First Year Curriculum of
Postgraduate Degree in Chemical Engineering

A. Structure of curriculum

Master of Chemical Engineering

Semester I

Sr. No	Category of Course	Code No.	Course Title	Hours per week			Total conta contact hrs/ week	Credits	E	M	I	V	Total
				L	T	P							
1	Program Core I	CH3101	Numerical Methods in Chemical Engineering	3	1	0	4	4	70	30	20	30	150
2	Program Core II	CH3102	Advanced Reaction Engineering	3	0	2	5	4	70	30	20	30	150
3	Program Elective I	CH3103/04	Program Elective I	3	0	2	5	4	70	30	20	30	150
4	Program Elective II	CH3105/06	Program Elective II	4	0	0	4	4	70	30	0	0	100
5	Research Methodology and IPR	MH3105	Research Methodology	2	0	0	2	2	0	0	20	30	50
6	Audit Course -I	MH3106	English for Research paper writing	2	0	0	2	0	30	20	0	0	50
Total Credits							22	18	Total				650

List of Program Electives:-

Types	Code No.	Choice of Subjects
Program Elective-I	CH3103	Advanced Computer Aided Design
	CH3104	Process Modeling andSimulation
Program Elective-II	CH3105	Nano-Technology
	CH3106	Advanced Separation Process

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Semester-II

Sr. No	Category of Course	Code No.	Course Title	Hours per week			Total contact hrs/ week	Credits	E	M	I	V	Total
				L	T	P							
1	Program Core III	CH3107	Advanced Process Dynamics & Control	3	0	2	5	4	70	30	20	30	150
2	Program Core IV	CH3108	Advanced Chemical Engineering Thermodynamics	3	0	0	3	3	70	30	0	0	100
3	Program Core- V	CH3109	Advanced Transport Phenomena	2	0	0	2	2	70	30	0	0	100
4	Program Elective III	CH3110/ 11	Program Elective III	3	0	0	3	3	70	30	0	0	100
5	Program Elective IV	CH3112/ 13	Program Elective IV	4	0	0	4	4	70	30	0	0	100
6	Open Elective-I	CH3114/15	Open Elective- I	2	0	0	2	2	70	30	0	0	100
7	Audit Course -II	MH3107	Technology Management	2	0	0	2	0	70	30	0	0	100
Total Credits							21	18	Total				750

List of Program/Open Electives:-

Types	Code No.	Choice of Subjects
Program Elective-III	CH3110	Energy Management
	CH3111	Cleaner Production
Program Elective-IV	CH3112	Chemical Reactor Design
	CH3113	Catalysts and Adsorbents
Open Elective-I	CH3114	Fluidization Engineering
	CH3115	Piping Engineering

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Course code and definition:

Course code	Definitions
L	Lecture
T	Tutorial
P	Practical
E	Theory External Examination Marks
M	Theory Internal Examination Marks
I	Practical Internal Examination Marks
V	Practical External Examination Marks

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UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3101
Subject Name: Numerical Methods in Chemical Engineering

Semester: -I

Type of course: Program Core-I

Prerequisite: Knowledge in applied mathematics and basic aspects of chemical engineering.

Rationale: Mathematical modeling of chemical engineering system may result in system of linear algebraic equations, system of non-linear algebraic equations, ordinary differential equation, partial differential equation etc. Proper numerical techniques are required to solve mathematical model.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	1	0	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Linear Algebraic Equations**: System of linear algebraic equations, conditions for existence of solution, solution by matrix decomposition, Gauss-Jordan, Jacobi, Gauss-Siedel and Convergence of iterative solution schemes: analysis of asymptotic behavior of linear difference equations using Eigen values, convergence of iterative solution schemes, examples of well-conditioned and ill-conditioned linear systems. **Nonlinear Algebraic Equations**: Method of successive substitutions, derivative free iterative solution approaches, Wegsteine iterations, Modified Newton's method and Qausi-Newton method with Broyden's update.	**8**
2	**Interpolation & Curve Fitting**: Least square Method, Newton's Interpolation Formulae, Newton's Divided Difference Formulae, Lagrange	**6**

	Interpolating Polynomials, Spline Interpolation, Pade Approximations, Cubic Spline Approximations, Extrapolation Techniques	
3	**Ordinary Differential Equations** - Introduction of Initial Value Problems (ODE-IVPs), Numerical solutions of ODE-IVP: step size and marching, concept of implicit and explicit methods, Taylor series based and Runge-Kutta methods, multi-step (predictor-corrector) approaches, Stability of ODE-IVP solvers, choice of step size and stability envelopes, stiffness and variable step size implementation, Introduction to solution methods for differential algebraic equations (DAEs).	**8**
	SECTION-B	
4	Ordinary Differential Equations – Boundary Value Problems (ODE-BVPs): Method of least squares for solving ODE-BVP, Gelarkin's method and generic equation forms arising in problem discretization, Errors in Discretization, Discretization using approximation theory, finite difference method for solving ODE-BVPs with examples, Single shooting method for solving ODE-BVPs.	**5**
5	Partial Differential Equations (PDEs): Introduction to PDEs, finite difference method for solving PDEs with examples, Orthogonal Collocations method for solving PDEs, Galerkin finite element method for PDEs.	**5**
6	Optimization Techniques: Introduction, Golden Section Method, parabolic interpolation, Newton's Method, Brent's Method, Linear Programming, least cost treatment of wastewater.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	20	20	20	5	5

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. Gupta, S. K., "Numerical Methods for Engineers", Wiley Eastern, New Delhi,

1995.
2. Chapra, S., Canale, R., "Numerical Methods for Engineers", 7th ed., McGraw Hill, 2010.

Reference Books:

1. Riggs, J. B., "An Introduction to Numerical Methods for Chemical Engineers", 1st ed, Texas Tech. Univ. Press, 1994.
2. Gilbert S., "Linear Algebra and Its Applications", 4th Ed., Wellesley Cambridge Press, 2009.
3. Philips, G.; M.,Taylor, P. J., "Theory and Applications of Numerical Analysis" 2nd Ed., Academic Press, 1996.
4. Gourdin, A., Boumhrat, A., "Applied Numerical Methods", Prentice Hall India, New Delhi, 2000.
5. Linz, P., "Theoretical Numerical Analysis, Dover", New York, 1979.

List of Practical/ Tutorials:

1. Linear algebraic equation solution technique using Guass-Jordan Gauss seidel Techniques
2. Concept of Eigen value and eigen vectors.
3. Problems on Well-conditioned and ill conditioned linear systems.
4. Quasi newton technique with broyden's update example of a chemical reactor
5. Applications of least square methods.
6. Concept of Interpolation and extrapolation techniques.
7. Solution technique to differential algebraic equations in a ODE-IVP case.
8. Examples on shooting technique
9. Solution of a real-world problem using golden section method
10. Least cost treatment of wastewater: case study

Course Outcomes:

Students should be able to

Sr. No.	CO statement
CO-1	Recall the basic aspects of linear and non-linear algebraic equations
CO-2	Relate basic chemical engineering processes with differential equations
CO-3	Relate the role of optimization techniques in numerical methods

Master of Engineering
Subject Code: CH3101
Subject Name: Numerical Methods in Chemical Engineering

CO-4	Solve ordinary and partial differential equations using various numerical techniques
CO-5	Investigate the solution techniques applicable to basic mass transport processes
CO-6	Design a chemical process using a mathematical model

List of Open-Source Software/learning website:

- NPTEL Video Lectures
- NPTEL Web Contents

Master of Engineering
Subject Code: CH3102
Subject Name: Advanced Reaction Engineering

Type of course: Program Core II

Prerequisite: Knowledge of reaction engineering at undergraduate level.

Rationale: This subject deals with the heterogeneous reactions and non-ideal flow systems including performance of various types of reactors. The catalyst systems are also be covered in this.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	**36**
1	**Overview:** of Chemical Reaction Engineering, Reactor Design Equations for Ideal Vessels, Effect of Pressure Drop on Performance of Plug Flow Vessels, Design Equation of Plug Flow Recycle Reactor, Advantages of Plug Flow Recycle Reactor, Semi Batch Reactor Operation.	**6**
2	**Non-ideal Flow in Reactors:** Residence Time Distribution studies, Design Aspects of Reactors with Non-ideal Flow, Models for Non-ideal system, Micro and Macro Mixing in Reactors, One Dimensional & Two-Dimensional Models for PFR, Reactor scale-up.	**8**
3	**Heat Effects**: Energy Balance for Stirred Vessels, Heat Effects in Reversible Exothermic Reactions, Need for Multi-Staging, Optimal Design of Reactors for Reversible Exothermic Reactions, Isothermal, Adiabatic, Nonisothermal Reactors.	**6**

Master of Engineering
Subject Code: CH3102
Subject Name: Advanced Reaction Engineering

SECTION-B		
4	**Solid-Catalyzed Reactions:** Diffusion with Reaction in Porous Catalyst, Mechanism of Catalytic Reactions. Development of Rate Equations for Solid Catalyzed Fluid Phase Reactions; Estimation of Kinetic Parameters External/ Internal Mass and Heat Transfer Resistances in Catalyst Particles, Reactors for Solid Catalyzed Reactions.	**7**
5	**Heterogeneous Non-Catalytic Reactions:** The Shrinking Core Model, and Determination of Controlling Resistance, Reactors for Gas Solid Non catalytic Reactions, Theory of Mass Transfer with Chemical Reaction (Regimes and Examples), Design of Reactor for Fluid-Fluid System.	**5**
6	**Population Balance Modelling:** Deriving Particle Size Distribution for Continuous Fluid Beds via PBE, Deriving Design Equations for Gas Solid Reactions via PBE, Deriving Property Distributions in Reactor Regenerator Systems.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	20	20	20	15	05

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books:

1. Levenspiel O., "Chemical Reaction Engineering", Wiley, Third Edition 1999.

Reference Books:

1. Foggler H.S., "Elements of Chemical Reaction Engineering", Prentice Hall of India, 2008.
2. Smith J.M., "Chemical Engineering Kinetics", McGraw Hill, Third Edition, 1981.
3. Denbigh K.G., "Chemical Reactor Theory", Cambridge University Press, Second Edition, 1971.
4. Carberry James J., "Chemical and Catalytic Reaction Engineering", McGraw-Hill, Third Edition, 1976.

Master of Engineering
Subject Code: CH3102
Subject Name: Advanced Reaction Engineering

List of Practical/ tutorials:

1. Study the semi-batch reactor operation
2. To perform RTD studies in PFR
3. To perform RTD studies in CSTR
4. To perform RTD studies CSTR in Series
5. Study the adiabatic operation in batch reactor
6. Study the different types of adsorption isotherms
7. To compare catalytic and non-catalytic reaction conversion
8. Study the solid fluid non catalytic reaction of changing size
9. Study the solid fluid non catalytic reaction of unchanging size
10. Study the mass transfer with chemical reaction

Course Outcomes:

CO	CO statement
CO-1	Evaluate the performance of different reactors under various conditions.
CO-2	Categorize non-ideal flow models and reactor scale up.
CO-3	Design of reactor system for optimum condition.
CO-4	Estimation of kinetics of solid catalyzed reactions.
CO-5	Estimate the performance of multiphase reactors under various conditions.
CO-6	Choose a suitable approach for reactor design.

List of Open Source Software/learning website:

- NPTEL Video Lectures
- NPTEL Web Contents

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3103
Subject Name: Advanced Computer Aided Design

Semester: - I

Type of course: Program Elective I

Prerequisite: Basic knowledge of computer operation and fundamentals of core chemical engineering subjects (process calculation, heat transfer, mass transfer, reaction engineering and thermodynamics)

Rationale: The course focusses on the importance and applications of CAD in the field of chemical engineering. The student will become familiar to the basic structure and components of CAD software and importance of underlying topic related to process onion diagram.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Introduction to CAD:** Scope and applications in chemical engineering, Process Flow sheet Models, Steps in Product and Process Design, Environment Protection, Safety Considerations, Engineering Ethics, Green engineering, Equipment Sizing and Costing.	5
2	**Synthesis of reaction systems:** Chemical equilibrium, reaction rate, reactors for homogeneous systems, reactors for heterogeneous systems, thermal design issues, types of thermal design, selection of chemical reactors, synthesis of chemical reactor networks	5
3	**Synthesis of Separation Systems:** Separation methods, Selector analysis, Split sequencing, Separation of Zeotropic mixtures by distillation, Heuristics for sequencing, Complex columns, Sequence optimization, Enhanced distillation: Pressure-swing distillation, Extractive distillation, Azeotropic distillation, Residue curve	8

	maps, Separation by homogeneous azeotropic distillation, Separation by heterogeneous azeotropic distillation, Entrainer selection, DWC: design, control and applications	
	SECTION-B	
4	**Synthesis of Heat Exchanger Networks:** Introduction, basic heat exchanger network synthesis (HENS), HEN design, HEN design evolution, Grand Composite Curve (GCC), pinch design approach to inventing a network, Minimum utility cost, maximum energy recovery, minimum number of exchangers, threshold and optimum approach temperature, derivation of network structures for minimization of annual costs, Multiple utility design problems., Software tools for HEN, heat integrated distillation trains and multi effect distillation	**08**
5	**Mass Integration:** Introduction, Minimum Mass Separating Agent (MSA), Mass Exchanger Networks, Minimum External MSA, Minimum Number of Mass Exchangers	**05**
6	**Design and Scheduling of Batch Processes:** Single product batch plants, Multiple product batch plants, Transfer policies, Parallel units and intermediate storage, Sizing of vessels in batch plants, Inventories, Synthesis of flow shop plants.	**05**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
5	15	25	15	10	0

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. W D Seider, J D Seader and D R Lewin, Product and Process Design Principles- Synthesis, Analysis, and Evaluation, John Wiley and Sons Inc., 4th Edition, 2017.

Reference Books:

2. Lorens T. Biegler, E.Ignacio grossmann, Systematic Methods of Chemical Process Design:, Arthur W Westerberg Published by-Prentice Hall International, 1st Edition, 1997.
3. Douglas, J., Conceptual Design of Chemical Processes, New York, NY: McGraw-Hill, 1988. ISBN: 0070177627.

4. Robin Smith, Chemical Process Design and Integration, Wiley, 2005, ISBN: 978-1-119-99014-7.
5. Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz., Analysis, Synthesis, and Design of Chemical Processes, Prentice Hall, 2nd Edition, 2002, ISBN-10: 0-13-064792-6

Course Outcomes:

Upon completing the course, the student will be able to

Sr. No.	CO statement
CO-1	list out steps in product and process design.
CO-2	explain various reactor models and design reactor network system.
CO-3	discuss various separation operations and design split sequence based on theory and heuristics.
CO-4	calculate energy targets and design heat exchanger network.
CO-5	illustrate potential of material saving potential in chemical process industries.
CO-6	classify various transfer policies for designing and scheduling batch processes.

LIST OF EXPERIMENTS:

1. Minimum utility target and pinch point using HINT software
2. Minimum utility target and pinch point using LP in MS Excel
3. Minimum utility target and pinch point using LP in GAMS
4. Reactor network synthesis for manufacture of maleic anhydride
5. Material balance over multicomponent separation columns
6. Design of heat exchanger network using HINT/THEN Software
7. Design and scheduling of batch process
8. Sequencing of multiple distillation columns
9. Design of mass exchange network.
10. Simulation of distillation process.

List of Open-Source Software/learning website:

- Students can refer to video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets.
- Students can explore open sources software HINT, DWSIM, SCILAB, Chemsep etc.

Master of Engineering
Subject Code: CH3103
Subject Name: Process Modeling and Simulation

Semester: - I

Type of course: Program Elective - I

Prerequisite: Basic knowledge of material and energy balance and mathematics.

Rationale: The Process Modeling and Simulation of Chemical Engineering unit operation has attracted the attention of Chemical Engineers because of its advantages in designing and optimization of process equipment. This course includes the concepts of modeling, and simulation of different unit operations used chemical plants.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Modelling Aspects:** Definition of process model, Physical and Mathematical modelling, Deterministic and Stochastic process, Classification of models, Model building, Black-box model, White box model, Gray model, Classification of Mathematical methods.	**5**
2	**Mathematical methods of chemical engineering systems:** Introduction, Uses of mathematical models, Principles of formulation, Fundamental laws, Continuity equations, Energy equations, Equation of motion, Transport equation, Equation of state, Equilibrium, Kinetics.	**7**
3	**Examples of mathematical models of chemical engineering systems:** Introduction, Series of Isothermal, Constant-Hold up CSTRs, CSTRs with variable Holds up, Two heated tanks, Gas-phase, Pressurized CSTR, Non-isothermal CSTR, Single-Component vaporizer, Multicomponent Flash drum, Batch Reactor, Reactor with Mass transfer, Ideal Binary distillation column, Multicomponent non ideal Distillation column, Batch distillation with holdup.	**6**
	SECTION-B	

4	**Simulation:** Degree of freedom analysis, Types of simulation problems: Design, rating, flow sheeting etc. usefulness and limitation of process simulation	**6**
5	**Simulation Examples:** Modes of simulation, Decomposition of networks, Gravity-Flow Tank, Three CSTRs in Series, Non-isothermal CSTR, Binary Distillation Column, Multicomponent Distillation Column.	**6**
6	**Simulators and Solvers:** Introduction to various professional simulators and equation solver software.	**6**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	20	30	15	15	0

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books:

1. William L. Luyben," Process Modeling, Simulation and Control for Chemical Engineers", McGraw Hill International Editions, 2nd Ed., 2014.

Reference Books:

1. B Wayne Bequette," Process Dynamics: Modeling, Analysis and Simulation", Prentice Hall International Inc, 3rd Ed., 2002.
2. B.V. Babu, "Process Plant Simulation", Oxford University Press, 1st Ed., 2004.
3. R Turton, R C Bailie, W B Whiting and J A Shaeiwitz," Analysis, Synthesis and Design of Chemical Processes", Prentice Hall International In, 5th Ed., 2018.
4. W D Seider, J D Seader and D R Lewin,"Product and Process Design Principles- Synthesis, Analysis, and Evaluation" John Wiley and Sons Inc, 4th Ed., 2017.

Course Outcomes:

Upon completing the course, the student will be able to

Sr. No.	CO statement
CO-1	Describe various types of simulation models.
CO-2	Discuss conservation principles for process modelling.

Master of Engineering
Subject Code: CH3103
Subject Name: Process Modeling and Simulation

CO-3	Prepare process models for different unit operation using conservation principles.
CO-4	Illustrate design and flow sheeting.
CO-5	Solve process models for different unit operation using computational techniques.
CO-6	Assess simulated process models using MATLAB/CHEMCAD.

LIST OF EXPERIMENTS:

1. Physical and thermodynamic property estimations
2. Mass and Energy balances
3. Design of CSTR
4. Design of PFR
5. Design of distillation column
6. Design of heat exchangers
7. Design of absorbers
8. Solution of system of non-linear equations.
9. Solution of ordinary differential equations.
10. Simulation of a process flow sheet.

List of Open Source Software/learning website:

- Reference to NPTEL lectures can be made for a better understanding.
- Literature available on modeling and simulation.

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Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3015
Subject Name: Nanotechnology
Semester: - I

Type of course: Program Elective II

Prerequisite: Nanotechnology is a highly interdisciplinary science, which requires knowledge of chemistry, physics, biology, pharmacy, and engineering.

Rationale: The course will provide an overview over Nanotechnology. It will show that the nano regime is so different from other regimes because both classical and quantum effects can be active thus leading to unique properties of nano devices. Nanotechnology is a highly interdisciplinary science, which will be reflected in the course. Applications of Nanotechnology, as they are already in use today or as they are planned for the future, will be discussed.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	--	--	100

Content:

Sr. No.	Content	Total Hrs.
	Section A	**48**
01	Introduction to nanomaterials: Zero-, One-, Two- and Three-dimensional structure (nanowires, nano clusters, quantum wells), role of size in nanomaterials, Properties of materials & nanomaterials (Mechanical, Optical, Electrical, Electronic, Magnetic properties; Surface plasmon Resonance etc. Top down and Bottom up approach of nanomaterial synthesis.	8
02	Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation; Metal nano crystals by reduction, Sol-gel synthesis; Micro-emulsions; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sono-chemical synthesis; Electrochemical synthesis; Photochemical synthesis,	8

Master of Engineering
Subject Code: CH3015
Subject Name: Nanotechnology

	Synthesis in Supercritical fluids	
03	Fabrication of Nanomaterials by Physical Methods: -Inert gas condensation, Arc discharge, Plasma arc technique, RF plasma, MW plasma, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapour deposition method and Electro deposition.	8
	Section B	
04	Nanocomposites: An Introduction: Types of Nano composite (i.e. metal oxide, ceramic, glass and polymer based); Core-Shell structured nanocomposites Super hard Nano composite: Synthesis, applications and milestones.	8
05	Structural Characterization: X-ray diffraction, Small angle X-ray Scattering, Optical Microscope and their description, Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), TEM and EDAX analysis, Scanning Tunnelling Microscopy (STM), Atomic force Microscopy (AFM).	8
06	Applications of nanomaterials: Cosmetics and Consumer Goods, Nano Sensor, Nano catalysts, Water Treatment and the Environment, Paints, Food and Agriculture Industry, Solar Energy, Fuel Cells and Energy Storage etc	8

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	40	10	10	05	05

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Blooms Taxonomy)

Master of Engineering
Subject Code: CH3015
Subject Name: Nanotechnology

Text Books:

1. Rao C. N. R., Muller A., Cheetham A. K., "The Chemistry of Nanomaterials: Synthesis, Properties and Applications", WILEY VCH Verlag GmbH & Co. KGaA, Weinheim, First Edition, 2004

Reference Books:

1. Shaw Leon L., "Processing & properties of structural Nanomaterials - Nanochemistry: A Chemical Approach to Nanomaterials", Royal Society of Chemistry, Cambridge UK, First Edition 2005.
2. Egerton Ray F., "Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM", Springer, 2nd ed. 2016 Edition.
3. Eggins Brian, R,"Chemical Sensors and Biosensors", Wiley, New York, Chichester, First Edition, 2002.
4. Linden,"Hand book of Batteries and fuel cells", Mc Graw Hill, 1984.

Course Outcomes:

CO	CO statement
CO-1	Identify nanotechnology different bottom-up and top-down-approaches.
CO-2	Describe the extraordinary properties of nanomaterials.
CO-3	Compare various synthesis methods used for nanomaterial.
CO-4	Describe various fabrication techniques of nanomaterials.
CO-5	Explain important characterization techniques for nanomaterials.
CO-6	Illustrate applications of nanotechnology.

List of Open Source Software/learning website:

- NPTEL Video Lectures
- NPTEL Web Contents

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3106
Subject Name: Advanced Separation Process

Semester: - I

Type of course: Program Elective II

Prerequisite: 1. Mass Transfer fundamentals, Knowledge of various types of separation processes involved.

Rationale: The aim of this subject is to impart comprehensive understanding to the students regarding various novel and advanced separation techniques and its advancement which have profound significance in Industrial and Research arenas.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
4	0	0	4	70	30	00	00	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Fundamentals of separation Process:** Various Separation processes and identification of novel separation processes, separation from liquids, separation from gasses and vapors, separation from solids and separation methods in bioprocessing: aqueous two-phase separation	6
2	**Membrane based separation processes** Fundamentals, Definition of a membrane and membrane processes, classifications such as microfiltration, reverse osmosis, ultrafiltration, Various terms, Characterization of membrane, permeability and perm selectivity. Type of membrane modules, plate and frame device, and spiral wound, tubular and hollow-fiber. Membrane uses and applications for dialysis, electrodialysis, in food, biochemical and pharmaceutical industry. Membrane technology in gas separation and gas permeation, pervaporation.	12
3	**Ion Exchange:** Ion exchange mechanism, ion exchange media, equilibrium, equipment and design procedure and industrial applications	4

	SECTION-B	
4	**Adsorption and centrifugation as a separation process:** Mechanism, Types and choice of adsorbents, Normal adsorption techniques, settling rates in centrifuge, Sigma values and scale up issues, Separation of liquids, Solved examples.	**8**
5	**Chromatographic separation:** Fundamentals of HPLC, Chromatographic column, Basic principles of capillary electro chromatography, mobile phase composition, Stationery phases used in CEC, Liquid-Liquid Chromatography (LLC), Difference of LLC with modern high performance liquid chromatography (HPLC)	**10**
6	**Supercritical Fluid Extraction:** Commonly used supercritical (SC) solvents, Critical Conditions, Why CO2 is a supercritical fluid (SCF), Important parameters for SCF extraction, Mechanism of solubilization of solutes from solid materials.	**8**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	30	20	15	10	05

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Seader J.D. and Henley E.J., "Separation process principles", John Wiley & Sons Inc, 3rd edition, 1998.

Reference Books:

1. Breslau B.R. and Cross R.A., "An Introduction to Membrane Separation Technology," An Introduction to Separation Science, 2nd edition, John Wiley, NewYork, 1982.
2. Ruthern, M. Douglas, Encyclopedia of separation technology, Wiley-Interscience, 1st edition, 1997.
3. Perry R.H and Green D., "Perry Chemical Engineers Handbook", McGraw Hill Publication, 7th Edition, 1997.

Master of Engineering
Subject Code: CH3106
Subject Name: Advanced Separation Process

Course Outcomes:

After successful completion of the course, student will be able to

Sr. No.	CO statement
CO-1	To recall and outline the students with various advanced aspects of separation processes and the selection of separation processes.
CO-2	To describe, summarize and enable students the principles and processes of membrane separation for liquid as well as gas separation with live examples and case studies.
CO-3	To illustrate students on Ion exchange mechanism and their application in industrial applications
CO-4	To enable students to analyze and understand the principles of adsorption, and centrifugation methods.
CO-5	To outline and interpret on various chromatographic separation methods like HPLC and LLC
CO-6	To discuss and to make the students aware about supercritical fluid extraction and their industrial application

List of Open-Source Software/learning website:

- NPTEL lecture series

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: MH3105
Subject Name: Research Methodology

Semester: - I

Type of course: Research Methodology

Prerequisite: Research interest and eagerness to learn new things and invent novel ideas into practical reality.

Rationale: The purpose of this subject is to orient the students to the scientific methodology of research and presenting their thesis. Student will learn to present and defend the problem and the solution he/she has found, in a simple and easy manner. During the process of learning students will also learn to use proper technical language, refine the content and articulation part that can be presentable in a unified manner.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
2	0	0	2	00	00	30	20	50

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1.	**Introduction research, research methodology & research gaps** What is research? Types of research. What is not research? How to read a Journal paper? Identify specific requirements for evaluation/review and what constitutes completion of your work, Find where the source is available Learn to Critique existing knowledge and how to find the gap.	6
2.	**Defining the research Problem** Understand what the key aspects of your problem statement should be Examples of effective and ineffective Titles, identify problem and experimental/theoretical data for comparison with your model, Learn how to extrapolate/scale data for validation, Find what acceptable level of error and justification thereof	6

3.	**Learning from Literature Search** Differentiate between journals, conferences, books, magazines and their Quality, Understand how to establish their quality and authenticity, Finding Information, Identify main ideas in scholarly literature, Write notes to organize your ideas.	4
	SECTION-B	
4.	**Report writing, Writing Skills and Presentation Steps** How to write Report, How to write a research paper? Problem Identification and solving, Developing a Research Proposal, Format to write research proposal, How to review and finalize your work	4
5.	**Intellectual Property** Process of Patenting and Development: Technological research Innovation, patenting, development, National and International Scenario, International cooperation on Intellectual Property.	2
6.	**Patent Rights** Scope of Patent Rights. Licensing and transfer of technology, Patent information and databases. Geographical Indications. Case studies on: IPR of Biological Systems, Computer Software etc.	2

Text Books

1. Kothari, C. K. "Research Methodology: Methods and Techniques", New Age Internationals, 2004.

Reference Books:

1. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
2. Mayall, "Industrial Design", McGraw Hill, 1992.
3. Niebel, "Product Design", McGraw Hill, 1974.
4. Asimov, "Introduction to Design", Prentice Hall, 1962.
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

Course Outcome:

At the end of the course the students should be able to:

Sr. No.	CO statement
CO-1	To brief and outline a quality literature review and find the research gap
CO-2	To discuss on Problem Statement & its Validation
CO-3	To demonstrate on literature search, how to prepare the key points and organize research ideas
CO-4	To formulate and develop the Writing Skills and Presentation Steps in an effective manner in written or in spoken form

Master of Engineering
Subject Code: MH3105
Subject Name: Research Methodology

CO-5	To describe on Intellectual Property rights and analyze principles on National and International Scenario.
CO-6	To illustrate on IPR protection and Patent Right

List of Open-Source Software/learning website:

- NPTEL lecture series

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: MH3106
Subject Name: English for Research paper writing

Semester: - I

Type of course: Audit Course-I

Prerequisite: Basic English Grammar.

Rationale: This paper is quite CH at the master's level. It will create necessary skill of writing papers or technical articles which are the essential part of the research work.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
2	0	0	0	30	20	0	0	50

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Planning and Preparation:** Word Order, breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness	5
2	**Highlighting Your Findings**: Clarifying Who Did What, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction	4
3	**Review of the Literature:** Methods, Results, Discussion, Conclusions, The Final Check	3
	SECTION-B	
4	**Writing a Title**: key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature	4
5	**Writing the Methods:** skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions	5
6	**Useful phrases:** how to ensure paper is as good as it could possibly be the first- time submission	3

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks

Master of Engineering
Subject Code: MH3106
Subject Name: English for Research paper writing

R Level	U Level	A Level	N Level	E Level	C Level
30	20	20	15	15	0

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Adrian Wallwork, "English for Writing Research Papers", Prentice Hall International In, 2nd Ed., 2016.

Reference Books:

1. Day R., "How to Write and Publish a Scientific Paper", Cambridge UniversityPress, 8th Ed., 2016.
2. Highman N, "Handbook of Writing for the Mathematical Sciences", SIAM. Highman's Book, 3rd Ed., 2020.
3. Goldbart R., "Writing for Science", Yale University Press, 1st Ed., 2006.

Course Outcomes:

Upon completing the course, the student will be able to

Sr. No.	CO statement
CO-1	Recall word order to structure paragraphs and sentences.
CO-2	Discuss different sections of paper and review of literature.
CO-3	Apply key skills to write an abstract, title, introduction and different other sections of paper.
CO-4	Examine the written paper and compare it with already present literature.
CO-5	Use phrases to enhance the quality of paper.
CO-6	Categorize different literature to analysze.

List of Open-Source Software/learning website:

- Reference to NPTEL lectures can be made for a better understanding.

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3107
Subject Name: Advanced Chemical Process Control

Semester: -II

Type of course: Program Core-III

Prerequisite: Basics of Process Control at undergraduate level.

Rationale: Advanced process control is concerned with the usage of techniques for control of digital systems, systems operating under constraints, optimal control that takes into account control efforts and control of multivariate processes

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	30	70	20	30	150

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Discrete- Time control systems**: Sampling and Z- transforms. Inversion of Z-Transform. Hold elements. Laplace transform of the impulse-modulated function. General conditions for stability. Open-Loop and Closed-Loop response, Stability analysis of discrete-time control systems	8
2	**Analysis and Design of Advanced Control Systems**: Compensatory control system, Feedback control of systems with large dead time. Dead time compensation. Control system with inverse response. Multiple loop control systems- Cascade control, Selective control system, Split range control system. Feed forward control, Ratio control, Feed forward-Feedback control, Adaptive control, Inferential Control	8
3	**Multiple-Input, Multiple-Output (MIMO) Systems**: Introduction to MIMO systems, Design questions for MIMO control systems, Degrees of freedom and number of controlled and manipulated variables, Generation of alternative loop configurations, Extension to interacting systems.	8
	SECTION-B	
4	**Digital computer control loops**: The digital computer, computer process interface for data acquisition and control, computer control loops, New	4

	control design problems, Digital approximation of classical controllers, Design of optimal regulatory control systems.	
5	**Analysis of Nonlinear Control Systems:** Nonlinear Systems, Methods of Phase-Plane analysis.	**4**
6	**Design of control systems for complete plant**: Case Studies	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	**20**	**30**	**10**	**10**	**5**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Stephanopoulos, G., "Chemical Process Control: An Introduction to Theory and Practice", Prentice- Hall India, 2003.

Reference Books:

1. Luyben, W.L., "Process Modelling Simulation and Control for Chemical Engineers", McGraw-Hill, 1990.
2. Oggunnaike, B., Ray, W. H., "Process Dynamics, Modeling and Control", Oxford University Press, 1995.
3. Seborg, D.E., Edgar, T.F., Mellichamp, D.A., "Process Dynamics and Control", John Wiley & Sons Inc., 2003

List of Practical:

1. Determination of response/behavior of linear control systems.

2. Dynamic behavior of a Pneumatic control valve

3. Temperature control using PID controller

4. Flow control using PID controller

5. Cascade control using PID controller

6. Level control using PID controller

7. Characterization of a control valve

8. Tuning of controller parameters

9. Dynamics of higher order systems

10. Minor course projects

Course Outcomes:

Sr. No.	CO statement
CO-1	Describe the various control configurations of simple chemical processes
CO-2	Identify various components of a control systems
CO-3	Analyze and design advanced control systems. Linear and non-linear systems
CO-4	Understand industrial applications of control theory
CO-5	Learn the complex control techniques.
CO-6	Identify, formulate, and solve problems for control system design of complete chemical plant.

List of Open Source Software/learning website:

- NPTEL Video Lectures
- NPTEL Web Contents

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3108
Subject Name: Advanced Chemical Engineering Thermodynamics
Semester: -II

Type of course: Program Core-IV

Prerequisite: Basic UG course in thermodynamics or statistical mechanics.

Rationale: This course aims to impart knowledge of advanced thermodynamics concepts and molecular simulation methods. Unlike the standard undergraduate chemical engineering thermodynamics, we will follow a rather physics-based treatment of thermodynamics based on statistical mechanics concepts and molecular theories.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	1	0	4	70	30	-	-	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Introduction and scope of the course**: Probability and distributions. Boltzmann approximation and concept of thermodynamic Equilibrium. Molecular origin of entropy.	4
2	**Basic Laws of thermodynamics and Ensembles**: Laws of thermodynamics, thermodynamic functions, Legendre transformation, Maxwell relations. Averages and fluctuations, Method of Lagrange multipliers. Introduction to thermodynamic ensembles, partition function	8
3	**Thermodynamic Properties of Mixtures**: Derivation of thermodynamic properties in different ensembles, definition of temperature, Phase equilibrium, Gibbs phase rule, mixing and phase separation, chemical potential, osmotic pressure	8
	SECTION-B	
4	**Theories of solutions**: Liquid models with special emphasis on NRTL, UNIQUAC and UNIFAC theories; Solid-Liquid Equilibria (SLE); Vapour-Liquid-Liquid Equilibria (VLLE)	8

Master of Engineering
Subject Code: CH3108
Subject Name: Advanced Chemical Engineering Thermodynamics

5	**Introduction to Monte Carlo Simulations:** Lattice model of solutions, phase space and Hamiltonian. Theoretical basis of molecular simulations	**4**
6	**Introduction to Molecular Dynamics:** Numerical integration of equations of motion, temperature and pressure control, force-fields, Analysis and interpretation of results, efficiency and parallelization.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	30	15	15	15	5

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Hanson, R. M., Green S., "Introduction to Molecular Thermodynamics", University Science Books, 2008.

2. Prausnitz, J. M., Lichtenthaler R.N., Azevedo, E.G., "Molecular Thermodynamics of Fluid-Phase Equilibria", Prentice-Hall, 1999.

Reference Books:

1. J. M. Smith, H. C. V. Ness and M.M. Abott, "Introduction to Chemical Engineering Thermodynamics", McGraw Hill, 7th Ed., 2005.
2. Mcquarrie, D. A., "Statistical Mechanics", University Science Books, 1st Ed., 2000.
3. Firoozabadi, A., Abbas, F., "Thermodynamics of Hydrocarbon reservoirs", McGraw-Hill Professional Publishing, 1999.
4. Letcher, T., "Chemical Thermodynamics for Industry", Royal Society of Chemistry, London, 2004.
5. Leach, A. R., "Molecular Modeling: Principles and Applications", Pearson Education, 2001.

Course Outcomes:

Sr. No.	**CO statement**
CO-1	Recall the basics of classical thermodynamics
CO-2	Understand the concept of Ensembles
CO-3	Understand the concept of molecular simulation
CO-4	Apply the basics of molecular simulation in solving complex industrial and research problems
CO-5	Examine different thermodynamic models for explaining solution behavior

Master of Engineering
Subject Code: CH3108
Subject Name: Advanced Chemical Engineering Thermodynamics

CO-6	Inspect the role of molecular thermodynamics in analyzing the non-ideal systems

List of Open Source Software/learning website:

- NPTEL Video Lectures
- NPTEL Web Contents

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3109
Subject Name: Advanced Transport Phenomena

Semester-II

Type of course: Program Core- V

Prerequisite: Basics of Fluid Mechanics, Heat Transfer and Mass Transfer Operations.

Rationale: Momentum, Heat and Mass Transfer are three basic transport processes in chemical engineering. It is very important to understand mathematical modeling and analogical aspects of chemical process systems where these transport processes occur simultaneously. This course focuses such typical situations and thereby its complete understanding on axial as well as radial profiles.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
2	0	0	2	70	30	-	-	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Principles of Momentum Transport**: Shell momentum balances and equation of changes: Navier-Stoke's equation and its applications, Velocity distributions in laminar flow, creeping flow around a sphere.	**4**
2	**Unsteady State Momentum Transport**: Time dependent flow of laminar Newtonian fluids: Unsteady Laminar Flow between two parallel plates. Time-Smoothed Equations of Change for Incompressible Fluids and Velocity distributions, Boundary layer flow.	**4**
3	**Principles and Applications of Energy Transport**: Molecular and convective energy transport, Shell energy balances, Heat conduction with various heat sources, Equation of changes in non-isothermal systems and its applications to solve steady state forced and free convection and viscous heat generation problem, Unsteady state heat conduction, temperature distributions in laminar tube flow and laminar forced convection near heated flat plate. Temperature distribution in boundary layer.	**6**
	SECTION-B	

Master of Engineering
Subject Code: CH3109
Subject Name: Advanced Transport Phenomena

4	**Principles of Mass Transport:** Molecular and convective mass transport, Theory of binary and multicomponent diffusion in gases and liquids, Shell mass balances and concentration distribution in laminar flow.	**4**
5	**Applications of Mass Transport:** Use of the Equations of Changes to solve Simultaneous heat and mass transport and concentration profile in a tubular reactor principles of unsteady state diffusion.	**4**
6	**Analogies in Momentum, Heat and Mass Transfer**: Introduction, Reynolds analogy, Prandtl Taylor analogy, Van Karman analogy, Martinelli analogy, Chilton analogy	**2**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	20	20	25	15	00

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E:Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Bird R.B., Stewart W.E., Lightfoot E.N., Transport Phenomena, 2nd Edition, John Wiley & Sons, 2002

Reference Books:

1. James Welty, Charles E. Wicks and Wilson, Gregory L Rorrer, "Fundamentals of Momentum, Heat and Mass transfer", 5th Edition, 2008.
2. Geankoplis C.J., Transport Processes and Separation Process Principles,4th Edition
3. Slattery J.C., Advanced Transport Phenomena, Cambridge University Press.

Course Outcomes:

CO	CO statement
CO-1	Understand the mechanism of momentum, heat and mass transport for steady and unsteady flow.
CO-2	Conceptualize momentum, energy, and mass balances for a given system at macroscopic and microscopic scale.
CO-3	Solve the governing equations to obtain velocity, temperature and concentration profiles.
CO-4	Illustrate models of momentum, heat and mass transport under turbulent conditions.
CO-5	Develop analogies among momentum, energy and mass transport.
CO-6	Use different aspects of mass, momentum, and energy balance equations to solve real world problems.

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3110
Subject Name: Energy Management

Semester: - II

Type of course: Program Elective III

Prerequisite: Knowledge of various forms of energy and energy unit conversion.

Rationale: Renewable Energy Management covers the basic understanding of the potential of renewable energy resources. REM offers the different renewable energy conversion technologies for a specific purpose and evaluating the sustainability of energy systems.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	00	00	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Introduction to energy sources:** Energy sources, national energy security and plan, Scenario of Renewable Energy (RE) Sources: Needs of renewable energy, advantages and limitations of RE, present energy scenario of conventional and RE sources	6
2	**Energy Audit:** Concept of energy management program, Energy auditing services, basic components of an Energy audit, types of energy audit, Industrial, commercial and residential audit planning, energy performance index, Energy conservation act and its features, Duties and responsibilities of energy managers and auditors, Energy audit instruments/ tools	6
3	**Energy Policy, Legislation and Management:** Energy system challenges, Energy policy, Energy policy triangle, complementary and competing goals, Energy policy legislation, Review of specific energy policies (case based)	6
	SECTION-B	

Master of Engineering
Subject Code: CH3110
Subject Name: Energy Management

4	**Solar energy:** Solar radiation & related terms, measurement of solar radiation, solar energy collectors, Basics of Solar Thermal Conversion, Solar thermal systems and applications, Basics of Solar Photovoltaics, Solar Photovoltaic energy conversion and utilization, Solar Photo•catalysis	**6**
5	**Wind and Hydro Energy:** Wind resource assessment Basic principles, power in wind, force on blades & turbines, wind energy conversion, site selection, basic components of wind energy conversion systems (WECS), classification of WECS, wind energy collectors, applications of wind energy Introduction to Hydropower, Classification of Hydropower Plants, Status of Hydropower, Worldwide, Advantages and Disadvantages of Hydropower, Selection of site for hydroelectric plant, Components of Hydropower Plants	**6**
6	**Bioenergy and Geothermal Energy:** Introduction, energy plantation, biomass conversion technologies, photosynthesis, biogas generation, factors affecting biogas generation, classification of biogas plants & their comparisons, types of biogas plants, community plants & site selection, digester design considerations, design calculations, methods of maintaining & starting biogas plants, properties & utilization of biogas, thermal gasification of biomass, pyrolysis, alternative liquid fuels. Geothermal resources, hydrothermal resources, liquid dominated systems, geopressured resources and applications of geothermal energy	6

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	30	20	05	05	00

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Rai G.D., Nonconventional energy sources. Khanna Publication, 1st Ed., 1988, ISBN: 9788174090737.

Reference Books:

2. Mital K.M. Biogas Systems, Principle and Applications. New Age International Ltd., 1st Ed., 1996, ISBN: 9788122409475.

3. Sunil S. Rao and Dr. B.B. Parulekar, Energy Technology (Non-Conventional, Renewable and Conventional), Khanna pub., 3rd Ed., 1999, ISBN: 978-81-7409-040-9.
4. Ravindranath N.H. David O. Hall, Biomass, Energy and Environment, A developing country perspective from India. Oxford University Press, 1st Ed., 1995, ISBN: 9780198564362.
5. S. P. Sukhatame and J. K. Nayak, Solar Energy: Principles of Thermal Collections and Storage, Tata McGraw Hill, 2nd Ed., 1996, ISBN: 9780074624531.

Course Outcomes:

Upon completing the course, the student will be able to

Sr. No.	CO statement
CO-1	Identify sources of energy along with its merits and demerits.
CO-2	Explain the types of energy audit and its types.
CO-3	Discuss the energy policies and associate with the energy system challenges
CO-4	Describe the concepts of solar energy along with the thermal systems and applications.
CO-5	Explain concept of wind and hydro renewable energy along with the classification of various WECS and hydropower Plants
CO-6	Summarize the types of bioenergy and geothermal energy generation systems

List of Open-Source Software/learning website:

- https://mnre.gov.in/
- https://energytech-global.com/
- World energy outlook - www.iea.org
- NPTEL lecture series

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3111
Subject Name: Cleaner Production

Semester:-II

Type of course: Program Elective III

Prerequisite: Knowledge of environment engineering

Rationale: Production (Cleaner Production) is a method, which enables companies and governments to implement a pro-active environmental strategy. With Cleaner Production industries reduce pollution in their production processes by means of preventive measures. It's a structural business strategy that increases the efficiency and the gross returns (profit).

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Introduction to cleaner's production** (CP), Concept of CP, Theory of CP, Role of CP in sustainable development of Chemical industries	**06**
2	**Methodology for CP** Six steps methodology for CP, Designation of cleaner production team, Analyse process steps, generating cleaner production opportunities, selecting cleaner production solutions, Implementation, maintaining cleaner production	**07**
3	**Good Housekeeping** Significance of good housekeeping, Methods for good housekeeping, role of good housekeeping in CP, Process Modification/Change, Equipment Modification/Change. Recycle and reuse.	**05**

Master of Engineering
Subject Code: CH3111
Subject Name: Cleaner Production

SECTION-B		
4	**Introduction to Energy Audit** Energy Audit Methodology, detail of Energy Audit and Energy Conservation, Energy conservation via Cleaner Technology Options, Use of clean fuels inclusive of H_2 as a clean fuel of tomorrow	**06**
5	**C.P. as Remedial Measures** C.P. as Remedial Measures for Mitigating Climate Change, Ozone layer depletion and current practices to avoid depletion. Resource recovery / by product recovery from manufacturing process for small scale industries by Cleaner Production Technology (CPT).	**07**
6	**Designing Cleaner Production** Green Processes, Financial Analysis of CP, case studies on CP.	**05**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	40	10	10	05	05

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Paul M. R., "Engineers Guide to Cleaner Production Technologies", Technomic, 1st Ed, 1996.

Reference Books:

1. Ahluwalia V. K., "Green Chemistry: Environmentally Benign Reactions" Ane Books Pvt. Ltd.1st Ed, 2006.
2. Hoyle W., Lancaster M., "Clean Technology for Manufacture of Specialty Chemicals" Royal Society of Chemistry, U.K., 1st Ed, 2001.
3. Cleaner Production Worldwide, 1993, United Nations Environment Programme, Industry and Environment, Paris, France, 1st Ed,1993.
4. Cleaner Production: Training Resource Package, UNEP IE, Paris, 1st Ed,1996.

Master of Engineering
Subject Code: CH3111
Subject Name: Cleaner Production

Course Outcomes:

Students should be able to

Sr. No.	CO statement
CO-1	Define the role of environment in CP
CO-2	Describe the methodology for CP
CO-3	Apply the housekeeping techniques for CP
CO-4	Perform the energy audit via various CP technologies
CO-5	Solve the problems associated with natural disasters through CP
CO-6	Evaluate the case studies for CP

List of Open-Source Software/learning website:

- NPTEL Video Lectures
- NPTEL Web Contents

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3112
Subject Name: Chemical Reactor Design

Semester: - II

Type of course: Program Elective - IV

Prerequisite: Knowledge of Chemical Reaction Engineering at Undergraduate Level

Rationale: This subject deals with the design and performance analysis of multiphase flow reactors

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
4	0	0	4	70	30	-	-	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Introduction:** Chemical factors 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 behaviour for mixed flow reactor. Transient CSTR analysis, Hot spot equation; Optimization using Lagrange multiplier.	5
2	**Fixed bed catalytic reactor:** The importance and scale of fixed bed catalytic processes, factors in preliminary design, modelling of fixed bed reactor. Pseudo-homogeneous model, the multibed adiabatic reactor, auto-thermal operation, non-steady-state model with axial mixing, two dimensional pseudo-homogeneous models, heterogeneous models, global and intrinsic rates,	7
3	**Engineering properties** : Mechanism of catalytic reactions, Engineering properties of catalysts -	6

	BET surface area, pore volume, pore size, pore size distribution, one dimensional and two dimensional model equation	
	SECTION-B	
4	**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.	**6**
5	**Design model for multiphase flow reactors :** 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.	**7**
6	**Temperature effects in reactor:** 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.	**5**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
16	16	14	20	14	20

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books:

1. G.F. Fromment. and K.B. Bischoff, "Chemical Reactor Analysis and Design", Wiley,3rd Ed., 2010.

Reference Books:

1. O. Levenspiel, "Chemical Reaction Engineering", Wiley, 3RD Ed., 1998.
2. H.S. Foggler, "Elements of Chemical Reaction Engineering", Prentice Hall of India, 3RD Ed., 2008.
3. J.M. Smith, "Chemical Engineering Kinetics", McGraw Hill, 3rd Ed., 1981.
4. K.G. Denbigh, "Chemical Reactor Theory", Cambridge University Press, 2nd Ed., 1971.

Master of Engineering
Subject Code: CH3112
Subject Name: Chemical Reactor Design

Course Outcomes:

Upon completing the course, the student will be able to

Sr. No.	CO statement
CO-1	Perform the material, energy and momentum balance for reactor design
CO-2	Design Fixed bed catalytic reactors
CO-3	Identify mechanism of heterogeneous catalytic reactions
CO-4	Classify multiphase flow reactors
CO-5	Choose a design model for multiphase flow reactor
CO-6	Estimate the performance of multiphase reactors under non-isothermal conditions

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3113
Subject Name: Catalysts and Adsorbents
Semester: - II

Type of course: Program Elective - IV

Prerequisite: Knowledge of Chemical Reaction Engineering at Undergraduate Level

Rationale: This subject deals with the synthesis, characterization of solid catalyst. It also emphasizes on heterogeneous catalytic reactions and evaluation of performance of various types of catalytic reactors.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
4	0	0	4	70	30	-	-	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Concepts of Heterogeneous Catalysis**: Introduction to heterogeneous catalysis, Definition History, Energy Profile Diagram and Diffusion of Gas, Catalysts and Catalytic Properties,	5
2	**Classification of Catalyst**: Catalyst preparations, types of catalysts, meso and micro porous materials, nano material catalysts and significance, zeolites and related molecular sieves, supported and bifunctional catalysts and catalyst regeneration, activity and life of the catalysts, active centres, promoters and poisons, catalyst deactivations.	7
3	**Characterization of Solid Catalysts:** Structure and surface morphology, porosity, pore volume and diameter, particle size, surface area, X-ray diffraction, DTA-TG, SEM, TEM, X-ray absorption spectroscopy.	6
	SECTION-B	

Master of Engineering
Subject Code: CH3113
Subject Name: Catalysts and Adsorbents

4	**Mechanism of Catalytic Reactions**: General Mechanism of Catalytic Reactions (Diffusion, Adsorption – Desorption, Surface Reaction), Determination of rates of various steps in catalytic reactions, Heterogeneous Catalysis Area of Application.	**6**
5	**Adsorption isotherm and mechanism:** Nature of Catalytic Reactions, Adsorption on Solid Surfaces, Surface Chemistry and Adsorption, Langmuir Treatment of Adsorption, Chemisorption and physisorption: Langmuir adsorption isotherm, Langmuir assumptions, Molecular adsorption of a compound, Dissociative adsorption of a compound, BET adsorption isotherm. Mechanism of Langmuir- Hinshelwood: competitive and non-competitive adsorption. Eley- Rideal Adsorption mechanism	**7**
6	**Reactor Design for catalytic reactions**: Design calculation for ideal catalytic reactor operating at isothermal, adiabatic and non-adiabatic conditions. Deviations from ideal reactor performance. Design of industrial fixed-bed, fluidized bed and slurry reactors. Thermal stability of packed bed and fluidized bed reactors.	**5**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
14	20	16	16	20	14

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books:

1. H.S. Foggler, "Elements of Chemical Reaction Engineering", Prentice Hall of India, 3RD Ed., 2008.
2. J.M. Smith, "Chemical Engineering Kinetics", McGraw Hill, 3rd Ed., 1981.

Reference Books:

1. O. Levenspiel, "Chemical Reaction Engineering", Wiley, 3RD Ed., 1998.
2. K.G. Denbigh, "Chemical Reactor Theory", Cambridge University Press, 2nd Ed., 1971.
3. G.F. Fromment. and K.B. Bischoff, "Chemical Reactor Analysis and Design", Wiley,3rd Ed., 2010.

Master of Engineering
Subject Code: CH3113
Subject Name: Catalysts and Adsorbents

Course Outcomes:

Upon completing the course, the student will be able to

Sr. No.	CO statement
CO-1	Identify mechanism of heterogeneous catalytic reactions.
CO-2	Synthesis various solid catalyst.
CO-3	Characterize different properties of solid catalyst.
CO-4	Apply various adsorption isotherms.
CO-5	Evaluate the performance of nonisothermal catalytic reactors.
CO-6	Design of catalytic reactors.

UPL -University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject code: CH3114
Subject Name: Fluidization Engineering

Semester: - II

Type of course: Open Elective-I

Prerequisite: The student should have knowledge of fluid mechanics and particulate solids.

Rationale:

Fluidization engineering subject involves wider application of Fluidization Engineering in chemical, petroleum, and petrochemical engineering in terms of reactors, combustors and other process units. It also include fluidization phenomena, analyzing the behaviour associated with typical fluidized bed systems. and analysis techniques to enable more reliable design and operation of industrial-scale fluidized bed systems.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
2	0	0	2	70	30	-	-	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Introduction:** The phenomenon of fluidization; liquid like behaviour of a fluidized bed; Comparison with other contacting methods.	2
2	**Industrial applications of fluidized beds:** Coal gasification; gasoline from other petroleum fractions; Gasoline from natural and synthesis gases; Heat exchange; Coating of metal objects with plastics.	4
3	**Fluidization and mapping of regimes:** Minimum fluidization velocity; Pressure drop vs. velocity diagram; effect of temperature and pressure on fluidization; Geldart classification of particles; terminal velocity of	6

	particles; turbulent fluidization; pneumatic transport of solids; fast fluidization; solid circulation systems; Voidage diagram; Mapping of regimes of fluidization.	
	SECTION-B	
4	**Bubbles in dense bed:** Single rising bubbles; Davidson model for gas flow at bubbles; Evaluation of models for gas flow at bubbles. Bubbling Fluidized beds: Experimental findings; Estimation of bed porosities; Physical models: simple two phase model; K-L model.	**6**
5	**Solids Movement, Mixing, Segregation and staging**: Vertical movement of solids; Horizontal movement of solids; Staging of fluidized beds.	**2**
6	**Gas Dispersion and Gas interchange in Bubbling Beds:** Dispersion of gas in beds; Gas interchange between bubble and emulsion; Estimation of gas interchange coefficients.	**4**

Suggested Specification table with Marks (Theory): (For BE only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
25	25	15	15	10	10

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books:

1. D. Kunii and O. Levenspiel, "Fluidization Engineering" Butterworth-Heinemann, 2nd ed., London,1999.

Reference Books:

1. M. L. Passos, M. S. Barrozo, A. S. Majumdar, "Fluidization Engineering Practice", 2nd ed., Laval-Canada, 2014.

2. Gibilaro, L. G., "Fluidization – Dynamics", Butterworth – Heinemann, 2001.

3. Davidson, J. F., R. Clift, D. Harrison, "Fluidization", 2nd ed., Academic Press 1985.

4. J. F. Davidson and Harrison, "Fluidization", 10th ed., Academic Press, London, 1994.

Course Outcomes:

On successful completion of the course, the student should be able to

Sr. No.	CO statement
CO-1	Explain the basics of fluidization.
CO-2	Discuss the various industrial applications of fluidization.
CO-3	Illustrate the various fluidization regimes, classification of particles.
CO-4	Investigate the K-L bubbling model.
CO-5	Justify the staging of fluidized beds.
CO-6	Assess gas interchange between regions.

List of Open-Source Software/learning website:

- NPTEL lectures.

UPL University of Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Master of Engineering
Subject Code: CH3115
Subject Name: Piping Engineering

Semester: -II

Type of course: Open Elective-I

Prerequisite: The student should have basic understanding of fluid mechanics, engineering and mechanical properties associated with the material.

Rationale: Piping design and engineering is a key area in various streams of engineering. Piping and accessories constitute over 25% of the total capital investment in the chemical process industry, petroleum and petrochemical industry, pharmaceutical industry, power plants, and so on. The present course is intended to familiarize undergraduate students about the fundamental design aspects of piping components and their applications in process industries.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
2	0	0	2	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Introduction and fundamentals of Piping Design and Engineering** Evolution of piping, Manufacturing methods, Piping materials and selection Codes and standards, vibration in piping systems and its prevention and control. Schedule number. Pipe dimensioning. Common piping abbreviations.	3
2	**Piping components** Type of Fittings - elbows, weld tee, stub in, couplings, reducers, weld cap, screwed and socket welded fittings, Pipe nipples, flanged fittings and use of fittings. Different types of flanges, Types, P-T ratings and facings Gaskets, bolts and nuts.	4

Master of Engineering
Subject Code: MH3107
Subject Name: Technology Management

3	**Design calculations for piping** Determination of pipe size, Calculation of pressure drop in pipe. Equivalent length of pipeline for fittings and valves. Energy losses in a pipeline. Different types of pumps and their selection criteria, NPSHA & NPSHR, Power required by pump. Calculation of flow measurement in a pipeline.	**5**
SECTION-B		
4	**Flow through pipes** Navier-Stokes equation of motion- Initial conditions and boundary conditions. Viscous flow-Couette flow Hagen-Poiseuille equation-flow between parallel plates. Turbulent flow in pipes- Prandtl's mixing length theory, velocity distribution- Smooth and rough boundaries-water hammer phenomenon.	**4**
5	**Mechanical design of piping** Operating pressure and temperature, Design Pressure & Design Temperature for Piping Systems, Design equation for longitudinal, hoop and allowable stresses Determinations of thickness required by steel pipe for withstanding internal and external pressure.	**4**
6	**Pipe support** Functions of supports, Type of piping supports, Load on Supports, Design of piping Supports, Determination of support location, Maximum span between the supports suggested by ASME B 31.1 Thermal expansion in a pipeline, Different types of expansion joints and their applications, difference between a PFD and P&ID.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
25	25	15	15	10	10

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

Master of Engineering
Subject Code: MH3107
Subject Name: Technology Management

1. Gupta S.K. "Perfect Knowledge of Piping Engineering", 1st Edition,2015.

Reference Books:

1. Perry R.H., "Chemical Engineers Handbook", McGraw-Hill, 2009
2. Nayyar M.L.," Piping Handbook", 7th Edition, Tata McGraw Hill Publication, 2000.
3. Coulson J.M, Richardson J.F. and Sinnot R.K.," Coulson and Richardson'sChemical Engineering", Vol.6,4th Edition, Elesevier, New Delhi, 2006.
4. Ludwig E., "Chemical Process Equipment Design" ,3rd Edition, Gulf Publications, 2002.
5. Kellogg, M.W Company., "Design of Piping Systems", Pullman Power Products, New York, 1976

Course Outcomes:

Sr. No.	CO statement
CO-1	Relate the fundamentals of piping engineering
CO-2	Describe the various components of piping
CO-3	Solve the process design of piping
CO-4	Examine the flow through pipes
CO-5	Assess the Mechanical design of piping
CO-6	Design the piping supports.

List of Open-Source Software/learning website:

- Students can refer to the video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets. Students can develop their own programs/spreadsheets for the solution of problems.
- MIT Open course lecture on Equipment design.
- Literature available for Process design of equipment in plant / industry.
- PLANT DESIGN MANAGMENET SYSTEM (PDMS):Equipment Modeling.
  Pipe Routing.
- Equipment Modeling

Master of Engineering
Subject Code: MH3107
Subject Name: Technology Management

Semester: - II

Type of course: Audit Course - II

Prerequisite: Basic knowledge of science.

Rationale: To give students, an orientation in business and technology management and to sharpen entrepreneurship skills**.**

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
02	-	-	00	70	30	-	-	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Chemical Technology** Chemical Technology, Technology Evaluation, Effectiveness in Technology, Networking in Technology	**4**
2	**Commercialization of Technology** Commercialization of technology, Interfaces between R&D and others, Pilot Plant & Scale up, Technology Forecasting, Customer Focused Technology	**4**
3	**Marketing** Principles of Marketing, Evolution of Marketing, Marketing Concepts, Markets in 21st Century, Marketing Mix (Controllable / Non-controllable), Marketing plan, Industrial Marketing,	**4**
	SECTION-B	
4	**Marketing and Pricing** Consumer Market Product, Price & Placement, Pillars of Marketing – Segmentation, Target Markets, Differentiation & Position, New Product Marketing Corporate Strategy for Product Planning New Product Decision Product Introduction New Product Development & Promotion Market Potential for New Products	**4**
5	**Finance Accounting** Basic concepts in Finance Accounting - Assets & Liabilities, Expenses &	**4**

	Income, Depreciation, Cash–Mercantile Accounting, Preparation of Receipts/Payment, Balance Sheet, and Income/Expenditure Sheets, Exposure to Accounting system (Double entry Book-keeping), Financial Performance Appraisal using Ratio Analysis, Fund flow Analysis & Cash Flow Analysis, Valuation of tangible and intangibles-DCF, other methods, Corporate Taxation – Direct and indirect	
6	**Project Management** Project identification / evaluation, process selection, site selection, Elements of Project Management, Construction of Project networks, PERT / CPM techniques, Time limited scheduling, Project crashing, Time & Resource analysis, Project monitoring. Computers in project scheduling	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	20	30	20	0	0

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Text Books

1. Schermerhorn J R., Bachrach D. "Introduction to Management" Wiley, 13th Ed., 2015.

Reference Books:

1. Lucas H. C. "Information Technology for Management" 1st Ed., 1996.
2. Kotler P., "Marketing Management" Prentice Hall, Inc, 3rd Ed., 2016.
3. Aaker, D. A., "Strategic Market Management", Wiley, New York, 5th Ed., 1998.
4. Luck D J., Rubin R. S., "Marketing Research" Prentice Hall India, 7th Ed., 1987.
5. Homgren, C.T., Sundem G. L., Statton W. O., "Introduction to Management Accounting" Pearson; 12th Ed., 2001.

Course Outcomes:

Sr. No.	CO statement
CO-1	Describe technology and its evaluation.
CO-2	Compare different commercialization technologies.
CO-3	Examine principles of marketing.
CO-4	Identify market and pricing for development of new product.
CO-5	List the concept of finance and accounting.
CO-6	Inspect process selection, site, time and project network.

List of Open Source Software/learning website:

Reference to NPTEL lectures can be made for a better understanding.