DEPARTMENT OF CHEMICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY (INDIAN SCHOOL OF MINES), DHANBAD

COURSE STRUCTURE & SYLLABUS

FOR

B.TECH

IN

CHEMICAL ENGINEERING

Effective from 2019-2020

COURSE STRUCTURE
B.Tech in Chemical Engineering

SEMESTER: 3

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DC1	CHC201	Chemical Process Calculations	3	0	0	9
DC2	CHC202	Fluid and Particle Mechanics	3	1	0	11
DC3	CHC203	Heat Transfer	3	1	0	11
E/SO1	CHE201	Engineering Thermodynamics	3	0	0	9
E/SO2	E/SO2		3	0	0	9
DP1	CHC204	Computational Tools for Chemical Engineers Lab	0	0	2	2
DP2	CHC205	Fluid and Particle Mechanics Lab	0	0	2	2
					Total	**53**
Contact Hrs.			**15**	**2**	**4**	**21**

SEMESTER: 4

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
E/SO3	CHE202	Transport Phenomena	3	0	0	9
DC4	CHC206	Chemical Engineering Thermodynamics	3	0	0	9
DC5	CHC207	Principles of Mass Transfer	3	1	0	11
DC6	CHC208	Chemical Process Technology	3	0	0	9
DC7	CHC209	Process Dynamics and Control	3	0	0	9
DP3	CHC210	Heat Transfer Lab	0	0	2	2
DP4	CHC211	Process Control Lab	0	0	3	3
					Total	**52**
Contact Hrs.			**15**	**1**	**5**	**21**

SEMESTER: 5

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DC8	CHC301	Separation Processes	3	0	0	9
DC9	CHC302	Chemical Kinetics and Reaction Engineering	3	1	0	11
DC10	CHC303	Process Design and Economics	3	0	0	9
HSS1/ MS1	HSS1		3	0	0	9
E/SO4	E/SO4		3	0	0	9
DP5	CHC304	Chemical Kinetics and Reaction Engineering Lab	0	0	3	3
DP6	CHC305	Mass Transfer Lab	0	0	3	3
		Total				**53**
Contact Hrs.			**15**	**1**	**6**	**22**

SEMESTER: 6

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DC11	CHC306	Chemical Process Equipment Design	3	0	0	9
DC12	CHC307	Process Modelling and Simulation	3	0	0	9
MS2/ HSS2	MS1		3	0	0	9
OE2	OE2		3	0	0	9
OE3	OE3		3	0	0	9
DP7	CHC308	Chemical Process Equipment Design Lab	0	0	3	3
DP8	CHC309	Process Simulation Lab	0	0	2	2
		Total				**50**
Contact Hrs.			**15**	**0**	**5**	**20**

SEMESTER: 7

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DE1	CHD4**	To be taken from basket I	3	0	0	9
DE2	CHD4**	To be taken from basket II	3	0	0	9
OE4	OE4		3	0	0	9
OE5	OE5		3	0	0	9
OE6	OE6		3	0	0	9
DC13	CHS401	UGP-1	0	0	6	6
DC14	CHS402	Internship/Vocational Training	0	0	0	S/X
		Total				**51**
Contact Hrs.			**15**	**0**	**6**	**21**

SEMESTER: 8

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DE3	CHD4**	To be taken from basket I	3	0	0	9
DE4	CHD4**	To be taken from basket II	3	0	0	9
OE7	OE7		3	0	0	9
HSS/OE	HSS/OE		3	0	0	9
DC15	CHS403	UGP-2	0	0	6	6
		Total				**42**
Contact Hrs.			**12**	**0**	**6**	**18**

LIST OF DEPARTMENTAL ELECTIVES (DE)

PROPOSED DEPARTMENTAL ELECTIVE (DE)				
Course No.	**Name (Basket I)**		**Course No.**	**Name (Basket II)**
CHD401	Petrochemical Technology		CHD411	Catalytic Reaction Engineering
CHD402	Polymers Science and Engineering		CHD412	Process Optimization
CHD403	Food Processing Technology		CHD413	Advanced Separation Processes
CHD404	Bioprocess Technology		CHD414	Computational Fluid Dynamics
CHD405	Energy Technology		CHD415	Interfacial Phenomena and Microfluidics
CHD406	Nanotechnology		CHD416	Fluidization Engineering
CHD407	Materials Characterization		CHD417	Membrane Science and Engineering
CHD408	Process Data Analytics		CHD418	Electrochemical Science and Engineering

*Department Electives DE1& DE3 will be taken from Elective Basket I and DE2 & DE4 will be taken from Elective Basket II

LIST OF SO/ESO COURSES (DE)

Course No.	**Name**	**Offering Semester**	**Mandatory for Departmental Students**
CHE201	Engineering Thermodynamics	Monsoon	YES
CHE202	Transport Phenomena	Winter	YES

LIST OF OPEN ELECTIVES (OE)

Course No.	**Name**
CHO301	Petroleum Refining
CHO302	Industrial Safety and Hazards Management
CHO401	Process Integration
CHO402	Biofuels and Biomass Conversion Technology

Department of Chemical Engineering, IIT (ISM) Dhanbad
Program: 4 Year B. Tech (Chemical Engineering)
(For Students Admitted in Academic Year 2019-20)

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CHC201	Chemical Process Calculations	3	1	0	11

Course Objective
This basic course aims to provide the students an introduction to the principles and calculation techniques used in the field of chemical engineering and to acquaint them with the basics of material and energy balances.
Learning Outcomes
It is expected that this course will lay the foundation of basic knowledge and calculation skills that is frequently used in subsequent chemical engineering courses as well as professional life.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction to chemical process calculations:** Unit, unit conversion dimension, dimensionless number, dimensional consistency analysis, Steady-state and dynamic processes; lumped and distributed processes, intensive and extensive variables, degrees of freedom	08	Students will know the principles and calculation techniques
2	**Behaviour of gas, liquid and solid:** Terminologies, behaviour of ideal gases and gaseous mixtures, vapour pressure, humidity and saturation, Phase equilibrium, Processes involving vaporization and condensation	08	Basic understanding of behaviour of gases, liquids and solids
3	**Material balance:** Introduction, material balances for processes without chemical reaction, material balances involving recycle, bypass and purge; application in chemical industries	08	Students will acquaint with material balance in process industries
4	**Energy balances:** Introduction to energy balances, terminologies, Steady state energy balances for the processes	08	Students will acquaint with basic energy

	without reaction, steady state energy balances for the processes with reaction		balance in chemical and allied industries
5	**Combustion calculations:** Introduction, combustion stoichiometry, combustion calculations using solid, liquid and gaseous fuels	**07**	Preliminary calculations related to combustion of various fuels, mainly fossil fuels

Textbooks:

1. Himmelblau, D. M. and Riggs, J. B. (2012). Basic Principles and Calculations in Chemical Engineering. 8th Ed., PHI, Eastern Economy Edition

Reference books:

1. Hougen, O. A., Watson, K. M. and Ragatz, R. A. (2004). Chemical process principles, 2nd Ed., John Wiley and Asia Publishing
2. Perry, R. H. and Green, D. (Ed.) (2007). Perry' Chemical Engineering Handbook, 8th Ed., McGraw Hill
3. Sinnott, R. K. (2005). Coulson & Richardson's Chemical Engineering – Vol VI, Butterworth and Heinemann

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Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CHC202	Fluid and Particle Mechanics	3	1	0	11

Course Objective
To provide knowledge on necessary fundamental concepts of fluid flow, transportation and metering of fluids, particle characterization, handling and processing of particles.
Learning Outcomes
Students will have essential knowledge on fluids, flow behaviour, boundary layer theory, pipe flows, flow measurement techniques, fluid transportation, characterization and processing techniques for particles.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
	Section A: Fluid Mechanics		

1	**Basic concepts:** Fluids and properties, fluid statics, flow phenomena, Reynolds number, shear rate, shear stress, rheological properties of fluids	**07**	Introduction to fluid and its properties
2	**Mechanism of fluid flow**: Mechanism of compressible and non-compressible fluid flow, equation of continuity, Bernoulli's theorem, velocity profiles in laminar and turbulent system, basic concept of boundary layers	**06**	Students will know basic flow behaviors and governing equation
3	**Friction factor and fittings**: Friction factor and friction losses in pipes, roughness factor and its significance, pipe fittings and valves, equivalent length of fittings and valves, energy loss calculations	**08**	Basic understanding of applications in pipe flow
4	**Transportation and metering:** Reciprocating and centrifugal pumps, pump characteristics, pump power calculations, pump selection, priming, cavitation, NPSH of pumps, fans, blowers, compressors, orifice meter, venturi meter, pitot tube, rotameters, coefficient of discharge and calculations	**08**	Students will be introduced to pumps and flow measuring instrument
	<u>Section B: Fluid Particle Mechanics</u>		
5	**Characterization and size reduction of particles:** Particle size distribution, size reduction, crushing efficiency and laws of crushing, classification and selection of size reduction equipment	**06**	Introduction to particle size and distribution and size reduction
6	**Fluid-Particle flow Systems**: Motion of solid particles in a fluid, free and hindered settling, fluid flow through a packed bed of particles, pressure drop – flow relationship, basics of fluidization, bubbling and non-bubbling fluidization, slurry transport	**07**	Students will understand dynamics of particles in fluid
7	**Mechanical Separations**: Classification, filtration, sedimentation, centrifugal and cyclone separators	**07**	Expected to know various mechanical separation methods
8	**Mixing and Agitation**: Introduction to mixing and agitation	**03**	Basic introduction to mixing and agitation

Textbooks:

1. Mc-Cabe, W.L., Smith J.M., and Harriott, P., (2004). Unit Operations in Chemical Engineering, 7th edition McGraw Hill.
2. de Nevers, N. (2012). Fluid Mechanics for Chemical Engineers,3rd Ed., Tata McGraw-Hill.

Reference books:

1. Coulson, J. M., Richardson, J. F. Backhurst, J. R. and Harker. J. H. (1999). Chemical Engineering, Fluid Flow, Heat Transfer and Mass Transfer, Volume 1, 6th Ed., Elsevier Butterworth Heinemann.
2. Richardson, J. F. Backhurst, J. R. and Harker, J. H. (1990). Chemical Engineering, Particle Technology and Separation Processes, Volume 2, 4th Ed., Elsevier Butterworth Heinemann.

3. Lapple, C. E. (2013). Fluid and Particle Mechanics, Literary Licensing, LLC.
4. Michell, S.J. (2013). Fluid and Particle Mechanics, Pergamon.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC203**	**Heat Transfer**	**3**	**1**	**0**	**11**

Course Objective
The students will learn the different mechanisms of heat transfer. The course will teach the concepts and methodology needed to develop mass and energy balances and to simplify them and obtain solutions that are applicable to real problems.
Learning Outcomes
Upon successful completion of this course, students will: • Understand the basic laws and modes of heat transfer and analyze problems involving steady state and transient heat conduction • Understand the fundamentals of convective heat transfer and evaluate heat transfer coefficients for natural and forced convection • Analyze the performance of heat exchanger and evaporator • Calculate radiation heat transfer between black body and gray body surfaces

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** Introduction to heat transfer, modes of heat transfer - conduction, convection and radiation, combined mechanisms of heat transfer	**03**	Introduction to different heat transfer mechanisms
2	**Conduction**: Basic equations of conduction, steady and unsteady state conduction in slabs, cylinders and spheres, critical thickness of insulation, lumped system of analysis	**10**	Ability to solve small real time conduction problems
3	**Convection:** Basic concept, hydrodynamic and thermal boundary layers, forced convection inside tubes, over cylinders and spheres under laminar and turbulent conditions, natural convection, heat transfer with phase change	**15**	Ability to solve small real time convection problems

4	**Radiation:** Introduction, black body and gray body radiation, shape factor, Kirchhoff's law, radiation shields, radiation from gases	07	Ability to solve small real time radiation problems
5	**Heat exchangers:** Basic types of heat exchangers, overall heat transfer coefficient, LMTD method, effectiveness-NTU method	12	Design of heat exchangers
6	**Evaporation:** Evaporator capacity, economy and types, single and multiple effect evaporators, forward and backward feed evaporation	05	Design of evaporators

Textbooks:

1. Yunus A. Cengel, Afshin J. Ghajar, (2016) Heat and Mass Transfer 5th Ed., McGraw Higher Education.
2. J. P. Holman, (2011) Heat transfer 10th Ed., McGraw Higher Education.

Reference Books:

1. Kern, D. Q. (2001) Process Heat Transfer 1st Ed., McGraw Higher Education.
2. Warren L. McCabe, Julian C. Smith, Peter Harriott, (2014). Unit Operations of Chemical Engineering 7th Ed., McGraw Higher Education.
3. Frank P. Incropera, David P. Dewitt, Theodore L. Bergman, Adrienne S. L. (2018). Principles of Heat and Mass Transfer, Wiley India Edition.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC206**	**Chemical Engineering Thermodynamics**	**3**	**0**	**0**	**9**

(Prerequisite: Engineering Thermodynamics)

Course Objective
The objective of this course is to provide a comprehensive exposition of the thermodynamic properties of fluid mixtures with application to vapor/liquid equilibrium essential to study the phase equilibrium and chemical reaction equilibrium.
Learning Outcomes
After completion of the course students are expected to know determination of the thermodynamic properties of the solution that are essential to study the phase equilibrium and chemical reaction equilibrium.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Solution Thermodynamics:** Introduction to chemical engineering thermodynamics, concept of fugacity and fugacity coefficient, fugacity of pure species and of component in mixture, generalized correlations for the fugacity coefficient, concept of chemical potential, partial properties and their evaluation, excess properties, activity coefficient and its estimation from VLE data, Gibbs Duhem's equation, excess Gibb's free energy models	**12**	Basic introduction to chemical engineering thermodynamics in relation to homogeneous fluid mixtures
2	**Application of Solution Thermodynamics and VLE:** The nature of equilibrium, phase rule, Duhem's theorem, Raoult's law, Henry's law, thermodynamic consistency test of VLE data, bubble and dew point calculations for ideal and non-ideal mixtures, flash calculations, azeotrope calculations	**12**	Students will know the application of thermodynamics in the unique domain of chemical engineering
3	**Chemical reaction equilibria:** Introduction, concept of reaction coordinate, equilibrium criteria to chemical reactions, standard Gibbs-energy change and the equilibrium constant, effect of temperature on the equilibrium constant, evaluation of equilibrium constants, relation of equilibrium constants to composition for gas and liquid phase reactions, equilibrium conversions for single phase-single reactions, multi-reaction equilibria	**15**	Students will be familiar with equilibrium conversion of chemical reactions required for chemical-reactor design and operation

Textbooks:

1. Smith, J. M.; van Ness, H.C. and Abbott, M. M. (2010). Introduction to Chemical Engineering Thermodynamics. 7th Ed., McGraw-Hill India.
2. Rao, Y. V. C. (1997). Chemical Engineering Thermodynamics. Universities Press.
3. K. V. Narayanan. (2013). A Textbook of Chemical Engineering Thermodynamics. 2nd Ed., Prentice Hall of India.

Reference Books:

1. Kyle, B. G. (2015). Chemical and Process Thermodynamics. 3rd Ed., Pearson.
2. Sandler, S. I. (1998). Chemical and Engineering Thermodynamic. 3rd Ed., John Wiley & Sons.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC207**	**Principles of Mass Transfer**	**3**	**1**	**0**	**11**

Course Objective

The objective of this course is to develop the fundamental theoretical concepts of mass transfer operations that are essential for the designing of mass transfer equipment.
Learning Outcomes
Upon successful completion of this course, student will: • learn the concept of mass transfer principles • have basic competence related to other courses involving separation systems and processes

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction to Mass Transfer Operations:** Introduction, choice of separation methods, fundamentals of diffusion: molecular diffusion in gases, liquids and solids, estimation of binary diffusion coefficients in gases, liquids and solids	05	Understanding the fundamentals of mass transfer operations.
2	**Ficks law of Diffusion**: Concepts of mass/molar flux, and Fick's second law of diffusion, diffusive and convective flux, solution of mass transfer in homogeneous and heterogeneous systems	04	It will help student to understand the fundamentals of diffusion and mass transfer rate.
3	**Mass Transfer Coefficients:** Concept of convective mass transfer coefficients, relations between mass transfer coefficients, theories of mass transfer, mass, heat and momentum transfer analogies	06	It will provide the concept of mass transfer coefficient and relation with other transport phenomena.
4	**Interphase Mass Transfer:** Concept of equilibrium, diffusion between phases, two resistance theory concept of theoretical stage, material balances in steady state co-current and counter-current stage processes	05	It will provide the idea of interface mass transfer, and single and multistage mass transfer operations.
5	**Absorption:** Absorption equilibrium, choice of solvent, single component absorption material balances, counter-current multistage operations, absorption in packed columns	07	It will help student to understand absorption operation. It will also provide the detail understanding of tray and packed column.
6	**Distillation:** Binary vapor-liquid systems, phase diagrams, concept of relative volatility, flash vaporization, differential distillation, steam distillation, continuous multi-stage distillation,	12	It will provide the concept of distillation unit operation. It will also educate student about the

	McCabe-Thiele graphical stage method, tray efficiencies, introduction to multi-component distillation, azeotropic and extractive distillations		calculation of number of stages required for desired mass transfer.

Textbooks:

1. Treybal, R.E. (1981). Mass Transfer operations, 3rd Ed. McGraw-Hill Publication.

Reference Books:

1. Dutta, B. K. (2007). Principles of Mass Transfer and Separation Processes. Prentice Hall India.
2. Wankat, P. (1993). Equilibrium Stages Separations. Prentice Hall.
3. Seader, J. D. and Henley, E. J. and Roper, D. K. (2010). Separation Process Principles, 3rd Ed., Wiley

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Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC208**	**Chemical Process Technology**	**3**	**0**	**0**	**9**

Course Objective
The course aims to study process technologies, availability of raw materials, production trends, preparation of flow sheets, engineering and environmental problems of various chemical industries along with an emphasis on recent technological development.
Learning Outcomes
Improvement of knowledge towards the different chemical processes and their recent technological development.

Unit No.	Topic to be covered	Lecture Hours	Learning outcome
1	**Introduction:** Introduction to chemical industries, unit operation and unit proces concepts, general principles	05	Basic idea on the chemical industries and process
2	**Inorganic chemical industries:** Inorganic acids -sulfuric, nitric, phosphoric acids, chlor-alkali industry, and cement industries	09	Details process used for mentioned chemicals
3	**Fertilizers:** Ammonia, urea, phosphates -SSP, TSP	05	Details process used for mentioned fertilizers
4	**Natural products industries:** Pulp and paper, sugar, oil, and fats, soaps and detergents, glycerin	07	Details process used for mentioned natural products
5	**Petroleum refining and petrochemicals:** Refining processes, polymerization-polypropylene, polyvinyl chloride, nylon and polyester synthetic fibers	05	Details process used for mentioned petrochemicals
6	**Fermentation industries:** Alcohols	04	Details process used for alcohols
7	**Chemicals from Sea:** Salt, magnesium compounds, potassium, bromine, sea floor minerals	04	Details process used to recover chemicals from Sea

Textbook:

1. Gopala Rao M. and Marshall S. (1997). Dryden's Outlines of Chemical Technology. East-West Press.
2. Austin, G. T. (2017). Shreve's Chemical Process Industries Handbook," 5th Ed., McGraw Hill.
3. Pandey, G. N. (2000). Textbook of Chemical Technology Vol-1, and Vol-2, Sangam Books Ltd.

Reference books:

1. J. A. Moulijn, M. Makkee, A. E. Van Diepen (2013), Chemical Process Technology, 2nd Edition, Wiley.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC209**	**Process Dynamics and Control**	**3**	**0**	**0**	**9**

Course Objective
The objective of this course is to provide introductory knowledge to bridge the classical approach to process dynamics and control problems with the current and future trends and needs.
Learning Outcomes
After completion of the course students are expected to know basic control aspects of a chemical process.

Unit No.	Topic to be covered	Lecture Hours	Learning Outcome
1	**Introduction:** Introduction to process control, terminologies, various control configurations, basic hardware elements for control system, introduction to basic process instrumentation	**08**	Basic introduction about the course
2	**Laplace transform and block diagram:** Laplace transform, applications of Laplace transform to process control, concept of transfer function, block diagram, block diagram reduction, forcing functions	**05**	Development of input-output models analysis using Laplace transformations
3	**Dynamic behaviour of processes:** Introduction to first, second and higher order linear systems, basic modelling and analysis of dynamic behaviour of these systems	**07**	Introduce the students to the modelling and method to analyse the dynamic behaviour of processing systems
4	**Feedback control system:** Open loop and closed loop systems, feedback control system, stability analysis, root locus diagram, frequency response analysis, Bode plot, Bode and Nyquist stability criterion, design of controller, dynamics of some complex processes	**12**	Analysis and design of basic feedback control systems
5	**Control Valve:** Control valves and its characteristics	**03**	Design and selection of final control element
6	**Advanced control systems:** Introduction advanced control systems, cascade, feedforward and ratio control system, application of control systems to chemical process equipment such as chemical reactors, heat exchangers, distillation columns, etc.	**04**	Analysis and design of more complex control systems

Textbooks:

1. Stephanopoulos, G. (2008). Chemical Process Control: An Introduction to Theory and Practice, 3rd Ed., Prentice Hall.

2. Seborg, D. E., Mellichamp, D. A., Edgar, T. F., and Doyle, F. J.(2009). Process Dynamics and Control, 2nd Ed., John Wiley & Sons.
3. Coughanowr, D.R., and LeBlanc E Steven. (2017). Process Systems Analysis and Control, 3rd Ed., McGraw-Hill Higher Education.

Reference Books:

4. Ogunnaike, B. A., and Ray, W. H. (1994). Process Dynamics, Modeling and Control, Oxford University Press.
5. Marlin, T. E. (2012). Process Control: Designing Processes and Control Systems for Dynamic Performance, 2nd Ed., McGraw–Hill.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC301**	**Separation Processes**	**3**	**0**	**0**	**9**

Course Objective
The objective of this course is to apply principles of mass transfer in designing of equipment used for separation processes
Learning Outcomes
Upon successful completion of this course, student will: • learn the concept of separation process and system • have basic competence related to other courses involving separation processes.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Humidification:** Introduction, psychometric charts, theory of adiabatic saturation and wet bulb temperature, dehumidification and water cooling, evaporative cooling, classification and design of cooling towers	**06**	Understanding the fundamental of humidification and dehumidification. It will also help to student design precept of cooling towers
2	**Liquid - Liquid Extraction:** Introduction, ternary liquid equilibria, choice of solvent, single stage and multistage cross – current and counter – current operations, super critical fluid extraction, single stage, multistage and continuous contacting equipment	**10**	It will help students to understand liquid-liquid extraction unit operation. It will educate students about single and multi-stages extraction process

3	**Leaching:** Introduction and industrial applications, solid – liquid equilibrium, single stage and multistage cross – current and counter – current operations, equipment used in solid liquid extraction	**06**	It will educate students to understand solid-liquid extraction unit operation. It will educate students about single and multi-stages leaching process
4	**Adsorption:** Theory of adsorption, industrial adsorbents, adsorption equilibria, Freundlich and Langmuir equation, single and multistage operations, unsteady state adsorption, equipment for single stage and continuous contact, ion-exchange	**05**	It will teach students concept of adsorption unit operation. It will educate students about single and multi-stages adsorption process
5	**Drying:** Drying equilibria, drying rate curve, batch and continuous drying, time of drying calculations, mechanism of batch drying, equipment's for batch and continuous drying operations	**07**	Understanding the drying process. It will teach students drying mechanism.
6	**Crystallization:** Crystals and crystal geometry, equilibrium solubility, supersaturation, factors governing nucleation and crystal growth rates, controlled rate of crystals, crystallization equipment	**05**	It will educate students to understand crystallization unit operation. It will also help students to learn about crystallization equipment.

Textbooks:

1. Seader, J. D. and Henley, E. J. and Roper, D. K. (2010). Separation Process Principles, 3rd Ed., Wiley
2. Treybal, R.E. (1981). Mass Transfer operations, 3rd Ed. McGraw-Hill Publication.

Reference Books:

1. Dutta, B. K. (2007). Principles of Mass Transfer and Separation Processes. Prentice Hall India.
2. Wankat, P. (1993). Equilibrium Stages Separations. Prentice Hall.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC302**	**Chemical Kinetics and Reaction Engineering**	3	1	0	11

Course Objective
The objectives of this course are to study the kinetics of homogeneous and heterogenous reactions and interpret the kinetic data that helps to perform the design of chemical reactors.
Learning Outcomes
At the end of the course, the student would be able to understand the ideal and non-ideal reactor systems under isothermal and non-isothermal conditions. Design methodology of reactors for homogeneous and heterogeneous reactions would be understood by the students.

Unit No.	Topic to be covered	Lecture Hours	Learning Outcome
1	**Kinetics of Homogeneous Reactions:** Introduction to chemical reaction engineering, kinetics of homogeneous reactions, kinetic models, testing kinetic models, effect of temperature on reaction rates	**04**	Develop rate expressions for homogeneous reactions
2	**Interpretation of Kinetic Data:** Interpretation of batch reactor data for single and complex reactions, differential and integral methods of analysis of batch reactor data, half-life and fractional life methods	**04**	Know about testing of kinetic models
3	**Ideal Reactors:** Design of single homogeneous reactors: ideal reactors, design equations for ideal batch reactor, plug flow reactor (PFR) and mixed flow reactor (MFR), size comparison of single ideal flow reactors, optimum reactor size problems	**04**	Design ideal reactors for single reactions
4	**Design for Single Reactions:** Combination of ideal flow reactors, recycle reactor, autocatalytic reactions	**03**	Design recycle reactors for auto catalytic reaction
5	**Design for Multiple Reactions:** Series reactions, parallel reactions, series–parallel reactions, special reactions schemes (Denbigh, van de vusse, etc.), product distribution in various types of ideal reactors	**03**	Design ideal reactors for complex reactions
6	**Design of Non-isothermal Reactors:** General graphical design procedure, steady state non–isothermal design of ideal reactors for single and multiple reactions, stability of reactor	**05**	Design steady-state non-isothermal reactors and perform

			calculations on heat exchange.
7	**Basics of Non–ideal Reactors:** Reasons for non–ideal flow behavior, interpretation of residence time distribution (RTD) functions, calculation of mean residence time and variance from the RTD data, limitation of RTD	**03**	Understand basics of non-ideality
8	**Design of Non–ideal Reactors:** Conversion in non–ideal reactors, concepts of micro and macromixing, segregated flow model, tanks in series model, axial dispersion model,two–parameter models for stirred tank flow reactor	**05**	Propose design alternatives to carry out reactions in real reactors.
9	**Heterogeneous Reactions:** Introduction to heterogeneous reactions, shrinking core model (SCM) for particles of constant size	**04**	Apply the SCM for non-catalytic reactions
10	**Solid Catalyzed Reactions:** Kinetics of solid catalyzed reactions, reaction and diffusion in porous catalysts: effectiveness factor, Thiele modulus, global rate equations	**04**	Apply pore diffusion criteria to catalytic reactions

Textbooks:

1. Levenspiel, O. (2006). Chemical Reaction Engineering, 3rd Ed., Wiley.
2. Fogler, H. S. (2008). Elements of Chemical Reaction Engineering, 4th Ed., Prentice Hall.

Reference Books:

1. Smith, J. M. (2013). Chemical Engineering Kinetics, 3rd Ed., McGraw–Hill.
2. Hayes, R. E., and Mmbaga, J. P. (2013). Introduction to Chemical Reactor Analysis, 2nd Ed., CRC Press.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC305**	**Chemical Process Equipment Design**	**3**	**0**	**0**	**9**

Course Objective
The objectives of this course are to provide training to the students for specifying and Chemical process equipment used in Chemical and process industries.

Learning Outcomes
upon successful completion of this course, students will: • have ability to design general process equipment use in CPI. • be able to make use of basic principles of unit operations and codes in process design. • be able to provide a preliminary dimensioning of the material of construction. • be able to use various codes of practice in mechanical design.

Unit No.	Topic to be covered	Lecture Hours	Learning Outcome
	A. Process Design		
1	**Fluid Transport and mixing:** Fluid transport, mixing and storage, Design of pumps and compressors and centrifugal and reciprocal; Design of Storage bins, receivers, etc. Design of mixing equipment- Gas, Liquid and Solid-pastes.	**07**	Ability to design pipes/ piping, mixers, pumps, etc.
2	**Heat Transfer:** Heat exchanger Analysis - Effectiveness and NTU Concept, Shell and tube heat exchangers - standards and codes, various design methods; Condensers, reboilers and vapourizers, jacketed vessels/ internal coils, agitated vessels.	**08**	Will have basic knowledge in designing heat transfer equipment used in process industries.
3	**Separation:** Separation Equipment Distillation Column for binary systems- Plate and packed columns, plate hydraulics and packings, column internals, height and diameter	**09**	Awareness of basics in designing separation columns for binary mixtures and column internals.
	B. Mechanical Design		
5	**Vessels & Storage vessels**: Introduction to vessel design; selection of type of vessels; material of construction; selection and design considerations; introduction of codes for pressure vessel design; classification of pressure vessels as per codes; inspection and testing of pressure vessels.	**05**	Familiarity with mechanical design aspects of vessels, materials of construction and use of codes.

6	**Shell:** Design of cylindrical and spherical shells under internal and external pressure; selection and design of closures and heads; compensation of openings.	**05**	Basic knowledge for shells, columns and heads.
7	**Tall Towers & Supports:** Mechanical design of tall tower, Design of supports, gaskets and standard flanges.	**05**	Basic design of tall towers and associated parts.

Textbooks:

1. Mc-Cabe, W.L. Smith J.M. and Harriott, P. (2004). Unit Operations in Chemical Engineering, 7th Ed., McGraw Hill.
2. Sinnott, R. K. (2005). Chemical Engineering Design. 4th Ed. Vol 6, 4th Ed., Elsevier Butterworth Heinemann.
3. Mahajani, V. V. and Umarji, S. B. (2016). Joshi's. Process Equipment Design. 5th Ed., Trinity press.
4. Couper, J.R, Penney, W.R and James R. F. (2012). Chemical Process Equipment: Selection and Design, 3rd Ed., Butterworth-Heinemann.

Reference Books:

1. Green D. W. and Perry R. H. (2008). Perry's Chemical Engineers' Handbook, 8th Ed., McGraw Hill.
2. Stephen H. (2012). Rules of Thumbs for Chemical Engineer, 5th Ed. Elsevier Butterworth-Heinemann.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC306**	**Process Modelling and Simulation**	**3**	**0**	**0**	**9**

Course Objective
The objective of the course is to develop skills to build process models using the fundamental concepts and techniques of chemical engineering and to impart knowledge for numerical simulation of the developed models.
Learning Outcomes
At the end of the course, students are expected to be able to build a mathematical model of a chemical process and solve it using available computational tools.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome

1	**Introduction:** Introduction to mathematical modelling and simulation, aims and objectives of process modelling and simulation, terminologies, classification of models, concept of degree of freedom analysis	07	Introduction to basic modelling and simulation and related terminologies
2	**NAE models:** Nonlinear algebraic equation (NAE) based models, steady state models of flash vessels, equilibrium staged processes distillation columns, absorbers, strippers, CSTR, etc., review of solution procedures and available numerical software libraries	12	Familiarity with NAE based model
3	**DAE models**: Differential algebraic equation (DAE) based models, rate-based approaches for staged processes, modelling of differential contactors distributed parameter models of packed beds, packed bed reactors, review of solution strategies for DAEs, partial differential equations (PDEs), and available numerical software libraries	12	Familiarity with DAE based model
4	**Flowsheeting:** Introduction to steady-state flowsheeting, approaches to flowsheeting systems, introduction to commercial process simulators	08	Will have basic knowledge of flowsheeting and application of commercial simulators.

Textbooks:

1. Ramirez, W. F. (1997). Computational Methods for Process Simulation. 2nd Ed., Butterworth-Heinemann
2. Luyben, W.L. (1989). Process Modelling, Simulation and Control. 2nd Ed. McGraw-Hill.
3. Bequette, B. W. (1998). Process Dynamics: Modeling, Analysis and Simulation. Prentice Hall International
4. Westerberg, A. W.; Hutchison, H. P.; Motard, R. L.; Winter, P. (1979). Process Flowsheeting. Cambridge University Press

Reference Books:

1. Frank, R. E. (1972). Modelling and Simulation in Chemical Engineering. John Wiley & Sons

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Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CHC401**	**Process Design and Economics**	**3**	**0**	**0**	**9**

Course Objective
This course aims to furnish the engineering principles involved in the development of chemical process design and the role of software in process design. This course also provides basic understanding of the concepts of chemical process economics including cost and asset accounting, interest and investment costs,

cost estimation, taxes and insurance, depreciation, profitability analysis of investments. Inventory control tools and optimum design strategies will also be briefed.
Learning Outcomes
After the completion of the course, the student would be acquainted with the engineering principles involved in the flowsheet synthesis along with the optimum design strategies. The student would also be able to perform various calculations on interest, depreciation and pay back periods etc. related to chemical process plants.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
01	**Introduction:** Introduction to process design, general design considerations	**03**	Identify the goal of process design. and understand the factors involved in choosing a plant site, preparing plant layout, etc.
02	**Process Design Development:** Introduction, development of design database, process creation, types of process design, process flow diagrams, piping and instrumentation diagrams, scale-up of equipment in design	**05**	Learn the principles involved in the process design development and understand the scale-up methods.
03	**Flowsheet Synthesis:** Introduction, process information, functions diagram, operations diagram, analysis and evaluation of flowsheets, criteria for evaluating designs, role of software in process design, software selection	**06**	Synthesize and evaluate process flowsheets & realize the use of software in process design.
04	**Optimum Economic Design:** Strategy for optimum production rates in plant operation, cyclic operations, and economic pipe diameter	**02**	Understand the application of optimization methods for optimum design
05	**Process Economics:** Introduction, basics of accounting procedure, interest types and their calculations, present worth and discount, perpetuities and capitalized costs, total capital, fixed capital and working capital investment, methods of estimation of investment, types of taxes, types of insurance	**06**	Carry out basic calculations on interests, annuities and investments. Incorporate taxes in order to calculate the gross and net profits.
06	**Cost Estimation:** Cash flow, factors involved in project cost estimation, cost index and scaling for equipment cost, estimation of total product cost	**05**	Perform economic analysis of production costs for chemical process plants.
07	**Depreciation:** Types and methods of determination of depreciation	**05**	Apply different methods to compute depreciation

08	**Profitability:** Profitability evaluation methods, practical factors in alternative investments and replacement studies	**07**	Assess the profitability through different methods and payback period.

Textbook:

1. Peters, M. S., and Timmerhaus, K. D. (1991). Plant Design and Economics for Chemical Engineers, 4th Ed., McGraw-Hill Inc.

References Books:

1. Couper, J. R. (2003). Process Engineering Economics, Marcel Dekker Inc.
2. Silla, H. (2003). Chemical Process Engineering Design and Economics, Marcel Dekker Inc.

Course Type	Course Code	Name of Course	L	T	P	Credit
ESO	**CHE201**	**Engineering Thermodynamics**	**3**	**0**	**0**	**9**

Course Objective
To impart basic knowledge on basic principles of thermodynamic concepts emphasizing on various laws of thermodynamics and their applications in the field of vapor compression power and refrigeration cycles.
Learning Outcomes
Students will be able to understand the system-surrounding interactions involving work and heat and to estimate relevant thermodynamic properties.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** Overview, basic concepts: work, energy, heat, internal energy, properties of a system, extensive and intensive properties, equilibrium, state and path functions, temperature and zeroth law of thermodynamics	**03**	Define thermodynamics, related concept and terminologies to analyze thermodynamic systems.
2	**First law of thermodynamics**: First law of thermodynamics, energy balance, reversible process, constant volume and constant pressure processes, concept of enthalpy, heat capacity, applications of first law applied to flow processes	**06**	Explain 1st law of thermodynamics, define heat, work and concept enthalpy of a system
3	**Volumetric Properties of Fluids**: Ideal gas, PVT behaviour of pure substances, equation of states and their	**08**	Students will understand behaviour of gases, liquids

	applications, equations for process calculations: isothermal process, isobaric process, isochoric process, adiabatic process, and polytropic process, properties of gas mixtures		and solids and related process using fluid mixtures
4	**Second and Third Law of Thermodynamics**: Statements of second law, heat engines, heat pumps, refrigerators, Carnot cycle and Carnot's theorem, statement of the third law of thermodynamics, concept of entropy, entropy balance, application of entropy principle	**09**	Define 2nd and 3rd law of thermodynamics and concept of entropy and their applications in engineering fields.
5	**Thermodynamic Properties of Fluids**: Fundamental property relations, residual properties, general relations for internal energy, enthalpy, and entropy changes of ideal and real gases, Maxwell's equations, temperature dependence of the vapor pressure of liquids, two-phase liquid/vapor systems, property tables and diagrams	**07**	Familiarization of fundamental property relations, residual properties, tables and diagrams for pure substance
6	**Applications of thermodynamics**: Vapor and gas power cycles, refrigeration and liquefaction processes	**06**	Learn about various thermodynamic cyclic processes and their applications

Textbooks:

1. Nag, P. K. (2018). Engineering Thermodynamics, 6th Ed., McGraw Hill Education (India) Pvt. Ltd.
2. Cengel, Y. A. and Boles, M. A. (2017). Thermodynamics: An Engineering Approach, 8th Ed., McGraw Hill Education (India) Pvt. Ltd.

Reference books:

1. Smith, J. M., van Nees, H.C., Abbott and Swihart. M. T. (2017). Introduction to Chemical Engineering Thermodynamics, 8th Ed., McGraw Hill Education (India) Pvt. Ltd.

Course Type	Course Code	Name of Course	L	T	P	Credit
ESO	**CHE202**	**Transport Phenomena**	**3**	**0**	**0**	**9**

Course Objective
To provide basic unifying principles of the conservation of momentum, energy and mass with emphasis on similarities and differences amongst various transport mechanisms and to apply them to solve problems encountered in engineering processes.
Learning Outcomes

Students will be able to correlate the phenomena of momentum, heat, and mass transport and appreciate the similarities between them and solve problems in these areas.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Vector Analysis:** Vector and tensor operations, concepts of gradient, divergence and curl, cartesian and curvilinear coordinate systems.	**04**	Proficiency in vector calculus with exposure to indicial notations
2	**Basics of Fluid Mechanics:** Continuum hypothesis, Newtons' law of viscosity, constitutive relations, non-Newtonian fluids diffusive and convective fluxes.	**04**	Understanding on basics of fluid mechanics and flux relations
3	**Equations of change:** Introduction to shell balance method: formulation and application: Laminar flow of falling film, laminar flow through circular pipe, Hagen-Poissuille equation, 1-D Problem solving using shell balance method	**05**	Ability to formulate equation of change: shell balance and NSE and apply different solution techniques for flow problems
	Derivation of equation of change for momentum, Navier-Stokes equation, Creeping flow, Problem solving using Navier Stokes equation.	**05**	
	Solution of unsteady flow problem: Semi-infinite domain using Similarity solution, parallel plate using Eigen value solution.	**04**	
4	**Boundary layer theory and Turbulence:** Potential flow, boundary layer theory and turbulence phenomena.	**03**	Understanding boundary layer theory and turbulence
5	**Energy Transport**: Fouriers law and application of shell balance method: Fin efficiency	**03**	Enabling students to make use of Fouriers law and application of shell balances method for conduction and convection
	Derivation of Energy equation and Solution of heat flow using energy equation	**05**	
6	**Mass Transport:** Ficks law of Diffusion, diffusive and convective flux, solution of mass transfer in homogeneous and heterogeneous systems	**04**	Familiarization of mass transfer aspects and solution to problems involving mass transport in different systems using equation of change
	Equations of change for mass transfer problems.	**01**	
7	Analogy: Analogy between momentum, mass and heat transfer.	**01**	Identification of analogy of various forms of transport and their usage

Textbooks:

1. Bird, R. B., Stewart, W. E. and Lightfoot, E. N. (2007). Transport Phenomena. 2nd Ed. McGraw Hill.

Reference Books:

1. Deen, W. M. (1998). Analysis of Transport Phenomena. Oxford Univ. Press.
2. Leal L.G. (2008). Advanced Transport Phenomena**:** Fluid Mechanics and Convective Transport Processes. Cambridge Univ. Press.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**CHO301**	**Petroleum Refining**	**3**	**0**	**0**	**9**

Course Objective
This course will present an overview of the modern, integrated petroleum refinery, its feedstocks, product slate and the processes employed to convert crude oil and intermediate streams into finished products. Hydrocarbon chemistry, crude oil properties and fuel product quality will be discussed. Each refining process will be presented, covering operating description and conditions, feedstock and catalyst selection, product yields, and the relationship between process parameters, unit performance and product output and properties.
Learning Outcomes
This course will provide major insights into both primary and secondary processes in a typical petroleum refinery industry.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Crude Oils:** Introduction to crude oils -composition and evaluation, testing of petroleum products	05	To gain knowledge about crude oil
2	**Preprocessing and Basic Separations:** Pretreatment of crude oil, atmospheric and vacuum distillation, temperature cuts and characteristics, various products -gasoline, kerosene/ATF (solvent extraction) and diesel production	10	To gain knowledge about preprocessing and basic separation processes of crude oil
3	**Enhancement of Refinery Products:** Thermal and catalytic cracking processes (FCC), rebuilding processes, reforming	10	To know about the different type of enhancement of refinery products
4	**Purification Processes:** Desulphurization and denitrogenation processes, removal of aromatics	05	To learn about the various purification processes of crude oil
5	**Lube Oil:** Manufacturing and dewaxing using various solvents	03	To learn about various lubricating oils
6	**Storage Processes:** Storage, stability, blending	03	Learn about various storage processes
7	**Environmental Issues:** Thermal efficiency and environmental aspects	03	Environmental aspects to realized

Textbooks:

1. Mall, I.D. (2018). Petroleum Refining Technology, 2nd Ed. CBS Publishing.

Reference Books:

1 James G. Speight, G. J. and Ozum, B. (2002). Petroleum Refining Processes. Marcel Dekker Inc., New York
2 Bhaskara, Rao B. K. (2017), Modern Petroleum Refining Process, 6th Ed. Oxford & IBH.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**CHO302**	**Industrial Safety and Hazards Management**	**3**	**0**	**0**	**9**

Course Objective
To teach the students about process safety, health and hazards issues and make them aware of the prevalent regulatory provisions.
Learning Outcomes
The students will be able to appreciate and deal with the HSE issues in chemical process industries.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Statutory Regulations Safety and Hygiene:** Industrial safety, toxicology and Industrial hygiene, models for dose and response, threshold limiting values (TLVs), government laws and regulations, OSHA standards, MOEF (India) guidelines for handling and storage of hazardous chemicals, sludges, materials, MSDS	**07**	Knowledge about requirements of statutory regulations and standards of Safety, Toxicology and hygiene
2	**Toxic Release and Dispersion Models:** Estimation of realistic and worst-case release of vapor and	**05**	Basic estimation of leaks/releases and their repercussions.

	liquid toxicant through hole in tank, pipe, and flange, dispersion of neutrally buoyant and dense gases		
3	**Fire and Explosion:** The fire triangle, flammability characteristics of chemicals and auto ignition, flammability diagram, explosion characteristics and blast diagram, dust, vapor, cloud and mist explosion, prevention of fire and explosion	**08**	Idea about fire, explosion, their characteristics and prevention techniques.
4	**Relief Devices:** Types and characteristics, relief systems and design consideration, relief sizing and vent area calculation	**06**	Design of relief system for high pressure, reactive, flammable systems.
5	**Hazard identification and Risk assessment:** Hazard survey and safety review, Event tree, fault tree and its minimum cut set	**05**	Basics of risk assessment techniques.
6	**Safety Procedure and Design:** Hierarchy, documentation, best practices, procedures for process safety design, safety aspects related to site, plant layout, process development and design stages	**08**	Understanding of safety design of processes

Textbooks:

1. Crown. D. A. (2011). Chemical Process Safety Fundamental with Application, 3rd ed., Prentice Hall International Series.
2. Fawcett, H. H., and Wood, W.S. (1966). Safety and Accident Prevention in Chemical Operations, John Wiley & Sons.

Reference books:

1. Mannan, S. (2012). Lees' Loss Prevention in the Process Industries: Hazard identification, Assessment and Control (3 Volumes), 4th Ed., Butterworth-Heinemann.
2. Haight, J.M. (2013). Handbook of Loss Prevention Engineering, Volume 1 & 2, John Wiley & Sons,

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Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**CHO302**	**Processes Integration**	**3**	**0**	**0**	**9**

Course Objective
To introduce the concept of pinch technology in integration of unit operations in process industries.

Learning Outcomes
Students shall be able to design and analyze complex network of unit processes.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** Introduction to hierarchal approach for process engineering design, the nature of chemical process, formulation of design problem, the hierarchy of chemical process	**06**	Students will have understanding of basic concepts of conceptual process design, technology selection, and integration
2	**Economic and Decision Making:** Role of economic in technology selection, calculation of economic potential, time value of money	**06**	Students will have understanding of economic importance of technology selection
3	**Reactor Selection:** Decision making based on input information, reaction path, reactor performance, choice of reactors, batch vs continuous,	**06**	Students will have understanding of selection of reactors, material and energy balance
4	**Separation and Recycling:** Selection of separation technologies and recycle operations, general structure of separation system, selection of recycle stream, compressor design and cost	**06**	Students will have understanding of importance and selection of separators as well as recycling units in process industries.
5	**Pinch Technology:** Introduction, basic concept, role of thermodynamic laws, problem addressed by pinch technology	**06**	Students will have understanding of Pinch technology widely employed to minimize energy losses
6	**Heat Exchanger Networks:** Designing of HEN, pinch design methods, design of maximum energy recovery (MER),	**06**	Students will have understanding of heat exchanger network which has critical role in profitability and energy optimization of any process
7	**Heat Integration:** Heat integration of equipment: heat engine, heat pump, distillation column	**03**	Students will have understanding of heat integration which helps to

			minimize energy losses

Textbooks:

1. Kemp I. C. (2007). Pinch Analysis and Process Integration: A user Guide on Process Integration for the Efficient Use of Energy. 2nd Ed., Butterworth-Heinemann
2. Smith R. (2005). Chemical Process Design and Integration. 2nd Ed., Wiley
3. Shenoy U. V. (1995). Heat Exchanger Network Synthesis. Gulf Publishing Company
4. Douglas, J. M. (1998). Conceptual Design of Chemical Processes, McGraw Hill

Reference Books:

1. El Halwagi M. M. (2006). Process Integration. 7th Ed., Academic Press

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Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**CHO402**	**Biofuels and Biomass Conversion Technology**	**3**	**0**	**0**	**9**

Course Objective
The primary focus of proposed course would be to teach the current trends in the area of biofuel and value-added chemicals production, the current status of bio-renewable energy, current opportunities, and emerging areas, major challenges towards sustainability and implementation of bio-based technologies. The course will also include waste (such as waste plastic) to wealth technologies.
Learning Outcomes
The students will have basic understanding of different biomass conversion technologies which can be used to design product centric biorefineries. Also, students would learn waste to wealth technologies with focus on biofuels and biomass conversion technologies.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** Introduction to biorenewable energy and chemicals, sources of biorenewable energy and chemicals, biorenewable energy and chemicals market	**04**	Students will have understanding of biomass availability, types, need for biomass conversion, potential market
2	**High Temperature Biomass Conversion Process:** Gasification, pyrolysis, supercritical processing of biomass, biooil upgradation technologies	**10**	Students will have understanding of high temperature methods for

			biomass conversion, catalytic materials for bio oil upgradation
3	**Waste to Wealth Conversion Technologies:** Integration of high temperature biomass conversion for waste plastic conversion, e-waste conversion	**04**	Students will have understanding of technologies for plastic waste and e-waste conversion
4	**Low Temperature Biomass Conversion Technologies:** Catalytic vis a vis non-catalytic processing of biomass, heterogeneous catalysts for biomass conversion	**08**	Students will have understanding of catalytic materials and processes for biomass conversion
5	**Building Block Platform Chemicals:** Pre-treatment and delignification of biomass, production	**06**	Students will have understanding of US DOE recommended multipurpose products (serves both as fuel and chemicals)
6	**Algal Biomass and Non-Edible Oils Resources:** Fuel production from non-edible oils, processing of algal biomass, and principles of green chemistry	**07**	Students will have understanding of conversion processes for non-lignocellulosic biomass

Textbooks:

1. Wertz, J-L. and Béduéand, O. (2013). Lignocellulosic Biorefineries, EPFL and CRC Press
2. Bhaskar, T., Pandey, A., Venkata Mohan, S., Lee, D.-J., Khanal, S. K. (2018). Waste Biorefinery: Potential and Perspectives, Elsevier.

Reference Books:

1. Gupta, S., Malik, A. and Bux, F. (2017). Algal Biofuels: Recent Advances and Future Prospects, Springer Nature.