Bharati Vidyapeeth

(Deemed to be University)

Faculty of Engineering and Technology

Programme: M. Tech. (Chemical) (2023 Course)

Curriculum Structure

Bharati Vidyapeeth
(Deemed to be University)
Faculty of Engineering and Technology

Programme: M. Tech. Chemical

Semester – I **CBCS 2023 Course**

Sr. No.	Course Code	Name of Course	Teaching Scheme (Hours/week)			Examination Scheme (Marks)						Credits			
			L	P	T	UE	IA	TW	OR	PR	Total	L	P	T	Total
1		Advanced Separation processes	04	-	-	50	50	-	-		100	4	-	-	4
2		Thermodynamics of Phase Equilibria	04	-	-	50	50				100	4	-	-	4
3		Multiphase Reaction Engineering	04	-	-	50	50				100	4	-	-	4
4		Open Elective - I	04	-	-	50	50				100	4	-	-	4
5		Lab Practice - I	-	04	-	-	-	25		25	50	-	2	-	2
6		Lab Practice - II	-	04	-	-	-	25		25	50	-	2	-	2
Total			**20**	**08**	**16**	**200**	**200**	**125**	**75**	**50**	**500**	**16**	**4**	**-**	**20**

Semester II

Sr. No.	Course Code	Name of Course	Teaching Scheme (Hours/week)			Examination Scheme (Marks)						Credits			
			L	P	T	UE	IA	TW	OR	PR	Tota l	L	P	T	Tota l
1		Modeling and simulation of chemical processes	04	-	-	50	50	-	-		100	4	-	-	4
2		Advanced transport processes	04	-	-	50	50				100	4	-	-	4
3		Process Intensification and	04	-	-	50	50				100	4	-	-	4

		Development													
4		Open Elective - II	04	-	-	50	50				100	4	-	-	4
5		Lab Practice - I	-	04	-	-	-	25		25	50	-	2	-	2
6		Lab Practice - II	-	04	-	-	-	25		25	50	-	2	-	2
Total			**20**	**08**	**16**	**200**	**200**	**12 5**	**75**	**50**	**500**	**16**	**4**	**-**	**20**

Semester III Total Duration: 08hrs/week **Total Marks :250** **Total Credits: 20**									
Subjects	**Teaching Scheme (Hours./week)**		**Examination Scheme (Marks)**						**Credits**
	L	**P**	**T**	**IA**	**TW**	**PR**	**Oral**	**Total**	
Seminar	--	02	--	--	50	--	50	100	05
Dissertation Stage - I	--	06	--	--	100	--	50	150	15
Total	**--**	**08**	**--**	**--**	**150**	**--**	**100**	**250**	**20**

List of Self Learning Courses, Department Electives and Open Elective

Department Elective - I	Department Elective - II
Advanced wastewater treatment	Artificial Intelligence
Synthesis and application of nano materials	Waste to Energy Conversion

Semester IV Total Duration: 08hrs/week **Total Marks :250** **Total Credits: 20**									
Subjects	**Teaching Scheme (Hours./week)**		**Examination Scheme (Marks)**						**Credits**
	L	**P**	**T**	**IA**	**TW**	**PR**	**Oral**	**Total**	
Dissertation Stage - II	--	08	--	--	150	--	100	250	20
Total	**--**	**08**	**--**	**--**	**150**	**--**	**100**	**250**	**20**

Programme: M. Tech Chemical (2023)

Semester- I (Chemical)

<table>
<tr><td colspan="4" align="center">ADVANCED SEPARATION PROCESSES</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Designation: Professional Core</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Pre-requisite Courses: Mass transfer, Reaction engineering, Thermodynamics</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="2">Teaching Scheme</td><td>Examination Scheme</td><td>Credits Allotted</td></tr>
<tr><td colspan="2">Lectures : 04Hours/Week</td><td>End Semester Examination : 50 Marks</td><td>Theory : 04</td></tr>
<tr><td colspan="2"></td><td>Internal Assessment : 50 Marks</td><td></td></tr>
<tr><td colspan="2">Total : 04 Hours/Week</td><td>Total : 100 Marks</td><td>Total Credits : 04</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Course Outcomes: Student will be able to</td></tr>
<tr><td>1</td><td colspan="3">Estimate diffusion with chemical reaction in a given system.</td></tr>
<tr><td>2</td><td colspan="3">Estimate parameters for design of multicomponent distillation column.</td></tr>
<tr><td>3</td><td colspan="3">Estimate flux and separation factors for design of membrane processes.</td></tr>
<tr><td>4</td><td colspan="3">Estimate the parameters affecting adsorption and ion exchange processes.</td></tr>
<tr><td>5</td><td colspan="3">Analyze novel separation techniques applicable to chemical processes</td></tr>
<tr><td colspan="4" align="center">Topics Covered</td></tr>
<tr><td>UNIT-I</td><td colspan="2">Diffusion
Steady State diffusion with heterogeneous chemical reaction, Steady state diffusion accompanied by homogeneous chemical reaction. Unsteady state molecular diffusion in isotropic media, unsteady state diffusion for typical cases of mass transfer in infinite, semi-infinite and finite plane media and in spherical and cylindrical media.</td><td>(08 Hours)</td></tr>
<tr><td>UNIT-II</td><td colspan="2">Multicomponent Distillation
Bubble point and dew point calculation; flash distillation calculation; Number of tray calculation: Fenske equation, underwood equation,lewismatheson equation, minimum stages and minimum reflux calculation, recentadvances in column</td><td>(08 Hours)</td></tr>
</table>

	design and operation-Petlyuk, divided wall, kaibel, pre-fractionators, post fractionator. Azeotropic distillation, Extractive distillation, Molecular distillation, Reactive distillation.	
UNIT-III	Membrane Processes Scope and significance of membrane processes; Types of membrane and preparation; Membrane characteristics; Transport processes involved in membrane separation processes such as ultrafiltration, nano-filtration, gas separation, reverse osmosis; Calculations of flux, separation factor, and design aspects of membrane processes such as ultrafiltration, nano-filtration, gas separation, reverse osmosis; Techo-economic aspects of membrane processes	**(08 Hours)**
UNIT-IV	Adsorption and Ion Exchange Scope and significance of adsorption and ion exchange processes; Batch adsorption and ion exchange- Effect of temperature, pressure, and initial concentration, Isotherms, Estimation of thermodynamic parameters; Continuous adsorption and ion exchange- Effect of initial concentration and superficial velocity, Breakthrough curves and models, Design aspects of fluidized bed.	**(08 Hours)**
UNIT-V	Novel Separation Techniques Extraction: Super critical fluid extraction, Reactive extraction, Microwave and ultrasound assisted extraction; Ionic Separation; Separation based on surface science;	**(08 Hours)**

Internal Assesment

1. Group discussion on separation of multicomponent mixture (selecting any case study)
2. Unit Test subjective or MCQ
3. Solution to any industry problem
4. Design of separation equipment for any one case study (Individual)
5. Preparation of a brief report on advanced separation processes applied in synthesis of any product.

Text Books/References

1	King, C. J., Separation Processes , Tata McGraw Hill Co., Ltd., 1982.
2	Phillip C. Wankat , Separation Process Engineering (2nd Edition), Printice Hall,2007
3	Marcel Mulder, Introduction to Membrane Science and Technology, Marcel Dekker, 1992.
4	Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997

5	Anthony L Hines , Robert N Maddox , Mass Transfer Fundamentals and Applications.
6	Sherwood, T. K., Pigford, R. L. & Wilke, C. R, Mass Transfer Mc Graw Hill, 1975
7	Seader, J.D. and Henley, E.J., Separation Process Principles, Wiley, New York (1998)

THERMODYAMICS OF PHASE EQUILIBRIA		
Designation: Professional Core.		
Course Pre-requisites: Process calculations, Basic concepts of residual and excess properties		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures : 4 Hours/Week	End Semester Examination : 50 Marks	Theory : 04
Total : 4Hours/Week	Internal Assessment : 50 Marks	Total Credits : 04
	Total :100 Marks	

Course Outcomes	
After completion of the course the student will be able to:	
1.	Determine residual and excess properties to quantify deviation from an ideality
2.	Apply modified Raoults law for VLE and estimate activity coefficient using various models.
3..	Apply concept of fugacity for solid fluid equilibria
4.	Apply thermodynamic principles to interfacial phase equilibria
5..	Determine Gibbs free energy for homogeneous and heterogeneous reactions.
6.	Apply thermodynamic principles to perform energy analysis of the system.

Topics covered		
UNIT-I	**Thermodynamics of Multi-component mixtures:** Ideal mixtures and excess mixture properties, Fugacity of species in gaseous, liquid and solid mixtures, Criteria for phase equilibrium in multi-component systems, Modified Roult’s law and its significance, Gibbs Duhem equation, Hydrogen bonding and charge transfer complexing Equilibrium	**(08 Hours)**
UNIT-II	**Vapor liquid Equilibrium of mixtures** Vapor Liquid equilibrium (VLE) of ideal mixtures, Low pressure VLE in non-	**(08 Hours)**

	ideal mixtures, High pressure VLE using equation of states, Solubility of gas in liquid, Liquid-Liquid Equilibrium, Vapor Liquid-Liquid Equilibrium, Models for activity coefficient, UNIFAC method, UNIQUAC equation, Osmotic pressure, osmotic equilibrium	
UNIT-III	**Mixture phase equilibrium involving solids** Solubility of solid in liquid and supercritical fluid, Solid Liquid Equilibrium, Partitioning of solid between two liquid phases, distribution coefficient, Freezing point depression of solvent due to presence of solute, freezing point of liquid mixtures in presence of solid.	**(08 Hours)**
UNIT-IV	**Surfaces, Interfaces and Adsorption** Thermodynamics of interfaces, Gibbs surface model and surface tension, Surface energy of solids, Surface effects on heterogeneous phase equilibrium, effect of particle size on vapor pressure, effect of bubble size on the boiling temperature of pure substances, solubility and nucleation, effect of particle size on melting temperature, Gibbs adsorption equation, Gibbs-Donnan equilibrium.	**(08 Hours)**
UNIT-V	**Chemical Reaction Equilibria, Energy analysis** Chemical equilibrium in single phase system, Heterogeneous chemical reactions, Chemical equilibrium when several reaction occurs in single phase, Combined chemical and phase equilibrium. Phase rule and Duhem's theorem for reacting systems, Degree of freedom analysis for non-reacting and reacting systems. Defining Exergy, Control Volume Energy Rate Balance, Exergetic Efficiency, Introduction to Energy Costing.	**(08 Hours)**

Internal Assessment: Each student will submit assignments based on different topics in consultation with faculty, in the area of thermodynamics of phase Equilibria, keeping track of the recent technological trends and developments. Internal assessmentwill be carried out for each unit using one or combination of following, which is for guidance faculty can design and provide relevant means of assessment in addition to these

1.	Unit Test can be conducted based on each unit, it may be subjective/objective.
2.	Solving numerical in connection with phase equilibria
3.	Surprise and/or open book test

4.	Presentation/report based on recent advances in a given domain (Individual student and/or group)
5.	Industrial relevance case studies of the subject.
6.	Enhancement in collaborative learning is done through, group assignments that will be given to encourage students to work with classmates to discuss and complete homework assignments.
7.	Solution to industry oriented problem
8.	Preparation of a brief report on applicability of liquid-liquid equilibrium (LLE) in chemical engineering systems.
Text Books/References:	
1.	J. M. Smith and H. C. Van Ness, "Introduction to Chemical Engineering Thermodynamics", McGraw-Hill Publication
2.	Stanley I. Sandler, "Chemical, Biochemical and Engineering Thermodynamics", McGraw- Hill Publication
3.	Savein Stolen, Tor Grande, Neil Allan, "Chemical Thermodynamics of Materials", John Whilly and Sons.
4.	K.V. Narayanan," Chemical Engineering Thermodynamics", PHI Learning Pvt. Ltd.
5.	Kenneth Denbigh, "Principles of Chemical Equilibrium" 4th Edition, Cambridge University Press
6.	Y. V. C. Rao, "Chemical Engineering thermodynamics", Oxford University Press
7.	B. F. Dodge, "Chemical Engineering Thermodynamics", McGraw- Hill Publication
8.	T. E. Daubert, " Chemical Engineering Thermodynamics", McGraw- Hill Publication
9.	Glasstone S., "Thermodynamics for Chemists", Affiliated East-West Press
10.	B. G. Kyle, "Chemical and Process Thermodynamics" 3rd Edition, PHI Learning Pvt. Ltd

MULTIPHASE REACTION ENGINEERING

Designation: Professional Core

Pre-requisite Courses: Material and energy balance calculations, Fluid mechanics, Heat transfer, Mass transfer, Homogeneous reaction engineering

Teaching Scheme		Examination Scheme		Credits Allotted	
Lectures	: 04 Hours/Week	End Semester Examination	: 50 Marks	Theory	: 04
Practical	: - Hours/Week	Internal Assessment	: 50 Marks	Practical	: -
Tutorial	: -	Term work/Practical	: -	Tutorial	: -
Total	: 04 Hours/Week	Total	: 100 Marks	Total Credits	: 04

Course Outcomes

1	Estimate equilibrium composition of multiphase reaction.
2	Estimate multiphase reaction rate controlling step and determine overall rate of reaction.
3	Estimate flow structure and phase hold-up of a given multiphase reactor.
4	Estimate flow non-ideality in a given multiphase reactor.
5	Estimate heat and mass transfer coefficient in a given multiphase reactor.
6	Design and scale up a given multiphase system.

Topics Covered

UNIT-I	**Introduction** Classification of heterogeneous reaction; Qualitative description; Examples of industrial importance **Thermodynamics of Multiphase Reactions** Criteria of chemical reaction equilibrium; Standard Gibbs free energy change and equilibrium constant; Estimation of equilibrium constant; Effect of temperature and pressure on equilibrium constant; Equilibrium conversions for single and multi-reaction systems.	**(08 Hours)**

UNIT-II	**Kinetics of Multiphase Reactions** Mechanisms of heterogeneous reactions; Determination of rate controlling step; Estimation of overall rate of reaction; Factors affecting the rate of reaction; Heterogeneous catalysis: selection of catalyst, external and internal diffusion effects, catalyst deactivation.	**(08 Hours)**
UNIT-III	**Hydrodynamics and Mixing** Hydrodynamic characteristics of different multiphase reactors: Mechanically Agitated Contactors (MAC), Bubble Columns, Slurry Reactors, Fluidized Beds, Loop Reactors and Modified Versions. Experimental methods to measure phase mixing; Effect of geometrical, system, and operating parameters on phase mixing in multiphase reactors; Quantification of phase mixing; Development of a mathematical model	**(08 Hours)**
UNIT-IV	**Heat and mass transfer** Experimental methods to measure heat transfer coefficient; Effect of geometrical, system, and operating parameters on heat transfer coefficient in multiphase reactors; Quantification of heat transfer coefficient; Application of correlations available to different multiphase reactors. Experimental techniques used for estimation of mass transfer coefficient and selection of suitable technique for a multiphase reactor; Effect of geometrical, system, and operating parameters on mass transfer coefficient in multiphase reactors; Quantification of mass transfer coefficient; Application of correlations available to different multiphase reactors.	**(08 Hours)**
UNIT-V	**Design and scale up of multiphase reactors** Generalized methodology of design and scale up of multiphase reactors; Examples of industrial importance.	**(08 Hours)**

Internal Assessment: Internal assessment will be carried out for each unit using one or combination of following:

1	Unit test: Subjective and/or MCQ
2	Surprise and/or open book test

3	Presentation/report based on recent advances in a given domain (Individual student and/or group)
4	Solution to industry oriented problem
5	Design of experiment to estimate design parameters pertaining to any one multiphase system
Text Books/References	
1	V. G. Pangarkar, “Design of multiphase reactors”, 1st Edition, Wiley, 2015
2	L. K. Doraiswamy and M. M. Sharma, “Heterogeneous Reactions”, 2nd Edition, Volume I and II.
3	G. B. Tatterson, ”Fluid Mixing and Gas Dispersion in Stirred Reactors”, 10th Edition, Academic Press, London, 1994
4	W. D. Deckwer, “Bubble Column Reactors”, Cambridge University Press, New York, 2000.
5	Diazo Kunji and O. Levenspiel, “Fluidization Engineering”, 2nd Edition, Butterworth Heinemann, 1991
6	J. F. Devidson and Harrison, ” Fluidization”, 10th Edition, Academic Press, London, 1994.
7	J. M. Smith, H. C. Van Ness and M. M. Abbott, “Introduction to Chemical Engineering Thermodynamics”, 5th Edition, McGraw Hill International, Singapore, 1996.

ELECTIVE -I: ADVANCED WASTE WATER TREATMENT

Designation: Open Elective-I

Pre-requisite Courses: Mechanical operations, Engineering chemistry.

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04Hours/Week	End Semester Examination	: 50 Marks	Theory	: 04
Practical	: -Hours/Week	Internal Assessment	: 50 Marks	Practical	: -
Tutorial	: -	Term work/Practical	: -	Tutorial	: -
Total	: 04 Hours/Week	Total	: 100 Marks	Total Credits	: 04

Course Outcomes

1	Explain the conventional waste water treatment methods.
2	Identify various membrane based advanced waste water treatment methods.
3	Demonstrate basics of advanced oxidation processes (AOPs).
4	Analyze various emerging AOPs and their mechanism.
5	Identify the various wastewater treatment methodsused in chemical and allied industries

Topics Covered

UNIT-I	**Conventional waste water treatment methods:** Physical methods: Mixing; Flocculation;Gravity separation, Grit removal, Sedimentation; Adsorption; Floatation. Chemical methods: Coagulation; Precipitation;Chemical oxidation. Biological methods: Aerobic oxidation; Anaerobic oxidation; Anaerobic fermentation and oxidation; Aerobic biodegradation; Activated sludge process; Trickling filters. Limitations of conventional methods.	**(08 Hours)**
UNIT-II	**Membrane based advanced wastewater treatment:** Membrane separation techniques: Brief introduction of microfiltration,	**(08 Hours)**

	ultrafiltration, nanofiltration, membrane materials; Dialysis: membranes details, characteristics, industrial application; Electrodialysis: membranes details, characteristics, industrial application; Membrane bioreactors: membranes details, characteristics, industrial applications;Membrane modules: plate and frame module, spiral wound module, tubular module, capillary module, hollow fiber module,comparison between module configuration, industrial applications.	
UNIT-III	**Advanced oxidation processes (AOPs):** Fundamentals and background of AOPs for water and wastewater treatment; basic reaction mechanism of AOPs; Role of hydroxyl radicals and their generation; Reaction kinetics and degradation mechanisms of organic pollutants by hydroxyl radicals; Effects of process parameters and scavenging media on degradation efficiency; oxidation potential of AOPs; merits and demerits of various AOPs.	**(08 Hours)**
UNIT-IV	**Emerging AOPs:** Electrochemical oxidation; Ultrasound processes; Principles of sonochemistry and acoustic cavitation;Ultrasound cavitation and its combination with other AOPs;Synergistic and antagonistic effects;Hydrodynamic cavitation and its combination with other AOPs.	**(08 Hours)**
UNIT-V	**Case study on wastewater treatment in various chemical and allied industries:** Sources; Characteristics; Methodology and processes for the treatment of industrial wastes of sugar industry, beverage industry, tannery industry, textile industry, paper and pulp mill, fertilizer industry, dye industry, oil refinery etc.; Rules and regulations for disposal of wastewater; Water reclamation and reuse.	**(08 Hours)**

Internal Assessment: Internal assessmentwill be carried out for each unit using one or combination of following:

1	Unit test: Subjective and/or MCQ
2	Surprise and/or open book test
3	Presentation/report based on recent advances in a given domain (Individual student and/or group)
4	Presentation/report related tocase study on wastewater treatment in various chemical and allied

	industries.
5	Group discussion on the topic related to various advanced wastewater treatments.
Text Books/References	
1	Metcalf & Eddy, “Waste Water Engineering Treatment & Reuse”, Tata Mc Graw-Hill, Fourth Edition, 2003.
2	Simon Parsons, Advanced oxidation processes for water and wastewater treatment, IWA Publishing, 2004.
3	C.S.Rao, “Environmental Pollution Control Engineering”, Wiley Eastern Ltd, New age international, second print 1994.
4	Jean-Pierre Franc, Jean-Marie Michel, “Fundamentals of Cavitation”, Kluwer Academic Publishers, Dordrecht.
5.	Richard W. Baker, “Membrane technology and applications”, John Wiley and Sons, Ltd.

ELECTIVE-I: NANOMATERIALS SYNTHESIS AND APPLICATIONS
Designation: Elective
Pre-requisite Courses: Basic chemistry, Physical chemistry, Mass transfer, Fluid flow operations, Chemical Engineering Thermodynamics

Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Lectures : 4 Hours/Week	End Semester Examination : 50 Marks	Theory : 04
Practical : 2 Hour /Week	Internal Assessment : 50 Marks	TW/Practical :
	Term-work (TW) :	Tutorial :
	Total : 100Marks	Total credits : 04

Course Outcomes:	
After completion of the course students would be able to:	
1	Define the importance of nanotechnology and their property optimization
2	Design the methodology for synthesis of nanomaterials
3	Determine suitable process for analysis of nanomaterials and evaluate their properties
4	Define the applications of nanomaterials and their property requirements for desired applications
5	Explain environmental issues and risks involved during nanomaterial applications and design safe pathway

Topics covered		
UNIT-I	**Introduction toNano-Materials** Importance of Nanotechnology, opportunity at the nano scale, length and time scale in structures, energy landscapes, interdynamic aspects of inter molecular forces, classification based on the dimensionality, nanoparticles, nanoclusters, nanotubes, nanowires and nanodots, semiconductor nanocrystals carbon	**(08 Hours)**

	nanotubes, influence of nano structuring on mechanical, optical, electronic, magnetic and chemical properties	
UNIT-II	**Nanomaterials synthesis** Synthesis and processing, method of nano structuredmaterial preparation – mechanical grinding, wet chemical synthesis, sol-gel processing, gasphase synthesis, gas condensation processing, chemical vapor condensation, nano compositesynthesis – processing Biological methods of synthesis: Use of bacteria, fungi, Actinomycetes for nanoparticlesynthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; S-layerproteins, Viruses as components for the formation of nanostructured materials; Synthesis processand application, Role of plants in nanoparticle synthesis	**(08 Hours)**
UNIT-III	**Analysis of nanomaterial properties** X-ray Diffraction, Thermal Analysis Methods, Differential Thermal Analysis and Differential scanning calorimetry, Spectroscopic techniques, UV-Visible Spectroscopy, IR Spectroscopy, Microwave Spectroscopy, Raman Spectroscopy, Electron Spin Resonance Spectroscopy, NMR Spectroscopy-Particle size characterization: Zeta Potential Measurement, Particle size Analysis, X-ray Photoelectron spectroscopy, Optical microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunneling Microscopy	**(08 Hours)**
UNIT-IV	**Applications of nanonaterials** Industrial applications of nanomaterials, in the areas of electronics, photonics, biology, healthand environment, medicine, defence, chemicals, catalysts, textiles, etc. Application ofnanotechnology in remediation of pollution, photocatalysis and other nanocatalysts, greenhousegases, global warming.	**(08 Hours)**
UNIT-V	**Environmental aspects and risk analysis of nanomaterials** Identification of Nano-specific risks, responding to the challenge, human health hazard, risk reduction, standards, safety, transportation of nanoparticles, emergency responders. Riskassessment, environmental impact, predicting hazard, environmental and	**(08 Hours)**

	policy making, ecotoxicitymeasurement of nanomaterials, vacuum packaging under inert gas atmosphere, methodology for stabilization, human safety in nanomaterial processing area.	

Text Books/References:	
1	P.P. Simeonova, N. Opopol and M.I. Luster, Nanotechnology - Toxicological Issues andEnvironmental Safety, Springer USA 2006.
2	Mick Wilson, KamaliKannangara, Geoff Smith, Michelle Simmons, BurkarRaguse,Nanotechnology:Basic sciences and emerging technologies, Overseas Press, 2005
3	Charles P. Poole, Frank J. Owens, Introduction to Nanotechnology‖, Wiley Interscience, USA 2003.
4	Mark A. Ratner, Daniel Ratner, Nanotechnology: A gentle introduction to the next Big Idea‖, 1st Ed. Prentice Hall P7R:USA, 2002
5	G. Cao and Y.Wang, Nanostructures and Nanomaterials: synthesis, properties and applications, 2nd Ed., World Scientific, Singapore, 2011
6	H. S. Nalwa, Encyclopedia of nanoscience and nanotechnology, American ScientificPublishers, USA 2007
7	Willard, H. H, Merritt Jr., L. L, Dean, J. A., Settle Jr., F. A, Instrumental methods of analysis, Van NostrandNew York, N.Y. USA, 2014
Internal Assesment: Below is the list of possible topics, which is for guidance faculty can design and provide relevant topics in addition to these	
1	Prepare a report on detail of Nano material, preparation, characterization, module and process design for anyone application
2	Technical interview based on knowledge of Nano technology.
3	Students have to study any five NPTEL/you-tube videos related to Nano technology and prepare/present power point presentation.
4	Group discussions on Nano science and technology related topics.
5	Prepare a report on innovations in Nano technology and their practical importance.
6	Students have to study any five research papers related to specific topic and prepare/present power point presentation
7	With the help of this subject knowledge, write a report on how you would apply your concepts in

	industry.	
8	Case study on emerging trends in process/product innovation considering nano-technology.	
9	Students have to visit chemical industry and make a detailed report on nano-technologies used in the process.	
10	Write a report on your visit to research and development laboratory of national/international repute.	
11	Write a report on nano-technologies for addressing the problems of Water and Energy.	
Syllabus for Unit Test:		
Unit Test : I	Units : I, II, and III	
Unit Test : II	UNIT : IV, V, and VI	

SEMESTER- II

MODELLING AND SIMULATION OFCHEMICAL PROCESSES					
Designation: Professional Core					
Pre-requisite Courses: Material and energy balance calculations, Fluid mechanics, Heat transfer, Mass transfer, reaction engineering, Process Control, Thermodynamics					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04Hours/Week	End Semester Examination	: 50 Marks	Theory	: 04
		Internal Assessment	: 50 Marks		
Total	: 04 Hours/Week	Total	: 100 Marks	Total Credits	: 04

Course Outcomes	
1	Estimate mass balance, energy balance and momentum balance equation for various chemical process systems.
2	Develop models for heat transfer, mass transfer and reaction engineering equipment.
3	Estimate modelstructure, estimate parameters and recognize the simulation method applicable.
4	Estimate the design of system and apply appropriate optimization method.
5	Apply novel modeling approach to chemical systems.

Topics Covered

UNIT-I	**Basics of phenomenological modelling** Introduction to modeling: systematic approach to model building, fundamentals of mathematical modeling, principles of formulations. Classification ofmodels: simple vs. rigorous, lumped parameter vs. distributed parameter, Steady state vs. dynamic, concept of degree of freedom for steady state and unsteady state systems.Fundamental laws: continuity equations, energy equation, equation of motion, transport equations, equation of state, equilibrium, chemical kinetics.	**(08 Hours)**
UNIT-II	Mathematical models of heat-transfer equipment's: heated tanks, heat exchangers, vaporizer, and jacketed vessels. Mathematical models of mass-transfer equipment's:batch and continuous distillation columns, flash drum, reactive distillation columns,packedabsorption columns. Mathematical models of reactors: batch reactors, semi-batch reactor, continuousstirred tank reactor, plug-flow reactors, reactor with axial dispersion etc.	**(08 Hours)**
UNIT-III	**Empirical model building , analysis and Simulation** Empirical model building procedure: Methods-reaction curve and statistical method, Model structure and form, parameter estimation, verification. ill-conditioned systems,lumped and distributed parameter models and their solution strategies, development of grey box models. Fundamentals of simulations: Ab-initio methods, basis sets, Hartree-Fock theory, density functional theory, geometry optimization, vibrational analysis; elementary,classical statistical mechanics, elementary concepts of temperature, ensembles andfluctuations, partition function, ensemble averaging.	**(08 Hours)**
UNIT-IV	**Optimization and design of systems** Deterministic approach; stochastic approach; Single variable optimization; Multivariable optimization; gradient based techniques; Unconstraint One Dimension Methods: Newton's Method, Quadratic Interpolation, Cubic Interpolation; Unconstraint Multiple Variable: Random search, Grid search, Simplex search, QuasiNewton method	**(08 Hours)**
UNIT-V	**Novel modeling approach** Error analysis: Terminologies related to error analysis, Formulation errors and data uncertainty, tests of significance, analysis of variance; Artificial Neural Networks (ANNs):Biological background, ANN classification, Computational	**(08 Hours)**

	properties of ANNs, Modeling a single neuron; Building blocks of feed-forward neural network: Bias, processing elements, input layer, hidden layer, output layer, learning rate, momentum, transfer function,error back propagation.	

Internal Assessment

1. Write a mathematical model for unit operation and processes involved in any specific chemical industry.
2. Collect experimental data from literature and estimate unknown parameters for chemical reactors/heat exchanger/distillation unit.
3. Unit Test subjective or MCQ
4. Solving numerical based on modelling, simulation and optimisation concept.
5. Group discussion on any industrial problem

Text Books/References

1	W. L. Luyben, “Process Modeling Simulation and Control for Chemical Engineers”, McGraw Hill, 1990.
2	R. E. G. Franks, “Modeling and Simulation in Chemical Engineering”, WielyIntrscience, NY, 1972.
3	B.V. Babu, “Process Plant Simulation”, Oxford University Press, NY 2004.
4	D. Himmelblau, K.B. Bischoff, “Process Analysis and Simulation”, John Wiley & Sons, 1968
5	M.E.Davis, Modeling and Numerical Methods in Chemical Engineering, John Wiley & Sons, 1984.
6	S. S. Tambe, B. D. Kulkarni, P. B. Deshpande, Elements of Artificial Neural Networks with Selected Applications in Chemical Engineering, and Chemical & Biological Sciences, 1st Ed., Louisville: Simulations& Advanced Controls Inc., KY 1996.
7	K. M. Hangos and I. T. Cameron, “Process Modeling and Model Analysis”, Academic Press, 2001

ADVANCED TRANSPORT PROCESSES					
Designation: Professional Core					
Pre-requisite Courses: Fluid mechanics, Heat transfer, Mass transfer					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04Hours/Week	End Semester Examination	: 50 Marks	Theory	: 04
Practical	: -Hours/Week	Internal Assessment	: 50 Marks	Practical	: -
Tutorial	: -	Term work/Practical	: -	Tutorial	: -
Total	: 04 Hours/Week	Total	: 100 Marks	Total Credits	: 04

Course Outcomes

1	Develop shell momentum balancesand velocity distributions for momentum transport in laminar flow.
2	Apply differential equations of fluid flow, interphase transport and macroscopic momentum balances for steady-state problems.
3	Developshell energy balances and temperature distribution equations in solids and in laminar flow.
4	Determine heat transfer coefficient for interphase transport in non-isothermal systems.
5	Developshell mass balances and concentration distribution equations in solids and in laminar flow.

Topics Covered

UNIT-I	**Shear stress in laminar flow:** Newtonian and non-Newtonian fluids; Rheological models; theories of transport	**(08 Hours)**

	properties of gases and liquids; effect of pressure and temperature. **One dimensional momentum transport in laminar flow (shell balance):** General method of shell balance approach to momentum transfer problems; momentum flux and velocity distribution for flow of Newtonian and non-Newtonian fluids in pipes, planes, slits and annulus; Fluid flow of two immiscible fluids.	
UNIT-II	**Differential equations of fluid flow:** Control volume approach; Differential continuity equation; Navier-Stokes Equation and Bernoulli's equation; Applications of differential equations of fluid flow **Interphase transport in isothermal system:** Friction factors for fully developed laminar, turbulent and transition flow in circular conduits; Friction factors for packed columns. **Macroscopic momentum balances:** The macroscopic mass, momentum and mechanical energy balances; Use of macroscopic balances for steady-state problems.	**(08 Hours)**
UNIT-III	**Mechanism of energy transport:** Fourier's law of heat conduction; Thermal conductivity of liquids and solids; Effective thermal conductivity ofcomposite solids. **Shell energy balances and temperature distribution in solids and in laminar flow:** Heat conduction through composite walls; Heat conduction in a cooling Fin; Forced convection; Free convection.	**(08 Hours)**
UNIT-IV	**The equation of change for non-isothermal systems:** Theequation of energy; The equation of motion for forced and freeconvection;Use of equations of change to solve the steady-state problems **Unsteady heat conduction in solids:** Heating of a semi-infinite slab; Heating of a finite slab; Unsteady heat conduction near thewall with sinusoidal heat flux **Interphase transport in non-isothermal systems:** Heat transfer coefficients for forced convection in tubes and throughpacked beds; Heat transfer coefficients for free and mixed convection; Heat transfer coefficients for condensation of pure vapors on solid surfaces.	**(08 Hours)**

UNIT-V	**Introduction of diffusivity and mechanism of mass transport:** Definitions of concentrations. Velocities and mass fluxes. Fick's law of diffusion. Temperature and pressure dependence of mass diffusivity. **Concentration distribution in solids and in laminar flow:** Shell mass balances and boundary conditions. Diffusion through stagnant gas film. Diffusion with heterogeneous chemical reaction. Diffusion with homogeneous chemical reaction.Diffusion in falling liquid film. Diffusion and chemical reactions inside a porous catalyst. **Analogies of momentum, heat and mass transfer.**	**(08 Hours)**

Internal Assessment: Internal assessmentwill be carried out for each unit using one or combination of following:

1	Unit test: Subjective and/or MCQ
2	Surprise and/or open book test
3	Presentation/report based on recent advances in a given domain (Individual student and/or group)
4	Assignment related tosolving numerical based on momentum, heat and mass transport.
5	Group discussion on the topic related to various transport processes.

Text Books/References

1	W. E. Stewart, E. N. Lightfoot, R. B. Bird, “Transport Phenomena”, John Wiley & Sons
2	J. R. Welty, C. W. Wicks, R. E. Wilson, G. Rorrer, “Fundamentals of momentum, heat and mass transfer", Wiley INDIA
3	J.C. Slattery, “Advanced transport phenomena”, Cambridge University Press
4	J. G. Knudsen, D. L. Kaz, “Fluid Dynamics and Heat Transfer", McGraw Hill

PROCESS INTENSIFICATION AND DEVELOPMENT					
Designation: Professional Core					
Pre-requisite Courses: Material and energy balance calculations, Fluid mechanics, Heat transfer, Mass transfer, Homogeneous reaction engineering					
Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04Hours/Week	End Semester Examination	: 50 Marks	Theory	: 04
Practical	: -Hours/Week	Internal Assessment	: 50 Marks	Practical	: -
Tutorial	: -	Term work/Practical	: -	Tutorial	: -
Total	: 04 Hours/Week	Total	: 100 Marks	Total Credits	: 04

Course Outcomes	
1	Estimate need and methodology for process intensification.
2	Define the reactor for process and its optimized output
3	Design and separation and recycle flow patterns for enhanced output.
4	Analyze chemical storage and handling related hazards and define and control system for handling.
5	Analyze the risk and define safe handling process, while minimizing risk.
6	Design and scale up a given process system.

Topics Covered		
UNIT-I	**Introduction to SDCP** Significance of SDCP in chemical process industry, Hierarchy of chemical	**(08 Hours)**

	processdesign: Hierarchy, approach to process design, performance. Preliminary ProcessSynthesis, Synthesis of reaction: Function of process recycle, vapor cycles andpurges, vapor verses liquid cycles, batch processes, process yield, Introduction to scale-up methods, pilot plants, models and principles of similarity.Industrial applications.	
UNIT-II	**Chemical transformation and reactors** Choice of reactor: Reaction path, types of reaction systems, reactor Continuous orBatch Processing, Chemical state, Process Operations, Synthesis Steps, SynthesisTree, Heuristics, Algorithmic Methods..	**(08 Hours)**
UNIT-III	**Process intensification, separation and recycle** Recycle structure, Recycle material balances, Reactor heat effects, Equilibrium limitations, Reactor design, Separation system, vapor recovery system,Liquid separation system, Distillation column sequencing, azeotropic systems,Residue Curves for Heterogeneous Systems.	**(08 Hours)**
UNIT-IV	**Industrial and Occupational Hazards:** Chemical hazards classification, Storage and handling of chemicals, Radiation hazards and control of exposure to radiation, Fire hazards, Types of fire and prevention methods, layout of storage, Mechanical hazards, Electrical hazards, Construction hazards, Occupational diseases and prevention methods, Instrumentation and control for safe operation, Pressure, Temperature and Level controllers, Personal protective equipments, Industrial lighting and ventilation, Industrial noise	**(08 Hours)**
UNIT-V	**Safety and Risk Management** Risk analysis techniques, hazard and operability (HAZOP) studies, hazard analysis (HAZAN), fault–tree analysis, consequence analysis, onsite and offsite emergency management plans, human and accident error analysis, economics of risk management; Economics of safety. Financial costs to individual, family, organization and society, Budgeting for safety. Safety audit – objective and procedure, audit and safety reports,Specific case studies, Factory Act. ESI Act, Environmental Act. Workmen -	**(08 Hours)**

	compensation Act, Provisions under various acts,	

Internal Assessment: Internal assessmentwill be carried out for each unit using one or combination of following:

1	Unit test: Subjective and/or MCQ
2	Surprise and/or open book test
3	Presentation/report based on recent advances in a given domain (Individual student and/or group)
4	Solution to industry oriented problem
5	Design of experiment to estimate design parameters pertaining to any one process

Text Books/References

1	Robin Smith, "Chemical Process Design and Integration", 2nd Edition, McGraw Hill, 2016
2	Gael D. Ulrich "A Guide to Chemical Engineering Process Design and Economics", John Wiley and Sons, 1984
3	Gavin Towler, Ray Sinnott, "Chemical EngineeringDesignPrinciples, Practice and Economicsof Plant and Process Design" 2ndEdition, Elsevier, 2013
4	Richard Turton, Joseph A. Shaeiwitz, Debangsu Bhattacharyya, "Analysis, Synthesis, and Design of Chemical Processes" 5thEdition, Prentice Hall, 2018.
5	Center for Chemical Process Safety, "Guidelines forImplementing Process SafetyManagement Systems", American Institute of Chemical Engineers, New York, 1994
6	Center for Chemical Process Safety of theAmerican Institute of Chemical Engineers, "Safe Design and Operation ofProcess Vents and EmissionControl Systems", Wiley Interscience, 2006
7	Warren D. Seider, Daniel R. Lewin, J. D. Seader, SoemantriWidagdo, Rafiqul Gani, Ka Ming Ng, "Product and Process Design Principles", 4th Edition, Wiley, 2017.

ELECTIVE-II : ARTIFICIAL INTELLIGENCE		
Designation: Professional Elective		
Pre-requisite Courses: Basic knowledge of Engineering Mathematics, Computer Programming		
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Lectures : 04 Hours/Week	End Semester Examination : 50 Marks	Theory : 04
Total : 04 Hours/Week	Internal Assessment : 50 Marks	Total Credits : 04
	Total : 100 Marks	

Course Outcomes	
After completion of the course students would be able to	
1	Estimate principle components for a given system/process data.
2	Estimate artificial neural network modeling parameters for chemical process.
3	Estimate genetic programming modeling parameters for chemical process.
4	Formulate problem statement of chemical engineering process using artificial intelligence.
5	Estimate economic artificial intelligence based optimization procedure for chemical process.

Topics Covered		
UNIT-I	**Introduction** Introduction to Artificial Intelligence (AI); Applications of AI to Chemical Engineering; Introduction to various AI- based formalisms; Principal component analysis; Cause and effect relationships. Black box modelling.	**(08 Hours)**

UNIT-II	**Artificial Neural Networks (ANNs)** Biological background; ANN classification; Computational properties of ANNs; Modelling a single neuron; Building blocks of feed-forward neural network: Bias, Processing elements, Input layer, hidden layer, Output layer, Learning rate, Momentum, Transfer function; Error back propagation.	**(08 Hours)**
UNIT-III	**Genetic Programming (GP)** Introduction to evolutionary algorithms; Dependent variables; Independent variables; Mathematical operators; Initial population; Candidate solution; Tree structure; Initialization; Fitness evaluation and selection; Crossover; Mutation.	**(08 Hours)**
UNIT-IV	**Evolutionary Algorithms (EA)** Introduction to stochastic evolutionary algorithms; Applications; Genetic algorithms; Particle Swarm method; Ant Colony method.	**(08 Hours)**
UNIT-V	**Applications and Case Studies** Chemical Engineering based different case studies solution using AI-based modelling and optimization formalisms	**(08 Hours)**

Assignments/Technical reports/Seminar/Case studies	
1.	Group discussions on any of the following topics: a) Role of Artificial Intelligence in Chemical Engineering b) Phenomenological, empirical and AI-based modelling c) Artificial Intelligence and Chemical Industries
2.	Make a complete chart of various AI based modeling formalisms with suitable schematics.
3.	Preparation of seminar report and oral presentation based on recent advances in Chemical Engineering with Artificial Intelligence.
4.	Students have to study any five NPTEL videos related to Artificial Intelligence and prepare/present power point presentation.
5.	Solving numerical based on core chemical engineering process problems using AI formalisms.
6.	Collect and read recent research papers on Artificial Neural Network and chemical process

	modelling and prepare summery report.
7.	Collect and read recent research papers on Genetic Programming and chemical process modelling and prepare summery report.
8.	Analyse the results for case study with Principal Component Analysis and interpret the results.
9.	Prepare question bank with appropriate answers based on the whole subject renewable energy.
10.	Enhancement in collaborative learning is done through, group assignments that will be given to encourage students to work with classmates to discuss and complete homework assignments.
*Students in a group of 3 to 4 shall complete any one project/assignments from the above list.	
Internal Assessment	
The internal assessment shall consist of case study solved using AI-based formalisms mentioned in the syllabus OR shall be based on the technical report/seminar based AI-based studies carried out by individual or small group of students.	
Text Books/References	
1	C.M. Bishop, Neural Networks for Pattern Recognition, Oxford University Press, Oxford, 1995.
2	S.S. Tambe, P.B. Deshpande, B.D. Kulkarni, Elements of Artificial Neural Networks with Selected Applications in Chemical Engineering, and Chemical & Biological Sciences, Simulation & Advanced Controls, Inc., Louisville, 1996.
3	J. Koza, Genetic Programming: On the Programming of Computers by Means of Natural Selection, MIT Press, Cambridge, M.A, 1992.
4	V. Vapnik, The Nature of Statistical Learning Theory, Springer-Verlag, New York, 1995.
5	K. Deb, Optimization for Engineering Design: Algorithms and Examples, Prentice-Hall, New Delhi, 1995.
6	D.E. Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley, Reading, MA, 1989.

ELECTIVE-II : WASTE TO ENERGY CONVERSION

Designation: Professional Core

Pre-requisite Courses: Basic knowledge of Chemical Process Industry, Energy engineering

Teaching Scheme		**Examination Scheme**		**Credits Allotted**	
Lectures	: 04Hours/Week	End Semester Examination	: 50 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 50 Marks	Total Credits	: 04
		Total	: 100Marks		

Course Outcomes

1	To enable students to understand of the concept of Waste to Energy. .
2	To link legal, technical and management principles for production of energy form waste.
3	To learn about the best available technologies for waste to energy.
4	To analyze of case studies for understanding success and failures for different industries.
5	To facilitate the students about centralized and decentralized energy plants.
6	To analyze the environmental implication.

Topics Covered

UNIT-I	**Introduction** The Principles of Waste Management and Waste Utilization. Waste Management Hierarchy and 3R Principle of Reduce, Reuse and Recycle. Waste as a Resource and Alternate Energy source.	**(08 Hours)**
UNIT-II	**Waste Sources & Characterization** Waste production in different sectors such as domestic, industrial, agriculture, postconsumer, waste etc. Classification of waste – agro based, forest residues,	**(08 Hours)**

	domestic waste, industrial waste (hazardous and non-hazardous). Characterization of waste for energy utilization. Waste Selection criteria.	
UNIT-III	**Technologies for Waste to Energy Biochemical Conversion** Energy production from organic waste through anaerobic digestion and fermentation. Thermo-chemical Conversion – Combustion, Incineration and heat recovery, Pyrolysis, Gasification; Plasma Arc Technology and other newer technologies.	**(08 Hours)**
UNIT-IV	**Waste to Energy Options** Landfill gas, collection and recovery. Refuse Derived Fuel (RDF) – fluff, briquettes, pellets. Alternate Fuel Resource (AFR) – production and use in Cement plants, Thermal power plants and Industrial boilers. Conversion of wastes to fuel resources for other useful energy applications.	**(08 Hours)**
UNIT-V	**Centralized and Decentralized Waste to Energy Plants** Waste activities – collection, segregation, transportation and storage requirements. Location and Siting of 'Waste to Energy' plants. Industry Specific Applications – In-house use – sugar, distillery, pharmaceuticals, Pulp and paper, refinery and petrochemical industry and any other industry. Centralized and Decentralized Energy production, distribution and use. Comparison of Centralized and decentralized systems and its operations. Carbon Credits: Carbon foot calculations and carbon credits transfer mechanisms. Indian Scenario on Waste to Energy production distribution and use in India.	**(08 Hours)**

Internal assessment

1	Understand physical and chemical analysis of municipal solid wastes and apply them for a management system that will be set up.
2	Analyze the various aspects of Waste to Energy Management Systems.
3	Design a compost facility, incineration facility and make site selection for a landfill.
4	Explain the hierarchical structure in solid waste management and a requirement for an integrated solution.
5	Implement the concept of waste to energy for any one industry and make a detail report.
6	Design a Gasifier and understand operational aspect of a typical Gasifier.
7	Design a biomass Combustor and understand operational aspect of a biomass Combustor.

8	Design a Biogas plant and understand the operational aspect of a Biogas plant.
9	Report on Energy production from organic wastes through anaerobic digestion.
10	Study energy production from algae.
11	Environmental standards for Waste to Energy Plant operations.
12	Understand physical and chemical analysis of municipal solid wastes and apply them for a management system that will be set up.
Te1xt Books/References	
1	K.C.Khandelwal, S.S. Mahdi "Biogas Technology - A Practical Hand Book", Vol. I & II Tata McGraw Hill Publishing Co. Ltd., 1983.
2	D.S.Challal, "Food, Feed and Fuel from Biomass", IBH Publishing Co. Pvt. Ltd., 1991.
3	K.L.Shah, "Basic of Solid and Hazardous Waste Management Technology", Prentice Hall, Reprint Edition, 2000.
4	D.Edgard,A.Mercier, "Energy Recovery", Nova Science Publishers,2009.
5	W.A.Worrell, P.A. Vesilind, "Solid Waste Engineering", Cengage Learning, 2012.
6	G. Tchobanoglous,H.Theisen,S.A.Vigil, "Integrated Solid Waste Management", Mc Graw Hill Publishing Co. Ltd., 1993.
7	P. Basu, "Biomass Gasification and Pyrolysis", , Academic Press/ElsevierInc, 2010.
Syllabus for Unit Tests	
Unit Test I	Units I, II, and III
Unit Test II	Units IV, V, and VI