COURSE SCHEME
EXAMINATION SCHEME
ABSORPTION SCHEME
&
SYLLABUS

Of

First, Second, Third & Fourth Semester
Choice Base Credit System (CBCS)

Of
Master of Technology (M.Tech)

In
CHEMICAL ENGINEERING

Of
RASHTRASANT TUKDOJI MAHARAJ
NAGPUR UNIVERSITY, NAGPUR

RASHTRASANT TUKDOJI MAHARAJ NAGPUR UNIVERSITY, NAGPUR
FIRST SEMESTER M.TECH (C.B.C.S.) (CHEMICAL ENGINEERING)

Sr. No.	Code (Board) Theo./Pract	Subject	Workload				Credit				MARKS				Total Marks
											Theory		Practical		
			L	P	T	Total	L	P	T	Total	Sessional	University	Sessional	University	
1.	PGCHE 101T	Modeling & Simulation in Chemical Engineering	4	-	-	4	4	-	-	4	30	70	-	-	100
2.	PGCHE 102T	Advanced Transport Phenomena	4	-	-	4	4	-	-	4	30	70	-	-	100
3.	PGCHE 103T	Advanced Reactor Design	4	-	-	4	4	-	-	4	30	70	-	-	100
4.	PGCHE 104T	Elective-I	4	-	-	4	4	-	-	4	30	70	-	-	100
5.	PGOPEN 105T	Elective-II	4	-	-	4	4	-	-	4	30	70	-	-	100
6.	PGCHE 106P	Modeling & Simulation of Chemical Processes	-	4	-	4	-	2	-	2	-	-	100	100	200
Total			20	4	-	24	20	2	-	22	150	350	100	100	700

Elective	Subject Name			
	BOARD			
	BTCHE			
Elective-I (Discipline Specific)	1. Process Design, Integration and Intensification	2. Advanced Optimization Techniques	3. Fluidization Engineering	4. Computational Fluid Dynamics
Elective-II (Open)	1. Chemical Engineering Mathematics	2. Modern Chemical Instrumentation		

RASHTRASANT TUKDOJI MAHARAJ NAGPUR UNIVERSITY, NAGPUR
SECOND SEMESTER M.TECH (C.B.C.S.) (CHEMICAL ENGINEERING)

Sr. No.	Code (Board) Theo./Pract	Subject	Workload				Credit				MARKS				Total Marks
			L	P	T	Total	L	P	T	Total	Theory		Practical		
											Sessional	University	Sessional	University	
1.	PGCHE 201T	Advanced Separation Processes	4	-	-	4	4	-	-	4	30	70	-	-	100
2.	PGCHE 202T	Advanced Process Dynamics & Control	4	-	-	4	4	-	-	4	30	70	-	-	100
3.	PGCHE 203T	Advanced Biochemical Engineering	4	-	-	4	4	-	-	4	30	70	-	-	100
4.	PGCHE 204T	Elective-III	4	-	-	4	4	-	-	4	30	70	-	-	100
5.	PGFD 205T	Research Methodology	4	-	-	4	4	-	-	4	30	70	-	-	100
Total			20	-	-	20	20	-	-	20	150	350	-	-	500

Elective	Subject Name			
	BOARD			
	BTCHE			
Elective-III (Discipline Specific)	1. Energy Conservation & Planning	2. Artificial Neural Network and Evolutionary Algorithms	3. Multiphase Flow	4. Fuel Cell Technology

RASHTRASANT TUKDOJI MAHARAJ NAGPUR UNIVERSITY, NAGPUR
THIRD SEMESTER M.TECH (C.B.C.S.) (CHEMICAL ENGINEERING)

Sr. No.	Code (Board) Theo./Pract	Subject	Workload				Credit				MARKS				Total Marks
			L	P	T	Total	L	P	T	Total	Theory		Practical		
											Sessional	University	Sessional	University	
1.	PGOPEN 301T	Elective IV	4	-	-	4	4	-	-	4	30	70	-	-	100
2.	PGFD 302T	Project Planning and Management	4	-	-	4	4	-	-	4	30	70	-	-	100
3.	PGCHE 303P	*Project Seminar	-	3	-	3	-	8	-	8	-	-	100	100	200
Total			8	3	-	11	8	8	-	16	60	140	100	100	400

Elective-IV (Open)	1. Advanced Petroleum Refining	2. Nanotechnology		

*For Work Load: 2 Hours/week/faculty

RASHTRASANT TUKDOJI MAHARAJ NAGPUR UNIVERSITY, NAGPUR
FOURTH SEMESTER M.TECH (C.B.C.S.) (CHEMICAL ENGINEERING)

Sr. No.	Code (Board) Theo./Pract	Subject	Workload				Credit				MARKS				Total Marks
			L	P	T	Total	L	P	T	Total	Theory		Practical		
											Sessional	University	Sessional	University	
1.	PGCHE 401P	*Project	-	6	-	6	-	16	-	16	-	-	200	200	400
Total			-	6	-	6	-	16	-	16	-	-	200	200	400

* For Work Load: 3 Hours/week/faculty

Scheme of Absorption for 1st semester M.Tech. Old Pattern to CBCS Pattern of 1st Semester M. Tech. (Chemical Engineering)							
As Per Rashtrasant Tukadoji Maharaj Nagpur University (Old Semester Pattern)					As Per Rashtrasant Tukadoji Maharaj Nagpur University (CBCS Pattern Scheme)		
1st Semester M. Tech (Chemical Engineering)					1st Semester M. Tech (Chemical Engineering)		
Sr. No.	**Sub Code Theory/ Practical**	**Subject**	**Theory/ Practical**		**Sub Code Theory/ Practical**	**Subject**	**Theory/ Practical**
1	CT 1.01	Modern Chemical Instrumentation	Theory		PGOPEN 105T	Elective-II- Modern Chemical Instrumentation	Theory
2	CE 1.02	Science & Technology of Materials	Theory		----	---	
3.	CE 1.03	Momentum and Heat Transfer			PGCHE 102T	Advanced Transport Phenomena	Theory
4.	CE 1.04	Advanced Chemical Reaction Engineering	Theory		PGCHE 103T	Advanced Reactor Design	Theory
5.	CE 1.05	Plant Design	Theory		----	---	
6	----	---			PGCHE 104T	Elective-I	Theory
7	----	---			PGOPEN 105T	Elective-II	Theory
8	----	---			PGCHE 106P	Modeling & Simulation of Chemical Processes	Practical

Students will have to appear in University theory and practical examination as per the new scheme.

Scheme of Absorption for 2nd semester M.Tech. Old Pattern to CBCS Pattern of 2nd Semester M. Tech. (Chemical Engineering)							
As Per Rashtrasant Tukadoji Maharaj Nagpur University (Old Semester Pattern)					As Per Rashtrasant Tukadoji Maharaj Nagpur University (CBCS Pattern Scheme)		
2nd Semester M. Tech (Chemical Engineering)					2nd Semester M. Tech (Chemical Engineering)		
Sr. No.	**Sub Code Theory/ Practical**	**Subject**	**Theory/ Practical**		**Sub Code Theory/ Practical**	**Subject**	**Theory/ Practical**
1	CT 2.01	Biotechnology	Theory		PGCHE 203T	Advanced Biochemical Engineering	Theory
2	CE 2.02	Environmental Engineering	Theory		---	----	
	CE 2.05	Process Dynamics and Control	Theory		PGCHE 202T	Advanced Process Dynamics & Control	Theory
3	CE 2.03	Mass Transfer	Theory		PGCHE 201T	Advanced Separation Processes	Theory
4.	CE 2.04	Optimization and Mathematical Modeling	Theory		----	---	
5.	----	---			PGCHE 204T	Elective-III	Theory
6.	----	---			PGFD 205T	Research Methodology	Theory

Students will have to appear in University theory and practical examination as per the new scheme.

Scheme of Absorption for 3rd semester M.Tech. Old Pattern to CBCS Pattern of 3rd Semester M. Tech. (Chemical Engineering)		
As Per Rashtrasant Tukadoji Maharaj Nagpur University (Old Semester Pattern)		As Per Rashtrasant Tukadoji Maharaj Nagpur University (CBCS Pattern Scheme)
3rd Semester M. Tech (Chemical Engineering)		3rd Semester M. Tech (Chemical Engineering)

Sr. No.	Sub Code Theory/ Practical	Subject	Theory/ Practical		Sub Code Theory/ Practical	Subject	Theory/ Practical
1	CE 3.01	Elective	Theory		PGOPEN 301T	Elective IV	Theory
2	----	---			PGFD 302T	Project Planning and Management	Theory
3	CE 3.02	Seminar	Practical		PGCHE 303P	Project Seminar	Practical
4.	CE 3.03	Minor Project Sessional Practical	Practical		PGCHE 303P	Project Seminar	Practical

Students will have to appear in University theory and practical examination as per the new scheme.

Scheme of Absorption for 4th semester M.Tech. Old Pattern to CBCS Pattern of 4th Semester M. Tech. (Chemical Engineering)							
As Per Rashtrasant Tukadoji Maharaj Nagpur University (Old Semester Pattern)					**As Per Rashtrasant Tukadoji Maharaj Nagpur University (CBCS Pattern Scheme)**		
4th Semester M. Tech (Chemical Engineering)					**4th Semester M. Tech (Chemical Engineering)**		
Sr. No.	**Sub Code Theory/ Practical**	**Subject**	**Theory/ Practical**		**Sub Code Theory/ Practical**	**Subject**	**Theory/ Practical**
1	CE 4.01	Major Project Viva-Voice	Practical		PGCHE 401P	Project	Practical

Students will have to appear in University theory and practical examination as per the new scheme.

FIRST SEMESTER M. Tech Chemical Engineering

Subject : PGCHE 101T (BCHE) **Modeling & Simulation in Chemical Engineering (Theory)**

Lecture : 4 Hours
No. of Credits : 4
University : 70 Marks
College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Introduction to process modeling, Applications of models, classification of models, Principles of Formulation, fundamental laws, general modeling procedure, industrial usage of process modelling and simulation; Macroscopic and microscopic mass, energy and momentum balances

Unit 2: Parameter estimation techniques in theoretical as well as numerical models, population balance, stochastic, and empirical models

Unit 3: Modeling of various mass and heat transfer equipment: distillation, absorption, extraction columns; evaporators; furnaces; heat exchangers; flash vessels etc.

Unit 4: Modeling of Chemical Reactors: single phase and multiphase reactors

Unit 5: Numerical Methods for chemical engineering applications. Introduction and use of different softwares for modeling and simulation

Recommended Books:

1. W. L. Luyben, Process Modeling Simulation and Control for Chemical Engineers, McGraw Hill, 1990.
2. S.C. Chapra, R.P. Canale, Numerical Methods for Engineers, 6th Edition, Tata-McGraw Hill Publications, 2012.
3. R.E.G. Franks, Modeling and Simulation in Chemical Engineering, Wiely Intrscience, NY, 1972.
4. J. Ingam, I. J. Dunn, Chemical Engineering Dynamic Modeling with PC simulation, VCH Publishers, 2008.
5. D. Himmelblau, K.B. Bischoff, Process Analysis and Simulation, John Wiley & Sons, 1968.

Subject : PGCHE 102T (BCHE) **Advanced Transport Phenomena (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Review of mathematics: Scalar, Vectors, Tensors, divergence, relation between rectangular coordinates and cylindrical coordinates, relation between rectangular coordinates and spherical coordinates, partial derivative, substantial derivative, total derivative, line integral, surface integral, integral theorems.

Unit 2: Equations of continuity, equation of motion, the equation of mechanical energy, application of Navier-Stokes equation to solve problems, the equations of change for incompressible non- Newtonian fluids.

Unit 3: Developing equations for obtaining velocity & shear stress distribution for flow of Newtonian, Bingham plastic & power law fluids in spheres etc. from I^{st} principle, Introduction to 2 dimensional & turbulent momentum transfers

Unit 4: Equations of energy, the energy equation in curvilinear coordinates, use of equations of change to set up steady state heat transfer for problems.

Unit 5: Unsteady state heat conduction expression for rectangular, spherical and cylindrical co-ordinate system from I^{st} principles, Numerical methods for 2 dimensional steady state conduction and Schmidt method for unsteady state heat conduction with / without surface resistance for obtaining temperature profiles

Recommended Books:

1. R.B. Bird, W. E. Stewart and E. N. Light foot Transport Phenomena Wiley international Edition, New York 2002.
2. James R. Welty, Charles E. Wicks and Robert E. Wilson, Fundamentals of momentum, heat and mass transfer, John Wiley & sons, Inc, New York, 2008.

Subject : PGCHE 103T (BCHE) **Advanced Reactor Design (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Non ideal flow, RTD function, characteristics of RTD, Zero-parameter models, one-parameter models, two-parameter models

Unit 2: Heterogeneous catalysis: Diffusion with reaction in porous catalyst, Mechanism of catalytic reactions. Langmuir - Hinshelwood model, Rideal - Eiley Mechanism, Rate controlling steps**,** Development of rate equations for solid catalysed fluid phase reactions; External/internal mass and heat transfer resistances in catalyst particles, catalyst deactivation.

Unit 3: Heterogeneous Catalytic Reactors: Isothermal and adiabatic fixed bed reactors, Non-isothermal and non-adiabatic fixed bed reactors.

Unit 4: Introduction to multiphase reactor design, fluidized bed reactor, slurry reactor, Trickle bed reactor, Photocatalytic reactor, Sonochemical reactors

Unit 5: Theory of mass transfer with chemical reaction (regimes and examples), model contactors

Recommended Books:

1. H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice – Hall, 1986.
2. O. Levenspeil, Chemical Reaction Engineering, 3rd Edition, Wiley, 1999.
3. J.M. Smith, Chemical Engineering Kinetics, McGraw-Hill, 1981.
4. G.F. Froment, K.B. Bischoff, Chemical Reactor Design and Analysis, Addision -Wesley, 1982.
5. L.K. Doraiswamy, M.M. Sharma, Heterogeneous Reactions vol. I and II, John Wiley & Sons Inc.
6. P.V. Danckwerts, Gas Liquid Reactions, McGraw-Hill Book Co., New York, 1970.

Subject : PGCHE 104T (BCHE) **Elective I-** 1. **Process Design, Integration and Intensification (Theory)**

Lecture : 4 Hours
University : 70 Marks
Duration of Examination: 3 Hours

No. of Credits : 4
College Assessment : 30 Marks

Unit 1: Introduction to chemical process design, integration and intensification. Hierarchy and approach of chemical process design and integration

Unit 2: Choice of reactors: Performance, conditions, configurations, heat integration of reactors etc.

Unit 3: Distillation sequencing: multicomponent, extractive, azeotropic distillation systems etc. with and without heat integration.

Unit 4: Heat exchanger networks: Energy Target and network design, trade-off & utilities, Heat & power integration.

Unit 5: Case studies on chemical process design, integration and intensification.

Recommended Books:

1. R. Smith, Chemical Process Design and Integration, John Wiley and Sons. Ltd., New Delhi, 2005.
2. J. Douglas, Conceptual Design of Chemical Processes. New York, NY: McGraw-Hill Science/Engineering/Math, 1988.
3. W. D. Seider, J. D. Seader, D. R. Lewin. Product and Process Design Principles: Synthesis, Analysis, and Evaluation. 2nd ed. New York, Wiley, 2004.
4. R. Turton, R. C. Bailie, W. B. Whiting, J. A. Shaeiwitz. Analysis, Synthesis, and Design of Chemical Processes, 2nd Edition, Prentice Hall, 2002.
5. L.T. Biegler, I.E. Grossmann, A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall, 1997.

Subject : PGCHE 104T (BCHE) **Elective I –** 2. **Advanced Optimization Techniques (Theory)**

Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Introduction to process optimization; formulation of various process optimization problems and their classification. Basic concepts of optimization-convex and concave functions, necessary and sufficient conditions for stationary points.

Unit 2: Optimization of one dimensional functions, unconstrained multivariable optimization direct search methods.

Unit 3: Indirect first order and second order method. Gradient-based methods

Unit 4: Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method of multipliers.

Unit 5: Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent) method, Newton's method.

Recommended Books:

1. S.S. Rao, Optimization Theory and Applications, Wiley Eastern Ltd., 1979.
2. T.F. Edgar, D.M. Himmelblau, optimization of chemical processes, McGraw Hill International editions, Chemical Engineering Series, 1989.
3. G.S. Beveridge, R.S. Schechter, Optimization theory and practice, McGraw Hill, New York, 1970.
4. G.V. Rekllitis, A. Ravindran, K.M. Ragdell, Engineering Optimization-Methods and Applications, John Wiley, New York, 1983.

Subject : PGCHE 104T (BCHE) **Elective I-** 3. **Fluidization Engineering (Theory)**

Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Introduction: Phenomenon of fluidization, behavior of fluidized bed, contacting modes, advantages and disadvantages of fluidization, fluidization quality, selection of contacting mode

Unit 2: Mapping of fluidization regimes: Characterization of particles, minimum fluidization velocity, pressure drop versus velocity diagram, The Geldart classification of solids, fluidization with carryover of particles, terminal velocity of particles, distributor types, gas entry region of bed, pressure drop requirements, design of gas distributor, power consumption

Unit 3: Bubbles in dense bed: Davidson model for gas flow, the wake region and movement of solids at bubbles, coalescence and splitting of bubbles, bubble formation above a distributor, slug flow. **Bubbling fluidized beds:** Emulsion movement, estimation of bed properties, bubble rise velocity, scale up aspects, flow models, two phase model, K-L model

Unit 4: Entrainment and elutriation: Freeboard behavior, gas outlet, entrainment from tall vessel, freeboard entrainment model, high velocity fluidization, pressure drop in turbulent and fast fluidization. **Solids movement:** Vertical and horizontal movement of solids, Dispersion model, large solids in beds of smaller particles, staging of fluidized beds. **Gas dispersion:** Gas dispersion in beds, gas interchange between bubble and emulsion, estimation of gas interchange coefficient

Unit 5: Design of fluidized bed reactors: Design of catalytic reactors, pilot plant reactors, information for design, bench scale reactors, design decisions, deactivating catalysts, Design of noncatalytic reactors, kinetic models for conversion of solids, models for shrinking particles, conversion of solids of unchanging size

Recommended Books:

1. O. Levenspiel, D. Kunnii, Fluidization Engineering, John Wiley, 1972.
2. Liang-Shih Fan, Gas-Liquid-Solid Fluidization Engineering, Butterworths, 1989.

Subject : PGCHE 104T (BCHE) **Elective I-** 4. **Computational Fluid Dynamics (Theory)**

Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Conservation Laws of Fluid Motion and Boundary Conditions: Governing equations of fluid flow and heat transfer, Equations of state, Navier-Stokes equations for a Newtonian fluid, Classification of physical behaviour, Classification of fluid flow equations, Auxiliary conditions for viscous fluid flow equations

Unit 2: Turbulence and its Modelling: Transition from laminar to turbulent flow, Effect of turbulence on time-averaged Navier-Stokes equations, Characteristics of simple turbulent flows, Free turbulent flows, Flat plate boundary layer and pipe flow, Turbulence models, Mixing length model,The k-e model, Reynolds stress equation models, Algebraic stress equation models

Unit 3: The Finite Volume Method for Diffusion Problems: Introduction, one dimensional steady state diffusion, two-dimensional diffusion problems, three dimensional diffusion problems, discretised equations for diffusion problems

Unit 4: The Finite Volume Method for Convection-Diffusion Problems: Steady one dimensional convection and diffusion, The central differencing scheme, Properties of discretisation schemes-Conservativeness, Boundedness, Transportiveness, Assessment of the central differencing scheme for convection-diffusion problems, The upwind differencing scheme, The hybrid differencing scheme, The power-law scheme, Higher order differencing schemes for convection-diffusion, Quadratic upwind differencing scheme

Unit 5: The Finite Volume Method for Unsteady Flows and Implementation of Boundary Conditions: One-dimensional unsteady heat conduction, Discretisation of transient convection-diffusion equation, Solution procedures for unsteady flow calculations, Implementation of Inlet, outlet and wall boundary conditions, constant pressure boundary condition.

Recommended Books:

1. H. K. Versteeg, W. Malalasekera, An introduction to computational fluid dynamics: the finite volume method , Longman scientific & technical publishers, 2007
2. John D. Anderson, Computational fluid dynamics: The Basics with Applications McGraw-Hill, .New York, 1995.
3. Vivek V. Ranade, Computational flow modeling for chemical reactor engineering, Academic Press, San Diego, 2002

Subject : PGOPEN 105T (BCHE) **Elective II-**

Subject : PGCHE 106P (BCHE) **Modeling & Simulation of Chemical Processes (Practical)**

Practical	: 4 Hours	No. of Credits	: 2
University	: 100 Marks	College Assessment	: 100 Marks

Modeling and Simulations should be performed based on but not limited to the following List of examples

1. Dynamics of a Stirred Tank Heater with variable Volume
2. Modeling and Dynamics of a Quadruple Tank System.
3. Decoupled SISO control of the Quadruple Tank System.
4. Multi-variable Control of the Quadruple Tank System.
5. Dynamic Matrix Control of the Stirred Tank System.
6. Experiment on Programmed Adaptive Control System
7. Experiment on Time-delay compensation (Smith-Predictor)
8. Experiment on Inverse Response compensation
9. Experiment on multiple outputs controlled by a single input
10. Experiment on a single output controlled by multiple input
11. Introduction to process simulators and CFD software- ASPEN PLUS, HYSYS.
12. Simulation of steady state and Dynamic processes using ASPEN PLUS
13. Simulation of a batch reactor, CSTR, Tubular Reactor, multiphase reactor systems
14. Simulation of a shell and tube heat exchanger
15. Simulation of a condenser
16. Simulation of a pump/compressor
17. Simulation of a fixed bed absorber
18. Simulation of a staged distillation column
19. Simulation of flow in channels and pipes
20. Simulation of flow in sudden expansion/contraction systems
21. Simulation of flow in a square cavity, cylindrical venturi, slit venturi and orifice plate.
22. Process simulation study (flow sheeting)- Production of hydrogen by stream reforming
23. Process simulation study (flow sheeting)- Production of vinyl chloride monomer flowsheet
24. Process simulation study (flow sheeting)- Production of nitric acid from anhydrous ammonia

For the simulation of the above Processes/Process Equipment using Computer Programs or Simulation Packages such as ASPEN PLUS/CHEMCAD/HYSYS (UNISIM)/gPROMS etc. can be used.

SECOND SEMESTER M. Tech Chemical Engineering

Subject : PGCHE 201T (BCHE) **Advanced Separation Processes (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Flux Definition, Differential Equations of Mass transfer, Molecular diffusivities, Molecular diffusion, Mass Transfer coefficients

Unit 2: Multicomponent distillation: Bubble point and dew point calculations, Lewis and Matheson calculation, Method of Thiele and Geddes; Azeotropic distillation; Extractive distillation; Molecular distillation; Reactive distillation

Unit 3: Azeotropic and extractive fractional distillation: Separation of homogeneous azeotropes, separation of heterogeneous azeotropes, quantitative treatment of separation of binary heterogeneous azeotropes, selection of addition agents, selectivity, factors affecting selectivity, methods for prediction, mechanism of relative volatility change, choice of entrainer or solvent, design of an azeotropic distillation process, design of an extractive distillation process, methods of solvent recovery

Unit 4: Membrane separation processes: Fundamentals, mechanism and equilibrium relationships, types and structure of membranes, membrane permeation of liquids and gases, effects of concentration, pressure and temperature, dialysis: mechanism, basic idea on dialyser design, industrial application, reverse osmosis, definitions and theory, design considerations, applications, ultra filtration.

Unit 5: Adsorption and Ion Exchange Processes: Adsorption and ion exchange equilibria. Various isotherms. Contact filtration, design of fixed bed adsorber including breakthrough curve.

Recommended Books:

1. R.E. Lacey, S. Loaeb, Industrial Processing with Membranes, Wiley –Inter Science, New York, 1972.
2. C.J. King, Separation Processes, Tata McGraw - Hill Publishing Co., Ltd., 1982.
3. C.J. Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
4. R.E. Treybal, Mass-Transfer Operations, McGraw-Hill, New York, 1980.
5. J.D. Seader, E.J. Henley, Separation Process Principles, Wiley, 2011.
6. B.K. Dutta, Principles of Mass Transfer and Separation Processes, PHI, 2006
7. T.K. Sherwood, R.L. Pigford, C.R. Wilke, Mass Transfer, McGraw-Hill, New York, 1975.
8. H.M. Schoew, New Chemical Engineering Separation Techniques, Interscience Publishers, 1972.
9. Osadar, Varid Nakagawa, Membrance Science and Technology, Marcel Dekkar, 1992.

Subject : PGCHE 202T (BCHE) **Advanced Process Dynamics & Control (Theory)**

Lecture : 4 Hours
University : 70 Marks
Duration of Examination: 3 Hours
No. of Credits : 4
College Assessment : 30 Marks

Unit 1: Process Identification and Non-Linear Systems. Introduction and analysis of Non-liner control system. Phase plane analysis of second order control system, Analysis of critical points. Method of isoclines for non linear system.

Unit 2: Control of complex processes Process modeling and dynamic response of gas absorber, steam jacketed kettle, heat exchanger, distributed parameter model, non-interacting continuous stirred tank reactors, non-interacting stirred tank heaters.

Unit 3: Feedforward-feedback control configuration. Industrial examples of feedforward-feedback control of heat exchanger, jacketed continuous stirred tank reactor for exothermic and endothermic reactions, stirred tank heater, distillation column, drum boiler, level control, extraction column.

Unit 4: Industrial control system. Control configuration of Supervisory control and data acquisition SCADA, Working control components and network communication of SCADA. Industrial examples of SCADA. Control configuration of distributed control system DCS. Working of Programmable logic controller PLC. Real time monitoring control.

Unit 5: Programmed adaptive control, Gain programmed adaptive control. Reference model adaptive control, Inferential control. Industrial examples of adaptive and inferential control. Reaction curve method.

Recommended Books:

1. B. A. Ogunaike, W. H. Ray, Process Dynamics, Modeling and Control, Oxford University Press, NY, 1994
2. B. W. Bequette, Process Dynamics: Modeling, Analysis and Simulation, Prentice Hall International Series, 1998
3. D. E. Seborg, D. A. Mellichamp, T. F. Edgar, F. J. Doyle III, Process Dynamics and Control, 3rd Edition, Wiley.
4. G. Stephanopoulos, Chemical Process Control, Prentice-Hall, Englewood Cliffs, NJ, 1984
5. T. Marlin, Process Control, 2nd Edition, McGraw Hill Inc, US, 2000.
6. R.P. Vyas, Process control and Instrumentation, Seventh Edition, Denett& Co. publication, 2015.
7. R.P. Vyas, Measurement and Control, Denett& Co. Publication 2010.

Subject : PGCHE 203T (BCHE) **Advanced Biochemical Engineering (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Enzyme Kinetics: Models for complex enzyme kinetics, modeling of effect of pH and temperature, models for insoluble substrate, models for immobilized enzyme systems, diffusion limitations in immobilized enzyme system, electrostatic and steric effects.

Unit 2: Major metabolic pathways, bioenergetics, Glucose metabolism, metabolism of nitrogenous compounds, respiration, metabolism of hydrocarbons, anaerobic metabolism, autotrophic metabolism.

Unit 3: Bioreactors: Sterilization techniques, Modifications of batch and continuous reactors, chemostat with recycle, multistage chemostat, fed-batch operation, perfusion system, active and passive immobilization of cells, diffusional limitations in the immobilized system, fermenters.

Unit 4: Homogeneous and heterogeneous reactions in bioprocesses: Reaction thermodynamics, growth kinetics with Plasmid instability, The Thiele Modulus and effectiveness factor, diffusion and reaction in waste treatment lagoon. Reactors and choice of reactors.

Unit 5: Biological waste water treatment: Microbial participation in natural cycle of matter, activated sludge process, design and modeling of activated sludge process, Nitrification, anaerobic digestion, mathematical modeling of anaerobic digester, anaerobic denitrification, phosphate removal.

Recommended Books:

1) Michael L. Shuler, Fikret Kargi, Bioprocess Engineering: Basic Concepts, 2nd Edition, Prentice Hall, 2001.
2) J. E. Bailey, D. F. Ollis, Biochemical Engineering Fundamentals, McGraw- Hill, 1986.
3) P. M. Doran, Bioprocess Engineering Principles, Academic Press, 2nd Edition, 2012.
4) J. M. Lee, Biochemical Engineering, Prentice Hall, Englewood Cliffs, New Jersey, 1992.

Subject : PGCHE 204T (BCHE) **Elective III-** 1. **Energy Conservation & Planning (Theory)**

Lecture : 4 Hours
University : 70 Marks
Duration of Examination: 3 Hours
No. of Credits : 4
College Assessment : 30 Marks

Unit 1: Energy Outlook, Energy conservation and its importance, Energy intensive industries

Unit 2: Global industrial energy efficiency benchmarking, Engineering fundamentals related to energy efficiency

Unit 3: Principles on energy management, Energy Audit, Detailed thermodynamic analyses of common unit operations

Unit 4: Opportunities and techniques/methods for energy conservation in equipment and utility systems in process industries, Process synthesis, Thermo-economics, Energy Management Information Systems (EMIS).

Unit 5: Software tools for industrial energy efficiency and savings, Case studies on energy conservation and management in process industries

Recommended Books:

1. W.F. Kenney, Energy Conservation in the Process Industries. Academic Press Inc., 1984.
2. Vladimir S. Stepanov, Analysis of Energy Efficiency of Industrial Processes. 1st Edition, Springer-Verlag, 1993.
3. Jakob de Swaan Arons, Hedzer van der Kooi, Krishnan Sankaranarayanan, Efficiency and Sustainability in the Energy and Chemical Industries, 1st Edition, Marcel Dekker, Inc., 2004.

Subject : PGCHE 204T (BCHE) **Elective III-** 2. **Artificial Neural Network and Evolutionary Algorithms (Theory)**

Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Biological Neuron and neural network, McCulloch-Pitts Neuron, Thresholds logic unit (TLU), simple net with bias, Hebb craining algoritm

Unit 2: Feed forward error back propagation network, flow chart algorithm, topology, architecture, learning principals, applications to chemical process modeling, advantages , limitations.

Unit 3: Fuzzy logic: Introduction, examples, principal fuzzy logic controller applications including chemical processes

Unit 4: Evolutionary algorithm I: Genetic algorithm, natural genetics, advantages applications and algorithm.

Unit 5: Evolutionary algorithm II: Bee algorithm principle, flow chart, algorithm, chemical reactor optimization, swarm particle optimization, case based reasoning system

Recommended Books:

1. James A. Anderson, An introduction to neural networks, MIT Press, 1995.
2. S. L. Pandharipande, Artificial neural networks with free software CD, Dennet and Co. 2004.
3. S. N. Shivanandan, S. N. Deepa, Principles of soft computing, Wiley International, 2nd Edition, 2011.
4. Lan Cloete, J.M. Zurada, Knowledge based neuro computing, University Press (India) Ltd. 2002.

Subject : PGCHE 204T (BCHE) **Elective III-** 3. **Multiphase Flow (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Two phase flow: Gas/Liquid and Liquid/liquid systems: Flow patterns in pipes, analysis of two phase flow situations

Unit 2: Prediction of holdup and pressure drop or volume fraction, Bubble size in pipe flow, Lockchart-Martinelli parameters, Bubble column and its design aspects, Minimum carryover velocity. holdup ratios, pressure drop and transport velocities and their prediction.

Unit 3: Flow patterns - identification and classification - flow pattern maps and transition - momentum and energy balance - homogeneous and separated flow models -correlations for use with homogeneous and separated flow models - void fraction and slip ratio correlations - influence of pressure gradient - empirical treatment of two phase flow - drift flux model - correlations for bubble, slug and annular flows

Unit 4: Introduction to three phase flow, Dynamics of gas-solid liquid contactors (agitated vessels, packed bed, fluidized bed, pneumatic conveying, bubble column, trickle beds), Flow regimes, pressure drop, holdup, distributions, mass and heat transfer, reactions, Applications of these contactors

Unit 5: Measurement techniques in multiphase flow: Conventional and novel measurement techniques for multiphase systems (Laser Doppler anemometry, Particle Image Velocimetry)

Recommended Books:

1. R. Clift, M.E. Weber, J.R. Grace, Bubbles, Drops, and Particles, Academic Press, New York, 1978.
2. Y. T. Shah, Gas-Liquid-Solid reactors design, McGraw Hill Inc, 1979
3. L. S. Fan, C. Zhu, Principles of Gas-solid Flows, Cambridge University Press, 1998
4. G. W. Govier, K. Aziz, The Flow of Complex Mixture in Pipes, Van Nostrand Reinhold, New York, 1972.
5. G.B. Wallis, One Dimensional Two Phase Flow, McGraw Hill Book Co., New York, 1969.
6. C. T. Crowe, M. Sommerfeld, Y. Tsuji, Multiphase Flows with Droplets and Particles, CRC Press, 1998
7. C. Kleinstreuer, Two-phase Flow: Theory and Applications, Taylor & Francis, 2003
8. M. Rhodes, Introduction to Particle Technology, John Wiley & Sons, New York. 1998.

Subject : PGCHE 204T (BCHE) **Elective III-** 4. **Fuel Cell Technology (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1: Hydrogen Production Methods Production: from fossil fuels, electrolysis, thermal decomposition, photochemical, photocatalytic, hybrid; Hydrogen Storage Methods Storage: Metal hydrides, Metallic alloy hydrides, Carbon nano-tubes; Sea as the source of Deuterium.

Introduction and overview of fuel cells technology: low and high temperature fuelcells.

Unit 2: Fuel cell thermodynamics. Fuel cell reaction kinetics: Introduction to electrode kinetics. Exchange current and electrocatalysis, Simplified activation kinetics, Catalyst electrode design. Fuel cell thermodynamics - second law analysis of fuel cells, efficiency of fuel cells fuel cell electrochemistry - Nernst equation, Electrochemical kinetics,Butler-Volmer equation

Unit 3: Fuel cell types Classification by operating temperature/electrolyte type, Fuel Cell Performance, Activation, Ohmic and Concentration over potential Fuel cell charge and mass transport. Fuel cell characterization.

Unit 4: Fuel cell modeling and system integration: Balance of plant.

Unit 5: Safety issues and cost expectation and life cycle analysis of fuel cells. Description of some commercially available fuel cell stacks, overview on research activities on fuel cells in world, Research and development related to fuel cell development in India

Recommended Books:

1. R.P. O'Hayre, S. Cha, W. Colella, F.B. Prinz, Fuel Cell Fundamentals, Wiley, NY, 2006.
2. A. J. Bard, L. R. Faulkner, Electrochemical Methods, Wiley, N.Y. 2004.
3. S.(Ed) Basu, Fuel Cell Science and Technology, Springer, N.Y. 2007.
4. H. Liu, Principles of fuel cells, Taylor & Francis, N.Y. 2006.

Subject : PGFD 205T (BCHE) **Research Methodology (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 80 Marks College Assessment : 20 Marks
Duration of Examination: 3 Hours

Unit 1 Research Foundation

What is Research, Objectives of Research, Types of Research, Scientific Research, Research and Theory, Conceptual and theoretical Models, Importance of research methodology in scientific research

Unit 2 Review of Literature

Need for Reviewing Literature, What to Review and for what purpose, Literature Search Procedure, Sources of Literature, Planning of Review work, Note Taking, Library and documentation

Unit 3 Planning of Research

The planning process, Selection of a Problem for Research, Formulation of the Selected Problems, Hypothesis formation, Measurement, Research Design/Plan

Unit 4 Processing of Data and Statistical Analysis of Data

Introduction to Statistical Software, MINITAB, SPSS, Measures of Relationship, Simple Regression Analysis, Multiple Correlation and Regression, Partial Correlation, MATLAB and Neural Network based optimization, Optimization of fuzzy systems, Error Analysis, Results and their discussions

Unit 5 Report and Thesis writing

Types of Reports, Planning of Report Writing, Research Report Format, Principles of Writing, Data and Data Analysis Reporting in a Thesis, Use of Endnote, Bibliography, API , appendix, table, Observations arrangement, Preparation of type script and lay-out of thesis, Use of LATEX Indexing of Journals, Impact factor and social Media for Researchers.

Recommended Books:

1. Research Methodology: Methods and Techniques by C. R. Kothari, New Age International Publishers, ISBN:81-224-1522-9
2. Statistical Methods for Research Workers by Fisher R. A., Cosmo Publications, New Delhi ISBN:81-307-0128-6
3. Design and Analysis of Experiments by Montogomery D.C. (2001), John Wiley, ISBN: 0471260088
4. MINITAB online manual
5. Methodology of Research in Social Sciences by O. R. Krishnaswamy and M. Rangnatham Himalaya publication House, 2005, ISBN: 8184880936
6. SPSS online manual

THIRD SEMESTER M. Tech Chemical Engineering

Subject : PGOPEN 301T (BCHE) **Elective IV-**

Subject : PGFD 302T (BCHE) **Project Planning and Management (Theory)**
Lecture : 4 Hours No. of Credits : 4
University : 70 Marks College Assessment : 30 Marks
Duration of Examination: 3 Hours

Unit 1 : ***Basics of Project Management:*** Introduction, Need for Project Management, Project Management Knowledge Areas and Processes, The Project Life Cycle, The Project Manager (PM), Phases of Project Management Life Cycle, Project Management Processes, Impact of Delays in Project Completions, Essentials of Project Management Philosophy, Project Management Principles

Unit 2 : ***Project Identification and Selection:*** Introduction, Project Identification Process, Project Initiation, Pre-Feasibility Study, Feasibility Studies, Project Break-even point
Project Planning: Introduction, Project Planning, Need of Project Planning, Project Life Cycle, Roles, Responsibility and Team Work, Project Planning Process, Work Breakdown Structure (WBS)
Organisational Structure and Organisational Issues: Introduction, Concept of Organisational Structure, Roles and Responsibilities of Project Leader, Relationship between Project Manager and Line Manager, Leadership Styles for Project Managers, Conflict Resolution, Team

Unit 3: ***Resources Considerations in Projects:*** Introduction, Resource Allocation, Scheduling, Project Cost Estimate and Budgets, Cost Forecasts
Project Risk Management: Introduction, Risk, Risk Management, Role of Risk Management in Overall Project Management, Steps in Risk Management, Risk Identification, Risk Analysis, Reducing Risks

Unit 4: ***Project Quality Management and Value Engineering:*** Introduction, Quality, Quality Concepts, Value Engineering
Project Management Information System: Introduction, Project Management Information System (PMIS), Planning of PMIS, Design of PMIS
Purchasing and Contracting for Projects: Introduction, Purchase Cycle, Contract Management, Procurement Process

Unit 5: ***Project Performance Measurement and Evaluation:*** Introduction, Performance Measurement, Productivity, Project Performance Evaluation, Benefits and Challenges of Performance Measurement and Evaluation, Controlling the Projects
Project Execution and Control: Introduction, Project Execution, Project Control Process, Purpose of Project Execution and Control
Project Close-out, Termination and Follow-up: Introduction, Project Close-out, Steps for Closing the Project, Project Termination, Project Follow-up
Project Management Software: Introduction, Advantages of Using Project Management Software, Common Features Available In Most of the Project Management Software, Project 2000.

Reference Books:

1. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, by John W. Creswell, 2nd Edition , Sage Publication, 2003
2. Qualitative Inquiry and Research Design: Choosing among Five Approaches, by John W. Creswell, 3rd Edition, Sage publication, 2013.
3. Evaluation: A Systematic Approach, Peter H. Rossi, Mark W. Lipsey, and Howard E. Freeman, 7th edition , Sage publications, 2007.
4. Handbook of Practical Program Evaluation, Joseph S. Wholey, Harry P. Hatry, Kathryn E. Newcomer. 4th edition, Wiley, 2015
5. Program Evaluation and Performance Measurement: An Introduction to Practice, James C. McDavid and Laura R. L. Hawthorn, Sage Publication, 2013.
6. Evaluation, Carol H. Weiss, 2nd Edition, ABE books, 1997.
7. Case Study Research: Design and Methods, Robert K. Yin, 3rd Edition, Sage Publications, 2011

Subject	**: PGCHE 303P** (BCHE)	**Project Seminar**	
Practical	: 3 Hours	No. of Credits	: 8
University	: 100 Marks	College Assessment	: 100 Marks

Each student will undertake an independent project seminar. The student is required to select the topic in consultation with his/her Guide. Student should undertake project concerning Chemical Engineering applications such as design and development, experimental work, industry based problems, generation of new ideas and concept, modification in the existing process/system, development of computer programs, modelling and simulation etc. A preliminary work is to be carried out in this stage of the project. Two neatly typed copies of the Report on the completed work at this stage include comprehensive report on literature survey, design and fabrication of experimental set up and/or development of model, relevant computer programs and the plan for stage II should be submitted at end on the 3rd semester. University and college assessment would be made on the basis of the submitted report and the presentation cum viva-voce examination conducted by the board of examiners.

FOUTH SEMESTER M. Tech Chemical Engineering

Subject	**: PGCHE 303P** (BCHE)	**Project**	
Practical	: 6 Hours	No. of Credits	: 16
University	: 200 Marks	College Assessment	: 200 Marks

Project work undertaken in the 3rd semester will be continued and completed at the end of fourth semester. This stage will include comprehensive report on the work carried out at this stage and relevant portions from project seminar stage, including experimental studies, analysis and/or verification of theoretical model, conclusions. Two neatly typed and bound copies of the report consisting of project seminar stage of 3rd semester and project stage from 4th semester combined together along with its soft copy should be submitted at the end of fourth semester. The student are expected to publish at least one national/international paper based on the project work. The publication/accepted paper for publication shall be included in the report. University and college assessment would be made on the basis of the submitted report and the presentation cum viva-voce examination conducted by the board of examiners.