, Transient heat conduction.

UNIT-3 **[8L]**

Convective Heat Transfer: Natural Convection: Physical mechanism of natural convection; buoyant force; empirical heat transfer relations natural convection over vertical planes and a cylinder, horizontal planes, and cylinders, and a sphere - Forced Convection: Basic concept; hydrodynamic boundary layer; thermal boundary layer; flow over a flat plate; flow across a single cylinder and a sphere; flow inside tubes; empirical heat transfer relations; the relation between fluid friction and heat transfer; liquid metal heat transfer.

UNIT-4 **[6L]**

Thermal Radiation: Basic radiation concept; radiation properties of surfaces; black body radiation laws; Kirchhoff's Law, Plank Law, and Wien's Displacement Law, view factor concept; black body radiation exchange; radiation exchange between diffuse nonblack bodies in an enclosure; radiation shields; solar radiations.

UNIT-5 **[8L]**

Heat Exchangers & Evaporators: Type of heat exchangers; fouling factor; overall heat transfer coefficient; logarithmic mean temperature difference (LMTD) method; effectiveness-NTU method; compact heat exchangers. Evaporation, single and multiple effect operation, material and Energy balance in evaporators, boiling point elevation.

UNIT-6 **[5L]**

Condensation and Boiling: Introduction to condensation phenomena; heat transfer relations for laminar film condensation over vertical surfaces and a horizontal tube; pool boiling.

Lab Component

LIST OF EXPERIMENT (Heat Transfer Operations)

1. Conduction

a. To determine the thermal conductivity of metal bar.
b. To determine Heat transfer through composite wall.
c. To determine the thermal conductivity of insulating powder.
d. To plot the radial temperature distribution and to determine the thermal conductivity of pipe insulation.

2. Convection

a. To determine the variation of temperature along the length of pin fin under forced convection.
b. To determine the convective heat transfer coefficient for heated vertical cylinder loosing heat to the ambient by free or natural convection.
c. To determine the convective heat transfer coefficient for a horizontal pipe through which air flows under forced convection.

3. Radiation

a. To determine the Emissivity of a grey surface at different temperatures.
b. To determine the value of Stefan Boltzmann constant for radiation heat transfer.

TEXT BOOKS / REFERENCE BOOKS:

1. Heat Transfer by J.P.Holman, McGraw Hill Book Company.2017
2. Fundamentals of Heat Transfer by F.P Incorpera and P.D.Dewitt, John Wiley and Sons, Fifth Edition. 2018
3. Heat Transfer Principles and applications, Binay K. Dutta, Prentice Hall of India Pvt. Ltd., Fourteenth Edition, 2015.

COURSE CODE	CHN13105
COURSE NAME	Fluid Particle Mechanics and Mechanical Operations
NUMBER OF CREDITS	5
(L: T: P)	3: 1: 2

COURSE LEARNING OBJECTIVES:

- The students will learn properties and handling of particulate solids, size reduction, techniques of solid –solid, solid-fluid separation and mixing.

COURSE CONTENT

UNIT – 1 **[6 L]**

PROPERTIES OF PARTICULATE SOLID: Introduction to unit operations and their role in Chemical Engineering industries. Types of Mechanical Operations, Characteristics of particulate solids: sampling techniques, specification and screen analysis, particle size distribution, particle size measurement, Surface area measurements and statistical mean diameters.

UNIT – 2 **[5 L]**

HANDLING OF PARTICULATE SOLID: Transportation, conveying of bulk solids, classification and selection of conveyors. Storage of solids in bulk protected and unprotected piles, bines, silos, hoppers, mass flow and funnel flow Bins, Flow assisting devices, feeders.

UNIT – 3 **[8 L]**

SIZE REDUCTION & MECHANICAL SEPARATION: Principles of size reduction: Specific properties of solids for size reduction. Energy required for size reduction. Crushing and grinding efficiency. Laws of crushing, pulverization and ultrafine grinding. Classification of crushing and grinding equipment. Classification of separation methods for mixtures of solid-solid, solid-gas and solid-liquid. Screening, Classifiers, magnetic separation, electrostatic separation, Centrifugal separation, Cyclone separators, bag filters, scrubbers.

UNIT – 4 **[5L]**

MIXING OF SOLIDS & PASTES: Mixing and agitation - Mixing of liquids (with or without solids), mixing of powders, selection of suitable mixers, power requirement for mixing.

UNIT – 5 **[6L]**

FILTRATION: Theory of filtration, Batch and continuous filters, Flow through filter cake and filter media, compressible and incompressible filter cakes, filtration equipment - selection, operation and design of filters and optimum cycle of operation, filter aids.

Lab Component:

LIST OF EXPERIMENT

1. To determine the effect of initial concentration & initial suspension height on

sedimentation rates.
2. To study the batch settling process.
3. To study the operation of filter press in the laboratory and to evaluate specific cake resistance and
medium resistance.

4. Batch filtration studies using a plate and frame filter press.
5. Size distribution of sand particles using sieve shaker.
6. To study the characteristics of fluidized bed.
7. To study the characteristics of fixed bed.
8. To determine the efficiency of jaw crusher for crushing the material of known index.
9. To study the operation of a hammer mill.
10. To study effect of RPM on the power consumption of a ball mill (Variable/ Constant speed).
11. To study the drying characteristics of a solid material under batch drying condition.
12. To study the reduction ratio in jaw crusher.
13. To study the separation characteristics of elutriator.

TEXT BOOKS / REFERENCE BOOKS:

1. Chemical Engineering, Vol.2, Coulson and Richardson.
2. Chemical Engineers Hand Book, Perry R.H. & Chilton C.H.
3. Principles of Unit Operations, Foust A. S. & Associates.
4. Unit Operation in Chemical Engineering, McCabe Smith.

COURSE CODE	MAN13101
COURSE NAME	Numerical methods and statistical techniques
NUMBER OF CREDITS	3
(L: T: P)	3: 1: 0

COURSE CONTENT:

Unit-I Algebraic and Transcendental Equations **[8L]**
Errors in numerical computation and their analysis, Bisection method, Iteration method, Newton-Raphson Method, Method of False Position, rate of convergence, Method for complex root, Muller's Method, Quotient Difference method.

Unit-II Interpolation: **[9L]**
Introduction, Errors in Polynomial interpolation, Finite differences, Decision of errors, Newton's formula for interpolation, Gauss, Sterling, Bessel's, Everett's Formula, Interpolation by unevenly spaced points, Lagrange interpolation formula, Divided Difference, Newton's General interpolation Formula.

Unit-III Curve Fitting, Cubic Spline & Approximation: **[7L]**
Introduction, Method of Least Square curve fitting procedures, Fitting a straight line, Curve fitting by sum of exponential, Data fitting with cubic splines, Approximation of functions.

Unit-IV Numerical Integration and Differentiation: **[5L]**
Introduction, Numerical differentiation, Picard Iteration Method of Solution, Numerical integration, Trapezoidal rule, Simpson 1/3 rule, Simpson 3/8 rule, Booles & Weddles rule, Euler-Maclaurin's formula, Gaussian Formula, Numerical evaluation of singular integrals.

Unit-V Numerical Linear Algebra: **[6L]**
Numerical techniques for finding solution of system of linear equations and eigen values: Gauss Jordan, Gauss Seidel methods, Power method for estimating eigen values: LU and LL *factorization of matrices.

Unit –VI Statistical Computations: **[7L]**
Frequency Chart, Regression Analysis, Least Square fit, Polynomial fit, Linear and Nonlinear Regression, Multiple Regression, Statistical Quality Control Methods.

TEXT BOOKS / REFERENCE BOOKS:

1. R. K. Jain and S. R. K. Iyenger, Advanced Engineering Mathematics, Narosa Pub. House
2. M.K.Jain, S.R.K.Iyenger and R.K.Jain, Numerical Methods for Scientific and Engineering Computation, Wiley Eastern Ltd.
3. S.S Sastry, Introductory Methods of Numerical Analysis, Prentice Hall
4. S.Rajasekharan, Numerical Methods for Science and Engineering, S.Chand.
5. James I. Buchman and Peter R.Turner, Numerical Methods and Analysis, McGraw-Hills Inc.

COURSE CODE	HSN13601 /HSN14601
COURSE NAME	Management Concepts And Applications
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

Management concept and application is very useful subject to engineering student as this subject make them enable to understand the organization work culture. This will be also helpful to them in their development of decision-making abilities. Work management and stress-free work environment can be developed if an engineer knew the various dimensions of management.

COURSE CONTENT:

Unit I: Introduction and Development of Management Approaches
Concept and definition of management, Various ways to understand the management, function of Managers, managerial skill, Role of managers, Functional areas of management, Principles of management, Management Vs. Administration. Approaches to management, Classical theories, Management process approach, Bureaucracy Approach, Neo-classical approach, Behavioral Sciences Approach, System Approach, Contingency Approach,Functions of Management.

Unit II: Planning
Nature and Definition of planning, Benefits of planning, Principles of planning, Kind of planning, steps in planning, Standing and single use planning, corporate planning and strategy formulation, Management by Objective, Management by Exception, Planning premises.

Unit III: Organizing
Concept and definition of Organization, Organization structure, Principles of organization, Form of organization, Departmentation, Formal and informal organization, Organizational culture and conflict management.

Unit IV: Direction
Concept and definition of direction, principles of direction, supervision and its significance, Leadership, Motivation, Communication and Coordination.

Unit V: Control and other Managerial Practices
Concept and definition of control, characteristics and principles of control, Control techniques, Budgetary Control, Change Management, Stress management, Emerging challenges in Management, Case Studies and Social Entrepreneurship.

TEXT BOOKS / REFERENCE BOOKS:

1. VSP RAO-Managing Organization (EXCEL 1 EDITION)
2. Chaturvedi& Saxena -Managing Organization (Himalaya Publication)
3. Stoner, Freeman & Gilbert Jr - Management (Prentice Hall of India)
4. 4 Robbins-Organization Behavior -15 e Prentice Hall
5. Koontz Harold &Weihrich Heinz – Essentials of management

6. T.N. Chhabra- Principles and Practices of Management, (Dhanpat Rai & Co.)
7. Luthans Fred - Organizational Behaviour (Tata Mc Graw Hill)
8. Mc Shane L. Steven, Glinow Mary Ann Von & Sharma Radha R. - Organizational
9. Behaviour (Tata Mc Graw Hill)

SEMESTER-IV

COURSE CODE	CHN14106
COURSE NAME	Environmental Pollution Monitoring and Control
NUMBER OF CREDITS	5
(L: T: P)	3: 1: 2

COURSE LEARNING OBJECTIVES:

- The aim of this course is to create awareness in every engineering graduate about the importance of environment,
- The effect of technology on the environment and ecological balance and make them sensitive to the environment problems.
- To understand the problems of pollution and its treatment methodology

COURSE CONTENT

UNIT-1 **[5L]**

INTRODUCTION Ecology & Environment, Biodiversity, Interaction of man and environment, Overall picture of environmental pollution, Ambient air and water quality criteria, Standards and Acts-Indian, EPA& EURO, Effects and control of noise, thermal and radioactive pollution.

UNIT-2 **[8L]**

AIR POLLUTION Types of pollutants – Natural and manmade air pollutants, Dispersion of pollutant in the atmosphere, Gaussian dispersion model, Meteorological factors, Stability and inversion of atmosphere, Plume behaviour, Control of air pollution from stationary and mobile sources, Methods of measuring and sampling of gaseous and particulate pollutants in ambient air and industrial waste gases, measurement of smoke density and visibility. Control of gaseous pollutants - SO_x, NO_x, H_2S, VOCS, Auto exhaust. Stack design, Classification, selection and design of equipment's like cyclones, electrostatic precipitators, bag filters, wet scrubbers, settling chambers.

UNIT-3 **[8L]**

WATER POLLUTION Wastewater characteristics – Physical and chemical composition, Biochemical oxygen demand (BOD), Pathogenic bacteria and chemical toxicity. Types of pollutants in wastewater of chemical industries, Methods of sampling, preservation of samples and analysis. Methods for the treatment of liquid wastes to control pollution, Classification viz. physical, chemical and biological methods, Selection and design of equipment like hydrocyclone, settling tanks, filters, ion- exchange.

UNIT-4 **[7L]**

SOLID WASTE MANAGEMENT Characterization of solid wastes, Problems of collection and handling, Various processing techniques used in solid waste management such as compaction, incineration, Composting, landfills, and biological processing, and Solid waste as resource material.

UNIT-5 **[6L]**

POLLUTION ABATEMENT IN CHEMICAL INDUSTRIES Pollution abatement in important chemical industries like fertilizers, petroleum refineries and petrochemicals, Pulp and Paper, Pharmaceuticals, Tannery, Sugar, Distillery, food processing, cement, and electroplating.

UNIT-6 **[5L]**

MISCELLANEOUS Soil pollution, Marine pollution, Noise pollution, Thermal pollution, and nuclear hazards, carbon trading.

Lab Component

List of Experiment

1. To study the increase in loss of head with respect to time in the filter bed.
2. To study the effect of parameters like pH and temperature on adsorbents.
3. To study change in alkalinity of wastewater by bubbling acidic gas.
4. To check the acidity and alkalinity of water resources.
5. To calculate the amount of solids in a suspension.
6. To measure COD level in wastewater.
7. To measure the conductivity of various wastewater.
8. To plot the pressure drop profile through the filter bed.
9. To measure the sediment removal efficiency and relating this to the hydraulic characteristics of a sedimentation tank.
10. To study the characteristics of anaerobic digester.
11. To determine the effect of velocity of water for separation of equal sized particles of different densities.

TEXT BOOKS / REFERENCE BOOKS:

1. Howard S. Peavy, D. R. Rowe & C. Tchobonoglous "Environmental Engineering", McGraw Hill.7th Edition,1987.
2. Metcalf & Eddy, "Waste Water Engineering Treatment, Disposal & Reuse", Tata McGraw Hill.4th Edition, 2017.
3. Werner Strauss, 'Air Pollution Control: Measuring and monitoring air pollutant' Wiley.1st Edition,1984.
4. Pandey G. N. and Carney G. C., "Environmental Engineering ". Tata McGraw Hill.1st Edition 2017.

COURSE CODE	CHN14107
COURSE NAME	Mass Transfer Operations -I
NUMBER OF CREDITS	5
(L: T: P)	3: 1: 2

COURSE LEARNING OBJECTIVES:

- To learn the basics of molecular diffusion in fluids.
- To understand the concept of convective and interphase mass transfer.
- To apply the concept of interphase mass transfer in absorption
- To learn simultaneous heat and mass transfer operations and their applications

COURSE CONTENT

UNIT-1 **[6 L]**

Diffusion: - Fick,s Law of diffusion, Molecular and Eddy diffusion, Pseudo steady state diffusion, Measurement and calculation of diffusivities, Diffusion in gaseous mixture, liquid mixtures and solids, Unsteady state diffusion.

UNIT-2 **[6L]**

Mass transfer coefficients and their correlations, Mass transfer coefficients in laminar and turbulent flow, Theories of mass transfer, Mass, momentum and heat transfer analogies, Interphase mass transfer: Equilibrium, Diffusion between phases, Local overall mass transfer coefficients.

UNIT-3 **[10L]**

Absorption:- Solubility theory, Principle of gas absorption, Choice of solvent, Packing characteristics, Design of packed towers: Gas- Liquid equilibria, Pressure drop and limiting flow rates, Equipments: Batch and Continuous stage wise contactors, Differential contactors, HTU, NTU, HETP concepts for calculation of height of packed column, Diameter of packed column, Absorption with chemical reactions.

UNIT-4 **[6L]**

Humidification theory, Psychometric chart, Adiabatic saturator, Wet bulb theory, Gas-Liquid contact operations, Methods of humidification and dehumidification, Cooling tower theory, Design of cooling towers, Industrial cooling towers, Recirculating water-gas humidification system.

Unit-5 **[6L]**

Drying: Theory and Mechanism, drying characteristics, Drying rate curve, Modes of drying operation, Classification of driers, Design of batch and continuous driers. Application of Driers.

Unit-6 **[6 L]**

Crystallization: Principle and solubility curve of crystallization, theory of super saturation, nucleation and crystal growth rate, controlled growth of crystals, equilibrium yield, Heat and mass transfer rates in crystallization, Classification and design of industrial crystallizers and their applications.

Lab Component

LIST OF EXPERIMENT (Mass Transfer Operations-I)

1. Diffusion of an organic vapor in air:
To determine the diffusion coefficient of an organic vapour in air and to study the effect of temperature on it.

2. Mass Transfer With or Without Chemical Reaction: (Solid-Liquid System)
To study the dissolution of benzoic acid in an aqueous NaOH solution and to compare the observed enhancement factor for mass transfer with those predicted by film and boundary layer model.

3. To study the Absorption process

4. Water Cooling Tower:
(i) To determine the overall heat transfer coefficient in a forced draft counter current cooling tower
(ii) To measure Tower Characteristic parameter KV/L for various liquid and air flow rates (L/G) in a counter-current Forced draft Cooling Tower.

5. Forced Draft Tray Dryer:
To study the drying characteristics of a solid under forced draft condition and draw the drying curve for a tray dryer.

6. To study the effect of temperature on surface evaporation

7. Swenson Walker Crystallizer:
To study the performance of a Swenson Walker Crystallizer by determining the crystal yield and the efficiency of Crystallizer

TEXT BOOKS / REFERENCE BOOKS:

1. R. E. Treybal, "Mass Transfer Operations", 3rd Edn., McGraw Hill Book Co., New York, 1981
2. W.L. McCabe, J.C. Smith and P. Harriot, "Unit Operations of Chemical Engineering", 7th Edn., McGraw Hill Book Co., New York, 2004.
3. Seader, J.D. and Henley, E.J., “Separation Process Principles”, 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).
4. C.J.Geankoplis, “Transport Processes and Separation Process Principles,” IV edition,Prentice Hall of India Pvt. Ltd, New Delhi, 2004.
5. E. L. Cussler, “Diffusion: Mass Transfer in Fluid Systems”, Cambridge University Press; edition, 2009.

COURSE CODE	CHN14108
COURSE NAME	Chemical Reaction Engineering-I
NUMBER OF CREDITS	5
(L: T: P)	3: 1: 2

Course Learning Objective:

The objective is to enable understanding of engineering activity concerned with the exploitation of Homogeneous chemical reactions on a commercial scale.

COURSE CONTENT

UNIT-1 **[4L]**

Kinetics of reactions: Introduction, Kinetics of homogeneous reactions: Concentration dependent & Temperature dependent terms of rate equation, Searching for a reaction mechanism.

UNIT-2 **[8L]**

Interpretation of kinetic data: Constant-volume batch reactor, Varying-volume batch reactor, Dependency of rate equation on temperature, Searching for a rate equation.

Kinetics of enzyme reactions (Michaelis-Menten and Monod models)

UNIT-3 **[8L]**

Design of Ideal Reactors for Single Reactions: Introduction to ideal reactors for a single reaction, Ideal batch reactor, Ideal mixed flow reactor, and Ideal plug flow reactor, Size comparison of single reactors, Multiple reactor systems, Recycle reactor, and Autocatalytic reactor.

UNIT-4 **[8L]**

Design of Reactors for Multiple Reactions: Design for multiple Reactions: Reactions in parallel, reactions in series, and series - parallel reactions.

UNIT-5 **[6L]**

Design of Non-isothermal Reactor: Temperature and pressure effects on single and multiple reactions. Design of non-isothermal batch reactor, mixed flow reactor, and plug flow reactor. Design of adiabatic reactors.

UNIT-6 **[6L]**

Flow Behavior of Reactors: Non-ideal flow: Residence time distribution studies: C, E, and F curves, conversion calculations directly from tracer studies. Single parameter models: tank-in series and dispersion models.

Lab component

LIST OF EXPERIMENT: CHEMICAL REACTION ENGINEERING LAB

Batch Reactor

1. To study the kinetics and determine the reaction rate constant (k) for the given saponification reaction in a Batch Reactor at fixed temperature.

2. To determine the effect of temperature on rate constant (k) of saponification in a Batch Reactor.

3. To study the kinetics and determine the reaction rate constant (k) for the given saponification reaction in a single Continuous Stirred Tank Reactor (CSTR) at fixed temperature.

CSTR

4. To determine the effect of temperature on rate constant (k) of saponification in a single CSTR.
5. To study the kinetics and determine the reaction rate constant (k) for the given saponification reaction in a Plug Flow Reactor at fixed temperature.

PFR

6. To determine the effect of temperature on rate constant (k) of saponification in a Plug Flow Reactor.
7. To study the kinetics and determine the reaction rate constant (k) for the given saponification reaction in a Coiled Type Plug Flow Reactor at fixed temperature.

Coiled PFR

8. To determine the effect of temperature on rate constant (k) of saponification in a Coiled Type Plug Flow Reactor.
9. To study the kinetics and determine the reaction rate constant (k) for the given saponification reaction in a Semi Batch Reactor at fixed temperature.

Semi Batch Reactor

10. To determine the effect of temperature on rate constant (k) of saponification in a Semi Batch Reactor.

TEXT BOOKS / REFERENCE BOOKS:

1. Octave Levenspiel, "Chemical Reaction Engineering", 3rd ed., (An Indian Adaptation) Wiley India Pvt. Ltd 2021.
2. H. Scott Fogler, “Elements of Chemical Reaction Engineering”, 5th ed, PHI, 2016.
3. M. Davis and R. Davis, “Fundamental of Chemical Reaction Engineering”, McCraw Hill, New York.
4. J.M. Smith, "Chemical Engineering Kinetics",3rd ed, McCraw Hill, New York, 2014.
5. Lanny D. Schmidt, “The engineering of chemical reactions” 2nd ed., Oxford University Press, New York, 2007.

COURSE CODE	CHN14109
COURSE NAME	PROCESS DYNAMICS AND CONTROL
NUMBER OF CREDITS	5
(L: T: P)	3: 1: 2

COURSE LEARNING OBJECTIVES:

- To learn the scientific and engineering principles underlying process dynamics and control systems.
- To understand the insights of chemical process control systems and get acquainted with industrial control systems.

COURSE CONTENT

UNIT – 1

INTRODUCTION **[6L]**

Introduction to process control - need of process control, process control strategies, process control activities; Theoretical models of chemical processes - modelling principles, dynamic models and their solutions; Laplace transforms.

UNIT – 2 :- FIRST AND HIGHER ORDER SYSTEMS **[6L]**

Development and properties of transfer functions; Linearization of non-linear models; Response of first- and second- order processes; Dynamic response of more complicated processes.

UNIT – 3 :- FEEDBACK CONTROLLERS **[8L]**

Concept & type of feedback control- Proportional controller, Proportional Integral (PI) controller and Proportional derivative (PD) controller and PID controller; Block diagram representation; Regulatory and servo problems; Time delay; Approximation of time delay systems

UNIT – 4 :- DESIGN, TUNING AND STABILITY **[8L]**

Controller tuning- Cohen-Coon method, Direct synthesis, IMC tuning, Ziegler Nichols method, Tyreus Luyben method, Autotune method. Influence of process design on process control; degrees of freedom for process control; Selection of variables; Dynamic behavior and stability of closed loop system- closed loop representation, transfer functions, Routh stability analysis.

UNIT – 5 :- FREQUENCY DOMAIN ANALYSIS **[6L]**

Control system design, Root locus, Bode plot, Nyquist plot, phase margin, gain margin.

UNIT – 6:- ADVANCED CONTROL STRATEGIES **[6L]**

Multiloop control & multivariable control, Process identification; Introduction to advanced control-cascade control, feed forward control, ratio control, dead time compensation, Internal model control, control valves–valve characteristics

Lab Component

List of Exercises:

1. To study control valve characteristics

2. To study dynamic behaviour of first order system.
3. To study I to P and P to I converter.
4. To study the dynamic response of liquid level in two tank interacting/non-interacting liquid level system.
5. To study the U-tube manometer.
6. To study the performance of cascade controller.
7. To study the performance of ON-OFF/P/PI/PD/PID controllers for pressure control.
8. To study the performance of ON-OFF/P/PI/PD/PID controllers for temperature control.
9. To understand Cohen Coon tuning method using MATLAB.
10. To understand ZN tuning method using MATLAB.
11. To study Bode stability analysis using MATLAB.

TEXT BOOKS / REFERENCE BOOKS:

1. Dale E Seborg, Thomas F. Edgar and Duncan A. Mellichamp, Process Dynamics and Control, Wiley India, New Delhi, 3rd edition, 2013.
2. George Stephanopoulos, Chemical Process Control, Prentice Hall India Pvt. Ltd., New Delhi, 2015.
3. CR Coughanowr and LM Koppel, Process System Analysis and Control, McGraw Hill, 2013.B. I. Bhatt, "Stoichiometry", 5th Edn., Tata McGraw Hill Publishers Ltd., New Delhi, 2010.

SEMESTER-V								
S. No.	**Course Code**	**Name of Course**	**Cat**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	CHN15110	Mass Transfer Operations-II	CEE	3	1	2	5	6
2	CHN15111	Heterogenous Reaction Engineering	CEE	3	1	2	5	6
3	CHN15112	Chemical Technology	CEE	3	0	2	4	5
4	CHN15250-59	5^{th} Sem Pool	CEL	3	0	0	3	3
5	CHN15250-59	5^{th} Sem Pool	CEL	3	0	0	3	3
Total							**20**	**23**

Theory Courses = 05, Lab courses = 03

SEMESTER-VI								
S. No.	**Course Code**	**Course Name**	**Cat**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	CHN16113	Transport Phenomena	CEE	3	1	0	4	4
2	CHN16114	Process Equipment Design	CEE	3	1	0	4	4
3	CHN16300	Computer Aided Process Engineering Lab	CEE	0	0	4	2	4
4	CHN16260 - 269	6^{th} Sem Pool	CEE	3	0	0	3	3
5	CHN16260 - 269	6^{th} Sem Pool	CEE	3	0	0	3	3
6	CHN16260 - 269	6^{th} Sem Pool	CEE	3	0	0	3	3
Total							**19**	**21**

Theory Courses = 05, Lab courses = 01

SEMESTER-V

COURSE CODE	CHN15110
COURSE NAME	Mass Transfer Operations -II
NUMBER OF CREDITS	5
(L: T: P)	3: 1: 2

COURSE LEARNING OBJECTIVES:

- To study the basic theory of conventional mass transfer operations.
- To learn the concept of equilibrium and operating line in two phase mass transfer
- To understand the modes of operation in mass transfer equipment.
- To design and analysis of mass transfer equipment in process industries.

COURSE CONTENT

UNIT-1 **[8L]**

Distillation: Vapor- Liquid equilibria, Pressure-temperature-concentration and enthalpy-concentration diagrams for ideal and non-ideal solutions, Concept of relative volatility, Maximum and Minimum boiling mixtures, Single stage distillation: Flash vaporization, differential or simple, steam and vacuum distillation.

UNIT-2 **[8L]**

Multi stage Distillation: Multi stage tray column: Continuous rectification, reboiler and condenser, Design calculations using McCabe-Thiele and Ponchon-Savarit methods, Use of side stream and open steam, Separation efficiencies, Multistage batch distillation, Types of trays, Azeotropic and Extractive distillation.

UNIT-3 **[8L]**

Liquid-Liquid Extraction: Principle, Ternary liquid equilibria, Effect of pressure and temperature on LLE, Solubility criteria, Partially miscible and immiscible systems, Continuous Stagewige contact: co-current & cross current operations, stage calculation, Continuous differential contact: calculation of height of packed tower, Equipment: mixer settlers, plate column, spray and packed column.

UNIT -4 **[8L]**

Leaching: Solid-liquid equilibrium, Methods of calculation: Single and multistage crosscurrent and countercurrent leaching, , Determination of number of stages. Overall stage efficiency, Equipment: unsteady state and steady state operations.

UNIT-5 **[8L]**

Adsorption: Introduction, Types of adsorption, Applications, Nature of adsorbents, Adsorption equilibria, Adsorption hysteresis, Continuous Stagewise operation: determination of number of stages, Continuous differential contact operation, Unsteady state fixed-bed adsorption, Mechanism of Break through plot and its effect.

LAB COMPONENT

List Of Experiment (Mass Transfer Operations LAB-II)

1. **Vapour-Liquid Equilibrium:**
   (i) To draw the VLE curve for a binary (*CCl_4- toluene)* mixture
   (ii) To draw the VLE curve for a binary (Benzene – Toluene) mixture

2. **Differential Distillation:**
   To verify the Rayleigh's equation for a differential distillation in a binary system

3. **Bubble Cap Distillation Column**:
   To study the given model of multistage batch type distillation column and analyze the composition of the Top and Bottom product by using
   (i) Constant Reflux Ratio
   (ii) Variable Reflux Ratio

4. **Steam Distillation**:

   To study the characteristics of steam distillation using turpentine oil as a feed stock.

5. **Liquid-liquid Extraction**:

   To study the extraction of acetic acid from its mixture with toluene using water .

6. **Adsorption in Packed bed**
   To study the adsorption isotherm (Langmuir isotherm) of acetic acid on activated charcoal and determine the adsorption constant (k) and the maximum adsorbed amount of acetic acid per gram of charcoal.
7. **Batch adsorption:** To study the Freundlich isotherm in batch adsorption

TEXT BOOKS / REFERENCE BOOKS:

7. R. E. Treybal, "Mass Transfer Operations", 3rd Edn., McGraw Hill Book Co., New York, 1981
8. W.L. McCabe, J.C. Smith and P. Harriot, "Unit Operations of Chemical Engineering", 7th Edn., McGraw Hill Book Co., New York, 2004.
9. Seader, J.D. and Henley, E.J., "Separation Process Principles", 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).
10. C.J.Geankoplis, "Transport Processes and Separation Process Principles," IV edition,Prentice Hall of India Pvt. Ltd, New Delhi, 2004.
11. M. Coulson and J.F. Richardson, "Chemical Engineering", Vol - II, 5th Edn., Pergamon Press, New York, 2002.

COURSE CODE	CHN15111
COURSE NAME	Heterogeneous Reaction Engineering
NUMBER OF CREDITS	5
L: T: P	3: 1: 2

COURSE LEARNING OBJECTIVES:

The objective is to develop an insight into the heterogeneous reaction systems with a view to tackle real industrial challenges and to develop understanding about reactor analysis and design for heterogeneous systems.

COURSE CONTENT

UNIT-1 **[6L]**

General Considerations: Introduction to design for Heterogeneous Reacting Systems: Rate equation for heterogeneous reactions, contacting pattern for two-phase systems. Mixing of fluids: Self mixing of single fluids, mixing of two miscible fluids.

UNIT-2 **[7L]**

Non-Catalytic Fluid-Particle Reactions System: Models for non-catalytic fluid-particle reaction systems, limitations, and selection. Fluid-particle reactors design

UNIT-3 **[7L]**

Non-Catalytic Fluid-Fluid Reactions System: Rate equations for instantaneous, fast, intermediate, slow, and infinitely slow reactions. Slurry reaction kinetics, fluid-fluid reactors design.

UNIT-4 **[6L]**

Catalysis and Characteristics of Catalyst: Introduction to catalysis, catalyst: definition and properties, promoters, inhibitors, poisons, solid catalyzed reaction system, rate equation and mechanism of heterogeneous catalytic reactions.

UNIT-5 **[8L]**

Reactors and Kinetics of Solid Catalyzed Reactions: Kinetics of solid catalytic reactions, the rate equation for surface kinetics, controlling resistances, adsorption isotherms, rates of chemisorption, evaluation and elimination of internal and external diffusion resistances, porous catalyst particles, pore diffusion resistance, effectiveness factor, heat effects, and reactor for solid catalyzed reaction systems.

UNIT-6 **[6L]**

Catalyst Deactivation: Mechanism of catalyst deactivation, the rate and performance equations.

LAB COMPONENT

List Of Experiment (CHEMICAL REACTION ENGINEERING LAB-II)

Cascade CSTRs -

1. To study the kinetics and determine the reaction rate constant (k) for the given saponification reaction in a multiple reactor (Cascade CSTRs) at fixed temperature.
2. To determine the effect of temperature on rate constant (k) of saponification in a multiple reactor (Cascade CSTRs).

Combined CSTR & PFR –

1. To study the kinetics and determine the reaction rate constant (k) for the given saponification reaction in a multiple reactor (Combined CSTR & PFR) at fixed temperature.
2. To determine the effect of temperature on rate constant (k) of saponification in a multiple reactor (Combined CSTR & PFR).

CSTR –

1. To study the residence time distribution in a CSTR. To plot the exit time distribution of the reactor and thereby obtain E-curve, F-curve and mean residence time, t.

Cascade CSTRs –

1. To study the residence time distribution in a multiple reactor (Cascade CSTRs). To plot the exit time distribution of the reactor and thereby obtain E-curve, F-curve and mean residence time, t.

Combined CSTR & PFR –

1. To study the residence time distribution in a multiple reactor (Combined CSTR & PFR). To plot the exit time distribution of the reactor and thereby obtain E-curve, F-curve and mean residence time, t.

Packed Bed Reactor –

1. To perform residence time distribution (RTD) studies in a packed bed reactor.
2. To study the effect of different kinds of packing in a packed bed reactor.

Trickle Bed Reactor –

1. To study the flooding characteristics and pressure drops in a trickle bed reactor.

TEXT BOOKS / REFERENCE BOOKS:

1. Octave Levenspiel, "Chemical Reaction Engineering", 3rd ed., (An Indian Adaptation) Wiley India Pvt. Ltd 2021.
2. H. Scott Fogler, “Elements of Chemical Reaction Engineering”, 5th ed, PHI, 2016.
3. M. Davis and R. Davis, “Fundamental of Chemical Reaction Engineering”, McCraw Hill, New York.
4. J.M. Smith, "Chemical Engineering Kinetics",3rd ed, McCraw Hill, New York, 2014.
5. Lanny D. Schmidt, “The engineering of chemical reactions” 2 nd ed., Oxford University Press, New York, 2007.

COURSE CODE	CHN15112
COURSE NAME	Chemical Technology
NUMBER OF CREDITS	4
L: T: P	3: 0: 2

COURSE LEARNING OBJECTIVES:

- To get acquainted with various chemical process industries
- To get acquainted with batch and continuous processing
- To learn the basics of unit processes and operations involved in chemical process industries
- To learn about the importance of flowcharts and schematic representation in scaled-up production of chemicals

COURSE CONTENT

UNIT – 1 **[3L]**
Chlor-alkali industries: Manufacture of soda ash; Manufacture of sodium bicarbonate; Manufacture of caustic soda, chlorine, bleaching powder

UNIT – 2 **[3L]**
Fuel and industrial gases: Natural gas; Water gas; Synthesis gas; Carbon dioxide; Hydrogen, Producer gas; Acetylene

UNIT – 3 **[3L]**
Cements: Portland cements; Other cements; Lime; Gypsum; Miscellaneous calcium compounds; Magnesium compounds

UNIT – 4 **[5L]**
Nitrogen industries: Ammonia; Nitric acid; Nitrogenous fertilizers; Mixed fertilizers

UNIT – 5 **[5L]**
Phosphorus and potassium industries: Phosphate rock; Superphosphate; Wet process for phosphoric acid; Electric furnace process for phosphoric acid; Potassium chloride; Potassium sulphate; Potassium bisulphate; Potassium permanganate

UNIT – 6 **[3L]**
Surface coating industries: Paints; Pigments; Varnishes; Industrial coatings; Antifouling coating; Corrosion mitigation with nano-coatings

UNIT – 7 **[3L]**
Pulp and paper industries: Kraft pulping process with black liquor recovery and reuse; Mechanical and thermomechanical pulping; Wet process for the manufacture of paper; Linkage of woody biomass to paper industries

UNIT – 8 **[5L]**

Petroleum processing and petrochemicals: Petroleum products; Manufacture of petrochemicals from methane; Manufacture of petrochemicals from ethylene; Manufacture of petrochemicals from propylene and butylene

LAB COMPONENT

List Of Experiment (CHEMICAL TECHNOLOGY)

1. To determine the aniline point and mixed aniline point of a given oil sample.
2. To determine viscosity of a given oil sample by tar viscometer.
3. To determine the flash point of a given oil sample using Pensky-Martens apparatus.
4. To determine the flash point and fire point of a given oil sample using Cleveland open cup apparatus.
5. To determine Conradson carbon residue (CCR) content of a given oil sample.
6. To determine pour point of a given oil sample.
7. To carry out distillation characteristics of a lighter oil fraction via ASTM D86 method.
8. To prepare lye soap via saponification process.
9. To prepare pigment as a precursor for paint.
10. To determine the calorific value of a given sample by using bomb calorimeter.
11. To determine asphaltenes content of a given fuel oil sample.
12. To carry out proximate analysis of a carbonaceous material.
13. To determine cellulose, hemicellulose, and lignin content of a given woody biomass sample.
14. To determine degree API of a given oil sample.
15. To study the effect of temperature and holding time on syngas production in lab-scale gasifier.
16. To study the effect of temperature and holding time on char production from petroleum coke in a thermal cracking assembly.
17. Flow sheeting of urea manufacturing using ASPEN PLUS including biuret

TEXT BOOKS / REFERENCE BOOKS:

1. G. T. Austin, “Shreve’s Chemical Process Industries”, McGraw-Hill, 1984.
2. M. Sitting, M.G. Rao, “Dryden’s outlines of Chemical technology”, East-West Press, 2010.
3. L. J. Carpentire, "New Developments in Phosphate Fertilizer Technology", Elsevier, 1971.

COURSE CODE	CHN15250
COURSE NAME	Food Technology & Engineering
NUMBER OF CREDITS	3
L: T: P	3:0:0

COURSE LEARNING OBJECTIVES:

To impart information about various food processes and unit operations for the manufacture, processing, packaging and preservation of food products considering various aspects such as nutrition retention, stability and shell life.

COURSE CONTENT

UNIT – 1 **[6L]**

Food process engineering –fundamentals-Fundamentals of food process engineering, water activity and food storage application of quantitative methods of material and energy balance in food engineering practice, units operations in food industries

UNIT – 2 **[6L]**

Food Preservation - Basic principles of food preservation, refrigeration, freezing, preservation of food by removal or supply of heat, dehydration, irradiation, addition of chemicals and fermentation.

UNIT – 3 **[6L]**

Food canning and packaging technology- Fundamentals of food canning technology, Heat sterilization of canned food, containers - metal, glass and flexible packaging, passive, active and smart packaging.

UNIT – 4 **[6L]**

Extrusion and rheology- Basics and principles of extrusion, cold extrusion and extrusion cooking, Single and twin screw Extruders, Introduction to rheology, types of fluids, Newtonian and non Newtonian fluids, viscoelastic liquids and solids, burger model, creep test, types of rheometer

UNIT – 5 **[6L]**

Improvement of nutritive quality-Process such as fortification, enrichment, germination fermentation, inactivation of nutritional factors, stabilization of nutrients and increasing the availability of nutrient

TEXT BOOKS / REFERENCE BOOKS:

1. WC Frazier, “Food Microbiology”, Tata McGraw Hill, Delhi
2. R. P. Singh & R. D. Heldman “Introduction to Food Engineering", 4th Edn.,Elsevier, London, 2009.
3. Norman N., Potter, Hotchkiss, Joseph H., Hotchkiss, “Food Science” 5th Edn, Springer, Berlin, 1995.

COURSE CODE	CHN15251
COURSE NAME	Process Instrumentation and Measurement
NUMBER OF CREDITS	3
L: T: P	3:0:0

COURSE LEARNING OBJECTIVES:

To impart knowledge of basic process instrumentations and measurements used in the chemical industries along with performance characteristics of measuring instruments and analysis of experimental data.

COURSE CONTENT

UNIT – 1 **[6L]**

Introduction to Instruments and Their Representation: - Application of instrument systems, functional elements of a measurement system, classification of instruments, standards and calibration.

UNIT – 2 **[6L]**

Temperature Measurements: Temperature Scales, temperature measuring instruments: liquid in glass thermometer, bimetallic thermometer, resistance temperature detectors (RTD), thermocouples, pyrometry.

UNIT – 3 **[6L]**

Pressure Measurements: Measurement of moderate pressure, high pressure and low pressure (vacuum), calibration and standardization.

UNIT – 4 **[6L]**

Flow Measurements: Positive displacement meters, variable head meters, variable area meters (rotameters), weirs and notches, pitot tube, electromagnetic flow meter.

UNIT – 5 **[6L]**

Miscellaneous Measurements: Liquid level, pH, viscosity, humidity, introduction to chromatography techniques, XRD, Analysis of experimental data.

TEXT BOOKS / REFERENCE BOOKS:

1. D. P. Eckman, "Industrial Instrumentation", CBS Publishers, New Delhi, 2004.
2. J.P. Holman, "Experimental methods for Engineers", 7th Edn., Tata McGraw Hill, New Delhi, 2007.
3. B.C. Nakra, K.K.Chaudhry, "Instrumentation, Measurement and Analysis", 2nd Edn., Tata McGraw Hill, New Delhi, 2004.
4. Doebelin, E., "Measurement Systems: Applications and Design", 4th Edn., McGraw Hill Higher Education, New York, 1990.

COURSE CODE	CHN15253
COURSE TITLE	Bioenergy Engineering
PREREQUISITE	Engineering Thermodynamics, Heat and Mass Transfer.
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

The course focuses on bioenergy and in particular on the exploitation of biomass for energy recovery. Moreover, this course encompasses thermochemical energy processes (combustion, gasification and pyrolysis) and chemical processes (oil extraction and trans-esterification), finally biochemical processes (fermentation and anaerobic digestion).

COURSE CONTENT

UNIT – 1 :- **[6 L]**

Biomass sources, characteristics & preparation, chemical composition and properties of different biomass materials, energy plantations, pre-treatment techniques for the utilization of biomass, size reduction, briquetting of loose biomass, drying, storage and handling of biomass.

UNIT – 2 :- **[5 L]**

Combustion of biomass and cogeneration systems, theory, calculations and design of equipment, cogeneration in biomass processing industries. Case studies: combustion of rice husk, use of bagasse for cogeneration.

UNIT – 3 :- **[8 L]**

Pyrolysis and gasification of biomass, thermo-chemical conversion of ligno-cellulose biomass, biomass processing for liquid fuel production, pyrolysis of biomass, pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles, effect of pressure, temperature and of introducing steam and oxygen, design and operation of fixed and fluidized bed gasifiers.

UNIT – 4 :- **[5 L]**

Bio-ethanol and bio-diesel technology: production of fuel ethanol by fermentation of sugars, gasohol as a substitute for leaded petrol, trans-esterification of oils to produce bio-diesel.

UNIT – 5:- **[6 L]**

Biogas technology, feedstock for biogas production, aqueous wastes containing biodegradable organic matter, animal residues, microbial and biochemical aspects, operating parameters for biogas production. Digesters for rural application, high-rate digesters for industrial waste water treatment.

TEXTBOOK/REFERENCE BOOK(S)

1. Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes, A. Chakraverthy.

2. Biogas Systems: Principles and Applications, K.M. Mital.
3. Fuels from Biomass and Wastes, D.L. Klass, G.M. Emert

COURSE CODE	CHN15254
COURSE NAME	Petroleum Refining and Petrochemicals
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To learn about crude oil assay
- Understanding of primary crude oil processing in petroleum refineries
- Understanding of thermal conversion and catalytic conversion processes
- To learn about the role of basic building blocks, viz. ethylene, propylene, and butylene in polymer industries and linkage of refining industry with manufacturing of petrochemicals

COURSE CONTENT

UNIT – 1 **[5 L]**

World and Indian petroleum refining scenario, composition of crude oil, classification of crude oil, UOP Characterization factor, types of refineries, BIS specifications regarding physico-chemical properties petroleum products, testing methods and their significance.

UNIT – 2 **[4 L]**

Dehydration and desalting of crude oil, descriptive account of atmospheric distillation, vacuum distillation, various straight-run products, properties and applications, treatment techniques for the straight-run products.

UNIT – 3 **[4 L]**

Thermal conversion processes, reactions involved in thermal conversion processes, free radical mechanism, thermal cracking, coil visbreaking, coil-soaker visbreaking, delayed coking, fluid coking, flexi coking.

UNIT – 4 **[5 L]**

Catalytic conversion processes, reactions involved in catalytic conversion processes, carbonium ion mechanism, catalytic cracking, fixed bed catalytic cracking and fluidized catalytic cracking, hydrotreating, hydrocracking, catalytic reforming, isomerisation, alkylation.

UNIT – 5 **[6 L]**

Emerging petroleum refinery operation, Gasification of petroleum coke, downdraft gasifier, updraft gasifier, fluidized bed gasifier, entrained flow gasifier, Co-gasification of petroleum coke and biomass, Hydrogen-rich syngas from gasification and co-gasification of petroleum coke.

UNIT – 6 **[6 L]**

World and Indian petrochemicals scenario, petroleum refinery and petrochemical industries integration, manufacture of syngas and chemicals from natural gas, naphtha cracking as building block for petrochemicals manufacturing, ethylene derivatives, propylene derivatives, and butylene derivatives, styrene butadiene rubber, pyrolysis of waste plastic and used tyres.

TEXT BOOKS / REFERENCE BOOKS

1. B. K. Bhaskara Rao, “Modern Petroleum Refining Processes”, Oxford and IBH Publishing Company, 1990.

2. J.H. Gary, G.E. Handwerk, M.J. Kaiser, “Petroleum Refining: Technology and Economics”, Marcel Dekker Publication, 2007.
3. J.G. Speight, “The Chemistry and Technology of Petroleum”, Marcel Dekker Publication, 2006.
4. L.F. Hatch, S. Matar, “From hydrocarbons to Petrochemicals”, Gulf Pub. Co., 1981.
5. R. Prasad, “Petroleum Refining Technology”, Khanna Publishers, 2002.
6. R.N. Watkins, “Petroleum Refinery Distillation”, Gulf Publishing Co., 1973.
7. W.L. Nelson, “Petroleum Refinery Engineering”, McGraw Hill Publication, 1958.

COURSE CODE	CHN15255
COURSE NAME	Industrial Corrosion & Surface Coating
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

To develop a understanding about surface engineering technique for industrial applications

COURSE CONTENT

UNIT-1 **[6 L]**

Corrosion definition - Electrochemical and thermodynamic principles, electrode potential of metals, EMF and galvanic series, Faraday's laws Pourbaix diagram and its importance to iron, aluminium and magnesium metals, Corrosion in fossil fuel & power plants, automotive industry, aerospace industry, chemical processing industries, corrosion in petroleum production operations and refining, corrosion of pipelines.

UNIT-2 **[6 L]**

Atmospheric, galvanic, crevice, pitting, stress corrosion cracking, intergranular corrosion, corrosion fatigue, hydrogen damage, cavitation, fretting corrosion and high temperature oxidation-description, causes and remedial measures.

UNIT-3 **[6 L]**

Purpose of testing, laboratory, semi-plant and field tests, susceptibility tests of IGC, stress corrosion cracking and pitting, ASTM standards for corrosion testing; polarization methods to measure corrosion rate, surface characterisation techniques.

UNIT-4 **[6 L]**

Corrosion rate expressions, Exchange current density, polarization - concentration, activation and resistance, Tafel equation, passivity, electrochemical behaviour of active-passive metals, factors governing metals exhibiting passivity, mixed potential theory and its application.

UNIT-5 **[6 L]**

Surface modification of ferrous and nonferrous metals- carburizing, nitriding, cyaniding, hot dipping, galvanizing, chromating, anodizing, phosphating of aluminium; Surface engineering by energy beams, Plasma for surface engineering, Laser assisted surface modification Film deposition techniques: Sputter deposition of thin films and coatings by RF, MF, DC, Magnetron, Pulsed laser, Ion beam, Ion implantation, electroplating, electroless plating, electro polishing, electroforming, chemical vapour deposition (CVD) and plasma enhanced CVD, atomic layer deposition, atomic layer chemical vapour deposition, molecular beam epitaxy, lithography, Langmuir Blodgett, Spin Coating.

TEXT BOOKS / REFERENCE BOOKS

1. D. A. Jones, "Principles and Prevention of Corrosion", 2nd edition, Prentice Hall, USA, 1996.

2. H. H. Uhlig and R. W. Revie, "Corrosion and corrosion control : An introduction to Corrosion science and engineering", 4th edition, John Wiley & Sons, 2008.

3. F.-W. Bach, A. Laarmann, and T. Wenz, “Modern Surface Technology”, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2006.

4. M. H. Francombe, S. M. Rossnagel, A. Ulman, “Frontiers of Thin Film Technology”, Vol. 28, Academic press, 2001.

5. M. G. Fontana, N. D. Greene, “Corrosion Engineering”, 2nd edition, McGraw-Hill, USA, 1983.

6. P. A. Schweitzer, “Fundamentals of corrosion : mechanisms, causes, and preventative methods”, CRC Press, 2010.

7. R. Baboian, “Corrosion Tests & Standards: Application & interpretation”, ASTM International, 2010.

8. M. Dornbusch, “Corrosion analysis”, CRC Press, 2019.

9. K. L. Chopra, “Thin Film Phenomena”, McGraw Hill, 1979.

10. R. F. Bunshah, “Deposition Technologies for Films and Coatings”, Noyes Publications, New Jersey, 1982.

11. M. Ohring, Materials Science of Thin Films, 2nd edition, Academic Press, San Diego, 2002.

COURSE CODE	CHN15256
COURSE NAME	Upstream Hydrocarbon Engineering
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To learn about different on-shore and off-shore drilling operations
- To learn about enhanced oil recovery methods
- To acquaint with the difference between gaseous and liquid fossil fuels exploration and production.
- To gain insights into association of upstream hydrocarbon activities with downstream hydrocarbon activities

COURSE CONTENT

UNIT – 1 **[5 L]**

World exploration and production (E&P) scenario, Indian exploration and production (E&P) scenario, petroleum Exploration basics, concept of source, reservoir, migration, stratigraphic and combinational traps, primary and secondary migration, techniques of petroleum exploration, geochemical, gravity, magnetic, electrical and seismic method of hydrocarbon exploration.

UNIT – 2 **[6 L]**

Basics of drilling fluid, functions of drilling fluid, classification of drilling fluids, properties of drilling fluids, nature of drilling fluid, generic drilling fluid system. Drilling fluids equipment related to pressure and separation. Formulations of drilling fluid, separation of drilled solids from drilling fluid, various rheology models of drilling fluids.

UNIT – 3 **[6 L]**

Bulk volume, grain Volume, effective pore volume and net volume, porosity, compressibility, Darcy's Law. Absolute and Effective Permeability, Permeability averaging, Transmissibility, Measurements of Permeability heterogeneity, Darcy's law of directional permeability, rock fluid interactions.

UNIT – 4 **[7 L]**

Enhanced oil recovery methods, Toe-to-heal air injection (THAI), Catalytic upgrading process in situ (CAPRI), correlation of capillary pressure to rock properties, wettability, capillary pressure, equivalent height and transition zone, mobility, relative mobility and flow capacity.

UNIT – 5 **[6 L]**

Composition of natural gas, properties, fields & reserves in world and in India, energy scenario, major natural gas producing industries of India and their contribution to Indian economy, techniques of utilization, specifications of natural gas for transportation in pipelines, concept of gas to liquid (GTL).

TEXT BOOKS / REFERENCE BOOKS

1. D. L. Katz, R. L. Lee, "Natural Gas Engineering-Production and Storage", McGraw-Hill, 1990.

2. G.D. Hobson, W. Pohl, “Modern Petroleum Technology”, Wiley & Sons Publication, 1973.
3. J. J. Milson, A. Eriksen, “Field Geophysics”, John Wiley and Sons, 2011.
4. J. W. Amyx, D.H. Bass, R. L.Whiting, “Petroleum Reservoir Engineering”, McGraw Hill, 1960.
5. W.L. Nelson, “Petroleum Refinery Engineering”, McGraw Hill Publication, 1958.

COURSE CODE	CHN15257
COURSE NAME	Introduction To Nanoscience And Nanotechnology
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To understand basic concepts of nanoscience.
- To learn different methods involved in synthesis and characterization of nanomaterials.

COURSE CONTENT

UNIT 1 **[5L]**

Overview of nanoscience: Important concepts such as size, quantum effect, and Moore's law. Characteristic length scales determining the behavior of physical and biological systems.

UNIT 2 **[8L]**

Fundamental phenomena as a function of size and reduced dimensionality; different types of nanomaterials (metal, magnetic, quantum dots, lanthanide based nanoparticles, polymer nanoparticles, carbon nanotubes and their properties).

UNIT 3 **[11L]**

Synthesis and organization of nanomaterials: Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and coprecipitation; Metal nanocrystals by reduction, Sol gel synthesis; Microemulsions or reverse micelles, Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sono chemical synthesis; self-assembly; lithography; microfluidics; and chemical vapor deposition; surface modification of nanoparticles.

UNIT 4 **[10L]**

Characterization techniques: Beam probe methods (TEM, EDX, SEM, EDX, and Xray scattering), Scanning probe methods (STM and AFM) and other techniques (Optical Spectroscopy, Chromatography, Surface Plasmon Resonance and Light Scattering).

UNIT 5 **[6L]**

Application of nanoscience and technology: Drug delivery, Tissue engineering, biosensors, catalysis, and electronics.

TEXT BOOKS / REFERENCE BOOKS:

1. Christof M. Niemeyer, Chad A. Mirkin , Nanobiotechnology: Concepts, applications and perpectives, Wiley lnterscience (2004)

2. Geoffery A. Ozin, Andre C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, RSC publishing (2005)

3. M. Gross, Travels to the nanoworld, Plenum Publishing Corporation (2001)

COURSE CODE	CHN15258
COURSE NAME	Lifecycle Assessment & EIA
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

The objective of this course is to introduce the students to the fundamental concepts related to interaction of industrial and environmental/ecological systems, sustainability challenges facing the current generation, and systems-based approaches required to create sustainable solutions for society.

COURSE CONTENT

UNIT-1 **[6 L]**

An Introduction to Sustainability Concepts and Life Cycle Analysis: Introduction, Material flow and waste management, Water energy and food nexus, Risk, Environmental Risk Assessment, Chemicals and Health Effects, Environmental Problems.

UNIT-2 **[6 L]**

Environmental Data Collection and LCA Methodology: Environmental Data Collection Issues, Statistical Analysis of Environmental Data, Common Analytical Instruments, Overview of LCA Methodology- Goal Definition, Life Cycle Inventory, Life Cycle Impact Assessment, Life Cycle Interpretation, LCA Software tools.

UNIT-3 **[6 L]**

Life Cycle Assessment-Detailed Methodology and ISO Framework: Detailed Example on LCA Comparisons, LCA Benefits and Drawbacks, Historical Development and LCA Steps from ISO Framework.

UNIT-4 **[6 L]**

Life Cycle Inventory and Impact Assessments: Unit Processes and System Boundary Data Quality, Procedure for Life Cycle Impact Assessment, LCIA in Practice with Examples, Interpretation of LCIA Results.

UNIT-5 **[6 L]**

Factors for Good LCA Study: ISO Terminologies, LCA Steps Recap, Chemical Release and Fate and Transport, and Green Sustainable Materials, Environmental Design for Sustainability: Economic, Environmental Indicators, Social Performance Indicators, Sustainable Engineering Design Principles and Environmental Cost Analysis.

TEXT BOOKS / REFERENCE BOOKS

1. Olivier Jolliet, Myriam Saadé-Sbeih, Shanna Shaked, Alexandre Jolliet, Pierre Crettaz, “Environmental Life Cycle Assessment”, Taylor & Francis Group, LLC, 2016.

2. R. K. Jain, L. V. Urban, G. S. Stacey, H. E. Balbach and M. D. Webb, “Environmental Assessment”, New York: McGraw-Hill, 2001.

3. J. B. Guinee, “Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards”, New York, Boston, Dordrecht, London, Moscow: Kluwer Academic Publishers, 2004.
4. J. Glasson, R. Therivel, A. Chadwick, “Introduction to environmental impact assessment”, 3rd edition, London and New York: Routledge, 2005.
5. B. F. Noble, “Introduction to environmental impact assessment: A guide to principles and practice”, 2nd edition, Don Mills, Ontario: Oxford University Press, 2010.
6. Steinemann, “Improving alternatives for environmental impact assessment”, Environmental Impact Assessment Review, 21 (1), 3-21, 2001.
7. Tukker, “Life cycle assessment as a tool in environmental impact assessment”, Environmental Impact Assessment Review, 20, 435-456, 2000.

SEMESTER-VI

COURSE CODE	CHN16113
COURSE NAME	Transport Phenomena
NUMBER OF CREDITS	4
L: T: P	3: 1: 0

COURSE LEARNING OBJECTIVES:

- The objective is to enable understanding to model chemical engineering problems at macroscopic level where momentum, heat and mass transport are involved either individually or together.
- To learn the skills of solving these models using analytical methods.

COURSE CONTENT

UNIT – 1 **[8L]**

Laminar Flow: Viscosity and the Mechanisms of Momentum Transport, Velocity distribution in Laminar flow - Shell momentum balances -Flow through tubes, surfaces, Flow of non-Newtonian fluids.

UNIT – 2 **[8L]**

Equation of Motion: Vector and tensor, Equation of change for isothermal process – One dimensional equation of motion and continuity - Euler and Navier - Stokes equation, Dimensional analysis of equation of change.

UNIT – 3 **[8L]**

Heat Transfer Analysis: Thermal Conductivity and Mechanisms of energy transport, Temperature distribution in solids and fluids in laminar flow - Equations of energy.

UNIT – 4 **[8L]**

Mass Transfer Analysis: Diffusivity and the mechanism of Mass Transport, Concentration distribution in solids and in fluids, laminar flow - Equations of change for multi component systems.

UNIT – 5 **[8L]**

Turbulent Flow: Velocity distribution in turbulent flow - Semi empirical expressions for Reynolds stress, Inter-phase transport in isothermal system - Ergun's equation.

TEXT BOOKS / REFERENCE BOOKS

1. Stuart, J.L., “Transport Phenomena”, John Wiley, New York, 1982.
2. Thomson, W. J., “Introduction to Transport Phenomena”, Prentice Hall, 2000.
3. Bird R.B., Stewart W.E. and Light Foot E.N. Transport Phenomena, 2nd Edition, John Wiley and Sons., 2007.
4. Geankopolis, C. J. "Transport Processes in Chemical Operations", Prentice Hall of India, New Delhi, 1996.

5. James Welty, Charles E. Wicks, Gregory L. Rorrer, Robert E. Wilson, "Fundamentals of Momentum, Heat and Mass Transfer", 5th edition, Wiley; 2007.

COURSE CODE	CHN16114
COURSE NAME	Process Equipment Design
NUMBER OF CREDITS	4
L: T: P	3:1:0

COURSE LEARNING OBJECTIVES: -

- To learn the basics of design procedure, standard codes and drawings of various process equipment
- To develop understanding about pressure vessel design, storage tank, mixer, reaction vessels and mass transfer equipment design.
- To learn thermal design of heat exchangers, evaporators and crystallizers.

COURSE CONTENT

UNIT 1 **[6L]**

Nature of process equipment, general design procedure, basic considerations in design, standards codes and their significance, equipment classification and their selection, design pressure, design temperature, design stress, review of fabrication techniques and environmental considerations in design procedure.

UNIT 2 **[6L]**

Proportioning of pressure vessels, selection of L/D ratio, optimum proportions of vessels. Design of unfired pressure vessels subjected to combined loading, purging of vessels. Selection and design of various heads such as flat, hemispherical, elliptical and conical, opening/nozzles, manholes, nozzle reinforcement design, etc. Flanged joints, classification of flanges, design of non standard flanges, types of gaskets, their selection, and design, storage vessel, types, design and applications

UNIT 3 **[6L]**

Types of agitators, their selection, applications, baffling, power consumption which includes twisting moment, equivalent bending moment, design of blades etc. Reaction vessels- Introduction, classification, heating systems, design of vessels, study and design of various types of jackets like plain, half coil

UNIT4 **[6L]**

Design of heat transfer equipment-Design of Heat Transfer equipment such as heat exchangers with and without phase change, evaporators, crystallizers.

UNIT 5 **[6L]**

Design of mass transfer equipment-Design of mass transfer equipment such as distillation columns and extraction columns.

Text/Reference Books

1. M.V. Joshi, V. V. Mahajani, "Process Equipment Design", 3rd Edn., Macmillan India Ltd., Noida 2000.

2. Serth, R.W., " Kern's Process Heat Transfer: Principles and Applications" Elsevier Ltd., Amsterdam, 2007.
3. J.M. Coulson, J. F. Richardson, R. K. Sinnott, "Coulson and Richardson's Chemical Engineering: Chemical Engineering Design" Vol.6, 3rd Edn., Butterworth – Heinemann, Oxford, 2004.
4. A.K.Coker, "Ludwig's Applied Process Design for Chemical and Petrochemical Plants", Vol 1-3, Elsevier Ltd., Amsterdam, 2004.
5. Indian standards Institution, "Code for Unfired Pressure Vessels", IS – 2825.

COURSE CODE	CHN16300
COURSE NAME	Computer Aided Process Engineering Lab
NUMBER OF CREDITS	2
L: T: P	0: 0: 4

COURSE LEARNING OBJECTIVES:

- This course aims at modelling & simulation techniques of chemical processes using MATLAB and to gain skills in using process simulators.

COURSE CONTENT

UNIT – 1 **[6L]**

Introduction to MATLAB: Basics of MATLAB, matrix operations, arrays and in-built functions, solution to linear and non-linear algebraic equations, ordinary differential equations, differential algebraic equations partial differential equations, basics of optimization.

UNIT – 2 **[6L]**

Introduction to Mathematical Modelling: Use and scope of mathematical modelling, model formulation, degree-of-freedom analysis, selection of design variables, model formulation of heat exchangers, batch and semi-batch reactors, continuous stirred tank reactor (CSTR) and plug flow reactor (PFR), Modelling of multicomponent distillation columns using MESH equations.

UNIT – 3 **[6L]**

Using MATLAB: Calculation of bubble and dew point temperatures, Calculation of activity coefficient and fugacity coefficient via different thermodynamic models and equation of states, Txy and Pxy plots for zeotropic and azeotropic mixtures. Simulation of batch, semi-batch reactors, CSTR and PFR reactors, Simulation of Flash distillation, Simulation of binary, multicomponent, Extractive and azeotropic distillation columns.

UNIT – 4 **[6L]**

Using Process Simulator: Simulation of individual equipment's e.g., Mixer, Heat Exchangers, CSTR, PFR, Binary Distillation Column, Extractive and Azeotropic Distillation, Reactive Distillation. Simulation of flow sheets. Use of Design spec, Sensitivity analysis and Optimization in Process Simulators. Simulation of different processes based on real case studies.

TEXT BOOKS / REFERENCE BOOKS

1. Pratab, R., "Getting Started with MATLAB", Oxford University Press, 2009.
2. Fausett L.V. "Applied Numerical Analysis Using MATLAB", 2nd, Pearson Education, 2007.
3. Severance, F.L., "System Modelling and Simulation-An introduction", John Wiley and Sons, 2001.
4. Finlayson, Bruce A. Introduction to chemical engineering computing. John Wiley & Sons, 2012.
5. Jana, A. K. Chemical process modelling and computer simulation. PHI Learning Pvt. Ltd, 2011.

COURSE CODE	CHN16260
COURSE NAME	Fertilizer Technology
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To understand the importance of fertilizers for agricultural activities.
- To learn the process of manufacturing different fertilizers.

COURSE CONTENTUNIT 1 **[7L]**

Importance of fertilizers for sustainable agricultural activities, elements required for plants growth, general function of each of nitrogen, phosphorus, and potassium fertilizers and nitrogen fixation from the air. Classification of fertilizer industries in India, role of co-operative initiatives in fertilizer industry.

UNIT 2 **[8L]**

Processes for manufacturing of raw materials for nitrogen, phosphorus, and potassium based fertilizers, viz. ammonia, nitric acid by ammonia oxidation process, phosphoric acid from phosphate rock by strong sulphuric acid process, potassium chloride from sylvinite. Mining of phosphate rock.

UNIT 3 **[8L]**

Manufacturing of urea (and biuret formation), ammonium carbamate, ammonium nitrate, and ammonium sulphate with reactions involved and process conditions for each of these fertilizers.

UNIT 4 **[8L]**

Processes for manufacture of potassium nitrate, potassium sulphate, recovery of Potassium salts. Specification and storage of potassium chloride and potassium nitrate.

UNIT 5 **[9L]**

Manufacturing of single super phosphate, triple super phosphate, calcium phosphate, sodium phosphate, mono-ammonium phosphate, di-ammonium phosphate, bio- fertilizers, plant growth promoting rhizobacteria, and root colonization.

TEXTBOOKS/REFERENCE BOOKS

1. G. T. Austin, “Shreve’s Chemical Process Industries”, McGraw-Hill, 1984.

2. L. J. Carpentire, "New Developments in Phosphate Fertilizer Technology", Elsevier, 1971.

3. M. Sitting, M.G. Rao, “Dryden’s outlines of Chemical technology”, East-West Press, 2010.

COURSE CODE	CHN16261
COURSE NAME	Two Phase Flow And Heat Transfer
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

- The objective is to develop an insight into design procedure of process equipment handling the two-phase flow with heat transfer.

COURSE CONTENT

UNIT 1 **[6L]**

Introduction to two phase flow: type and applications, Flow Patterns in Adiabatic Flow, Flow Pattern Transitions in Adiabatic Flow, Flow Patterns in Diabatic Flow, Void Fraction and Slip Ratio, Methods of identifications for two-phase flow, Measurement technique in two phase flow. Introduction to two phase flow problems in process industry.

UNIT 2 **[8L]**

Homogeneous Model/Drift Flux Model, Separate-Phase/ Two-Fluid Model, Models for Flow Pattern Transition, Models for Bubbly Flow, Models for Slug Flow, Models for Annular Flow, Models for Stratified Flow in Horizontal Pipe, Models for Transient Two-Phase Flow.

UNIT 3 **[8L]**

Local Pressure Drop, Analytical Models for Pressure Drop Prediction: Bubbly Flow, Slug Flow, Annular Flow, Stratified Flow; Empirical Correlations for various flow types, Pressure Drop in Rod Bundles, Pressure Drop in Flow Restriction.

UNIT 4 **[8L]**

Introduction to two phase heat transfer, Modes of pool boiling, boiling curve, Heat transfer mechanism in pool boiling: bubble nucleation, growth and departure from a Heated Surface, Bubble emission Frequency, Waiting Period, Correlation of Nucleate Boiling Data, Pool Boiling Crisis, Film Boiling in a Pool; Forced convection boiling, Burnout.

UNIT 5 **[6L]**

Type of condensation, Film condensation, Drop-wise condensation, Condensation on a vertical plate, Condensation on tubes and spheres.

UNIT 6 **[4L]**

Introduction to enhanced heat transfer, Techniques for enhanced heat transfer: Active Techniques, Passive techniques and compound techniques.

TEXTBOOKS/REFERENCE BOOKS

1. L. S. Tong and Y. S. Tang, “Boiling Heat Transfer and Two-Phase Flow”, Second Edition, Taylor& Francis.
2. S. G. Kandlikar, "Handbook of Phase Change: Boiling and Condensation" Taylor & Francis.
3. Jean J. Ginoux, Two phase flow and heat transfer.
4. Bergles, Collier & Hewitt, Two phase flow and heat transfer

COURSE CODE	CHN16262
COURSE NAME	Industrial Catalysis
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

To develop a understanding about heterogeneous catalyst preparation, characterization and catalyst deactivation.

COURSE CONTENT

UNIT-1 **[8 L]**

Heterogeneous catalytic processes, types of heterogeneous reactions, Absorption, absorption isotherms, rates of absorption, Physisorption and chemisorptions, Solid catalysis, types of catalysts, catalyst formulations and Preparation methods, Catalysts Characterization methods : Surface area and pore volume determinations, XRD, various Spectroscopic techniques, Temperature programmed reduction & oxidation, Electron microscopy.

UNIT-2 **[4 L]**

Testing of catalysts , various types of reactors, activity and selectivity studies, Effect of external transport processes on observed rate of reactions, Effect of internal transport processes: reactions and diffusion in porous catalysts.

UNIT-3 **[6 L]**

Mechanism of catalytic reactions, Rates of adsorption, desorption, surface reactions, rate determining steps, Kinetic modelling and Parameter estimations, Model discriminations.

UNIT-4 **[6 L]**

Catalysts promoters, Inhibitors, catalyst deactivations, kinetics of catalyst deactivations, Industrial processes involving heterogeneous solid catalysts.

UNIT-5 **[6 L]**

New development in solid catalysis, monolith catalysts , nanocatalysts, Fuel cell catalysts, Environmental catalysts, Insitu characterization, Design of catalysts: simulation techniques.

TEXT BOOKS / REFERENCE BOOKS

1. G. Ertl, H. Knozinger and J. Weitkamp, "Handbook of Heterogeneous Catalysis", Vol 1, Wiley – VCH, 2008.
2. B. Viswanathan, S. Sivasanker , A.V. Ramaswamy, "Catalysis : Principles & Applications", CRC Press, 2002.
3. J. M. Smith , "Chemical Engineering Kinetics", McGraw-Hill Book Company, 1981.
4. J. M. Thomas and W. J. Thomas, "Principles and Practice of Heterogeneous Catalysis", Wiley- VCH, 2015.
6. H. S. Fogler, "Elements of Chemical reaction engineering", Third edition, Prentice-Hall of India, 2004.
7. J.J. Carberry , "Chemical and catalytic reaction Engineering", Dover Publications, 2001.
8. C. H. Bartholomew and R. J. Farrauto "Fundamentals of Industrial catalytic Processes",

Second Edition, Wiley- VCH, 2010.

COURSE CODE	CHN16263
COURSE NAME	Advances in Fluidization Engineering
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

The course aims to develop models for fluidized bed systems with emphasis on entrainment, elutriation, heat and mass transport in fluidized beds.

COURSE CONTENT

UNIT – 1 **[5L]**

Introduction to fluidization, types of fluidization, industrial applications of fluidized beds, cracking and reforming of hydrocarbons, gasification, carbonization, gas - solid reactions.

UNIT – 2 **[6L]**

Gross behavior of fluidized bed, minimum and terminal velocities in fluidized beds, design of distributors, void age in fluidized beds, variation in size distribution with height, viscosity and fluidity of fluidized beds, power consumption, bed expansion.

UNIT – 3 **[6L]**

Davidson's model, frequency measurements, bubble behavior, bubbles in ordinary bubbling bed model for bubble phase, emulsion phase, experimental findings, bubbling bed model for emulsion phase interchange co-efficient.

UNIT – 4 **[6L]**

Flow pattern of gas through fluidized beds, bubbling bed model for gas inter-change interpretation of gas mixing data, heat and mass transfer between fluid and solid, experiment findings on heat and mass transfer, heat and mass transfer rates from bubbling bed model.

UNIT – 5 **[7L]**

Heat transfer between fluidized beds and surfaces, theories of bed heat transfer, comparison of theories, model for entrainment and application of the entrainment model to elutriation. Principles of semi fluidization, production of various bed parameters, industrial applications, design of fluidized bed reactors.

TEXT BOOKS / REFERENCE BOOKS

1. D. Kunii and O. Levenspiel, "Fluidisation Engineering", 2nd Edn., Butterworth Heinemann, 1991.
2. Shah Y.T., “Gas-Liquid-Solid Reactor Design”, McGraw Hill Int. New York, 1979. 2. J.F. Davidson, D. Harrison, “Fludization”, Academic Press, 1971.
3. C. K. Gupta, D. Sathiyamoorthy, “Fluid Bed Technology in Materials Processing”, CRC Press, 1998.
4. F.A. Zenz, D.F. Othmer, “Fludization and Fluid Particles Systems”, Reinhold Publishing, 1960.

COURSE CODE	CHN16264
COURSE NAME	Polymer Science and Technology
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES: -

- To impart the knowledge of basic fundamental of polymers and their properties.
- To learn the reaction engineering and manufacturing of polymers.
- To learn various processing techniques to convert polymer into end use applications.

COURSE CONTENT

UNIT-1 **[8 L]**

Characteristics and Analysis of polymers: The science of large molecules**,** Theory of polymer solutions**,** Average molecular weight, Molecular weight distribution, Determination of molecular weight and size, Polymer Analysis and testing of polymers**.**

UNIT-2 **[8L]**

Polymer material structure and Properties: Morphology in crystalline polymers**,** Polymer structure and physical properties**,** Mechanical properties of polymers**,** Reheological studies: Deformation, flow and melt characteristics**,** Temperature dependence of viscosity, Simple linear viscoelastic models.

UNIT-3 **[8L]**

Reaction Engineering: Condensation and Addition polymers**,** Kinetics of step growth polymerization, radical and ionic chain polymerizations, Co-polymerization, Coordination polymerization.

UNIT-4 **[8L]**

Industrial Polymers: Polymerization techniques, Manufacturing processes and applications: Hydrocarbon plastics and elastomers, Other carbon chain polymers, Hetero chain thermoplastics, Thermosetting resins.

UNIT-5 **[8L]**

Processing of polymers: Processing techniques for plastics, fibers and elastomer applications: extrusion, injection molding, blow molding, Rotational molding, compression and transfer molding, thermoforming, fiber spinning.

TEXT BOOKS / REFERENCE BOOKS:

1. F.W. Billmeyer, "Text Book of Polymer Science", 3rd Edn., Wiley Inter Science.
2. V. R. Gowariker, Polymer Science, New age international publisher
3. J.R. Fried, “Polymer Science and Technology”, Prentice Hall, Inc
4. “Encyclopedia of Polymers Science and Technology", John Wiley-Inter Science

5. F. Rodriguez, "Principles of polymer systems", 4th Edn., Taylor and Francis, Washington

COURSE CODE	CHN16265
COURSE NAME	Green Hydrogen and Fuel Cells
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

To impart knowledge on use of hydrogen for achieving sustainable growth and facilitate analysis of the challenges in transition to hydrogen economy in Fuel Cells.

COURSE CONTENT

UNIT-1 **[10L]**

HYDROGEN ENERGY: Introduction to hydrogen economy, production, storage and transportation systems, hydrogen from fossil fuels, electrolysis of water, thermo chemical cycles, transmission and infrastructure requirements, safety and environmental impacts, economics of transition to hydrogen systems.

UNIT-2 **[10 L]**

FUEL CELLS: Concept, key components, physical and chemical phenomena in fuel cells, advantages and disadvantages, different types of fuel cells and applications, characteristics, Nernst equation, relation of the fuel consumption versus current output.

UNIT-3 **[10L]**

FUEL CELL DESIGN AND PERFORMANCE: Stoichiometric coefficients and utilization percentages of fuels and oxygen, mass flow rate calculation for fuel and oxygen in single cell and fuel cell stack, total voltage and current for fuel cells in parallel and serial connection, over-potential and polarizations, DMFC operation scheme, general issues-water flooding and water management, polarization in PEMFC.

UNIT-4 **[8 L]**

FUEL CELLS -APPLICATION AND ECONOMICS: Fuel cell usage for domestic power systems, large scale power generation, automobile, space applications, economic and environmental analysis on usage of fuel cell, future trends of fuel cells.

TEXT BOOKS / REFERENCE BOOKS:

1. Hydrogen Fuel Production, Transport and Storage Edited by Ram B Gupta published July 30, 2008 by CRC Press , ISBN 9781420045758 - CAT# 4575X.
2. Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz, "Fuel Cell Fundamentals", (3rd edition), Wiley, 2016.
3. Supramaniam Srinivasan, "Fuel Cells: From Fundamentals to Applications", 1st Edition, Springer 2006.
4. Allen J. Bard, Larry R. Faulkner, "Electrochemical Methods: Fundamentals and Applications", 2nd Edition, Wiley 2000.
5. Viswanathan B and Aulice Scibioh, Fuel cells: Principles and Applications, University Press, 2006.
6. William H. Shaw, III , Review of: Peter Hoffman, Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet, 13 RISK 185 (2002).

COURSE CODE	CHN16266
COURSE NAME	Introduction To Electrochemical Engineering
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

To impart necessary basic knowledge in order to understand, analyse and solve problems related to electrochemical processes. Moreover, students will have a practical ability to analyse electrochemical design models, thermal behaviour of reactors and electrochemical reactors.

COURSE CONTENT

UNIT – 1 **[6 L]**

ELECTROCHEMICAL PRINCIPLES:

Cell voltage and its components- types of anodes and cathodes-necessity of diaphragms; Physicochemical properties of molten & aqueous electrolytes like conductivity, decomposition potential, density etc; Current and energy efficiency- features of aqueous and molten salt electrolysis distinction between electro winning and refining.

UNIT – 2 **[5 L]**

ELECTRODES AND SEPARATORS:

Electrodes and separators for the electrolytic production of chemicals – preparation, characteristics and applications of graphite, noble metal coated anodes, noble metal oxide coated anodes, Perovskite platinum and nickel anodes, steel cathodes, coated cathodes and ion exchange membranes.

UNIT – 3 **[8 L]**

FUNDAMENTALS OF ELECTROCHEMICAL REACTION KINETICS

Fundamentals of reaction kinetics, rate of electrochemical reaction, thermodynamics-heat of reaction and reaction equilibria, electrochemical thermodynamics, practical cell voltage requirements and polarization; Electrochemical transfer processes.

UNIT – 4 **[5 L]**

ELECTROCHEMICAL TECHNIQUES

Ion selective electrodes: Principles of potentiometry and amperometry, Potential step method (chronoamperometry) under diffusion control derivation of Cottrell equation for a planar and spherical electrode.

UNIT – 5 **[6 L]**

ELECTROCHEMICAL ENERGY CONVERSION AND STORAGE

Introduction to super capacitors, types of super capacitors; Introduction to fuel cells, types of fuel cells and technology development. Polymer electrolyte and solid oxide fuel cells; Microbial fuel cells.

TEXTBOOK BOOKS/REFERENCE BOOKS

1. Electrochemical Reaction Engineering, Scott. K.
2. Chemistry in Engineering and Technology, Vol.1 & 2, J.C. Kuriakose and J. Rajaram.
3. Electrochemical Engineering Principles, Geoffrey A.
4. Electrochemical Methods: Fundamentals and Applications, Allen J. Bard and Larry R. Faulkner.
5. Principles of Electrochemical Reactor Analysis, T.Z.Fahidy.

COURSE CODE	CHN16267
COURSE NAME	Solid Waste Management
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To get acquainted with various types of solid wastes and basics of collection, transportation, and disposal techniques
- To understand the theme of reduction, reuse, and recycle in solid waste management
- To understand recovery of energy and value-added products through various technological advances
- To understand the role of specific conversion processes for specific solid waste generated

COURSE CONTENT

UNIT – 1 **[5 L]**

Philosophy and organization, status of solid waste management, composition of an integrated waste management strategy, evolution of solid waste management, legislation and government agencies.

UNIT – 2 **[6 L]**

Types of solid waste, sources of solid waste, physico-chemical properties of solid waste, materials flow in society, reduction in raw materials usage, reduction in solid waste quantities, reuse of solid waste materials.

UNIT – 3 **[6 L]**

Generation of solid waste, onsite handling, storage, and processing, collection of solid wastes, transfer and transport, processing techniques and equipment, hazardous waste and their management, process management issues.

UNIT – 4 **[6 L]**

Recovery of resources from solid waste, waste to energy concept, energy recovery methods, chemical and biological methods, land filling, source reduction, recycling, incineration, composting.

UNIT – 5 **[7 L]**

Case studies on major industrial solid waste generation units, coal fired power plant, textile industry, brewery, distillery, oil refinery. Use of refuse-derived fuels.

TEXT BOOKS / REFERENCE BOOKS

1. G. Tchobanoglous, F. Kreith, "Handbook of Solid Waste Management", McGraw-Hill, 2002.
2. G. Tchobanoglous, H. Theisen, R. Eliassen, "Solid Wastes: Engineering Principles and Management Issues", McGraw-Hill, 1977.
3. H.S. Peavy, D.R. Rowe, G. Tchobanoglous, "Environmental Engineering", McGraw-Hill, 1985.
4. S. K. Garg, R. Garg, R. Garg, "Environmental Science and Ecological Studies", Khanna Publishers, 2006.

COURSE CODE	CHN16268
COURSE NAME	Introduction to Biochemical Engineering
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

Course Objectives

This course introduces the basic aspects of biochemical engineering and bioprocess technology and their commercial implications to the students from various disciplines.

UNIT 1 **[6L]**

Introduction to microbiology and biochemistry, classification and characteristics of microorganism, Essential chemicals of life - lipids, sugars and polysaccharides, RNA and DNA, amino acids and proteins.

UNIT 2 **[6L]**

Enzymes and their classification, enzyme kinetics, immobilization of enzymes and whole cells, immobilized enzyme kinetics

UNIT 3 **[6L]**

Cell metabolism, regulation, stoichiometry, end products, cell growth kinetics, product formation kinetics, thermal death kinetics, media and air sterilization

UNIT 4 **[6L]**

Transport phenomena in cellular systems, oxygen transfer rates, mass transfer coefficient and interfacial area, mechanical agitation and power requirement

UNIT 5 **[6L]**

Bioreactors: Type, design, operation and scale-up, instrumentation and control. Down-stream processing, environmental concerns

TEXT BOOKS / REFERENCE BOOKS

1. 1. J.E. Bailey, D.F. Ollis, "Biochemical Engineering Fundamentals" 2nd Edn.., McGraw Hill International, New Delhi, 1987.
2. 2. M.L. Shuler, F.Kargi "Bioprocess Engineering: Basic Concepts" 2nd Edn., Prentice-Hall, new Delhi, 2003.
3. 3. H.W. Blanch, D.S. Clark, "Biochemical Engineering" Marcel Dekker Inc., New York, 1997.
4. 4. P.F. Stanbury, A.Whitaker, "Principles of Fermentation Technology," 2nd Edn., Elsevier, Oxford, 1995.

COURSE CODE	CHN16269
COURSE TITLE	Nanomaterials for Energy & Environment
NUMBER OF CREDITS	3
L: T: P	3:0:0

COURSE LEARNING OBJECTIVES:-

- The objectives of this course are to give an idea about the nanomaterials used for energy and environmental applications.
- Principles of designing of nanomaterials used for these applications.

COURSE CONTENT

UNIT-1 **[6 L]**

Introduction and principles of nanotechnology in energy and environmental applications: Nano Engineering materials for Pollution Prevention, Green Chemistry, Energy efficient resources and materials, Nano technology products- Carbon Nanotubes (CNT), Graphenes, Fullerenes, Nano Peapods, Quantum Dots and Semiconductor Nanoparticles, Metal-based Nanostructures (Iron Oxide Nanoparticles) and Nanowires, Polymer-based Nanostructures including dendrimers.

UNIT-2 **[7 L]**

Synthesis of Nanomaterials: Synthesis of nanomaterials by Physico-chemical Approaches, Advanced Characterization Methods: Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunneling Microscopy, Optical Absorption and Emission Spectroscopy, Thermogravimetric Analysis, Differential Scanning Calorimetry, Thermomechanical Analysis, X-Ray diffraction.

UNIT-3 **[10 L]**

Nanomaterials for Energy Applications: Chemical fuels, energy related reactions, introduction to heterogeneous catalysis, Performance parameter for nanocatalysts – surface area, activity, selectivity, chemical kinetics, active sites, Functionality of Catalytic Materials – chemisoption, adsorption isotherms, activity, kinetics, Sabatier principle, molecular activation and interaction with surfaces, d-band model, dissociation and activation barriers, designer catalysts, Introduction to Solar Energy- solar resource, solar thermal, thermo-electric, photon excitation in semiconductors, electron-hole pairs, photocatalysis, current-voltage characteristic, Shockley-Queisser efficiency, n and p-type doping in semiconductors, charge carrier concentration, majority and minority carriers, p-n junction, depletion layer and electron hole pair separation, band structures and photon absorption in Si and GaAs, materials parameters for single crystal solar cells, Organic photovoltaics, Materials for Energy Storage - mainly batteries and capacitors – battery principles and architectures, electrochemical potential, Nernst equation, Gibbs free energy, charging and discharging profiles, Batteries and Nanomaterials, Fuel Cells – architectures, thermodynamics, current-voltage characteristics, kinetic losses, Proton exchange membrane (PEM) cell, electrolyte materials, electrode structure and catalysts, thermodynamics of heat engine/fuel cell combinations, solid oxide fuel cells (SOFC).

UNIT-4 **[10 L]**

Nanotechnology in environmental remediation: Nanoremediation: Identification and characterization of Hazardous waste, Nano Pollution, Air- Water - Soil Contaminants, Identification and Characterization of Organic and inorganics, Environmental cleanup technologies. Nanomaterials-Remediation: Nano Membranes, Nano Meshes, Nano Fibres,

Nano Clays and Adsorbents, Zeolites, Nano Catalysts, Carbon Nano Tubes, Bio Polymers, Single Enzyme Nano particles, Bio Metallic Iron Nano Particles, Nano Semi-Conductors, Photo catalysis, Nano-sensors. Nano Remediation Technologies: Environmental Nano Remediation Technology - Thermal, Physico-Chemical and Biological Methods, Nano Filtration for treatment of waste – removal of organics & inorganics and pathogens, Nanotechnology for water remediation and purification. Treatment of hi-tech industrial waste waters using nano particles/ modified structures/devices. Environmental Benefits of nanomaterials.

UNIT-5 **[7 L]**

Sustainable Nanotechnology: Application of industrial ecology to nanotechnology, Fate of nanomaterials in environment, environmental life cycle of nano materials, environmental and health impacts of nano materials, toxicological threats, eco-toxicology, exposure to nano particles – biological damage, threat posed by nano materials to humans, environmental reconnaissance and surveillance. Corporate social responsibility for nanotechnology, Nano materials in future - implications.

TEXT BOOKS / REFERENCE BOOKS

1. Mark Wiesner and Jean-Yves Bottero, "Environmental Nanotechnology: Applications and Impacts of Nanomaterials", McGraw-Hill Education, 2007.
2. Jingbo Liu Sajid Bashir, "Advanced Nanomaterials and Their Applications in Renewable Energy", Elsevier Science, 2015.
3. Junhui He, "Nanomaterials in Energy and Environmental Applications", CRC Press, 2016.
4. Zhanhu Guo, Yuan Chen, Na Luna Lu, "Multifunctional Nanocomposites for Energy and Environmental Applications", Wiley, 2018.
5. M.H. Fulekar, "Nanotechnology: Importance and Application", IK International, 2010.

SEMESTER-VII								
S. No.	**Course Code**	**Name of Course**	**Cat**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	CHN17115	Plant Design and Economics	CEE	3	1	0	4	4
2	CHN17116	Hazards and Safety in Process Industry	CEE	3	0	0	3	3
3	CHN17270-279	7^{th} Sem Pool	CEE	3	0	0	3	3
4	CHN17351	Minor Project	CEE	0	0	6	6	6
Total							**16**	**16**

Theory Courses = 03, Project = 01

SEMESTER-VIII								
S. No.	**Course Code**	**Course Name**	**Cat**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	CHN18352	Industrial Training/ Major Group Project/ Entrepreneurship	CEE	0	0	16	16	-
Total							**16**	-

SEMESTER-VII

COURSE CODE	CHN17115
COURSE NAME	Plant Design and Economics
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES:

To impart information about overall plant design for a particular process for the manufacture of particular product considering various aspects such as site selection, plant layout, material of construction, and economic principles involved in construction of a process plant.

COURSE CONTENT

UNIT-1 **[6L]**

Methods of Process Design: General design considerations, material and fabrication selection, hierarchy of chemical process design, economic design criteria, nature of process synthesis and analysis

UNIT-2 **[6L]**

Flow sheeting-Introduction, Flow sheet Presentation, Process Simulation Programs, Specification of Components and Physical Property Models, Simulation of Unit Operations, User Models, Flow sheets with Recycle, Flow sheet Optimization, Dynamic Simulation

UNIT-3 **[6L]**

Process Integration: Process heuristics, Heat exchange networks synthesis and utilities, energy targets

UNIT -4 **[6L]**

Cash Flow and Investments: Cash flow for industrial operations, factors effecting investment and production cost, estimation of capital investments, cost factors in capital investment, production costs, fixed charges, plant overhead costs, financing, interest and investment cost, present worth and discount annuities, cost due interest on investment, type of taxes.

UNIT-5 **[6L]**

Depreciation and Profitability: Depreciation, types of depreciation, services life, methods for determining depreciation, profitability, alternative investments and replacements, profitability standards, discounted cash flow, capitalized cost, pay out period.

TEXT BOOKS / REFERENCE BOOKS:

1. M.S. Peters, K.D. Timmerhaus, "Plant Design and Economics for Chemical Engineering",5th Edn., McGraw-Hill Education, New York, 2017.
2. W.D. Seider, J.D. Seader, D.R. Lewin et al., "Product and Process Design Principles: Synthesis, Analysis, and Evaluation", 4th Edn. John Wiley, New York, 2016.
3. Perry's Chemical Engineer's Handbook, 8th Edn., McGraw-Hill Inc, New York, 2007.

COURSE CODE	CHN17116
COURSE NAME	Hazards and Safety in Process Industries
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

To introduce awareness on the importance of plant safety and hazards analysis.

COURSE CONTENT

UNIT-1 **[7L]**

INTRODUCTION

Safety terminology, Safety programs, Safety policy, Safety committee: structure and functions, psychological factors in industrial safety. Past accident analysis of Flixborough, Bhopal gas tragedy, Three-mile Island Chernobyl accident, Fukushima Daiichi, Port Wentworth, Pasadena, Jacksonville, Feyzin disaster, Seveso accident analysis.

UNIT-2 **[7L]**

INDUSTRIAL HYGIENE AND OCCUPATIONAL HEALTH

Definition of Industrial Hygiene, Govt. regulations and evaluation, Concept of threshold: TLV, OSHA, FAR, Fatality rate, Occupational health hazards: toxicological studies, Dose versus response, Personal protective equipment (PPE), Material safety data sheet (MSDS), Ergonomics: definition, aims and scope, application of ergonomics in industry for safety, health and environment.

UNIT-3 **[5L]**

SAFETY MANAGEMENT

Process safety management, Risk management and its tools, Safety health and environment (SHE) management, Safety audit, Safety report: preparation and assessment, Safety surveys and review, Emergency response and preparedness.

UNIT -4 **[5L]**

FIRE AND EXPLOSION

The fire triangle, Potable fire extinguishers, Effects of explosion, Explosions: deflagration, detonation, TNT& TNO, Confine & unconfined explosion, Over pressure, Flash fire, Jet fire, Pool fire, VCE, BLEVE, Fire ball.

UNIT-5 **[6L]**

HAZARD AND RISK ANALYSIS

Hazard identification, Comprehensive risk analysis, Preliminary hazard analysis, FMEA, HAZOP study, Checklists/ What if analysis, Event tree and fault tree analysis, Hazards and their control in: textile industry, fertilizer industry and petroleum refineries, etc.

TEXT BOOKS / REFERENCE BOOKS:

1. Chemical Process Safety: Fundamentals with Applications, Daniel Crowl, Joseph F. Louvar.
2. Methodologies in Hazard Identification and Risk Assessment, K. V. Raghavan and A. A Khan.
3. Loss Prevention in Process Industries Vol. I, II & III, Frank P. Less.

COURSE CODE	CHN17270
COURSE NAME	Process Modelling and Simulation
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

The objective is to develop an insight into design and simulation of chemical process equipment.

COURSE CONTENT

UNIT-1

Introduction to modelling and simulation, classification, Uses of mathematical models, Principles of model formulation, Fundamental laws- continuity equation, energy equation, equations of motion, Transport equations, equations of state, equilibrium and kinetics, Introduction to process simulators and mathematical tools.

UNIT-2

Numerical solution of model equations with linear and nonlinear algebraic equations in one and more than one variable, ordinary differential equations in one and more than one variable

UNIT-3

Numerical solutions of model equations with partial differential equations using finite difference method, Model parameters estimation: Introduction, method of least squares, curve fitting, etc.

UNIT-4

Lumped Parameter Models: Formulation and solution techniques for vapor-liquid equilibrium models, batch and continuous distillation column, mixing tank, stirred tank with heating, CSTR with multiple reactions. N- CSTRs in series, Non-isothermal CSTR.

UNIT-5

Steady State Distributed Parameter Models: Formulation and solution of split boundary value problems - shooting technique, quasi-linearization techniques, counter current heat exchanger, tubular reactors.

UNIT-6

Unsteady State Distributed Parameter Models: convective problems, diffusive problems, combined convective and diffusive problems.

TEXT BOOKS / REFERENCE BOOKS:

1. K. M. Hangos and I. T. Cameron, “Process Modeling and Model Analysis”, Academic Press, 2001.
2. W.L. Luyben, “Process Modelling, Simulation and Control for Chemical Engineers”, 2nd Edn., McGraw Hill Book Co., New York, 1990.
3. W. F. Ramirez, “Computational Methods for Process Simulation”, Butterworths, 1995.
4. Process Dynamics: Modeling, Analysis and Simulation, B Wayne Bequette, Prentice Hall. International Inc.
5. Computational Methods for Process Simulation, 2nd ed., W F Remirez, Butterworth-Heinemann.
6. Roger E. Franks, “Modeling and Simulation in Chemical Engineering”, JohnWiley and Sons, 1972.
7. Mark E. Davis, “Numerical Methods and Modeling for Chemical Engineers”, John Wiley & Sons, 1984.

8. Singiresu S. Rao, “Applied Numerical Methods for Engineers and Scientists” Prentice Hall, Upper Saddle River, NJ, 2001.
9. Seinfeld and Lapidus, “Mathematical Methods in Chemical Engineering”, Prentice Hall, 1974

COURSE CODE	CHN17271
COURSE NAME	Process Integration
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

•To expose students to the techniques for energy minimization in the Process.
•To retrofit and set up targets for energy minimization

COURSE CONTENT

UNIT-1 **[4L]**

INTRODUCTION TO PINCH ANALYSIS

Thermodynamical review of the process; Pinch Analysis- basic concepts of pinch analysis, data extraction, energy targeting, area targeting, super targeting

UNIT-2 **[6L]**

HEAT EXCHANGER NETWORK

Heat exchanger network design- basic principles, stream splitting, network relaxation, retrofit design, temperature enthalpy diagram

UNIT-3 **[6L]**

PINCH DESIGN AND OPTIMIZATION

Networks for maximum energy recovery, Pinch design method, Flexibility criteria of the pinch

UNIT -4 **[8L]**

PROCESS INTEGRATION

Heat Integration Issues for Utilities; Heat and Power Systems (Combined Heat and Power, Heat Pumps, Refrigeration Systems, Total Site Analysis); Process Modifications for Energy Efficiency (applied to Distillation Columns); Wastewater Minimization.

UNIT-5 **[6L]**

PROCESS DATA ANALYSIS

Data Reconciliation; Gross Error Detection and Identification; Multiple Gross Errors; Industrial Applications.

TEXT BOOKS / REFERENCE BOOKS:

1. Robin Smith, Chemical Process Design and Integration, Wiley – India, 2006
2. Ian C. Kemp, Pinch Analysis and Process Integration. 2nd Edition, Butterworth-Heinemann, 2006.
3. James M. Douglas, Conceptual Design of Chemical Process, McGraw Hill, New York, 1988.
4. D.W. Linnhoff et al., User Guide on Process Integration for the efficient use of Energy, Institution of Chemical Engineers, U.K., 1994.

COURSE CODE	CHN17272
COURSE NAME	Plantwide Control
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To make students understand the importance and principles of plantwide control in chemical industry.
- To prepare students for tackling the challenges in controlling complex processes using suitable control strategies.

COURSE CONTENT

UNIT-1 **[4L]**

IMPORTANCE OF PLANTWIDE CONTROL

Introduction to plantwide control in industrial perspective; Conventional control techniques; Advanced control techniques. Controller design for SISO & MIMO systems.

UNIT-2 **[6L]**

MULTIVARIABLE SYSTEMS

Multiloop & multivariable control systems; Interaction study; Relative gain array analysis; Singular value decomposition; Dynamic decoupling.

UNIT-3 **[6L]**

CONTROL OF COMPLEX UNIT PROCESSES

Control of- simple distillation, complex column configurations, reactors.

UNIT -4 **[8L]**

PLANTWIDE CONTROL STRUCTURE DESIGN

Steady-state to dynamic state- sizing of equipment, plumbing rules; Development of a plantwide regulatory control system and controller tuning- control degree of freedom analysis; selection of throughput manipulator; study of recycle dynamics; Systematic plantwide control techniques. Performance criterial of evaluation of designed plantwide control system.

UNIT-5 **[6L]**

USES OF PROCESS SIMULATORS AND CASE STUDIES

Dynamic simulation and plantwide control of complex processes (such as styrene, toluene hydrodealkylation, ethyl benzene, etc.).

TEXT BOOKS / REFERENCE BOOKS:

1. W. Luyben, Plantwide Dynamic Simulators in Chemical Processing and Control, CRC Press,2002.
2. G. P. Rangaiah, Vinay Kariwala, Plantwide Control: Recent Developments and Applications, Wiley, 2012.
3. Dale E Seborg, Thomas F. Edgar and Duncan A. Mellichamp, Process Dynamics and Control, Wiley India, New Delhi, 3rd edition, 2013.

COURSE CODE	CHN17274
COURSE NAME	Introduction To Biochemical Engineering
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

This course introduces the basic aspects of biochemical engineering and bioprocess technology and their commercial implications to the students from various disciplines.

COURSE CONTENT

UNIT-1 **[6L]**

Introduction to microbiology and biochemistry, classification and characteristics of microorganism, Essential chemicals of life - lipids, sugars and polysaccharides, RNA and DNA, amino acids and proteins.

UNIT-2 **[6L]**

Enzymes and their classification, enzyme kinetics, immobilization of enzymes and whole cells, immobilized enzyme kinetics

UNIT-3 **[6L]**

Cell metabolism, regulation, stoichiometry, end products, cell growth kinetics, product formation kinetics, thermal death kinetics, media and air sterilization

UNIT -4 **[6L]**

Transport phenomena in cellular systems, oxygen transfer rates, mass transfer coefficient and interfacial area, mechanical agitation and power requirement

UNIT-5 **[6L]**

Bioreactors: Type, design, operation and scale-up, instrumentation and control. Down-stream processing, environmental concerns

TEXT BOOKS / REFERENCE BOOKS:

1. J.E. Bailey, D.F. Ollis, "Biochemical Engineering Fundamentals" 2 nd Edn.., McGraw Hill International, New Delhi, 1987.
2. M.L. Shuler, F.Kargi "Bioprocess Engineering: Basic Concepts" 2 nd Edn., Prentice-Hall, new Delhi, 2003.
3. H.W. Blanch, D.S. Clark, "Biochemical Engineering" Marcel Dekker Inc., New York, 1997.
4. P.F. Stanbury, A.Whitaker, "Principles of Fermentation Technology," 2 nd Edn., Elsevier, Oxford, 1995.

COURSE CODE	CHN17275
COURSE NAME	Fluid Flow and Heat Transfer in Microchannel
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

The objective is to develop an insight into design procedure micro-structured devices being used are to be used process industries.

COURSE CONTENT

UNIT-1 **[4L]**

Introduction and applications of fluid flow in microchannel; Micro-fabrication techniques; Dimensional analysis and role of dimensionless numbers in microchannel.

UNIT-2 **[8L]**

Design of microfluidic devices: Fundamental Transport Equations viz. Momentum balance, Mass Balance and Energy balance in microchannel.

UNIT-3 **[8L]**

Statistical mechanics, Continuum assumption and limits of linear transport properties; multiphase flow in microsystem; pressure drop models in single- and two-phase flow in microchannels. Slip velocity, Continuum flow (with slip), free molecular flow, Electro-osmotic flow, electric double layer; Capillary filling, passive valves, electro-wetting.

UNIT -4 **[9L]**

Introduction to heat transfer in micro-channels. Convective Heat transfer in microchannel with and without phase change. Boiling and Condensation in microchannels. Concepts and examples of micro heat exchange devices.

UNIT-5 **[9L]**

Micro-mixing and its characterization; Heat transfer in multi-channel stack with chemical reactions; Viscous heating and entropy generation in channel flow; Microfluidic network for heat and mass transfer, Dispersion in micro-channel; entrance effect, Field flow fractionation.

TEXT BOOKS / REFERENCE BOOKS:

1. Oliver Brand, Gary K. Fedder, Christofer Hierold, Jan G. Korvink, and Osamu Tabata; Advanced Micro & Nano systems, Volume 5, Micro Process Engineering: Fundamentals, Devices, Fabrication, and Applications; Wiley –VCH.
2. Satish G. Kandlikar , Srinivas Garimella, Dongqing Li, Dongqing Li, Heat transfer and fluid flow in minichannels and microchannels; Elsevier.
3. By Nam-Trung Nguyen, Nam-Trung Nguyen Steven T. Wereley; Fundamentals and Applications of Microfluidics; Artech house

COURSE CODE	CHN17275
COURSE NAME	Scale-Up In Process Industries
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To make students understand the procedure for process scale and its importance in industry.
- To prepare students for tackling the challenges in scaling up the processes from laboratory scale to industrial scale.

COURSE CONTENT

UNIT-1 **[4L]**

INTRODUCTION TO SCALE UP: Introduction to pilot plants and Models; Process Development; Process study; The principle of similarity and similarity criteria.

UNIT-2 **[6L]**

PILOT PLANTS AND PLANT MODELS: Dimensional analysis and its application in scaling-up or scaling-down the chemical process plant; Project engineering; Practical consideration; Safety considerations; Successful plant operations and case studies.

UNIT-3 **[6L]**

MATHEMATICAL EQUATIONS: Mathematical equations representing the mechanical, thermal, diffusional and chemical processes, and derivation of the dimensionless groups from these differential equations; Rate of chemical reaction of homogeneous and heterogeneous chemical reactions.

UNIT - 4 **[6L]**

SCALE UP CONSIDERATIONS: Chemical dynamics and regimes; Effect of temperature on physical and chemical reactions; Similarly criteria for the principle types of regime and scale equations.

UNIT-5 **[8L]**

SCALE UP OF PROCESS EQUIPMENTS : Scale-up methods for heat-transfer equipments - heat exchangers, steam or vapor heaters, evaporators, condensers and coolers; Scale-up methods for mixing equipment and other miscellaneous equipments used in chemical process industries.

TEXT BOOKS / REFERENCE BOOKS:

1. Oliver Brand, Gary K. Fedder, Christofer Hierold, Jan G. Korvink, and Osamu Tabata; Advanced Micro & Nano systems, Volume 5, Micro Process Engineering: Fundamentals, Devices, Fabrication, and Applications; Wiley –VCH.
2. Satish G. Kandlikar , Srinivas Garimella, Dongqing Li, Dongqing Li, Heat transfer and fluid flow in minichannels and microchannels; Elsevier.
3. By Nam-Trung Nguyen, Nam-Trung Nguyen Steven T. Wereley; Fundamentals and Applications of Microfluidics; Artech house

COURSE CODE	CHN17276
COURSE NAME	Solar Photovoltaic Energy Systems
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To get acquainted with the role of solar energy in sustainable environment
- Basics of solar electrical energy systems
- To learn about solar radiation, PV cells and modules
- To learn about stand-alone PV schemes with battery energy storage and grid-connected PV schemes

COURSE CONTENT

UNIT-1

Fossil fuel energy usage and global warming; role of renewable energy in sustainable development; renewable energy sources; global potential for solar electrical energy systems.

UNIT-2

Solar radiation: Extra-terrestrial and terrestrial solar spectrum; clear sky direct-beam radiation; total clear sky insulation on a collecting surface; radiation on the collector in tracking systems; calculation of average monthly insolation from measured data.

UNIT-3

PV cells and modules: Photovoltaic cell and its simple model; PV modules and arrays; effect of shading, use of bypass and blocking diodes; influence of temperature; types of solar cells and their performance; schemes for maximum power point tracking; solar PV concentrators

UNIT -4

PV inverters: Grid-connected single phase PV inverter schemes and control; power processing schemes based on single string, multi-string and ac module technologies; types of grid interface; power electronic converters used in single phase PV systems and their operation; transformer less inverters, centralized grid-connected three-phase inverters for large PV installations.

UNIT-5

Schemes with battery energy storage: Power processing schemes and control for stand-alone applications; batteries for energy storage– types, charging, battery sizing and turn-around efficiency; other types of energy storage for PV systems; grid connected schemes with standby energy storage.

TEXT BOOKS / REFERENCE BOOKS:

1. C. S. Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications", PHI Learning Pvt Ltd, 2009.
2. R. A. Messenger, J. Ventre,"Photovoltaic Systems Engineering", CRC Press, 2004.
3. G. M. Masters, "Renewable and Efficient Electric Power Systems", John Wiley & Sons, 2004.

COURSE CODE	CHN17277
COURSE NAME	Biorefinery Engineering
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To know about different biomass sources and their properties.
- To study about different techniques for bio products formation.

COURSE CONTENT

UNIT-1

Biomass sources, characteristics, preparation, chemical composition and properties of different biomass materials. Energy plantations, pretreatment techniques for the utilization of biomass, size reduction, briquetting of loose biomass, drying, storage and handling of biomass.

UNIT-2

Biogas technology, feedstock for biogas production, aqueous wastes containing biodegradable organic matter, animal residues, microbial and biochemical aspects, and operating parameters for biogas production. Kinetics and mechanism, dry and wet fermentation, digesters for rural application, and high rate digesters for industrial waste water treatment.

UNIT-3

Bio-ethanol and bio-diesel technology: production of fuel ethanol by fermentation of sugars, gasohol as a substitute for leaded petrol, trans-esterification of oils to produce bio-diesel.

UNIT -4

Pyrolysis and gasification of biomass, thermo-chemical conversion of ligno-cellulose biomass, biomass processing for liquid fuel production, pyrolysis of biomass, pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles, effect of pressure, temperature and of introducing steam and oxygen. Design and operation of fixed and fluidized bed gasifiers.

UNIT-5

Combustion of biomass and cogeneration systems, theory, calculations and design of equipments, cogeneration in biomass processing industries. Case studies: combustion of rice husk, use of bagasse for cogeneration.

TEXT BOOKS / REFERENCE BOOKS:

1. A. Chakraverthy, “Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes”, Oxford & IBH publishing 1989.
2. K.M. Mital, “Biogas Systems: Principles and Applications”, New Age International Publishers Pvt. Ltd., 1996.
3. D.L. Klass, G.M. Emert, “Fuels from Biomass and Wastes”, Ann Arbor Science Publication, 1985.

COURSE CODE	CHN17278
COURSE NAME	Biomass Conversion Technologies
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- Understanding of fundamental information about various bio-resources
- Understanding of energy valorization from bio-resources through thermochemical conversion processes
- Understating of bioethanol and biogas production through biochemical conversion processes
- To analyze opportunities and challenges associated with thermochemical and biochemical conversion processes for specific feedstocks

COURSE CONTENT

UNIT-1

Biomass sources, chemical composition and physical properties of different biomass materials, dedicated energy plantations, pretreatment techniques for the utilization of biomass, size reduction, briquetting of loose biomass, drying, storage and handling of biomass.

UNIT-2

Pyrolysis and gasification of biomass, thermo-chemical conversion of ligno-cellulose biomass, biomass processing for liquid fuel production, pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles, effect of pressure, temperature and of introducing steam and oxygen, design and operation of fixed and fluidized bed gasifiers.

UNIT-3

Combustion of biomass and cogeneration systems, theory, calculations and design of equipments, cogeneration in biomass processing industries, logistics involved. Case studies: combustion of rice husk, use of bagasse for cogeneration.

UNIT -4

Bio-ethanol and bio-diesel technology: production of fuel ethanol by fermentation of sugars, gasohol as a substitute for leaded petrol, trans-esterification of oils to produce bio-diesel. Concept of bio-refinery.

UNIT-5

Biogas technology, feedstock for biogas production, aqueous wastes containing biodegradable organic matter, animal residues, microbial and biochemical aspects, operating parameters for biogas production. Kinetics and mechanism, dry and wet fermentation, digesters for rural application, high rate digesters for industrial waste water treatment.

TEXT BOOKS / REFERENCE BOOKS:

1. A. Dahiya, "Bioenergy: Biomass to Biofuels", Academic Press, 2014.
2. A. Chakraverthy, "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing, 1989.
3. D.L. Klass, G.M. Emert, "Fuels from Biomass and Wastes", Ann Arbor Science Publication, 1985.

4. K.M. Mital, “Biogas Systems: Principles and Applications”, New Age International Publishers Pvt. Ltd., 1996.
5. P. Lund, J. A. Byrne, G. Berndes, I. Vasalos, “Advances in Bioenergy: The Sustainability Challenge”, Wiley, 2015.

COURSE CODE	CHN17279
COURSE NAME	Green Processes and Product Design
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES: -

To impart fundamental knowledge about various unit systems for chemical process calculations and to give insight of material and energy balances in various unit operations and processes.

COURSE CONTENT

Unit I

Introduction: Introduction, Definition and Principles of Green Processes and Chemistry, Challenges to the sustainability of chemical industry, toxicity of chemicals, material safety data sheet (MSDS), concept of zero pollution technologies, atom economy, functional toxicity vs non-functional toxicity, alternative solvents, energy minimization, microwave and sonochemical reactions, renewable feed stock

Unit II:

Product Design : Product Design Principles, Understanding customer needs, consumer products, Converting needs to specification, Ideas, Selection using thermodynamics and kinetics, product manufacture, case studies on bioplastic, biopolymers. Unit III:

Green Synthesis: Bio Catalytic Reactions , Green Chemistry Using Bio Catalytic Reactions , Introduction - Fermentation and Bio transformations - Production of Bulk and fine chemicals by microbial fermentation, Case Studies.

Unit IV:

Biorefinery and Agro Chemicals Design : Introduction too Bio refinery, Bio refinery chemicals from fatty acids-Polymer from Renewable Resources –Biodiesel from various feed stocks, Agrochemicals – Introduction, Biocides: types and applications, Organic Insecticides, Fungicide, Case Studies.

REFERENCE BOOKS

1. Cussler and Moggridge .Chemical Product Design. Cambridge University Press, Ist Edition, 2001.

2. Anastas & Warner. Green Chemistry: Theory & Practice ,Oxford Univ. Press, New York,1998

SEMESTER-VIII

COURSE CODE	CHNXXXX
COURSE NAME	Industrial Training/Major Group Project/Entrepreneurship
NUMBER OF CREDITS	16
(L: T: P)	0: 0: 16

BTech
+
Honors

B.Tech. (Chemical Engineering) Honors List of Courses in Honors Basket								
S.No.	**Semester in which you can choose the subject**	**Subject Name**	**Cat**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	Even Semester (6^{th})	Process Intensification	CHH	3	1	0	4	4
2	Even Semester (6^{th})	Novel Separation Processes	CHH	3	1	0	4	4
3	Odd Semester (7^{th})	Mathematical Methods in Chemical Engineering	CHH	3	1	0	4	4
4	Odd Semester (5^{th} or 7^{th})	Elective Pools (Honors)	CHH	3	1	0	4	4
	Total						**16**	**16**

** Process Intensification, Novel Separation Processes and Mathematical Methods in Chemical Engineering would be run as compulsory courses.

List of Courses in Elective Pool (Honors)								
S.No.	**Semester in which to choose the subject**	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	Odd Semester (5^{th} or 7th)	Artificial Intelligence in Process Engineering	HN	3	1	0	4	4
2	Odd Semester(7^{th})	Advanced Enginneering Thermodynamics	HN	3	1	0	4	4
3	Odd Semester(7^{th})	Chemical Reactor Analysis and Design	HN	3	1	0	4	4
4	Odd Semester (5^{th} or 7th)	Colloidal Science and Engineering	HN	3	1	0	4	4
5	Odd Semester(7^{th})	Advanced Process Control	HN	3	1	0	4	4
6	Odd Semester(7^{th})	Computational Fluid Dynamics	HN	3	1	0	4	4

COURSE CODE	CHN XXXX
COURSE NAME	PROCESS INTENSIFICATION
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

- To understand the scientific background, techniques and applications of intensification in the
- To provide the knowledge leading compact, safe, energy-efficient and environment-friendly novel equipments and processes.

COURSE CONTENT

UNIT– 1 **[4 L]**

INTRODUCTION TO PROCESS INTENSIFICATION

Need of process intensification; Process intensifying equipments and methods; Examples of their application on the commercial scale.

UNIT – 2 **[6 L]**

PROCESS INTENSIFICATION FOR ENHANCED MISING AND HEAT EXCHANGE

Mixing in stirred tanks; Scale up of mixing; High gravity fields; Micro-channel heat exchangers; Phase-change heat transfer.

UNIT – 3 **[8 L]**

PROCESS INTENSIFICATION IN REACTORS

Monolithic catalyst and reactors; Higee reactor; Spinning disc reactors; Reverse flow reactor; Micro-reactors; Membrane reactors/bioreactors.

UNIT – 4 **[6 L]**

PROCESS INTENSIFICATION SEPATATING COLUMNS

Reactive- distillation, extraction, adsorption, absorption, fermentation-pervaporation; adsorptive distillation; Hybrid columns.

UNIT – 5 **[6 L]**

PROCESS INTENSIFICATION IN OTHER OPERATIONS

Energy based intensifications; Sonochemical intensifications; Microwave assisted intensifications.

TEXTBOOK/REFERENCE BOOK(S)

1. Stankiewicz, A.; Moulijn, J.A. "Re-engineering the chemical processing plant: process intensification" Marcel Dekker, Inc., New York, 2004.
2. 2. Mizrahi, J. "Developing an industrial chemical process: an integrated approach" CRC Press, 2002.
3. Keil ,F. J."Modeling of Process Intensification" Wiley-VCH Verlag Germany, 2007.
4. Reay, D.;Ramshaw,C.; Harvey, A.Process Intensification, Elsvier, 2013.
5. Boodhoo, K.; Harvey, A. Process Intensification for Green Chemistry, Wiley, 2013.

COURSE CODE	CHN XXXX
COURSE NAME	Novel Separation processes
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

- To understand the principles, modelling and design concepts of novel separation techniques and their applications.
- Perform the process and design calculations for the solution of specific problems.

COURSE CONTENT

UNIT-1 **[14L]**

MEMBRANE SEPARATION PROCESSES: Preparation, characterization, types and choice of membranes, Membrane modules, Design of membrane process: reverse osmosis, ultrafiltration, microfiltration, nanofiltration, dialysis, gas separation and pervaporation, Membrane reactors.

UNIT-2 **[8L]**

ADSORPTIVE SEPARATION: Review of fundamentals, Nature of Adsorbents, adsorption equilibrium, Kinetic effects, Pressure and temperature swing regeneration of spent adsorbents, Adsorption equipments.

UNIT-3 **[4L]**

CHROMATOGRAPHIC SEPARATION: Fundamentals, Chromatographic techniques, Development of gradient-elution separations, Retention theory, Types of chromatography, Equipment and commercial processes.

UNIT-4: **[6L]**

IONIC SEPARATIONS: Ion exchange: Ion exchange resins, Ion exchange equilibrium, Ion movement theory, Electrodialysis, Electrophoresis, Commercial applications.

UNIT-5: **[8L]**

OTHER TECHNIQUES: Liquid membrane permeation, Surfactant based separation: micellar separations, Supercritical fluid extraction.

TEXT BOOKS / REFERENCE BOOKS:

1. Marcel Mulder, “Basic Principles of Membrane Technology”,2 Ed., Springer Publications, 2007
2. Kaushik Nath,”Membrane Separation Processes”, PHI Learning Pvt. Ltd., New Delhi, India, 2008
3. Reverse Osmosis and Ultra Filtration ProcessPrinciple, Sourirajan, S. &Matsura, T.,NRC Publication, Ottawa, 1985.
4. R.W. Rousseau, “Handbook of separation Process Technology”, Wiley-India.
5. J.M. Coulson, J.F. Richardson, "Chemical Engineering", Vol.-2, Butterworth - Heinemann London
6. C.J. King, Separation Processes, Tata McGraw Hill (1981).
7. C. Loeb, R. E. Lacey, "Industrial Processing with Membranes", Wiley Inter Science.
8. T. A. Hatton, J. F. Scamehorn, J. H., Harvell, “Surfactant Based Separation Processes”, Vol. 23, Surfactant Science Series, Marcel Dekker Inc., New York *1989.*
9. McHugh, M. A. &Krukonis, V. J., Supercritical Fluid Extraction, Butterworth,1985

COURSE CODE	CHNXXXX
COURSE NAME	Mathematical Methods in Chemical Engineering
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES:

This course aims to learn, different mathematical techniques to solve and analyse the algebraic, ordinary differential or partial differential equations widely occurs in different chemical engineering problems.

COURSE CONTENT

UNIT – 1 **[8L]**

Modelling of different chemical engineering systems such as reactors, heat exchangers, process flowsheets and their vector formulations, types of equation, vectors, metrics, norms, inner products, normed linear space, dimension of vector spaces, change of basis, gram-Schmidt ortho-normalization.

UNIT – 2 **[8L]**

Matrices, operators and transformations, eigenvalues and eigen vectors, repeated eigenvalues, algebraic and geometric multiplicity and their applications.

UNIT – 3 **[8L]**

Solving linear algebraic equations, homogeneous and non-homogeneous ordinary differential equations using eigenvalue-eigenvector methods, application of these methods to chemical engineering problems, Rayleigh quotient, non-self-adjoint systems.

UNIT – 4 **[8L]**

Classification of PDE, boundary conditions, developing PDE in chemical engineering systems, Infinite dimensional spaces, Fourier series & finite Fourier transforms. Application on ODE & PDE, maximum principles, energy methods, monotone iteration method, numerical analysis, method of continuation.

UNIT – 5 **[8L]**

Contraction mapping and unique steady state, linear stability of a dynamic system, bifurcation theory, Landau-Hopf scenario, characteristic of trajectories.

TEXT BOOKS / REFERENCE BOOKS

1. S. Pushpavanam, “Mathematical Methods in Chemical Engineering” PHI, New Delhi, 1998.
2. Loney, N.W. “Applied Mathematical Methods for Chemical Engineers” CRC Press, 2nd Edition, 2006.
3. A. Varma & M. Morbidelli,” Mathematical Method in Chemical Engineering”
4. Oxford University Press, 1997.
5. Harold S. Mickley, Thomas S. Sherwood, Charles E. Reed, “Applied Mathematics in Chemical Engineering” Tata McGraw Hill Publishing Company Limited, Second Edition, 1975.

6. Richard G. Rice & Duong D. D, “Applied Mathematics and Modelling for Chemical Engineers” John Wiley & Sons, 1995.

COURSE CODE	CHNXXXX
COURSE NAME	CHEMICAL REACTOR ANALYSIS AND DESIGN
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

The objective is to enable understanding of design of industrially important reactors both for homogeneous and heterogeneous chemical reactions on a commercial scale.

COURSE CONTENT:

Unit I: **[6 L]**

Introduction to Chemical Reaction Engineering: chemical reactions, reaction order, molecularity, conversion, rate law and stoichiometry, elementary and non- elementary reactions, reaction rate constant, chemical equilibrium. Design of Isothermal Reactors: batch reactor, continuous stirred tank reactor (CSTR), plug-flow tubular reactor (PFTR), semi-batch reactor and recycle reactors.

Unit II: **[7 L]**

Design of Non-isothermal Reactor: energy balance, reactors heat generation and removal, non-isothermal continuous flow reactor, energy balance in a CSTR and PFTR, adiabatic reactors, trajectories and phase-plane plots, trajectories of wall-cooled reactors.

Unit III: **[10 L]**

Catalyst & Catalysis: catalytic reactions, reaction rates, rate equation for surface kinetics, porous catalysts, pore diffusion, and temperature dependence of catalytic reaction rates. Design of packed bed reactor for catalytic reactions.

Unit IV: **[10 L]**

Multiphase Reactors: introduction, types, and mass balance equations for multiphase reactors, interfacial surface area, mass transfer between phases, equilibrium between phases, membrane reactors, falling film reactor, bubble column reactors, trickle bed reactor, slurry reactor.

Unit V: **[7 L]**

Models for Non-ideal Reactors: basics of non-ideal flow, residence time distribution (RTD) in ideal reactors; residence time distribution (RTD) in non-ideal reactors, Tanks-in-Series (T-I-S) model, Dispersion model,reaction and dispersion, Tanks-in-Series model versus Dispersion model.

TEXT BOOKS / REFERENCE BOOKS

1. Octave Levenspiel, "Chemical Reaction Engineering", 3 rd ed., (An Indian Adaptation) Wiley India Pvt. Ltd 2021.
2. H. Scott Fogler, “Elements of Chemical Reaction Engineering”, 5 th ed, PHI, 2016.
3. M. Davis and R. Davis, “Fundamental of Chemical Reaction Engineering”, McCraw Hill, New York.
4. J.M. Smith, "Chemical Engineering Kinetics",3 rd ed, McCraw Hill, New York, 2014.
5. Lanny D. Schmidt, “The engineering of chemical reactions” 2 nd ed., Oxford University Press, New York, 2007.

COURSE CODE	CHN XXXX
COURSE NAME	Colloidal Science and Engineering
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

This course is aimed at introducing the basic concepts and tools for the analysis of colloidal and interfacial properties and their applications in adhesion, particle-aggregation, wetting, detergency, oilrecovery, flotation, nucleation, bio-surfaces, chromatography, paints, composite materials.

COURSE CONTENT

UNIT – 1 **[10L]**

Introduction, Surface Tension, Adhesion and Capillarity:
Effects of confinement and finite size, Concepts of surface and interfacial energies and tensions, Apolar (van der Waals) and polar (acid-base) components of interfacial tensions, Young-Laplace equation of capillarity; examples of equilibrium surfaces, multiplicity, etc. Stability of equilibrium solutions, Contact angle and Young's equation, Determination of apolar (van der Waals) and acid-base components of surface/interfacial tensions, Free energies of adhesion, Kinetics of capillary and confined flows.

UNIT – 2 **[10 L]**

Intermolecular, nanoscale and interfacial forces**:**
Van der Waals, Electrostatic double layer, Acid-base interactions including hydrophobic attraction and hydration pressure.

UNIT – 3 **[8 L]**

Mesoscale Thermodynamics, Mesoscale Phenomena in Soft Matter and Applications: Gibbs treatment of interfaces, concept of excess concentration; variation of interfacial tensions with surfactant concentration, adhesion, wetting, nucleation, flotation, patterning of soft material by self - organization and other techniques.

UNIT – 4 **[8 L]**

Stability of Nanoparticle Dispersions, Nanofluidics:
DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in a potential field/Brownian movement, stability of thin (< 100 nm) films, self-organization in confined systems, meso-patterning.

UNIT – 5 **[4 L]**

Advanced and Functional Interfaces:
Superhydrophobicity, functional coatings, structural colors, nano-adhesives, nanocomposites.

TEXTBOOK/REFERENCE BOOK(S)

1. Hiemenz, Paul C. "Principles of Colloid and Surface Chemistry", Marcel Dekker, any edition starting with the 2nd edition, 1986.
2. Adamson, Arthur W. Physical Chemistry of Surfaces" Wiley, 5th edition, 1990.

3. Hunter, Robert J. "Foundations of Colloid Science", Clarendon, Oxford, Volume 1, 1989.

4. Russel, W. B., Saville, D. A. and Schowalter, W. R. "Colloidal Dispersions", Cambridge University Press, 1989.

5. Israelachvili, Jacob N." Intermolecular and Surface Forces", Academic Press, 1992 or later editions.

6. Oss, C. J. Van "Interfacial Forces in Aqueous Media", Marcel Dekker or Taylor & Francis, 1994.

COURSE CODE	CHN XXXX
COURSE NAME	Advanced Process Control
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

- To expose students to the advanced control methods used in industries and modern research.
- To prepare students for tackling open ended process control problems.

COURSE CONTENT

UNIT – 1 **[6L]**

CONTROL SYSTEM DESIGN

Control system design in Laplace, time, and frequency domains; Controller design using Laplace, time and frequency response; Controller tuning; Stability analysis; Process identification.

UNIT – 2 **[6 L]**

SYSTEMS WITH COMPLEX DYNAMICS

Inverse response systems; Design of inverse response compensator; Time delay systems; Smith predictor method.

UNIT – 3 **[6 L]**

ADVANCED CONTROL TECHNIQUES

Special Control Techniques: Advanced control techniques- cascade, ratio, feed forward, adaptive control, Smith predictor, internal model control, model predictive control.

UNIT – 4 **[6 L]**

MULTILOOP & MULTIVARIABLE SYSTEMS

Control degrees of freedom analysis; Multivariable Control Analysis: Introduction to state-space methods; Controller design for multiloop & multivariable systems; Interaction and pairing of control loops; Bristol arrays; Niederlinski index; Decoupling; Tuning of multivariable controllers.

UNIT – 5 **[6 L]**

DIGITAL CONTROLLERS

Control of complex processes; Digital computer control; Sampling & filtering of continuous measurements; Discrete time models; Dynamic response of discrete time systems; Introduction to PLC and DCS.

TEXTBOOK/REFERENCE BOOK(S)

1. Dale E Seborg, Thomas F. Edgar and Duncan A. Mellichamp, Process Dynamics and Control, Wiley India, New Delhi, 3rd edition, 2013.
2. Cecil L. Smith, Advanced Process Control: Beyond Single Loop Control, Wiley, 2010.
3. CR Coughanowr and LM Koppel, Process System Analysis and Control, McGraw Hill, 2013.B. I. Bhatt, "Stoichiometry", 5th Edn., Tata McGraw Hill Publishers Ltd., New Delhi, 2010.
4. W.L.Luyben,"Process modeling, simulation and control for chemical Engineers" McGraw Hill,1973.
5. B.W. Bequette, 'Process Control: Modeling, Design and Simulation', PHI, 2006.

BTech with Research

BTech (Chemical Engineering) Research List of Courses in Research Basket								
S.No.	**Semesters in which you can choose the subject**	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	Odd Semester (7^{th} Sem)	Advanced Chemical Engineering Thermodynamics	CHR	3	1	0	4	4
2	Odd Semester (7^{Th} Sem)	Chemical Reactor Analysis and Design	CHR	3	1	0	4	4
3	Even Semester (6^{th} Sem)	Experimental Data and Statistical Analysis	CHR	3	1	0	4	4
4	Even Semester (6^{th} Sem)	Elective Pool	CHR	3	1	0	4	4
	Total						**16**	**16**

List of Courses in Elective Pool (Research)								
S.No.	**Semester in which to choose the subject**	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	Even Semester(6^{th})	Research Methodology	RS	3	1	0	4	4
2	Even Semester(6^{th})	Process Intensification	RS	3	1	0	4	4
3	Even Semester(6^{th})	Bioprocess and Biosystems Engineering	RS	3	1	0	4	4
4	Even Semester(6^{th})	Colloidal Science and Engineering	RS	3	1	0	4	4
5	Even Semester(6^{th})	Multiphase Flow and Heat Transfer	RS	3	1	0	4	4
6	Even Semester(6^{th})	Characterization of Materials	RS	3	1	0	4	4
7	Even Semester(6^{th})	Novel Separation Processes	RS					

COURSE CODE	CHNXXXX
COURSE NAME	CHEMICAL REACTOR ANALYSIS AND DESIGN
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

The objective is to enable understanding of design of industrially important reactors both for homogeneous and heterogeneous chemical reactions on a commercial scale.

COURSE CONTENT:

Unit I: **[6 L]**

Introduction to Chemical Reaction Engineering: chemical reactions, reaction order, molecularity, conversion, rate law and stoichiometry, elementary and non- elementary reactions, reaction rate constant, chemical equilibrium. Design of Isothermal Reactors: batch reactor, continuous stirred tank reactor (CSTR), plug-flow tubular reactor (PFTR), semi-batch reactor and recycle reactors.

Unit II: **[7 L]**

Design of Non-isothermal Reactor: energy balance, reactors heat generation and removal, non-isothermal continuous flow reactor, energy balance in a CSTR and PFTR, adiabatic reactors, trajectories and phase-plane plots, trajectories of wall-cooled reactors.

Unit III: **[10 L]**

Catalyst & Catalysis: catalytic reactions, reaction rates, rate equation for surface kinetics, porous catalysts, pore diffusion, and temperature dependence of catalytic reaction rates. Design of packed bed reactor for catalytic reactions.

Unit IV: **[10 L]**

Multiphase Reactors: introduction, types, and mass balance equations for multiphase reactors, interfacial surface area, mass transfer between phases, equilibrium between phases, membrane reactors, falling film reactor, bubble column reactors, trickle bed reactor, slurry reactor.

Unit V: **[7 L]**

Models for Non-ideal Reactors: basics of non-ideal flow, residence time distribution (RTD) in ideal reactors; residence time distribution (RTD) in non-ideal reactors, Tanks-in-Series (T-I-S) model, Dispersion model,reaction and dispersion, Tanks-in-Series model versus Dispersion model.

TEXT BOOKS / REFERENCE BOOKS

1. Octave Levenspiel, "Chemical Reaction Engineering", 3 rd ed., (An Indian Adaptation) Wiley India Pvt. Ltd 2021.
2. H. Scott Fogler, “Elements of Chemical Reaction Engineering”, 5 th ed, PHI, 2016.
3. M. Davis and R. Davis, “Fundamental of Chemical Reaction Engineering”, McCraw Hill, New York.
4. J.M. Smith, "Chemical Engineering Kinetics",3 rd ed, McCraw Hill, New York, 2014.
5. Lanny D. Schmidt, “The engineering of chemical reactions” 2 nd ed., Oxford University Press, New York, 2007.

COURSE CODE	CHN XXXX
COURSE NAME	Process Intensification
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

- To understand the scientific background, techniques and applications of intensification in the
- To provide the knowledge leading compact, safe, energy-efficient and environment-friendly novel equipments and processes.

COURSE CONTENT

UNIT– 1 **[4 L]**

INTRODUCTION TO PROCESS INTENSIFICATION

Need of process intensification; Process intensifying equipments and methods; Examples of their application on the commercial scale.

UNIT – 2 **[6 L]**

PROCESS INTENSIFICATION FOR ENHANCED MISING AND HEAT EXCHANGE

Mixing in stirred tanks; Scale up of mixing; High gravity fields; Micro-channel heat exchangers; Phase-change heat transfer.

UNIT – 3 **[8 L]**

PROCESS INTENSIFICATION IN REACTORS

Monolithic catalyst and reactors; Higee reactor; Spinning disc reactors; Reverse flow reactor; Micro-reactors; Membrane reactors/bioreactors.

UNIT – 4 **[6 L]**

PROCESS INTENSIFICATION SEPATATING COLUMNS

Reactive- distillation, extraction, adsorption, absorption, fermentation-pervaporation; adsorptive distillation; Hybrid columns.

UNIT – 5 **[6 L]**

PROCESS INTENSIFICATION IN OTHER OPERATIONS

Energy based intensifications; Sonochemical intensifications; Microwave assisted intensifications.

TEXTBOOK/REFERENCE BOOK(S)

1. Stankiewicz, A.; Moulijn, J.A. “Re-engineering the chemical processing plant: process intensification” Marcel Dekker, Inc., New York, 2004.
2. 2. Mizrahi, J. “Developing an industrial chemical process: an integrated approach” CRC Press, 2002.
3. Keil ,F. J.“Modeling of Process Intensification” Wiley-VCH Verlag Germany, 2007.
4. Reay, D.;Ramshaw,C.; Harvey, A.Process Intensification, Elsvier, 2013.
5. Boodhoo, K.; Harvey, A. Process Intensification for Green Chemistry, Wiley, 2013.

COURSE CODE	CEL XXXX
COURSE NAME	Bioprocess And Biosystems Engineering
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

- To introduce the engineering principles of bioprocesses including microbial kinetics, sterilization principles and design considerations.

COURSE CONTENT

UNIT– 1 **[6 L]**

Media Preparation, Media design and optimization. Microbial growth patterns and kinetics in batch culture, Microbial growth parameters, Environmental conditions affecting growth kinetics, Kinetics of thermal death of microorganisms, Heat Generation by microbial growth, Quantitative analysis of microbial growth by direct & indirect methods.

UNIT – 2 **[11 L]**

Sterilization: concept and methods. Type of Sterilizations, Batch heat sterilization of liquids, Estimation of sterilizer efficiency, Continuous heat sterilization of liquids, Sterilization of air: Methods & Mechanism, Design of depth filter and estimation of its efficiency. Stoichiometric calculations, Theoretical prediction of yield coefficients, Stoichiometry of growth and product formation, Maximum possible yield, Theoretical oxygen demand, Stoichiometry of single-cell protein synthesis.

UNIT – 3 **[8 L]**

Ideal Reactor Operation: Batch, Fed Batch & Continuous operation of mixed bioreactors, Microbial pellet formation, Kinetics and dynamics of pellet formation. Chemostate with immobilized cells, Chemostate with cell recycle, substrate utilization and product formation in bioreactor, Scale up of Bioreactors.

UNIT – 4 **[8 L]**

Role of diffusion in Bioprocessing, Convective mass transfer, Gas-liquid mass transfer, Oxygen uptake in cell cultures, Factor affecting cellular oxygen demand, Oxygen transfer in bioreactors, Measurement of volumetric oxygen transfer coefficient, Oxygen transfer in large bioreactor.

UNIT – 5 **[7 L]**

Bioreactor control mechanism, Physical, Chemical and Biological environment of bioreactor, Manual control system, Role of physical, chemical & biological sensors, Advanced control strategies viz. PID controllers, Fuzzy logic based controllers and artificial neural network based Controllers. Basic concepts of computer modeling and optimization in bioprocess applications.

REFERENCE BOOKS

1. Biochemical Engineering Fundamentals, by J.E. Bailey and D.F. Ollis, McGraw-Hill Book Co., New York.

2. Bioprocess Engineering principles, P.M. Doran, 5th ed.

3. Bioprocess Engineering: Basic Concepts, Shular & Kargi.

4. Principles of fermentation technology, P F Stanbury and A Whitaker, Pergamon press.

COURSE CODE	CHN XXXX
COURSE NAME	Colloidal Science and Engineering
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

This course is aimed at introducing the basic concepts and tools for the analysis of colloidal and interfacial properties and their applications in adhesion, particle-aggregation, wetting, detergency, oilrecovery, flotation, nucleation, bio-surfaces, chromatography, paints, composite materials.

COURSE CONTENT

UNIT – 1 **[10L]**

Introduction, Surface Tension, Adhesion and Capillarity:
Effects of confinement and finite size, Concepts of surface and interfacial energies and tensions, Apolar (van der Waals) and polar (acid-base) components of interfacial tensions, Young-Laplace equation of capillarity; examples of equilibrium surfaces, multiplicity, etc. Stability of equilibrium solutions, Contact angle and Young's equation, Determination of apolar (van der Waals) and acid-base components of surface/interfacial tensions, Free energies of adhesion, Kinetics of capillary and confined flows.

UNIT – 2 **[10 L]**

Intermolecular, nanoscale and interfacial forces**:**
Van der Waals, Electrostatic double layer, Acid-base interactions including hydrophobic attraction and hydration pressure.

UNIT – 3 **[8 L]**

Mesoscale Thermodynamics, Mesoscale Phenomena in Soft Matter and Applications: Gibbs treatment of interfaces, concept of excess concentration; variation of interfacial tensions with surfactant concentration, adhesion, wetting, nucleation, flotation, patterning of soft material by self - organization and other techniques.

UNIT – 4 **[8 L]**

Stability of Nanoparticle Dispersions, Nanofluidics:
DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in a potential field/Brownian movement, stability of thin (< 100 nm) films, self-organization in confined systems, meso-patterning.

UNIT – 5 **[4 L]**

Advanced and Functional Interfaces:
Superhydrophobicity, functional coatings, structural colors, nano-adhesives, nanocomposites.

TEXTBOOK/REFERENCE BOOK(S)

1. Hiemenz, Paul C. "Principles of Colloid and Surface Chemistry", Marcel Dekker, any edition starting with the 2nd edition, 1986.
2. Adamson, Arthur W. Physical Chemistry of Surfaces" Wiley, 5th edition, 1990.

3. Hunter, Robert J. "Foundations of Colloid Science", Clarendon, Oxford, Volume 1, 1989.

4. Russel, W. B., Saville, D. A. and Schowalter, W. R. "Colloidal Dispersions", Cambridge University Press, 1989.

5. Israelachvili, Jacob N." Intermolecular and Surface Forces", Academic Press, 1992 or later editions.

6. Oss, C. J. Van "Interfacial Forces in Aqueous Media", Marcel Dekker or Taylor & Francis, 1994.

COURSE CODE	CHN XXXX
COURSE NAME	Novel Separation processes
NUMBER OF CREDITS	4
(L: T: P)	3: 1: 0

COURSE LEARNING OBJECTIVES: -

- To understand the principles, modelling and design concepts of novel separation techniques and their applications.
- Perform the process and design calculations for the solution of specific problems.

COURSE CONTENT

UNIT-1 **[14L]**

MEMBRANE SEPARATION PROCESSES: Preparation, characterization, types and choice of membranes, Membrane modules, Design of membrane process: reverse osmosis, ultrafiltration, microfiltration, nanofiltration, dialysis, gas separation and pervaporation, Membrane reactors.

UNIT-2 **[8L]**

ADSORPTIVE SEPARATION: Review of fundamentals, Nature of Adsorbents, adsorption equilibrium, Kinetic effects, Pressure and temperature swing regeneration of spent adsorbents, Adsorption equipments.

UNIT-3 **[4L]**

CHROMATOGRAPHIC SEPARATION: Fundamentals, Chromatographic techniques, Development of gradient-elution separations, Retention theory, Types of chromatography, Equipment and commercial processes.

UNIT-4: **[6L]**

IONIC SEPARATIONS: Ion exchange: Ion exchange resins, Ion exchange equilibrium, Ion movement theory, Electrodialysis, Electrophoresis, Commercial applications.

UNIT-5: **[8L]**

OTHER TECHNIQUES: Liquid membrane permeation, Surfactant based separation: micellar separations, Supercritical fluid extraction.

TEXT BOOKS / REFERENCE BOOKS:

1. Marcel Mulder, “Basic Principles of Membrane Technology”,2 Ed., Springer Publications, 2007
2. Kaushik Nath,”Membrane Separation Processes”, PHI Learning Pvt. Ltd., New Delhi, India, 2008
3. Reverse Osmosis and Ultra Filtration ProcessPrinciple, Sourirajan, S. &Matsura, T.,NRC Publication, Ottawa, 1985.
4. R.W. Rousseau, “Handbook of separation Process Technology”, Wiley-India.
5. J.M. Coulson, J.F. Richardson, "Chemical Engineering", Vol.-2, Butterworth - Heinemann London
6. C.J. King, Separation Processes, Tata McGraw Hill (1981).
7. C. Loeb, R. E. Lacey, "Industrial Processing with Membranes", Wiley Inter Science.
8. T. A. Hatton, J. F. Scamehorn, J. H., Harvell, “Surfactant Based Separation Processes”, Vol. 23, Surfactant Science Series, Marcel Dekker Inc., New York *1989.*
9. McHugh, M. A. &Krukonis, V. J., Supercritical Fluid Extraction, Butterworth,1985

MINOR: Energy Engineering and Sustainability

MINOR: Energy Engineering and Sustainability [For B. Tech. Students of Other Branches]								
S.No.	**Semester in which the subject can be chosen**	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Contact Hours**
1	3rd Sem	Chemical Process Principles	Compulsory	3	0	0	3	3
2	3rd or 5th Sem	Engineering Thermodynamics	Compulsory	2	1	0	3	3
3	5th Sem	Energy Resources, Economy and Sustainability	Compulsory	3	0	0	3	3
4	6th Sem	Green Hydrogen and Fuel Cells	Compulsory	3	0	0	3	3
5	7th Sem	7th Sem Elective Pool(Minor)	Elective	3	0	0	3	4
6	7th Sem	Special Study/Colloquium	Compulsory	0	0	2	2	2
	Total						**17**	**17**

COURSE CODE	CHN11101
COURSE NAME	CHEMICAL PROCESS PRINCIPLES
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:-

- To understand the fundamental knowledge in units and conversions and also the basic laws governing chemical operations.
- To impart knowledgeable on material and energy balance with and without reactions.

COURSE CONTENT

UNIT-1 **[5 L]**

Stoichiometry: Introduction - Units and Dimensions - Stoichiometric principles –composition relations, density, and specific gravity.

UNIT-2 **[5L]**

Ideal Gases and Vapor Pressure: Behaviour of Ideal gases - kinetic theory of gases - application of ideal gas law - gaseous mixtures - volume changes with change in composition. Vapour pressure-effect of temperature on vapour pressure - vapour pressure plots - vapour pressure of immiscible liquids - solutions.

UNIT-3 **[6L]**

Humidity and Solubility: Humidity - saturation - vaporization - condensation - wet and dry bulb thermometry Solubility and Crystallisation - Dissolution - solubility of gases.

UNIT-4 **[8 L]**

Material Balance: Material Balance - Processes involving chemical reaction - Combustion of coal, fuel gases, and sulphur - Recycling operations - bypassing streams - Degree of conversion – excess reactant - limiting reactant. Unsteady state problems.

UNIT-5 **[8 L]**

Energy Balance: Thermo chemistry - Hess's law of summation - heat of formation, reaction, combustion, and mixing - mean specific heat - Theoretical flame Temperature.

TEXT BOOKS / REFERENCE BOOKS:

1. Richard M. Felder, Ronald W. Rousseau, Lisa G. Bullard, “Elementary Principles of Chemical Processes”, 4th edition, wiley, 2016.
2. O. A .Hougen, K. M. Watson and R. A. Ragatz, “Chemical Process Principles", Vol-I, CBS Publishers and Distributors, New Delhi, 1995.
3. V.Venkataramani, N.Anantharaman and K.M. Meera Sheriffa Begum, 2nd Edn., ’Process Calculations’ Prentice Hall of India Ltd, New Delhi. 2013
4. B. I. Bhatt, "Stoichiometry", 5th Edn., Tata McGraw Hill Publishers Ltd., New Delhi, 2010.
5. Himmelblau, “Basic Principles and Calculations in Chemical Engineering", 8th Edn., Prentice Hall of India Ltd, India 2012.

COURSE CODE	CHN11102
COURSE NAME	Engineering Thermodynamics
NUMBER OF CREDITS	3
(L: T: P)	2: 1: 0

COURSE LEARNING OBJECTIVES:-

- To understand the fundamental knowledge in units and conversions and also the basic laws governing chemical operations.
- To impart knowledgeable on material and energy balance with and without reactions.

COURSE CONTENT

UNIT – 1 **[4L]**

Introduction to thermodynamics System, surroundings, boundaries, classification of systems. Unit and dimensions, conversion factors. Properties of systems, equilibrium, processes, heat and work interaction. The work interaction. Thermodynamic definition of work. characteristics of the work interaction. Evaluation of work. Adiabatic systems and processes.

UNIT – 2 **[6L]**

Diathermic boundary, Zeroth law. Isothermal states. Empirical temperature. Principles of thermometry. Scales of temperature. Gas thermometer. The ideal gas. Ideal gas temperature scale. The first law. Basic form. Energy of a system. The heat interaction. Sign convention. First law for open systems. Steady-flow energy equation and its applications.

UNIT – 3 **[8L]**

Equations of state. Properties of gases. Properties of steam. Introduction to steam tables. Other equations of state. Vander Waals gas. Critical state. Reduced equation of state. The second law. Kelvin-Planck and Clausius statements. Equivalence of statements. Carnot theorem. Thermodynamic temperature. Kelvin scale. Carnot engine, refrigerator and heat pump.

UNIT – 4 **[6L]**

Clausius in equality. Definition of entropy. Combined first and second law, Evaluation of entropy. Principle of increase of entropy. Irreversibility and energy. Exergy concepts and Lost work.

UNIT – 5 **[6L]**

Introduction to cycles. Classifications of cycles. Gas power cycles- Otto, Diesel, Brayton, Vapour power cycle- Rankine cycle, vapour- compression refrigeration cycle.

TEXT BOOKS / REFERENCE BOOKS

1. P. K Nag; Engineering Thermodynamics; Tata McGraw Hill Education Pvt. Ltd.; New Delhi.4th Ed.; 2008.
2. E. Radhakrishna; Fundamentals of Engineering Thermodynamics; Prentice Hall of India Pvt. Ltd., New Delhi, 2nd Ed.; 2011.
3. G. Rogers, Y. Mayhew; Engineering Thermodynamics-Work and Heat Transfer; Pearson Education Ltd., 7th Ed.; 2012.
4. Y. A. Cengel, M. A. Boles; Thermodynamics – An Engineering Approach; Tata McGraw Hill Education Pvt. Ltd. New Delhi.4th Ed; 2012.

COURSE CODE	CEL XXXX
COURSE NAME	Energy Resources, Economics and Sustainability
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES: To provide the basic knowledge about energy systems and resources along with economic and sustainability principles.

COURSE CONTENT

UNIT-1 **[5L]**

Overview of World energy scenario, primary energy demand and supply, fossil fuel reserves - estimates, overview of India's energy scenario and its comparison with other countries, trends in energy use patterns, energy and development linkage, formulation of energy Sankey diagrams,

UNIT-2 **[5L]**

Energy chain, primary energy analysis, net energy analysis examples

UNIT-3 **[8L]**

Energy economics - simple payback period, time value of money, internal rate of return, net present value, life cycle costing, levelized cost of energy, Project cost and benefits, economic and financial models, cost of saved energy.

UNIT-4 **[7L]**

Environmental impacts of energy use - air pollution, particulates solid and water pollution, formation of pollutants, measurement and controls; sources of emissions, effect of operating and design parameters on emission.

UNIT -5 **[8L]**

Introduction to Life cycle assessment (LCA) and its relation with environmental decision support, LCA framework methods and standards, LCA: mass flow, data estimation, multi functionality, Input-Output methods, impact categories, mid-point and end-point indicators, interpretation: consistency and sensitivity.

UNIT-6 **[5L]**

Future energy scenarios and elements of sustainability.

TEXT BOOKS / REFERENCE BOOKS:

1. Energy and the Challenge of Sustainability, World energy assessment, Denim Anderson, UK, Michael Jefferson, UK, John P. Holdren, US, UNDP New York - 2000
2. Sustainable Energy - without the hot air, David JC MacKay, UIT Cambridge, England, version 3.5.2, November 03, 2008
3. Life Cycle Assessment Handbook: A Guide for Environmentally Sustainable Products, Mary Ann Curran, Wiley - 2012
4. Introduction to Energy Economics, Subhes C. Bhattacharyya, Springer London Dordrecht Heidelberg, New York 2011
5. The Age of Sustainable Development, Jeffrey D. Sachs, Ki-moon Ban, Columbia University Press 2015

COURSE CODE	CEL XXXX
COURSE NAME	Green Hydrogen Energy and Fuel Cells
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

To impart knowledge on use of hydrogen for achieving sustainable growth and facilitate analysis of the challenges in transition to hydrogen economy in Fuel Cells.

COURSE CONTENT

UNIT-1 **[10L]**

HYDROGEN ENERGY: Introduction to hydrogen economy, production, storage and transportation systems, hydrogen from fossil fuels, electrolysis of water, thermo chemical cycles, transmission and infrastructure requirements, safety and environmental impacts, economics of transition to hydrogen systems.

UNIT-2 **[10 L]**

FUEL CELLS: Concept, key components, physical and chemical phenomena in fuel cells, advantages and disadvantages, different types of fuel cells and applications, characteristics, Nernst equation, relation of the fuel consumption versus current output.

UNIT-3 **[10L]**

FUEL CELL DESIGN AND PERFORMANCE: Stoichiometric coefficients and utilization percentages of fuels and oxygen, mass flow rate calculation for fuel and oxygen in single cell and fuel cell stack, total voltage and current for fuel cells in parallel and serial connection, over-potential and polarizations, DMFC operation scheme, general issues-water flooding and water management, polarization in PEMFC.

UNIT-4 **[8 L]**

FUEL CELLS -APPLICATION AND ECONOMICS: Fuel cell usage for domestic power systems, large scale power generation, automobile, space applications, economic and environmental analysis on usage of fuel cell, future trends of fuel cells.

TEXT BOOKS / REFERENCE BOOKS:

1. Hydrogen Fuel Production, Transport and Storage Edited by Ram B Gupta published July 30, 2008 by CRC Press , ISBN 9781420045758 - CAT# 4575X.
2. Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz, "Fuel Cell Fundamentals", (3rd edition), Wiley, 2016.
3. Supramaniam Srinivasan, "Fuel Cells: From Fundamentals to Applications", 1st Edition, Springer 2006.
4. Allen J. Bard, Larry R. Faulkner, "Electrochemical Methods: Fundamentals and Applications", 2nd Edition, Wiley 2000.
5. Viswanathan B and Aulice Scibioh, Fuel cells: Principles and Applications, University Press, 2006.
6. William H. Shaw, III , Review of: Peter Hoffman, Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet, 13 RISK 185 (2002).

COURSE CODE	XXXXX
COURSE NAME	Solar Photovoltaic Energy Systems
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To get acquainted with the role of solar energy in sustainable environment
- Basics of solar electrical energy systems
- To learn about solar radiation, PV cells and modules
- To learn about stand-alone PV schemes with battery energy storage and grid-connected PV schemes

COURSE CONTENT

UNIT-1

Fossil fuel energy usage and global warming; role of renewable energy in sustainable development; renewable energy sources; global potential for solar electrical energy systems.

UNIT-2

Solar radiation: Extra-terrestrial and terrestrial solar spectrum; clear sky direct-beam radiation; total clear sky insulation on a collecting surface; radiation on the collector in tracking systems; calculation of average monthly insolation from measured data.

UNIT-3

PV cells and modules: Photovoltaic cell and its simple model; PV modules and arrays; effect of shading, use of bypass and blocking diodes; influence of temperature; types of solar cells and their performance; schemes for maximum power point tracking; solar PV concentrators

UNIT -4

PV inverters: Grid-connected single phase PV inverter schemes and control; power processing schemes based on single string, multi-string and ac module technologies; types of grid interface; power electronic converters used in single phase PV systems and their operation; transformer less inverters, centralized grid-connected three-phase inverters for large PV installations.

UNIT-5

Schemes with battery energy storage: Power processing schemes and control for stand-alone applications; batteries for energy storage– types, charging, battery sizing and turn-around efficiency; other types of energy storage for PV systems; grid connected schemes with standby energy storage.

TEXT BOOKS / REFERENCE BOOKS:

4. C. S. Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications", PHI Learning Pvt Ltd, 2009.
5. R. A. Messenger, J. Ventre,"Photovoltaic Systems Engineering", CRC Press, 2004.
6. G. M. Masters, "Renewable and Efficient Electric Power Systems", John Wiley & Sons, 2004.

COURSE CODE	EEXXXX
COURSE TITLE	Bioenergy Engineering
PREREQUISITE	Engineering Thermodynamics, Heat and Mass Transfer.
NUMBER OF CREDITS	3
L: T: P	3: 0: 0

COURSE LEARNING OBJECTIVES:

The course focuses on bioenergy and in particular on the exploitation of biomass for energy recovery. Moreover, this course encompasses thermochemical energy processes (combustion, gasification and pyrolysis) and chemical processes (oil extraction and trans-esterification), finally biochemical processes (fermentation and anaerobic digestion).

COURSE CONTENT

UNIT – 1 :- **[6 L]**

Biomass sources, characteristics & preparation, chemical composition and properties of different biomass materials, energy plantations, pre-treatment techniques for the utilization of biomass, size reduction, briquetting of loose biomass, drying, storage and handling of biomass.

UNIT – 2 :- **[5 L]**

Combustion of biomass and cogeneration systems, theory, calculations and design of equipment, cogeneration in biomass processing industries. Case studies: combustion of rice husk, use of bagasse for cogeneration.

UNIT – 3 :- **[8 L]**

Pyrolysis and gasification of biomass, thermo-chemical conversion of ligno-cellulose biomass, biomass processing for liquid fuel production, pyrolysis of biomass, pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles, effect of pressure, temperature and of introducing steam and oxygen, design and operation of fixed and fluidized bed gasifiers.

UNIT – 4 :- **[5 L]**

Bio-ethanol and bio-diesel technology: production of fuel ethanol by fermentation of sugars, gasohol as a substitute for leaded petrol, trans-esterification of oils to produce bio-diesel.

UNIT – 5:- **[6 L]**

Biogas technology, feedstock for biogas production, aqueous wastes containing biodegradable organic matter, animal residues, microbial and biochemical aspects, operating parameters for biogas production. Digesters for rural application, high-rate digesters for industrial waste water treatment.

TEXTBOOK/REFERENCE BOOK(S)

5. Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes, A. Chakraverthy.
6. Biogas Systems: Principles and Applications, K.M. Mital.
7. Fuels from Biomass and Wastes, D.L. Klass, G.M. Emert

COURSE CODE	XXXXX
COURSE NAME	Biorefinery engineering
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- To know about different biomass sources and their properties.
- To study about different techniques for bio products formation.

COURSE CONTENT

UNIT-1

Biomass sources, characteristics, preparation, chemical composition and properties of different biomass materials. Energy plantations, pretreatment techniques for the utilization of biomass, size reduction, briquetting of loose biomass, drying, storage and handling of biomass.

UNIT-2

Biogas technology, feedstock for biogas production, aqueous wastes containing biodegradable organic matter, animal residues, microbial and biochemical aspects, and operating parameters for biogas production. Kinetics and mechanism, dry and wet fermentation, digesters for rural application, and high rate digesters for industrial waste water treatment.

UNIT-3

Bio-ethanol and bio-diesel technology: production of fuel ethanol by fermentation of sugars, gasohol as a substitute for leaded petrol, trans-esterification of oils to produce bio-diesel.

UNIT -4

Pyrolysis and gasification of biomass, thermo-chemical conversion of ligno-cellulose biomass, biomass processing for liquid fuel production, pyrolysis of biomass, pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles, effect of pressure, temperature and of introducing steam and oxygen. Design and operation of fixed and fluidized bed gasifiers.

UNIT-5

Combustion of biomass and cogeneration systems, theory, calculations and design of equipments, cogeneration in biomass processing industries. Case studies: combustion of rice husk, use of bagasse for cogeneration.

TEXT BOOKS / REFERENCE BOOKS:

4. A. Chakraverthy, "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing 1989.
5. K.M. Mital, "Biogas Systems: Principles and Applications", New Age International Publishers Pvt. Ltd., 1996.
6. D.L. Klass, G.M. Emert, "Fuels from Biomass and Wastes", Ann Arbor Science Publication, 1985.

COURSE CODE	XXXXX
COURSE NAME	Biomass Conversion Technologies
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES:

- Understanding of fundamental information about various bio-resources
- Understanding of energy valorization from bio-resources through thermochemical conversion processes
- Understating of bioethanol and biogas production through biochemical conversion processes
- To analyze opportunities and challenges associated with thermochemical and biochemical conversion processes for specific feedstocks

COURSE CONTENT

UNIT-1

Biomass sources, chemical composition and physical properties of different biomass materials, dedicated energy plantations, pretreatment techniques for the utilization of biomass, size reduction, briquetting of loose biomass, drying, storage and handling of biomass.

UNIT-2

Pyrolysis and gasification of biomass, thermo-chemical conversion of ligno-cellulose biomass, biomass processing for liquid fuel production, pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles, effect of pressure, temperature and of introducing steam and oxygen, design and operation of fixed and fluidized bed gasifiers.

UNIT-3

Combustion of biomass and cogeneration systems, theory, calculations and design of equipments, cogeneration in biomass processing industries, logistics involved. Case studies: combustion of rice husk, use of bagasse for cogeneration.

UNIT -4

Bio-ethanol and bio-diesel technology: production of fuel ethanol by fermentation of sugars, gasohol as a substitute for leaded petrol, trans-esterification of oils to produce bio-diesel. Concept of bio-refinery.

UNIT-5

Biogas technology, feedstock for biogas production, aqueous wastes containing biodegradable organic matter, animal residues, microbial and biochemical aspects, operating parameters for biogas production. Kinetics and mechanism, dry and wet fermentation, digesters for rural application, high rate digesters for industrial waste water treatment.

TEXT BOOKS / REFERENCE BOOKS:

6. A. Dahiya, "Bioenergy: Biomass to Biofuels", Academic Press, 2014.
7. A. Chakraverthy, "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing, 1989.
8. D.L. Klass, G.M. Emert, "Fuels from Biomass and Wastes", Ann Arbor Science Publication, 1985.

9. K.M. Mital, “Biogas Systems: Principles and Applications”, New Age International Publishers Pvt. Ltd., 1996.
10. P. Lund, J. A. Byrne, G. Berndes, I. Vasalos, “Advances in Bioenergy: The Sustainability Challenge”, Wiley, 2015.

COURSE CODE	XXXXX
COURSE NAME	Green Processes and Product Design
NUMBER OF CREDITS	3
(L: T: P)	3: 0: 0

COURSE LEARNING OBJECTIVES: -

To impart fundamental knowledge about various unit systems for chemical process calculations and to give insight of material and energy balances in various unit operations and processes.

COURSE CONTENT

Unit I:

Introduction: Introduction, Definition and Principles of Green Processes and Chemistry, Challenges to the sustainability of chemical industry, toxicity of chemicals, material safety data sheet (MSDS), concept of zero pollution technologies, atom economy, functional toxicity vs non-functional toxicity, alternative solvents, energy minimization, microwave and sonochemical reactions, renewable feed stock

Unit II:

Product Design : Product Design Principles, Understanding customer needs, consumer products, Converting needs to specification, Ideas, Selection using thermodynamics and kinetics, product manufacture, case studies on bioplastic, biopolymers. Unit III:

Green Synthesis: Bio Catalytic Reactions , Green Chemistry Using Bio Catalytic Reactions , Introduction - Fermentation and Bio transformations - Production of Bulk and fine chemicals by microbial fermentation, Case Studies.

Unit IV:

Biorefinery and Agro Chemicals Design : Introduction too Bio refinery, Bio refinery chemicals from fatty acids-Polymer from Renewable Resources –Biodiesel from various feed stocks, Agrochemicals – Introduction, Biocides: types and applications, Organic Insecticides, Fungicide, Case Studies.

REFERENCE BOOKS

1. Cussler and Moggridge .Chemical Product Design. Cambridge University Press, Ist Edition, 2001.

2. Anastas & Warner. Green Chemistry: Theory & Practice ,Oxford Univ. Press, New York,1998

COURSE CODE	XXXXX
COURSE NAME	Special Study/Colloquium
NUMBER OF CREDITS	2
(L: T: P)	0: 0: 2
COURSE LEARNING OBJECTIVES:	
COURSE CONTENT	
TEXT BOOKS / REFERENCE BOOKS:	