M. Tech. (Chemical Engineering)

Department of Chemical Engineering

School of Technology, PDEU, Gandhinagar

Pandit Deendayal Energy University, Gandhinagar
School of Technology
Department of Chemical Engineering

VISION

To impart quality education in an industry research driven modules to motivate the young chemical engineers for creating knowledge wealth to help generate employability following professional ethics and focus towards a sustainable environment and benefits to the society.

Mission

- To facilitate the chemical engineering students with the state-of-the-art facilities with focus on skill development, creativity, innovation and enhancing leadership qualities.
- To nurture creative minds thru' mentoring, quality teaching & research for building a value based sustainable society.
- To work in unison with the national and international level academic and industrial partners by venturing into collaborations to tackle problems of bigger interest to society.
- To build an encouraging environment for the young faculties and staff by providing safe work culture, transparency, professional ethics and accountability that will empower them to lead the department in right spirit.
- To inculcate the culture of continuous learning among the faculties by encouraging them to participate in a professional development programs and envisage to address the social, economic and environmental problems.

Pandit Deendayal Energy University, Gandhinagar
School of Technology
Department of Chemical Engineering

Program Education Objectives (PEOs)

- Acquire the fundamental principles of science and chemical engineering with modern experimental and computational skills.
- Ability to handle problems of practical relevance of society while complying with economical, environmental, ethical, and safety factors.
- Demonstrate professional excellence, ethics, soft skills and leadership qualities.
- Graduates will be active members ready to serve the society locally and internationally.

Semester I

Sr. No	Course Code	Course Name	Teaching Scheme					Exam Scheme					
			L	T	P	C	Hrs/ wk	Theory			Practical		Total Marks
								MS	ES	IA	LW	LE	
1	20MA 503T	Advanced Numerical Techniques and Computer Programming	3	1	0	4	4	25	50	25	--	--	100
2	20MA 503P	Advanced Numerical Techniques and Computer Programming Lab	0	0	2	1	2	--	--	--	50	50	100
3	20CH 501T	Advanced Transport Phenomena	3	0	0	3	3	25	50	25	--	--	100
4	20CH 502T	Advanced Chemical Reaction Engineering	3	0	0	3	3	25	50	25	--	--	100
5	20CH 503T	Advanced Chemical Engineering Thermodynamics	3	0	0	3	3	25	50	25	--	--	100
6	20CH 504P	Advanced Chemical Engineering Lab	0	0	4	2	4	--	--	--	50	50	100
7	20CH 50X	Elective-I	3	0	0	3	3	25	50	25	--	--	100
Total			15	1	6	19	22	125	250	125	100	100	700

Code	Elective Basket (1st Sem)
20CH505	Advanced Separation Technology
	Renewable & Non-Renewable Energy
20CH 507	Chemical Process Synthesis

20MA 501T					ADVANCED NUMERICAL TECHNIQUES					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	1	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

1. To understand and acquaint the concept of various numerical methods.
2. To develop numerical skills in solving problem of engineering interest.
3. To enrich the concept of finite element techniques.
4. To extract the roots of a polynomial equation.

UNIT 1 EIGEN VALUES EIGEN VECTORS AND INTERPOLATION 10 Hrs

Eigen values and eigen vectors: Numerical evaluation of largest as well as smallest (numerically) Eigen values and corresponding Eigen vectors. Interpolation: Introduction, Newton Gregory Forward Interpolation Formula, Newton Gregory Backward Interpolation Formula, Central difference interpolation formula, Lagrange's Interpolation Formula for unevenly spaced Formula, Error in interpolation, Newton's Divided Difference Formula, cubic spline interpolation, surface interpolation.

UNIT 2 NUMERICAL SOLUTION NON LINEAR EQUATIONS AND POLYNOMIAL 8 HRS

Introduction, Solution of non linear simultaneous equations, Descarte's Sign rule, Horner's method, Lin-Bairstow's method, Graeffe's root squaring method, Muller's method, Comparison of various methods.

UNIT 3 NUMERICAL SOLUTION OF ODEs AND PDEs 14 HRS.

Taylor's method, Euler's method, Runge-Kutta methods of various order, Modified Euler's method, Predictor corrector method: Adam's method, Milne's method. Solution of Boundary value problems using finite differences. Finite difference approximation of partial derivatives, Classification of 2nd order PDEs, different type of boundary conditions, solutions of Elliptic, parabolic and hyperbolic equations of one and two dimensions, Crank- Nicholson method, ADI method.

UNIT 4 FINITE ELEMENT METHOD 8 HRS.

Introduction, Method of Approximation, The Rayleigh-Ritz Method, The Galerkin Method, Application to One dimensional and two dimensional problems.

40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – To apply a suitable numerical technique to extract approximate solution to the problem whose solution cannot be obtained by routine methods.

CO2 - To estimate the errors in various numerical methods.

CO3 - To analyse/ interpret the achieved numerical solution of problems by reproducing it in graphical or tabular form.

CO4 - To approximate the data generated by performing an experiment or by an empirical formula with a polynomial on which operations like division, differentiation and integration can be done smoothly.

CO5 - To evaluate a sufficiently accurate solution of various physical models of science as well as engineering interest whose governing equations can be approximated by nonlinear ODEs or PDEs or system of ODEs or PDEs.

CO6 - To design/ create an appropriate numerical algorithm for various problems of science and engineering.

TEXT/REFERENCE BOOKS

1. B.S. Grewal, Numerical Methods in Engineering and Science with Programs in C & C++, Khanna Publishers (2010).
2. S.S. Sastry, Introductory Methods for Numerical Analysis, 4th Ed., Prentice Hall of India (2009).
3. M.K. Jain, S.R.K. Iyenger and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, 5th Ed., New Age International (2007).
4. C F Gerald and P O Wheatley, Applied Numerical analysis, Pearson education, 7th edition, 2003.
5. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley publication, 9th edition. 2005
6. R.K. Jain & S.R.K. Iyenger, Advanced Engineering Mathematics, 3rd Ed., Narosa (2002).
7. S C Chapra, Raymond P. Canale, Numerical Methods for Engineers, Tata McGraw Hill Pub. Co. Ltd.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A : 4 questions of 6 marks each 24 Marks (40 min)

Part B: 4 questions of 10 marks each 40 Marks (80 min)

Part C: 3 questions of 12 marks each 36 Marks (60 min)

20CH501T					Advanced Transport Phenomenon					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To make understand the basic and fundamental concepts of various transport processes in chemical engineering
2. To analyze various transport processes with understanding of solution approximation methods and their restrictions
3. Application of different correlations used in momentum, heat and mass transfer problems to solve chemical engineering problems

UNIT 1 Vectors And Tensors 7 Hrs.

Introduction: Vectors And Tensors, Conservation Principles, Eulerian &Lagrangian Observers. Equations Of Change. Integral and Differential Forms, Newtonian &Non-Newtonian Fluids

UNIT 2 Momentum Transport 14 Hrs.

Momentum Transport Mechanisms, Laminar flow between plate's, velocity profiles, shear stress & pressure drop in steady flow, Time smoothed equations for turbulent flow. Boundary layers flow past bodies

UNIT 3 Energy Transport 11 Hrs.

Energy Transport Mechanisms, Laminar flow temperature profiles - the Graetz problem.Steady and unsteady free convection, Boundary layers, Time smoothed equations and analogy with turbulent flow momentum transfer

UNIT 4 Mass transport 10 Hrs.

Mass transport mechanism: Diffusion; Constitutive Laws: Diffusion Flux Laws/ Coefficients, general constraints, Laminar flow concentration profiles. Steady and unsteady convective mass transfer, Diffusion in gases and liquids.

Max. 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Recall the knowledge in vector calculus and numerical methods and define the momentum, energy and mass fluxes in various coordinate system and their individual components

CO2 - Explain the mechanisms for momentum transfer for various flow systems and show how these mechanisms influence heat and mass transfer.

CO3 - Application of shell balance methods and develop modeling thoughts to solve fundamental transport equations including non-steady state equations of momentum, energy and mass transport in terms of flux quantities>

CO4 - Analyze and simplify various equations of change developed in shell balance equations of momentum, energy and mass transport

CO5 -Recommend boundary conditions and mathematical techniques to solve equations of change involving momentum, energy and mass transport

CO6 - Formulate the dimensionless groups and develop correlations to analyze and solve various transport problems

TEXT/REFERENCE BOOKS

1. R. B. Bird, W. E Stewart, and E. N. Lightfoot, Transport Phenomena, Edition-2 John Wiley, 2007
2. J. Welty, G. L. Rorrer, D. G. Foster, 'Fundamentals of Momentum, Heat, and Mass Transfer', Revised 6th Edition, Wiley, 2014
3. J R Backhurst, J H Harker, J.F. Richardson, and J.M. Coulson, 'Chemical Engineering Volume 1: Fluid Flow, Heat Transfer and Mass Transfer', 6th Edition, Butterworth-Heinemann, 1999.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: <Question with no choice> <25> Marks

Part B/Question: <Questions based on units with choice> <75> Marks

20CH502T					**Advanced Chemical Reaction Engineering**					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To develop understanding of non ideal reactor design.
2. Understand the concept of heterogeneous reaction system for reactor design.
3. Study Complex heterogeneous chemical reaction mechanisms and kinetics
4. Reactor design and stability, including consideration of multiple steady states using non isothermal energy balance

UNIT 1 Non ideal and non-isothermal reactor study 10 Hrs.

Review of isothermal and Adiabatic reactor design. Steady and unsteady state operations. Heat effects. Concept of multiple study state in CSTR. Homogeneous reactor design and analysis for non ideal reactors. Residence time distributions (RTD) studies. Single and multi parameter models for real reactor behavior, macro and micro mixing, segregated flow model

UNIT 2 Heterogeneous reactor studies 10 Hrs.

Heterogeneous reactors-gas-solid systems-Reviews of kinetics of gas-solid catalytic reactions with and without diffusion limitations. Solid catalysts and theirs application in reactor design for fixed and fluidized bed reactors.

UNIT 3 Study of gas liquid reactive systems 10 Hrs.

Design for non catalytic gas-liquid reactions. Review of kinetic regimes in reactor design, case studies. Gas-liquid systems, basic theories of mass transfer with chemical reaction. Reactor design for mechanically agitated and bubble column reactors, selected case studies

UNIT 4 Development of Research Methodology 10 Hrs.

Bio Chemical Reaction and Bio reactors: Enzyme Fermentation, microbial fermentation, substrate-limiting and product limiting Microbial fermentation. Bio-reactor design.

Max: 40 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Understanding and analyzing various Non-ideal reactors using RTD studies.

CO2 - Conversion predictions and design by applying Non ideal models using zero, single and multiparameter models

CO3 - Study and comparison of non-iosthermal reactors using overall energy balance equations.

CO4 - Analyzing and evaluate the mechanisms of heterogeneous and multiphase reaction studies with various rate limiting steps.

CO5 - Design of a reactor for homogeneous and heterogeneous reactions using modeling tools like MATLAB/ASPEN.

CO6 - Understand biochemical reactions and with qualitative comparison with non-biological chemical reactions.

TEXT/REFERENCE BOOKS

1. Rawlings J.B. and Ekerd, J.G., Chemical Reactor Analysis and Design Fundamentals Nole. Hill 2002
2. Scot Foggler, H, Elements of Chemical Reaction Engg – PHI- 4th Edition- 2005.
3. Carberry, J.J. Chemical and Catalytic reaction engineering, Doven Publishers, 2001
4. O. Levenspiel,"Chemical Reaction Engineering" WilleyEastern,3rd Ed., 2000

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question1: Non-ideal reactors using RTD studies <> Marks

Part A/Question2: Conversion predictions and design by applying Non ideal model <> Marks

Part A/Question3: ccomparison of non-iosthermal reactors using overall energy balance equations <> Marks

Part A/Question4: Mechanisms of heterogeneous and multiphase reaction studies <> Marks

Part A/Question5: Biochemical reactions and with qualitative comparison with non-biological chemical reactions <> Marks

20CH 503					Advanced Chemical Engineering Thermodynamics- M.Tech					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To learn and apply the group contribution methods for the estimation of physical and thermodynamic properties of pure components/mixtures.
2. To learn and apply phase equilibrium models with ideal and non-ideal conditions.
3. To learn and predict various models and theories for multi component phase equilibrium.
4. To gain knowledge of excess functions and statistical thermodynamics.

UNIT 1 The estimation of physical properties 10 Hrs.

Application of molecular thermodynamics to estimate physical properties. Pure component constants, Group contribution methods for estimation of pure component constants. Availability of data and computer software. Estimation of thermodynamics properties (ΔG and ΔH) of ideal gases>

UNIT 2 Fluid phase equilibria in binary solution 10 Hrs.

Ideal Vapour-liquid Equilibrium models, Raoult's law and Henry's law, PVT relationship of fluid mixtures. Redlich-Kwong-Soave and Peng-Robinson equation of state, excess functions, Fugacity and activity coefficients: Gibbs-Duhem Equation: The $\gamma - \varphi$ approach of Phase equilibrium models.

UNIT 3 Multicomponent phase equilibrium 10 Hrs.

Fluid phase equilibria in multi component system: Vapor liquid equilibrium models using equations of state and activity coefficient approach. excess free energy-based mixing rules; Theories of solutions; Liquid models with special emphasis on NRTL, UNIQUAC and UNIFAC theories>

UNIT 4 Statistical and molecular thermodynamics> 10 Hrs.

Fundamental concepts of statistical mechanics: Micro-canonical ensemble, canonical ensemble, ensemble averages, Maxwell-Boltzmann distribution, Partition function, Application of Statistical Thermodynamics to gas mixture and solutions.

Max. 40 Hrs.

COURSE OUTCOMES: On completion of the course, student will be able to

CO1 - Analyze and estimate physical properties of compounds applying Group contribution methods.
CO2 - Analyze and evaluate the ideal phase equilibrium models.
CO3 - Solve phase equilibrium problems using the $\gamma - \varphi$ approach.
CO4 - Demonstrate theories of solution and activity coefficient models.
CO5 - Derive various solution thermodynamics relations, excess functions, fugacity and activity.
CO6 - Demonstrate and apply statistical thermodynamics to entropy and other properties.

TEXT/REFERENCE BOOKS

1. R.C. Reid, J.M. Prausnitz and B.E. Poling, Properties of Gases and Liquids, 4th ed., McGraw-Hill, 1987
2. INTRODUCTION TO CHEMICAL ENGINEERING THERMODYNAMICS, 8th Edition by J. M. Smith, H. C. Van Ness, M. M. Abbott, M. T. Swihart: McGraw-Hill Education, 2 Perm Plaza, New York, NY 10121
3. Terrell L. Hill, Statistical Mechanics: Principles and Selected Applications, Dover Publications, 1987

20CH504P					Advanced Chemical Engineering Lab					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	4	2	4	00	00	00	50	50	100

COURSE OBJECTIVES

1. To understand various experiment and methods related with Chemical Engineering.
2. To understand the limitations of the various synthesis techniques.
3. To understand various mathematical software related with Chemical Engineering.
4. To understand the use of Matlab, Polymath and GAMS.

List of experiments:

Experimental Lab:-

1. To study the FTIR Techniques.
2. To study the gas separation techniques using GC-MS.
3. Synthesize copper oxide nanoparticles by sol-gel method and determine the average size of nanoparticles using Particle Size Analyzer.
4. To study Ball milling route for making nanoparticles and particle size distribution estimation.
5. To study Microwave assisted synthesis of ZnO nanoparticles.
6. To Synthesis and Characterization of carbon nanotubes by cracking of gas mixture
7. Fabricate silver nanoparticles embedded in silica glass by ion exchange method and study surface Plasmon resonance using UV-visible spectroscopy.
8. Fabricate copper nanoparticles embedded in silica glass by ion exchange method and determine the size of nanoparticles using optical absorption spectroscopy.
9. Fabrication of suitable structures on thin films for device applications.
10. To investigate refluxing and distillation techniques for synthesis of II-VI ceramic nanostructures.
11. To study solvothermal synthesis method of nanoparticles

Software Lab:-

1. Introduction to Matlab
2. Linear regression in Matlab
3. Use and practice of CFTOOL in Matlab
4. Solution of single and multiple differential equations in Matlab
5. Use and practice of toolboxes such as Neural network, Simulink, System identification, Optimization, etc
6. Solution of bracketing and non-bracketing problems in Matlab
7. Introduction to Polymath and Solution of algebraic equations in Polymath
8. Solution of nonlinear and differential equations in Polymath
9. Introduction to GAMS
10. Linear Programming in GAMS
11. Comparison of results of optimization problems in GAMS and Matlab

20CH505T					Advanced Separation Technology					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To gain knowledge of membrane separation processes.
2. To gain knowledge of adsorption and ion exchange processes and study adsorption equilibrium and isotherms for different type of systems.
3. To gain knowledge of ionic liquid as separation media.

UNIT 1 Introduction 2 Hrs.

Fundamentals of separation processes, Separation factor, various separation processes.

UNIT 2 Membrane Separation 13 Hrs.

Membrane separation processes, materials, module design and characteristics, Pressure driven membrane processes, ion exchange techniques and operation, Gas separation, mixing model for gas separation, cross flow model, single stage membrane separation, multistage membrane separation, differential permeation with point permeate withdrawal.

UNIT 3 Adsorption 13 Hrs.

Introduction, Adsorption isotherms. Single-stage and multi-stage, Cross-current and counter current operations, Equilibrium and operating lines, Liquid-solid agitated vessel, Packed continuous contactor, Rate equations for non-porous and porous adsorbents, Non-isothermal operation, pressure-swing adsorption, Principles of ion exchange, Analogy between adsorption and ion exchange.

UNIT 4 Ionic Liquid 12 Hrs.

Room Temperature Ionic liquids (RTIL), Physico-chemical properties of RTIL, reactivity, solvating power, Ionic Liquids as advanced materials in analytical separations, absorption/adsorption, membrane separations; Applications of Ionic Liquids in biotechnology and bio-refining, Chemicals and petrochemicals, CO_2- separation, Environmental remediation, Waste treatment.

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Define the principle of separation processes.

CO2 – Explain the knowledge of separation processes.

CO3 –Identify the separation process in the given condition.

CO4 – Analyze the problems related to separation processes.

CO5 – Determine the separation under desired condition.

CO6 –Design module for separation processes like membrane, adsorption.

TEXT/REFERENCE BOOKS

1. R. Rautenbach, and R. Albercht, Membrane Processes, John Wiley & Sons,(1994)
2. Simon Judd., Principles and Applications of Membrane Bioreactors for Water and Wastewater Treatment, Elsevier, 9780080465104, 2011
3. Scott T. Handy, Application of Ionic liquids in Science and Technology, InTech Publication, ISBN 978-953-307-605-8, 2011
4. Elsa Lundanes, Leon Reubsaet, Tyge Greibrokk, Chromatography: Basic Principles, Sample Preparations and Related Methods, Wiley-VCH , 2014, ISBN: 978-3-527-33620-3

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: <Details> <> Marks

Part B/Question: <Details> <> Marks

Course Code					Renewable and Non-Renewable Energy					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	-	-	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To impart knowledge on classification of energy sources and their environmental aspects
2. Learn the present energy scenario and concept of sustainable energy
3. Explain the concept of various forms of renewable energy and discuss the scientific principles underpinning the sustainable conversion of energy
4. To impart problem oriented in depth knowledge of renewable energy sources

UNIT 1:ENERGY CLASSIFICATION AND NON-RENEWABLE ENERGY 10 Hrs

Global & National energy scenarios, Interrelationship between energy and environment, Energy classification- Primary & Secondary energy, commercial & non-commercial energy, non-renewable & renewable energy, primary energy resources, commercial energy production, energy conservation and its importance Non-Renewable energy and their impact on the ecology, Key factors in the exploitation, production and use. Forms & characteristics of renewable energy sources.

UNIT 2:SOLAR ENERGY 10 Hrs

Principles of solar radiation - Origin, nature and availability of solar radiation, estimation of solar radiation, solar geometry, and heat transfer considerations relevant to solar energy.Solar energy collection - Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis. Solar energy storage and applications - Sensible, latent heat and stratified storage, solar ponds. Solar Applications- solar heating/cooling technique, solar distillation and drying, Photovoltaic energy conversion, p-n junction, solar cells, PV systems, Stand-alone, Grid connected solar power

UNIT 3: WIND, HYDRO AND GEOTHERMAL ENERGY 10 Hrs

Principle of wind energy conversion, basic components of wind energy conversion systems - Lift and Drag– Effect of density, frequency variances, angle of attack, and wind speed - design considerations of horizontal and vertical axis wind machines - analysis of aerodynamic forces acting on wind turbine blades and estimation of power output - wind data and site selection considerations. Principles of working, lay out, Site selection classification and arrangement of hydroelectric plants, run off size of plant and choice of units, operation and maintenance, hydro systems, and interconnected systems. Geothermal Energy - nature of geothermal energy, resources like hydrothermal, geo-pressured hot dry rock, magma. Advantages, disadvantages and application of geothermal energy, prospects of geothermal energy in India.

UNIT 4: OTHER RENEWABLE ENERGY SOURCES 12 Hrs

Biogas - Principles of Bio-Conversion, types of Bio-gas digesters, gas yield, combustion characteristics of bio-gas, utilization for cooking, Biomass gasification - Biomass conversion technologies, Constructional details of gasifier, Biofuels - Introduction and perspective of biofuels, biofuel production and applications, environmental impact of biofuel, Biofuel operated I.C. Engine operation and economic aspects. Energy from Ocean – Basic cycles of Ocean Thermal Energy Conversion, basic principle of tidal power, wave energy conversion devices. Fuel Cells - Introduction, Design principle and operation of fuel cell and its types, conversion efficiency of fuel cell, application. Hydrogen Energy - Introduction, Hydrogen Production methods, Hydrogen storage, hydrogen transportation, hydrogen as alternative fuel for vehicles.

Max : 42 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1: Define different forms of energy and list advantages and disadvantages of different sources of energy
CO2: Understand the principles of solar radiation, its availability at various locations and extend the knowledge to different applications
CO3: Develop knowledge to harness energy from different sources for various applications like heating, cooling, water distillation, electricity etc. and model their performance.
CO4: Analyse and compare different energy sources and their impacts
CO5: Interpret the suitability and determine the best possible energy resource for a particular location
CO6: Design and develop innovative methods to harness energy and propose sustainable solutions.

TEXT/REFERENCE BOOKS

1. Sukhatme, S.P. and Nayak, J.K., 2017. Solar energy. McGraw-Hill Education
2. Duffie, J.A., Beckman, W.A. and Worek, W.M., 2013. Solar engineering of thermal processes (Vol. 3). New York: Wiley
3. Kothari, D.P., Singal, K.C. and Ranjan, R., 2011. Renewable energy sources and emerging technologies. PHI Learning Pvt. Ltd.

20CH507					Chemical Process Synthesis (Elective)					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES
1. To understand the basics of chemical process development and approach to process design.
2. To know about the type of reactor and its performance.
3. Learn to understand choice of separator and distillation sequencing.
4. To understand the various safety and health considerations.

Unit I: Introduction to Chemical Process Design 9 hrs
Introduction, approach to process development, development of new process, different considerations, development of particular process, overall process design, hierarchy of process design, onion model, approach to process design.

Unit II: Choice of Reactor 10 hrs
Reaction path, types of reaction systems, reactor performance, idealized reactor models, reactor concentration, temperature, pressure, phase, catalyst.

Unit III: Choice of Separator and distillation sequencing 12 hrs
Separation of heterogeneous mixtures, separations of homogeneous mixtures, distillation, azeotropic distillation, absorption, evaporation, drying etc. Distillation sequencing using simple columns, heat integration of sequences of simple distillation columns, distillation sequencing using thermal coupling.

Unit IV: Safety and Health considerations 9 hrs
Fire, explosion, toxic release, intensification of hazardous materials, attenuation of hazardous materials, quantitative measures of inherent safety, overall safety and health considerations.

COURSE OUTCOMES
On completion of the course, student will be able to
CO1: List out various new chemical process developments.
CO2: Outline the hierarchical approach to conceptual process design.
CO3: Apply the concept for choice of reactor, reaction systems and reactor performance.
CO4: Categorize the various separation process for homogeneous and heterogeneous mixtures
CO5: Recommend distillation sequencing using simple columns, heat integration and thermal coupling.
CO6: Adopt various quantitative measures of inherent safety, overall safety and healthconsiderations.

TEXT/REFERENCE BOOKS
1. Chemical process design- Robin Smith, Wiley.
2. Conceptual design of chemical process-James Douglas, McGraw Hill Book Company.
3. Unit process in organic synthesis – P.H. Groggins, Tata McGraw Hill Publishing Company Ltd.
4. Dryden’s Outline of Chemical Engineering, Rao and M Gopala, East-WestPress.

SEMESTER II			M.TECH. CHEMICAL ENGINEERING										
Sr. No	Course Code	Course Name	Teaching Scheme					Exam Scheme					
			L	T	P	C	Hrs/ wk	Theory			Practical		Total
								MS	ES	IA	LW	LE	Marks
1	20CH 508T	Computer Aided Process Engineering	3	0	0	3	3	25	50	25	--	--	100
2	20CH 508P	Computer Aided Process Engineering Lab	0	0	4	2	4	--	--	--	50	50	100
3	20CH 509T	Advanced Process Control	3	0	0	3	3	25	50	25	--	--	100
4	20CH 510T	Unit Operations and Processes in Environmental Engineering	3	0	0	3	3	25	50	25			100
5	20CH 51X	Elective II	3	0	0	3	3	25	50	25	--	--	100
6	20CH 51X	Elective III	3	0	0	3	3	25	50	25	--	--	100
7		Intellectual Property Rights (IPR)	2	0	0	2	2	--	--	--	50	50	100
8	CE 527T	Successful Research Program Development	2	0	0	Au	2	--	--	--	--	--	NP/PP
Total			19	0	4	19	23	125	250	125	100	100	700

Code	Elective Basket (2nd Sem)
20CH 511	Nano-science and Energy Storage
20CH 512	Modeling and Simulation
20CH514	Colloids and Interfacial Science and Engineering
20CH506	Advanced Biochemical Engineering
	Computational Fluid Dynamics
20EN518T	Carbon Sequestration and Clean Development Mechanism

20CH508T16					Computer Aided Process Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To learn about the usage and role of computer tools for integrated process plant engineering.
2. To provide the students with a clear understanding of what is process simulation & process optimization using commercial software (Aspen/Hysis).
3. To solve practical problems commonly encountered in process engineering.
4. To learn how the use of computer aided tools will play an important role in life

UNIT 1 Integrated Chemical-Process Design: CAPE Perspectives 10 Hrs.

Introduction to Process Plant Design and Simulation: hierarchy levels, depth, and basic steps; components in a simulation package. CAPE problem formulation, Steady-state sequential modular and equation-oriented approach: decomposition of networks; Tearing algorithms, Sensitivity analyses, Design specifications.

UNIT 2 Databases and modelling in Thermophysical properties 10 Hrs.

Thermodynamic property estimation, methods and models in process simulations: Property data requirements and input, Physical property analysis, EOS and activity coefficient models, Data regression and estimation of parameters. Stream and block parameters, recycle convergence algorithms, Dynamic simulation.

UNIT 3 Equipment and Process Design 9 Hrs.

Separation equipment, distillation and absorption design, Azeotropic distillation using pressure swing, Heat exchangers: design, rating and simulation, ideal and non-ideal reactors, Pressure changers, case studies, Ammonia process, petroleum refining process, etc.

UNIT 4 Process Energy analysis and Economic evaluation 11 Hrs.

Process Energy integration, identifying energy and greenhouse gas reduction in the design process, Heat Exchanger Network Diagram and Composite Curves. Pinch analysis. Process Economic Analysis: Costing Options and Utilities, Mapping Unit Operations, Sizing and Evaluating for CAPEX and OPEX, case studies>

Max. 40 Hrs.

COURSE OUTCOMES: On completion of the course, student will be able to

CO1 - Understand, create, select, and Describe computer tools for chemical process Engineering>

CO2 – Examine and explain thermodynamic properties estimation using computer tools>

CO3 - apply stream and block parameters to a chemical unit operation for computer aided simulation>

CO4 - solve process design and simulation calculations of various processes using Aspen software with cost>

CO5 – determine process simulation with economic analysis using Aspen software >

CO6 – Outline process energy analysis and construct Heat exchanger networks.

TEXT/REFERENCE BOOKS

1. Chemical Process Design and Simulation: Aspen Plus and Aspen Hysys Applications by Juma Haydary, 2019 John Wiley & Sons, Inc.
2. Computer Aided Process & Product Engineering, Dr. Luis Puigjaner, 2006, WILEY-VCH Verlag GmbH & Co
3. Aspen documentation and manuals, Aspen Tech

20CH508P					Computer Aided Process Engineering Lab					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	4	2	4				50	50	100

COURSE OBJECTIVES

1 to learn and apply appropriate modern software tool (Aspen plus/ hysis simulator) including modelling to complex chemical engineering processes with an understanding of the limitations.
2. Identify the components of physical and thermodynamic property models and Learn software aspects of rapid solution.
3 Learn application and solve chemical process flow sheeting problems more quickly, efficiently and successfully using computer aided tools
4. Learn concepts of process integration and to solve heat exchanger network problems.

Process Simulation Exercises Using Aspen Plus:

1. Construct a simulation sheet with process blocks and streams
2. Physical property estimation, Critical properties, ΔH, ΔG etc.
3. Thermodynamic property estimation and analysis, T-xy, P-xy and xy diagrams
4. Data Regression, Vapour-liquid equilibrium data, Flash separation, dew point, bubble point,
5. Mass and Energy balances calculations in Aspen platform
6. heat exchangers, design, rating, calculation with TEMA specification
7. Thermal analysis, simulation of heat exchanger
8. Process simulations of reactors
9. Design and Simulation of distillation and absorption column,
10. Azeotropic distillation using pressure swing distillation
11. Costing and economic analysis; (case study: ammonia production process)
    - Open loop process
    - Closed loop process
12. Dynamic simulation of a reactor
13. Solving Heat exchanger network

COURSE OUTCOMES: On completion of the course, student will be able to

CO1 - Estimate, physical and thermodynamic properties of new organic compounds.
CO2 –Estimate and list mass and energy balance of a process flow sheet using Aspen plus.
CO3 –Construct thermodynamic phase diagrams using activity coefficient and Equation of state models using computer simulation.
CO4 - determine flow sheeting solution by using design specification and sensitivity analysis approach.
CO5 - solve process design and simulation calculations of various unit operations using Aspen software.
CO6 – demonstrate Heat exchanger networks using Aspen Process simulators.

TEXT/REFERENCE BOOKS

1. Chemical Process design and Simulation by Juma Haydary, 2019 John Wiley &sons, Inc
2. Aspen Plus: All Manuals and PDF documents

20CH509T					Advanced Process Control					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. Introduce the student to grey and black-box modelling.
2. To provide understanding of Kalman filering.
3. Provide knowledge of Stability conditions and pole-placement methods.

UNIT 1 Introduction 10 Hrs.

Basic control theory, transfer function, poles and zeros, stability conditions, P,PI, PID controllers, Controller tuning.

UNIT 2 Development of Mechanistic models 12 Hrs.

State-space modeling, transfer function matrix, Introduction to discrete systems and sampling, state-space models for discrete systems, Grey box models.

UNIT 3 Stability analysis 8 Hrs.

Contrast between stability of continuos and discrete time systems. Use of Z-transforms, Lyapunov Functions, State Estimation and Kalman Filtering.

UNIT 4 Control Actions 10 Hrs.

Linear Quadratic Optimal Control and Model Predictive Control, Pole Placement, State Feedback Control Design and Introduction to Linear Quadratic Gaussian (LQG) Control.

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Highlighting basic control theory with all of its components.
CO2 - Comparing and contrasting continuous time and discrete time processes.
CO3 - Implementing Laplace and Z transforms to various types of control systems
CO4 - Estimating Grey and black box models from data.
CO5 - Predicting full state using Kalman filtering.
CO6 - Building different control techniques.

TEXT/REFERENCE BOOKS

1. K.J. Åström and B. Wittenmark, Computer-Controlled System – Theory and Design.
2. NPTEL Course on Advanced Process Control by Prof. Sachin Patwardhan.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: Problems with multiple questions each carrying 2-3 marks 40-50 Marks

Part B/Question: Problems with multiple questions each carrying 5-10 marks 50-60 Marks

20CH510T					Unit Operations and Processes in Environmental Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To understand the chemical engineering approaches in environmental engineering.
2. To identify and understand design approach for water and waste water treatment.
3. To understand and identify preliminary unit operations in water and wastewater treatment.
4. To understand and identify biological treatment of wastewater treatment.

UNIT 1 – INTRODUCTION 10 Hrs.

Water demand, Wastewater generation, Water & wastewater quality criteria, Water &wastewater treatment system overview, Mass balances, Flow models & reactors.

UNIT 2 – DISSOLVED OXYGEN BALANCE AND MODEL 9 Hrs.

Dissolved oxygen balance, Dissolved oxygen model, Oxygen sag curve, Oxygentransfer and mixing, Estimation of lumped oxygen transfer concentration,Aeration&Agitation for environmental processes.

UNIT 3 – PRELIMINARY & PRIMARY UNIT OPERATIONS AND PROCESSES 9 Hrs.

Equalization, Sedimentation, Coagulation and Flocculation, Filtration, Adsorption, Ion exchange membranes, Desalination, Leaching.

UNIT 4 – BIOLOGICAL TREATMENT OF WASTES 12 Hrs.

Batch& continuous processes: Mixed cultures, Activated sludge process, Trickling filters and Rotary biological contactors, Stabilization ponds and Aerated lagoons, Anaerobic digestion, Aerobic digestion, Solids Handling: Land treatment of municipal wastewater and sludges, Sludge incineration, Sludge disposal.

Max:- 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Define the basic knowledge of unit operations and processes in environmental engineering.
CO2– Classify flow models & reactors implicated in environmental engineering.
CO3 –Apply knowledge in mass balances, oxygen sag curve and lumped oxygen transfer concentration.
CO4– Examine water and wastewater quantity and quality.
CO5– Explain dissolved oxygen concept, preliminary, primary and biological treatment processes.
CO6 –Design and discuss the units involved in the treatment processes and operations of wastes.

TEXT/REFERENCE BOOKS

1. Tom D. Reynolds, Paul Richards, Unit Operations and Processes in Environmental Engineering, CL Engineering, second edition, 1995.
2. R. Noyes, Unit Operations in Environmental Engineering, first edition, Noyes Publications, 1994.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs
Part A/Question: <Details> <> Marks
Part B/Question: <Details> <> Marks

20CH 511T					Nano-science and Energy Storage					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To understand the fundamentals of Nano Science and Energy Storage.
2. Explain the nanoscale paradigm in terms of properties at the nano scale dimension.
3. Identify current nanotechnology solutions in design, engineering andmanufacturing.
4. To understand the use of nanotechnology in Energy Storage.

UNIT I 10 hrs

Introduction of Nanoscience and technology, Nanoparticles and their properties, Case studies demonstrating non-classical behavior at nanoscale in successful and emergenttechnologies, Quantum Mechanics, Chemical Kinetics at nano-scale.

Unit –II 10 hrs

Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation; Metal nanocrystals by reduction, Sol-gel synthesis; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; Electrochemical synthesis; , Photochemical synthesis, Synthesis in supercritical fluids.

Unit III 12 hrs

Detailed characterization technique based on radiation matter interactions and their analytical applications like Scanning Electron, Transmission electron microscope, Atomic force microscope, scanning tunneling microscope and spectroscopy will be used in interpreting the nano structured objects.

Unit-IV 10 hrs

Fuel Cells, Polymer membranes for fuel cells, PEM fuel cell. Acid/ alkaline fuel cells, design of fuel cells, Carbon Nanotubes for energy storage, Hydrogen Storage in Carbon Nanotubes, Use of nanoscale catalysts to save energy and increase the productivity in industry, Rechargeable batteries based on nanomaterials, Nanocomposites for electrodes and electrolyte applications. The safety and energy storage issues and the impact of nanotechnology on the environment will be stressed at the end.

Max:- 42 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1:- Tell the basics of Nano-science and technology along with properties.
CO2:- Explain the chemical methods for synthesis of nanoparticles.
CO3:- Develop various nanomaterials and basic understanding in the relevant analytical techniques.
CO4:- Categorize the various techniques for nano-materials characterization.
CO5:- Explain the physical methods for design of fuels cells, carbon nanotubes for energy storage.
CO6:- Discuss the use of nanotechnology in Energy Storage.

TEXT/REFERENCE BOOKS

1. Nanoscale science and technology, John Wiley & Sons.,2005.
2. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press,2009.
3. Sulabha K. Kulkarni, Nanotechnology: Principles and Practices, Capital Publishing Company,2007.
4. Nanobiotechnology, concepts, applications and perspectives, Wiley-VCH,2004.
5. Ozin G. A, Andre C. Arsenault, Nanochemistry A chemical approach to nanomaterials, Royal society of chemistry,UK,2005.

20CH 512					Modelling & Simulation					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce a range of molecular simulation techniques that are used in modelling materials and complex-fluids.
2. To demonstrate the predictive capabilities of these methods by considering a set of applications.
3. To able to learn efficient programming skills in accordance with the methods and algorithms of molecular modelling

UNIT 1 Introduction and general concepts 10 Hrs.

Objectives and background, Modelling space and time, Examples of chemical engineering & bio-medical modelling, Introduction to high performance computing in modelling, concepts of statistical mechanics – partition functions and thermodynamic properties

UNIT 2 Material Simulation techniques – Monte Carlo & Molecular Dynamics 10 Hrs.

Monte Carlo Simulations: Metropolis algorithm in various ensembles, free energy calculations, configuration bias MC, End-bridging Monte Carlo, lattice Monte Carlo simulations, MC Simulations of polymer melts and thin films, grand canonical MC simulations; Molecular Dynamics Simulations: Basics of Molecular Dynamics Simulations, Numerical algorithms to solve equation of motion, concept of thermostat and barostat, unconstraint and constrained dynamics, Energy minimization, NVT, NPT and NVE ensemble, Introduction to Brownian dynamics

UNIT 3 Quantum Mechanical Modelling 10 Hrs.

Quantum mechanical model of an atom, From many-body to single-particle: Quantum modeling of molecules, Quantum modeling of solids: Basic properties, QM Modelling of materials and complex fluids

UNIT 4 Applications and real-life problems 10 Hrs.

Polymers and polyelectrolytes in solutions, adsorption of polymers and surfactants at surfaces/interfaces, transport property calculations (diffusivity, viscosity), Applications of MC and MD techniques for– drug delivery, batteries, CO_2 sequestration, glassy melts

Max : 40 hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – recall and relate the basic concepts of modelling and simulations.

CO2 – outline the application areas in Engineering where concept of molecular modelling & first principles can be applied.

CO3 – choose an appropriate molecular simulation technique and model a material or process

CO4 – analyse the problem statement and compare solutions obtained from different algorithms of MC and MD.

CO5 – estimate the properties (structure, dynamics and thermochemical) of a material or complex fluid using computer simulations.

CO6 – formulate and solve a real-life problem statement by doing thorough literature review of scientific literature.

TEXT/REFERENCE BOOKS

1. Tuckerman M. Statistical mechanics: theory and molecular simulation. Oxford university press; 2010 Feb 11.
2. Leach AR, Leach AR. Molecular modelling: principles and applications. Pearson education; 2001.
3. Frenkel D, Smit B. Understanding molecular simulation: from algorithms to applications. Elsevier; 2001 Oct 19.
4. Gao J, Thompson MA. Combined quantum mechanical and molecular mechanical methods. Washington, DC: American Chemical Society; 1998 Dec 28.
5. Gubbins KE, Quirke N, editors. Molecular simulation and industrial applications: methods, examples, and prospects. Taylor & Francis; 1996.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: 12 short answer questions of 2 marks each 24 Marks

Part B/Question: 6 long answer questions 76 Marks

Pandit Deendayal Energy University

<table>
<tr><td colspan="5">20CH514T</td><td colspan="6">Colloids and Interfacial Science and Engineering</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="6">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="3">Theory</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
<tr><td>MS</td><td>ES</td><td>IA</td><td>LW</td><td>LE/Viva</td></tr>
<tr><td>3</td><td></td><td></td><td>3</td><td>3</td><td>25</td><td>50</td><td>25</td><td>--</td><td>--</td><td>100</td></tr>
</table>

COURSE OBJECTIVES

1. Understanding of nomenclature, concepts and tools of colloid and interface science and engineering.
2. A clear understanding of differences between the surface and bulk dominated regimes and behavior.

UNIT 1 Surface Tension, Adhesion and capillarity: 12 Hrs.

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

UNIT 2 Intermolecular and interfacial forces 10 Hrs.

van der Waals, Electrostatic double layer, Maxwell-Boltzmann equation, Debye screening length, Acid-base interactions including hydrophobic attraction and hydration pressure.

UNIT 3 Mesoscale & Surface thermodynamics 8 Hrs.

Gibbs treatment of interfaces; concept of excess concentration; variation of interfacial tensions with surfactant concentration.

UNIT 4 Stability of colloidal dispersions 10 Hrs.

DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in a potential field/Brownian movement

Max: 40 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Highlighting various applications of Colloid and Interface Science.

CO2 - Categorizing various types of interactions between colloids.

CO3 - Implementing various theories to find e

CO4 - Explaining the conditions for stability of colloid systems.

CO5 - Measuring the magnitudes of interaction forces between colloids.

CO6 - Building a model related to interface in Surface Evolver and solving any colloid interaction problem by numerical programming.

TEXT/REFERENCE BOOKS

1. Jacob N. Israelachvili, Intermolecular and Surface Forces, cademic Press, 1992 or later editions.
2. W. B. Russel, D. A. Saville and W. R. Schowalter, Colloidal Dispersions, ambridge UniversityPress, 1989.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: Problems with multiple questions each carrying 2-3 marks 60-70 Marks

Part B/Question: Problems with multiple questions each carrying 5 marks 30-40 Marks

20CH506T					Advance Biochemical Engineering					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To get acquainted with the detail designing aspects of Bioreactors
2. To understand the fundamentals of various unit operations as well different aspects of Transport phenomenon involved in Biochemical processes

UNIT 1 – INTRODUCTION TO ENZYME KINETICS, INHIBITION AND IMMOBILISATION 10 Hrs.
Introduction to biochemical reactions, diversity in the biological reactions, immobilized enzyme processes, preparation methods, characterization, and mechanisms and applications of enzyme catalysis (biocatalysis), enzyme inhibition and deactivation, enzyme kinetics, reactor engineering aspects of enzymatic process

UNIT 2 – KINETIC MODEL FOR MICROBIAL GROWTH 9 Hrs.
Microbial growth, phases of cell growth in batch cultures; kinetic models for microbial growth; growth associated product formation kinetics; batch cultivation profiles, stoichiometry of product formation, models of microbial, continuous culture, animal cell culture, mixed cultures, bio-product recovery, bio-separations and purification.

UNIT 3 – TRANSPORT PHENOMENON IN BIOPROCESS SYSTEM 10 Hrs.
Mass transfer in biochemical reaction systems, rheology of the cell culture, heat transfer processes in biological systems, oxygen transfer fermentation processes, oxygen uptake transfer coefficients, transport correlations, role of aeration and agitation/mixing in oxygen transfer, power input to bioreactor.

UNIT 4 – DETAIL DESIGN OF BIOREACTORS 10 Hrs.
Detail designing of bioreactors, materials of construction, different types of bioreactors, multiphase reactors for plant and animal cell propagation, reactors for waste water-treatment processes, continuous/batch operational modes of reactors, recycles and continuous cultivation bioreactors, scale-up and scale-down criteria.

Max. 39 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Outline the interdisciplinary approach of bioprocess systems

CO2- Understand in detail about the various models pertaining to microbial growth kinetics

CO3- Reenact various concepts of transport phenomena prevailing in the Biochemical system

CO4 – Analyze different types of bioreactors for batch and continuous systems

CO5- Evaluate the fundamentals of mass transfer and heat transfer operations used in biochemical industries

CO6- Facilitate the importance of Biochemical engineering in allied industries

TEXT/REFERENCE BOOKS

1. J. E. Baley, D. F. Ollis, Biochemical Engineering Fundamentals, 2nd ed. McGraw Hill, 1986

2. Coulson and Richardson's Chemical Engineering- Vol-3, Chemical and Biochemical Reactors and process control, Asian Book Pvt. Ltd.

3. M.L.Shuler, F.Kargi, Bioprocess Engineering: Basic concepts, PHI Learning Private Ltd.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: <Details> <> Marks

Part B/Question: <Details> <> Marks

<table>
<tr><td colspan="5">20EN518T</td><td colspan="6">Carbon Sequestration and Clean Development Mechanism</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="6">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="3">Theory</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
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</table>

COURSE OBJECTIVES

1. To better understand about physical/scientific evidence for climate change science
2. To acquire better knowledge about for CO_2 separation from industrial gas streams, sustainable energy production and environment.
3. To understand about CO_2 mitigation through sequestration and utilization
4. To understand about cleaner production linked to CO_2 market and economics

UNIT 1 Climate Change Science 10 Hrs.

Global warming and climate change: Greenhouse gases, CO_2 emission and Global temperature; scientific data and evidence on climate change: UNFCCC and IPCC roles and reports, Energy and environment, carbon footprint, Global climate models, predictions, stabilization strategies and socio-economic impact.

UNIT 2 Carbon Capture 10 Hrs.

CO_2 emission from large point sources, Technology options/challenges for clean energy/power production, CO_2 capture technologies: Absorption, Adsorption, membrane separation etc., Process requirements and research needs, CO_2transportation, CO_2 capture case studies and economics. >

UNIT 3 Carbon Sequestration and Utilization 10 Hrs.

Geological CO_2 storage: storage in aquifer and depleted Oil and gas fields, CO_2 Storage through Enhanced Oil Recovery (EOR), Enhanced Coal Bed Methane Recovery, trapping mechanism and CO_2 integrity. CO_2 Utilization: fuels, bio-fuels and chemicals from CO_2, building material form Carbon mineralization, CO_2 curing concrete.

UNIT 4 Clean Development mechanism 10 Hrs.

UNFCC, IPCC and Kyoto Protocol, Conference of Parties and police making. Cleaner production and flexible mechanisms for CO_2 reduction. CDM Projects: Eligibility, execution and implementation, base line and life cycle; challenges in energy efficiency, solar, wind and conventional fuel power projects, case studies.

Max. 40 Hrs.

COURSE OUTCOMES: On completion of the course, student will be able to

CO1 - Showcase and interpretClimate Change data, predictions and impact on environment>

CO2 - Estimate carbon footprint and analyze power plant technologies for Clean energy production>

CO3 - Demonstrate processes for CO_2 separation from industrial flue gas streams >

CO4 - Demonstrate and analyze options for CO_2 sequestration, trapping and integrity, environmental safety >

CO5 - Analyse technology for CO_2 utilization, perceiving advantage/disadvantage/ economic and research needs >

CO6 - List and demonstrate CDM projects, base line and life cycle analysis with case studies>

TEXT/REFERENCE BOOKS

1. Climate Change Science: A Modern Synthesis, Volume I: The Physical Climate by G. Thomas Farmer • John Cook, Springer, 2018
2. Clean -Coal engineering Technology by Bruce G.Miller, ISBN 978-0-12-811365-3, @2017 Elsevie
3. Carbon Capture and Storage, second edition by Stephen A. Rackley, ISBN: 978-0-12-812041-5 @2018 Elsevier
4. Clean Development mechanism, CDM Methodologies 11th ed., by UNFCCC, 2019>

					Intellectual Property Rights					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
2	0	0	1	2	25	50	25	--	--	100

COURSE OBJECTIVES

1. To understand the basics importance of sustainability and green chemistry
2. To understand principal, application and synthesis methods.
3. To learn Conventional Process and Operations-Current status.
4. Learn to understand new process developments.

UNIT – 1: Intellectual Property Rights (IPR) – An Introduction 6 Hrs

Basic concept of Intellectual Property, Characteristics and Nature of Intellectual Property right, Justifications for protection of IP, IPR and economic development.

UNIT – 2: Publications & Patents 8 Hrs

Effective technical writing: how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

UNIT – 3: Understanding Intellectual Property Rights (IPR) 8 Hrs

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT – 4: Patents & Copyrights 8 Hrs

Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System, Traditional knowledge Case Studies, IPR and IITs.

Max: 30 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1: Find the importance of Intellectual property.

CO2: Show the ability to write paper developing a Research Proposal and patent.

CO3: Apply the knowledge for Process of Patenting and Development

CO4: Distinguish between the Scope of Patent Rights, Licensing and transfer of technology.

CO5: Access and understand of New Developments in IPR.

CO6:- Develop the technique for IPR protection provides and follow the research ethics.

TEXT/REFERENCE BOOKS

1. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
2. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
3. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: <Questions with no choice> <25> Marks

Part B/Question: <Questions with choice> <75> Marks

20CE527T					**Successful Research Development Program**					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
2	0	0	2	2	25	50	25	--	--	100

COURSE OBJECTIVES

1. To develop understanding of the basic framework of research process
2. To develop an understanding of various research designs and techniques.
3. To identify various sources of information for literature review and data collection.
4. To develop an understanding of the ethical dimensions of conducting applied research
5. Appreciate the components of scholarly writing and evaluate its quality

UNIT 1 Research Organization 9 Hrs.

Objectives & Goals of a Research Organization, Components of a research organization,
Sponsors & Funding Agencies: Funding Agencies – Types, Types of Interface with Funding & Sponsor Agencies, Call for Proposals & Opportunity Tracking, Types of Proposals & Grants, Contracting Vehicles & Arrangements, Deliverables, Interim & Final Reviews, Cost & Performance Audits, Contract Laws &

UNIT 2 Development of Proposal Writing 9 Hrs.

Proposals for Research Program Funding: Centre & Consortia Proposals, Individual Principal Investigator Proposals, Continuation & Renewal Proposals, Prime Subcontractor Relationships & Contracting, Cost Accounting, Laws and Regulations. intellectual Property & Patent Laws, Writing a Successful Research Proposal: Technical Proposal, Management Proposal, Cost Proposal, Technology Proposal, Statement of Work & Deliverables, Case Studies>

UNIT 3 Development of Research Methodology 9 Hrs.

The Research Process – I: Steps in development of successful research program, Quality and Cost consideration, Laboratories and infrastructure setup, Staffing & Support Models, Peer−Review, Independent Verification & Validation, Internal & External Review processes, Ethics & Regulatory Laws & Guidelines, Case Studies.

Max:- 27 Hrs

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Students should be able to identify the overall process of designing a research study from its inception

CO2 - Students should understand the characteristics of various kinds of research (quantitative and qualitative).

CO3 - Students should apply the knowledge of a forward chronological, backward chronological and manual search method in framing the literature review for a scholarly educational study.

CO4 - Students should be analyze with conducting scholarly educational study: a. The steps in the overall process. b. The types of databases often searched. c. The criteria for evaluating the quality of a study. d. The ways of organizing the material found. e. The different types of literature reviews.

CO5 - Student can able to exercise on various Ethical issues in conducting research.

CO6 - Develop research designs and project proposals in achieving project deliverables in stipulated period of time and cost.

TEXT/REFERENCE BOOKS

1. Research Methodology (Methods and Techniques) book by CR Kothari New age Publications 3rd edition
2. Research Methodology book by Ranjith Kumar, Sage Publications 3rd edition (Softcopy Available)
3. Nptel Lectures: Introduction to Research,Prof. Prathap Haridoss, Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Madras

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question1: <identifying overall research process> <> Marks

Part A/Question2: <relation between quantitative and qualitative> <> Marks

Part A/Question3: <literature review process> <> Marks

Part A/Question4: <hypothesizing and concept building> <> Marks

Part A/Question5: <Ethical issues in conducting research> <> Marks

<table>
<tr><td colspan="5"><Course Code></td><td colspan="6">Computational Fluid Dynamics</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="6">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="3">Theory</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
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</table>

COURSE OBJECTIVES

1. Introduce the student to various discretization schemes.
2. To provide understanding of various solution schemes.
3. Implementation of CFD in softwares.

UNIT 1 Introduction to Computational Fluid Dynamics [CFD] 10 Hrs.

Introduction to Computational Fluid Dynamics and its applications, Revisting transport equations and their coupling, and various boundary conditions. Quick introduction to Numerical Methods.

UNIT 2 Discretization 10 Hrs.

Discretization principles: Pre-processing, Solution, Post-processing, Finite Element Method, Finite difference method, Well-posed boundary value problem, Possible types of boundary conditions, Conservativeness, Boundedness, Transportiveness, Finite volume method (FVM), Illustrative examples:1-D steady state heat conduction with and without constant source term.

UNIT 3 Methods of Solution 10 Hrs.

Solution of finite difference equations, iterative methods, matrix inversion methods, ADI technique, QUICK scheme, SIMPLE, SIMPLER and MAC algorithm, pressure-velocity coupling algorithms, velocity-stream function approach, solution of Navier-Stokes equations, operator splitting, Fast Fourier transform.

UNIT 4 CFD using programming and Open FOAM 10 Hrs.

Development of simple CFD codes in Python or Julia. Introduction to Open FOAM, defining geometry and mesh, implementation of solvers. Solution to some basic problems related to heat transfer and fluid flow in Open FOAM.

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 -Highlighting basic transport equations and boundary conditions.
CO2 -Associating coupled fluid dynamics problems with numerical analysis.
CO3 –Choose an appropriate discretization method.
CO4 -Breaking-down a CFD problem in various parts.
CO5 -Assess various solution schemes in CFD.
CO6 -Programming using Python/Julia and Building CFD codes in Open FOAM.

TEXT/REFERENCE BOOKS

1. Computational Fluid Dynamics, T. J. Chung, Cambridge University Press, 2010.
2. Introduction to Computational Fluid Dynamics: The Finite Volume Method, Versteeg, H. K. and Malalasekara, W., Second Edition (Indian Reprint) Pearson Education, 2008.
3. Computational Fluid Dynamics, J. D. Anderson Jr., McGraw-Hill International Edition, 1995.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 Exam Duration: 3 Hrs

Part A/Question: Problems with multiple questions each carrying 2-3 marks 40-50 Marks

Part B/Question: Problems with multiple questions each carrying 5-10 marks 50-60 Marks

SEMESTER III			M.TECH. CHEMICAL ENGINEERING										
Sr. No	Course Code	Course Name	Teaching Scheme					Exam Scheme					
			L	T	P	C	Hrs/wk	Theory			Practical		Total
								MS	ES	IA	LW	LE/Viva	Marks
1	20MT611	Seminar-I	--	--	--	5	--	40	60	--	--	--	100
2	20MT612	Dissertation	--	--	--	14	--	40	60	--	--	--	100
		Total	--	--	--	19	10	--	--	--	--	--	200

SEMESTER IV			M.TECH. CHEMICAL ENGINEERING										
Sr. No	Course Code	Course Name	Teaching Scheme					Exam Scheme					
			L	T	P	C	Hrs/wk	Theory			Practical		Total
								MS	ES	IA	LW	LE/Viva	Marks
1	20MT621	Seminar-II	--	--	--	5	--	40	60	--	--	--	100
2	20MT622	Dissertation	--	--	--	23	--	40	60	--	--	--	100
		Total	--	--	--	28	--	--	--	--	--	--	200