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UNIVERSITY OF MUMBAI

Revised Syllabus for the

M. E. (Chemical Engineering)

Program: M.E.

Course: Chemical Engineering

(As per Credit Based Semester and Grading System with effect from the academic year 2012–2013)

University of Mumbai

Program Structure for

ME (Chemical Engineering)

With Effect from 2012-2013)

Semester I

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHC101	Advanced Fluid Dynamics	04	--	--	04	--	--	04
CHC102	Advanced Reaction Engineering	04	--	--	04	--	--	04
CHC103	Advanced Thermodynamics	04	--	--	04	--	--	04
CHE101X	Elective I	04	--	--	04	--	--	04
CHE102X	Elective II	04	--	--	04	--	--	04
CHL101	Laboratory I - Advanced Fluid Dynamics	--	02	--	--	01	--	01
CHL102	Laboratory II - Advanced Reaction Engineering	--	02	--	--	01	--	01
Total		**20**	**04**	**--**	**20**	**02**	**--**	**22**

Subject Code	Subject Name	Examination Scheme							
		Theory					Term Work	Pract/ oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test1	Test 2	Avg.					
CHC101	Advanced Fluid Dynamics	20	20	20	80	03	--	--	100
CHC102	Advanced Reaction Engineering	20	20	20	80	03	--	--	100
CHC103	Advanced Thermodynamics	20	20	20	80	03	--	--	100
CHE101X	Elective I	20	20	20	80	03	--	--	100
CHE102X	Elective II	20	20	20	80	03	--	--	100
CHL101	Laboratory I - Advanced Fluid Dynamics	--	--	--	--	--	25	25	50
CHL102	Laboratory II - Advanced Reaction Engineering	--	--	--	--	--	25	25	50
Total		**100**	**100**	**100**	**400**	**--**	50	**50**	**600**

Semester II

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHC201	Advanced Mass Transfer	04	--	--	04	--	--	04
CHC202	Advanced Process Dynamics & Control	04	--	--	04	--	--	04
CHC203	Process Heat Transfer	04	--	--	04	--	--	04
CHE201X	Elective III	04	--	--	04	--	--	04
CHE202X	Elective IV	04	--	--	04	--	--	04
CHL201	Laboratory III - Advanced Mass Transfer	--	02	--	--	01	--	01
CHL202	Laboratory IV - Advanced Process Dynamics & Control	--	02	--	--	01	--	01
Total		**20**	**04**	**--**	**20**	**02**	**--**	**22**

Subject Code	Subject Name	Examination Scheme							
		Theory					Term Work	Pract./ oral	Total
		Internal Assessment			End Sem.Exam.	Exam. Duration (in Hrs)			
		Test1	Test 2	Avg.					
CHC201	Advanced Mass Transfer	20	20	20	80	03	--	--	100
CHC202	Advanced Process Dynamics & Control	20	20	20	80	03	--	--	100
CHC203	Process Heat Transfer	20	20	20	80	03	--	--	100
CHE201X	Elective III	20	20	20	80	03	--	--	100
CHE202X	Elective IV	20	20	20	80	03	--	--	100
CHL201	Laboratory III - Advanced Mass Transfer	--	--	--	--	--	25	25	50
CHL202	Laboratory IV - Advanced Process Dynamics & Control	--	--	--	--	--	25	25	50
Total		**100**	**100**	**100**	**400**	--	**50**	**50**	**600**

Semester III

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHS301	Seminar	--	06	--	--	03	--	03
CHD301	Dissertation I	--	24	--	--	12	--	12
Total		**--**	30	--	--	15	--	15

Subject Code	Subject Name	Examination Scheme						
		Theory				Term Work	Pract./ Oral	Total
		Internal Assessment			End Sem.Exam.			
		Test1	Test 2	Avg.				
CHS301	Seminar	**--**	**--**	**--**	--	50	50	100
CHD301	Dissertation I	**--**	**--**	**--**	--	100	--	100
Total		**--**	**--**	**--**	**--**	**150**	**50**	**200**

Semester IV

Subject Code	Subject Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHD401	DissertationII	--	30	--	--	15	--	15
Total		**--**	30	--	--	15	--	15

Subject Code	Subject Name	Examination Scheme						
		Theory				Term Work	Pract./ Oral	Total
		Internal Assessment			End Sem.Exam.			
		Test1	Test 2	Avg.				
CHD401	DissertationII*	**--**	**--**	**--**	--	100	100	200
Total		**--**	**--**	**--**	**--**	**100**	**100**	**200**

Note:

- In case of Seminar, 01 Hour / week / student should be considered for the calculation of load of a teacher.
- In case of Dissertation I, 02 Hour / week / student should be considered for the calculation of load of a teacher
- In case of Dissertation II, 02 Hour / week / student should be considered for the calculation of load of a teacher

Subject Code	Elective I	Subject Code	Elective II
CHE1011	Environmental Engineering	CHE1021	Energy Audit & Conservation in Process Industries
CHE1012	Chemical Process Synthesis	CHE1022	Petroleum Refining
CHE1013	Advanced Chemical Analysis	CHE1023	Advanced Process Optimization

Subject Code	Elective III	Subject Code	Elective IV
CHE2011	Advanced Computer Aided Design	CHE2021	Corrosion in Industry and its Control
CHE2012	Polymerization Reaction Engineering	CHE2022	Advanced Separation Techniques
CHE2013	Nanotechnology	CHE2023	Catalysis

Subject Code	Subject Name	Credits
CHC101	Advanced Fluid Dynamics	**04**

Module	Detailed content
1	**(1) Introduction:-** Equation of continuity, equation of motion, Navier Stokes equation, Euler equation, Bernoulli equation, Momentum boundary layer theory (Laminar boundary theory & turbulent boundary layer theory), dimensionless number and its significance, **(2) Non-Newtonian Fluids**: - Classification of fluid behavior, Laminar flow(Fluid with a yield stress)- Laminar flow in cylindrical tubes, Laminar flow between parallel plates, Laminar flow in annuli(Newtonian fluids Bingham Plastic Fluids), Laminar flow(fluids without a yield stress), Power law fluids.
2	**Compressible fluids** : - Flow through variable area-conduits, Flow of gas through a nozzle or orifice (isothermal flow, non isothermal flow), Flow in a pipe (Energy balance for flow of ideal gas, isothermal flow of an ideal gas in a horizontal pipe, Flow with fixed upstream pressure and variable downstream pressure, Non- isothermal flow of an ideal gas in a horizontal pipe, Adiabatic flow of an ideal gas in a horizontal pipe)
3	**Agitation and Mixing:** - Agitation of Liquids, Mixing mechanisms (Laminar mixing, Turbulent mixing), Circulation, Velocities in stirred tanks, Flow patterns in stirred tanks, Power consumptions in stirred vessels, Mixing Equipments (Impellers. Propellers Turbines, Extruders, Baffles).
4	**Flow of multiphase mixtures:-** Two phase gas vapor liquid flow, horizontal and vertical flows of gas - liquids, liquid, gas – solid mixtures, slip and hold up effects, phase separation and settling behavior, pressure, momentum and energy relations, practical methods for evaluating pressure drop.
5	**Motion in the fluidized bed:-** conditions for fluidization, behavior of the fluidized bed, minimum fluidization velocity, different types of fluidization, particulate fluidization, bubbling fluidization, semi fluidization, mixing and segregation in fluidized bed, application of fluidization
6	**Jets and Sprays:-** Jet ejector, jet mixer, spray nozzle, high velocity spray nozzle.

References:

(1) "**The Flow of Complex Mixtures in Pipes"** by Govier and Aziz.

(2) "**Non Newtonian Flow and Heat Transfer"** by A. H. P. Skelland

(3) "**Chemical Engineering"** by Coulson and Richardson, Volume I.

Assessment:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Subject Code	Subject Name	Credits
CHC102	Advanced Reaction Engineering	**04**

Module	Detailed content
1	Module No. 1 ***RTD for Chemical Reactors*** General characteristics, Measurement of RTD characteristics, RTD in ideal Reactors, Zero Parameter Models, Segregation Model
2	Module No. 2 ***Analysis of Non-Ideal reactors*** Basic Data, one parameter Models, The tank in the series Models, The dispersion model, two parameter model, Testing the model and determining its parameters, Other models of the non ideal reactors using the CSTR's and PFR's using the RTD
3	Module No. 3 ***Rate equation for Fluid-Solid reactions*** Rate of the absorption, desorption,surface reaction,synthesizing rate law,mechanism and rate limiting steps, design of the reactors for the gas solid reactions, heterogeneous data analysis for the reactor designs, catalysts deactivation, moving bed reactors
4	Module No. 4 ***External diffusion effects on the Heterogeneous Reactions*** Binary diffusion, External resistance to Mass Transfer, The shrinking core model
5	Module No. 5 ***Diffusion and Reaction in Porous Catalysts*** Diffusion and Reactions in spherical catalyst pellets, Internal effectiveness factor, Flasefied kinetics, Overall effectiveness factor, Estimation of diffusion and reaction limited regimes, mass transfer and reaction in packed bed, The determination of limiting situation from reaction data
6	Module No. 6 ***Design of Heterogeneous Catalytic Reactors*** Isothermal and adiabatic fixed bed reactors, Non-Isothermal, Non-adiabatic fixed bed reactors, slurry reactors, trickle bed reactors

Reference Books:

H.Scott Foggler, Element of Chemical Reaction Engineering, 2nd edition, Prentice Hall of India

J.M.Smith, Chemical Engineering Kinetics, 3rd edition, Mc Graw Hill Publications

J.Canberry, Chemical and Catalytic Reaction Engineering, Mc Graw Hill Publications

O. Levenspiel, Chemical Reaction Engineering, 3rd edition, John Wiley & Sons, 2004.

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Subject Code	Subject Name	Credits
CHC103	Advanced Thermodynamics	**04**

Module	Detailed content
1	Module 1 Classical Thermodynamics of Phase Equilibria
2	Module 2 Thermodynamic Properties from Volumetric Data
3	Module 3 Fugacities in Gas Mixtures
4	Module 4 Fugacities in Liquid Mixtures: Excess Functions
5	Module 5 Fugacities in Liquid Mixtures: Models and Theories of Solutions

Reference Books:

Reference Books:

J.M.Prausnitz, Molecular Thermodynamics of Fluid-Phase Equilibria, Prentice Hall Inc, New Jersey

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Subject Code	Subject Name	Credits
CHE1011	Environmental Engineering	**04**

Module	Detailed content
1	Module No. 1 Pollution & its measurement (involves Water Pollution, Air Pollution, Noise & Nuclear Pollution)
2	Module No.2 Introduction (includes Industrial pollution) Analysis of Pollutants (involves COD, DO, BOD, TS,TSS,TVSS,TDS,MLSS, MLVSS) with case study of industrial effluents / water
3	Module No.3 Pollution control for specific pollutants Removal of BOD, Removal of Chromium, Removal of Mercury, Removal of Ammonia / Urea
4	Module No.4 Treatment of Phenolic effluents Removal of Particulate matters, Removal of Sulphur dioxide, Removal of Oxides of Nitrogen, Removal of Organic vapour from effluent gases
5	Module No.5 Pollution control in selected process industries General consideration of pollution control in chemical industries, Pollution control in Petroleum refineries and Petrochemical units
6	Module No.6 Pollution control in Paper industries, miscellaneous industries

Reference Books:

A.Mahajan, Pollution control in process industries (1985), Mc Graw Hill publishing Co.

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Subject Code	Subject Name	Credits
CHE1012	Chemical Process Synthesis	**04**

	Detailed content
	Synthesis of steady state flow sheet. Optimization of flow sheet with the respective heat-exchanger network. Optimization of steady state flow sheet with respect to adjustment of the concentration. Synthesis of process flow sheet. Safety in Chemical plant designing. Trouble shooting hazard analysis. Fault diagnosis in chemical plant through data analysis and computation. Reliability consideration in maintenance policies of a chemical plant

Reference Books:

Anil Kumar, Chemical Process Synthesis and Engineering Design, (1981), Tata McGraw Hill.

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Subject Code	Subject Name	Credits
CHE1013	Advanced Chemical Analysis	**04**

	Detailed content
	Introduction to Spectroscopical Methods Of Analysis analysis. Molecular Spectroscopy, Atomic Spectroscopy, Polarimetry And Digital control : Hardware & Software requirement, Introduction of DDC, Refractometry, Electrometric Methods Of Analysis, XRD Analysis Thermal Methods, Chromatographic Methods QUANTITATIVE SPECTROSCOPY: Beer-Lambert's Law, Limitations, Deviations (Real, Chemical, Instrumental). Nesslerimetry, Duboscq colourimetry, Estimation of inorganic ions such as Fe, Ni and estimation of Nitrite using Beer-Lambert's Law. Various electronic transitions in organic and inorganic compounds effected by UV, Visible and infra red radiations, Various energy level diagrams of saturated, unsaturated and carbonyl compounds, excitation by UV and Visible radiations, Woodward-Fischer rules for the calculation of absorption maxima (dienes and carbonyl compounds), Effects of auxochromes and effects of conjugation on the absorption maxima, Instrumentation for UV, VISIBLE and IR spectroscopies (Source, Optical parts and Detectors), Multicomponent analysis, Classification of chromatographic methods, Column, Thin layer, Paper, Gas,High Performance Liquid Chromatographical methods (Principle, mode of separation and Technique). Separation of organic compounds by column and Thin layer, mixture of Cu, Co and Ni by Paper, separation of amino acids by paper, estimation of organic compounds by GC and HPLC.

Reference Books:

1. Parikh V.M., " Absorption Spectroscopy of Organic Molecules ",
Addison - Wesley Publishing Company, 1974.
2. Willard, H.H., Merritt. I.I., Dean J.A., and Settle, F.A., " Instrumental
Methods of Analysis", Sixth edition, CBS publishers, 1986.
3. Skoog D.A. and West D.M., " Fundamentals of Analytical
Chemistry", Saunders-College Publishing, 1982.
4. Banwell, G.C., " Fundamentals of Molecular Spectroscopy", TMH,
1992.

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Subject Code	Subject Name	Credits
CHE1021	Energy Audit & Conservation in Process Industries	**04**

Module	Detailed content
1	Module No. 1 Introduction Energy outlook in India and Global Energy outlook, Need for Energy Conservation in Process Industries
2	Module No. 2 Energy Audit Characterizing Energy Use, Energy Audit Procedure, Factors to be considered during Energy Audit
3	Module No. 3 Energy Efficient Operations Optimum performance of existing facilities, Facilities Improvement
4	Module No. 4 Thermodynamics and Economics-Part 1 Second Law of Thermodynamics revisited, Methodology of Thermodynamic analysis, Thermodynamic analysis of common unit operations F.E. Albert Thumann, Handbook of Energy Audits,(1979). The Environment Press.
5	Module No. 5 Thermodynamics and Economics-Part 2 Use of Thermodynamic analysis to improve energy efficiency, Systematic design methods
6	Module No. 6 Guidelines and Recommendations for Energy Efficiency Guidelines and Recommendations for improving process operation

Reference Books:

W. F. Kenny, Energy Conservation in the Process Industries (1984), Academic Press Inc. (London) Ltd.

Practical Technique for saving Energy in Chemical, Petroleum and Metal industries, (1977), Noyes Data Operations.

N. Boustead , G. F.Hancock, Handbook of Industrial Energy Analysis (1979), Ellis Horwood Ltd. Chichester (UK)

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Subject Code	Subject Name	Credits
CHE1022	Petroleum Refining	**04**

	Detailed content
	Physical and Chemical operations to produce and products from crude oil, Blending of stocks to meet products specifications, Design of selected refinery units. Selection and conversion of petroleum feedstock's to chemicals, cracking oxidation, alkylation, dealkylation, isomerization and disproportionation processes. Basics and Design aspects, Economics considerations

Reference Books:

W.L.Nelson, Petroleum Engineering, (1961), McGraw Hill

R.J.Hengaleback, Petroleum Refining (1959), McGraw Hill

V.Y. Stern, Gas Phase Oxidation, Petroleum Technology. 4th Edition, (1973), Applied Science, London.

L.F. Hatch and S. Matar, From Hydrocarbon to Petrochemicals (1981), Gulf Publishers, Houston.

Assessment:

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Subject Code	Subject Name	Credits
CHE1023	Advanced Process Optimization	**04**

Module	Detailed content
1	Introduction to optimization Basic concept of optimization, Mathematical formulation of optimization problems; Classification of Optimization Problems – single variable problems, multivariable problems with constraints, maximization and minimization problems Optimization of Unconstrained functions one dimensional search; analytical methods, numerical methods, scanning and bracketing techniques, region elimination techniques, examples.
2	Multivariable Search – Analytical Methods: Classification, stationary points, direct substitution, constrained variation, penalty function, Kuhn-Tucker theorem, Quadratic Programming, Geometric programming
3	Multivariable Search – Numerical Methods: General principles of numerical search, direction of search, final stage in search, direct search, pattern search, acceleration in direct search, gradient methods, the complete method of box
4	Non-linear Programming with constraints and its applications Quadratic Programming, Generalized reduced gradients methods, successive linear and successive quadratic programming, integer and mixed integer programming
5	Applications of optimization in chemical engineering Optimization of stagedand discrete processes, optimization of liquid-liquid extraction process, economic operation of fixed bed filter
6	Non-traditional Optimzation Techniques Statistical Optimzation Techniques – Genetic Algorithm, simulated Annealing, Ant colony optimization, TABU search, multi objective optimization. Artificial neural Network, Fuzzy Logic.

Reference Books:

1. Optimization in Chmical Processes, Edger, Himmelblau, Lasdon, McGraw Hill Publication
2. Optimization Theory & Practice, Gordon S.G. Beveridge and Robert S Schecter, McGraw Hill Publication
3. Engineering Optimization – Theory and Practice, Singiresu S. Rao, New Age International Publishers
4. Product and Process design Principles, Warren D Sieder, J.D. Sieder, Daniel R Lewin, John Wiley & Sons Inc.
5. Systematic Methods of Chemical Process Design, Lorens T. Biegler, E. Ignacio Grossmann, Arthur W Westerberg, PHI
6. Engineering Optimization Methods and Applications, Rekllaities F.V., ravindran A. and ragsdell K.M., John Willey, 1983

Assessment:

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End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Subject Code	Subject Name	Credits
CHL101	**Laboratory I - Advanced Fluid Dynamics**	**01**

Minimum Seven Practicals should be performed from the following List of Experiments

List of Experiments:

1. Boundary Layer formation over a flat surface

2. Flow around a cylinder placed in wind stream

3. Experiment on fluidization (gas- solid)

4. Experiment on fluidization (solid- liquid)

5. Flow through Helical Coil

6. Hydro dynamics of packed bed

7. Mixing Efficiency in a Stirred Tank.

8. Flow of Non-Newtonian fluid through Duct

9. Computational Fluid Dynamics

10. Experimental Studies of Flow Parameters on Optimising the Mixing Time in Jet Mixer

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
CHL102	**Laboratory III - Advanced Reaction Engineering**	**01**

Minimum Seven Practicals should be performed from the following List of Experiments

List of Experiments:

1. Batch Reactor
2. Plug Flow Reactor
3. Single Continuous Stirred Tank Reactor(CSTR)
4. Two CSTR's in series
5. CSTR followed by PFR
6. Residence time distribution in CSTR
7. Residence time distribution in PFR
8. Adsorption Isotherm
9. Packed Bed Reactor
10. Semi-batch Reactor

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
CHC201	Advanced Mass Transfer	**04**

Module No	Content
1	Multi Component Distillation - Selection of operating pressure, Equilibrium for Multi component System, Methods for Multi Component Distillation, Design of Batch Distillation for Multi component with Rectification with constant reflux & constant over head component
2	Continuous distillation of multi component system, Energy Conservation in Distillation column, Advance topics in distillation
3	Membrane Separation Techniques - Basic Equation for membrane separation for permeable & semi permeable membrane, Membrane types & their selection criteria, Technology based Membrane separation like Micro filtration, Ultra filtration, Reverse Osmosis, Nano filtration
4	Advances in Absorption - Criteria for selection of packed tower, tray tower, Spray chamber, Venturi Scrubber etc. Design of Falling Film Absorption, Design of Spray Chamber , Design of Venturi Scrubber, Advantage of Falling Film Absorber
5	Degree of Freedom for Different Equipments, such as distillation column, reactor, heat exchanger, pump etc
6	Super heated steam Drying, Introduction, Numericals

Text Books:

1. Introduction to Process Engineering and design by S.B.Thakore & B.I. Bhatt
2. Chemical Engineering Handbook 7th edition by R.H.Perry & Green D.
3. Mass Transfer Operation 3rd Edition by R.E.Treybal
4. B.D. Smith, Design of Equilibrium Staged Processes, McGraw Hill.
5. Van Winkle , Distillation, McGraw Hill.

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Subject Code	Subject Name	Credits
CHC202	Advanced Process Dynamics & Control	**04**

Module	Detailed content
1	**(1) Feed Back Control systems** : - Concept of feedback control, block diagram development, closed loop transfer functions, closed loop transient response, closed loop stability, root locus diagram. **(2) Conventional Feed Back Controller design** : - Preliminary consideration, Controller design principles, controller tuning with fundamental process models, Controller tuning using approximate process models, control valve and its characteristics, controller tuning using frequency response models, Nyquist stability criterion, Bode stability criterion, controller tuning without a model.
2	**(1) Design of more complex control structures :** - Process with significant disturbance, cascade control, feed forward control, feedback augmented feed forward control, ratio control, processes with multiple outputs controlled by a single input (Override controllers, Auctioneering control), Process with single output controlled with multiple input (Split range control, multiple input for improved dynamics), antireset windup. **(2) Controller design for with processes with difficult dynamics**: - Characteristics of difficult process dynamics, non minimum phase system, Time delay system, time delay compensation, inverse response system, inverse response compensation, open loop unstable systems.
3	**(1) Controller design for non linear systems**:- Nonlinear controller design philosophies, linearization and classical approach, adaptive control principles (Scheduled adaptive control, model reference adaptive control, self tuning adaptive control), variable transformations. **(2) Model based control**: - Solving the process control problem, model based approaches (Direct synthesis approach, optimization approach), controller design by direct synthesis, internal model control, generic model control, optimization approaches. **(3) Introduction to multivariable systems**:- Nature of multivariable systems, multivariable process model, multivariable transfer functions and open loop dynamic analysis.
4	**(1) Interaction analysis and multiple single loop design**: - Preliminary considerations of interaction analysis and loop pairing, relative gain array, loop pairing using RGA, loop paring for nonlinear systems, loop pairing for nonsquare systems, controller design procedure. **(2) Design of multivariable controllers**: - Decoupling, feasibility of steady state decoupler design, steady state decoupling by singular value decomposition. **(3) Introduction to Sampled Data Systems**: sampling and conditioning of continuous signals, signal conditioning, continuous signal reconstruction, mathematical description of discrete – time system, theoretical modeling of discrete time systems.
5	**(1) Tools of discrete time system analysis: -** Basic concepts of z – transforms, inverting z – transforms, Pulse transfer functions. **(2) Dynamic analysis of discrete time systems:** - Open loop responses, characteristics of open loop pulse transfer functions, block diagram analysis of sampled data systems, stability. **(3) Design of digital controllers:** - The digital controller and its design, discrete PID controller from the continuous domain, other digital controller based on continuous domain strategies, digital controllers based on discrete domain strategies.
6	**(1) Model Predictive Control: -** General principles of model predictive control, Model algorithmic control, commercial model predictive control schemes, academic and other contributions, nonlinear model predictive control, closing remarks. **(2) Statistical Process Control**: - The CUSUM chart, serial correlation effects and standard process control, stochastic process control.

Reference Books:

"Process Dynamics, Modeling, and Control" by Babatunde A. Ogunnaike, W. Harmon Ray**.**

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Subject Code	Subject Name	Credits
CHC203	Process Heat Transfer	**04**

Module	Detailed content
1	Module No. 1 Introduction and importance of the subject, Relevance of subject in industrial environment, Techniques of heat transfer, Dissipation of energy in industry, Concept of flow patterns and its uses in industry, Analogy between momentum of heat transfer.
2	Module No.2 Comparative study of Newtonian and non-Newtonian fluid in context with heat transfer, Newtonian and non-Newtonian heat transfer in circular tube, coils and other configuration, Non-Newtonian heat transfer in PFR, CSTR, Concept of vibrating / oscillating heat transfer.
3	Module No.3 Concept of multi phase flow, Concept of flow patterns and gas hold up in multi-phase flow, Momentum analysis in multiphase flow, Spouted bed heat transfer, Concept of semi fluidization and its industrial use, Porosity determination and its importance, Design of fluidized bed boiler and other related equipments.
4	Module No.4 Design concept of heat exchanger, Concept of LMTD method and its merits & demerits, Use of LMTD technique in designing heat exchangers, Recruparator, Condensers etc.
5	Module No.5 Purpose of introducing NTU techniques, its merits & demerits over LMTD method, Comparative design of double pipe heat exchanger, shell & tube heat exchanger, reboilers, oscillating heat exchanger.
6	Module No.6 Mechanisms of heat transfer in packed, fluidized and moving bed reactor, heat transfer in dilute phase transport, application of basic heat transfer equation in a design Use of heat transfer in furnaces, pipe still, thermo siphoning and other industries.

Reference Books:

Knudson D.G. and Katz D.L., Fluid dynamics & heat transfer, Mc Graw Hill (NY) (1958)

Hewitt G F, Shires G L, Bott T R, Process heat transfer CRC process (NY) (1994)

Max. Leva, Fluidization, John Wiley & Sons (NY) (1956)

Harison & Davidson, Fluidization engg, Mc Graw Hill (1968)

Skelland A H P, Non-Newtonian flow and heat transfer, Gesner Goizdl, Moscow (1984)

Srivastav R P S, Outlines of fluid flow operation, Khanna publishers, (New Delhi) (1984)

Assessment:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Subject Code	Subject Name	Credits
CHE2011	Advanced Computer Aided Design	**04**

Module	Detailed content
1	Module No. 1 Physical Properties of Liquids and Gases Introduction, Estimation of Physical Properties of Liquids and Gases, Diffusion Coefficients (Diffusivities)
2	Module No. 2 Sizing of Vertical and Horizontal Separators Introduction, Sizing of Vertical and horizontal separators, Sizing of partly filled vessels and tanks, Preliminary vessel design
3	Module No. 3 Design of Cyclone Separators and Gas Dryers Cyclone Separator design, Methods for Gas Dehydration and Gas Purification, Gas dryer (dehydration) design
4	Module No. 4 Thermodynamics and Thermodynamic Properties Vapors-Liquid Equilibrium, Estimation of Bubble Point and Dew Point of Gas Mixtures, Compressibility Z-Factor of Natural Gases
5	Module No. 5 Mass Transfer Determination of Plates in Fractionating Columns by the Smoker Equations, Multicomponent Distribution and Minimum Trays in Distillation Columns
6	Module No. 6 Engineering Economics Introduction, Methods for Project Evaluation, Capital Cost Estimation

Reference Books:

A.Kayode Coker, Fortran Programs for Chemical Process Design, Analysis and Simulation (1995), Gulf Publishing Co.

A.L. Kohl and R.B. Nielsen, Gas Purification (1997), Elsevier

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six questions to be set each of 20 marks, out of these any four questions to be attempted by students.
Minimum 80% syllabus should be covered in question papers of end semester examination.

Subject Code	Subject Name	Credits
CHE2012	Polymerization Reaction Engineering	**04**

	Detailed content
	Classification of polymerization reactions. Chain chemical reaction and polyaddition, Reactor mechanisms and rate equations, order polymerization reactions. Molecular weight distribution in batch and continuous reactors. Average molecular weight and experimental determinations based viscosity osmotic pressure etc., free radical polymerization, semi-batch reactor operation, design of batch and continuous reactors Heterogeneous, poly-addition reactions, suspensions and emulsion polymerization, Smith-Ewart's theory and Stockmayers equation. Continuous emulsion Polymerization, Anionic and Cationic polyaddition, Copolymerization, Mayo's equation and reaction, Alireg-price equation, Rate of copolymerization and Skiest's Equation. Polycondensation, reactions, Flory equations and molecular weight distributions.

Reference Books:

Anil Kumar and Rakesh K. Gupta, Fundamentals of Plymerization, (1998), McGraw Hill.

Anil Kumar and S. Gupta, Reaction Engineering of step Groeth Polymerization, (1989), Plennum Press, New York.

G.W. Billemeyer, Encyclopedia of Polymer science and Technology,(1969),Interscience.

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Subject Code	Subject Name	Credits
CHE2013	Nanotechnology	**04**

	Detailed content
	Introduction to Nanotechnology – History of nano-revolution, nano scale materials and their applications, Carbon nano tubes, organic and inorganic nano structures. Future of the nanotechnology. **Materials used in Nanotechnology –** An overview of the physical (mechanical, electrical) and chemical properties of different classes of solid materials such as metals, semiconductors, insulators and polymers. Examples of size effects of properties observed in thin films, colloids and nanocrystals. **Conventional Fabrication Techniques –** Topdown and bottom up process, techniques used in conventional microfabrication including thin film deposition (e.g. CVD, PVD(, lithography, chemical etching and electrodeposition. **Analytical Techniques –** Analytical techniques such as Scanning Electron Microscopy (SEM), Electron and X-ray Diffraction, Ellipsometry, Photoelectron, Optical and Ion spectroscopy and Probe Microscopy. Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM) **Applications –** Examples of applications in Micro and Nano technology including, Micro fluidics, Micro Electron Mechanical Systems (MEMS) Literature survey on Project / Dissertation topic, planning of work, membrane technology, and catyalyst and coatings

Reference Books:

1. M. Wilson, K.K.G. Smith, M. Simmons and B.Raguse; Nanotechnology, Chapman & Hall

Assessment:

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Subject Code	Subject Name	Credits
CHE2021	Corrosion in Industry & its Control	**04**

Module	**Detailed content**
1	Module No. 1 Introduction The economics aspects of corrosion. Case studies. Some examples of catastrophic corrosion failures.
2	Module No. 2 Design aspects to minimize the corrosion, Temporary corrosion prevention methods and use of inhibitors in industry.
3	Module No. 3 Design of cathodic and anodic protection systems. Selection of the material for sacrificial anodes –anodes for impressed current methods of protection. Corrosion in pipe lines, internal and external protection of pipe line.
4	Module No. 4 Corrosion of Stainless Steel, Plastics and Elastomers Principal engineering materials for equipment, Corrosion control using the exotic materials. Fabrication of special alloys, Stainless Steel, less common metals, composite materials, Welding techniques and corrosion behavior of weld metals, Plastics and Corrosion of Plastics and Elastomers.
5	Module No.5 Corrosion inspection, instrumentation and monitoring. Use of DSA in electrochemical industries, Electrochemical Machining, Chemical cleaning of an equipment.
6	Module No. 6 Corrosion and Control methods for water supply systems, cooling systems heavy water systems, underground and marine environments. Corrosion nuclear reactors and boilers. Corrosion of reinforcements concrete structure. Corrosion control in industrial environments

Reference Books:

M.G.Fontana, Corrosion Engineering, Tata McGraw-Hill (New Delhi), 3rd Ed.

G.L.Shvartz and M.M.Kristal, Corrosion of Chemical Apparatus (1959) Chapman Hall Ltd. London.

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Subject Code	Subject Name	Credits
CHE2022	Advanced Separation Techniques	**04**

	Detailed content
	Solute Transport parameter for membrane performance prediction in RO/UF systems involving aqueous and non-aqueous solution. Physic-Chemical, polar, non-polar-criteria governing RO separation, membrane transport mechanism. Membrane fouling and compaction. TFC membrane development RO/UF/ED process design module analysis. RO/UF/ED and DD in acid and enzyme recovery from scarified hydrolytes. Membrane technique in reclamation of water and chemical along with pollution control from industrial effluents. Cost benefit analysis and resources recycling and environmental quality improvement by MT. Industrial processing with membrane, membrane reactor concept in biotechnology concentration. Gas separation by RO.

Reference Books:

S. Sourirajan and T. Malaura, RO-UF: Principles and Applications (1986), NRCC publications. Ottawa, Canada.

Munir Cheryan , Uf Applications Handbook, (1986), Technic Publishing CO. Lancaster, USA

Assessment:

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Subject Code	Subject Name	Credits
CHE2023	Catalysis	**04**

Module	Detailed content
1	Catalysts properties, types of catalysts, heterogenous catalytic processes, adsorption, adsorption isotherms, rates of adsorptions, rates of adsorptions, physisorptions and chemisorptions.
2	Kinetics of Catalytic Reactions, Finding mechanism, rate limiting steps and rate law for catalytic reactions. Laboratory Reactors for studying Catalytic reactions
3	Deactivation of catalysts. Deactivation by Sintering. Deactivation by coking or fouling. Deactivation by poisoning. Empirical Decay Laws, catalyst carriers, Promoters, Accelarators, Poisons and Inhibitors.
4	Catalyst Preparations. Testing catalysts. Catalyst characterization methods, surface area, pore volume and adsorption capacity determination.
5	Industrial Catalytic Reactors. Packed Bed Reactors, Moving Bed Reactors, Straight Trough Transport Reactors, Surface and Enzymatic Reactors
6	New Developments in Solid Catalysts, monolithic catalysts, nano catalysts, Fuel catalysts, Environmental Catalysts.

Reference Books:

1. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice – Hall of India.
2. Lanny D. Schimdt, The engineering of Chemical Reactions, Oxford University Press.
3. Paul H Emmet, Catalysis.
4. G. Ertl, H. Knozinger and J. Weitkamp, Handbook of heterogenous Catalysis, Vol. 1 -5, Wiley International.
5. B. Vishwanathan, S. Sivasanker, A.V. Ramaswamy, Catalysis – Principles & Applications
6. Octave Levenspiel, Chemical Reaction Engineering.

Assessment:

Internal: Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

End Semester Examination: Some guidelines for setting the question papers are as, six questions to be set each of 20 marks, out of these any four questions to be attempted by students. Minimum 80% syllabus should be covered in question papers of end semester examination.

Subject Code	Subject Name	Credits
CHL201	**Laboratory III - Advanced Mass Transfer**	**01**

Minimum Seven Practical should be performed from the following List of Experiments

List of Experiments:

1. Pressure activated Membrane Process
2. Reverse Osmosis
3. Nano Filtration
4. Ultra Filtration
5. Micro Filtration
6. Supercritical Fluid Chromatography
7. Counter-Current Multistage Extraction
8. Membrane Separation of Gases at High Pressures
9. Cyclic Adsorption Process
10. Electrolysis and Ion-Exchange
11. Bubble Cap Distillation Column(Continuous Distillation)

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
CHL202	**Laboratory IV - Advanced Process Dynamics & Control**	**01**

Minimum Seven Practical should be performed from the following List of Experiments

List of Experiments:

1. Dynamics of a Stirred Tank Heater with variable Volume
2. Modeling and Dynamics of a Quadruple Tank System.
3. Decoupled SISO control of the Quadruple Tank System.
4. Multi-variable Control of the Quadruple Tank System.
5. Dynamic Matrix Control of the Stirred Tank System.
6. Experiment on Programmed Adaptive Control System
7. Experiment on Time-delay compensation (Smith- Predictor)
8. Experiment on Inverse Response compensation
9. Experiment on multiple outputs controlled by a single input
10. Experiment on a single output controlled by multiple input

In the Practical Examination students must be able to simulate any of the above Processes/Process Equipment using Computer Programs or Simulation Packages such as Aspen/Aspen Plus/ChemCad/Design II/Hysis (Unisim)/gProms etc.

Assessment:

End Semester Examination: Practical/Oral examination is to be conducted by pair of internal and external examiners

Subject Code	Subject Name	Credits
CHS301	**Seminar**	**03**

Guidelines for Seminar

- Seminar should be based on core areas in Chemical Engineering.

- Students should do literature survey and identify the topic of seminar and finalize in consultation with Guide/Supervisor. Students should use multiple literatures and literature survey is to be based on the broader areas of interest in recent developments in Chemical Engineering. Students should understand the topic and compile the report in standard format and present it in front of Panel of Panel of Internal & External Examiner. The external examiner should be selected from - approved panel of examiners for Seminar by University of Mumbai, OR faculty from Premier Educational Institutions /Research Organizations such as IIT, NIT, LIT, ICT, BARC, etc. OR a person having minimum Post-Graduate qualification with at least five years' experience in Industries.

- Seminar assessment should be based on following points
  - Quality of Literature survey and Novelty in the topic
  - Relevance to the specialization
  - Understanding of the topic
  - Quality of Written and Oral Presentation

IMPORTANT NOTE :

1. Assessment of Seminar will be carried out by a pair of Internal and External examiner. The external examiner should be selected from approved panel of examiners for Seminar by University of Mumbai, OR faculty from Premier Educational Institutions /Research Organizations such as IIT, NIT, BARC, TIFR, DRDO, etc. OR a person having minimum Post-Graduate qualification with at least five years' experience in Industries.

2. Literature survey in case of seminar is based on the broader area of interest in recent developments and for dissertation it should be focused mainly on identified problem.

3. At least 4-5 hours of course on Research Methodology should be conducted which includes Literature Survey, Problems Identification, Analysis and Interpretation of Results and Technical Paper Writing in the beginning of 3rd Semester.

Subject Code	Subject Name	Credits
CHD301 / CHD401	**Dissertation (I and II)**	**12 + 15**

Guidelines for Dissertation

- Students should do literature survey and identify the problem for Dissertation and finalize in consultation with Guide/Supervisor. Students should use multiple literatures and understand the problem. Students should attempt the solution to the problem by analytical/simulation/experimental methods. The solution to be validated with proper justification and compile the report in standard format.

Guidelines for Assessment of Dissertation I

- Dissertation I should be assessed based on following points
  - Quality of Literature survey and Novelty in the problem
  - Clarity of Problem definition and Feasibility of problem solution
  - Relevance to the specialization
  - Clarity of objective and scope
- Dissertation I should be assessed through a presentation by a panel of internal examiners appointed by the Head of the Department/Institute of respective Program.

Guidelines for Assessment of Dissertation II

- Dissertation II should be assessed based on following points
  - Quality of Literature survey and Novelty in the problem
  - Clarity of Problem definition and Feasibility of problem solution
  - Relevance to the specialization or current Research / Industrial trends
  - Clarity of objective and scope
  - Quality of work attempted
  - Validation of results
  - Quality of Written and Oral Presentation
- Dissertation II should be assessed through a presentation jointly by Internal and External Examiners appointed by University of Mumbai,

Students should publish at least one paper based on the work in reputed International / National Conference (desirably in Refereed Journal)