PUDUCHERRY TECHNOLOGICAL UNIVERSITY
PILLAICHAVADY, PUDUCHERRY – 605 014.
(A Technological University of Govt. of Puducherry)

Curriculum and Syllabi

for

M.Tech. (Chemical Engineering)

(Effective from the Academic Year 2022 – 23)

Recommended in the first Board of Studies Meeting in Chemical Engineering held on 9th May 2022

(To be Placed in the Academic Council)

CURRICULUM

The curriculum of M.Tech. (Chemical Engineering) is designed to fulfill the Programme Educational Objectives (PEO) and Programme Outcomes (PO) listed below:

PROGRAMME EDUCATIONAL OBJECTIVES (PEO)

PEO1	To produce scholarly and competent graduates in the core areas of Chemical Engineering.
PEO2	To inculcate intellectual capacity, research aptitude and independent thinking to inquire, study and explore the frontier areas of the domain.
PEO3	To arouse the interest for application centric learning through intensive laboratory practices towards producing confident and industry ready human resource.
PEO4	To nurture and evoke the spirit of innovation, creativity and entrepreneurship
PEO5	To develop life skills, ethical disposition and sensitivity towards environment and safety.

PROGRAMME OUTCOMES (PO)

PO1	Ability to evolve as knowledgeable and competent graduates with a global perspective in the areas of Chemical Engineering.
PO2	Ability to be innovative and develop aptitude for independent research and development.
PO3	Ability to demonstrate a degree of mastery in the areas of Chemical Engineering.
PO4	Ability to apply the knowledge of science, mathematics and engineering principles and propose ingenious solutions to practical problems with due considerations for public health and safety, cultural, societal and environmental factors.
PO5	Ability to contribute to the technological advances through quality research.
PO6	Capacity for applying knowledge, modern techniques and tools to design and conduct experiments as well as to analyze and interpret data to build practical systems.
PO7	Ability to collaborate and work in a multi-disciplinary environment towards higher academic and research objectives.
PO8	Understanding of engineering and management principles to lead and manage projects efficiently towards fulfilling the envisaged outcomes.
PO9	Ability to articulate and present the ideas and thoughts precisely and with clarity.
PO10	Ability to engage in life-long learning with commitment to stay relevant and contemporary.
PO11	Ability to understand and appreciate ethical principles and social responsibilities.
PO12	Ability to take on challenging issues, be progressive in endeavours and learn from the outcomes.

PROGRAMME SPECIFIC OUTCOMES (PSO)

PSO1	Ability to identify, formulate, design and solve engineering challenges in separation and transport processes, reactor analysis and design.
PSO2	Explore evolving technologies in nano and bio-process engineering, process intensification and cleaner technologies.
PSO3	Ability to understand and use contemporary tools for process optimization, synthesis, design and analysis.

Distribution of Credits among the subjects grouped under various categories:

Courses are grouped under various categories and the credits to be earned in each category of courses are as follows:

Sl. No.	Category	Credits	Course Category Code (CCC)
1	Programme Core Courses	24	PCC
2	Programme Specific Elective Courses	15	PSE
3	Open Elective Courses	03	OEC
4	Professional Activity Courses (Project Work, Seminar)	28	PAC
5	Mandatory Audit Courses	Non Credit	MAC
	Total	**70**	

Semester Wise Courses and Credits

Semester I

Course Code	Course	CCC	Periods			Credits
			L	T	P	
CH251	Computational Methods in Chemical Engineering	PCC	3	0	0	3
CH252	Advanced Chemical Reaction Engineering	PCC	3	0	0	3
CH253	Advanced Chemical Engineering Thermodynamics	PCC	3	0	0	3
CHZNN	Programme Specific Elective - 1	PSE	3	0	0	3
CHZNN	Programme Specific Elective - 2	PSE	3	0	0	3
CH254	Computational and Simulation Laboratory	PCC	0	0	4	2
CH255	Research Methodology and IPR	PCC	2	0	0	2
AD2NN	Audit Course – I	MAC	2	0	0	0
Total			**23**			**19**

Semester II

Course Code	Course	CCC	Periods			Credits
			L	T	P	
CH256	Advanced Transport Phenomena	PCC	3	0	0	3
CH257	Advanced Separation Processes	PCC	3	0	0	3
CH258	Advanced Process Control	PCC	3	0	0	3
CHZNN	Programme Specific Elective - 3	PSE	3	0	0	3
CHZNN	Programme Specific Elective - 4	PSE	3	0	0	3
CH259	Advanced Chemical Engineering Laboratory	PCC	0	0	4	2
CH260	Mini Project and Seminar	PAC	0	0	4	2
AD2NN	Audit Course – II	MAC	2	0	0	0
Total			**25**			**19**

Semester III

Course Code	Course	CCC	Periods			Credits
			L	T	P	
CHZNN	Programme Specific Elective - 5	PSE	3	0	0	3
OE2NN	Open Elective	OEC	3	0	0	3
CH261	Dissertation – Phase I	PAC	0	0	20	10
Total			**26**			**16**

Semester IV

Course Code	Course	CCC	Periods			Credits
			L	T	P	
CH262	Dissertation – Phase II	PAC	0	0	32	16
Total			**32**			**16**

Total Credits: 70

Audit Courses (MAC)

AD201	English for Research Paper Writing
AD202	Disaster Management
AD203	Value Education
AD204	Constitution of India
AD205	Pedagogy Studies
AD206	Stress Management by Yoga

Open Elective Courses (OEC)

OE201	Business Analytics
OE202	Industrial Safety
OE203	Operation Research
OE204	Cost Management and Engineering
OE205	Composite Materials

Programme Specific Electives (PSE)

I Semester **PSE - 1** **PSE -2**	**CHZ01**	Advanced Downstream Processing
	CHZ02	Transport Process in Porous Media
	CHZ03	Modern Concepts in Catalysis and Surface Engineering
	CHZ04	Membrane Technology and Applications
	CHZ05	Process Design and Synthesis
	CHZ06	Food Processing Technology
	CHZ07	Fluidization Engineering
	CHZ08	Design of Experiments and Parameter Estimation
II Semester **PSE -3** **PSE - 4**	**CHZ09**	Process Intensification
	CHZ10	Process Integration
	CHZ11	Process Plant Design and Flow Sheeting
	CHZ12	Bioprocess Engineering
	CHZ13	Application of Nanotechnology in Chemical Engineering
	CHZ14	Process Modeling and Simulation
	CHZ15	Micro and nano-fluidics
	CHZ16	Industrial Pollution Control
III Semester **PSE - 5**	**CHZ17**	Optimization of Chemical Processes
	CHZ18	Chemical Reactor Analysis
	CHZ19	Chemo informatics
	CHZ20	Cleaner Production

XX – Department Code; **NN** – Running double digit number; **N** – Running single digit number

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="8">Programme: M. Tech. (Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: I</td><td colspan="4">Course Category Code: PCC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH251</td><td>Computational Methods in Chemical Engineering</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Formulate and solve problems in chemical engineering represented by Linear Algebraic Equations</td></tr>
<tr><td>CO2</td><td colspan="7">Formulate and solve problems in chemical engineering represented by Nonlinear Algebraic Equations</td></tr>
<tr><td>CO3</td><td colspan="7">Formulate and solve problems in chemical engineering represented by Ordinary Differential Equations - IVP</td></tr>
<tr><td>CO4</td><td colspan="7">Formulate and solve problems in chemical engineering represented by Ordinary Differential Equations - BVP</td></tr>
<tr><td>CO5</td><td colspan="7">Formulate and solve problems in chemical engineering represented by Partial Differential Equations</td></tr>
<tr><td>UNIT I</td><td colspan="4">Linear Algebraic Equations</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Vector Spaces, Vector Norms, Matrix Norms, Condition Number, Cramer's Rule, Gauss Elimination, LU decomposition, Iterative Methods - Jacobi's method, Gauss-Seidel method, Successive Relaxation method, Case studies - Multi-component Flash, Linear Process Flow Sheet, Polynomial Regression</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="4">Nonlinear Algebraic Equations</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Bisection method, Secant method, Fixed Point iteration, Picard's method, Newton Raphson method, System of non-linear algebraic equations -Picard's method, Newton Raphson method, Case Studies - Redlich - Kwong and Peng - Robinson EOS, Nonlinear Flash calculations, Bubble Point and Dew Point calculations,</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="4">Ordinary Differential Equations - IVP</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Explicit Euler method, Implicit Euler method, Predictor - Corrector method, Runge - Kutta methods, Numerical stability, System of ODEs, Stiff systems, Case studies - CSTR with fluctuating inlet, Liquid level dynamics and control, Non-isothermal PFR</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="4">Ordinary Differential Equations - BVP</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Boundary conditions - Dirichlet, Neuman and Robin boundary conditions, Finite difference approximations, Shooting method, Method of Orthogonal Collocation, Case study - Reaction - Diffusion in a packed bed, PFR with axial dispersion</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="4">Partial Differential Equations</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Classification of first order and second order PDEs, Hyperbolic PDEs (Convective Systems) - Finite differences in space and time, Crank - Nicholson method, Method of lines, Case Study - Transient PFR, Parabolic PDEs (Diffusive Systems) - Finite differences in space and time, Crank - Nicholson method, Method of lines, Transient PFR with Axial Dispersion</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Numerical Methods with Chemical Engineering Applications, Kevin D Dorfman, Prodromos Daoutidis, Cambridge University Press, 2017
2. Computational Techniques for Process Simulation and Analysis using MATLAB, Niket S. Kaisare, CRC Press, 2018
3. Introduction to chemical engineering computing, Bruce A Finlayson, John Wiley and Sons, 2012
4. Numerical Methods for Engineers, S. K. Gupta, New Age Publishers, 2019</td></tr>
</table>

Department: **Chemical Engineering**		Programme: **M. Tech. (Chemical Engineering)**						
Semester: **I**		Course Category Code: **PCC**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
CH252	**Advanced Chemical Reaction Engineering**	3	-	-	3	40	60	100
Prerequisite								

Course Outcome	On completion of the course, the student will be able to	
	CO1	Evaluate heterogeneous reactor performance considering mass transfer limitations
	CO2	Perform the energy balance and obtain concentration profiles in multiphase reactors.
	CO3	Estimate the performance of multiphase reactors under non-isothermal conditions.
	CO4	Understand modern reactor technologies for mitigation of global warming
	CO5	Understand the kinetic Modeling of reactors.

UNIT I	**Kinetics of Non-Elementary Reactions and Non-Isothermal Reaction Modeling**	**Periods : 9**	
Non-elementary Kinetics Importance: Approximations for formulations of Rate laws, Formulations of Kinetic model. Effect of flow on conversions in Reactors: Semi-batch Reactors : Importance and examples of applications , Material Balance on Semi-batch Reactor, Multiple reaction in Semi-batch Reactors, Conversion Vs Rate in Reactors Non-Isothermal reaction modeling in CSTR & Semi-Batch reactor: Energy Balance equations for CSTR, PFR and Batch reactors, Adiabatic operations Temperature conversion profiles in PFR, CSTR, Steady state tubular reactor with heat exchange.			**CO1**
UNIT II	**Multi-Staging and Optimal Design of Reactors**	**Periods : 9**	
Need for Multi-staging CSTR with multiple stages: Exothermic and Endothermic Reaction with examples, CSTR with heat effects, Multiple reactions in CSTR and PFR with heat effects, Semi batch Reactors with heat exchange. Design of PFR and Packed Bed Tubular Reactors: Radial and Axial mixing in Tubular reactors, unsteady state in non-isothermal energy balance, CSTR, Energy balance in Batch Reactors, Volume of reactors calculations for non-isothermal reactors. Optimal Design of Reactors for Reversible exothermic reactions: Unsteady state non-isothermal reactor design, adiabatic operation in batch, Heat effects in semi batch unsteady state operation. Auto thermal Plug flow reactors and packed tubular reactors.PFR with inter stage cooling. Shift of Energy and material balance lines for reversible reactions in CSTR, Examples of optimal design of PFR and Semi-batch and CSTR Exothermic Reactions.			**CO2**
UNIT III	**Catalytic Reactions**	**Periods : 9**	
Catalytic reactions: theory and modeling: Global rate of reaction, Types of Heterogeneous reactions Catalysis, Different steps in catalytic reactions, Theories of heterogeneous catalysis. Steady State approximation, formulations of rate law Rate laws derived from the PSSH, Rate controlling steps, Eiley-Rideal model, Reforming catalyst example :Finding mechanism consistent with experimental observations Evaluation of rate law parameters, packed beds : Transport and Reactions, Gradients in the reactors : temperature. Porous media reactors: Mass transfer coefficients, Flow effects on spheres tube and cylinders, External Mass Transfer pore diffusion, structure and concentration gradients Internal Effectiveness Factor Catalytic wall reactor: limiting steps reactions and mass transfer limiting PorouscatalystontubewallreactorsDesignofpackedbedporouscatalyticreactors: Mass transfer limited reactions in Packed bed.			**CO3**
UNIT IV	**Heterogeneous Reactors**	**Periods : 9**	
Fluidized bed reactor modeling: Geldart Classification of powders, Fixed bed vs fluidized bed Why fluidized bed, important parameters pressure drop in fixed bed, Class I model Arbitrary Two Region Flow			**CO4**

Models, Class II Chemical Reactor: Plug Flow or Mixed Flow Model. Class III Modeling the Bubbling Fluidized Bed Reactor, BFB, The Kunii-Levenspiel bubbling bed model, Gas Flow Around and Within a Rising Gas Bubble in a Fine particle BFB, Reactor performance of BFB.				
UNIT V	**Applications of Chemical Reaction Engineering**		**Periods** : **9**	
Application of Population Balance Equations for reactor modeling: Particle size distribution, Distribution Functions in Particle Measuring Techniques, Particle distribution model in colloidal particle synthesis in batch reactor, Moments of Distribution, Nucleation rate based on volumetric holdup versus crystal growth rate. Reaction engineering and mitigation of Global warming: CO_2 absorption in high pressure water, different techniques of mitigation of CO_2, methods of separations. Recent advancements, automotive monolith catalytic converter example, removal and utilization of CO_2 for thermal power plants. Bio Chemical Reactors – Modeling and design aspects				**CO5**
Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**	

Reference Books

1. K.G.Denbigh:ChemicalReactorTheory,1971.CambridgeUniversityPress,Second Edition,
2. J.M. Smith: Chemical Engineering Kinetics, 1981.McgrawHill,Third Edition
3. Levenspiel. O, Chemical ReactionEngineering,1998.Wiley,
4. Foggler,H.S, Elements of Chemical Reaction Engineering,2008.Prentice Hall of India,
5. Froment G.F. and Bischoff K.B., Chemical Reactor Analysis and Design, 2010. John Wiley

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<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech. (Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: I</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH253</td><td>Advanced Chemical Engineering Thermodynamics</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
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<table>
<tr><td rowspan="6">Course Outcome</td><td colspan="2">At the end of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td>Understand the importance of phase equilibrium</td></tr>
<tr><td>CO2</td><td>Able to estimate thermodynamic properties from volumetric data</td></tr>
<tr><td>CO3</td><td>Understand intermolecular forces, corresponding states and osmotic systems</td></tr>
<tr><td>CO4</td><td>Able to compute fugacity in gases mixtures and liquid mixtures</td></tr>
<tr><td>CO5</td><td>Understand fundamentals of statistical thermodynamics.</td></tr>
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<table>
<tr><td>UNIT I</td><td>Phase Equilibrium</td><td>Periods : 9</td></tr>
<tr><td colspan="2">The phase equilibrium Problem: Essence of the problem, Application of thermodynamics to phase equilibrium problems; Classical Thermodynamics of Phase equilibria: Homogenous closed system, homogeneous open system, equilibrium in heterogeneous closed system, the Gibbs-Duhem equation, the phase rule, the chemical potential, fugacity and activity, a simple application to Raoult's law</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td>Thermodynamic Properties from Volumetric Data and Cubic Equation of State</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Thermodynamic Properties with independent variables P and T, Fugacity of a component in mixture at moderate pressures, fugacity of a pure liquid or solid; Thermodynamic Properties with independent variables V and T, Fugacity of a component in a mixture according to van der Waals equation</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td>Intermolecular Forces, Corresponding States and Osmotic Systems</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Potential energy functions, electrostatic forces, polarizability and induced dipoles, intermolecular forces between non-polar molecules, Mie's potential energy function for non-polar molecules, structure effects, specific(chemical) forces, hydrogen bond, electron donor –electron acceptor complexes, hydrophobic interaction, molecular interaction in dense fluid media(osmotic pressure, Donnan equilibria, molecular theory of corresponding state theory to more complicated molecules</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td>Fugacity in Gases Mixtures and Liquid Mixtures</td><td>Periods : 9</td></tr>
<tr><td colspan="2">The Lewis fugacity rule, the Virial equation of state, extension to mixtures, fugacity from the Virial equation. The Ideal solution, Fundamental relation of excess functions, activity and activity coefficients, Activity coefficient from excess functions in binary mixtures, Wohl's expansion for the Gibbs energy, Wilson, NRTL and UNIQUAC equation</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td>Introduction to Statistical Thermodynamics</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Thermodynamic states and quantum states of a system, ensembles and basic postulates, the canonical ensemble, the grand canonical ensemble, the semi classical partition function: two basic combinatorial relations, maximum-term method and Stirling's formula</td><td>CO5</td></tr>
</table>

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

<u>Reference Books</u>

1. John M Prausniz, Rudiger N Lichtenthaler, Edmundo Gomes de Azevedo, Molecular Thermodynamics of Fluid-phase equilibria, 3rd edition Prentice Hall PTR(Pearson Education).
2. Stanley I Sandler, *Chemical* and *Engineering Thermodynamics, Wiley,2016*
3. Balzhiser, Samuels and Eliassen, Chemical Engineering Thermodynamics, the study of energy, entroy and equilibrium, Prentice Hall internation,1972.
4. Leonard K Nash, Elements of statistical thermodynamics, Dover publication1974.
5. Terrell L. Hill, An Introduction to Statistical thermodynamics, Dover 1986
6. J. Rajaram and J.C.Kuriacose, Chemical Thermodynamics: Classical, statistical and irreversible, Pearson education india 1st edition, 2013.
7. Tomas Engel and Philip Reid, Physical chemistry, Pearson Education India; 1st edition (1 January 2013)

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech. (Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: I</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: LB</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH254</td><td>Computational and Simulation Laboratory</td><td>-</td><td>-</td><td>4</td><td>2</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
</table>

<table>
<tr><td rowspan="5">Course Outcome</td><td colspan="2">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td>Write programs in MATLAB / OCTAVE for solving simple problems</td></tr>
<tr><td>CO2</td><td>Write programs in MATLAB / OCTAVE for solving linear / nonlinear algebraic equations</td></tr>
<tr><td>CO3</td><td>Write programs in MATLAB / OCTAVE for solving ODEs and PDEs</td></tr>
<tr><td>CO4</td><td>Simulate simple chemical engineering processes using DWSIM / ASPEN</td></tr>
</table>

<table>
<tr><td colspan="2">List of Experiments :</td></tr>
<tr><td>Programming in MATLAB / GNU OCTAVE - Data structures, Matrix and vector manipulation, Input / output, Logical flow - Conditional statements, If statement and If-else statement, Loops, Functions, General features - Evaluation of an Integral, Interpolation, Solving algebraic equations, Solving ODEs - IVP, Plotting, Import / Export data, Programming GUIs</td><td>CO1</td></tr>
<tr><td>Solution of Linear and Nonlinear Algebraic Equations - Case Studies from Units I and II of CH251 - Equations of State, VLE calculations, Isothermal Flash, Chemical Reaction Equilibria, Mass Balances with Recycle Steams, Multicomponent distillation</td><td>CO2</td></tr>
<tr><td>Solution of ODEs and PDEs - Case Studies from Units III, IV and V of CH251 - Isothermal PFR, Non-isothermal PFR, Chemical reactors with mole changes and variable density, Chemical Reactors with mass transfer limitations, Transient CSTRs, Diffusion and Reaction across a flat slab, Diffusion and Reaction across a spherical domain, Transient heat transfer, Linear adsorption - Chromatography, Pressure Swing Adsorption</td><td>CO3</td></tr>
<tr><td>Process Simulation using DWSIM / ASPEN - Ammonia Process, Benzene Process, Integrated Gasification Combined Cycle</td><td>CO4</td></tr>
</table>

Lecture Periods: -	**Tutorial Periods: -**	**Practical Periods: 60**	**Total Periods: 60**

<u>Reference Books</u>

1. Introduction to Chemical Engineering Computing, Bruce A Finlayson, John Wiley and Sons, 2012
2. Numerical Methods with Chemical Engineering Applications, Kevin D Dorfman, Prodromos Daoutidis, Cambridge University Press, 2017

Department: **Chemical Engineering**		Programme: **M. Tech.(Chemical Engineering)**						
Semester: **I**		Course Category Code: **PCC**			Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
CH255	**Research Methodology and IPR**	2	-	-	2	40	60	100
Prerequisite								

Course Outcome	On completion of the course, the student will be able to	
	CO1	Understand research problem formulation and methods
	CO2	Analyze research related information and follow research ethics
	CO3	Gain competency in writing a research paper and proposal
	CO4	Comprehend the need for IPR for growth of individuals & nation.
	CO5	Be aware that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

UNIT I	**Research Problem Formulation**	**Periods** : **6**	
Meaning of research problem, Sources of research problem, Criteria and Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary methods.			**CO1**
UNIT II	**Research Procedure and Ethics**	**Periods** : **6**	
Effective literature studies approaches, analysis, Plagiarism, Research ethics			**CO2**
UNIT III	**Outcomes of Research**	**Periods** : **6**	
Effective technical writing, how to write report/ Paper. Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.			**CO3**
UNIT IV	**Intellectual Property**	**Periods** : **6**	
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.			**CO4**
UNIT V	**Patent Rights**	**Periods** : **6**	
Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System			**CO5**

Lecture Periods: 30	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 30**

Reference Books

1. Stuart Melville and Wayne Goddard, "Research methodology: An introduction, Second edition , Juta & Co, 2007
2. Kothari, C.R., Research Methodology-Methods and Techniques, Wiley Eastern Limited, New Delhi, 2020.
3. Ranjit Kumar, "Research Methodology: A Step by Step Guide for beginners", 2nd Edition, Pearson Education, Singapore, 2005.
4. D.J.Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
5. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
6. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008.

<table>
<tr><td colspan="3">Department: Chemical Engineering</td><td colspan="8">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="3">Semester: II</td><td colspan="4">Course Category Code: PCC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="4">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td colspan="2">TM</td></tr>
<tr><td>CH256</td><td colspan="2">Advanced Transport Phenomena</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td colspan="2">100</td></tr>
<tr><td>Prerequisite</td><td colspan="10"></td></tr>
<tr><td></td><td colspan="10">On completion of the course, the student will be able to</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="9">Relate all transport equations in vector and tensor notations</td></tr>
<tr><td>CO2</td><td colspan="9">Write conservation equations and</td></tr>
<tr><td>CO3</td><td colspan="9">Solve conservation equations in limiting cases</td></tr>
<tr><td>CO4</td><td colspan="9">Solve heat transfer problems</td></tr>
<tr><td>CO5</td><td colspan="9">Solve mass transfer problems</td></tr>
<tr><td>UNIT I</td><td colspan="6">Basics of Transport Phenomena</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="9">Continuum hypothesis, reference frames and coordinate systems, scalar, vector and tensor fields; Kinetics and dynamics, Eulerian and Lagrangian specifications, differentiation following the motion, decomposition of motion, irrotational and solenoidal flows; body and surface forces and Cauchy's fundamental theorem for stress</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Conservation Equations and Constitutive Equations</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="9">Conservation equations and control volumes, mass conservation, linear momentum conservation, angular momentum conservation, energy conservation; constitutive equations, pressure, heat flux and stress; initial and boundary conditions, rigid impermeable walls, fluid-fluid interface, boundaries at infinity, symmetry boundaries, flow equations ,dimensional analysis approximate solutions</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Applications</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="9">Slow flow, inviscid flow , nearly non accelerating flow, boundary layer flow</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Transport Approach for Heat Transfer</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="9">Foundations for energy transfer: Energy, Entropy and behavior of materials; Differential balances in energy transfer; integral averaging in energy transfer and applications</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Transport Approach for Mass Transfer</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="9">Foundations for mass transfer; differential balances in mass transfer; integral averaging in mass transfer and applications.</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="11"><u>Reference Books</u></td></tr>
<tr><td colspan="11">1. Rutherford Aris, Vectors, Tensors and the Basic Equations of Fluid Mechanics, Dover Publications Inc.; New edition (17 September 1990)
2. Stefan M Richardson, Fluid Mechanics, Hemisphere publishing corporation, Taylor and Francis,1989
3. John C. Slattery Advanced Transport phenomena, Cambridge University Press, 1999.
4. K.S.Gandhi, Heat and Mass Transfer A transport phenomena approach, New age international publishers, 2011.
5. R. Byron Bird, Warren E. Stewart, et al. Transport Phenomena, Revised 2ed (An Indian Adaptation),Wiley, 2021
6. William M. Deen, Analysis of transport phenomena, Oxford University Press; Edition (18 October 2013)
7. P.A.Ramachandra, Advanced transport phenomena analysis, modeling and computations, Cambridge University Press, 2014.</td></tr>
</table>

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: II</td><td colspan="3">Course Category Code: PCC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH257</td><td>Advanced Separation Processes</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
</table>

<table>
<tr><td rowspan="6">Course Outcome</td><td colspan="2">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td>List and select various separation processes based on various properties</td></tr>
<tr><td>CO2</td><td>Understand various bubble fractionation and membrane separation processes</td></tr>
<tr><td>CO3</td><td>Classify organic and inorganic membranes and various industrial applications</td></tr>
<tr><td>CO4</td><td>Explain various special separation processes</td></tr>
<tr><td>CO5</td><td>Describe various chromatographic separation processes</td></tr>
</table>

<table>
<tr><td>UNIT I</td><td>Conventional Separation processes</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Introduction: Conventional separation processes - Absorption, Adsorption, Distillation, Drying, Extraction, Diffusion, Leaching, Crystallization, Advances in separation techniques based on size, Advances in separation techniques based on surface properties, Advances in separation techniques based on ionic properties, Cross flow filtration, Electro filtration, Dual functional filter, Surface based solid-liquid separations involving a second liquid, Sirofloc filter</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td>Bubble, Foam Fractionation and Membranes</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Nature of bubbles and foams, stability of foams, foam fractionation techniques, batch, Continuous, single stage and multistage columns. Types and choice of membranes, Plate and frame, spiral wound membranes, Tubular and hollow fibre membrane reactors, Membrane Permeates: Dialysis, Reverse osmosis, Nano-filtration, ultra-filtration, microfiltration, Donnan dialysis, Ceramic membranes</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td>Membrane Separation</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Characteristics of organic and inorganic membranes, basis of membrane selection, osmotic pressure, partition coefficient and permeability, concentration polarization, electrolyte diffusion and facilitated transport, macro-filtration, ultra-filtration, reverse osmosis, electro-dialysis. Industrial applications.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td>Special Processes</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Liquid membrane separation, super-critical extraction, adsorptive separation-pressure, vacuum and thermal swing, pervaporation and permeation, nano-separation</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td>Chromatographic Methods of Separation</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Gel, solvent, ion and high performance liquid chromatography, Gas Chromatography, Moving Bed Chromatography, Size based Exclusion chromatography and Bio-molecular Separation.</td><td>CO5</td></tr>
</table>

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

<u>Reference Books</u>

1. King C.J., “Separation Processes”, Tata McGraw Hill. 1982.
2. Nakagawal, O. V., “Membrane Science and Technology”, Marcel Dekker, 1992
3. Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
4. Wankat P.C., “Separation Process Engineering”, 2nd Ed., Prentice Hall.2006.
5. Seader J.D. and Henley E.J., “Separation Process Principles”, 2nd Ed.,Wiley.2006
6. Phillip C. Wankat , Separation Process Engineering (2nd Edition), Prentice Hall,2007
7. Rousseau, R. W., “Handbook of Separation Process Technology”, John Wiley, New York, 2009.

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: II</td><td colspan="4">Course Category Code: PCC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH258</td><td>Advanced Process Control</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
</table>

<table>
<tr><td rowspan="6">Course Outcome</td><td colspan="2">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td>List and select various separation processes based on various properties</td></tr>
<tr><td>CO2</td><td>Understand various bubble fractionation and membrane separation processes</td></tr>
<tr><td>CO3</td><td>Classify organic and inorganic membranes and various industrial applications</td></tr>
<tr><td>CO4</td><td>Explain various special separation processes</td></tr>
<tr><td>CO5</td><td>Describe various chromatographic separation processes</td></tr>
</table>

<table>
<tr><td>UNIT I</td><td>Review of Stability Analysis and PID Controller Tuning</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Bode's and Nyquist Stability Criteria - Relative Stability Calculations, Gain Margin and Phase Margin, Nichols Chart and Peak Gain ; PID controller tuning - Zeigler -Nichols tuning formula, Direct Synthesis tuning, IMC tuning, Controller tuning using approximate process models - Cohen - Coon tuning rules, Time Integral tuning rules, Auto tuning with relay controller</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td>State Space Methods and Multivariable Control</td><td>Periods : 9</td></tr>
<tr><td colspan="2">State variables and State Space description, Open loop dynamic analysis in state space, Multivariable Process Models, Multivariable Transfer Functions and open loop dynamic analysis, Closed loop dynamic analysis, Interaction analysis and loop pairing, Relative Gain Array (RGA), Design of Multivariable controllers, Decoupling, Decoupling by Singular Value Decomposition, Model Based Controllers for Multivariable Processes, State observers and state feedback controllers</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td>Sampled - Data Control Systems</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Introduction to Sampled -Data systems, Z-Transform, Pulse Transfer Functions, Dynamic analysis of discrete - time systems, Design of digital controllers - Discrete PID and other controllers based on continuous domain strategies</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td>Theoretical Analysis of Distributed Parameter Systems</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Distributed Parameter Systems - Heat Conduction into a Solid, Transportation lag as a distributed parameter system, Double Pipe Heat Exchanger - Approximate transfer function models, Tubular Reactor with Axial Dispersion - dynamic model for axial mixing and estimation of Peclet Number</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td>Special Topics in Control</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Model Predictive Control - General Principles of MPC, Dynamic Matrix Control (DMC), SISO unconstrained problem, Extension to Multivariable systems, Model Algorithmic Control (MAC), Commercial MPC schemes, Introduction to State Estimator and Kalman Filter.</td><td>CO5</td></tr>
</table>

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

<u>Reference Books</u>

1. Process Dynamics, Modeling, and Control, B.A. Ogunnaike, W. Harmon Ray, Oxford University Press, 1994
2. Process Systems Analysis and Control, D. R. Coughanowr, McGraw-Hall, 1991
3. Chemical Process Control: An Introduction to Theory and Practice, George Stephanopoulos, Prentice Hall, 1984
4.Process Dynamics and Control, D.E. Seborg, T.F. Edgar, D.A. Mellichamp, Wiley - India, 2005

Department: Chemical Engineering			Programme: **M. Tech.(Chemical Engineering)**						
Semester: **II**			Course Category Code: **PCC**			Semester Exam Type: **LB**			
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
CH259	**Advanced Chemical Engineering Laboratory**		-	-	4	2	40	60	100
Prerequisite									
	On completion of the course, the student will be able to								
Course Outcome	**CO1**	Knowledge of mass transfer operations and mechanical operations							
	CO2	Students should be able to know the synthesis of materials and applications in separation processes.							
	CO3	Students will be able to provide applicable solutions to separation processes							
	CO4	Able to verify and calculate heat and mass transfer parameters							

List of experiments: Advanced Separation Processes

1) Separation of phenolic compounds in a pilot plant RO membrane system
2) Study the effect of pressure on permeate flux and solution rejection in RO system
3) Determination of phenolic compounds in waste water using a HPLC system
4) Deducing the identity of an unknown hydrocarbon using gas chromotograph
5) Studies on flooding and weeping characteristics in tall columns
6) Studies on effect of filter aids on effectiveness of filtration
7) RDC studies on rotary dryer
8) Colour removal from synthetic effluent using Adsorption column and analysis using UV/Visible spectrophotometer
9) Studies on bare and finned tube vertical condenser
10) Non-Newtonian fluid characteristics: an experiment using capillary tube
11) Batch sedimentation- verification of Kynch theory
12) Extraction studies using RDC/Paced Columns
13) A study on absorption with chemical reaction
14) Studies on fluid flow/heat transfer in helical coils
15) Studies on draining a fluid from a tank
16) Supercritical extraction of the fragrance.
17) Study the reaction with mass transfer: e.g. Synthesis of calcium carbonate.
18) Study the reactive distillation system considering batch and continuous mode

Lecture Periods:	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 60**

Reference Books

1. Perry’s Chemical Engineers Hand book ,McGraw Hill, 2018
2. Handbook of separation process technology, Edited by Ronald W. Rousseau, Wiley India (1 January 2009)
3. Hand book of Analytical techniques, Editor(s):Prof. Dr. Helmut Günzler, Alex Williams,WILEY-VCH Verlag GmbH,2001
4. Garlapati Chandrasekhar, Laboratory experiments in chemical and allied engineering: emphasis on low cost experiments, Penram international publishing (India) Pvt. Ltd, 2017.
5. Appropriate Journal papers

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="8">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: II</td><td colspan="4">Course Category Code: PAC</td><td colspan="4">Semester Exam Type: LB</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="4">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td colspan="2">CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH260</td><td>Mini Project and Seminar</td><td>-</td><td>-</td><td>4</td><td>2</td><td colspan="2">100</td><td>-</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9">-</td></tr>
<tr><td rowspan="4">Course Outcome</td><td colspan="9">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="8">Ability to carry out a portion of a research work</td></tr>
<tr><td>CO2</td><td colspan="8">Ability to extend the project to find an application for society</td></tr>
<tr><td>CO3</td><td colspan="8">Ability to work in a team and present the ideas and thoughts with a clarity</td></tr>
<tr><td colspan="8">In the course of the degree programme each group of not more than two students has to identify a mini project work in the area of their specialization and the mini project will be implemented under the supervision of a faculty. The progress of the work will be monitored and assessed internally. A project report has to be submitted at the end of the semester after completion of the project work.</td><td colspan="2">CO1, CO2, CO3</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: 60</td><td colspan="4">Total Periods: 60</td></tr>
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<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: III</td><td colspan="4">Course Category Code: PAC</td><td colspan="3">Semester Exam Type: PR</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH261</td><td>Dissertation – Phase I</td><td>-</td><td>-</td><td>20</td><td>10</td><td>250</td><td>250</td><td>500</td></tr>
<tr><td>Prerequisite</td><td colspan="8">-</td></tr>
<tr><td rowspan="3">Course Outcome</td><td>CO1</td><td colspan="7">Ability to transform knowledge into an experimental process</td></tr>
<tr><td>CO2</td><td colspan="7">Ability to demonstrate the motivation to extend the work to a research</td></tr>
<tr><td>CO3</td><td colspan="7">Ability to identify and apply appropriate tools to solve a problem and also has the capability to examine hypotheses</td></tr>
<tr><td colspan="8">Each student will do an exhaustive literature survey and identify an experimental and / or a theoretical project to be carried out under a supervision of a guide. The phase I of the project work has to be completed by the end of third semester. The progress of the work will be monitored and assessed internally for 250 marks by a committee comprising departmental faculty members and project guide. A project report has to be submitted at the end of the semester after completion of the phase I of the project work. The external assessment will be carried out for 250 marks as per regulations.</td><td>CO1, CO2, CO3</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: 300</td><td colspan="3">Total Periods: 300</td></tr>
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<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: IV</td><td colspan="4">Course Category Code: PAC</td><td colspan="3">Semester Exam Type: PR</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CH262</td><td>Dissertation – Phase II</td><td>-</td><td>-</td><td>32</td><td>16</td><td>250</td><td>250</td><td>500</td></tr>
<tr><td>Prerequisite</td><td colspan="8">-</td></tr>
<tr><td rowspan="3">Course Outcome</td><td>CO1</td><td colspan="7">Ability to transform knowledge into an experimental process</td></tr>
<tr><td>CO2</td><td colspan="7">Ability to demonstrate the motivation to extend the work to a research</td></tr>
<tr><td>CO3</td><td colspan="7">Ability to identify and apply appropriate tools to solve a problem and also has the capability to examine hypotheses</td></tr>
<tr><td colspan="7">The phase II of the project work has to be completed by the end of the fourth semester. The progress of the work will be monitored and assessed internally for 250 marks by a committee comprising departmental faculty members and project guide. A project report summarizing the entire project work has to be submitted at the end of the semester after completion of the phase II of the project work. The external evaluation will be carried out as per regulations for 250 marks.</td><td colspan="2">CO1, CO2, CO3</td></tr>
<tr><td colspan="2">Lecture Periods: -</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: 480</td><td colspan="3">Total Periods: 480</td></tr>
</table>

PROGRAMME SPECIFIC ELECTIVES

<table>
<tr><td colspan="3">Department: Chemical Engineering</td><td colspan="8">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="3">Semester: I</td><td colspan="4">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ01</td><td colspan="2">Advanced Downstream Processing</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="9">On completion of the course, the students will be able to</td></tr>
<tr><td>CO1</td><td colspan="8">To learn concepts of downstream processing in chemical industry.</td></tr>
<tr><td>CO2</td><td colspan="8">Understand the role of downstream processing in petrochemical industry</td></tr>
<tr><td>CO3</td><td colspan="8">Analyze reactors, upstream and downstream processes in production</td></tr>
<tr><td>CO4</td><td colspan="8">Understand the concepts of advanced distillation process</td></tr>
<tr><td>CO5</td><td colspan="8">Understand the separation methods for non-ideal mixtures</td></tr>
<tr><td>UNIT I</td><td colspan="6">Introduction</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Introduction to Downstream processes theory, applications in chemical separation for Gas-Liquid system, Gas-Solid system. Super critical fluids extraction in food, pharmaceutical, environmental and petroleum applications, water treatment, desalination, Bio separation, dialysis, industrial dialysis.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Downstream Processes in Petrochemical Industry</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Cryogenic distillation for refinery, petrochemical off gases, natural gases, gas recovery-Olefin, Helium, Nitrogen, Desulfurization - coal, flue gases</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Advanced Distillation Processes</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Azeotropic & extractive distillation - residue curve maps, homogeneous azeotropic distillation, Pressure swing distillation, Column sequences, heterogeneous azeotropic distillation.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Energy Conservation in Separation Processes</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Energy balance, molecular sieves - zeolights, adsorption, catalytic properties, manufacturing processes, hydrogel process, application, New trends.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Non-Ideal Mixtures and Ion Exchange</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Separations process synthesis for nonazeotropic mixtures, non ideal liquid mixtures, separation synthesis algorithm, Ion exchange - manufacture of resins, physical & chemical properties, capacity, selectivity, application, regeneration, equipment, catalysis used</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="10"><u>Reference Books</u></td></tr>
<tr><td colspan="10">1. Perry’s “Chemical Engg. Handbook”: McGraw Hill Pub.
2. Douglas J.M., “Conceptual Design of Chemical Processes”, McGraw Hill
3. Liu Y.A., “Recent Developments in Chemical Process & Plant Design”, John Wiley & Sons Inc.
4. Timmerhaus K.D., “Cryogenic Process Engg.”, Plenum Press
5. Othmer Kirk “Encyclopaedia of Separation Technology, Vol. I & II”, Wiley Inter-science</td></tr>
</table>

Department: **Chemical Engineering**	Programme: **M. Tech.(Chemical Engineering)**
Semester: **I**	Course Category Code: **PSE** / Semester Exam Type: **TY**

Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
CHZ02	**Transport Process in Porous Media**	3	-	-	3	40	60	100
Prerequisite								

Course Outcome	On completion of the course, the students will be able to
CO1	Quantify fundamentals
CO2	Calculate Effective properties
CO3	Solve exact solutions
CO4	Do modeling
CO5	Give real-time engineering solutions

UNIT I	**Fundamentals**	**Periods** : **9**	
Mass, momentum and energy transport, Darcy and Non-Darcy equations, equilibrium and non-equilibrium conditions, species transport, radioactive decay.			**CO1**
UNIT II	**Effective Medium Approximation**	**Periods** : **9**	
Equivalent thermal conductivity, viscosity, dispersion.			**CO2**
UNIT III	**Exact Solutions**	**Periods** : **9**	
Flow over a flat plate, flow past a cylinder, boundary-layers, reservoir problems.			**CO3**
UNIT IV	**Special Topics**	**Periods** : **9**	
Field scale and stochastic modeling, Turbulent flow, compressible flow, multiphase flow, numerical techniques, hierarchical porous media, nano-scale porous media, multiscale modeling.			**CO4**
UNIT V	**Engineering Applications**	**Periods** : **9**	
Groundwater, waste disposal, oil and gas recovery, regenerators, energy storage systems. Experimental techniques: Flow visualization, quantitative methods, inverse parameter estimation.			**CO5**
Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Principles of Heat Transfer in Porous Media, by M. Kaviany, Springer New York (1995).
2. Transport Phenomena in Porous Media, Volumes I-III, edited by D. R. Ingham and I. Pop, Elsevier, New York (1998-2005).
3. Dynamics of Fluids in Porous Media, J. Bear, Dover (1988).
4. Introduction to Modeling of Transport Phenomena in Porous Media, J. Bear and Y. Bachmat, Kluwer Academic Publishers, London (1990).
5. The Mathematics of Reservoir Simulation, R.E. Ewing, SIAM Philadelphia (1983).
6. Stochastic Methods for Flow in Porous Media: Coping with Uncertainties, Zhang, D., Academic Press, California (2002).
7. The Method of Volume Averaging, S. Whitaker, Springer, New York (1999).

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<tr><td colspan="2">Semester: I</td><td colspan="4">Course Category Code: PSE</td><td colspan="5">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ03</td><td>Modern Concepts in Catalysis and Surface Engineering</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the students will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">To understand the concepts of homogenous and heterogeneous catalysis, with specific examples</td></tr>
<tr><td>CO2</td><td colspan="7">To study reaction mechanisms and kinetics of homogenous and heterogeneous catalytic reactions.</td></tr>
<tr><td>CO3</td><td colspan="7">To familiarize with the characterization of catalysts</td></tr>
<tr><td>CO4</td><td colspan="7">To estimate characteristics of catalysts used in chemical industry.</td></tr>
<tr><td>CO5</td><td colspan="7">To understand the application and mechanisms of several types of catalysts in chemical industry.</td></tr>
<tr><td>UNIT I</td><td colspan="5">Introduction to Catalysis</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Definition of Catalytic activity, Magnitude of Turnover Frequencies and Active Site Concentrations, Evolution of Important Concepts and Techniques in Heterogeneous Catalysis, Classification of Catalysts - Homogeneous, Heterogeneous, Biocatalysts, Dual Functional Catalysts, Enzymes, Solid Catalysts, Powder Catalysts, Pellets, Composition, Active Ingredients, Supportive materials, Catalysts Activation, Catalyst Deactivation.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Adsorption in Catalysis</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Adsorption and its importance in Catalysis, Adsorption and potential energy curves, Surface Reconstruction, Adsorption Isotherms and Isobars, Dynamical Considerations, Types of Adsorption Isotherms and their Derivation from Kinetic Principles, Mobility at Surfaces, Kinetics of surface Reactions, Photochemistry on oxide and metallic surfaces, Characterization of the adsorbed molecules</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Catalyst Characterization</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Catalyst Characterization Methods - Their Working Principle and Applications - XRF, XRD, IR Spectroscopy, XPS, UPS, ESR, NMR; Infrared, Raman, NMR, Mossbauer and X-Ray Absorption spectroscopy, Surface Acidity and Toxicity, Activity, Life time, Bulk density, Thermal stability Crystal Defects, Peroviskites, Spinels, Clays, Pillared Clays, Zeolites</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Significance of Pore Structure and Surface Area</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Importance of Surface Area and Pore Structure, Experimental Methods for Estimating Surface Area-Volumetric, Gravimetric, Dynamic Methods, Experimental Methods for Estimating Pore Volume and Diameter - Gas Adsorption and Mercury Porosimeter Method, Models of the Pore Structure -Hysteresis Loops, Geometric Models, Wheeler’s Model, Dusty Gas Model, Random Pore Model, Diffusion in Porous Catalysts - Effective Diffusivity, Knudsen Diffusion, Effect of Intra particle Diffusion, Non-isothermal Reactions in Pores, Diffusion Control.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Industrial Applications - Case Studies</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Industrial processes involving heterogeneous solid catalyst: Synthesis of Methanol, Fischer-Tropsch Catalysis, Synthesis of Ammonia, Automobile Exhaust Catalysts and Catalyst Monolith, Photo catalytic Breakdown of Water and the Harnessing of Solar Energy. Contribution of homogeneous catalytic process in chemical industry: Oxidations of Alkenes such as production of acetaldehyde, propylene oxide etc., Polymerization such as production of polyethylene, polypropylene or polyester production</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
</table>

Reference Books
1. Emmett, P.H. - "Catalysis Vol. I and II, Reinhold Corp.", New York, 1954 2. Smith, J.M. - "Chemical Engineering Kinetics ", McGraw Hill, 1971 3.Thomas and Thomas - "Introduction to Heterogeneous Catalysts ", Academic Press, London 1967 4. Piet W.N.M. van Leeuwen, Homogeneous catalysis: Understanding the Art, Springer, 2004 5. Piet W.N.M. van Leeuwen, and John C. Chadwick, Homogeneous catalysis: Activity-Stability deactivation, Wiley, VCH, 2011.

Department: **Chemical Engineering**		Programme: **M. Tech.(Chemical Engineering)**							
Semester: **I**		Course Category Code: **PSE**				Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
CHZ04	**Membrane Technology and its Applications**	3	-	-	3	40	60	100	
Prerequisite									

Course Outcome	On completion of the course, the students will be able to	
	CO1	Understand the principle behind membrane separation
	CO2	Design various membrane separation processes
	CO3	Describe the key aspects of membrane bioreactors
	CO4	Discuss on various pretreatment techniques to prevent membrane fouling
	CO5	Know various case studies on membrane based water and waste water treatment systems

UNIT I	**Introduction**	**Periods** : 9
Solid Liquid separation systems-Filtration systems- Theory of Membrane separation – mass Transport Characteristics Cross Flow filtration-Membrane Filtration- Types and choice of membranes, porous, non porous, symmetric and asymmetric – Plate and Frame, spiral wound and hollow fibre membranes – Liquid Membranes		**CO1**
UNIT II	**Membrane Processes and Systems**	**Periods** : 9
Microfiltration – Ultrafiltration- Nano Filtration – Reverse Osmosis – Electro dialysis- Pervaporation - Membrane manufactures – Membrane Module/Element designs – Membrane System components – Design of Membrane systems - pump types and Pump selection – Plant operations – Economics of Membrane systems		**CO2**
UNIT III	**Membrane Bioreactors**	**Periods** : 9
Introduction and Historical Perspective of MBRs, Bio-treatment Fundamentals, Biomass Separation MBR Principles, Fouling and Fouling Control, MBR Design Principles, Design Assignment, Alternative MBR Configurations, Commercial Technologies, Case Studies		**CO3**
UNIT IV	**Pretreatment Systems**	**Periods** : 9
Membrane Fouling – Pretreatment methods and strategies – monitoring of Pretreatment – Langlier Index, Silt Density Index, Chemical cleaning, Bio foulant control		**CO4**
UNIT V	**Case Studies**	**Periods** : 9
Case studies on the design of membrane-based water and wastewater treatment systems – zero Liquid effluent discharge Plants		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Jorgen Wagner, Membrane Filtration handbook, Practical Tips and Hints, Second Edition, Revision Osmonics Inc., 2001
2. K. Yamamoto and Urase T, Membrane Technology in Environmental management, special issue, Water Science and technology, Vol.41, IWA Publishing, 2000
3. Mulder, M., Basic Principle of Membrane Technology, Kluwer Academic Publishers, 1996
4. Noble, R.D. and Stern, S.A., Membrane Separations Technology: Principles and Applications, Elsevier, 1995.
5. Symon Jud, MBR Book – Principles and application of MBR in water and wastewater treatment, Elsevier, 2006
6. Water Environment Federation (WEF), Membrane Systems for Wastewater Treatment, McGraw-Hill, USA, 2005

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: I</td><td colspan="3">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
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<tr><td>CHZ05</td><td>Process Design and Synthesis</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
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<table>
<tr><td rowspan="6">Course Outcome</td><td colspan="2">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td>Understand the usage of commercial flow sheeting software to process design applications</td></tr>
<tr><td>CO2</td><td>Apply life cycle assessment techniques in process industries</td></tr>
<tr><td>CO3</td><td>Design processes involving reactor networks</td></tr>
<tr><td>CO4</td><td>Integrate and apply techniques and knowledge to design separation based equipment</td></tr>
<tr><td>CO5</td><td>Design and synthesis processes for heat exchanger networking applications</td></tr>
</table>

UNIT I	**Introduction**	**Periods** : 9
Introduction to fundamental concepts and principles of process synthesis and design and use of flow sheet simulators to assist process design. Process Flow sheet Models: An Introduction to Design, Chemical process synthesis, analysis and optimization.		**CO1**

UNIT II	**Product Design and Developments**	**Periods** : 9
Process engineering economics and project evaluation Life Cycle Assessments of process: From design to product development, Engineering Economic Analysis of Chemical Processes, Project costing and performance analysis, Environmental concerns, Green engineering, Engineering ethics, Health and safety		**CO2**

UNIT III	**Reactor Networks**	**Periods** : 9
Geometry of mixing and basic reactor types, The Attainable Region (AR) approach, AR in higher dimensions & for other processes, Reactive Separation processes, Fundamental behavior and problems, Separation through reactions. Reactive Residue Curve Maps		**CO3**

UNIT IV	**Synthesis of Separation Trains**	**Periods** : 9
Criteria for selection of separation methods, selection of equipment: Absorption, Liquid-liquid extraction Membrane separation, adsorption, leaching, drying, crystallization, Ideal distillation - Column and sequence fundamentals, Sharp splits & sequencing Phase diagrams for 2, 3 and 4 components, Feasibility and vapor flow rates for single columns, Residue curve basics.		**CO4**

UNIT V	**Heat Exchanger Network Synthesis**	**Periods** : 9
Minimum heating and cooling requirements, Minimum Energy Heat Exchanger Network, Loops and Paths, Reducing Number of Exchangers, HENS basics & graphics, The pinch point approach, Stream Splitting, Performance targets.		**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Douglas, J. “Conceptual Design of Chemical Processes”, New York, NY: McGraw-Hill Science/Engineering/Math, 1988. ISBN: 0070177627.
2. Seider, W. D., J. D. Seader, and D. R. Lewin. “Product and Process Design Principles: Synthesis, Analysis and Evaluation”,. 2nd ed. New York, NY: Wiley, 2004. ISBN: 0471216631.
3. Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz., “Analysis, Synthesis, and Design of Chemical Processes”, 2nd Edition, 2002, Prentice Hall ISBN-10: 0-13-064792-6
4. Biegler L.T., Grossmann I.E. and Westerberg A.W., “Systematic Methods of Chemical Process Design”, Prentice Hall, 1997.

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="8">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: I</td><td colspan="4">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code:</td><td rowspan="2">Course Name:</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ06</td><td>Food Processing Technology</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to:</td></tr>
<tr><td>CO1</td><td colspan="7">Understand the working and principles of various food handling equipments.</td></tr>
<tr><td>CO2</td><td colspan="7">Understand the working and principles of various food processing equipments.</td></tr>
<tr><td>CO3</td><td colspan="7">Understand various food preservation techniques.</td></tr>
<tr><td>CO4</td><td colspan="7">Understand various methods of food processing.</td></tr>
<tr><td>CO5</td><td colspan="7">Understand and demonstrate the production of various types of value added and innovative food products of commercial importance.</td></tr>
<tr><td>UNIT I</td><td colspan="5">Food Handling Equipments</td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="7">Principle considerations of food handling equipments; belt conveyor, screw conveyor, bucket elevator and pneumatic conveyors; equipments for size reduction, Size classification, Mixing, Kneading, Blending, Extrusion and emulsification.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Food Processing Equipments</td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="7">Principle considerations of food processing equipments; Types and Principle of dryers, heat exchangers, Evaporators, pasteurizer, Blancher, Retorts and distillation units; mechanical separation: filtration, sieving, centrifugation, sedimentation.</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Food Preservation</td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="7">Introduction; principles and methods of food preservation; High Temperature Preservation; Low temperature preservation; Drying, dehydration and concentration; Food irradiation; Preservation using sugar, salt and acids; Preservation by use of chemicals.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Recent Methods in Food Processing</td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="7">Introduction; PEF, HPP, ultrasound, dielectric heating; microwave heating, ohmic heating; infrared heating; UV light, X-rays, membrane processing, ozonisation; high intensity electric field in pulses; new hybrid drying technologies; monitoring by NMR and MRI Technology</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Innovative and Value Added Food Products</td><td colspan="3">Periods: 9</td></tr>
<tr><td colspan="7">Processing & Utilization of Soya bean for value added products; Innovative products from cereals, pulses and oilseeds; Extrusion technology for cereals; Oil seeds Processing; Prepared meat products; Manufacturing of fruit juice concentrates, Preparation of jam, jellies and marmalades; Preparation of preserved and candied fruits; Pickling of fruits and vegetables.</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Fundamentals of Food Process Engineering; Toledo RT; 2nd ed, 2000, CBS Publishers.
2. Carl.W. Hall. (1988). Processing Equipments for Agrl. Products. McGraw Hill Pub.Co.
3. Subbulakshmi.G., and Shobha A. Udipi, Food Processing and Preservation, New Age International Publications, New Delhi, 2007.
4. Toledo, R.T., “Fundamentals of Food Process Engineering”, CBS Publishers and Distribution, New Delhi, 1997.</td></tr>
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<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: I</td><td colspan="3">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
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<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ07</td><td>Fluidization Engineering</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td></td><td colspan="8">At the end of the course, the student will be able to</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Know industrial applications</td></tr>
<tr><td>CO2</td><td colspan="7">Map the various regimes</td></tr>
<tr><td>CO3</td><td colspan="7">Write various fluidization models</td></tr>
<tr><td>CO4</td><td colspan="7">Write dispersion models</td></tr>
<tr><td>CO5</td><td colspan="7">Design fluidization systems</td></tr>
<tr><td>UNIT I</td><td colspan="4">Introduction to Fluidization and Applications</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="6">Phenomenon of fluidization, behavior of fluidized bed, contacting modes, advantages and disadvantages of fluidization, fluidization quality, selection of contacting mode, Beds for Industrial applications, coal gasification, synthesis reactions, physical operations, cracking of hydrocarbons</td><td colspan="3">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="4">Mapping of Fluidization Regimes</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="6">characterization of particles, mechanics of flow around single 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</td><td colspan="3">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="4">Bubbling Fluidized Beds</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="6">Davidson model for bubble in a fluidized bed, and its implications, the wake region and movement of solids at bubbles, coalescence and splitting of bubbles, bubble formation above a distributor, slug flow, Turbulent and fast fluidization - mechanics, flow regimes and design equations, Emulsion movement, estimation of bed properties, bubble rise velocity, scale up aspects, flow models, two phase model, K-L model</td><td colspan="3">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="4">Solids Movement and Gas Dispersion</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="6">Vertical and horizontal movement of solids, Dispersion model, large solids in beds of smaller particles, staging of fluidized beds, gas dispersion in beds, gas interchange between bubble and emulsion, estimation of gas interchange coefficient, Heat and mass transfer in fluidized systems, Mixing in fluidized systems - measurements and models.</td><td colspan="3">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="4">Fluidized Bed Reactors and Applications</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="6">Entrainment and elutriation, Freeboard behavior, gas outlet, entrainment from tall vessel, freeboard entrainment model, high velocity fluidization, pressure drop in turbulent and fast fluidization, Slugging, Spouted beds, Circulating Fluidized Beds, fluidized bed driers.
Mathematical model of a homogeneous fluidized bed, Design of catalytic reactors, pilot plant reactors, information for design, bench scale reactors, design decisions, deactivating catalysts, Design of non catalytic reactors, kinetic models for conversion of solids, models for shrinking particles, conversion of solids of unchanging size</td><td colspan="3">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1.Levenspiel O. and Kunnii D., “Fluidization Engineering”, John Wiley, 1972
2. Liang-Shih Fan, “Gas-Liquid-Solid Fluidization Engineering”, Butterworths, 1989
3. Fluidization edited by J.F.Davidson and D.Harrison, Academic Press, 1971.
4. Gas fluidization technology edited by. D.Geldart, Wiley–Blackwell (3 December 1986)
5. JR Howard, Fluidized bed Technology principles and applications, Adam Hilger,1989.
6. Max Leva, Fluidization McGraw Hill, 1980</td></tr>
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<table>
<tr><td colspan="3">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="3">Semester: I</td><td colspan="3">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ08</td><td colspan="2">Design of Experiments and Parameter Estimation</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="9">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="8">Understand the basic concepts involved in design of experiments</td></tr>
<tr><td>CO2</td><td colspan="8">Use statistics in experimentation</td></tr>
<tr><td>CO3</td><td colspan="8">Include statistical approach to propose hypothesis from experimental data</td></tr>
<tr><td>CO4</td><td colspan="8">Estimate parameters by multi-dimensional optimization</td></tr>
<tr><td>CO5</td><td colspan="8">Apply Response surface methodology in practical cases</td></tr>
<tr><td>UNIT I</td><td colspan="6">Introduction , Data Analysis and Distributions</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Design of experiments. Basic concepts, Bias and confounding, controlling bias, causation, Random Variables - Exploratory Data Analysis- Variable types, Displaying the distribution, mean variance and typical spread, quartiles and unusual spread, multivariate data: finding relations- Probability</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Estimation Techniques and Linear Regression Analysis</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Point Estimation - Interval Estimation - Hypothesis Testing – Linear Regression Model –Parameter Estimation -Matrix approach to linear regression- ANOVA - quantifying regression fits of experimental data, Extra sum of squares approach, confidence intervals on regression coefficients, lack of fit analysis.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Single Factor Experiments</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Completely randomized design – Randomized block design – Effects of coding the observations, Latin square design- orthogonal contrasts- comparison of treatment means – Duncan’s Multiple range test, Newman – Keuel’s test, Tukey’s test.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Factorial Experiments</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Main and interacvtion effects – Rules for sum of squares and expected mean square, two and three factor full factorial design, 2k designs with two and three factors. Yate’s algorithm, practical applications</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Taguchi Techniques & Response Surface Methodology</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="9">Orthogonal designs – data analysis – parameter design- noise factors, objective functions (S/N ratios) – applications Response Surface Methodology: Method of steepest ascent, first and second order models, identification of optimal process conditions Introduction to Design of Experiments using R</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="10"><u>Reference Books</u></td></tr>
</table>

1. Douglas C. Montgomery (2005). Design of Experiments. John Wiley & Sons
2. Hanneman, Robert A., Kposowa, Augustine J., Riddle, Mark D. (2012). Research Methods for the Social Sciences: Basic Statistics for Social Research. John Wiley & Sons.
3. Saunders, Mark, Brown, Reva Berman (2007). Dealing with Statistics: What You Need to Know. McGraw-Hill Education.
4. Philip J.Ross(1989). Taguchi Techniques for quality Engineering, Prentice Hall.

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="8">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: II</td><td colspan="4">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
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<tr><td>CHZ09</td><td>Process Intensification</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Understand the basic techniques involved in Process Intensification</td></tr>
<tr><td>CO2</td><td colspan="7">Apply the process Intensification techniques to a range of chemical processes</td></tr>
<tr><td>CO3</td><td colspan="7">Develop various equipment to intensify the mixing processes</td></tr>
<tr><td>CO4</td><td colspan="7">Develop various strategies to intensify the heat exchange processes</td></tr>
<tr><td>CO5</td><td colspan="7">Understand the intensification processes applied in various fields</td></tr>
<tr><td>UNIT I</td><td colspan="5">Introduction</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Introduction: Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, Process Intensifying Equipment, Process intensification toolbox, Techniques for PI application.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Process Intensification in various processes</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Implementation of Micro-reaction Technology, From basic Properties To Technical Design Rules, Inherent Process Restrictions in Miniaturized Devices and their Potential Solutions, Micro-fabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes.</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Mixing</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Scales of mixing Flow patterns in reactors, Mixing in stirred tanks: Scale up of mixing, Heat transfer. Mixing in intensified equipment, Chemical Processing in High-Gravity Fields Atomizer Ultrasound Atomization, Nebulizers, High intensity inline MIXERS reactors Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers, Design Principles of static Mixers Applications of static mixers, Higee reactors.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Intensification in Heat Exchangers</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Combined chemical reactor heat exchangers and reactor separators: Principles of operation; Applications, Reactive absorption, Reactive distillation, Applications of RD Processes, Fundamentals of Process Modelling, Reactive Extraction Case Studies: Absorption of NOx Coke Gas Purification. Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluent heat exchangers, Integrated heat exchangers in separation processes, Design of compact heat exchanger - example.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Intensification in Enhanced fields</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation Reactors, Flow over a rotating surface, Hydrodynamic cavitation applications, Cavitation reactor design, Nusselt-flow model and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sonocrystallization, Reactive separations, Supercritical fluids</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.
3. KameliaBoodhoo (Editor), Adam Harvey (Editor),Process Intensification Technologies for</td></tr>
</table>

Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, Wiley, 2013.
4. Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.) Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.
5. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013.

Department: **Chemical Engineering**				Programme: **M. Tech.(Chemical Engineering)**					
Semester: **II**				Course Category Code: **PSE**			Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
CHZ10	**Process Integration**	3	-	-	3	40	60	100	
Prerequisite									

Course Outcome	On completion of the course, the student will be able to	
	CO1	Understand the various opportunities in the process integration in chemical industries.
	CO2	Understand the key elements involved in pinch technology
	CO3	Identify maximum heat recovery techniques for a given processes
	CO4	Integrate various energy intensive thermal separation operations
	CO5	Evaluate the process integration measures with waste treatment systems

UNIT I	**Introduction**	**Periods** : **9**	
Introduction to process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram.			**CO1**
UNIT II	**Pinch Technology**	**Periods** : **9**	
Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology, Key steps of Pinch Technology: Concept of T_{min} , Data Extraction, Targeting, Designing, Optimization Super targeting, Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve.			**CO2**
UNIT III	**Network Analysis**	**Periods** : **9**	
Heat exchanger networks analysis, Maximum Energy Recovery (MER) networks for multiple utilities and multiple, Chemical Engineering Pre-requisites: Knowledge of basic process design of process equipment. Pinches, design of heat exchanger network.			**CO3**
UNIT IV	**Heat Integrated Units**	**Periods** : **9**	
Heat integrated distillation columns, evaporators, dryers, and reactors			**CO4**
UNIT V	**Integration of Waste Treatment Systems**	**Periods** : **9**	
Waste and waste water minimization, flue gas emission targeting, and heat and power integration. Case studies.			**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Shenoy U.V.;"Heat Exchanger Network Synthesis", Gulf Publishing company.
2. Smith R.;"Chemical Process Design", McGraw-Hill.
3. Linnhoff B., Townsend D. W.,Boland D, Hewitt G. F., Thomas B.E.A., Guy A. R., and Marsland R. H.;"A User Guide on Process Integration for the Efficient Uses of Energy", Inst. of Chemical Engineers.

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: II</td><td colspan="3">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ11</td><td>Process Plant Design and Flow Sheeting</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
</table>

<table>
<tr><td rowspan="6">Course Outcome</td><td colspan="2">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td>Understand the basic principles involved in Process Design Development</td></tr>
<tr><td>CO2</td><td>Synthesize flow sheet for various systems and develop strategies for heat integration</td></tr>
<tr><td>CO3</td><td>Learn various flow sheet optimization techniques</td></tr>
<tr><td>CO4</td><td>Estimate fixed and working capital and operating costs for process plants</td></tr>
<tr><td>CO5</td><td>Apply optimization techniques for various plant operations</td></tr>
</table>

<table>
<tr><td>UNIT I</td><td>Introduction</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Basic concepts: General design considerations, Process design development, Layout of plant items, Flow sheets and PI diagrams, Economic aspects and Optimum design, Practical considerations in design and engineering ethics, Degrees of freedom analysis in interconnected systems, Network analysis, PERT/CPM, Direct and Indirect costs, Optimum scheduling and crashing of activities.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td>Flow Sheet Synthesis and Heat Integration</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Hierarchy of chemical process design; Nature of process synthesis and analysis; Developing a conceptual design and flow sheet synthesis. Synthesis of reaction-separation systems; Distillation sequencing; Energy targets. Heat integration of reactors, distillation columns, evaporators and driers; Process change for improved heat integration. Heat and mass exchange networks and network design.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td>Flow Sheet Generation and Optimization</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Synthesis of flow sheet: Propositional logic and semantic equations, Deduction theorem, Algorithmic flow sheet generation using P-graph theory, Sequencing of operating units, Feasibility and optimization of flow sheet using various algorithms viz, Solution Structure Generation (SSG), Maximal Structure Generation (MSG), Simplex, Branch-and-bound etc.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td>Cost Estimation</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Analysis of Cost estimation: Factors affecting Investment and production costs, Estimation of capital investment and total product costs, Interest, Time value of money, Taxes and fixed charges, Salvage value, Methods of calculating depreciation, Profitability, Alternative investments and replacements.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td>Optimum Design</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Optimum Design and Design Strategy: Break-even analysis, Optimum production rates in plant operation, Optimum batch cycle time applied to evaporator and filter press, Economic pipe diameter, Optimum insulation thickness, Optimum cooling water flow rate and optimum distillation reflux ratio.</td><td>CO5</td></tr>
</table>

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

<u>Reference Books</u>

1. Peters, M.A. and Timmerhaus, K.D., Plant Design and Economics for Chemical Engineers, McGraw Hill (2003).
2. Anil Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1982).
3. Ulrich, G.D., A Guide to Chemical Engineering Process Design and Economics, John Wiley & Sons (1984).
4. Perry, R.H. and Green, D., Chemical Engineer's Handbook, McGraw-Hill (1997).

<table>
<tr><td colspan="3">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="3">Semester: II</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td colspan="2" rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ12</td><td colspan="2">Bioprocess Engineering</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="9">On completion of the course, the students will be able to:</td></tr>
<tr><td>CO1</td><td colspan="8">Understand the different types of living cells and their use in biochemical processes.</td></tr>
<tr><td>CO2</td><td colspan="8">Understand enzymes and cell immobilization process.</td></tr>
<tr><td>CO3</td><td colspan="8">Understand and Analyze different bioreactors and upstream process used in production of bio-products.</td></tr>
<tr><td>CO4</td><td colspan="8">Analyze and understand various downstream processes used in production of bio-products.</td></tr>
<tr><td>CO5</td><td colspan="8">Understand the principles and applications of plant, animal and mixed microbial culture techniques.</td></tr>
<tr><td>UNIT I</td><td colspan="6">Introduction and Microbial Stoichiometry</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Introduction to Bioprocess engineering, overview of basics of microbial and enzyme kinetics, Stoichiometry of microbial growth and product formation: basic definitions, stoichiometric calculations, elemental balances, degree of reduction, theoretical predictions of yield coefficients, design of media.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Enzyme and Cell Immobilization</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Free and enzyme immobilized enzyme kinetics, external mass transfer limitations, Damkohler number, internal mass transfer limitations, Thiele modulus, immobilization efficiency, effectiveness factor, active immobilization of cells, passive immobilization and diffusional limitations in immobilized cell systems.</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Bioreactors</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Batch growth kinetics, continuous culture (chemostat/turbidostat), Chemostat with recycle, multistage chemostat, fed batch and perfusions reactors, bioreactors considerations in immobilized cell and enzyme systems, Selection, scale-up, scale down of bioreactors, bioreactor instrumentation and control, sterilization of processes fluids.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Recovery and Purification of Products</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Strategies to recover and purify products, separation of insoluble products, cell disruption: mechanical, chemical and enzymatic methods; separation of soluble products: extraction, ATPS, precipitation, adsorption, filtration, Chromatography.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Bioprocess Considerations in Using Animal, Plant Cell and Mixed Cultures</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Methods used for cultivation of animal and plant cells; Bioreactor considerations for animal and plant cell culture; products of animal cell culture. Mixed cultures - introduction; models for interaction in mixed cultures; mixed cultures in nature; industrial utilization of mixed cultures; biological waste treatment using mixed cultures.</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="10"><u>Reference Books</u></td></tr>
<tr><td colspan="10">1. Shuler M.L., Kargi F., ”Bioprocess Engineering”, Prentice -Hall
2. Bailey J.E. and Ollis D.F., “Biochemical Engineering Fundamentals”, McGraw-Hill
3. Doran P.M., “Bioprocess Engineering Principles”, Academic Press
4. MukeshDoble, SathyanarayanaN.Gummadi., “Biochemical Engineering”, PHI learning Pvt Ltd.</td></tr>
</table>

Department: **Chemical Engineering**			Programme: **M. Tech.(Chemical Engineering)**						
Semester: **II**			Course Category Code: **PSE**				Semester Exam Type: **TY**		
Course Code	Course Name		Periods / Week			Credit	Maximum Marks		
			L	T	P		CA	SE	TM
CHZ13	**Application of Nanotechnology in Chemical Engineering**		3	-	-	3	40	60	100
Prerequisite									

Course Outcome	On completion of the course, the students will be able to:	
	CO1	Conceptualize the fundamentals of nanotechnology
	CO2	Understand the various synthesis and characterization techniques of nano materials
	CO3	Gain knowledge on semiconductors and quantum dots
	CO4	Describe polymer nano particles and nano composites
	CO5	List down the applications of nanotechnology in safety and environment

UNIT I	**Introduction to Nanotechnology**	**Periods** : **9**	
Introduction to nanotechnology, Feynman's Vision-There's Plenty of Room at the Bottom, Classification of nanostructures, Nanoscale architecture, Chemical interactions at nanoscale, Types of carbon based nanomaterials, Synthesis of fullerenes, Graphene, Carbon nanotubes, Functionalization of carbon nanotubes, One, two and multidimensional structures, Crystallography.			**CO1**
UNIT II	**Approaches to Synthesis of Nanoscale Materials and Characterisation**	**Periods** : **9**	
Top down approach, Bottom up approach, Bottom-up vs. top-down fabrication; Top-down: Atomization, Sol gel technique, Arc discharge, Laser ablation, RF sputtering; Bottom-up: Chemical Vapor Deposition (CVD), Metal Oxide Chemical Vapor Deposition (MOCVD), Atomic layer deposition (ALD), Molecular beam Molecular self-assembly; Ultrasound assisted, microwave assisted, Mini, micro and nano emulsion. Wet grinding method, Spray pyrolysis, Ultrasound assisted pyrolysis, atomization techniques. Surfactant based synthesis procedures, Types of molecular modeling methods. Size, shape, crystallinity, topology, chemistry analysis using X-ray imaging, Transmission Electron Microscopy, HRTEM, Scanning Electron Microscopy, SPM,AFM,STM,PSD, Zeta potential, DSC and TGA			**CO2**
UNIT III	**Semiconductors and Quantum Dots**	**Periods** : **9**	
Intrinsic semiconductors, Extrinsic semiconductors, Review of classical mechanics, de Broglie's hypothesis, Heisenberg uncertainty principle Pauli exclusion principle Schrödinger's equation Properties of the wave function, Applications: quantum well, wire, dot, Quantum cryptography			**CO3**
UNIT IV	**Polymer based and polymer filled Nanocomposites**	**Periods** : **9**	
Nanoscale Fillers, Nanofiber or Nanotube Fillers, Plate-like Nanofillers, Equi-axed Nanoparticle Fillers, Inorganic Filler Polymer Interfaces, Processing of Polymer Nanocomposites, Nanotube/Polymer Composites, Layered Filler Polymer Composite Processing, Nanoparticle/Polymer Composite Processing: Direct Mixing, Solution Mixing, In-Situ Polymerization, In-Situ Particle Processing, In-Situ Particle Processing Metal/Polymer Nanocomposites, Properties of nanocomposites.			**CO4**
UNIT V	**Applications to Safety, Environment and Others**	**Periods** : **9**	
Chemical and Biosensors- Classification and Main Parameters of Chemical and Biosensors, Nanostructured Materials for Sensing, Waste Water Treatment, Nanobiotechnology, Drug Delivery, Nanocoatings, Self cleaning Materials, Hydrophobic Nanoparticles, Photocatalysts, Biological nanomaterials, Nanoelectronics, Nanomachines & nanodevices, Societal, Health and Environmental Impacts.			**CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Louis Hornyak G., DuttaJoydeep, Tibbals Harry F. and Rao Anil K., "Introduction to Nanoscience", (CRC Press of Taylor and Francis Group LLC), May 2008, 856pp, ISBN-13: 978142004805

2. Ajayan P. M., Schadler L. S., Braun P. V., “Nanocomposite Science and Technology”, Edited by WILEY-VCH Verlag GmbH Co. KGaA, Weinheim ISBN: 3-527-30359-6, 2003.
3. Kelsall Robert W.,Hamley Ian W.,GeogheganMark, “Nanoscale Science and Technology”,John Wiley & Sons, Ltd, 2006.
4. KalRanganathan Sharma, “Nanostructuring Operations in Nanoscale Science and Engineering”, McGraw-Hill Companies, Inc. ISBN: 978-0-07-162609-5, 2010.
5. “Organic and inorganic nanostructures”.-(Artech House MEMS series), Nabok, Alexei, ISBN 1-58053-818-5, 2005.

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M.Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: II</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ14</td><td>Process Modeling and Simulation</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Understand various classes of mathematical models and formulate a mathematical model for any particular chemical engineering system and classify it appropriately</td></tr>
<tr><td>CO2</td><td colspan="7">Formulate a mathematical model for any chemical engineering system represented by ODE with constant coefficients and obtain appropriate analytical solution for it.</td></tr>
<tr><td>CO3</td><td colspan="7">Formulate a mathematical model for any chemical engineering system represented by ODE with variable coefficients and obtain appropriate analytical solution for it.</td></tr>
<tr><td>CO4</td><td colspan="7">Formulate a mathematical model for any chemical engineering system represented by PDE and obtain appropriate analytical solution for it</td></tr>
<tr><td>CO5</td><td colspan="7">Formulate mathematical models for chemical engineering systems represented by PDEs and solve it using similarity solution method or using Green's function</td></tr>
<tr><td>UNIT I</td><td colspan="5">Formulation and Classification of Mathematical Models</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Lumped parameter Steady State Models - Equations of State, Stage wise separation process, Reactors in series ; Lumped parameter unsteady state models - models resulting in ODEs IVP - dynamics of a CSTR, Two-pool Urea kinetic model for haemo dialysis, Bio-artificial membrane device for controlled insulin release; Distributed parameter steady state models - models resulting in ODEs BVP - Heat diffusion with generation in composite cylinders, modelling of a bio-filtration, modelling of a differential contactor for extractive fermentation ; Models resulting in partial differential equations - unsteady state heat transfer through a rectangular fin, unsteady state heat conduction in a rectangular solid, oxygen transport in tissues, absorption of a drug through the skin, slow release of fertilizer through polymer coating, controlled release of drug through a Drug-Eluting Stent (DES) ; Model equations in non-dimensional form</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Solution of ODEs and Applications</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Solution of First order ODEs - cooling of a ball by natural convection, modelling of cancer stem cell hypothesis, drug administration at regular intervals ; Solution of Second and Higher order linear ODEs with constant coefficients and Cauchy - Euler equation - Heat flow in a rod connecting two walls, microwave heating of a slab, solute transport in a haemodialyser, two - pool urea kinetic model for haemodialysis, oxygen limited growth of follicles, oxygen transport in tissues, axial dispersion in a tubular reactor, diffusion with reaction in membrane, diffusion and metabolic consumption of oxygen in small organism, gas absorption with chemical reaction in a slurry of catalyst particles, Facilitated transport through a membrane, diffusion controlled sensitivity of a semiconductor gas sensor, Slow release of a fertilizer, Mathematical modelling of a wound healing, diffusion controlled growth of a solid tumer, Laplace transform technique, system of linear ODEs</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Special Functions and Solution of ODEs With Variable Coefficients</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Gamma function, Beta function, Error function, Gamma distribution, Series solution of second order ODEs with variable coefficients, Series solution of second order ODEs leading to special functions - Bessel functions, Legendre function, Hyper geometric functions, Case studies - Heat transfer from a radial fin, Microwave heating of a slab, Bio heat transfer in a tumor, Modelling of diffusion - reaction in a hollow fibre bioreactor, Oxygen transport in a plant root</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Partial Differential Equations - I</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Common second order PDEs in Science and Engineering, Boundary Value Problems, Types of boundary conditions, Techniques of analytical solutions of a second order PDE - Separation of variable - Thermal transient in a large plane wall, Solution of non-homogeneous PDEs - method of partial solution - unsteady state heat conduction in a large wall with different surface temperatures, method of Eigen function</td><td colspan="2">CO4</td></tr>
</table>

expansion - Dynamics of an enzyme electrode, Steady state temperature distribution in a rectangular block, Unsteady state heat conduction in a long cylinder, Unsteady state heat conduction in a sphere, Steady state reaction - diffusion in a short cylinder catalyst pellet, Steady state concentration profile in a laminar flow tubular reactor for a first order reaction, Drug release from a cylindrical DES				
UNIT V	**Partial Differential Equations-II**		**Periods** : **9**	
Similarity solution - Unsteady heat conduction in a semi-infinite solid, Higbie's Penetration theory, Cooling of a stretching sheet in viscous flow, Moving Boundary Problems - Freezing of a large pool of water, Gas absorption with an instantaneous chemical reaction, Dissolution of a sphere in a large volume of stagnant liquid, Evaporation of a droplet, Principle of superposition - Unsteady state heating of a sphere with linearly time - varying surface temperature, Diffusion accompanied by a first order chemical reaction in a stagnant liquid, Unsteady state gas absorption with an accompanying first order reaction in a liquid pool of finite depth, Green Function - Solution of an ODE using Green's function, Solution of Diffusion equation and construction of the Green's function				**CO5**
Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**	

Reference Books

1. Mathematical methods in chemical and biological engineering, Binay K Dutta, CRC Press, 2020
2. Applied mathematics and modeling for chemical engineers, R.G. Rice, D.D. Do, John Wiley and Sons,1995
3. Mathematical methods in chemical engineering, Arvind Varma, Massimo Morbidelli, Oxford University Press, 2008
4. Mathematical methods in chemical engineering, S. Pushpavanam, Prentice Hall of India, 1998

Department: Chemical Engineering		Programme: **M.Tech.(Chemical Engineering)**							
Semester: II		Course Category Code: **PSE**			Semester Exam Type: **TY**				
Course Code	**Course Name**	Periods / Week			Credit	Maximum Marks			
		L	T	P		CA	SE	TM	
CHZ15	**Micro and Nano Fluidics**	3	-	-	3	40	60	100	
Prerequisite									

Course Outcome		
	On completion of the course, the student will be able to	
	CO1	Understand the basic principles involved in Microflows
	CO2	Apply various concepts involved in microfluids to device microfluid devices
	CO3	Analyse fluid flow in nano sized devices
	CO4	Understand the fabrication of microfluidic devices
	CO5	Describe the fundamentals of BioMEMS and medical microdevices

UNIT I	**Introduction**	**Periods** : **9**
Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions-Wall slip effects and accommodation coefficients, flow and heat transfer analysisof microscale Couette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility. Pressure Driven Liquid Microflow: apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro - flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis.		**CO1**
UNIT II	**Microfluids**	**Periods** : **9**
Laminar flow: Hagen-Poiseullieeqn, basic fluid ideas, Special considerations of flow in small channels, mixing, microvalves&micropumps, Approaches toward combining living cells, microfluidics and 'the body' on a chip, Chemotaxis, cell motility. Case Studies in Microfluidic Devices. Ionic transport: Polymer transport - microtubule transport in nanotube channels driven by Electric Fields and by KinesinBiomolecular Motors - Electrophoresis of individual nanotubulesinmicrofluidic channels.		**CO2**
UNIT III	**Nanofluids**	**Periods** : **9**
Fabrication techniques for Nanofluidic channels - Biomolecules separation using Nanochannels - Biomolecules Concentration using Nanochannels - Confinement of Biomolecules using Nanochannels. Hydrodynamics: Particle moving in flow fields - Potential Functions in Low Renoylds Number Flow - Arrays of Obstacles and how particles Move in them: Puzzles and Paradoxes in Low Re Flow.		**CO3**
UNIT IV	**Fabricate of Microfluidic Devices**	**Periods** : **9**
Microfluidics and Lab-on-a-chip: Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic Transport - Stacking and Scaling - Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of ProteinsStrategies- printing types- methods and characterization- Cell nanostructure interactions-networks for neuronal cells. Applications in Automatic DNA sequencing, DNA and Protein microarrays		**CO4**
UNIT V	**Micro Electro Mechanical System**	**Periods** : **9**
BioMEMS (Micro-Electro-Mechanical Systems): Introduction and Overview, Biosignal Transduction Mechanisms: Electromagnetic Transducers Mechanical Transducers, Chemical Transducers, Optical Transducers - Sensing and Actuating mechanisms (for all types). Case Studies in Biomagnetic Sensors, Applications of optical and chemical transducers. Ultimate Limits of Fabrication and Measurement, Recent Developments in BioMEMS and BioNEMS - An alternative approach to traditional surgery, Specific targeting of tumors and other organs for drug delivery, Micro-visualization and manipulation, Implantation of microsensors, microactuators and other components of a larger implanted device or external system (synthetic organs).		**CO5**

Lecture Periods: 45	Tutorial Periods: -	Practical Periods: -	Total Periods: 45
Reference Books			
1. Joshua Edel "Nanofluidics" RCS publishing, 2009. 2. PatricTabeling "Introduction to Microfluids" Oxford U. Press, New York 2005. 3. K. Sarit "Nano Fluids; Science and Technology", RCS Publishing, 2007. 4. M. Madou, Fundamentals of Microfabrication, CRC Press, 1997 5. G. Kovacs, Micromachined Transducers, McGraw-Hill, 1998 6. Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006			

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: II</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ16</td><td>Industrial Pollution Control</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td></td><td colspan="8">On Completion of the Course, the Student will be able to</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="7">Understand different types of wastes generated in an industry, their environmental regulatory legislations and standards.</td></tr>
<tr><td>CO2</td><td colspan="7">Analyze the mechanism of proliferation of pollution</td></tr>
<tr><td>CO3</td><td colspan="7">Develop methods for pollution abatement and waste minimization</td></tr>
<tr><td>CO4</td><td colspan="7">Design treatment methods for gas, liquid and solid wastes</td></tr>
<tr><td>CO5</td><td colspan="7">Understand about analysis and quantification of hazardous solid waste, treatment and disposal.</td></tr>
<tr><td>UNIT I</td><td colspan="5">Industries & Environment</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Industrial scenario in India - Industrial activity and Environment - Industrial wastes & their sources: various industrial processes, sources and types of wastes-solid, liquid, gaseous, noise & radiation emissions. Characterization of emission and effluents, - Industrial waste survey - Industrial wastewater generation rates, - Population equivalent - Toxicity of industrial effluents and Bioassay tests. Environmental Laws and rules, standards for ambient air, noise emission and effluents.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Industrial Noise pollution</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Sources of noise pollution, characterization of noise pollution prevention& control of noise pollution, Factories Act 1948 for regulatory aspects of noise pollution, Pollution Control acts.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Air Pollutant Abatement</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Air pollutants scales of concentration, lapse rate and stability, plume behaviour, dispersion of air pollutants, atmospheric dispersion equation and its solutions, Gaussian plume models. Air pollution control methods, Source correction methods, Design concepts for pollution abatement systems for particulates and gases. Such as gravity chambers, cyclone separators, filters, electrostatic precipitators, condensation, adsorption and absorption, thermal oxidation and biological processes.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Waste Water Treatment Processes</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Design concepts for primary treatment, secondary - Bacterial population dynamics, kinetics of biological growth and its applications to biological treatment, determination of kinetic coefficients, activated sludge process. Design, trickling filter design considerations, advanced treatment processes, Study of environment pollution from process industries and their abatement: Fertilizer, paper and pulp, inorganic acids, petroleum and petrochemicals, recovery of materials from process effluents.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Solid Waste and Hazardous Waste Management</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Sources and classification, properties, public health aspects, Sanitary land fill design, Hazardous waste classification and rules, management strategies, Nuclear waste disposal Treatment methods -component separation, chemical and biological treatment, incineration, solidification and stabilization, and disposal methods, Latest Trends in solid waste management, Soil Management.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="9">Reference Books</td></tr>
</table>

1. Rao C.S., “Environmental Pollution Control Engineering”, 2nd edition
2. Mahajan S.P., “Pollution Control in Process Industries”.
3. Stern A.C., “Air pollution”, Volumes I to VI, Academic Press, New York, 1968
4. Peterson and Gross .E Jr., “Hand Book of Noise Measurement”, 7th Edn., 2003.
5. Pollution Control Acts, Rules, Notifications issued there under” CPCB, Ministry of Env. and Forest, G.O.I., 3rd Ed. (2006).
6. Industrial Water Pollution Control, 3rd edition Eckenfelder W. W.,
7. Handbook of Solid Waste Management, 2nd edition Kreith F. and Tchobanoglous G.

<table>
<tr><td colspan="2">Department: Chemical Engineering</td><td colspan="7">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="2">Semester: III</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ17</td><td>Optimization of Chemical Processes</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Formulate an Optimization Problems in chemical engineering domain</td></tr>
<tr><td>CO2</td><td colspan="7">Formulate and solve single and multivariable unconstrained optimization problem</td></tr>
<tr><td>CO3</td><td colspan="7">Analyze equality and inequality constrained optimization problems by applying Lagrangian multiplier technique and KKT optimality criterion</td></tr>
<tr><td>CO4</td><td colspan="7">Formulate and solve LP,QP and IP problems</td></tr>
<tr><td>CO5</td><td colspan="7">Solve problems in optimization of staged and discrete processes using dynamic programming and Generalized Bender Decomposition methods</td></tr>
<tr><td>UNIT I</td><td colspan="5">Formulation of Optimization Problem and Concepts of Unconstrained Optimization</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Formulation of Optimization Problems in Chemical Engineering – Case Studies – Optimization of liquid storage tank, Optimization of Pump Configuration, Optimization of systems with chemical reactions, Calculation of optimum insulation thickness, optimization of simple heat exchanger network, optimum cost of an alloy using LP problem, Least square method

Basic concepts of unconstrained optimization - vectors and matrices, eigenvectors and Eigen values, vector and matrix norms, quadratic form, classification of functions, optimality conditions – necessary and sufficient conditions for local optimality</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Single and Multi-Variable Unconstrained Optimization</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Single variable unconstrained optimization methods – Direct Search Methods – Region elimination method, Dichotomous search, Interval halving method, Fibonacci method, Golden section method, Derivative based method – Newton's method, Quasi Newton method, Secant method, Polynomial approximation method – quadratic interpolation and cubic interpolation methods, Trust Region method

Multivariable unconstrained optimization – Direct Search Methods – Grid search method, Univariate method, Pattern search methods – Powell's method, Hooke – Jeeves method, Gradient Search method – Steepest descent method, Conjugate gradient method, Newton's method, Marquardt method, Levenberg – Marquardt algorithm, Quasi – Newton method, Trust Region methods – Convex model problems, Non-convex model problems</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Concepts of Constrained Optimization</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Problems with equality constraints – Lagrange multiplier method, Problems with inequality constraints – Necessary and sufficient conditions (KKT conditions) for optimality, Analysis of KKT conditions – Linearly constrained problems, Nonlinearly constrained problems, Second order conditions</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Linear, Quadratic and Integer Programming</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Linear Programming – Basic concepts, Simplex method for solving LP problems, Duality in Linear Programming, Karmarkar's Interior Point method ; Integer Linear Programming – Warehouse location and Blending Problem, Branch and Bound method ; Quadratic Programming – Generalized Reduced Gradient Method</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Optimization of Staged and Discrete Processes</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Dynamic Programming – Description of a multistage decision process, Application of dynamic programming to water distribution system and optimal replacement of equipment; Integer and Mixed Integer Programming – Formulation of MINLP, Generalized Bender Decomposition</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
</table>

Reference Books
1. Optimization of Chemical Processes, T.F. Edgar, D.M. Himmelblau, McGraw Hill, 1989 2. Nonlinear Programming - Concepts, Algorithms, and Applications to Chemical Processes, L.T. Biegler, SIAM, 2010 3. Optimization in Chemical Engineering, SumanDutta, Cambridge University Press, 2016

<table>
<tr><td colspan="3">Department: Chemical Engineering</td><td colspan="8">Programme: M. Tech.(Chemical Engineering)</td></tr>
<tr><td colspan="3">Semester: III</td><td colspan="4">Course Category Code: PSE</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>CHZ18</td><td colspan="2">Chemical Reactor Analysis</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9"></td></tr>
<tr><td></td><td colspan="9">At the end of the course, the student will be able to</td></tr>
<tr><td rowspan="5">Course Outcome</td><td>CO1</td><td colspan="8">Quantify factors affecting the choice of the reactor</td></tr>
<tr><td>CO2</td><td colspan="8">Write models for catalytic reactors and reactions</td></tr>
<tr><td>CO3</td><td colspan="8">Perform the energy balance and obtain concentration profiles in multiphase reactors</td></tr>
<tr><td>CO4</td><td colspan="8">Estimate the performance of multiphase reactors under non-isothermal conditions</td></tr>
<tr><td>CO5</td><td colspan="8">Calculate stability of reactor</td></tr>
<tr><td>UNIT I</td><td colspan="6">Factors Affecting Reactor Analysis</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Chemical factor affecting the choice of the reactor, fundamental mass, energy and momentum balance, Model for a semi-batch reactor, optimum operation policies and control strategies, optimal batch operation time, optimal temperature policies, stability of operation and transient behavior for mixed flow reactor. Transient CSTR analysis, Hot spot equation; Optimization using Lagrange multiplier, Poyntrgin's maximum principle.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Catalytic Reactor and Reactions</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Fixed bed catalytic reactor: The importance and scale of fixed bed catalytic processes, factors in preliminary design, modeling of fixed bed reactor. Pseudo-homogeneous model, the multi-bed adiabatic reactor, auto-thermal operation, non-steady-state model with axial mixing, two dimensional pseudo-homogeneous models, heterogeneous models, global and intrinsic rates, Mechanism of catalytic reactions, Engineering properties of catalysts - BET surface area, pore volume, pore size, pore size distribution, one dimensional and two dimensional model equation</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Multiphase Flow Reactors</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Multiphase flow reactor: Types of multiphase flow reactors, packed columns, plate columns, empty columns, stirred vessel reactors. Development of rate equations for solid catalyzed fluid phase reactions; Estimation of kinetic parameters. External mass and heat transfer in catalyst particles. Stability and selectivity Packed bed reactor, slurry reactor; Trickle bed reactor and fluidized bed reactor. Intra-particle heat and mass transfer - Wheelers parallel pore model, random pore model of Wakao and Smith. Deactivation of catalyst, Ideal and non-ideal flow in reactors.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Multiphase Flow Reactors Design</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Design model for multiphase flow reactors, gas and liquid phase in completely mixed and plug flow, gas phase in plug flow and liquid phase in completely mixed flow, effective diffusion model, two zone model, specific design aspects, packed absorber, two-phase fixed bed reactor, plate column, spray tower, bubble reactor, stirred vessel reactor. Computer - aided reactor design.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Temperature Effects In Reactor</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Introduction, well mixed system with steady feed, the stability and start-up of CSTR, limit cycles and oscillatory reactions, the plug flow reactors, tubular reactor, diffusion control, prorogation of reaction zone.</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
<tr><td colspan="10"><u>Reference Books</u></td></tr>
</table>

1. Froment G. F. and K.B. Bischoff, " Chemical Reactor Analysis and Design", John Wiley & Sons
2. Denbigh K. G. and J.C. Turner, " Chemical Reactor and Theory - an Introduction", 3rd edition Cambridge University Press.
3. Bruce Nauman, " Chemical Reactor Design", John Wiley & Sons
4. H. Scott Fogler , Elements of Chemical Reaction Engineering by, Pearson education
5. R.E. Hayes and J.P. mmbage, Introduction to chemical reactor Analysis, CRC Press, 2015.
6. Charles G. Hill & Thatcher W Root, Introduction to chemical Engineering Kinetics & Reactor Design, Wiley, 2014.
7. John B. Butt, reactor kinetics and reactor design second edition revised and expanded, Marcel Dekker Inc, 2000

Department: **Chemical Engineering**		Programme: **M. Tech.(Chemical Engineering)**						
Semester: **III**		Course Category Code: **PSE**			Semester Exam Type: **TY**			
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
CHZ19	**Chemo Informatics**	3	-	-	3	40	60	100
Prerequisite								

	On completion of the course, the student will be able to	
Course Outcome	**CO1**	Understand the concept of Chemo-informatics related to chemical structure databases and database search methods
	CO2	Understand the applications of chemical libraries and various pharma properties
	CO3	understand the quantum methods and models involved in drug discovery and targeted drug delivery
	CO4	Describe the various modeling and structure elucidation techniques
	CO5	Understand the models involved in drug delivery systems

UNIT I — **Introduction** — **Periods** : **9**

Introduction, scope and application, Basics of Chemo-informatics, Current Chemo-informatics resources for synthetic polymers, pigments. Primary, secondary and tertiary sources of chemical information, Databases: Chemical Structure Databases (PubChem, Binding database, Drug bank), Database search methods: chemical indexing, proximity searching, 2D and 3D structure and substructure searching. Drawing the Chemical Structure: 2D & 3D drawing tools (ACD Chemsketch) Structure optimization. — **CO1**

UNIT II — **Product Design and Developments** — **Periods** : **9**

Combinatorial chemistry (library design, synthesis and deconvolution), spectroscopic methods and analytical techniques, Representation of Molecules and Chemical Reactions: Different types of Notations, SMILES Coding, Structure of Mol files and Sd files (Molecular converter, SMILES Translator). — **CO2**

UNIT III — **Introduction to Quantum Methods** — **Periods** : **9**

Geometry of mixing and basic reactor types, The Attainable Region (AR) approach, AR in higher dimensions & for other processes, Reactive Separation processes, Fundamental behavior and problems, Separation through reactions. Reactive Residue Curve Maps — **CO3**

UNIT IV — **Target Identification** — **Periods** : **9**

Molecular Modeling and Structure Elucidation: Homology Modelling (Modeller 9v7, PROCHECK), Visualization and validation of the Molecule (Rasmol, Pymol Discovery studio), Applications of Chemoinformatics in Drug Research - Chemical Libraries, Virtual Screening, Prediction of Pharmacological Properties. — **CO4**

UNIT V — **Drug Discovery** — **Periods** : **9**

Structure based drug designing, Docking Studies (Target Selection, Active site analysis, Ligand preparation and conformational analysis, Rigid and flexible docking, Structure based design of lead compounds, Library docking), Pharmacophore - Based Drug Design, Pharmacophore Modeling (Identification of pharmacophore features, Building 2D/3D pharmacophore hypothesis), Toxicity Analysis-Pharmacological Properties (Absorption, Distribution and Toxicity), Global Properties (Oral Bioavailability and Drug-Likeness) (ADME, OSIRIS, and MOLINSPIRATION) — **CO5**

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Bajorath J (2004), "Chemoinformatics: Concepts, Methods and Tools for Drug Discovery" Humana Press
2. Leach A, Gillet V, "An Introduction to Chemoinformatics" Revised edition, Springer
3. Gasteiger J. Engel T. "A textbook of Chemoinformatics" Wiley- VCH GmbH & Co. KGaA
4. Bunin B. Siesel B. Guillermo M. "Chemoinformatics: Theory, Practice & Products", Springer

5. Bunin Barry A. Siesel Brian, Morales Guillermo, Bajorath Jürgen. Chemoinformatics: Theory, Practice, & Products Publisher: New York, Springer. 2006.
6. Leach Andrew R., Valerie J. Gillet, “An introduction to Chemoinformatics”, Publisher: Kluwer Academic, 2003. ISBN: 1402013477
7. Gasteiger Johann, Handbook of Chemoinformatics: From Data to Knowledge (4 Volumes), 2003. Publisher: Wiley-VCH.

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<tr><td colspan="3">Semester: III</td><td colspan="4">Course Category Code: PSE</td><td colspan="3">Semester Exam Type: TY</td></tr>
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<tr><td>CHZ20</td><td colspan="2">Cleaner Production</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="9"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="9">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="8">Explain the concepts and principles of cleaner production</td></tr>
<tr><td>CO2</td><td colspan="8">Describe various cleaner production methodologies</td></tr>
<tr><td>CO3</td><td colspan="8">Evaluate basic methods and techniques of pollution prevention during production</td></tr>
<tr><td>CO4</td><td colspan="8">Understand the financial evaluation of cleaner production methods</td></tr>
<tr><td>CO5</td><td colspan="8">Get knowledge on the practical application of cleaner production technology</td></tr>
<tr><td>UNIT I</td><td colspan="5">Introduction</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Cleaner production definition: Evaluation of cleaner production, Cleaner production network, Area covered by cleaner production (what is not cleaner production.
Difference between cleaner production and other methods, End of the pipe treatment to curb pollution, prerequisites of cleaner production.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Cleaner Production Methodology</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Waste reduction at source, (a) Good housekeeping, (b) Process changes: change in raw material, batter process, control, equipment modification and technology changes, Recycling: on site recovery and reuse creation of useful byproducts, Product modification.
Methods of environmental protection -- preventive strategy, Methods of environmental protection -- preventive strategy, making team for cleaner production, Analyzing process steps, Generating Cleaner Production opportunities, Selection of cleaner production solution, Implementing Cleaner production solution</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Cleaner Production Assessment Techniques</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Overview of CP Assessment Steps and skills, Preparing for the site visit, Information Gathering, and process flow diagram, material balance, CP Option Generation Technical and Environmental feasibility analysis-Economic valuation of alternatives fuels, Total cost analysis-CP ,Financing, Establishing a program, Organizing a program preparing a program plan-Measuring progress-pollution prevention and cleaner production Awareness plan -Waste audit-Environmental Statement. Energy audit related to cleaner production, Energy audit's need and scope, Types of energy audit. Preliminary or walk through energy audit. Detailed energy audit, Methodology of energy audit, Energy balance and identifying the energy conservation opportunities.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Financial Evaluation of cleaner production</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Gathering base line information, Determining the capital or investment cost, Establishing lifetime of equipment and annual depreciation, Determine revenue implication of the project. Estimating change in operating cost, Calculating incremental cash flow, Assessing project's viability.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Case studies and Cleaner Production Applications</td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="8">Application (Industrial application of CP,LCA, EMS and Environmental Audits. C.P in chemical process industry, Practical ways & means to save material loss in loading/unloading and unit operations equipment like distillation column, drying and other equipments like heat exchanger, vacuum unit, conveying, etc. Practical ways & means for energy saving in industries. Case Studies of cleaner production.</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="10"><u>Reference Books</u></td></tr>
<tr><td colspan="10">1.“Cleaner Production Worldwide”, 1993, United Nations Environment Programme, Industry and Environment, Paris, France, 1993
2. “Cleaner Production: Training Resource Package”, UNEP IE, Paris, 1996
3.“Clean Technology for manufacture of Specialty Chemicals”, Editor-W. Hoyle and M. Lancaster, Royal Society of Chemistry, U.K</td></tr>
</table>

4. Randall Paul M, "Engineers Guide to Cleaner Production Technologies".
5. Ahluvalia V. K., "Green Chemistry: Environmentally Benign Reactions".
6. Sanders R.E., "Chemical Process Safety: Learning from case Histories", Oxford Butter Worth Publication
7. "Training Manual Package" by NCPC

OPEN ELECTIVES

AND

MANDATORY AUDIT COURSES

FOR

M.TECH. PROGRAMMES

(Approved in Sixth Academic Council Meeting held on 20th March 2021)

O P E N   E L E C T I V E S

<table>
<tr><td colspan="2">Department: IT</td><td colspan="7">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester: III</td><td colspan="4">Course Category Code: OEC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>OE201</td><td>Business Analytics</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="5">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Students will demonstrate knowledge of data analytics.</td></tr>
<tr><td>CO2</td><td colspan="7">Students will demonstrate the ability of think critically in making decisions based on data and deep analytics.</td></tr>
<tr><td>CO3</td><td colspan="7">Students will demonstrate the ability to use technical skills in predicative and prescriptive modeling to support business decision-making.</td></tr>
<tr><td>CO4</td><td colspan="7">Students will demonstrate the ability to translate data into clear, actionable insights.</td></tr>
<tr><td>UNIT I</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Business analytics: Overview of Business analytics, Scope of Business analytics, Business Analytics Process, Relationship of Business Analytics Process and organisation, competitive advantages of Business Analytics.
Statistical Tools: Statistical Notation, Descriptive Statistical methods, Review of probability distribution and data modelling, sampling and estimation methods overview.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5"></td><td colspan="3">Periods : 8</td></tr>
<tr><td colspan="8">Trendiness and Regression Analysis: Modelling Relationships and Trends in Data, simple Linear Regression. Important Resources, Business Analytics Personnel, Data and models for Business analytics, problem solving, Visualizing and Exploring Data, Business Analytics Technology.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5"></td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Organization Structures of Business analytics, Team management, Management Issues, Designing Information Policy, Outsourcing, Ensuring Data Quality, Measuring contribution of Business analytics, Managing Changes. Descriptive Analytics, predictive analytics, predicative Modelling, Predictive analytics analysis, Data Mining, Data Mining Methodologies, Prescriptive analytics and its step in the business analytics Process, Prescriptive Modelling, nonlinear Optimization.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5"></td><td colspan="3">Periods : 10</td></tr>
<tr><td colspan="8">Forecasting Techniques: Qualitative and Judgmental Forecasting, Statistical Forecasting Models, Forecasting Models for Stationary Time Series, Forecasting Models for Time Series with a Linear Trend, Forecasting Time Series with Seasonality, Regression Forecasting with Casual Variables, Selecting Appropriate Forecasting Models. Monte Carlo Simulation and Risk Analysis: Monte Carle Simulation Using Analytic Solver Platform, New-Product Development Model, Newsvendor Model, Overbooking Model, Cash Budget Model.</td><td>CO3</td></tr>
<tr><td>UNIT V</td><td colspan="5"></td><td colspan="3">Periods : 8</td></tr>
<tr><td colspan="8">Decision Analysis: Formulating Decision Problems, Decision Strategies with the without Outcome Probabilities, Decision Trees, The Value of Information, Utility and Decision Making.</td><td>CO4</td></tr>
<tr><td>UNIT VI</td><td colspan="5"></td><td colspan="2">Periods :4</td><td></td></tr>
<tr><td colspan="8">Recent Trends in: Embedded and collaborative business intelligence, Visual data recovery, Data Storytelling and Data journalism.</td><td>CO4</td></tr>
<tr><td colspan="2">Lecture Periods: 48</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 48</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Business analytics Principles, Concepts, and Applications by Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, Pearson FT Press.
2. Business Analytics by James Evans, persons Education.</td></tr>
</table>

Department :**ME**	Programme: **M. Tech.**	
Semester :**III**	Course Category Code: **OEC**	Semester Exam Type: **TY**

Course Code	Course Name	Hours / Week			Credit	Maximum Marks		
		L	T	P	C	CA	SE	TM
OE202	**Industrial Safety and Maintenance**	3	0	0	3	40	60	100
Prerequisite								

Course Outcomes	On completion of the course, the student will be able to	
	CO1	Can appreciate the need of industrial safety requirements and can implement general guidelines of safety.
	CO2	Can understand fundamentals and principles of maintenance engineering.
	CO3	Can acquire the knowledge about conventional maintenance techniques adopted to reduce/prevent wear and corrosion.
	CO4	Can able to adopt Fault tracing techniques for general machines and equipments used in industries.
	CO5	Can apply periodic and preventive maintenance techniques used for general electrical and mechanical machines and equipments used in industries.

UNIT – I	**Industrial Safety**	**Periods : 9**
Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.		**CO1**
UNIT – II	**Fundamentals of Maintenance Engineering**	**Periods : 9**
Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.		**CO2**
UNIT – III	**Wear and Corrosion and their Prevention**	**Periods : 9**
Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.		**CO3**
UNIT – IV	**Fault Tracing**	**Periods : 9**
Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment’s like, I. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.		**CO4**

UNIT – V	Periodic and Preventive Maintenance		Periods : 9	
Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance.				**CO5**
Lecture Periods : 45	**Tutorial Periods : 0**	**Practical Periods : 0**	**Total Periods : 45**	
Reference Books				

1. L M Deshmukh, “Industrial Safety Management”, TATA McGraw Hill, 2010
2. Lindley R. Higgins. R. Keith Mobley and Darrin Wikoff, “Maintenance Engineering Handbook”, 7thedition, McGraw Hill publication, 2008.
3 Garg H. P, “Maintenance Engineering”, S. Chand and Company, 2010.
4. Audels, “Pump-hydraulic Compressors”, McGraw Hill Publication, 1978.
5. Hans F. Winterkorn, “Foundation Engineering Handbook”, Chapman & Hall London, 2013.

<table>
<tr><td colspan="2">Department :ME</td><td colspan="8">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester :III</td><td colspan="4">Course Category Code: OEC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Hours / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>C</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>OE203</td><td>Operations Research</td><td>3</td><td>0</td><td>0</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="5">Course Outcomes</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Students should able to apply the linear programming to solve problems of discreet and continuous variables.</td></tr>
<tr><td>CO2</td><td colspan="7">Students should able to apply the concept of non-linear programming.</td></tr>
<tr><td>CO3</td><td colspan="7">Students should able to carry out sensitivity analysis.</td></tr>
<tr><td>CO4</td><td colspan="7">Student should able to model the real world problem and simulate it.</td></tr>
<tr><td>UNIT – I</td><td colspan="4"></td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="7">Optimization Techniques, Model Formulation, models, General L.R Formulation, Simplex Techniques, Sensitivity Analysis, Inventory Control Models.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT – II</td><td colspan="4"></td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="7">Formulation of a LPP - Graphical solution revised simplex method - duality theory - dual simplex method - sensitivity analysis - parametric programming.</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT – III</td><td colspan="4"></td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="7">Nonlinear programming problem - Kuhn-Tucker conditions min cost flow problem - max flow problem - CPM/PERT.</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT – IV</td><td colspan="4"></td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="7">Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models - Geometric Programming.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT – V</td><td colspan="4"></td><td colspan="4">Periods : 9</td></tr>
<tr><td colspan="7">Competitive Models, Single and Multi-channel Problems, Sequencing Models, Dynamic Programming, Flow in Networks, Elementary Graph Theory, Game Theory Simulation.</td><td colspan="2">CO4</td></tr>
<tr><td colspan="2">Lecture Periods : 45</td><td colspan="2">Tutorial Periods : 0</td><td colspan="2">Practical Periods : 0</td><td colspan="3">Total Periods : 45</td></tr>
<tr><td colspan="9">Reference Books</td></tr>
<tr><td colspan="9">1. H.A. Taha, Operations Research, An Introduction, PHI, 2008
2. H.M. Wagner, Principles of Operations Research, PHI, Delhi, 1982.
3. J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008
4. Hitler Libermann Operations Research: McGraw Hill Pub. 2009
5. Pannerselvam, Operations Research: Prentice Hall of India 2010
6. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010</td></tr>
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<table>
<tr><td colspan="2">Department: CE</td><td colspan="6">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester: III</td><td colspan="3">Course Category Code: OEC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>OE204</td><td>Cost Management of Engineering Projects</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Understanding the cost controls, data inventory and decision making</td></tr>
<tr><td>CO2</td><td colspan="7">Understanding the project documentation from conception to commissioning</td></tr>
<tr><td>CO3</td><td colspan="7">Understanding the project cost and profit analysis during the commissioning</td></tr>
<tr><td>CO4</td><td colspan="7">Understanding the project resource planning and activity based cost management</td></tr>
<tr><td>CO5</td><td colspan="7">Understanding the project budgeting and quantitative techniques for cost management</td></tr>
<tr><td>UNIT I</td><td colspan="5">Project Cost Management</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Introduction and Overview of the Strategic Cost Management Process. Cost concepts in decision-making; Relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System; Inventory valuation; Creation of a Database for operational control; Provision of data for Decision-Making.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Project Execution</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Project: meaning, Different types, why to manage, cost overruns centre, various stages of project execution: conception to commissioning. Project execution as conglomeration of technical and nontechnical activities. Detailed Engineering activities. Pre project execution main clearances and documents Project team: Role of each member. Importance Project site: Data required with significance. Project contracts. Types and contents. Project execution Project cost control. Bar charts and Network diagram.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Project Commissioning</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Project commissioning: mechanical and process Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis. Various decision-making problems. Standard Costing and Variance Analysis.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Pricing Strategies</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector. Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Total Quality Management and Theory of constraints. Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Project Budgets</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="8">Budgetary Control; Flexible Budgets; Performance budgets; Zero-based budgets. Measurement of Divisional profitability pricing decisions including transfer pricing. Quantitative techniques for cost management, Linear Programming, PERT/CPM, Transportation problems, Assignment problems, Simulation, Learning Curve Theory.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 45</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi
2. Charles T. Horngren and George Foster, Advanced Management Accounting
3. Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting
4. Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheeler publisher
5. N.D. Vohra, Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd.</td></tr>
</table>

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1		2	1	3	3	3
CO2		2	1	3	3	3
CO3		2	1	3	3	3
CO4		2	1	3	3	3
CO5		2	1	3	3	3

Score: **3 –** High; **2 –** Medium; **1 –** Low

<table>
<tr><td colspan="2">Department: Physics</td><td colspan="8">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester: III</td><td colspan="4">Course Category Code: OEC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>OE205</td><td>Composite Materials</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
</table>

<table>
<tr><td rowspan="6">Course Outcome</td><td colspan="2">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td>Able to understand and describe the basic concept and classification of composite.</td></tr>
<tr><td>CO2</td><td>To Learn the concepts of reinforcements and its mechanical behaviour.</td></tr>
<tr><td>CO3</td><td>To acquire the knowledge in metal matrix, ceramic matrix and carbon composites and its applications.</td></tr>
<tr><td>CO4</td><td>To acquire the knowledge in polymer matrix composites and its processing methods.</td></tr>
<tr><td>CO5</td><td>to understand the behavior of strength of Laminates</td></tr>
</table>

<table>
<tr><td>UNIT I</td><td>Introduction to Composite Materials</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Definition – Classification and characteristics of Composite materials. Advantages and application of composites. Functional requirements of reinforcement and matrix. Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td>Reinforcements</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers. Properties and applications of whiskers, particle reinforcements. Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures. Isostrain and Isostress conditions.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td>Manufacture of Composites</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Manufacturing of Metal Matrix Composites: Casting – Solid State diffusion technique, Cladding – Hot isostatic pressing, Properties and applications. Manufacturing of Ceramic Matrix.
Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving. Properties and applications.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td>Fabrication of Polymer Matrix Composites</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Preparation of Moulding compounds and prepress – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding. Properties and applications.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td>Laminar Strength Analysis</td><td>Periods : 9</td></tr>
<tr><td colspan="2">Strength: Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hydrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.</td><td>CO5</td></tr>
</table>

Lecture Periods: 45	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 45**

Reference Books

1. Material Science and Technology – Vol 13 – Composites by R.W.Cahn – VCH, West Germany.
2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.
3. Hand Book of Composite Materials-ed-Lubin.
4. Composite Materials – K. K. Chawla.
5. Composite Materials Science and Applications – Deborah D.L. Chung.
6. Composite Materials Design and Applications – Danial Gay, Suong V. Hoa, and Stephen W. Tasi.

<table>
<tr><td colspan="2">Department: CE</td><td colspan="8">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester: III</td><td colspan="5">Course Category Code: OEC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>OE206</td><td>Waste to Energy</td><td>3</td><td>-</td><td>-</td><td>3</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Knowing about the types of sources of wastes and about its conversion techniques</td></tr>
<tr><td>CO2</td><td colspan="7">Understanding about the concepts of Pyrolysis and its application</td></tr>
<tr><td>CO3</td><td colspan="7">Understanding about the processes involved in gasification of biomass and its operation process</td></tr>
<tr><td>CO4</td><td colspan="7">Understanding the process of biomass combustion techniques and its design concepts in operation</td></tr>
<tr><td>CO5</td><td colspan="7">Knowing about the Biogas production techniques and about the status of production in India.</td></tr>
<tr><td>UNIT I</td><td colspan="5">Waste & Conversion Techniques</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digesters</td><td colspan="2">CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Biomass Pyrolysis</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Biomass Pyrolysis: Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.</td><td colspan="2">CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Biomass Gasification</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.</td><td colspan="2">CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Biomass Combustion</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.</td><td colspan="2">CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Biogas</td><td colspan="3">Periods : 9</td></tr>
<tr><td colspan="7">Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion -biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion -Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production -Urban waste to energy conversion - Biomass energy programme in India.</td><td colspan="2">CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 45</td><td colspan="3">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="2">Total Periods: 45</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Non-Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.</td></tr>
</table>

CO – PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6
CO1		2	1	3	3	3
CO2		2	1	3	3	3
CO3		2	1	3	3	3
CO4		2	1	3	3	3
CO5		2	1	3	3	3

Score: **3 –** High; **2** – Medium; **1** – Low

MANDATORY AUDIT COURSES

<table>
<tr><td colspan="2">Department: HS</td><td colspan="7">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester: I/II</td><td colspan="4">Course Category Code: MAC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>AD201</td><td>English for Academic Writing</td><td>2</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Understand principles of academic writing</td></tr>
<tr><td>CO2</td><td colspan="7">Understand the importance of proper literature review</td></tr>
<tr><td>CO3</td><td colspan="7">Develop critical perspective and analytical skills</td></tr>
<tr><td>CO4</td><td colspan="7">Overcome challenges faced in the process of academic writing</td></tr>
<tr><td>CO5</td><td colspan="7">Present research in the most effective way</td></tr>
<tr><td>UNIT I</td><td colspan="5">Academic Writing</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">What, why, how - Word Order – organizing and structuring sentences and paragraphs – grammar and punctuation – accuracy, brevity and clarity. Planning and Preparation,</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Literature Review</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Methods - reading techniques – Note taking , Hedging and Criticizing, Paraphrasing and annotation</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Critical Analysis and Evaluation</td><td colspan="3">Periods :6</td></tr>
<tr><td colspan="8">Academic tone and language - presenting results and discussion - preparation of outline – drafting - editing</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Sections of a Paper</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Title – abstract – Introduction – conclusion – thesis statement – research proposals – articles – theses</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Acknowledgements</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Referencing - bibliography - research ethics - academic integrity - plagiarism</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 30</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 30</td></tr>
<tr><td colspan="9">Reference Books</td></tr>
<tr><td colspan="9">1. Goldbort R (2006) Writing for Science, Yale University Press (available on Google Books)
2. Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press
3. Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM. Highman’s book.
4. Adrian Wall work , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011</td></tr>
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<table>
<tr><td colspan="2">Department: CE</td><td colspan="7">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester: I/II</td><td colspan="3">Course Category Code: MAC</td><td colspan="4">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>AD202</td><td>Disaster Management</td><td>2</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Knowing about the Types of Disasters</td></tr>
<tr><td>CO2</td><td colspan="7">Knowing about the economics and life after the different disasters</td></tr>
<tr><td>CO3</td><td colspan="7">Knowing the disaster zones in India and its epidemics</td></tr>
<tr><td>CO4</td><td colspan="7">Understanding the disaster preparations and disaster managing procedures</td></tr>
<tr><td>CO5</td><td colspan="7">Knowing the risk assessment procedure and mitigation techniques</td></tr>
<tr><td>UNIT I</td><td colspan="5">Types of Disasters</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Introduction: Disaster: Definition, Factors and Significance; Difference Between Hazard and Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Repercussions of Disasters And Hazards</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Economic Damage, Loss of Human and Animal Life, Destruction of Ecosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts and Famines, Landslides and Avalanches, Manmade disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks and Spills, Outbreaks of Disease and Epidemics, War and Conflicts.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Disaster Prone Areas in India</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Study of Seismic Zones; Areas Prone to Floods and Droughts, Landslides and Avalanches; Areas Prone to Cyclonic and Coastal Hazards with Special Reference to Tsunami; Post-Disaster Diseases and Epidemics.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Disaster Preparedness and Management Preparedness</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Monitoring of Phenomena Triggering A Disaster Or Hazard; Evaluation of Risk: Application of Remote Sensing, Data From Meteorological and Other Agencies, Media Reports: Governmental and Community Preparedness.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Disaster Risk Assessment & Mitigation</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People’s Participation in Risk Assessment. Strategies for Survival.

Meaning, Concept and Strategies of Disaster Mitigation, Emerging Trends in Mitigation. Structural Mitigation and Non-Structural Mitigation, Programs of Disaster Mitigation in India.</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 30</td><td colspan="2">Tutorial Periods:</td><td colspan="2">Practical Periods:</td><td colspan="3">Total Periods: 30</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. R. Nishith, Singh AK, “Disaster Management in India: Perspectives, issues and strategies “’New Royal book Company.
2. Sahni, Pardeep et.al. (Eds.),” Disaster Mitigation Experiences And Reflections”, Prentice Hall of India, New Delhi
3. Goel S. L. , Disaster Administration And Management Text And Case Studies”, Deep & Deep Publication Pvt. Ltd., New Delhi.</td></tr>
</table>

<u>CO – PO Mapping</u>

	PO1	PO2	PO3	PO4	PO5	PO6
CO1		2	1	3	3	3
CO2		2	1	3	3	3
CO3		2	1	3	3	3
CO4		2	1	3	3	3
CO5		2	1	3	3	3

<u>Score</u>: **3** – High; **2** – Medium; **1** – Low

<table>
<tr><td colspan="2">Department: HS</td><td colspan="7">Programme: M. Tech.</td></tr>
<tr><td colspan="2">Semester: I/II</td><td colspan="4">Course Category Code: MAC</td><td colspan="3">Semester Exam Type: TY</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td rowspan="2">Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>AD203</td><td>Value Education</td><td>2</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Understand the importance and need for value education</td></tr>
<tr><td>CO2</td><td colspan="7">Appreciate and develop desirable values</td></tr>
<tr><td>CO3</td><td colspan="7">Understand core values of one’s personality through self-analysis</td></tr>
<tr><td>CO4</td><td colspan="7">To be sensitized towards challenging social issues</td></tr>
<tr><td>CO5</td><td colspan="7">To inculcate an essential value system towards building a healthy society</td></tr>
<tr><td>UNIT I</td><td colspan="6">Purpose of Value Education</td><td colspan="2">Periods : 6</td></tr>
<tr><td colspan="8">Self exploration - values and self development – understanding needs - holistic living – ethics - duties and responsibilities - standards and rules of behavior - value judgments.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="6">Stages of Moral Development</td><td colspan="2">Periods : 6</td></tr>
<tr><td colspan="8">Developing objectivity - dedication, self-reliance, confidence, truthfulness, cleanliness, sincerity, honesty, humaneness, tolerance, international understanding - love for nature, discipline , self control – ethical public behaviour</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="6">Personality and Behavior Development</td><td colspan="2">Periods : 6</td></tr>
<tr><td colspan="8">SWOT analysis and introspection – scientific temper- positive thinking - integrity and discipline - punctuality, love and kindness - dignity of labour.</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="6">Human Rights</td><td colspan="2">Periods : 6</td></tr>
<tr><td colspan="8">Social inclusion – social evils and problems - impact of media, consumerism and globalization on the individual and his/her existence – value education for national and global development</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="6">Personal Values</td><td colspan="2">Periods : 6</td></tr>
<tr><td colspan="8">Family values - social values and individual attitudes – cultural values – national values - professional values – aesthetic values – social and professional behaviour</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 30</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 30</td></tr>
<tr><td colspan="9"><u>Reference Books</u></td></tr>
<tr><td colspan="9">1. Chakroborty, S.K: Values and Ethics for organizations Theory and practice, Oxford University Press, New Delhi
2. Das, M.S. & Gupta, V.K. : Social Values among Young adults: A changing Scenario, M.D. Publications, New Delhi, 1995 3. Bandiste, D.D.: Humanist Values: A Source Book, B.R. Publishing Corporation, Delhi, 1999
4. Values and Ethics for the 21st Century: BBVA,2011
5. Srivastava, Smriti. Human Values and Professional Ethics , S.K. Kataria & Sons, New Delhi,2011
6. Ruhela, Satya Pal. Dimensions of Value Education. New Delhi: Motilal Banaridass Publishing House.</td></tr>
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<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>AD204</td><td>Constitution of India</td><td>2</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">Understand and Discuss the emergence, evolution and meaning of Indian Constitution</td></tr>
<tr><td>CO2</td><td colspan="7">Comprehend the significance of constitutional rights and duties</td></tr>
<tr><td>CO3</td><td colspan="7">Understand and analyse the three organs of government and the system of governance</td></tr>
<tr><td>CO4</td><td colspan="7">Understand and describe decentralization, power and role</td></tr>
<tr><td>CO5</td><td colspan="7">Understand the role of constitutional and non-constitutional bodies</td></tr>
<tr><td>UNIT I</td><td colspan="5">Making of the Indian Constitution: Evolution and Development</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Historical background of the constituent Assembly – various committees (Composition & Working). Philosophy of the Indian Constitution: Preamble Salient Features -amendments</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Contours of Constitutional Rights & Duties</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Fundamental Rights - Right to Equality - Right to Freedom - Right against Exploitation - Right to Freedom of Religion - Cultural and Educational Rights - Right to Constitutional Remedies - Directive Principles of State Policy - Fundamental Duties.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Organs of Governance</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Parliament – Composition - Qualifications and Disqualifications - Powers and Functions – Executive – President – Governor - Council of Ministers - Judiciary, Appointment and Transfer of Judges, Qualifications - Powers and Functions. – system of government- the union and its territories – emergency provisions</td><td>CO3</td></tr>
<tr><td>UNIT IV</td><td colspan="5">Local Administration</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">District Administration: Role and Importance - Municipalities: Introduction, Mayor and role of Elected Representative, CEO of Municipal Corporation - Panchayat raj: Introduction, PRI: Zilla Panchayat - Elected officials and their roles, CEO Zilla Panchayat: Position and role - Block level: Organizational Hierarchy (Different departments) - Village level: Role of Elected and Appointed officials - Importance of grass root democracy.</td><td>CO4</td></tr>
<tr><td>UNIT V</td><td colspan="5">Constitutional and Non-Constitutional Bodies</td><td colspan="3">Periods : 6</td></tr>
<tr><td colspan="8">Election Commission: Role and Functioning - Chief Election Commissioner and Election Commissioners- State Election Commission: Role and Functioning - Institute and Bodies for the welfare of SC/ST/OBC and women – Equality and social justice</td><td>CO5</td></tr>
<tr><td colspan="2">Lecture Periods: 30</td><td colspan="2">Tutorial Periods: -</td><td colspan="3">Practical Periods: -</td><td colspan="2">Total Periods: 30</td></tr>
<tr><td colspan="9">Reference Books</td></tr>
<tr><td colspan="9">1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
3. M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis, 2014.
4. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.</td></tr>
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Department: **HS**		Programme: **M. Tech.**						
Semester: **I/II**		Course Category Code: **MAC**				Semester Exam Type: **TY**		
Course Code	Course Name	Periods / Week			Credit	Maximum Marks		
		L	T	P		CA	SE	TM
AD205	**Pedagogy Studies**	**2**	**-**	**-**	**-**	**-**	**-**	**-**
Prerequisite								

Course Outcome	On completion of the course, the student will be able to
CO1	Understand the pedagogical practices being used by teachers in formal and informal classrooms
CO2	Reflect on the different theories of learning
CO3	Apply appropriate instructional methods
CO4	Explore pedagogical innovation
CO5	Identify gaps in research and effectively apply concepts of communication theory

UNIT I	**Introduction and Methodology**	**Periods** : **6**
Aims and rationale, , Conceptual framework and terminology - Theories of motivation and learning, Curriculum, Teacher education : policies and programmes		**CO1**
UNIT II	**Pedagogical Theory and Approaches**	**Periods** : **6**
Thematic overview - historical perspective - teaching practices in formal and informal classrooms in developing countries – teacher education and training – attitudes and beliefs		**CO2**
UNIT III	**Pedagogic Strategies**	**Periods** : **6**
Effectiveness of pedagogical practices - - Theory of change – New learning – didactic, authentic, transformative perspectives – teacher competency and accountability – professional ethics		**CO3**
UNIT IV	**Professional Development**	**Periods** : **6**
Alignment with classroom practices and follow-up – classroom management - Peer and community support - - Curriculum and assessment – inclusive teaching – evaluation concepts and approaches –digital initiatives - Barriers to learning		**CO4**
UNIT V	**Research Gaps and Future Directions: Maintaining Standards**	**Periods** : **6**
Research design – Contexts – communication - Dissemination and research impact - innovation.		**CO5**

Lecture Periods: 30	**Tutorial Periods: -**	**Practical Periods: -**	**Total Periods: 30**

<u>Reference Books</u>

1. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2):245-261.
2. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.
3. Akyeampong K (2003) Teacher training in Ghana - does it count? Multi-site teacher education research project (MUSTER) country report 1. London: DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33 (3): 272–282.
5. Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
6. Chavan M (2003) Read India: A mass scale, rapid, ‘learning to read’ campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf.

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<tr><td rowspan="2">Course Code</td><td rowspan="2">Course Name</td><td colspan="3">Periods / Week</td><td>Credit</td><td colspan="3">Maximum Marks</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td></td><td>CA</td><td>SE</td><td>TM</td></tr>
<tr><td>AD206</td><td>Stress Management by Yoga</td><td>2</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Prerequisite</td><td colspan="8"></td></tr>
<tr><td rowspan="4">Course Outcome</td><td colspan="8">On completion of the course, the student will be able to</td></tr>
<tr><td>CO1</td><td colspan="7">To know the role of Yoga</td></tr>
<tr><td>CO2</td><td colspan="7">To understand the importance of mind and meditations</td></tr>
<tr><td>CO3</td><td colspan="7">To know how to overcome stress.</td></tr>
<tr><td>UNIT I</td><td colspan="5">Yoga</td><td colspan="3">Periods : 10</td></tr>
<tr><td colspan="8">Definition of yoga – Importance of yoga – Basic rules of yoga – Eight stages of yoga: Iyama – Niyama – Aasana – Pranayama – Prathyagara – Dhaarana – Dhyaana – Samaadhi – Asanas - Kayakalpa yoga - Mudras.</td><td>CO1</td></tr>
<tr><td>UNIT II</td><td colspan="5">Meditation</td><td colspan="3">Periods : 10</td></tr>
<tr><td colspan="8">Definition – Importance of meditation – Mental wave frequency – Benefits of Agna, Shanthi, Thuriyam and Thuriyaadheetham meditations.</td><td>CO2</td></tr>
<tr><td>UNIT III</td><td colspan="5">Stress Management</td><td colspan="3">Periods : 10</td></tr>
<tr><td colspan="8">Definition of Pain, Pleasure, Peace and Ecstasy – Reasons for Stress – Knowing the relation among self, nature and society - Analysis of Thoughts - Moralisation of Desire - Neutralisation of Anger - Eradication of Worries - Realisation of Self - Harmony in Life - Greatness of Women – Benefits of Blessings.</td><td>CO3</td></tr>
<tr><td colspan="2">Lecture Periods: 30</td><td colspan="2">Tutorial Periods: -</td><td colspan="2">Practical Periods: -</td><td colspan="3">Total Periods: 30</td></tr>
<tr><td colspan="9">Reference Books</td></tr>
<tr><td colspan="9">1. G.V. Vethathiri, Yoga for Modern Age, The World Community Service Centre Publications, 2010.
2. Yoga practices-2, The World Community Service Centre Publications, 2016.
3. The Mother, Foundations of Education, Sri Aurobindo Ashram, Pondicherry, 2012.</td></tr>
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