DEPARTMENT OF CHEMICAL ENGINEERING

M. TECH. CHEMICAL ENGINEERING
REGULATION – 2020 (Part Time)
(For students admitted from the Academic Year 2019-20)

DECLARATION

I, **Dr.N.Jaya Chitra**, Head of Chemical Engineering Department, hereby declare that this copy of the syllabus (M.Tech Chemical Engineering Part time 2020 Regulation) is the final version which is being taught in the class and uploaded in our University website. I assure that the Syllabus available in our University website is verified and found correct. The Curriculum and Syllabus have been ratified by our Academic Council / Vice Chancellor.

Date: **Signature**

DEPARTMENT OF CHEMICAL ENGINEERING

M.Tech – Chemical Engineering (Part Time)

Curriculum and Syllabus

2020 Regulation

I SEMESTER						
S.NO	**Sub.Code**	**Title of Subject**	**L**	**T**	**P**	**C**
1	MMA20019	Statistical And Numerical Methods For Chemical Engineers	3	0	0	3
2	MCT20C002	Advanced Separation Processes	3	0	0	3
3	MET20RM01	Research Methodology and IPR	2	0	0	2
4		Audit course - I	2	0	0	0
5	MCT20CL01	Laboratory 1 (Advanced separation processes)	0	0	4	2
		TOTAL	**10**	**0**	**4**	**10**

II SEMESTER						
S.NO	**Sub.Code**	**Title of Subject**	**L**	**T**	**P**	**C**
1.	MCT20C003	Advanced transport phenomena	3	0	0	3
2.	MCT20CEXX	Elective I - (Chemical Reactor Analysis I/Process Design and Synthesis/Fluidization Engineering)	3	0	0	3
3.		Audit Course-II	2	0	0	0
4.	MCT20CL02	Laboratory 2 (Process Modeling and Simulation laboratory)	0	0	4	2
		TOTAL	**8**	**0**	**4**	**8**

III SEMESTER						
S.NO	**Sub.Code**	**Title of Subject**	**L**	**T**	**P**	**C**
1.	MCT20C004	Advanced Reaction Engineering	3	0	0	3
2.	MCT20CEXX	Elective II - (Chemical Reactor Analysis I/Process Design and Synthesis/Fluidization Engineering)	3	0	0	3
3.	MCT20CEXX	Elective III - (Modern concepts in Catalysis and Surface Phenomenon/Advanced Downstream Processes/Computational Fluid Dynamics/Bioprocess Engineering)	3	0	0	3
4.	MCT20CL03	Laboratory 3 (Advanced Chemical Reaction Engineering laboratory)	0	0	4	2
		Total	**6**	**0**	**4**	**11**

IV SEMESTER						
S.NO	**Sub.Code**	**Title of Subject**	**L**	**T**	**P**	**C**
1.	MCT20CEXX	Elective IV- **(**Process Intensification/Phase transitions in Process Equipment/Micro and Nano fluidics/Process Integration/Transport in porous Media/Micro Flow Chemistry and Process Technology/Process Plant Design & Flow sheeting)	3	0	0	3
2.	MCT20CL04	Laboratory 4 (Advanced Chemical Engineering Laboratory)	0	0	4	2
3.	MCT20CL05	Mini Project	0	0	4	2
		Total	**6**	**0**	**4**	**7**

V SEMESTER						
S.NO	**Sub.Code**	**Title of Subject**	**L**	**T**	**P**	**C**
1.	MCT20CEXX	Elective V – (Design of Experiments and Parameter Estimation/Computer Aided Design/Cleaner Production)	3	0	0	3
2.	MCT20OEXX	Open Elective 1. Business Analytics 2. Industrial Safety 3. Operations Research 4. Cost Management of Engineering Projects 5. Composite Materials 6. Waste to Energy	3	0	0	3
3.	MCT20BL06	Dissertation Phase – I	0	0	20	10
		Total	**6**	**0**	**20**	**16**

VI SEMESTER						
S.NO	**Sub.Code**	**Title of Subject**	**L**	**T**	**P**	**C**
1.	MCT20BL07	Dissertation Phase – II	0	0	32	16
		Total	**0**	**0**	**32**	**16**

Audit course 1 & 2

1. English for Research Paper Writing
2. Disaster Management
3. Sanskrit for Technical Knowledge
4. Value Education
5. Constitution of India
6. Pedagogy Studies
7. Stress Management Through Yoga
8. Personality Development through Life Enlightenment Skills.

ELECTIVES (THEORY)					
Sub. Code	**Title of Subjects**	**L**	**T**	**P**	**C**
	ELECTIVE -II				
MCT20CE01	Chemical Reactor Analysis I	3	0	0	3
MCT20CE02	Process Design and Synthesis	3	0	0	3
MCT20CE03	Fluidization Engineering	3	0	0	3
	ELECTIVE -III				
MCT20CE04	Industrial Pollution Control	3	0	0	3
MCT20CE05	Application of Nanotechnology in Chemical Engineering	3	0	0	3
MCT20CE06	Chemo informatics	3	0	0	3
	ELECTIVE -IV				
MCT20CE07	Modern concepts in Catalysis and Surface Phenomenon	3	0	0	3
MCT20CE08	Advanced Downstream Processes	3	0	0	3
MCT20CE09	Computational Fluid Dynamics	3	0	0	3
MCT20CE10	Bioprocess Engineering	3	0	0	3
MCT20CE11	Process Intensification	3	0	0	3
MCT20CE12	Phase transitions in Process Equipment	3	0	0	3
MCT20CE13	Micro and Nano fluidics	3	0	0	3
	ELECTIVE -V				
MCT20CE14	Process Integration	3	0	0	3
MCT20CE15	Transport in porous Media	3	0	0	3
MCT20CE16	Micro Flow Chemistry and Process Technology	3	0	0	3
MCT20CE17	Process Plant Design & Flow sheeting	3	0	0	3
MCT20CE18	Design of Experiments and Parameter Estimation	3	0	0	3
MCT20CE19	Computer Aided Design	3	0	0	3
MCT20CE20	Cleaner Production	3	0	0	3

LIST OF OPEN ELECTIVES						
S.NO	**SUB. CODE**	**COURSE TITLE**	**L**	**T**	**P**	**C**
1	MCT20OE01	Business Analytics	3	0	0	3
2	MCT20OE02	Industrial Safety	3	0	0	3
3	MCT20OE03	Operations Research	3	0	0	3
4	MCT20OE04	Cost Management of Engineering Projects	3	0	0	3
5	MCT20OE05	Composite Materials	3	0	0	3
6	MCT20OE06	Waste to Energy	3	0	0	3

CREDIT DISTRIBUTION

SEMESTER	CREDITS
I	10
II	8
III	11
IV	7
V	16
VI	16
TOTAL	**68**

DEPARTMENT OF CHEMICAL ENGINEERING

PROGRAM OUTCOMES

PO1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems
PO2	Problem analysis: Identify, formulate, review research literature, and analyze complex Engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions
PO5	Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

MMA20019 Statistical and Numerical Methods For Chemical Engineers **3 0 0 3**

OBJECTIVES:

- To introduce the basic concepts in Statistical and Numerical methods

COURSE OUTCOMES:

- To understand the basic concepts in Random variables
- To understand the basic concepts in Correlation and Regression
- To understand the basic concepts in Estimation theory
- To solve System of Linear equations by Iterative and Matrix methods
- To solve System of Non-Linear equations by Iterative methods

UNIT I ONE DIMENSIONAL RANDOM VARIABLES 9Hrs

Random variables – Probability function – Moments – Moment generating functions and their properties – Binomial, Poisson, Exponential, and normal distributions – Functions of a Random variable.

UNIT II TWO DIMENSIONAL RANDOM VARIABLES 9Hrs

Joint distributions – Marginal and conditional distributions – Functions of two dimensional random variables – Correlation – Regression.

UNIT III ESTIMATION THEORY 9Hrs

Unbiased estimators – Method of moments –Maximum likelihood estimation – Curve fitting by Principle of least squares.

UNIT IV SYSTEM OF LINEAR EQUATIONS 9Hrs

Gauss Elimination method – Gauss-Jordan method – Iterative methods – Gauss-Jacobi method – Gauss-Seidel method – Matrix Inversion by Gauss-Jordan method- Eigen value problem-Power method.

UNIT V NON LINEAR EQUATIONS 9Hrs

Solution of Algebraic and Transcendental equations – Method of false position -Fixed point iteration method (single and multi variables)- Newton-Raphson method (single and multi variables).

Total no. of hrs: 45hrs

REFERENCE BOOKS:

- Richard Johnson A., *Miller & Freund's Probability and statistics for Engineers (8th ed)*, Prentice Hall of India, (2009).
- Richard Johnson A., Wichern .D.W, *Applied Multivariate Statistical Analysis (6th ed)*, Prentice Hall of India, (2007).
- Gupta S.C., Kapoor V.K., *Fundamentals of Mathematical Statistics*, S.Chand & Co., (2007).
- Veerarajan T., *Numerical Methods*, Tata McGraw Hill Publishing Co., (2007).
- Sastry S.S., *Introductory Methods of Numerical Analysis*, Prentice Hall of India, (2012).
- Kandasamy P., Thilagavathy, Gunavathy K., *Numerical Methods (Vol.IV)*, S.Chand & Co., (2008).

MCT20C002 **Advanced Separation Processes** **3 0 0 3**

OBJECTIVES:

- To familiarize students with various advanced aspects of separation processes and the selection of separation processes.
- To enable students to understand the principles and processes of adsorption, membrane separation and chromatography and to design an absorber or a membrane unit to achieve a specified separation.
- To introduce them to new trends used in the separation technologies.

COURSE OUTCOME:

- List situations where liquid–liquid extraction might be preferred to distillation, make a preliminary selection of a solvent using group-interaction rule, Size simple extraction equipment.
- Differentiate between chemisorptions and physical adsorption, List steps involved in adsorption of a solute, and which steps may control the rate of adsorption, explain the concept of breakthrough in fixed-bed adsorption.
- Explain how crystals grow, Explain the importance of super saturation in crystallization. Describe effects of mixing on super saturation, mass transfer, growth, and scale-up of crystallization.
- Explain membrane processes in terms of the membrane, feed, sweep, retentate, permeate, and solute membrane interactions. Distinguish among microfiltration, ultra filtration, nanofiltration, virus filtration, sterile filtration, filter-aid filtration, and reverse osmosis in terms of average pore size. Explain common idealized flow patterns in membrane modules.

UNIT I INTRODUCTION **9Hrs**

Conventional separation processes - Absorption, Adsorption, Conventional separation processes - Distillation, Drying, Conventional separation processes - Extraction, Diffusion, Conventional separation processes - Leaching, Crystalisation, 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

UNIT II BUBBLE AND FOAM FRACTIONATION **9Hrs**

Nature of bubbles and foams, stability of foams, foam fractionation techniques, batch, continuous, single stageand multistage columns. Types and choice of membranes, Plate and frame, spiral wound membranes, Tubular and hollow fibre membrane reactors, Membrane Permeates: Dialysis, Reverse osmosis, Nanofiltration, ultra filtration, microfiltration, Donnan dialysis, Ceramic membranes

UNIT III MEMBRANE SEPARATION **9Hrs**

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.

UNIT IV SPECIAL PROCESSES **9Hrs**

Liquid membrane separation, super-criticalextraction, adsorptive separation-pressure, vacuum and thermal swing,pervaporation and permeation, nano-separation.

UNIT V CHROMATOGRAPHIC METHODS OF SEPARATION **9Hrs**

Gel, solvent, ion and high performance liquid chromatography.

Total no. of hrs: 45hrs

REFERENCES

- King C.J., "Separation Processes", Tata McGraw Hill. 1982.
- Nakagawal, O. V., "Membrane Science and Technology", Marcel Dekker, 1992.
- Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
  Khoury F.M., "Multistage Separation Processes", 3rd Ed., CRC Press. 2004.
- Wankat P.C., "Separation Process Engineering", 2nd Ed., Prentice Hall.2006. Seader
  J.D. and Henley E.J., "Separation Process Principles", 2nd Ed.,Wiley.2006
- Basmadjian D., "Mass Transfer and Separation Processes: Principlesand Applications", 2nd Ed., CRC Press.2007.
- Phillip C. Wankat , Separation Process Engineering (2nd Edition),Printice Hall,2007
- Rousseau, R. W., "Handbook of Separation Process Technology", John Wiley, New York, 2009.

MET20RMO1 **Research Methodology and IPR** **2 0 0 2**

COURSE OUTCOME:

At the end of this course, students will be able to

- Develop and practice critical thinking skills required for research
- Identify and formulate a research topic by observations and literature survey
- Develop methods for data collection, analysis and interpretation using statistical methods
- Learn to use digital resources for research project management
- Learn to write a good research theses and paper
- Learn to present their research work to a peer review and apply for funding
- Understand the significance Intellectual Property rights and how best to use them in research
- Conduct the research following ethical principles of research

UNIT I

Selection, Analysis and statement of the Research Problem; Literature Review and Formulation of Objectives – using the following Critical thinking Skills – Drawing a Concept map, Oral Communication, Debating, Questioning, Collaborating, Evaluation and Reasoning.

UNIT II

Research Design – Types of Study, Types of Data, Measures of Variablility, Setting up the Hypotheses, data collection techniques and tools, sampling, Describing data – Charts and graphs ; Data processing – Categorization, coding, summarization.

UNIT III

Data Analysis and Report Writing: Statistical measures, Regression and correlation, significance test; Report writing – Purpose, format, content, editing and evaluation. Using Citation tools; Report for specific purposes – Theses, Journals, Grant application. Oral presentation to an audience; use of project management digital tools and plagiarism checking.

UNIT IV

Introduction to Intellectual property - Types of intellectual property rights – Patent, Copyright, Trade Mark, Industrial Design, Geographical Indication, Trade Secrets - Traditional Knowledge. Elements of Patentability - Novelty, Non Obviousness (Inventive Steps), Industrial Application – Non patentable inventions – Process of patenting – National and International – Form and Fees for IP India

UNIT V

Prior Art Search, Patent drafting - Drafting patent Claims – Types of claims - Registration Procedure, Rights and Duties of Patentee; Patent infringement; Licensing – Franchising - Joint ventures; Non-Disclosure Agreements (NDAs) - Material Transfer Agreements (MTAs).

REFERENCES:

- C. Vijayalakshmi and C. Sivapragasam (2011) Research Methods – Tips and Techniques, , MJP Publishers
- Deboraj Rumsey (2010) Statistics Essentials for Dummies, Wiley Publishing Incorporated
- Bouchoux (2013) Intellectual Property, DELMAR CENGAGE Learning, USA
- V K Ahuja (2017) Law Relating to Intellectual Property Rights, LexisNexis Butterworths India

IMPORTANT WEB LINKS

https://www.wipo.int/portal/en/index.html, http://ipindia.nic.in/, https://www.epo.org,https://www.uspto.gov

MCT20CL01 **Laboratory I - Advanced Separation Processes** **0 0 4 2**

OBJECTIVES:

- To familiarize students with various advanced aspects of separation processes and the selection of separation processes.
- To enable students to understand the principles and processes of adsorption, membrane separation and chromatography and to design an absorber or a membrane unit to achieve a specified separation.
- To introduce them to new trends used in the separation technologies.

COURSE OUTCOME:

At the end of the course, the student will be able to:

- Knowledge of mass transfer operations and mechanical operations
- Students should be able to know the synthesis of materials and applications in separation processes.
- Students will be able to provide applicable solutions to separation processes.

LIST OF EXPERIMENTS:

1. Separation of fluoride and arsenic using cellulose acetate asymmetric membrane separation process
2. Adsorption of dyes from waste water using nano adsorbents.
3. Supercritical extraction of the fragrance.
4. Study the effect of pressure on permeate flux and solution rejection in RO system.
5. Mass transfer studies and study the effect of parameters in separation system using liquid emulsion membrane.
6. Laboratory experiments on ion exchange membranes: effect of process parameters on flux etc.
7. Study the reaction with mass transfer: e.g. Synthesis of calcium carbonate.
8. Study the reactive distillation system considering batch and continuous mode

MCT20C003 **Advanced Transport Phenomena** **3 0 0 3**

OBJECTIVES:

- To familiarize the student with basic concepts of transport phenomena and brief review of mathematics.
- To enable students to understand the equations of change for isothermal flow and for non- isothermal flow.
- To introduce them details of equations of change for multi component systems.
- To give them insight into properties of two-dimensional flows and aspects of dimensional analysis

COURSE OUTCOME:

At the end of the course, the student will be able to:

- Understand the mechanism of momentum, heat and mass transport for steady and unsteady flow.
- Perform momentum, energy and mass balances for a given system at macroscopic and microscopic scale.
- Solve the governing equations to obtain velocity, temperature and concentration profiles.
- Model the momentum, heat and mass transport under turbulent conditions.
- Develop analogies among momentum, energy and mass transport.

UNIT I EQUATIONS OF CHANGE FOR ISOTHERMAL SYSTEMS 9Hrs

Equation of Continuity, Equation of Motion,Equation of Mechanical Energy, Equations of Change in terms of the Substantial Derivative, Use of the Equations to solve Flow Problems, Dimensional Analysis of the Equations of Change. Velocity Distributions with more than one Independent Variable: Time Dependent Flow of Newtonian Fluids. Velocity Distributions in Turbulent Flow -Comparisons of Laminar and Turbulent Flows, Time Smoothed Equations of Change for Incompressible Fluids, Time Smoothed Velocity Profile near a wall, Empirical Expressions for the Turbulent Momentum Flux, Turbulent Flow in Ducts, Turbulent Flow in Jets.

UNIT II MACROSCOPIC BALANCES FOR ISOTHERMAL SYSTEMS 9Hrs

The Macroscopic Mass Balance, The Macroscopic Momentum Balance, The Macroscopic Mechanical Energy Balance, Estimation of the Viscous loss, Use of the Macroscopic Balances for Steady-State Problems, Derivation of the Macroscopic Mechanical Energy Balance. Equations of Change for Non-Isothermal Systems: The Energy Equation, Special forms of the Energy Equation, The Boussine sq Equation of Motion for Forced and Free Convection, Use of the Equations of change to Solve Steady-State Problems, Dimensional Analysis of the Equations of Change for Non-Isothermal Systems.

UNIT III TEMPERATURE DISTRIBUTIONS IN SOLIDS AND IN LAMINAR FLOW 9Hrs

Heat Conduction with an Electrical Heat Source, Heat Conduction with a Viscous Heat Source. Temperature Distributions with more than One Independent Variable - Unsteady Heat Conduction in Solids, Steady Heat Conduction in Laminar, Incompressible Flow. Temperature Distributions in Turbulent Flow - Time- Smoothed Equations of Change for Incompressible Non-Isothermal Flow, Time-Smoothed Temperature Profile near a Wall, Empirical Expressions for the Turbulent Heat Flux Temperature Distribution for Turbulent Flow in Tubes.

UNIT IV MACROSCOPIC BALANCES FOR NON-ISOTHERMAL SYSTEMS 9Hrs

Macroscopic Energy Balance, Macroscopic Mechanical Energy Balance, Use Of The Macroscopic Balances To Solve Steady State Problems With Flat Velocity Profiles, Concentration Distributions in Solids and in Laminar Flow: Shell Mass Balances Boundary Conditions, Diffusion through a Stagnant Gas Film, Diffusion with a Heterogeneous Chemical Reaction. Concentration Distributions with more than One Independent Variable: Time-Dependent Diffusion, Steady-State Transport in Binary Boundary Layers, Concentration Distributions in

Turbulent Flow - Concentration Fluctuations and the Time-Smoothed Concentration, Time-Smoothing of the Equation of Continuity of A, Semi-Empirical Expressions for the Turbulent Mass Flux, Enhancement of Mass Transfer by a First-Order Reaction in Turbulent Flow.

UNIT V INTERPHASE TRANSPORT IN MULTI-COMPONENT SYSTEMS 9Hrs

Definition of Transfer Coefficients in One Phase, Analytical Expressions for Mass Transfer Coefficients, Correlation of Binary Transfer Coefficients in One Phase, Definition of Transfer Coefficients in Two Phases, Mass Transfer and Chemical Reactions. Macroscopic Balances For Multi-Component Systems: Macroscopic Mass Balances, Macroscopic Momentum, Use of the Macroscopic Balances to solve Steady-State Problems.

Total no. of hrs: 45hrs

REFERENCES

- Thomson W. J., Transport Phenomena, Pearson education, Asia, 2001.
- Geankopolis C. J., Transport Processes and Unit Operations, 4th Ed., Prentice Hall (India) Pvt. Ltd., New Delhi. 2004.
- Bird R. B., Stewart W. E. and Light Foot E. N., Transport Phenomena, Revised 2nd Edition, John Wiley & Sons, 2007.

MCT20CL02	**Laboratory II - Process Modeling and Simulation laboratory**	**0**	**0**	**4**	**2**

OBJECTIVES:

- To learn Process Modeling and Simulation of Chemical operations and processes.
- To understand Dynamic Behavior of processes.
- To understand Close loop control of processes.
- To learn Dynamic simulation of chemical processes.
- To get acquainted with Controllability Analysis of chemical processes.

COURSE OUTCOME:

At the end of the course, the student will be able to:

- Carry out thermodynamic property estimations using property estimation and property analysis in Aspen.
- Simulate Mixer, splitter, heat exchangers, reactors, distillation columns.
- Apply sensitivity, design specification and case study tools in Aspen.
- Solve linear and non-linear programming problems.

LIST OF EXPERIMENTS:

Simulation laboratory practical

1. Thermodynamic property estimations using property estimation and property analysis in Aspen.
2. Simulate Mixer, splitter, heat exchangers, and reactive distillation column.
3. Apply sensitivity, design specification and case study tools in Aspen
4. Solve linear and non-linear programming problems.
5. Controller tuning by Ziegler- Nichol's & Cohen- Coon methods
6. Stability analysis using Bode diagrams for control systems.
7. Simulation of Ideal Binary Distillation Column
8. Simulation of Heat/Mass Transfer coefficient in 3 phase fluidized bed column
9. Simulation studies of various unit operations using CHEMCAD.
10. Modeling and Simulation of cyclone separator

Note: Simulation can be done using C/C++ / MATLAB/ ASPEN PLUS/ CHEMCAD

SEMESTER III

MCT20C004	**Advanced Reaction Engineering**	**3**	**0**	**0**	**3**

OBJECTIVES:

- This Subject is essential for Design of Reactor especially heterogeneous reactors.
- Students will learn the energy balance, temperature and concentration profiles in different reactors, advance design aspects of multiple reactors.
- Students will get insight of importance of population balance of particles.
- Role of Reaction Engineering in mitigation of Global warming will also addressed.

COURSE OUTCOME

At the end of the course, the student will be able to:

- Evaluate heterogeneous reactor performance considering mass transfer limitations
- Perform the energy balance and obtain concentration profiles in multiphase reactors.
- Estimate the performance of multiphase reactors under non-isothermal conditions.
- Understand modern reactor technologies for mitigation of global warming

UNIT I NON-ELEMENTARY KINETICS IMPORTANCE 9Hrs

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 Semibatch Reactors, Conversion Vs Rate in Reactors, Use of POLYMATHS to solve the equations and understanding the profiles.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.

UNIT II NEED FOR MULTI-STAGING CSTR WITH MULTIPLE STAGES 9Hrs

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, STR, 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.

UNIT III CATALYTIC REACTIONS: THEORY AND MODELING 9Hrs

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 Porous catalyst on tube wall reactors Design of packed bed porous catalytic reactors: Mass transfer limited reactions in Packed bed.

UNIT IV FLUIDIZED BED REACTOR MODELING 9Hrs

Geld art 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 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 APPLICATION OF POPULATION BALANCE EQUATIONS FOR REACTOR MODELING 9Hrs

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: CO2 absorption in high pressure water, different techniques of mitigation of CO2, methods of separations. Recent advancements, automotive monolith catalytic converter example, removal and utilization of CO2 for thermal power plants.

Total no. of hrs: 45hrs

REFERENCES

- K.G. Denbigh : Chemical Reactor Theory, Cambridge University Press, Second Edition, 1971.
- J.M. Smith : Chemical Engineering Kinetics, Mcgraw Hill, Third Edition, 1981.
  Levenspiel O., Chemical Reaction Engineering, Wiley, 1998.
- Foggler,H.S., Elements of Chemical Reaction Engineering, Prentice Hall of India, 2008.
  Fromment G.F. and Bischoff K.B., Chemical Reactor Analysis and Design, John Wiley, 2010.

MCT20CL03 Laboratory III - Advanced Chemical Engineering Laboratory 0 0 4 2

OBJECTIVES:

- Analyze characteristics of a fluidized bed dryer
- Estimate efficiency of compact heat exchangers
- Evaluate the performance of a process intensification in catalytic reactions, ultrasound assisted reactions, reactive distillation column, micro reactor and advanced flow reactor
- Design controller for a given process
- Evaluate the performance of membrane separation process for water purification
- Characterize electrochemical phenomena such as corrosion

DETAILED SYLLABUS

1. Characteristics of a Fluidized bed dryer
2. Helical Coil heat exchanger
3. Determination of Effective thermal conductivity (ETC) in granular material
4. Plate Type Heat Exchanger
5. Kinetics for solid catalyzed esterification reaction in a batch reactor
6. Reactive distillation in Packed Column
7. Ultrasonic cavitation based reactions
8. Micro-reactor
9. Advanced Flow Reactor
10. Membrane Separation for water purification
11. Corrosion characteristics of a metal in a given electrolyte
12. Control of liquid level in non-interacting systems.
13. Identification and control of a three tank system.
14. pH control in a process.

SEMESTER IV

MCT20CL04	**Laboratory IV - Advanced Chemical Engineering Laboratory**	**0**	**0**	**4**	**2**

OBJECTIVES:

- Analyze characteristics of a fluidized bed dryer
- Estimate efficiency of compact heat exchangers
- Evaluate the performance of a process intensification in catalytic reactions, ultrasound assisted reactions, reactive distillation column, micro reactor and advanced flow reactor
- Design controller for a given process
- Evaluate the performance of membrane separation process for water purification
- Characterize electrochemical phenomena such as corrosion

DETAILED SYLLABUS

1. Characteristics of a Fluidized bed dryer
2. Helical Coil heat exchanger
3. Determination of Effective thermal conductivity (ETC) in granular material
4. Plate Type Heat Exchanger
5. Kinetics for solid catalyzed esterification reaction in a batch reactor
6. Reactive distillation in Packed Column
7. Ultrasonic cavitation based reactions
8. Micro-reactor
9. Advanced Flow Reactor
10. Membrane Separation for water purification
11. Corrosion characteristics of a metal in a given electrolyte
12. Control of liquid level in non-interacting systems.
13. Identification and control of a three tank system.
14. pH control in a process.

SEMESTER V

MCT20BL06	**Dissertation Phase – I**	**0**	**0**	**20**	**10**

Teaching Scheme Lab work: 20 and 32 hrs/week for phase I and II respectively

OBJECTIVES:

At the end of this course, students will be able to

- Ability to synthesize knowledge and skills previously gained and applied to an in-depth study and execution of new technical problem.
- Capable to select from different methodologies, methods and forms of analysis to produce a suitable research design, and justify their design.
- Ability to present the findings of their technical solution in a written report.

Presenting the work in International/ National conference or reputed journals.

SYLLABUS CONTENTS:

The dissertation / project topic should be selected / chosen to ensure the satisfaction of the urgent need to establish a direct link between education, national development and productivity and thus reduce the gap between the world of work and the world of study. The dissertation should have the following

- Relevance to social needs of society
- Relevance to value addition to existing facilities in the institute
- Relevance to industry need
- Problems of national importance
- Research and development in various domain The

student should complete the following:

- Literature survey Problem Definition
- Motivation for study and Objectives
- Preliminary design / feasibility / modular approaches
- Implementation and Verification
- Report and presentation

The dissertation stage II is based on a report prepared by the students on dissertation allotted to them. It may be based on:

- Experimental verification / Proof of concept.
- Design, fabrication, testing of Communication System.
- The viva-voce examination will be based on the above report and work.

Guidelines for Dissertation Phase – I and II

- As per the AICTE directives, the dissertation is a yearlong activity, to be carried out and evaluated in two phases i.e. Phase – I: July to December and Phase – II: January to June.
- The dissertation may be carried out preferably in-house i.e. department's laboratories and centers OR in industry allotted through department's T & P coordinator.
- After multiple interactions with guide and based on comprehensive literature survey, the student shall identify the domain and define dissertation objectives. The referred literature should preferably include Springer/Science Direct. In case of Industry sponsored projects, the relevant application notes, while papers, product catalogues should be referred and reported.

- Student is expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and phase wise work distribution, and submit the proposal within a month from the date of registration.
- Phase – I deliverables: A document report comprising of summary of literature survey, detailed objectives, project specifications, paper and/or computer aided design, proof of concept/functionality, part results, A record of continuous progress.
- Phase – I evaluation: A committee comprising of guides of respective specialization shall assess the progress/performance of the student based on report, presentation and Q & A. In case of unsatisfactory performance, committee may recommend repeating the phase-I work.

SEMESTER VI

MCT20BL07	**Dissertation Phase – II**	**0**	**0**	**32**	**16**

Teaching Scheme Lab work: 20 and 32 hrs/week for phase I and II respectively

OBJECTIVES:

At the end of this course, students will be able to

- Ability to synthesize knowledge and skills previously gained and applied to an in-depth study and execution of new technical problem.
- Capable to select from different methodologies, methods and forms of analysis to produce a suitable research design, and justify their design.
- Ability to present the findings of their technical solution in a written report.
- Presenting the work in International/ National conference or reputed journals.

SYLLABUS CONTENTS:

The dissertation / project topic should be selected / chosen to ensure the satisfaction of the urgent need to establish a direct link between education, national development and productivity and thus reduce the gap between the world of work and the world of study. The dissertation should have the following

- Relevance to social needs of society
- Relevance to value addition to existing facilities in the institute
- Relevance to industry need
- Problems of national importance
- Research and development in various domain The

student should complete the following:

- Literature survey Problem Definition
- Motivation for study and Objectives
- Preliminary design / feasibility / modular approaches
- Implementation and Verification
- Report and presentation

The dissertation stage II is based on a report prepared by the students on dissertation allotted to them. It may be based on:

- Experimental verification / Proof of concept.
- Design, fabrication, testing of Communication System.
- The viva-voce examination will be based on the above report and work.

Guidelines for Dissertation Phase – I and II

- As per the AICTE directives, the dissertation is a yearlong activity, to be carried out and evaluated in two phases i.e. Phase – I: July to December and Phase – II: January to June.
- The dissertation may be carried out preferably in-house i.e. department's laboratories and centers OR in industry allotted through department's T & P coordinator.
- After multiple interactions with guide and based on comprehensive literature survey, the student shall identify the domain and define dissertation objectives. The referred literature should preferably include Springer/Science Direct. In case of Industry sponsored projects, the relevant application notes, while papers, product catalogues should be referred and reported.
- Student is expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and phase wise work distribution, and submit the proposal within a month from the date of registration.

- Phase – II, student is expected to exert on design, development and testing of the proposed work as per the schedule. Accomplished results/contributions/innovations should be published in terms of research papers in reputed journals and reviewed focused conferences OR IP/Patents.
- Phase – II deliverables: A dissertation report as per the specified format, developed system in the form of hardware and/or software, A record of continuous progress.
- Phase – II evaluation: Guide along with appointed external examiner shall assess the progress/performance of the student based on report, presentation and Q & A. In case of unsatisfactory performance, committee may recommend for extension or repeating the work

ELECTIVE II

MCT20CE01 Chemical Reactor Analysis I 3 0 0 3

OBJECTIVES:

- To learn the heterogeneous catalyzed reactions and the models involved in reactor design
- To study mass and heat transfer mechanisms in the different reactors
- To appreciate the importance of both external and internal transport effects in gas-solid and liquid-solid systems
- To design isothermal and non-isothermal reactors for heterogeneous catalytic reactions

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- Evaluate heterogeneous reactor performance considering mass transfer limitations
- Perform the energy balance and obtain concentration profiles in multiphase reactors.
- Estimate the performance of multiphase reactors under non-isothermal conditions

UNIT I **9Hrs**

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, Poyntrgins maximum principle.

UNIT II FIXED BED CATALYTIC REACTOR **9Hrs**

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.

UNIT III MULTIPHASE FLOW REACTOR **9Hrs**

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.

UNIT IV **9Hrs**

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.

UNIT V TEMPERATURE EFFECTS IN REACTOR **9Hrs**

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.

Total no. of hrs: 45hrs

REFERENCE:

- Froment G. F. and K.B.Bischoff, " Chemical Reactor Analysis and Design", John Wiley & Sons
- Denbigh K. G. and J.C. Turner, " Chemical Reactor and Theory – an Introduction", 3rd edition Cambridge University Press.
- Bruce Nauman, " Chemical Reactor Design", John Wiley & Sons
- Elements of Chemical Reaction Engineering by H. Scott Fogler
- Chemical Engineering Kinetics by J. M. Smith.
- Chemical Reactor Design and Operation by K. R. Westerterp, W. P. M. Van Swaaij and A. A. C.
- M. BeenackersReference
- Chemical Reactor Analysis and Design by G. F. Froment and K. B. Bischoff

MCT20CE02 **Process Design and Synthesis** **3 0 0 3**

OBJECTIVES:

- To understand the systematic approaches for the development of conceptual chemical process designs
- To learn the advances in problem formulation and software capabilities which offer the promise of a new generation of practical process synthesis techniques based directly on structural optimization.
- Learning chemical process synthesis, analysis, and optimization principles
- Product design and development procedure and Process life cycle assessment.

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- Analyze alternative processes and equipment
- Synthesize a chemical process flow sheet that would approximate the real process
- Design best process flow sheet for a given product
- Perform economic analysis related to process design and evaluate project profitability

UNIT I INTRODUCTION **9Hrs**

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. Introduction to commercial process design software such as HYSYS, Aspen plus etc., Chemical Process (reactor, heat exchanger, distillation etc) analysis using commercial software

UNIT II PRODUCT DESIGNAND DEVELOPMENTS **9Hrs**

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.

UNIT III REACTOR NETWORKS **9Hrs**

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

UNIT IV SYNTHESIS OF SEPARATION TRAINS **9Hrs**

Criteria for selection of separation methods, select ion 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 ow rates for single columns, Residue curve basics, Non-ideal Distillation - Azeotropic systems; detecting binary azeotropes, Residue curve maps for azeotropic systems, Topological analysis, Feasibility for single azeotropic columns ,Binary VLLE and pressure- swing separation, Non-ideal distillation synthesis. Equipment sequencing: VLE + VLLE, Detailed Residue Curve Maps, Residue curve maps: Interior structure

UNIT V HEAT EXCHANGER NETWORK SYNTHESIS **9Hrs**

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, trade-off & utilities, Heat & power integration, HENS as mathematical programming

Total no. of hrs: 45hrs

REFERENCES:

- Douglas, J. "Conceptual Design of Chemical Processes",New York, NY: McGraw-Hill Science/Engineering/Math, 1988. ISBN: 0070177627.
- Seider, W. D., J. D. Seader, and D. R. Lewin. "Product and Process Design Principles: Synthesis, Analysis, and Evaluation",. *2*nd ed. New York, NY: Wiley, 2004. ISBN: 0471216631.
- 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
- Biegler L.T., Grossmann I.E. and Westerberg A.W., "Systematic Methods of Chemical Process Design", Prentice Hall, 1997.

MCT20CE03 **Fluidization Engineering** **3 0 0 3**

OBJECTIVES

- To study the phenomenon of fluidization with industrial processing objective
- To study the various regimes of fluidization and their mapping.
- To study the design of equipments based on fluidization technique

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- Performing and understanding the behavior fluidization in fluidized bed
- Evaluate the characterization of particles and power consumption in fluidization regimes
- Understanding the applicability of the fluidized beds in chemical industries

UNIT I INTRODUCTION TO FLUIDIZATION AND APPLICATIONS 9Hrs

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

UNIT II MAPPING OF FLUIDIZATION REGIMES 9Hrs

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

UNIT III BUBBLING FLUIDIZED BEDS 9Hrs

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

UNIT IV SOLIDS MOVEMENT AND GAS DISPERSION 9Hrs

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.

UNIT V FLUIDIZED BED REACTORS 9Hrs

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.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 noncatalytic reactors, kinetic models for conversion of solids, models for shrinking particles, conversion of solids of unchanging size

Total no. of hrs: 45hrs

REFERENCES:

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

ELECTIVE III

MCT20CE04	**Industrial Pollution Control**	**3**	**0**	**0**	**3**

OBJECTIVES

- To understand the importance of industrial pollution and its abatement
- To study the underlying principles of industrial pollution control
- To acquaint the students with case studies
- Student should be able to design complete treatment system

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- Recognize the causes and effects of environmental pollution
- Analyze the mechanism of proliferation of pollution
- Develop methods for pollution abatement and waste minimization
- Design treatment methods for gas, liquid and solid wastes

UNIT I INDUSTRIES & ENVIRONMENT 9Hrs

Industrial scenario in India - Industrial activity and Environment - Uses of Water by industry - Sources and types of industrial wastewater - Industrial wastewater and environmental impacts - Regulatory requirements for treatment of industrial wastewater - Industrial waste survey - Industrial wastewater generation rates, characterization and variables - Population equivalent - Toxicity of industrial effluents and Bioassay tests.

UNIT II INDUSTRIAL NOISE POLLUTION 9Hrs

Sources of noise pollution, characterization of noise pollution prevention& control of noise pollution, Factories Act 1948 for regulatory aspects of noise pollution.

UNIT III AIR POLLUTANT ABATEMENT 9Hrs

Air pollutants scales of concentration, lapse rate and stability, plume behavior, 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.

UNIT IV WASTE WATER TREATMENT PROCESSES 9Hrs

Design concepts for primary treatment, grid chambers and primary sedimentation basins, selection of treatment process flow diagram, elements of conceptual process design, design of thickner, biological treatment Bacterial population dynamics, kinetics of biological growth and its applications to biological treatment, process design relationships and analysis, 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.

UNIT V SOLID WASTE AND HAZARDOUS WASTE MANAGEMENT 9Hrs

Sources and classification, properties, public helth 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.

Total no. of hrs: 45hrs

REFERENCES:

- Rao C.S., "Environmental Pollution Control Engineering", 2nd edition
- Mahajan S.P., "Pollution Control in Process Industries".
- Nemerow N.L., "Liquid waste of industry- theories, Practices and Treatment", Addison Wesley, New York, 1971
- Weber W.J., "Physico-Chemical Processes for water quality control", Wiley Interscience New York, 1969
- Strauss W., "Industrial Gas Cleaning", Pergamon, London, 1975
- Stern A.C., "Air pollution", Volumes I to VI, academic Press, New York, 1968
- Peterson and Gross .E Jr., "Hand Book of Noise Measurement", 7th Edn, 2003.
- Antony Milne, "Noise Pollution: Impact and Counter Measures", David & Charles PLC, 2009.

MCT20CE05 Application of Nanotechnology in Chemical Engineering 3 0 0 3

OBJECTIVES:

- To understand the fundamentals of the preparation and properties of nanomaterials from a chemical engineering perspective.
- To gain knowledge of structure, properties, manufacturing, and applications of various nanomaterials and characterization methods in nanotechnology
- To give a survey of the key processes, principles, and techniques used to build novel nanomaterials and assemblies of nanomaterials

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- Understanding the different top down and bottom up approaches for nanoparticles
- Get to know the different applications of nanoparticles in chemical engineering field.
- Learning the characterization techniques for nanoparticles.

UNIT I INTRODUCTION 9Hrs

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.

UNIT II APPROACHES TO SYNTHESIS OF NANOSCALE MATERIALS AND CHARACTERIZATION 9Hrs

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 nanoemulsion. 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 usingX-ray imaging, Transmission Electron Microscopy, HRTEM, Scanning Electron Microscopy, SPM, AFM, STM, PSD, Zeta potential, DSC and TGA.

UNIT III SEMICONDUCTORS AND QUANTUM DOTS 9Hrs

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

UNIT IV POLYMER-BASED AND POLYMER-FILLED NANOCOMPOSITES 9Hrs

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.

UNIT V APPLICATIONS TO SAFETY, ENVIRONMENT AND OTHERS 9Hrs

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.

Total no. of hrs: 45hrs

REFERENCES

- Louis Hornyak G., Dutta Joydeep, Tibbals Harry F. and Rao Anil K., "Introduction to Nanoscience", (CRC Press of Taylor and Francis Group LLC), May 2008, 856pp, ISBN-13: 978142004805
- 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.
- Kelsall Robert W., Hamley Ian W., GeogheganMark, "Nanoscale Science and Technology",John Wiley & Sons, Ltd, 2006.
- MKal Ranganathan Sharma, "Nanostructuring Operations in Nanoscale Science and Engineering", McGraw-Hill Companies, Inc. ISBN: 978-0-07-162609-5, 2010.
- "Organic and inorganic nanostructures".-(Artech House MEMS series), Nabok, Alexei, ISBN 1- 58053-818-5, 2005.

MCT20CE06 **Chemo Informatics** **3 0 0 3**

OBJECTIVES:

- To give students a concept of Chemo-informatics related to chemical structure databases and database search methods
- To understand the quantum methods and models involved in drug discovery and targeted drug delivery
- To study the application of Chemical Libraries, Virtual Screening, Prediction of Pharmacological Properties

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- The course will introduce the students preparing for professional work in chemistry must learn how to retrieve specific information from the enormous and rapidly expanding chemical literature.
- The course will provide a broad overview of the computer technology to chemistry in all of its manifestations.
- The course will expose the student to current and relevant applications in QSAR and Drug Design.

UNIT I CHEMO-INFORMATICS 9Hrs

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, Drugbank), 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.

UNIT II INTRODUCTION TO QUANTUM METHODS 9Hrs

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).

UNIT III ANALYSIS AND USE OF CHEMICAL REACTION INFORMATION 9Hrs

Chemical property information, spectroscopic information, analytical chemistry information, chemical safety information, Drug Designing: Prediction of Properties of Compounds, QSAR Data Analysis, Structure-Activity Relationships, Electronic properties, Lead Identification, Molecular Descriptor Analysis.

UNIT IV TARGET IDENTIFICATION 9Hrs

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.

UNIT V DRUG DISCOVERY 9Hrs

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)

Total no. of hrs: 45hrs

REFERENCES:

- Bajorath J (2004), "Chemoinformatics: Concepts, Methods and Tools for Drug Discovery" Humana Press
- Leach A, Gillet V, "An Introduction to Chemoinformatics" Revised edition, Springer
- Gasteiger J. Engel T. "A textbook of Chemoinformatics" Wiley- VCH GmbH & Co. KGaA
- Bunin B. Siesel B. Guillermo M. "Chemoinformatics: Theory, Practice & Products", Springer
- Lavine B. (2005), "Chemometrics and Chemoinformatics", American Chemical Society
- Casteiger J. and Engel T (2003) "Chemoinformatics" Wiley-VCH
- Bunin Barry A. Siesel Brian, Morales Guillermo,Bajorath Jürgen. Chemoinformatics: Theory, Practice, & Products Publisher:New York, Springer. 2006.
- Leach Andrew R., Valerie J. Gillet, "An introduction to Chemoinformatics", Publisher: Kluwer academic, 2003. ISBN: 1402013477
- Gasteiger Johann, Handbook of Chemoinformatics: From Data to Knowledge (4 Volumes), 2003. Publisher: Wiley-VCH.

ELECTIVE IV

MCT20CE07 Modern concepts in Catalysis and Surface Phenomenon 3 0 0 3

OBJECTIVES:

- To give the students insight into advances in catalytic reaction engineering
- To understand the mechanisms involved in catalytic reactions
- To study the catalyst characterization techniques
- To study the advanced industrial applications in catalysis
- To understand the principles behind catalyst deactivation and study their models

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- To understand the concepts of homogenous and heterogeneous catalysis, with specific examples.
- To study reaction mechanisms and kinetics of homogenous and heterogeneous catalytic reactions.
- To familiarize with the characterization of catalysts
- To understand the application and mechanisms of several types of catalysts in chemical industry.

UNIT I INTRODUCTION TO CATALYSIS 9Hrs

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.

UNIT II ADSORPTION IN CATALYSIS 9Hrs

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

UNIT III CATALYST CHARACTERIZATION 9Hrs

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.

UNIT IV SIGNIFICANCE OF PORE STRUCTURE AND SURFACE AREA 9Hrs

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 Intraparticle Diffusion, Non-isothermal Reactions in Pores, Diffusion Control.

UNIT V INDUSTRIAL APPLICATIONS– CASE STUDIES 9Hrs

Industrial processes involving heterogeneous solid catalyst: Synthesis of Methanol, Fiscer-Tropsch Catalysis, Synthesis of Ammonia, Automobile Exhaust Catalysts and Catalyst Monolith, Photocatalytic 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

Total no. of hrs: 45hrs

REFERENCES:

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

MCT20CE08 Advanced Downstream Processes 3 0 0 3

OBJECTIVES

- To understand the unit processes involved in downstream processing.
- To study advanced treatment methods.
- To study the energy conservation in different separation processes
- To understand the underlying design principles

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- To learn effective strategies of downstream processing in chemical industry.
- Understand the role of downstream processing.
- Analyze reactors, upstream and downstream processes in production

UNIT I INTRODUCTION 9Hrs

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.

UNIT II DOWNSTREAM PROCESSES IN PETROCHEMICAL INDUSTRY 9Hrs

Cryogenic distillation for refinery, petrochemical off gases, natural gases, gas recovery-Olefin, Helium, Nitrogen, Desulfurization - coal, flue gases

UNIT III ADVANCED DISTILLATION PROCESSES 9Hrs

Azeotropic & extractive distillation - residue curve maps, homogeneous azeotropic distillation, pressure swing distillation, Column sequences, heterogeneous azeotropic distillation.

UNIT IV ENERGY CONSERVATION IN SEPARATION PROCESSES 9Hrs

Energy balance, molecular sieves - zeolights, adsorption, catalytic properties, manufacturing processes, hydrogel process, application, New trends.

UNIT V NON-IDEAL MIXTURES AND ION EXCHANGE 9Hrs

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 use.

Total no. of hrs: 45hrs

REFERENCES:

- Perry's "Chemical Engg. Handbook": McGraw Hill Pub.
- Douglas J.M., "Conceptual Design of Chemical Processes", McGraw Hill
- Liu Y.A., "Recent Developments in Chemical Process & Plant Design", John Wiley & Sons Inc.
- Timmerhaus K.D., "Cryogenic Process Engg.", Plenum Press
- Othmer Kirk "Encyclopedia of Separation Technology, Vol I & II", Wiley Interscience

MCT20CE09 Computational Fluid Dynamics 3 0 0 3

OBJECTIVES:

- To make students understand the governing equations of fluid dynamics and their derivation from laws of conservation
- To develop a good understanding in computational skills, including discretisation, accuracy and stability.
- To acquaint the students with a process of developing a mathematical and geometrical model of flow, applying appropriate boundary conditions and solving system of equations.

COURSE OUTCOMES:

- Understand the basic principles of mathematics and numerical concepts of fluid dynamics.
- Develop governing equations for a given fluid flow system.
- Adapt finite difference techniques for fluid flow models.
- Apply finite difference method for heat transfer problems.
- Solve computational fluid flow problems using finite volume techniques.
- Get familiarized to modern CFD software used for the analysis of complex fluid-flow systems.

UNIT I INTRODUCTION TO FLUID DYNAMICS 9Hrs

Concepts of Fluid Flow, Pressure distribution in fluids, Reynolds transport theorem, Integral form of conservation equations, Differential form of conservation equations, Different Types of Flows, Euler and Navier Stokes equations, Properties of supersonic and subsonic flows, Flow characteristics over various bodies. Philosophy of CFD, Governing equations of fluid dynamics and there physical meaning, Mathematical behavior of governing equations and the impact on CFD simulations, Simple CFD techniques and CFL condition. Numerical Methods in CFD:Finite Difference, Finite Volume, and Finite Element, Upwind and downwind schemes, Simple and Simpler schemes, Higher order methods, Implicit and explicit methods, Study and transient solutions

UNIT II GRID GENERATION 9Hrs

Basic theory of structured grid generation, Surface grid generation, Mono block, multi block, hierarchical multi block, Moving and sliding multiblock, Grid clustering and grid enhancement. Basic theory of unstructured grid generation, advancing front, Delaunay triangulation and various point insertion methods, Unstructured quad and hex generation, grid based methods, various elements in unstructured grids, Surface mesh generation, Surface mesh repair, Volume grid generation, Volume mesh improvement, mesh smoothing algorithms, grid clustering and quality checks for volume mesh. Adaptive, Moving and Hybrid Grids, Need for adaptive and, moving grids, Tet, pyramid, prism, and hex grids, using various elements in combination

UNIT III TURBULENCE AND ITS MODELLING 9Hrs

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

UNIT IV CHEMICAL FLUID MIXING SIMULATION 9Hrs

Stirred tank modeling using the actual impeller geometry, Rotating frame model, The MRF Model Sliding mesh model, Snapshot model, Evaluating Mixing from Flow Field Results, Industrial Examples

UNIT V POST-PROCESSING OF CFD RESULTS 9Hrs

Contour plots, vector plots, and scatter plots, Shaded and transparent surfaces, Particle trajectories and path line trajectories, Animations and movies, Exploration and analysis of data.

Total no. of hrs: 45hrs

REFERENCES

- Anderson John D., "Computational Fluid Dynamics: The Basics with Applications", Mc Graw Hill, 1995
- Ranade V.V., "Computational Flow Modeling for Chemical Reactor Engineering", Process Engineering Science, Volume 5, 2001
- Knupp Patrick and Steinberg Stanly, "Fundamentals of Grid Generation", CRC Press, 1994
- Wilcox D.C., "Turbulence Modelling for CFD", 1993
- Wesseling Pieter, "An Introduction to Multigrid Methods", John Wiley & Sons, 1992
- Thompson J.F., Warsi Z.U.A. and Mastin C.W., "Numerical Grid Generation: Foundations and Applications", North Holland, 1985
- Patankar S.V., "Numerical Heat Transfer and Fluid Flow", McGraw-Hill,1981
- Gatski Thomas B., Hussaini M. Yousuff and Lumley John L., "Simulation and Modelling of Turbulent Flows", Oxford University Press, 1996
- Laney, C. B., "Computational Gas Dynamics", Cambridge Uni. Press, 1998.

MCT20CE10 **Bioprocess Engineering** **3 0 0 3**

OBJECTIVES

- To learn the principles of bioprocessing for traditional chemical engineering in the design and development of processes involving biocatalyst.
- To study engineering principles in the development of products based on living cells or subcomponents of such cells.
- To learn and develop quantitative models and approaches related to bioprocesses
- To learn mechanisitic models for enzyme catalyzed reactions for large scale production of bioproducts

COURSE OUTCOMES:

At the end of the course, the students will be able to:

- Understand the different cells and their use in biochemical processes.
- Understand the role of enzymes in kinetic analysis of biochemical reaction.
- Analyze bioreactors, upstream and downstream processes in production of bio-products
- Demonstrate the fermentation process and its products for the latest industrial revolution

UNIT I INTRODUCTION **9Hrs**

Biotechnology and bioprocessing. An overview of biological basics. Basics of enzyme and microbial kinetics. Operating considerations for bioreactors: cultivation method, modifying batch and continuous reactors, immobilized cell systems, solid state fermentations.

UNIT II ADVANCE ENZYME KINETICS **9Hrs**

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

UNIT III BIOREACTORS **9Hrs**

Selection, scale-up, operation and control of bioreactors: Scale-up and its difficulties, bioreactor instrumentation and control, sterilization of process fluids.Modifications of batch and continuous reactors, chemostat with recycle, multistage chemostat, fed-batch operation, perfusion system, active and passive immobilization of cells, diffusional limitations in the immobilized system, solid state fomenters.

UNIT IV HOMOGENEOUS AND HETEROGENEOUS REACTIONS IN BIOPROCESSES9Hrs

Reaction thermodynamics, growth kinetics with Plasmid instability, The Thiele Modulus and effectiveness factor, diffusion and reaction in waste treatment lagoon. Reactors and choice of reactors.

UNIT V RECOVERY AND PURIFICATION OF PRODUCTS **9Hrs**

Strategies to recover and purify products, separation of insoluble products, cell disruption, separation of soluble products.

Total no. of hrs: 45hrs

REFERENCES

- Bailey J.E. and Ollis D.F., “Biochemical Engineering Fundamentals”, McGraw-Hill
- Doran P.M., “Bioprocess Engineering Principles”, Academic Press
- Shuler M.L., Kargi F., ”Bioprocess Engineering”, Prentice –Hall

MCT20CE11 **Process Intensification** **3 0 0 3**

OBJECTIVES:

- Understand the concept of Process Intensification.
- Know the limitations of intensification of the chemical processes.
- Applythe techniques of intensification to a range of chemical processes.
- Develop various process equipment used for intensifying the processes.
- Infer alternative solutions keeping in view point, the environmental protection, economic viability and social acceptance.

COURSE OUTCOMES:

At the end of this course, students are able to:

- Assess the values and limitations of process intensification, cleaner technologies and waste minimization options.
- Measure and monitor the usage of raw materials and wastes generating from production and frame the strategies for reduction, reuse and recycle.
- Obtain alternative solutions ensuring a more sustainable future based on environmental protection, economic viability and social acceptance.
- Analyze data, observe trends and relate this to other variables.
- Plan for research in new energy systems, materials and process intensification.

UNIT I INTRODUCTION 9Hrs

Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, ProcessIntensifying Equipment, Process intensification toolbox, Techniques for PI application.

UNIT II PROCESS INTENSIFICATION THROUGH MICRO REACTION TECHNOLOGY9Hrs

Effect of miniaturization on unit operations and reactions, Implementation of Microreaction Technology, From basic Properties To Technical Design Rules, Inherent Process Restrictions in Miniaturized Devices and Their Potential Solutions, Microfabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes.

UNIT III SCALES OF MIXING, FLOW PATTERNS IN REACTORS, MIXING IN STIRRED TANKS 9Hrs

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.

UNIT IV COMBINED CHEMICAL REACTOR HEAT EXCHANGERS AND REACTOR SEPARATORS 9Hrs

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.

UNIT-V ENHANCED FIELDS 9Hrs

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, Superctrical fluids

Total no. of hrs: 45hrs

REFERENCES:

- Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
- Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.
- Kamelia Boodhoo (Editor), Adam Harvey (Editor),Process Intensification Technologies for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, Wiley, 2013.
- Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.)Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.
- Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013.

MCT20CE12 **Phase transitions in Process Equipment** **3 0 0 3**

OBJECTIVES:

- Basic laws in thermodynamics.
- Basic statistical concepts and methods: heat, work, energy, temperature and the kinetic theory of matter; entropy, ensemble, partition function, etc
- Learning phase transition catalysis
- Have a good grasp of the basic thermodynamic interactions and process: adiabatic, isothermal, etc

COURSE OUTCOMES:

At the end of this course, students are able to:

- The student is expected to obtain considerable insight into various types of phase transitions, and how these can be described theoretically in different ways
- Predict relationships between physical quantities using the laws and methods of thermodynamics.
- Find probabilities and thermal quantities (free energy, entropy, etc) given the energy eigenvalues of a system.

UNIT I **9Hrs**

Thermodynamic aspects of phase transitions, Concept of phase, First-order phase transition, conditions for phase coexistence lines, free energy barrier of nucleation, and crystal-melt interfacial free energy, Ehrenfest classification of phase transitions, Van der Waals equation of state, Critical point

UNIT II **9Hrs**

Acid--base catalysis, Transition metal catalysis, Phase transfer catalysis, Micellar catalysis, Microemulsion catalysis, Electron transfer catalysis, Heteropoly acid catalysis, Homogeneous polymer catalysis, Heterogenisation of homogeneous catalysts.

UNIT III **9Hrs**

Applications to Multi-phase Systems Stability conditions for a homogeneous system, equilibrium between phases, phase transformations, general relations for a system with several components, general conditions for chemical equilibrium, chemical equilibrium between ideal gases, and the equilibrium constants in terms of partition functions.

UNIT IV **9Hrs**

Phase diagrams and transformations Phase rule- single and binary phase diagrams, lever rule, micro structural changes during cooling, Al_2O_3, Cr_2O_3, Pb-Sn, Ag-Pt and Fe-Fe_3C Systems phase diagrams, phase transformations, corrosion- theories of corrosion, control and prevention of corrosion

UNIT V **9Hrs**

Energy balance - heat capacity and calculation of enthalpy changes, Enthalpy changes for phase transitions, evaporation, clausius - clapeyron equation.

Total no. of hrs: 45Hrs

REFERENCES:

- Hegedus, L.S., Transition Metals in the Synthesis of Complex Organic Molecules, University Science Book (2010) 3rd ed.
- Raghavan V., Material Science and Engineering Prentice Hall of India, 1996
- David.M.Himmelblau, "Basic principles and calculations in chemical engineering", Prentice Hall of India Ltd., 6th Edition, 1998.
- A.Hougen, K.M. Watson and K.A.Ragatz, "Chemical Process Principles", Vol 1, John Wiley, 1960.

MCT20CE13 **Micro and Nano fluidics** **3 0 0 3**

OBJECTIVES:

- To introduce to the students, the various opportunities in the emerging field of micro and nano fluids.
- To the make students familiar with the important concepts applicable to small micro and nano fluidic devices, their fabrication, characterization and application.
- To get familiarize with the new concepts of real-time nano manipulation & assembly

COURSE OUTCOMES:

At the end of this course, students are able to:

- Introduce students to the physical principles to analyze fluid flow in micro and nano-size devices. It unifies the thermal sciences with electrostatics, electrokinetics, colloid science; electrochemistry; and molecular biology.

UNITI INTRODUCTION 9Hrs

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 analysis of 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.

UNIT II LAMINAR FLOW 9Hrs

Hagen-Poiseullie eqn, 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 nanotuble channels driven by Electric Fields and by Kinesin Biomolecular Motors - Electrophoresis of individual nanotubules in microfluidic channels.

UNIT III FABRICATION TECHNIQUES 9Hrs

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.

UNIT IV MICROFLUIDICS AND LAB-ON-A-CHIP 9Hrs

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.

UNIT V BIOMEMS (MICRO-ELECTRO-MECHANICAL SYSTEMS) 9Hrs

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).

Total no. of hrs: 45hrs

TEXT BOOKS:

- Joshua Edel "Nanofluidics" RCS publishing, 2009.
- Patric Tabeling "Introduction to Microfluids" Oxford U. Press, New York 2005.
- K. Sarit "Nano Fluids; Science and Technology", RCS Publishing, 2007.

REFERENCES

- M. Madou, Fundamentals of Microfabrication, CRC Press, 1997
- G. Kovacs, Micromachined Transducers, McGraw-Hill, 1998
- Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006

ELECTIVE -V

MCT20CE14	**Process Integration**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To introduce to the students, the various opportunities in the process integration in chemical industries.
- To the make students familiar with the important concepts process integration for heat recovery/minimization.
- To get familiarize with the case studies.

COURSE OUTCOMES:

At the end of this course, students are able to:

- Maximum heat recovery for a given process (both new processes, and retrofit of existing processes) identify opportunities for integration of high-efficiency energy.
- Energy-intensive thermal separation operations (distillation, evaporation) at an industrial process site.
- Evaluate the process integration measures with respect to energy efficiency, greenhouse gas emissions and economic performance.

UNITI INTRODUCTION **9Hrs**

Introduction to process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram.

UNIT II PINCH TECHNOLOGY-AN OVERVIEW **9Hrs**

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.

UNIT III HEAT EXCHANGER **9Hrs**

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.

UNIT IV **9Hrs**

Heat integrated distillation columns, evaporators, dryers, and reactors.

UNIT V **9Hrs**

Waste and waste water minimization, flue gas emission targeting, and heat and power integration. Case studies.

Total no. of hrs: 45hrs

REFERENCES:

- Shenoy U.V.;"Heat Exchanger Network Synthesis", Gulf Publishing company.
- Smith R.;"Chemical Process Design", McGraw-Hill.
- 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.

MCT20CE15 **Transport in porous Media** **3 0 0 3**

OBJECTIVES:

- Introduce the physics and governing mechanisms controlling flow and transport processes in porous media.
- Learning Liquid and solute transport in porous media.

COURSE OUTCOMES:

At the end of this course, students are able to:

- Students will understand the mechanisms involved in transport processes in porous media and will be able to work with the equations that govern the fate and transport of gas, water and solutes in porous media.

UNIT I FUNDAMENTALS **9Hrs**

Mass, momentum and energy transport, Darcy and Non-Darcy equations, equilibrium and non-equilibrium conditions, species transport, radioactive decay.

UNIT II EFFECTIVE MEDIUM APPROXIMATION **9Hrs**

Equivalent thermal conductivity, viscosity, dispersion.

UNIT III EXACT SOLUTIONS **9Hrs**

Flow over a flat plate, flow past a cylinder, boundary-layers, reservoir problems.

UNIT IV SPECIAL TOPICS **9Hrs**

Field scale and stochastic modeling, Turbulent flow, compressible flow, multiphase flow, numerical techniques, hierarchical porous media, nanoscale porous media, multiscale modeling.

UNIT V ENGINEERING APPLICATIONS **9Hrs**

Groundwater, waste disposal, oil and gas recovery, regenerators, energy storage systems. Experimental techniques: Flow visualization, quantitative methods, inverse parameter estimation.

Total no. of hrs: 45Hrs

REFERENCES:

- Principles of Heat Transfer in Porous Media, by M. Kaviany, Springer New York (1995).
- Transport Phenomena in Porous Media, Volumes I-III, edited by D. R. Ingham and I. Pop, Elsevier, New York (1998-2005).
- Dynamics of Fluids in Porous Media, J. Bear, Dover (1988).
- Introduction to Modeling of Transport Phenomena in Porous Media, J. Bear and Y. Bachmat, Kluwer Academic Publishers, London (1990).
- Enhanced Oil Recovery, L.W. Lake, Gulf Publishing Co. Texas (1989).
- The Mathematics of Reservoir Simulation, R.E. Ewing, SIAM Philadelphia (1983).
- Stochastic Methods for Flow in Porous Media: Coping with Uncertainties, Zhang, D., Academic Press, California (2002).
- The Method of Volume Averaging, S. Whitaker, Springer, New York (1999).

MCT20CE16 Micro Flow Chemistry and Process Technology 3 0 0 3

OBJECTIVES:

- Introduce the students to micro flow chemistry and process technology.
- Learning Micromixers, Mixing Principles.
- Learning micro reactor based chemicals production

COURSE OUTCOMES:

At the end of this course, students are able to:

- Students will understand the role of micro flow chemistry and process technology in chemical engineering.
- The student is expected to obtain considerable insight into various types of micro reactors.

UNIT I **9Hrs**

State of the Art of Microreaction Technology, Structural Hierarchy of Microreactors, Functional Classification of Microreactors, Fundamental Advantages of Microreactors, Advantages of Microreactors Due to Decrease of Physical Size, Advantages of Microreactors Due to Increase of Number of Units, Potential Benefits of Microreactors

UNIT II **9Hrs**

Modern Microfabrication Techniques for Microreactors, Evaluation of Suitability of a Technique, Anisotropic Wet Etching of Silicon, Dry Etching of Silicon, LIGA Process, Injection Molding, Wet Chemical Etching of Glass, Advanced Mechanical Techniques

UNIT III **9Hrs**

Micromixers, Mixing Principles and Classes of Macroscopic Mixing Equipment, Mixing Principles and Classes of Miniaturized Mixers, Mixing Tee-Type Configuration

UNIT IV **9Hrs**

Microsystems for Gas Phase Reactions, Catalyst Supply for Microreactors , Types of Gas Phase Microreactors, Microchannel Catalyst Structures, H_2/O_2 Reaction, Selective Partial Hydrogenation of Benzene, Selective Oxidation of 1-Butene to Maleic Anhydride, Selective Oxidation of Ethylene to Ethylene Oxide, Oxidative Dehydrogenation of Alcohols, Synthesis of Methyl Isocyanate and Various Other Hazardous Gases, Synthesis of Ethylene Oxide, Oxidation of Ammonia

UNIT V **9Hrs**

Microsystems for Energy Generation, Microdevices for Vaporization of Liquid Fuels, Microdevices for Conversion of Gaseous Fuels to Syngas by Means of Partial Oxidations, Hydrogen Generation by Partial Oxidations, Microdevices for Conversion of Gaseous Fuels to Syngas by Means of Steam Reforming

Total no. of hrs: 45hrs

REFERENCES:

- Wolfgang Ehrfeld, Volker Hessel, Holger Löwe MicroreactorsNew Technology for Modern Chemistry © WILEY-VCH Verlag GmbH, D-69469 Weinheim (Federal Republic of Germany), 2000.
- S.V. Luis and E. Garcia-Verdugo, Chemical Reactions and Processes under Flow Conditions, University Jaume I/CSIC, Castello´n, Spain, The Royal Society of Chemistry 2010
- Madhvanand N. Kashid, Albert Renken,and Lioubov Kiwi-Minsker, Microstructured Devices for Chemical Processing, Wiley-VCH Verlag GmbH & Co. KGaA, Boschstr ©2015 12, 69469 Weinheim, Germany
- Hessel, V., Renken, A., Schouten, J.C., Yoshida, Micro Process Engineering" A Comprehensive Handbook 2009, ISBN 978-3-527-31550-5.

MCT20CE17 Process Plant Design & Flow sheeting 3 0 0 3

OBJECTIVES:

- Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.
- Application of established engineering methods to complex engineering problem solving.
- Application of systematic engineering synthesis and design processes.

COURSE OUTCOMES:

At the end of this course, students are able to:

- Analyze, synthesize and design processes for manufacturing products commercially
- Integrate and apply techniques and knowledge acquired in other courses such as thermodynamics, heat and mass transfer, fluid mechanics, instrumentation and control to design heat exchangers, plate and packed columns and engineering flow diagrams
- Use commercial flow sheeting software to simulate processes and design process equipment
- Recognize economic, construction, safety, operability and other design constraints
- Estimate fixed and working capitals and operating costs for process plants

UNIT I INTRODUCTION 9Hrs

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.

UNIT II HIERARCHY OF CHEMICAL PROCESS DESIGN 9Hrs

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.

UNIT III FLOW-SHEETING 9Hrs

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.

UNIT IV ANALYSIS OF COST ESTIMATION 9Hrs

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.

UNIT V OPTIMUM DESIGN AND DESIGN STRATEGY 9Hrs

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.

Total no. of hrs: 45hrs

REFERENCES:

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

ELECTIVE V

MCT20CE18	**Design of Experiments and Parameter Estimation**	**3**	**0**	**0**	**3**

OBJECTIVES:

This subject provides students with the knowledge to

- Use statistics in experimentation;
- Understand the important role of experimentation in new product design, manufacturing process development, and process improvement;
- Analyze the results from such investigations to obtain conclusions; become familiar methodologies that can be used in conjunction with experimental designs for robustness and optimization.

COURSE OUTCOMES:

At the end of this course, students are able to:

- Plan experiments for a critical comparison of outputs
- Include statistical approach to propose hypothesis from experimental data
- Implement factorial and randomized sampling from experiments
- Estimate parameters by multi-dimensional optimization

UNIT I **9Hrs**

Design of experiments. Basic concepts, Bias and confounding, controlling bias, causation, Examples. Random Variables: Introduction to discrete and continuous random variables, quantify spread and central tendencies of discrete and continuous random variables.

UNIT II **9Hrs**

Exploratory Data Analysis Variable types, Displaying the distribution, mean variance and typical spread, quartiles and unusual spread, multivariate data: finding relations. Probability Definition of a random variable, expectation, percentiles, common distributions such as the binomial, Poisson and normal distributions.

UNIT III **9Hrs**

Point Estimation Estimators as random variables, sample mean and the central limit theorem, normal approximations, assessing normality. Interval Estimation Confidence intervals for the mean when the variance is known, confidence interval for the mean when the variance is unknown, confidence intervals for a single proportion, sample size, Student distribution. Hypothesis Testing Hypothesis testing for a mean or proportion, testing the equality of two means assuming equal variances, testing the equality of two means with unequal variances, comparison of two proportions.

UNIT IV **9Hrs**

Linear regression analysis, the linear regression model, Parameter estimation, accuracy of the coefficient estimates, checking the model, multiple linear regression, confidence and prediction intervals, potential issues, high leverage points, outliers. Matrix approach to linear regression, Variance-Covariance matrix, ANOVA in regression analysis, quantifying regression fits of experimental data, Extra sum of squares approach, confidence intervals on regression coefficients, lack of fit analysis.

UNIT V **9Hrs**

Response surface methodology, Method of steepest ascent, first and second order models, identification of optimal process conditions

Total no. of hrs: 45Hrs

REFERENCES:

- Hanneman, Robert A., Kposowa, Augustine J., Riddle, Mark D. (2012). Research Methods for the Social Sciences: Basic Statistics for Social Research. John Wiley & Sons.
- Saunders, Mark, Brown, Reva Berman (2007). Dealing with Statistics: What You Need to Know. McGraw-Hill Education.
- Cowles, Michael (2000). Statistics in Psychology: An Historical Perspective (2nd Edition).Lawrence Erlb

MCT20CE19 **Computer Aided Design** **3 0 0 3**

OBJECTIVES:

- To understand importance and applications of CAD in the field of chemical engineering
- To understand the basic structure and components of CAD software
- To understand the underlying thermodynamic and physical principles To give insight into the approaches used in the simulation of flow sheets
- To understand flow charts, computer languages and numerical methods used for writing algorithms

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- Students get the knowledge about computer Aided Flow Sheet Synthesis
- Computer aided equipment design of Evaporators; Distillation columns; Reactors, adsorption columns.

UNIT I INTRODUCTION **9Hrs**

Introduction to CAD, Scope and applications in chemical Engineering, Mathematical methods used in flow sheeting and simulation, Introduction to solution methods for linear and non-linear algebraic equations, solving one equation one unknown, solution methods for linear and nonlinear equations, general approach for solving sets of differential equations, solving sets of sparse non-linear equations.

UNIT II PROPERTIES ESTIMATION **9Hrs**

Physical properties of compounds, Thermodynamic properties of gases and binary mixtures, Viscosity, Vapour pressure, Latent heat, Bubble point and drew point calculation, phase equilidria, Vapour-liquid equilibria, Liquid phase activity coefficients, K-values, Liquid phase activity coefficients, K-values, Liquid-Liquid equilidria, Gas solutions.

UNIT III EQUIPMENT DESIGN **9Hrs**

Computer aided Design of Equipment: Design of Shell and Tube Heat exchangers; Design of Evaporators; Design of Distillation columns; Design of Reactors, Design of adsorption columns. Distillation columns (specific attention to multi components systems. Heat exchangers)

UNIT IV COMPUTER AIDED FLOW SHEET SYNTHESIS **9Hrs**

Computerized physical property systems – physical property calculations, degrees of freedom in process design, degrees of freedom for a unit, degrees of freedom in a flow sheet, steady state flow sheeting and process design, approach to flow sheeting systems, introduction to sequential modular approach, simultaneous modular approach and equation solving approach, sequential modular approach to flow sheeting, examples. Tear streams, convergence of tear streams, partitioning and tearing of a flow sheet, partitioning and precedence ordering, tearing a group of units. Flow sheeting by equation solving methods based on tearing.

UNIT V DYNAMIC SIMULATION **9Hrs**

Numerical recipes in CLinear and nonlinear equations, Ordinary and partial differential equations, Dynamic simulation of stirred tanks system with heating Multi component system, Reactors, Absorption and distillation columns, Application of orthogonal collocation and weighted residuals techniques in heat and mass transfer systems, Introduction to special software for steady and dynamic simulation of Chemical engineering systems. Introduction to various commercial design software and optimizers used in field of chemical engineering.

Total no. of hrs: 45hrs

REFERENCES

- Douglas James M., “Conceptual design of Chemical Processes", McGraw -Hill Book Company, New York, 1988
- Remirez, W.F. - " Computational methods for Process Simulations ", Butterworths, New York, 1989
- Sinnott R.K. "Chemical Engineering”, Volume 6, Pergamon Press, New York, 1989
- Westerberg A.W., et al, “Process Flow Sheeting”, Cambridge University Press
- Biegler Lorenz T, et al, “Systematic method of Chemical Process Design”, Prentice Hall
- Crowe C.M., et al, “Chemical Plant Simulation-An Introduction to Computer Aided Steady State Analysis”, Prentice Hall
- Anil Kumar, “Chemical Process Synthesis and Engineering Design”,TMH,1981

MCT20CE20 Cleaner Production 3 0 0 3

OBJECTIVES

- To give student an understanding about the concept of cleaner production.
- To understand in detail, the methodologies involved
- Financial evaluation of cleaner production technologies
- To study the practical applications of cleaner production technologies

COURSE OUTCOMES:

At the end of the course, the student will be able to:

- Explain the concept and principles of cleaner production.
- Suggest different unit operations in industrial production process to minimize pollutions.
- Plan good housekeeping practices for Industry/other places with concern of safety, hygiene and waste reduction.
- Suggest basic methods and techniques of pollution prevention during production.
- Suggest cleaner production methods for a given situation which will also lead to cost reduction in long run

UNIT I INTRODUCTION 9Hrs

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.

UNIT II CLEANER PRODUCTION TECHNIQUE 9Hrs

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.

UNIT III CLEANER PRODUCTION METHODOLOGY 9Hrs

Methods of environmental protection -- preventive strategy, Methods of environmental protection -- preventive strategy, making team for cleaner production, Analyzing process steps, Generating C.P opportunities Selection of C.P solution, Implementing C.P solution

UNIT IV CONCEPT OF CLEANER PRODUCTION 9Hrs

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 tocleaner 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.

UNIT V FINANCIAL ANALYSIS OF CLEANER PRODUCTION 9Hrs

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.

Total no. of hrs: 45hrs

Case studies and Cleaner Production applications

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.

REFERENCES

- "Cleaner Production Worldwide", 1993, United Nations Environment Programme, Industry and Environment, Paris, France, 1993
- "Cleaner Production: Training Resource Package", UNEP IE, Paris, 1996
- "Clean Technology for manufacture of Specialty Chemicals", Editor-W. Hoyle and M. Lancaster, Royal Society of Chemistry, U.K
- Randall Paul M, "Engineers Guide to Cleaner Production Technologies".
- Ahluvalia V. K., "Green Chemistry: Environmentally Benign Reactions".
- Sanders R.E., "Chemical Process Safety: Learning from case Histories", Oxford Butter Worth Publication
- "Training Manual Package" by NCPC

DEPARTMENT OF CHEMICAL ENGINEERING

OPEN ELECTIVES

MCT20OE01	**Business Analytics**	**3**	**0**	**0**	**3**

OBJECTIVE:

- Understand the role of business analytics within an organization.
- Analyze data using statistical and data mining techniques and understand relationships between the underlying business processes of an organization.
- To gain an understanding of how managers use business analytics to formulate and solve business problems and to support managerial decision making.
- To become familiar with processes needed to develop, report, and analyze business data.
- Use decision-making tools/Operations research techniques.
- Mange business process using analytical and management tools.
- Analyze and solve problems from different industries such as manufacturing, service, retail, software, banking and finance, sports, pharmaceutical, aerospace etc.

COURSE OUTCOMES:

- Students will demonstrate knowledge of data analytics.
- Students will demonstrate the ability of think critically in making decisions based on data and deep analytics.
- Students will demonstrate the ability to use technical skills in predicative and prescriptive modeling to support business decision-making.
- Students will demonstrate the ability to translate data into clear, actionable insights.

UNIT I BUSINESS ANALYTICS 9Hrs

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.

UNIT II TRENDINESS AND REGRESSION ANALYSIS 9Hrs

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.

UNIT III ORGANIZATION STRUCTURES OF BUSINESS ANALYTICS 9Hrs

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.

UNIT IV FORECASTING TECHNIQUES 9Hrs

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.

UNIT V

Decision Analysis: Formulating Decision Problems, Decision Strategies with the without Outcome Probabilities, Decision Trees, The Value of Information, Utility and Decision Making. Recent Trends in Embedded and collaborative business intelligence, Visual data recovery, Data Storytelling and Data journalism.

Total no. of hrs: 45Hrs

REFERENCE:

- Business analytics Principles, Concepts, and Applications by Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, Pearson FT Press.
- Business Analytics by James Evans, persons Education.

MCT20OE02 **Industrial Safety** **3 0 0 3**

UNIT I INDUSTRIAL SAFETY 9Hrs

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.

UNIT II FUNDAMENTALS OF MAINTENANCE ENGINEERING 9Hrs

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.

UNIT III WEAR AND CORROSION AND THEIR PREVENTION 9Hrs

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.

UNIT-IV FAULT TRACING 9Hrs

Fault tracing-concept and importance, decision treeconcept, 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,Electrical motors, Types of faults in machine tools and their general causes.

UNIT V PERIODIC AND PREVENTIVE MAINTENANCE 9Hrs

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

Total no. of hrs: 45hrs

REFERENCE:

- Maintenance Engineering Handbook, Higgins & Morrow, Da Information Services.
- Maintenance Engineering, H. P. Garg, S. Chand and Company.
- Pump-hydraulic Compressors, Audels, Mcgrew Hill Publication.
- Foundation Engineering Handbook, Winterkorn, Hans, Chapman & Hall London.

MCT20OE03 **Operations Research** **3 0 0 3**

COURSE OUTCOMES:

At the end of the course, the student should be able to

- Students should able to apply the dynamic programming to solve problems of discreet and continuous variables.
- Students should able to apply the concept of non-linear programming
- Students should able to carry out sensitivity analysis
- Student should able to model the real world problem and simulate it.

UNIT I **9Hrs**

Optimization Techniques, Model Formulation, models, General L.R Formulation, Simplex Techniques, Sensitivity Analysis, Inventory Control Models

UNIT II **9Hrs**

Formulation of a LPP - Graphical solution revised simplex method - duality theory - dual simplex method - sensitivity analysis - parametric programming

UNIT III **9Hrs**

Nonlinear programming problem - Kuhn-Tucker conditions min cost flow problem - max flow problem - CPM/PERT

UNIT IV **9Hrs**

Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models - Geometric Programming.

UNIT V **9Hrs**

Competitive Models,Single and Multi-channel Problems, Sequencing Models, Dynamic Programming, Flow in Networks, Elementary Graph Theory, Game Theory Simulation

Total no. of hrs: 45hrs

REFERENCES:

- H.A. Taha, Operations Research, An Introduction, PHI, 2008
- H.M. Wagner, Principles of Operations Research, PHI, Delhi, 1982.
- J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008
- Hitler Libermann Operations Research: McGraw Hill Pub. 2009
- Pannerselvam, Operations Research: Prentice Hall of India 2010
- Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010

MCT20OE04 Cost Management of Engineering Projects 3 0 0 3

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.
Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution : conception to commissioning. Project execution as conglomeration of technical and non technical 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. 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. 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. 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.

REFERENCES:

- Cost Accounting A Managerial Emphasis, Prentice Hall of India, NewDelhi
- Charles T. Horngren and George Foster, Advanced Management Accounting
- Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting
- Ashish K. Bhattacharya, Principles & Practices of CostAccounting A. H. Wheeler publisher
- N.D. Vohra, Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd.

MCT20OE05 Composite Materials 3 0 0 3

UNIT I INTRODUCTION 9Hrs

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.

UNIT II REINFORCEMENTS 9Hrs

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.

UNIT III MANUFACTURING OF METAL MATRIX COMPOSITES 9Hrs

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.

UNIT IV MANUFACTURING OF POLYMER MATRIX COMPOSITES 9Hrs

Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding. Properties and applications.

UNIT V STRENGTH 9Hrs

Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

Total no. of hrs: 45hrs

TEXT BOOKS:

- Material Science and Technology – Vol 13 – Composites by R.W.Cahn – VCH, West Germany.
- Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.

REFERENCES:

- Hand Book of Composite Materials-ed-Lubin.
- Composite Materials – K.K.Chawla.
- Composite Materials Science and Applications – Deborah D.L. Chung.
- Composite Materials Design and Applications – Danial Gay, Suong V. Hoa, and Stephen W. Tasi.

MCT20OE06 Waste to Energy 3 0 0 3

UNIT I INTRODUCTION 9Hrs

Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

UNIT II BIOMASS PYROLYSIS 9Hrs

Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

UNIT III BIOMASS GASIFICATION 9Hrs

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.

UNIT IV BIOMASS COMBUSTION 9Hrs

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.

UNIT V BIOGAS 9Hrs

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.

Total no. of hrs: 45hrs

REFERENCES:

- Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
- Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
- Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
- Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.

AUDIT 1 and 2: ENGLISH FOR RESEARCH PAPER WRITING 2 0 0 0

OBJECTIVES:

Students will be able to:

- Understand that how to improve your writing skills and level of readability
- Learn about what to write in each section
- Understand the skills needed when writing a Title
- Ensure the good quality of paper at very first-time submission

UNIT I

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding, Ambiguity and Vagueness.

UNIT II

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction.

UNIT III

Review of the Literature, Methods, Results, Discussion, Conclusions, the Final Check.

UNIT IV

Key skills are needed when 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.

UNIT V

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, and skills are needed when writing the Conclusions.

UNIT VI

Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission

SUGGESTED STUDIES:

- Goldbort R (2006) Writing for Science, Yale University Press (available on Google Books)
- Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press
- Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book .
- Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011

AUDIT 1 and 2: DISASTER MANAGEMENT 2 0 0 0

OBJECTIVES:

Students will be able to:

- learn to demonstrate a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- critically evaluate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
- develop an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- critically understand the strengths and weaknesses of disaster management approaches, planning and programming in different countries, particularly their home country or the countries they work in.

UNIT I INTRODUCTION DISASTER

Definition, Factors And Significance; Difference Between Hazard And Disaster; Natural And Manmade Disasters: Difference, Nature, Types And Magnitude

UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS

Economic Damage, Loss Of Human And Animal Life, Destruction Of Ecosystem.Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.

UNIT III DISASTER PRONE AREAS IN INDIA,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

UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT, PREPAREDNESS

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.

UNIT V RISK ASSESSMENT, DISASTER RISK

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.

UNIT VI

Disaster Mitigation, Meaning, Concept And Strategies Of Disaster Mitigation, Emerging Trends In Mitigation. Structural Mitigation And Non-Structural Mitigation, Programs Of Disaster Mitigation In India.

SUGGESTED READINGS:

- R. Nishith, Singh AK, "Disaster Management in India: Perspectives, issues and strategies "'New Royal book Company.
- Sahni, Pardeep Et.Al. (Eds.)," Disaster Mitigation Experiences And Reflections", Prentice Hall Of India, New Delhi.
- Goel S. L. , Disaster Administration And Management Text And Case Studies" ,Deep &Deep Publication Pvt. Ltd., New Delhi.

AUDIT 1 and 2: CONSTITUTION OF INDIA 2 0 0 0

OBJECTIVES:

- Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.
- To address the role of socialism in India after the commencement of the Bolshevik Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

COURSE OUTCOMES:

- Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
- Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
- Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
- Discuss the passage of the Hindu Code Bill of 1956.

Units	Content	Hours
1	• **History of Making of the Indian Constitution:** History Drafting Committee, (Composition & Working)	4
2	• **Philosophy of the Indian Constitution:** Preamble Salient Features	4
3	• **Contours of Constitutional Rights & Duties:** •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.	4
4	•Organs of Governance: • Parliament •Composition	4

	•Qualifications and Disqualifications •Powers and Functions • Executive •President •Governor •Council of Ministers •Judiciary, Appointment and Transfer of Judges, Qualifications •Powers and Functions	
5	•**Local Administration:** •District's Administration head: Role and Importance, •Municipalities: Introduction, Mayor and role of Elected Representative, CEO of Municipal Corporation. •Pachayati raj: Introduction, PRI: Zila Pachayat. •Elected officials and their roles, CEO Zila Pachayat: Position and role. •Block level: Organizational Hierarchy (Different departments), •Village level: Role of Elected and Appointed officials, •Importance of grass root democracy	4
6	• **Election Commission:** • 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.	4

SUGGESTED READING

- The Constitution of India, 1950 (Bare Act), Government Publication.
- Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
- M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis, 2014.
- D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

DEPARTMENT OF CHEMICAL ENGINEERING

AUDIT 1 and 2: PEDAGOGY STUDIES **2 0 0 0**

OBJECTIVES:

- Review existing evidence on the review topic to inform programme design and policy making undertaken by the DfID, other agencies and researchers.
- Identify critical evidence gaps to guide the development

COURSE OUTCOMES

- What pedagogical practices are being used by teachers in formal and informal classrooms in developing countries?
- What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
- How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

Units	Content	Hours
1	• Introduction and Methodology • Aims and rationale, Policy background, Conceptual framework and terminology • Theories of learning, Curriculum, Teacher education. • Conceptual framework, Research questions. • Overview of methodology and Searching.	4
2	• Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries. • Curriculum, Teacher education.	2
3	• Evidence on the effectiveness of pedagogical practices • Methodology for the in depth stage: quality assessment of included studies. • How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy? • Theory of change. • Strength and nature of the body of evidence for effective pedagogical practices. • Pedagogic theory and pedagogical approaches. • Teachers' attitudes and beliefs and Pedagogic strategies.	4
4	• Professional development: alignment with classroom practices and follow- up support • Peer support • Support from the head teacher and the community. • Curriculum and assessment • Barriers to learning: limited resources and large class sizes	4
5	**Research gaps and future directions** • Research design • Contexts • Pedagogy • Teacher education • Curriculum and assessment • Dissemination and research impact.	2

SUGGESTED READING

- Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2): 245-261.
- Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.
- Akyeampong K (2003) Teacher training in Ghana - does it count? Multi-site teacher education research project (MUSTER) country report 1. London: DFID.
- 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.
- Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
- Chavan M (2003) Read India: A mass scale, rapid, 'learning to read' campaign.
- www.pratham.org/images/resource%20working%20paper%202.pdf.

AUDIT 1 and 2: SANSKRIT FOR TECHNICAL KNOWLEDGE 2 0 0 0

OBJECTIVES

- To get a working knowledge in illustrious Sanskrit, the scientific language in the world
- Learning of Sanskrit to improve brain functioning
- Learning of Sanskrit to develop the logic in mathematics, science & other subjects enhancing the memory power
- The engineering scholars equipped with Sanskrit will be able to explore the huge knowledge from ancient literature

COURSE OUTCOMES

- Understanding basic Sanskrit language
- Ancient Sanskrit literature about science & technology can be understood
- Being a logical language will help to develop logic in students

Unit	*Content*	*Hours*
1	• Alphabets in Sanskrit, • Past/Present/Future Tense, • Simple Sentences	8
2	• Order • Introduction of roots • Technical information about Sanskrit Literature	8
3	• Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics	8

SUGGESTED READING

❖ "Abhyaspustakam" – Dr.Vishwas, Samskrita-Bharti Publication, New Delhi
❖ "Teach Yourself Sanskrit" Prathama Deeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
❖ "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi.

AUDIT 1 and 2: VALUE EDUCATION **2 0 0 0**

OBJECTIVES

Students will be able to

- Understand value of education and self- development
- Imbibe good values in students
- Let the should know about the importance of character

COURSE OUTCOMES

Students will be able to

- Knowledge of self-development
- Learn the importance of Human values
- Developing the overall personality

Syllabus

Unit	*Content*	*Hours*
1	• Values and self-development –Social values and individual attitudes. Work ethics, Indian vision of humanism. • Moral and non- moral valuation. Standards and principles. • Value judgements	4
2	• Importance of cultivation of values. • Sense of duty. Devotion, Self-reliance.Confidence,Concentration.Truthfulness, Cleanliness. • Honesty ,Humanity.Power of faith, National Unity. • Patriotism.Love for nature ,Discipline	6
3	• Personality and Behaviour Development - Soul and Scientific attitude.Positive Thinking.Integrity and discipline. • Punctuality, Love and Kindness. • Avoid fault Thinking. • Free from anger, Dignity of labour. • Universal brotherhood and religious tolerance. • True friendship. • Happiness Vs suffering, love for truth. • Aware of self-destructive habits. • Association and Cooperation. • Doing best for saving nature	6
4	• Character and Competence –Holy books vs Blind faith. • Self-management and Good health. • Science of reincarnation. • Equality ,Non violence ,Humility, Role of Women. • All religions and same message. • Mind your Mind ,Self-control. • Honesty, Studying effectively	6

SUGGESTED READING

❖ 1 Chakroborty , S.K. “Values and Ethics for organizations Theory and practice”, Oxford University Press ,New Delhi

AUDIT 1 and 2: STRESS MANAGEMENT THROUGH YOGA 2 0 0 0

OBJECTIVES

- To Understand the Basic Concepts of Yoga
- To Gain knowledge on Ashtanga yoga
- To Acquire knowledge of Techniques and Practice of Yogasanas
- To Understand stress and the causes
- To Attain the knowledge about stress busting through yoga

COURSE OUTCOMES:

- Understand the Basic Concepts of Yoga
- Gain knowledge on Ashtanga yoga
- To Understand stress and the causes
- Acquire knowledge of Techniques and Practice of Yogasanas
- Attain the knowledge about stress busting through yoga

Unit	*Content*	*Hours*
1	What is stress - Symptoms of stress - Why is stress helpful - Why is stress harmful - Stress versus burnout - Main types of stress - Know your stressors - Tips to Manage Stress	
2	Strength, Weaknesses, Opportunities and Threats (SWOT) Analysis, Who am I, Attributes, Importance of Self Confidence, Self Esteem. Emotional Intelligence What is Emotional Intelligence, emotional quotient why Emotional Intelligence matters, Emotion Scales. Managing Emotions	
3	What is Yoga – Definition and Its Branches - Hatha Yoga – Kundalini Yoga – Tantra Yoga – Kriya Yoga – Introduction To Ashtanga Yoga	
4	Mechanism of Stress related diseases: Psychic, Psychosomatic, Somatic and Organic phase. Role of Meditation & Pranayama on stress – physiological aspect of Meditation. Constant stress & strain, anxiety, conflicts resulting in fatigue among Executive. Contribution of Yoga to solve the stress related problems of Executive.	
5	Meaning and definition of Health – various dimensions of health (Physical, Mental, Social and Spiritual) – Yoga and health – Yoga as therapy. Physical fitness. Stress control exercise – Sitting meditation, Walking meditation, Progressive muscular relaxation, Gentle stretches and Massage.	

SUGGESTED READING

- ‘Andrews, Linda Wasmer., (2005). Stress Control for peace of Mind. London: Greenwich Editions Lalvani, Vimla., (1998). Yoga for stress. London: Hamlyn
- Nagendra, H.R., and Nagarathana, R., (2004). Yoga perspective in stress management. Bangalore: Swami Vivekananda Yoga Prakashana.
- Nagendra, H.R., and Nagarathana, R., (2004). Yoga practices for anxiety & depression. Bangalore: Swami Sukhabodhanandha Yoga Prakashana.
- Sukhabodhanandha, Swami., (2002). Stress Management. Banglore: Prasanna trust.
- Udupa, K.N., (1996). Stress management by Yoga. NewDelhi: Motilal Banaridass Publishers Private Limited

AUDIT 1 and 2: PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS **2 0 0 0**

OBJECTIVES

- To learn to achieve the highest goal happily
- To become a person with stable mind, pleasing personality and determination
- To awaken wisdom in students

COURSE OUTCOMES

- Study of Shrimad-Bhagwad-Geeta will help the student in developing his personalityand achieve the highest goal in life
- The person who has studied Geeta will lead the nation and mankind to peace and prosperity
- Study of Neetishatakam will help in developing versatile personality of students.

Unit	Content	Hours
1	Neetisatakam-Holistic development of personality • Verses- 19,20,21,22 (wisdom) • Verses- 29,31,32 (pride & heroism) • Verses- 26,28,63,65 (virtue) • Verses- 52,53,59 (dont's) • Verses- 71,73,75,78 (do's)	8
2	• Approach to day to day work and duties. • Shrimad Bhagwad Geeta : Chapter 2-Verses 41, 47,48, • Chapter 3-Verses 13, 21, 27, 35, Chapter 6-Verses 5,13,17, 23, 35 • Chapter 18-Verses 45, 46, 48.	8
3	• Statements of basic knowledge. • Shrimad Bhagwad Geeta : Chapter2-Verses 56, 62, 68 • Chapter 12 -Verses 13, 14, 15, 16,17, 18 • Personality of Role model. Shrimad Bhagwad Geeta : Chapter2-Verses 17,Chapter 3-Verses 36,37,42, • Chapter 4-Verses 18, 38,39 • Chapter18 – Verses 37,38,63	8

SUGGESTED READING

❖ "Srimad Bhagavad Gita" by Swami Swarupananda Advaita Ashram (Publication Department), Kolkata
❖ Bhartrihari's Three Satakam (Niti-sringar-vairagya) by P.Gopinath, ashtriya Samskrit Sansthanam, New Delhi.