AC 29/4/2013 Item no. 4.72

UNIVERSITY OF MUMBAI

Revised Syllabus

Program -Bachelor of Engineering

Course – Chemical Engineering

(Second Year – Sem.III& IV)

Under

FACULTY OF TECHNOLOGY

(As per Credit Based Semester and Grading System from 2013-14)

From Dean's Desk:

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education.The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Technology of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty of Technology, University of Mumbai, in one of its meeting unanimously resolved that, each Board of Studies shall prepare some Program Educational Objectives (PEO's) and give freedom to affiliated Institutes to add few (PEO's) and course objectives and course outcomes to be clearly definedfor each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner's learning process. It was also resolved that, maximum senior faculty from colleges and experts from industry to be involved while revising the curriculum. I am happy to state that, each Board of studies has adhered to the resolutions passed by Faculty of Technology, and developed curriculum accordingly. In addition to outcome based education, semester based credit and grading system is also introduced to ensure quality of engineering education.

Semester based Credit and Grading system enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. University of Mumbai has taken a lead in implementing the system through its affiliated Institutes and Faculty of Technology has devised a transparent credit assignment policy and adopted ten points scale to grade learner's performance.Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 12-13 weeks and remaining 3-2 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc.

Credit and grading based system was implemented for First Year of Engineering from the academic year 2012-2013. Subsequently this system will be carried forward for Second Year Engineering in the academic year 2013-2014, for Third Year and Final Year Engineering in the academic years 2014-2015 and 2015-2016 respectively.

Dr. S. K. Ukarande
Dean,
Faculty of Technology,
Member - Management Council, Senate, Academic Council
University of Mumbai, Mumbai

Preamble to the Revision of Syllabus in Chemical Engineering

The Chemical Process Industry has undergone dramatic changes in the last few years both nationally and internationally. In fact these very boundaries are merging into one global market with international competence. Today Chemical Engineering is considered as Molecular Engineering which operates at various scales to bring about transformations in a wide variety of materials. Chemical Engineering is becoming inclusive of Bio-technology, Nanotechnology and Material Science like never before. The professional arena of a Chemical Engineer has expanded greatly to cater to sectors as wide as Pharmaceutical and Electronics in addition to the more traditional Oil & Gas and Petrochemical Industries.

Parallel to these developments, the growth and expansion of theWorld Wide Web offers new opportunities as well as new challenges.Today the latest research trends have become accessible from drawing rooms across the globe. This acts as a positive feedback mechanism in increasing the pace of research in all fields including Chemical Engineering and Bio-technology. There is also an incredible amount of content, in a variety of formats, available on the net. The availability of free software such as Scilab and COCO vastly expands our boundaries of learning.

Hence, an Under-graduate Curriculum in Chemical Engineering must provide the necessary foundation for a Chemical Engineer to be able to specialize in any area as and when the need and opportunity arise.

The Curriculum must integrate knowledge of the basic sciences with problem solving abilities and communication skills. It must cultivate a willingness to face open-ended problems with inadequate data. The Curriculum must be broad enough to cover all areas from design to operation of Process plants. It should be deep enough to enable the graduates to carry out research and develop products to meet rapidly changing needs and demands.

With this scenario as the backdrop, a full day conference was organized at D. J. Sanghvi College of Engineering on the 30th of January 2013. It was attended by the various heads of departments of chemical engineering as well as experts from industry. The program objectives and outcomes were thoroughly discussed in this meeting and the core structure of the syllabus was formulated. A second meeting was held in TSEC on 5th of March 2013 to decide the subject experts for the subjects of III and IVsemesters.

Finally, a meeting of the Board of Studies in Chemical Engineering (Ad Hoc.) was conducted at the Fort Campus of the University of Mumbai, on the 20th of April 2013, where the final draft of the Core Structure and the detailed syllabus for semesters III and IV were approved.

Dr. Ramesh Vulavala

Chairman, Board of Studies in Chemical Engineering (Ad Hoc.)

University of Mumbai.

University of Mumbai
Scheme for SE: Semester-III

Teaching Scheme

Subject Code	Subject Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tutorial	Theory	Pract	Tut	Total
CHC301	Applied Mathematics-III	03	-	01	3.0	-	1.0	4.0
CHC302	Engineering Chemistry-I	04	-	-	4.0	-	-	4.0
CHC303	Fluid Flow (FF)	03	-	01	3.0	-	1.0	4.0
CHC304	Computer Programming & Numerical Methods	03	-	01	3.0	-	1.0	4.0
CHC305	Process Calculations	03	-	01	3.0	-	1.0	4.0
CHC306	Chemical Engineering Economics	03	-	01	3.0	-	1.0	4.0
CHL307	Chem. Engg. Lab (FF)	-	03	-	-	1.5	-	1.5
CHL308	Engineering Chemistry Lab I	-	03	-	-	1.5	-	1.5
CHL309	Computer Programming & Numerical Methods Lab	-	02	-	-	1.0	-	1.0
Total		19	08	05	19	4.0	5.0	28

Examination Scheme

Subject Code	Subject Name	Examination Scheme							
		Theory Marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Average of Test 1 and Test 2					
CHC301	Applied Mathematics-III	20	20	20	80	25	-	-	125
CHC302	Engineering Chemistry-I	20	20	20	80	-	-	-	100
CHC303	Fluid Flow (FF)	20	20	20	80	25	-	-	125
CHC304	Computer Programming & Numerical Methods	20	20	20	80	25	-	-	125
CHC305	Process Calculations	20	20	20	80	25	-		125
CHC306	Chemical Engineering Economics	20	20	20	80	25	-	-	125
CHL307	Chem. Engg. Lab (FF)	-	-	-	-	-	25	-	25
CHL308	Engineering Chemistry Lab I	-	-	-	-	-	25	-	25
CHL309	Computer Programming & Numerical Methods Lab	-	-	-	-	-	25	-	25
Total				120	480	125	75	-	800

University of Mumbai

Scheme for SE: Semester-IV

Teaching Scheme

Subject Code	Subject Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tutorial	Theory	Pract	Tut	Total
CHC401	Applied Mathematics-IV	03	-	1.0	3.0	-	1.0	4.0
CHC402	Engineering Chemistry-II	04	-	-	4.0	-		4.0
CHC403	Chemical Engg. Thermodynamics - I	03	-	1.0	3.0	-	1.0	4.0
CHC404	Material Science &Engineering	03	-	1.0	3.0	-	1.0	4.0
CHC405	Mechanical Equipment Design (MED)	03	-	1.0	3.0	-	1.0	4.0
CHC406	Solid Fluid Mechanical Operations (SFMO)	03	-	1.0	3.0	-	1.0	4.0
CHL407	Engineering Chemistry Lab II	-	03	-	-	1.5	-	1.5
CHL408	Chemical Engg Lab (SFMO)	-	03	-	-	1.5	-	1.5
CHL409	MED Lab	-	02	-	-	1.0		1.0
Total		19	08	05	19	4.0	5.0	28

Examination Scheme

Subject Code	Subject Name	Examination Scheme							
		Theory Marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Average of Test 1 and Test 2					
CHC401	Applied Mathematics-IV	20	20	20	80	25	-	-	125
CHC402	Engineering Chemistry-II	20	20	20	80	-	-	-	100
CHC403	Chemical Engg. Thermodynamics – I	20	20	20	80	25	-	-	125
CHC404	Material Science Engineering	20	20	20	80	25	-	-	125
CHC405	Mechanical Equipment Design (MED)	20	20	20	80	25	-	-	125
CHC406	Solid Fluid Mechanical Operations (SFMO)	20	20	20	80	25		-	125
CHL407	Engineering Chemistry Lab II	-	-	-	-	-	25	-	25
CHL408	Chemical Engg Lab (SFMO)	-	-	-	-	-	25	-	25
CHL409	M ED Lab	-	-	-	-	-	-	25	25
Total				120	480	125	50	25	800

General Guidelines

Tutorials:

- The number of tutorial batches can be decided based on facilities available in the institution.
- Tutorials can be creative assignments in the form of models, charts, projects, etc.

Term Work:

- **Term work will be an evaluation of the tutorial work done over the entire semester.**
- It is suggested that each tutorial be graded immediately and an average be taken at the end.
- A minimum of ten tutorials will form the basis for final evaluation.

Theory Examination:

- In general all theory examinations will be of 3 hours duration.
- Theory examination for MED in semester IV will be of 4 hour duration.
- Question paper will comprise of total six questions, each of 20 Marks.
- Only four questions need to be solved.
- Question one will be compulsory and based on maximum part of the syllabus.

Note: In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus as far as possible.

Practical Examination:

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments.

Project& Seminar Guidelines

- Project Groups: Students can form groups with minimum 2(Two) and not more than 3(Three)
- The load for projects may be calculated proportional to the number of groups, not exceeding two hours per week.
- Each teacher should have ideally a maximum of three groups and only in exceptional cases four groups can be allotted to the faculty.
- Seminar topics will be the consensus of the project guide and the students. Each student will work on a unique topic.
- The load for seminar will be calculated as one hour per week irrespective of the number of students
- Students should spend considerable time in applying all the concepts studied, into the project. Hence, eight hourseachwere allotted in Project A,B and three hours for Seminar to the students.

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ANNEXURE -I
Program Structure for S.E.Chemical Engineering
Mumbai University

Semester III

Teaching Scheme

Subject Code	Subject Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tutorial	Theory	Pract	Tut	Total
CHC301	Applied Mathematics-III	03	-	01	3.0	-	1.0	4.0
CHC302	Engineering Chemistry-I	04	-	-	4.0	-	-	4.0
CHC303	Fluid Flow (FF)	03	-	01	3.0	-	1.0	4.0
CHC304	Computer Programming & Numerical Methods	03	-	01	3.0	-	1.0	4.0
CHC305	Process Calculations	03	-	01	3.0	-	1.0	4.0
CHC306	Chemical Engineering Economics	03	-	01	3.0	-	1.0	4.0
CHL307	Chem. Engg. Lab (FF)	-	03	-	-	1.5	-	1.5
CHL308	Engineering Chemistry Lab I	-	03	-	-	1.5	-	1.5
CHL309	Computer Programming & Numerical Methods Lab	-	02	-	-	1.0	-	1.0
Total		19	08	05	19	4.0	5.0	28

Examination Scheme

Subject Code	Subject Name	Examination Scheme							
		Theory Marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Average of Test 1 and Test 2					
CHC301	Applied Mathematics-III	20	20	20	80	25	-	-	125
CHC302	Engineering Chemistry-I	20	20	20	80	-	-	-	100
CHC303	Fluid Flow (FF)	20	20	20	80	25	-	-	125
CHC304	Computer Programming & Numerical Methods	20	20	20	80	25	-	-	125
CHC305	Process Calculations	20	20	20	80	25	-		125
CHC306	Chemical Engineering Economics	20	20	20	80	25	-	-	125
CHL307	Chem. Engg. Lab (FF)	-	-	-	-	-	25	-	25
CHL308	Engineering Chemistry Lab I	-	-	-	-	-	25	-	25
CHL309	Computer Programming & Numerical Methods Lab	-	-	-	-	-	25	-	25
Total				120	480	125	75	-	800

Course Code	Course/Subject Name	Credits
CHC301	Applied Mathematics III	4

Prerequisites:

- Basics of complex numbers: modulus, argument; equation of a circle, roots of unity, Euler's formula; hyperbolic functions; matrices: symmetric, orthogonal and unitary matrices, rank, normal form, solutions of systems of linear equations; basics of LPP: graphical method; calculus: partial derivatives, Hessian, maxima/minima of functions of 1 and 2 real variables.

Course Objectives:

- To introduce students to the basic methods of Laplace transforms.
- Laplace transforms and inverse Laplace transforms of all the standard functions.
- To enable students to solve initial value ODE problems using L-transforms.
- To study Eigenvalues and Eigen spaces of matrices.
- Orthogonal and congruent reduction of quadratic forms.
- Complex analysis: C-R equations, Milne-Thomson method.
- Bilinear transformations and cross-ratios.
- Complex integration and applications of the residue theorem.
- Lagrange multiplier method for 2 and 3 variables with no more than two constraints.
- To introduce the basics of optimization using Kuhn-Tucker conditions.

Course Outcomes:

- The student will be able to solve initial value ODE problems.
- The student will have a good understanding of real and complex analysis.
- The student will have a thorough grounding in matrix algebra.
- The student will be ready for any further courses on optimization.

Module	Contents	No. of Hrs.
01	The Laplace transform: Definition and properties (without proofs); all standard transform methods for elementary functions including hyperbolic functions; Heaviside unit step function, Dirac delta function; the error function; evaluation of integrals using Laplace transforms; inverse Laplace transforms using partial fractions and H(t-a); convolution (no proof).	07
02	Matrices: Eigenvalues and eigenspaces of 2x2 and 3x3 matrices; existence of a basis and finding the dimension of the eigenspace (no proofs); non-diagonalisable matrices; minimal polynomial; Cayley - Hamilton theorem (no proof); quadratic forms; orthogonal and congruent reduction of a quadratic form in 2 or 3 variables; rank, index, signature; definite and indefinite forms.	07
03	Complex analysis: Cauchy-Riemann equations (only in Cartesian co-ordinates) for an analytic function (no proof); harmonic function; Laplace's equation; harmonic conjugates and orthogonal trajectories (Cartesian co-ordinates); to find f(z) when u+v or u - v are given; Milne-Thomson method; cross-ratio (no proofs); conformal mappings; images of straight lines and	07

	circles.	
04	Complex Integration Cauchy's integral formula; poles and residues; Cauchy's residue theorem; applications to evaluate real integrals of trigonometric functions; integrals in the upper half plane; the argument principle.	06
05	Statistics: (No theory questions expected in this module) Mean, median, variance, standard deviation; binomial, Poisson and normal distributions; correlation and regression between 2 variables.	05
06	Optimization (No theory) Non-linear programming: Lagrange multiplier method for 2 or 3 variables with at most 2 constraints; conditions on the Hessian matrix (no proof); Kuhn-Tucker conditions with at most 2 constraints.	07

References:

- Mathematical Methods in Chemical Engineering, V.G. Jenson and G.V. Jeffrey's, Academic Press, 1970.
- Laplace transforms, Murray Spiegel, Schaum's Outline Series, 1974
- Complex variables, Murray Spiegel, Schaum's Outline Series, 1964
- Linear Algebra, Murray Spiegel, Schaum's Outline Series, 1964
- Advanced Engineering Mathematics by *Erwin Kreyszig*, 9TH Edition, Wiley India.

Course Code	Course/Subject Name	Credits
CHC302	**Engineering Chemistry – I**	**4**

Prerequisites:

- Knowledge of Vander-Waal's forces, various bonds, Octet rule, Resonance theory, Hybridization.
- Knowledge of variable valency, ligands.
- Knowledge of properties of transition metals.
- Knowledge of intermediate steps involved in conversion of reactants to products.
- Knowledge of Inductive effect, Mesomeric effect, Resonance, Tautomerism, Hyperconjugation and bondcleavage to form reactive species. Knowledge of substitution reaction.

Course Objectives:

- To understand chemical bonding.
- To study chelation and its advantages.
- To understand structures of different bio-molecules and their chemistry.
- To study importance of iron compounds for life.
- To understand different concepts of organic reactions.
- To study the effect of temperature and time on chemical reactions.
- To become aware of industrially important reactions.
- To understand mechanism of aromatic substitution and elimination reactions.

Course Outcomes:

- Students will learn the basic areas in chemistry like different theories of chemical bonding, organometallic chemistry, mechanism and application of aromatic substitution, elimination reactions and the orientation of functional groups.
- Students will also be capable of defining the different basic terms related to electrochemistry, spectroscopic methods, different analytical techniques and the application of surfactants.
- Students will be aware of the significance of active methylene group during organic synthesis and the importance of catalyst. Moreover, on the basis of Huckel's rule, students will be able to differentiate between aromatic and non-aromatic compounds.
- Students will be able to carry out organic estimations, gravimetric analysis and handle different instruments in the laboratory.

Module No.	Contents	No. of Hours
1	**Basic Concepts of Chemistry and Molecular Structures** • Hydrogen bonding, Valence bond-Theory, Molecular orbital theory, Non-bonding and anti-bonding orbitals, LCAO method, VSEPR theory.Structure of BF_3, PCl_3, PCl_5 and SF_4. Molecular orbital structures of homonuclear and heteronuclear molecules H_2, BF_2, B_2, C_2, N_2, O_2, F_2, CO, HF, NO_2, metallic bond.	8
2	**Co-ordination chemistry** • Co-ordination number or ligancy, Complex ion, Co-ordination dative bond complex ions. Theories of coordination compounds such as Werner's Co-ordination theory, Valence bond-Theory, Crystal field theory (CFT), Ligand field theory. Effective Atomic Number (EAN). Nomenclature and isomerism (Only Geometrical and Structural) in co-ordination compounds with respect to co-ordination number 4 and 6. Application of CFT to tetrahedral and octahedral complexes, drawbacks of CFT, MOT as applied to octahedral complexes of Fe, Measurement of CFSE (10Dq), Numericals based on EAN and 10Dq measurement, Applications of coordination compounds.	10
3	**Organometallic compounds and Bio-inorganic chemistry** • Chemistry of Fe-carbonyls with respect to preparation, properties, structure and bonding. Biochemistry of proteins containing Cu, Fe and Zn chemistry of cytochromes and their application, O_2 atom transfer reactions of biomolecules containing Fe.	07
4	**Reaction Mechanism & Reactive Intermediates** • Transition state (T.S.), Intermediate. Difference between T.S. & intermediate. Equilibrium (Thermodynamically) controlled & rate (Kinetically) controlled reactions. • Explain w.r.t. Nitration of chlorobenzene, methylation of toluene by Friedel-Craft's reaction, sulphonation of naphthalene.	07
5	**Reactive intermediates** • Reactive intermediates • Carbocation, carbanion, carbon free radicals and carbenes – their formation, structure & stability. • Name reactions with mechanism w.r.t. each reactive intermediate. Carbocation – Pinacol - Pinacolone reaction. Carbanion – Michael reaction. Free radical - Wohl-Ziegler bromainationreaction. Carbene - Reimer-Tiemannreaction for aldehyde.	11
6	**Substitution reactions** A. Electrophilic substitution reactions. - In monocyclic aromatic compounds - Mechanism - Orientation influence - Friedel Craft alkylation B. Nucleohilic substitution reactions. - SN1 reaction with mechanism - SN2 reaction with mechanism C. Elimination reactions. - E1 reaction with mechanism - E2 reaction with mechanism	9

References:

- Advanced Inorganic Chemistry – J. D. Lee
- Vogels Textbook of Practical organic chemistry.
- Spectroscopy - Kalsi
- A textbook of Physical Chemistry - Glasston Samuel, Macmillan India Ltd. (1991)
- Organic Chemistry - I L Finar volume I and II.

Course Code	Course/Subject Name	Credits
CHC303	**Fluid Flow**	**4**

Prerequisites:

- Students are assumed to have adequate background in physics, units and dimensions and thermodynamics.

Course Objectives:

- Students should be able to understand the scope of the subject in chemical industry.
- They should be comfortable with measurement of pressure or pressure drop.
- They should be able to understand basic principles and equations of fluid flow.
- They should be able to calculate pressure drop and flow rates in conduits for incompressible as well as compressible fluids.
- They should be able to determine viscosity using different methods such as Stokes Law, Capillary viscometer.
- They should be able to calculate power requirement in agitation and to be able to select and calculate power requirement for pumps.
- They should be able to select proper valves.

Course Outcomes:

- After studying this subject, students would be able to measure pressure drop, flow rates etc. for incompressible and compressible fluids.
- They can select pumps and valves and would be able to calculate power requirement for pumping as well as agitation operations.

Module .No.	Contents	No. of Hours
1	**Introduction and Basic Concepts:** • Scope and Applications of fluid flow • Properties of fluids such as Density, viscosity, surface tension, capillarity effect, vapor pressure, compressibility factor, Enthalpy, Entropy.	**2**
2	**Pressure and Fluid Statics:** • Fluid Pressure at a Point, • Pascal's Law, • Pressure Variation in a fluid at rest. • Measurement of Pressure • Manometer. • Peizometer U-Table Manometer • Single Column manometer • U – Tube differential manometer • Inverted Differential U – tube manometer • Inclined manometer. • Hydrostatic Equilibrium	**4**
3	**Fluid Kinematics:** • Types of fluid flow namely steady and unsteady, Uniform and non-uniform, laminar and turbulent, compressible and incompressible,	**2**

	internal and external, one, two and three dimensional flow. • Concepts of Stream lines, stream tubes. Newton Law of Viscosity, Rheological behavior of fluid	
4	**Basic Equations of Fluid Flow** • Equation of Continuity, • Equation of motion: Euler's equation of motion, Bernoulli's equation from Euler's Equation. • Modified Bernoulli's equation.	**5**
5	**Practical Application of Bernoulli's Equation:** • Venturimeter: Horizontal and inclined. • Orificemeter, Pitot tube • Notches and Weirs: Introduction, classification, Derivation for V – notch.	**5**
6	**Flow through Circular Pipes:** • Shear – Stress, Distribution and velocity distribution for incompressible fluids in cylindrical tube • Relationship between Skin friction and wall shear, friction factor, Darcy's Weisbach equation • Reynolds experiment and Reynolds no., Formation of Boundary layer. **Laminar Flow through Pipes:** • Shear stress, velocity distribution, • Derivation of local velocity, maximum velocity, average velocity • Kinetic Energy Correction factor, Hagen – Poiseullie equation. **Turbulent Flow:** • Velocity distribution equations, Average velocity, local velocity, maximum velocity, kinetic energy correction factor.**Von Carman** equation and friction factors (No Numericals on universal velocity) • Equivalent diameter for circular and non circular ducts. • Pipes in series and Parallel. • Losses due to different fittings, sudden expansion etc.	**9**
7	**Compressible Fluids:** • Introduction, Mach no., Sonic, supersonic and subsonic flow, continuity equation and Bernoulli's equation, stagnation properties, Acoustic velocity. • Adiabatic Flow. • Isothermal Flow. • Isentropic Flow. **Flow past immersed bodies:** • Drag forces, Coefficient of drag, Terminal settling velocity, Stoke's Law. Capillary viscometer. **Power Consumption in Agitation:** • Power curves, Power No., types of impellers.	**6**
8	**Pumps and Valves:** • Classification and types, Centrifugal pumps, Introduction, main parts, Work done, Power required, Definitions of heads and efficiency, NPSH, Priming, Cavitations characteristic curves. • Specific speed, minimum speed. **Reciprocating Pump :** • Classifications and working **General idea about Compressors, Fans and Blowers**. **Types of Valves** • Globe valves, Check valves, Gate valves, butterfly valves and non – return valves.	**6**

References:

- Warren L. Mccabe, Julian C. Smith, Peter Harriott, Unit Operations of Chemical Engineering, McGraw Hill International Edition.
- Coulson J. M., Richardson J. F., Backhurst J. R. and J. H. Harker, Chemical Engineering, Vol. 1
- Fluid Mechanics and Hydraulics by SureshUkarande , Ane Books, 2012.
- Introduction to Fluid Mechanics, 7th edition, Robbert W. Fox, Philip J. Pritchard, Alan T. McDonald, WILEY, India Edition.
- Fluid Mechanics Fundamentals and Applications, Yunus A. Cengel, John M. Cimbala, Adapted by S. Bhattacharya, The McGraw Hill Companies.
- Fluid Mechanics and Hydraulic Machines, Dr. R. K. Bansal, Laxmi Publications Pvt. Ltd.

Course Code	Course/Subject Name	Credits
CHC304	Computer Programming and Numerical Methods	4

Prerequisites:

- Differential Calculus.
- Integral Calculus.
- Differential Equations.
- Linear Algebraic Equations.

Course Objectives:

- To familiarize students with the use of software in solving numerical problems.
- To develop analytical thinking in designing programs.
- To learn to interpret results of computer programs and debug the same.
- To learn to present results in graphical form.

Course Outcomes:

- The students will be able to solve linear algebraic equations.
- The students will be able to solve non-linear algebraic equations.
- The students will be able to solve differential equations.
- The students will be able to solve partial differential equations.
- The students will be able make plots of their results.

Module	Contents	No. of hrs
1	• Introduction to Scilab. • Handling vectors and matrices in Scilab. • Program control using For , While and Do loops. • Decision making with If and Case structures.	05
2	• Solution of algebraic and transcendental equations. • RegulaFalsi Method. • Successive substitution. • Secant Method. • Newtons Method one and two simultaneous equations.	9
3	• Systems of linear equations. • Gauss-Seidel Method. • Gauss-Jordan Method.	05
4	• Ordinary differential equations. • Eulers explicit and implicit methods. • Runge-Kutta second and fourth order methods. • Adams-Bashforth formulas.	9
5	• Partial differential equations. • Method of lines. • Crank-Nicholson method. • Laplace equation. • Iterative methods. • Parabolic equations. Bender-Schmidt method.	9
6	• Difference Equations	02

References:

- Programming in ScilabByVinu V Das, New Age International Publishers
- Numerical Methods, M. K. Jain, S. R. K. Iyengar, and R. K. Jain Sixth Edition.New Age International Publishers, New Delhi, 2012.
- Numerical Methods for Engineers. By Santosh K. GuptaNew Age Publishers, Second Edition, 2010
- Introduction to Chemical Engineering Computing by Bruce A. FinlaysonWiley-International, 2005.

Course Code	Course/Subject Name	Credits
CHC305	**Process Calculations**	**4**

Prerequisites:

- Linear algebra.
- Differential equations.

Course Objectives:

- Students will learn to write mass balances on various process equipmentswith and without recycle.
- Students will learn to write energy balances on various process equipmentswith and without recycle.
- Students will learn to write mass and energy balances for chemical reactionswith and without recycle.
- Students will learn to flow sheeting calculations.

Course Outcomes:

- Students will learn to calculate mass and energy flow rates into and out of various process equipments.
- Students will learn to calculate conversion, selectivity etc for various reactions with and without recycle.
- Students will learn to carry out degrees of freedom analysis for various units.

Module	Contents	No. of hrs
1	• Introduction • Units And Dimensions Various systems of units, conversion of units from one system to other • Basic Chemical Calculations, Density, specific volume, specific gravity, Concentration & composition of mixtures and solutions. Density of gases & vapors using Ideal Gas law & Van der waals equation of state, Dalton’s law, Amagat,s law, concept of VLE, Raoult’s law, Henry’s law.	6
2	• Material Balance (For Unit Operations) • General material balance equation, degree of freedom analysis for individual units, solving material balance problems for various unit operations using steady state equation • Material Balance for Unsteady Processes.	8
3	• Material Balance (for process involving Chemical Reaction)	9
4	• Recycle , Bypass and Purge Calculations (For Module 2 & 3)	3
5	• Calculations using Psychrometric chart; Humidity and saturation	3
6	• Energy Balance • Heat capacity, sensible heat, latent heat, calculation of enthalpy	10

	changes. • General energy balance equation; Energy balances for process involving chemical reaction including adiabatic reactions & combustion processes (Orsat Analysis & Net, Gross Calorific Value determination). Material and Energy Balance (Binary Distillation &Combustion)	

References:

- Stoichiometry- Bhatt , B. I. U., Vora S. M.: Tata McGraw Hill.
- Basic Principles & Calculations in Chemical Engineering- D. M. Himmelblau, Prentice Hall of India Pvt. Ltd.
- R. M. Felder, R. W. Rousseau, Elementary Principles of Chemical Processes; Jonn Wiley Sons, Inc, New York, 1978.

Course Code	Course/Subject Name	Credits
CHC306	Chemical Engineering Economics	4

Prerequisites:

- The concepts of basic Mathematics as well as a few concepts of higher mathematics.
- The concepts of basic chemistry, basic civil engineering, basic mechanical engineering, etc. in order to understand the concepts like, corrosion, corrosion allowance, construction costs, equipment costs, etc.

Course Objectives:

- To understand various economical terms and economics related activities which can be helpful to them during economical evaluation of any chemical engineering related problem.
- To learn about various basic economic aspects like need, demand, supply, price, cost and market.
- To make familiar to calculate the interest amount on investments as well as loans by different methods
- To understand the concepts of present and future worth of property.
- To understand existing rules and regulations as well as types related to taxes and insurance.
- To understand the methodology of cost estimation including fixed and variable costs by considering the concept of cost indices.
- To have the knowledge about evaluation of depreciation cost as well as salvage value, scrap value, book value of property
- To understand the concept of profitability evaluation of project and select best process alternative based on its economic evaluation.
- To understand the concept of balance sheet, profit and loss accounting and income statement.

Course Outcomes:

- Students will be able to calculate the profitability, rate of return on investments and cost estimation.
- After acquiring the knowledge in this subject, students become familiar with various aspects related to economics and can apply them for economic evaluation of chemical process and decide its economical feasibility.
- The knowledge in this subject will make the students well aware about economic evaluation of dissertation work that they will undertake in final year of their curriculum.

Module	Contents	No. of hrs
1	**Introduction to Basic Principles of Economics:** • Economics-various definitions • Concept of Need – hierarchy • Market - Concept of Price determination under particular market conditions – perfect competition market & monopoly market, causes • Price Discrimination-concept, types • Concept of Cost-total cost, fixed and variable cost, direct and indirect cost • Cost index – definition, types	**02**
2	**Demand and Supply analysis**: • Law of demand-assumptions and exceptions • Demand schedule and demand curve • Determinants of demand • Changes and variations in demand • Demand elasticity-definition, types, methods of measurement of elasticity, Income elasticity of demand, types. • Law of Supply-assumptions and exceptions • Supply schedule and supply curve • Determinants of supply, changes and variations in supply • Supply elasticity-definition, types, determinants • Methods of measurement of supply	**02**
3	**Economics of production and Growth:** • Production function-types of production economies • Diseconomies of scale • Features of growth • Growth v/s Development • Determinants of growth (economic and non-economic) • Stages of growth • Growth strategy- steady state and big – push growth strategy; balanced and unbalanced growth	**02**
4	**Cost Accounting:** • Outline of Accounting Procedure • Basic Relationship in Accounting • Balance Sheet- types of Asset; Current and Cash Ratio • Income Statement; Debits and Credits; General format of Journal and Ledger • Methods of cost accounting • Accumulation, inventory and cost-of-sales account • Material cost – Different Methods: current average, fifo, lifo	**03**
5	**Interests and Investment Costs:** • Importance of time value of money- Interest and Interest rate; • Types of Interest – Simple interest (ordinary and exact), Compound interest, Nominal and Effective interest rates, Continuous interest • Present worth and Discount • Annuities, Perpetuities and Capitalized costs • Cash Flow in Chemical Projects	**06**

6	**Taxes and Insurance:** • Concept of taxes and insurance • Types of Taxes - property tax, excise tax, income tax Capital gain tax, surtax, normal tax • Insurance types, Legal responsibilities, Self insurance • Effect of taxes and depreciation on annual income	**03**
7	**Cost Estimation:** • Cash flow to Industrial operation – Tree diagram; Cumulative Cash position • Factors affecting cost estimation; • Total, fixed, working capital investment • Breakdown of Fixed capital investment- Direct costs; Indirect costs; • Types of Capital Cost Estimates • Grass Root plant; Battery limit; • Estimation of equipment cost by scaling (six tenth rule); Components of costs in FCI; • Methods of Cost Estimation • Estimation of Total Product Cost; • Break even Analysis	**10**
8	**Profitability, Alternative Investments & Replacements:** • Introduction; Profitability Standards; • Mathematical methods for profitability evaluation- Rate of Return on investment method , Discounted cash flow method , Net present worth method, Capitalized Cost method , Pay out period method; Advantages & Disadvantages of Different Profitability Analysis Methods and their comparison • Alternative investments • Replacement analysis • Practical factors affecting investment and replacement decisions	**11**

References:

- Peters, M. S. and Timmerhaus, K. D. , "Plant design and economics for chemical engineers", latest edition, Mcgraw Hill, New York
- Pravin Kumar "Fundamentals of Engineering Economics" Wiley India.
- Kharbanda, O. P. and Stallworthy, E. A. "Capital cost estimating for process industries", Butterworths, Londen
- K. K Dewett and Adarshchand, " Modern Economic Theory", latest edition, S Chand and Company
- O. P Khanna, "Industrial Engineering and Management" DhanpatRai Publications (P) Ltd.
- AtulSathe, ShubhadaKanchan, "Chemical Engineering Economics", VipulPrakashan, Mumbai

Course Code	Course/Subject Name	Credits
CHL307	Chemical Engineering Lab (FF)	1.5

List of Experiments Suggested:

- Viscosity by Efflux time.
- Reynolds Apparatus.
- Bernoulli's apparatus
- Venturimeter
- Orificemeter
- Pitot tube
- V – Notch
- Friction through Circular pipe
- Flow through Annulus.
- Flow through Helical coil
- Pipe Fitting (Minor Losses)
- Centrifugal Pumps
- Power Consumption in agitated vessel
- Viscosity by Stoke's Law

Course Code	Course/Subject Name	Credits
CHL308	Engineering Chemistry-I Lab	1.5

List of Experiments Suggested:

Volumetric analysis:

Preparation of standard solutions and to find normality and deviation factor. [Any 3]

Titrimetric analysis:

- Analysis of talcum powder for Mg content by EDTA method
- Analysis of Aspirin as per I.P. or USP
- Determination of fluoride content in the toothpaste spectrophotometrically
- Estimation of CaO in cement
- Estiimation of Vitamin C using Ceric ammonium sulphate
- Estimation of Glycine by non aqueous titration using perchloricacid

Organic estimations

- Estimation of aniline
- Estimation of phenol
- Estimation of Acetamide

Gravimetric estimation of

- Barium as $BaCl_2$
- Tin as $SnCl_2$
- Nickel as Ni D.M.G.
- Zinc as $ZnSO_4$

Course Code	Course/Subject Name	Credits
CHL309	**Computer Programming and Numerical Methods Lab**	**1**

List of Experiments Suggested:

- Solving a single NLE by Successive Substitution.
- Solving a single NLE by Regula-Falsi method.
- Solving a single NLE by Newton's method.
- Solving a system of linear equations by Gauss Jordan method.
- Solving a system of linear equations by Gauss Seidel method.
- Solving an ODE by Euler's methods.
- Solving an ODE by RK methods.
- Solving an ODE by Adam-Bashforth method.
- Solving a PDE by Crank-Nicholson method.
- Solving a PDE by Bender-Schmidt method.

Semester IV

Teaching Scheme

Subject Code	Subject Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tutorial	Theory	Pract	Tut	Total
CHC401	Applied Mathematics-IV	03	-	1.0	3.0		1.0	4.0
CHC402	Engineering Chemistry-II	04		-	4.0			4.0
CHC403	Chemical Engg. Thermodynamics - I	03		1.0	3.0		1.0	4.0
CHC404	Material Science &Engineering	03		1.0	3.0		1.0	4.0
CHC405	Mechanical Equipment Design (MED)	03		1.0	3.0		1.0	4.0
CHC406	Solid Fluid Mechanical Operations (SFMO)	03		1.0	3.0		1.0	4.0
CHL407	Engineering Chemistry Lab II		03			1.5		1.5
CHL408	Chemical Engg Lab (SFMO)		03			1.5		1.5
CHL409	MED Lab		02			1.0		1.0
Total		19	08	05	19	4.0	5.0	28

Examination Scheme

Subject Code	Subject Name	Examination Scheme							
		Theory Marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Average of Test 1 and Test 2					
CHC401	Applied Mathematics-IV	20	20	20	80	25	-	-	125
CHC402	Engineering Chemistry-II	20	20	20	80			-	100
CHC403	Chemical Engg. Thermodynamics - I	20	20	20	80	25			125
CHC404	Material Science Engineering	20	20	20	80	25			125
CHC405	Mechanical Equipment Design (MED)	20	20	20	80	25	-	-	125
CHC406	Solid Fluid Mechanical Operations (SFMO)	20	20	20	80	25		-	125
CHL407	Engineering Chemistry Lab II						25		25
CHL408	Chemical Engg Lab (SFMO)						25		25
CHL409	M ED Lab							25	25
Total				120	480	125	50	25	800

Course Code	Course/Subject Name	Credits
CHC401	**Applied Mathematics-IV**	**04**

Prerequisites:

- **Vector Calculus**:-Multiple Integral, Partial differentiation, basic knowledge of vectors and their products,Knowledge of spherical and cylindrical coordinate system.
- Partial Differential Equation:- Integration, Knowledge of partial derivatives.

Course Objectives:

- The syllabus/module aims to introduce the above topics (to the Learner) so as to equip the learner with mathematic tools to effectively model, analyze and find the solution of various problems in Chemical Engineering processes.
- One can use vector formation and calculus together to describe and solve many problems in two/three dimension. The Fourier Transform and PDE module does the ground work for the techniques required to solve and find the answer for various physiochemical problems.

Course Outcomes:

- It is expected that the learner will develop the proactive approach towards the selection of methods to a solution of Chemical Engineering problems coming across while studying higher level of Chemical Engineering .(Example: Flow of Liquid through Pipes/Gases etc.)

Module	Contents	No. of Hours
01	**Fourier Series** • Expansion of functions in any interval (a, b) . Half range expansion; Complex form; Parseval's identity theorem; Orthogonal and Orthonormal functions. NO PROOFS REQUIRED.	9
02	• Fourier Integrals and Fourier Transform; sine & cosine Integrals, sine & cosine transforms, complex transforms. NO PROOFS REQUIRED.	10
03	**Partial Differential Equations** • Elliptic, Parabolic & Hyperbolic Equations; Laplace's equation; One dimensional Heat & Wave Equation, Two Dimensional wave equation. (ONLY NUMERICAL PROBLEMS. NO PROOFS REQUIRED).	10
04	**Vector Integration** • Green's Theorem in the plain; Conservative &Solenoidal Fields. Gauss Divergence Theorem, Stokes' Theorem. (ONLY NUMERICAL PROBLEMS. NO PROOFS REQUIRED).	10

References:

- Advanced Engineering Mathematics by *Erwin Kreyszig*, 9TH Edition, Wiley India.
- Schuam's outline series in Fourier series.
- Schuam's outline series in partial differential equations.
- Partial differential equations Vol 1 by Rutherford Aris.

Course Code	Course/Subject Name	Credits
CHC402	Engineering Chemistry – II	04

Prerequisites:

- Basic Concepts of Physical Chemistry and Titration Analysis.

Course Objectives:

- To understand applications of EMF measurement.
- To understand the principles of different instrumental and chromatographic techniques.
- To state and understand Nernstdistribution law in extraction.
- To be able to solve numerical on solvent extraction and ion exchange.
- To understand colloidal phenomenon and its applications.
- To be able to predict the significance of active methylene group.
- To state and understand the Huckel's rule of aromaticity and its application to aromatic hydrocarbons and heterocyclic compounds.
- To understand the effect of various parameters on catalytic reactions.

Course Outcomes:

- Students will understand the concepts of electrochemistry, chromatographic methods, different analytical techniques and the application of surfactants.
- Students will be aware of the significance of active methylene group during organic synthesis and the importance of catalyst. Moreover, on the basis of Huckel's rule, students will be able to differentiate between aromatic and non-aromatic compounds.
- Students will be able to carry out solvent extractions, optical methods and handle different instruments in the laboratory.

Module	Contents	No. of Hours
01	**Electrochemistry** • Conductance,specificconductance, equivalent conductance, molar conductance.Effect of dilution and temperature on conductance. Transportnumber.DebyeHuckel theory of strong electrolytes.Concentration cells with and without transference w.r.t. cations.Standardcells.Use of EMF measurement and other technique for determinationof solubility product, hydrogen ion concentration.	8
02	**Instrumental methods of Analysis** • **Conductometry** Principle and types of titrations - Acid-base, precipitationandcomplexometric. • **Potentiometr**y: Principle and types of titrations - Acid-base, precipitationandcomplexometric. • **AmperometryPolarography:**Methods and applications. • **Chromatography** Adsorption and partition. Study of Paper Chromatography, Thin	10

	Layer Chromatography, High Performance Liquid Chromatography,Gas (Liquid and solid) Chromatography –Principle and their applications. • **Optical Methods** (Principle, Instrumentation and applications) UV, IR, NMR, GC-MS spectroscopy, flame photometry.	
03	• **Ion exchange and solvent extraction techniques** Ion exchange resins, cation and anion exchangers. Desalination by ionexchange and separation of lanthanides. Solvent extraction. Nernstdistribution law. Distribution ratio. Batch, continuous and counter current extraction. Numericals based on solventextraction.	9
04	• **Colloids and surfactants** • Origin of charge on colloidal particles.Concept of electrical double layer. • Helmholtzand system models. Electro-kinetic Phenomenon-Electrophoresis, electro-osmosis, streaming potential and Dorn effect (Sedimentation potential). • Colloidal electrolytes, Donnam Membrane equilibrium Colloidal electrolytes. • Emulsions O/Wand W/O types, emulsifyingagents,surfactants. • Applications of surfactants in detergents, pesticide formulations and foodindustry.	9
05	• **Industrially important esters andAromaticity** • Synthesis and properties of malonic ester andaceto acetic ester • Aromaticityand aromatic character, Huckel's rule of aromaticity, Aromatic character of Benzene, Naphthalene, Anthracene,Pyrrole, Furan, Thiophene, Pyridine.	7
06	• **Catalysis** • Definition. Criteria of catalysis. Types (Homogeneous and Heterogeneous). • Catalytic promoters, poisons. Negative catalysis and inhibition. Autocatalysis and Induced catalysis. Activation energy and catalysis. Intermediate compound formation theory. Adsorption theory. Acid-Base catalysis and mechanism. Enzyme catalysis. Characteristics and mechanism of enzyme catalysis.	9

References:

- Organic Chemistry **-** I L Finar volume I and II
- Instrumental methods of Analysis **-** Willard, Merritt, CBS publishers and Distributors
- Instrumental Methods of Chemical Analysis **-**S.M.Khopkar
- A textbook of Physical Chemistry **-** Glasston Samuel, Macmillan India Ltd. (1991)
- Physical chemistry **-** Castellan G.W.AddisonHesly-Haroda Student Edition(1994)
- Inorganic chemistry **-** Huheey

Course Code	Course/Subject Name	Credits
CHC403	**Chemical Engineering Thermodynamics-I**	**04**

Prerequisites:

- Basic thermodynamic properties, laws and equations.
- Differential Equations, Linear Algebraic Equations.

Course Objectives:

- To make students familiar with the basics of Chemical Engineering Thermodynamics.
- To learn to apply to various Chemical Engineering processes.

Course Outcomes:

- The students will be able to apply thermodynamic laws and equations to various Chemical Engineering processes.

Module	Contents	No. of hours
01	• Concept of System, Surrounding, Processes, Cycle, State and • Path function, heat and work interactions, reversible and irreversible processes • Concept of Internal Energy and Enthalpy • First Law of Thermodynamics • Application of First Law of Thermodynamics to various types of processes, reactive processes and cycles • Thermodynamic Analysis of Flow Processes	7
02	• Second Law of Thermodynamics • Concepts of heat engine, heat pump and refrigerator. • Carnot Cycle and Carnot Principle • Clausius Inequality • Concept of Entropy and estimation of entropy of reversible and irreversible processes and cycles. • Concept of Exergy and Exergy of Chemical Processes	8
03	• Ideal Gas and real gas behavior • Equation of States- Van der Waals, Berthelot, Redlich-Kwong, Soave RedlichKwong, Virial and Peng Robinson. • Applications of above mentioned equations of states to pure fluids as well as to mixtures of gases	8
04	• Helmholtz Energy and Gibbs Energy. • Maxwell relations and various thermodynamic relations • Joule Thompson effects and estimation of Joule Thompson coefficient for gases.	8
05	• Residual Properties- Residual Enthalpy and Entropy • Thermodynamic Charts, Diagrams and their applications • Fugacity and fugacity coefficient	8

References:

- Stanley I Sandler, “Chemical and Engineering Thermodynamics”, John Wiley and Sons.
- Richard M Feldar, Ronald W Rousseau, “Elementary Principles of Chemical Processes”, Third Edition, Wiley publishers.
- Yunus A Cengel, Michael A Boles, “Thermodynamics- An Engineering Approach”, McGraw Hill.
- K.V Narayanan, “A textbook of Chemical Engineering Thermodynamics”, PHI learning.
- Rao Y.V.C, “Chemical Engineering Thermodynamics”, University Press.

Course Code	Course/Subject Name	Credits
CHC404	**Material Science & Engineering**	**4**

Prerequisites:

- Crystal Structures, X Ray Diffraction, Imperfections in Solids.
- Primary & Secondary Bonding, Types of Alloys, Corrosion & its types.

Course Objectives:

- To understand the basic fundamentals of Science behind Materials on atomic scale and in bulk materials.
- To find various types of Materials and analyze how properties change due to various effects.
- To apply the above knowledge for the selection of materials for process equipments.

Course Outcomes:

- Students would have knowledge about the existence of new materials and their properties.
- The students will be able to choose appropriate material for process equipments.

Module	Contents	No. of Hours
01	• Scope of Material Science & Engineering and its importance in Chemical Engineering Course • Introduction of Standard Model of an atom; Young's Double Slit Experiment for dual nature, Wave nature of electron, Heisenberg's Uncertainity Principle, De Broglie's Wavelength, Schrodinger's Wave Equation for 1-D Time Dependent.	7
02	• Introduction to Magnetic Materials, Influence of Temperature on Magnetic Behavior, Magnetic Storage, Superconductivity • Energy Band Structures in Solids, Electrical Conduction in Ionic Ceramics & in Polymers • Light Interaction with solids, Atomic & Electronic Interactions, Optical Properties of Metals, Optical Properties of Non Metals , Opacity & Translucency in Insulators like Glass	9
03	• Iron-Carbon System, Phase diagram for Iron-Carbon System, Cooling curve of Fe, Solid Phase Fe-Fe carbide phase diagram, Development of Microstructures in Iron-Carbon alloys • Deformation of Materials & Strengthening Mechanisms • Elastic Deformation, Plastic Deformation, Mechanisms of strengthening in Metals, Recovery, Recrystallization & Grain growth • Crystal Imperfections • Theories of Failure – Fatigue (cyclic stresses, S-N Curve, Crack Theory), Fracture (Types, Principles & Mechanisms)	10

	&Creep (Types)	
04	• Polymer alloys(Difference in properties with their parent polymers) & their applications (ABS- PS, PC-PET, SAN-EPDM, PET-PS), Plastics for Packaging for food, beverages, oil & Detergents • Composites (FRP in detail) • Graphite, Ceramics, Refractories, Clay	03
05	• Mechanism & Factors influencing Corrosion • Corrosion of Ceramic Materials • Degradation of Polymers	03
06	• Factors determining choice of Materials • MOC for Process Equipments • MOC for handling chemicals (in reactor, storage vessel and transportation) like Ammonium Chloride, Sulfuric Acid, Chlorine (Dry & Wet)	07

References:

- W. D. Callister, Fundamentls of Materials Science and Engineering, Wiley
- S.D.Dawande, Process Equipment Design, Denett& Co
- Beiser-Mahajan-Choudhary, Concepts of Modern Physics, McGrawHill
- Michael Ashby-Hugh Shercliff-David Cebon, Materials- Engineering, Science, Processing and Design, BH
- M.G.Fontana, Corrosion Engineering, Tata Mcgraw Hill

Course Code	Course/Subject Name	Credits
CHC405	Mechanical Equipment Design (MED)	4

Prerequisites

- Fundamentals of units
- Elementary theory of engineering mechanics
- Engineering drawing

Course Objectives*:*

- To understand the basics for design as per the codes & standards for the mechanical design of equipments used in the process industry.
- Selection of material of construction and stress analysis by determining values of stresses arising out of different loading conditions

Course Outcomes:

- Students will demonstrate ability to design various components of process equipment as heads, shell, flanges and supports and complete design of a chemical equipment
- Students will demonstrate understanding of design of storage vessel
- Students will demonstrate general understanding of fabrication techniques and equipment testing as a designer.

Module No.	Contents	No. of Hrs.
1	Introduction to Chemical process Equipment Design: Introduction to Chemical process Equipment Design Nature of process equipment, General design procedure. Basic consideration in process equipment design, Standards, codes & their significance, equipment classification & selection, Fundamentals of various stress due to compression, tension, bending, torsion& thermal stresses, Principal stress and theories of failure. Concept of hook's law, material behaviour and poison's ratio, material of construction for chemical process equipment, Design pressure, Design temperature, design stress & design loads, Significance of factor of safety and economic considerations	4
2	Design of Unfired Pressure Vessels: Type of pressure vessels, code & standard for pressure vessels (IS: 2825:1969), Material of Construction, Selection of corrosion Allowance & weld joint efficiency. Thin cylinder theory for internal pressure <u>PART A: Pressure Vessel Subjected to Internal Pressure.</u> Complete design of cylindrical pressure vessel as per IS: 2825: 1969 Study, selection & design of various heads such as Flat, hemispherical, tori-spherical, elliptical & conical.	10

	Openings/nozzles & manholes etc. Flanged joints: Gasket: Types, selection & design. Bolt design & selection Flange dimensions & optimization for bolt spacing PART B: Pressure Vessel Subjected to External Pressure. Design of shell, heads nozzles, flanged joints & stiffening rings as per IS 2825: 1969 Appendix F by use of charts. Analytical approach by elastic bucking & plastic deformation.	
3	Storage Vessels: Study of Various types of storage vessels and application. Atmospheric vessels, vessels for storing volatile & non-volatile liquids. Storage of gases, Losses in storage vessel. Various types of roofs used for storage vessels, Manholes, Nozzles and mounting. Design of cylindrical storage vessels as per IS: 803 should include base plates, shell plates ,roof plate and wind girders	6
4	Agitators: Study of various types of agitators & their application, Baffling, Power requirement of agitators & their applications, system which includes design of shaft based on equivalent twisting moment, equivalent bending moment and critical speed. Design of blades & Blade assembly, key & key ways. Design of rigid flange coupling, Study of seals and design of stuffing box and gland	6
5	Reaction Vessels: Introduction, Classification of reaction vessels, Material of Construction, Heating system, Design of vessel, Study & design of various types of jackets like plain and half coil.	4
6	Vessel Supports: Introduction & classification of support. Design of skirt Support considering stresses due to dead weight, wind load, Seismic load & period of vibration. Design of base plates, skirt bearing plate, anchor bolt and bolting chair. Introduction to bracket support. Design of saddle supports	5
7	Equipment fabrication and inspection: Metal forming techniques (bending, Rolling, Forming) & Metal Joining techniques – welding (Gas of Arc & Electric) for various types such as Butt, Lap, fillet, corner. Inspection of vessel by radiography.	4

References:

- Machine Drawing by N.D.Bhatt and V.M.Panchal, Charotar publication
- Process Equipment Design by M.V.Joshi and V.V.Mahajani,Macmilan India
- Process Equipment Design and Drawing by KiranGhadyalji,Nandu publication.
- Process Equipment Design- Vessel design by L.E.Brownell and E.H.Young,John Wiley
- Chemical Engineering Volume 6-Design by J.M.Coulson, J.F.Richardson and R.H.Sinnott,Pergamon Press.
- Pressure Vessel Handbook by Eugene F.Megyesy,Pressure vessel company

Course Code	Course/Subject Name	Credits
CHC406	**Solid Fluid Mechanical Operations**	**04**

Prerequisites

- Fluid Flow Operations
- Engineering Mechanics
- Differential Equations

Course Objectives

- Understanding basic principles of particlesize measurement and distribution.
- Basic knowledge in particle technology (particle size, shape, specific surface).
- Ability to understand phenomena related to specific surface of particles.
- Understanding concepts of sedimentation, flow through packed bed, filtration.
- Ability to understand solid mixing and solid conveying.

Course Outcomes

- The student would understand the concept of particle size measurement and distribution.
- The student would understand the concept of hindered settling, sedimentation and particle mechanics.
- The student would understand the concept of solid mixing, solid storage and solid conveying.
- The student would understand the concept of filtration.

Module	**Contents**	**No. of hours**
01	• Introduction:-Scope & Application of Solid Fluid Operation. • Particle Size Analysis:-Particle Size Measurement & distribution. • Sieve Analysis Screening Equipments, Capacity & Effectiveness.	5
02	• Introduction to Size Reduction Equipments, • Their Selection & Power Requirement in Milling Operations.	5
03	• Storage & Conveying of Solids: - Introduction to Storage Solids, Bins, Hoppers & Silos. • Jensen's Equation. • Conveying of Solids: - Introduction to Conveying of Solids, Belt Conveyor, Bucket Conveyor, Pneumatic Conveyor &Elevators.	7
04	• Flow through Packed Beds:-Characteristics of Packing, Ergen's Equation, Flow of a single fluid through a packed bed, Problems of Channeling & Wetting. • Fluidization.: - Fluidization Characteristics, aggregative & particulate fluidization, Minimum Fluidization, Voidage& Minimum Fluidization Velocity, Voidage Correlation, Gas-Solid fluidization characteristics • Filtration:-Flow through Filter Cakes & Medium	9

	• Washing (Numerical), Const Rate & Pressure Filtration, Filter aids, Selection of filtration Equipment.	
05	• Particle Mechanics:-Motion of Particles in fluids, Effect of particle shape, Stokes Law, Hindered Settling. • Sedimentation: - Gravity Settling, Batch Sedimentation, Kynch Theory of Sedimentation. • Area & Depth of Thickener. • Particle Separation Based on motion of Particles through fluids:-Froth floatation & Elutriation.	9
06	• Mixing of Solids & Paste. • Gas-Solid Separation Equipment:-Fabric Filter, Cyclone Separator, Electrostaticprecipitator	4

References:

- Unit Operations of Chemical Engineering, W C McCabe & J C Smith, McGraw Hill.
- Chemical Engineering, Vol. II, J M Coulson and J F Richardson,Pergamon press.
- Perry's Handbook for Chemical Engineers,Robert H. Perry & Don W. Green,8th edition, McGraw Hill.
- Unit Operations by Foust

Course Code	Course/Subject Name	Credits
CHL407	Engineering Chemistry Lab-II	1.5

List of Experiments Suggested:

- Organic spotting: Identification of organic compounds at least 05.

- Potentiometric titrations.
- Titration of strong acid and strong base potentiometrically.
- Determination of solubility and solubility product of AgCl.

- pH-metry.
- Determination of dissociation constant of dibasic organic acids such as malonicacid,succinic acid.

- Conductometric Titrations.
- Titration of strong acid with strong base.
- Weak acid against strong base.
- Titration of mixture of weak acid and strong acid against strong base.

- Flame photometry.
- Determination of Na / K / Ca present in the given sample.

- Chromatography.
- Estimation of Sodium by Ion Exchange chromatography.
- Paper Chromatography and TLC [Demonstration of techniques].

- Spectro-photometry.
- Estimation of Fe^{3+} ions by Spectrophotometry.

- Organic Estimations.
- Estimation of Glucose Iodometrically.
- Estimation of Ester by Hydrolytis.
- Volume strength and amount of H_2O_2.

Course Code	Course/Subject Name	Credits
CHL408	**Chemical Engineering Lab (SFMO)**	**1.5**

List of Experiments Suggested:

- Sieve Analysis
- Effectiveness of Screen
- Size Reduction by Jaw Crusher
- Size Reduction by Hammer Mill
- Size Reduction by Ball Mill
- Batch Sedimentation
- Flow through Packed Bed
- Flow through Fluidized Bed
- Filtration
- Sigma Mixer

Course Code	Course/Subject Name	Credits
CHL409	**MED Lab**	**1**

List of Suggested Drawing Sheets

- Assembly and Detailed drawings of Machine elements like shafts, key and keyways, Fasteners, Types of welding technique and symbols.
- Assembly and Detailed drawings of Pressure vessel parts such as types of heads,Nozzle joints and flanged joints, mountings (Sight glass, Light glass,man hole etc)
- Assembly and Detailed fabrication drawings of complete pressure vessel and its parts to a recommended scale.
- Assembly and Detailed fabrication drawings of complete storage vessel and its parts to a recommended scale.
- Assembly and Detailed fabrication drawings of Agitator vessel and its parts like coupling and stuffing box to a recommended scale
- Assembly and Detailed fabrication drawings various types of reaction vessel to a recommended scale
- Assembly and Detailed fabrication drawings of various types supports to a recommended scale

AC ??/??/2014 Item no. ?.??

UNIVERSITY OF MUMBAI

Revised Syllabus
Program - **Bachelor of Engineering**
Course - **Chemical Engineering**
(Third year - Sem V and VI)

under
Faculty of Technology
(As per Credit Based Semester and Grading System from 2014-15)

General Guidelines

Tutorials

- The number of tutorial batches can be decided based on facilities available in the institution.
- Tutorials can be creative assignments in the form of models, charts, projects, etc.

Term Work

- Term work will be an evaluation of the tutorial work done over the entire semester.
- It is suggested that each tutorial be graded immediately and an average be taken at the end.
- A minimum of ten (unless specified in course syllabus) tutorials will form the basis for final evaluation.

Theory Examination

- In general all theory examinations will be of 3 hours duration.
- Question paper will comprise of total six questions, each of 20 Marks.
- Only four questions need to be solved.
- Question one will be compulsory and based on maximum part of the syllabus.

Note: In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus as far as possible.

Practical Examination

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments(unless specified minimum requirement in syllabus).

University of Mumbai

Scheme for TE: Semester-V

Course Code	Course Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHC501	Chemical Engineering Thermodynamics - II	03	–	01	3.0	–	1.0	4.0
CHC502	Mass Transfer Operations - I (MTO-I)	03	–	01	3.0	–	1.0	4.0
CHC503	Heat Transfer Operations – I (HTO-I)	03	–	01	3.0	–	1.0	4.0
CHC504	Chemical Reaction Engineering - I (CRE-I)	03	–	01	3.0	–	1.0	4.0
CHC505	Chemical Technology	03	–	–	3.0	–	–	3.0
CHC506	Business Communication & Ethics	–	02* + 02	–	–	–	–	2.0
CHL507	Chemical Engg Lab (MTO-I)	–	03	–	–	1.5	–	1.5
CHL508	Chemical Engg Lab (CRE-I)	–	03	–	–	1.5	–	1.5
CHL509	Chemical Engg Lab (HTO-I)	–	03	–	–	1.5	–	1.5
CHL510	Chemical Engg Lab (Synthesis)	–	03	–	–	1.5	–	1.5
	Total	15	16	04	15.0	6.0	6.0	27.0

*Theory for entire class.

Examination Scheme

Course Code	Course Name	Examination Scheme							
		Theory marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Avg. of Test 1 and Test 2					
CHC501	Chemical Engineering Thermodynamics - II	20	20	20	80	25	–	–	125
CHC502	Mass Transfer Operations - I (MTO-I)	20	20	20	80	25	–	–	125
CHC503	Heat Transfer Operations – I (HTO-I)	20	20	20	80	25	–	–	125
CHC504	Chemical Reaction Engineering - I (CRE-I)	20	20	20	80	25	–	–	125
CHC505	Chemical Technology	20	20	20	80	–	–	–	100
CHC506	Business Communication & Ethics	–	–	–	–	50	–	–	50
CHL507	Chemical Engg Lab (MTO-I)	–	–	–	–	–	25	–	25
CHL508	Chemical Engg Lab (CRE-I)	–	–	–	–	–	25	–	25
CHL509	Chemical Engg Lab (HTO-I)	–	–	–	–	–	25	–	25
CHL510	Chemical Engg Lab (Synthesis)	–	–	–	–	–	–	25	25
			Total	100	400	100	75	75	750

Course Code	Course Name	Credits
CHC501	Chemical Engineering Thermodynamics - II	4.0

Prerequisites

Chemical Engineering Thermodynamics – I, Engineering Mathematics.

Course Objectives

The course objectives are

- The student should be able to relate thermodynamics to the Chemical Engineering Problems.
- The students should be able to use thermodynamics rules to find the equilibrium in phases.
- The students should be able to calculate and trace the equilibrium concentration and conversions of a reversible reaction.
- The students should be able to calculate the actual power required for given duty of refrigeration.

Course Outcomes

The student learn the application of First law and second law to the problem of phase equilibrium and reaction equilibrium . The students also learn to calculate the refrigerant flow rate for a given duty of refrigeration. This helps in estimating the compressor sizes and loads for refrigeration. The calculation of phase equilibria and the understanding of it is a fundamental concept to design of mass transfer equipment.

Detail syllabus

Module	Contents	No. of hrs
1	**Reaction Thermodynamics:** Calculation of heat of reaction for batch reactors, Calculation of heat of reaction for continuous reactors.	05
2	**Fundamentals of Phase Equilibria:** Concept of equilibrium in phases, The theory of ideal and non ideal solutions, Thermodynamic equations of Vapor Liquid Equilibrium for ideal and non ideal solutions, Liquid Liquid and Solid Liquid equilibria.	12
3	**Reaction Equilibria:** Representation of reaction stoichiometry, Concept of reaction equilibria, single and multiple reactions, Degrees of freedom for single and multiple reactions.	10
4	**Refrigeration:** Theory of refrigeration, Vapor Absorption Refrigeration, Vapor Absorption Refrigeration, Estimation of refrigerant flow rate and power of compression.	07
5	**Methods for estimation of Thermodynamics properties:** Estimation methods for critical parameters, Estimation method for Mixture Enthalpy and Entropy.	05

References

1. Stanley I. Sandler, Chemical, Biochemical, and Engineering Thermodynamics, 4 ed., Wiley Student Edition

2. M.J. Moran, H.N. Shapiro, Fundamentals of Engineering Thermodynamics, 6 ed., Wiley Student Edition

3. Peter Atkins, Physical Chemistry, 9 ed., Oxford University Press.

Note for the teacher/instructors: The teachers should encourage the student to use computer for solving problems. It would be worth mentioning that Microsoft Excel suffices for solving most of the problems in the syllabus. A total of twelve assignments and tutorials together should be given to the students at regular intervals. Students should be encouraged to submit assignment using word processor and as far as possible they should be allowed to submit it online in some form. As far as possible it should be multiple choice questions for problem based in mid term tests.

Course Code	Course Name	Credits
CHC502	Mass Transfer Operations - I (MTO-I)	4.0

Prerequisites

Knowledge of chemistry, physics, physical chemistry, mathematics, process calculations and unit operations.

Course Objectives

To give insight of mass transfer basic principle and mass transfer mechanisms.

Course Outcomes

At the end of the course students will be able to ...

- demonstrate the knowledge of mass transfer by applying principles of diffusion, mass transfer coefficients, and interphase mass transfer.
- understand the concept and operation of various types of gas-liquid contacts equipments.
- determine NTU, HTU, HETP and height of packed bed used for Absorption and Humidification operations.
- find time required for drying.

Detail syllabus

Module	Contents	No. of hrs
1	**Molecular Diffusion in Gases and Liquid:** Basics of Molecular Diffusion, Fick's First Law of Molecular Diffusion, Various fluxes and relations between them, Molecular Diffusion in binary gas mixtures – Steady state diffusion of one component in non-diffusing second component, Equimolal counter diffusion of two components. Molecular Diffusion in binary liquid solutions – Steady state diffusion of one component in non-diffusing second component, Steady State Equimolal counter diffusion of two components. Diffusivity of gases. Theoretical and experimental determination of diffusivities, Diffusivities of liquids – Theoretical Determination. Diffusion in Solids: Ficks law of diffusion in solids, Types of Solid Diffusion, Diffusion through Polymers, Diffusion through Crystalline Solids, Diffusion in Porous Solids	08
2	**Mass Transfer Coefficients:** Definition of Mass Transfer Coefficient, F-Type and K-Type Mass Transfer Coefficients and relations between them, Mass Transfer Coefficients in Laminar and Turbulent Flow. Heat, Mass and Momentum Transfer Analogies and dimensionless numbers, Interphase Mass Transfer – Individual and Overall Mass Transfer Coefficients and relation between them. Methods of contacting two insoluble phases – Continuous Contact, Stage-wise Contact.	08

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Module	Contents	No. of hrs
3	**Equipments for Gas-Liquid Contacting:** Classification of equipments for gas-liquid contacting • Gas dispersed and liquid continuous phase – Sparged Vessels (Bubble Columns), Mechanically Agitated Vessels, Tray Towers. • Liquid dispersed phase and gas continuous phase – Venturi Scrubbers, Wetted Wall Towers, Spray Towers and Spray Chambers, Packed Towers. Comparison of Packed Towers with Tray Towers.	06
4	**Gas Absorption:** Solubility of gases in liquids, Effect of temperature and pressure on solubility, Ideal and Non-ideal solutions, Choice of solvent for gas absorption, Single component gas absorption – Cross Current, Co-current, Countercurrent, Multistage Counter current Operation. Absorption with Chemical Reactions.	06
5	**Drying:** Introduction to drying, Equilibrium, Different types of moisture contents, Rate of Drying and drying curve, Batch Drying and calculation of time of drying, Continuous	06
6	**Humidification and Dehumidification:** Introduction, Vapour Pressure Curve, Properties of Vapour-Gas mixtures [Understanding various terms], Theory of wet bulb temperature, Adiabatic Saturation Curves,Humidity Charts, Adiabatic operation : (Air water systems) water coolers, cooling towers	06

References

1. Treybal R.E. , Mass transfer operation, 3 Ed., McGraw Hill New York, 1980.
2. McCabe W.L. and Smith J.C., Unit operation in chemical engineering, 5 Ed., McGraw Hill New York 1993.
3. Geankoplis C.J., Transport processed and unit operations, Prentice Hall , New Delhi 1997.
4. Coulson J.M. Richardson J.F., Backhurst J.R. and Harker J.H., Coulson and Richardson chemical engineering, vol 1 & 2, Butterworth Heinman, New Delhi, 2000.
5. R.K.Sinnot (Ed) Coulson and Richardson chemical engineering, vol 6, Butterworth Heinman, New Delhi, 2000.

Course Code	Course Name	Credits
CHC503	Heat Transfer Operations – I (HTO-I)	4.0

Prerequisites

Laws of thermodynamics, Units and dimensions, Fluid flow principles, Solution techniques of ordinary and partial differential equations.

Course Objectives

- Students should be able to calculate rate of heat transfer by all three modes of heat transfer.
- Understand the basic principles involved in mechanism and calculation of heat transfer rates.
- Able to deal with most common types of unsteady state operations of heat transfer.
- Should become familiar with equipments, used for heat transfer in industry.

Course Outcomes

Upon completion of this course the learners will be acquainted to process design concept of heat transfer equipments and prepared for heat transfer equipment design study.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** fundamentals of heat transfer, basic modes of heat transfer. Concept of driving force and heat transfer coefficients, rate expressions for three modes i. e. conduction, convection, radiation	02
2	**Steady state conduction:** Fourier's Law, thermal conductivity, conduction through a flat slab, composite slab, conduction through a cylinder, composite cylinder, conduction through sphere, composite sphere. Critical radius of insulation. Concept of thermal resistance, fouling factors, Wilson plot, calculation of overall heat transfer coefficients.	05
3	**Unsteady state conduction:** Lumped Parameter Analysis -systems with negligible internal resistance. Biot number, Fourier number, Heating a body under conditions of negligible surface resistance,, heating a body with finite surface and internal resistance, heat transfer to a semi-infinite wall.	04
4	**Heat transfer by convection:** Fundamental considerations in convective heat transfer, significant parameters in convective heat transfer such as momentum diffusivity, thermal diffusivity, Prandtl number, Nusselt number, dimensional analysis of convective heat transfer-Natural and Forced convection, convective heat transfer correlations for internal and external flows, equivalent diameter for heat transfer, estimation of wall temperature, correlations for heat transfer by natural convection from hot surfaces of different geometries and inclination.	07

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Module	Contents	No. of hrs
5	**Heat transfer in condensation and boiling:** Introduction, types of condensation, Nusselt's theory of condensation, correlations for vertical and horizontal tube, plate, for stack of tubes etc. Heat transfer to boiling liquids, regimes of pool boiling of saturated liquid, correlations for estimating the boiling heat transfer coefficients.	05
6	**Steam:** Properties of steam. Steam generation by utilizing process waste heat, efficient use of steam in plant.	04
7	**Heat transfer through extended surfaces:** longitudinal, transverse and radial fins, calculations with different boundary conditions, efficiency and effectiveness of fin, calculation of rate of heat transfer.	03
8	**Heat Exchangers:** Classification and types of heat exchangers, Double pipe heat exchanger, calculation of LMTD, effectiveness NTU method. Introduction to Shell and Tube Heat Exchanger. heat transfer in agitated vessel	05
9	**Radiation heat transfer:** Emissivity, absorptivity, black body, grey body, opaque body, Stephan Boltzmann law, Kirchoff's law. Equations for rate of heat transfer by radiation for various cases. Basic unsteady state radiation heat transfer.	04

References

1. D. Q. Kern, Process Heat Transfer, McGraw Hill, 1997.
2. Incropera Frank P., Dewitt David P., Bergman T. L., Lavine A. S., Seetharamu K. N., Seetharam T. R., Fundamentals of Heat and Mass Transfer, Wiley, 2014.
3. Holman, J. P., Heat Transfer, 9 ed., McGraw Hill, 2008.
4. R. K. Sinnott, Coulson & Richordsons Chemical Engineering Design, Vol. 6, Elsevier Butterworth-Heinemann.
5. J. M. Coulson and J. F. Richardson with J. R. Backhurst and J. H. Harker, Coulson & Richordsons Chemical Engineering Design, Vol. 1 & 2, Elsevier Butterworth-Heinemann, 1996.
6. W. D. Seider, J. D. Seader, D. R. Lewin, Product & Process Design Principles Synthesis, Analysis and Evaluation, John Wiley and Sons, Inc.
7. Robert W. Serth, Process Heat Transfer: Principles and Applications, Elsevier Science & Technology Books.
8. John H. Lienhard IV, John H. Lienhard V, A Heat Transfer Textbook, Phlogiston Press.
9. McCabe W.L., Smith J.C., Harriot P., Unit Oerations of Chemical Engineering, 5th ed., McGraw Hill, 1993

Course Code	Course Name	Credits
CHC504	Chemical Reaction Engineering - I (CRE-I)	4.0

Prerequisites

Students should know basic Chemistry pertaining to Chemical Reactions, Chemical formula etc. They are required to be aware of Chemical processes and unit operations used for the manufacturing of chemical products. Simple to complex numerical methods of solving one and two dimensional Mathematical equations.

Course Objectives

- Development of Kinetic model for homogeneous reactions giving emphasis on various types of reactions like reversible, irreversible, 1st order, 2nd order reactions, series parallel reactions, homogeneous catalytic reactions, autocatalytic reactions, reactions in adiabatic or non isothermal conditions.
- Development of design strategy for homogeneous reactions considering different types of reactors for example batch reactors, flow reactors, semi batch reactors, recycle reactors etc.Reactor design for reactions operating under adiabatic or non-isothermal conditions.

Course Outcomes

Students will be able to apply the knowledge they have gained to find the model equation and use this model to design the reactors used for homogeneous reactions taking place in isothermal or non isothermal conditions.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction and reaction kinetics of homogeneous systems:** Various types of reactions: Reversible Vs irreversible reactions. Homogeneous Vs heterogeneous reactions. Catalytic Vs non-catalytic reactions. Single vs multiple reactions. Auto catalytic reactions, Rate of reaction, Rate constants, Order/ molecularity. Formulation and solution of rate equations for batch reactors for simple and complex reactions. Effect of thermodynamic equilibrium. Temperature dependency-Various Theories. Reaction mechanism and it influence on kinetics, search for plausible mechanism via reaction kinetics	09
2	**Methods of analysis of experimental data:** For Constant volume & variable volume batch reactor – Integral method of analysis of experimental data, Differential method of analysis. Concept of half-life /fractional life. Over all order of irreversible reactions (initial rate method). Empirical rate equation for n^{th} order reactions. Analysis of complete rate of reactions. Partial analysis of rate of reaction. Reversible and irreversible reactions in parallel Reversible and irreversible reaction in series. Homogeneous catalysed reactions. Auto Catalytic reactions. Shifting order reactions	09

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Module	Contents	No. of hrs
3	**Design of reactor:** Ideal batch reactor and concept of batch time. Flow reactor and concept of space time / space velocity and holding time / residence time. Ideal mixed flow reactor (MFR) and plug flow reactor (PFR). Design for single reactions: Single reactor performance of reversible and irreversible first order, pseudo first order, second order reactions for MFR, PFR. Graphical and analytical techniques. Combination of reactors PFR in series / parallel, unequal size MFR in series, performance of the above for the first order and second order reactions. Recycle reactor and auto catalytic reactor. Semi batch reactor and recycle reactor. Design for complex reactions: Irreversible and Reversible reactions in series and parallel with same or different order in various combinations.	12
4	**Heat and pressure effects:** Heat of reaction and its variation with temperature. Variation of equilibrium constant and equilibrium conversion with temperature. Effect of temperature on reactor performance for adiabatic and non adiabatic operations. Case of exothermic reactions in mixed reactor. Optimum temperature progression. Multiple reactions- effect on product distribution. Temperature and scale effect on productivity of reactor. Various problems based on design of non-isothermal reactor are to be solved by using various numerical methods.	09

References

1. Levenspiel, O.,Chemical Reaction Engineering, 3 ed., John Wiley & Co.
2. Smith J.M., Chemical Engineering Kinetics, McGraw Hill.
3. Laidler, K.J., Chemical Kinetics, Tata McGraw Hill, 1997.
4. Hill C.G., Chemical Reaction Engineering.
5. Walas, Reaction Kinetics for Chemical Engineers, McGraw Hill.
6. Sharma M.M & L.K Doraiswamy, Heterogeneous Reactions, Vol 1
7. Fogler, H.S., Elements of Chemical Reaction Engineering, 4 ed.,PHI, 2008.

Course Code	Course Name	Credits
CHC505	Chemical Technology	3.0

Prerequisites

Knowledge of chemistry, physics, physical chemistry and mathematics. Knowledge of Unit Operations and Unit Processes. Knowledge of material balance and energy balance

Course Objectives

- To give students insight of different chemical processes.
- To understand development of process from its chemistry.
- To understand different engineering problems in process industry.

Course Outcomes

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

- demonstrate various manufacturing processes,
- explain industrial processing and overall performance of any chemical process,
- find out the overall process aspects including yield, waste etc.,
- draw and illustrate the process flow diagram.

Detail syllabus

Module	Contents	No. of hrs
1	Introduction: Unit Operations and Processes Concept Used in Chemical Industries. General principles applied in studying an industry, phases of development of chemical industries in India. An overview on industries such as: vegetable oils & animal fats, natural waxes / resins, essential oils & Flavour ingredients Industry, Food & Agro-Products An overview of other industrially important products: Paints, Varnishes & lacquers, Soaps & Detergents, Dyes & Intermediates, Agrochemicals, Pharmaceuticals: Penicillin.	07
2	Manufacturing of Acids: Sulphuric Acid (DCDA Process), Nitric Acid, Acetic Acid & Phosphoric Acid (WET Process), Manufacturing of Fertilizers: Ammonia, Urea, Superphosphate (SSP, TSP) & Ammonium Sulphate	08
3	Sugar, starch & alcohol industries. Introduction to biodiesel processing. Chloro-Alkali Industries: Manufacturing of Caustic Soda, Hydrochloric Acid and Hydrogen, Soda Ash (Solvay and Dual Process).	07
4	Synthesis of Important Heavy Organic Chemicals and Intermediates : Styrene , Phenol, Purified Terephthalic acid.	07
5	Synthesis of Polymers: Polyethylene: LDPE, LLDPE and HDPE; Polyster Fibre, Nylon and PVC.	06

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Module	Contents	No. of hrs
6	Basic Building Blocks of Petrochemical Industry: Treatment of Crude oils and the products there from; refining vs. cracking; manufacture of Acetylene, Ethylene, Benzene Toluene, Xylene.	05

References

1. Austin, G. T., Shreve's Chemical Process Industries, 5 Ed., McGraw Hill International Edition.
2. Pandey, G. N., A text book of Chemical Technology, Vol. I and II., Vikas Publications, 1984
3. Rao, G. N. and Sittig, M. Drydens outlines of Chemical Technology for 21st Century, East West Press, 3rd edition
4. Heaton, C. A., An introduction to industrial chemistry, Leonard Hill, 1984
5. Thomson, R., Moden inorganic chemicals industries, Royal Society of chemistry, 2nd ed., 1994
6. Kirk-Other's, Encyclopedia of chemical technology, John Wiley and sons Inc., 4th ed. 1990
7. Ullmanns Encyclopedia of Industrial Chemistry, VCH, 1985
8. McKettas Encyclopedia of chemical processing and design, Marcel Dekker, 1999
9. Pletcher, D. and Walsh, F. C., Industrial Electro-chemistry, Chapman & Hall, 1990
10. Alok Adholeya and Pradeepkumar Dadhich, Production and Technology of Biodiesel: seeding a change, TERI Publication, New Delhi, 2008
11. NIIR Board of consultants and Engineers, The complete book on Jatropha (Biodiesel) with ashwagandha, stevia, brahmi and Jatamansi Herbs (cultivation, processing and uses), Asia Pacific Business Press Inc.

Course Code	Course Name	Credits
CHC506	Business Communication & Ethics	2.0

Course Objectives

- To inculcate in students professional and ethical attitude, effective communication skills, teamwork, skills, multidisciplinary approach and an ability to understand engineers social responsibilities.
- To provide students with an academic environment where they will be aware of the excellence, leadership and lifelong learning needed for a successful professional career.
- To inculcate professional ethics and codes of professional practice.
- To prepare students for successful careers that meets the global Industrial and Corporate requirement provide an environment for students to work on Multidisciplinary projects as part of different teams to enhance their team building capabilities like leadership, motivation, teamwork etc.

Course Outcomes

A learner will be able to

- Communicate effectively in both verbal and written form and demonstrate knowledge of professional and ethical responsibilities,
- participate and succeed in Campus placements and competitive examinations like GATE, CET,
- possess entrepreneurial approach and ability for life-long learning,
- have education necessary for understanding the impact of engineering solutions on Society and demonstrate awareness of contemporary issues.

Detail syllabus

Module	Contents	No. of hrs
1	Report Writing: Objectives of report writing Language and Style in a report Types of reports Formats of reports: Memo, letter, project and survey based	7
2	Technical Proposals Objective of technical proposals Parts of proposal	2
3	Introduction to Interpersonal Skills Emotional Intelligence Leadership Team Buliding Assertiveness Conflict Resolution Negotiation Skills Motivation Time Management	7
4	Meetings and Documentation Strategies for conducting effective meetings Notice Agenda Minutes of the meeting	2
5	Introduction to Corporate Ethics and etiquettes Business Meeting etiquettes, Interview etiquettes, Professional and work etiquettes, Social skills Greetings and Art of Conversation Dressing and Grooming Dinning etiquette Ethical codes of conduct in business and corporate activities (Personal ethics, conflicting values, choosing a moral response, the process of making ethical decisions)	2
6	Employment Skills Cover letter Resume Group Discussion Presentation Skills Interview Skills	6

References

1. Fred Luthans, Organizational Behavior , Mc Graw Hill, edition
2. Lesiker and Petit, Report Writing for Business , Mc Graw Hill, edition
3. Huckin and Olsen, Technical Writing and Professional Communication, McGraw Hill
4. Wallace and Masters, Personal Development for Life and Work , Thomson Learning, 12th edition
5. Heta Murphy, Effective Business Communication , Mc Graw Hill, edition
6. R.C Sharma and Krishna Mohan, Business Correspondence and Report Writing,
7. B N Ghosh, Managing Soft Skills for Personality Development, Tata McGraw Hill. Lehman,
8. Dufrene, Sinha, BCOM, Cengage Learning, 2nd edition
9. Bell . Smith, Management Communication Wiley India Edition,3rd edition.
10. Dr. K. Alex ,Soft Skills, S Chand and Company
11. Dr.KAlex,SoftSkills,S Chand and Company
12. R.Subramaniam, Professional Ethics Oxford University Press 2013.

Course Code	Course Name	Credits
CHL507	Chemical Engg Lab (MTO-I)	1.5

Concept for experiments

The laboratory work shall consist of a record of minimum eight experiments performed during the term. The design of experiments should cover all concepts (such as Mass transfer coefficient, Gas liquid contacts, Absorption, Drying, Humidification etc.) mentioned in the syllabus. Each and every experiment should conclusively demonstrate / verify the theory. The students should be able to explain variations (if any) between observed and expected results based on technical knowledge. Each experimental report should contain a discussion of the results obtained.

Course Code	Course Name	Credits
CHL508	Chemical Engg Lab (CRE-I)	1.5

Concept for experiments

Minimum 8 experiments need to be performed by the students on following concepts.

- Effect of concentration and temperature on reaction rate.
- Batch reactor.
- Arrhenius constants.
- Differential and integral analysis.
- Acidic hydrolysis.
- Condensation polymerisation kinetics.
- Constant flow stirred tank reactor (CSTR).
- Plug flow reactor (PFR).
- CSTRs connected in series.
- PFR-CSTR combination in series.

Course Code	Course Name	Credits
CHL509	Chemical Engg Lab (HTO-I)	1.5

Concept for experiments

Minimum seven practical including experiments on conduction, unsteady state conduction, forced and natural convection, condensation, heat exchangers should be done. These can include any additional experiment based on the syllabus.

Course Code	Course Name	Credits
CHL510	Chemical Engg Lab (Synthesis)	1.5

Concept for experiments

Concept for experiments to be designed by instructor is students should developed an approach towards engineering a chemical process. Following are some of the suggested processes,

- Preparation of a soap.
- Preparation of a detergent.
- Preparation of paper.
- Preparation of polymer product.
- Preparation of a pharmaceutical product.
- Preparation of a membrane.
- Preparation of a nano-particles.
- Preparation of a dye.
- Preparation of rubber.
- Preparation of a biochemical.
- Preparation of biodiesel.
- Preparation of a food product.
- Hydrogenation of oil.

examples of few lab prepared chemicals along with raw materials can be

Sr. No.	PREPARETION	Chemicals required	Apparatus/ glassware required
1	SOAP	Sodium hydroxide (20% solution), ethanol saturated solution of sodium chloride ,calcium chloride (5% solution), magnesium chloride (5% solution), ferric chloride (5% solution), cooking oil, phenolphthalein indicator solution.	250-mL beaker, 100- mL beaker; wire gauze; laboratory burner; glass stirring rod; test tubes; filter flask and Büchner funnel; filter paper ;graduated cylinder
2	ALUM FROM ALUMINUM	Aluminum can or aluminum metal, Crushed ice, 9M H_2SO_4, 1.5M KOH solution, Methanol, $NaHCO_3$ (sodium bicarbonate)	Glass filter funnel, Büchner filter funnel, filter paper, Steel wool, two 150 mL and two 150 ml beakers, 500 ml beaker, thermometer, ruler, stirring rod.

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Sr. No.	PREPARETION	Chemicals required	Apparatus/ glassware required
3	ASPRIN	2 gm salicylic acid, 5.0 ml of acetic anhydride, five drops of 85% phosphoric acid, distilled water	burette clamp, burner, stand with iron ring, wire gauze, ice bath,50 ml flask beaker, Büchner funnel aspirator
4	METHYL ORANGE	0.29 g of anhydrous sodium carbonate, 1.0 g of sulfanilic acid monohydrate, 0.375 g of sodium nitrite, 0.7 ml of dimethylaniline and 0.5 mL of glacial acetic acid, 10% aqueous sodium hydroxide, 1.25 ml of concentrated hydrochloric acid	50 ml Erlenmeyer flask, filter,100 ml beaker, test tube
5	THIOKOL RUBBER	Sodium hydroxide solution, 1M Sulfur 1,2-dichloroethane distilled or deionized water	Copper wire, approximately 6 inches long (15 cm); two 10 ml vials with teflon cap liners, two 400 ml beakers ,10 ml graduated cylinder ,glass pipette (dropper), hot plate, chemical resistant gloves
6	RUBBER BALL FROM RUBBER LATEX	15 ml rubber latex, 15 ml vinegar, 15 ml water	Two paper cups (5 ounce), stirring rod (popsicle stick or equivalent), small bucket or large beaker (1000 ml or larger)
7	p-BROMO-NITROBENEZENE FROM BROMOBENEZENE	Conc. H_2SO_4, conc. HNO_3, bromobenzene, ethyl alcohol, conical flask, funnel, filter paper, water Bath.	Conical flask,funnel, filter paper, water bath.
8	DETERGENT	Dodecanol (dodecyl alcohol), sulphuric acid, concentrated sodium hydroxide, 6M phenolphthalein solution, 1% sodium chloride	Erlenmeyer flask, 125 ml beakers, 400 ml, 150 ml, 100 ml graduated cylinders, 10 ml, 25 ml, 125 ml funnel, spatula, stirring rod, Cheese cloth, watch glass, scissors

University of Mumbai

Scheme for TE: Semester-VI

Subject Code	Subject Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHC601	Instrumentation	03	–	01	3.0	–	1.0	4.0
CHC602	Mass Transfer Operations – II (MTO-II)	03	–	01	3.0	–	1.0	4.0
CHC603	Heat Transfer Operations – II (HTO-II)	03	–	01	3.0	–	1.0	4.0
CHC604	Chemical Reaction Engineering – II (CRE-II)	03	–	01	3.0	–	1.0	4.0
CHC605	Plant Engineering	04	–	–	4.0	–	–	4.0
CHE606	Elective – I	04	–	–	4.0	–	–	4.0
CHL607	Chemical Engg Lab (MTO-II)	–	03	–	–	1.5	–	1.5
CHL608	Chemical Engg Lab (CRE-II)	–	03	–	–	1.5	–	1.5
CHL609	Chemical Engg Lab (HTO-II)	–	02	–	–	1.0	–	1.0
	Total	20	08	04	20.0	4.0	4.0	28.0

Examination Scheme

Subject Code	Subject Name	Examination Scheme							
		Theory marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Avg. of Test 1 and Test 2					
CHC601	Instrumentation	20	20	20	80	25	–	–	125
CHC602	Mass Transfer Operations – II (MTO-II)	20	20	20	80	25	–	–	125
CHC603	Heat Transfer Operations – II (HTO-II)	20	20	20	80	25	–	–	125
CHC604	Chemical Reaction Engineering – II (CRE-II)	20	20	20	80	25	–	–	125
CHC605	Plant Engineering	20	20	20	80	–	–	–	100
CHE606	Elective – I	20	20	20	80	–	–	–	100
CHL607	Chemical Engg Lab (MTO-II)	–	–	–	–	–	25	25	50
CHL609	Chemical Engg Lab (CRE-II)	–	–	–	–	–	25	–	25
CHL610	Chemical Engg Lab (HTO-II)	–	–	–	–	–	25	–	25
			Total	120	480	100	75	25	800

Elective Streams(CHE606)

Sem.	Management Stream	Technology Stream	Process System Engineering Stream
VI	Operations Research	Advanced Material	Computational Fluid Dynamics

Course Code	Course Name	Credits
CHC601	Instrumentation	4.0

Prerequisites

Process Calculations.

Course Objectives

- To understand the primary mechanisms of sensors
- To understand how measured quantities are processed for transmission and control
- To understand how alarms and interlocks are incorporated into over-all instrumentation and control
- To understand basic control configurations of typical process units

Course Outcomes

- The student will be able to calculate the output of various measuring schemes
- The student will be able to select a DAQ card for any given application
- The student will be able to select the appropriate type of instrument for any application
- The student will be able to prepare a basic control scheme for process units
- The student will be able to write programs for a PLC

Detail syllabus

Module	Contents	No. of hrs
1	**Fundamentals of Measuring Instruments:** Introduction Standards and Calibration, Elements of Measuring Systems, Classification of Instruments, Performance Characteristics, Errors in Measurement.	04
2	**Primary Sensing Mechanisms:** Introduction, Resistive Sensing Elements, Capacitive Sensing Elements, Inductive Sensing Elements, Thermo-electric Sensing Elements, Piezo-electric Sensing Elements, Elastic Sensing Elements, Pneumatic Sensing Elements, Differential Pressure Sensing Elements, Expansion Sensing Elements.	04
3	**Signal Conversion:** Signal Conditioning , Wheatstone Bridge, Potentiometer Measurement System, Signal Processing, Mechanical Amplifier, Electronic Amplifier, A/D and D/A conversion, Signal Transmission, Selection of DAQ cards.	04
4	**Measuring Instruments:** Flow Measurement, Temperature Measurement, Level Measurement, Pressure Measurement.	10
5	**Valves and Drives:** Introduction, Control Valve Characteristics, Sizing and Selection of Valves, Variable Drives.	04

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Module	Contents	No. of hrs
6	**Programmable Logic Controllers:** Introduction, Ladder Logic, Applications of PLCs to typical processes.	04
7	**Introduction to Safety Relief Systems:** Introduction, Types of Relieving Devices, Relief Valves, Rupture Discs, Over-pressurization, Emergency De-pressurization, Introduction to SIL Classification, LOPA Methods, Basic Process Control Schemes.	10

References

1. K. Krishnaswamy and S. Vijayachitra, Industrial Instrumentation, second Edition, New Age International.
2. B. E. Noltingk, Jones Instrument Technology, Vol. 4 and 5, Fourth Edition, Butterworth-Heinemann.
3. W. Bolton, Instrumentation and Control Systems, First Edition, Newnes, Elsevier, 2004.
4. Stephanopoulos, Chemical Process Control, Prentice Hall of India.
5. John P. Bentley, Principles of Measurement Systems, Third edition, Addison Wesley Longman Ltd., UK, 2000.
6. Doebelin E.O, Measurement Systems - Application and Design, Fourth edition, McGraw-Hill International Edition, New York, 1992.
7. Noltingk B.E., Instrumentation Reference Book, 2nd Edition, Butterworth Heinemann, 1995.

Course Code	Course Name	Credits
CHC602	Mass Transfer Operations – II (MTO-II)	4.0

Prerequisites

- Knowledge of chemistry, physics, physical chemistry and mathematics.
- Knowledge of process calculations.
- Knowledge of diffusion, mass transfer coefficients, modes of contact of two immiscible phases.

Course Objectives

- To understand design methods for distillation columns.
- To understand design of extractor and leaching equipments.
- To understand membrane separation.

Course Outcomes

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

- understand equilibrium in all separation process
- describe the mass transfer equipments
- design distillation column
- choose choose the separation operation which will be economical for the process
- optimize the process parameters
- understand membrane separation processes principle and working

Detail syllabus

Module	Contents	No. of hrs
1	**Distillation:** Introduction to Distillation, Vapor-liquid Equilibria – At constant Pressure and At constant temperature, Minimum and maximum boiling Azeotropes. Methods of distillation [binary mixtures] – Flash Distillation, Differential distillation, Rectification. Calculations of number of ideal stages in multistage countercurrent rectification. McCabe Thiele Method. Ponchon-Savarit Method, Lewis-Sorel Method, Concepts of [Brief Discussion], Steam Distillation, Azeotropic Distillation, Extractive Distillation, Reactive Distillation, Molecular Distillation, Introduction to Multicomponent Distillation	12
2	**Liquid-Liquid Extraction:** Introduction to Liquid-Liquid Extraction, Choice of Solvent for Liquid-Liquid Extraction, Triangular coordinate system, Ternary Equilibria [Binodal Solubility Curve with effect of temperature and pressure on it], Single Stage Operation, Multistage Cross Current Operation, Multistage Counter Current Operation[with and without reflux], Equipments for liquid-liquid extraction.	06

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Module	Contents	No. of hrs
3	**Leaching:** Representation of Equilibria, Single stage leaching, Multistage Cross Current Leaching, Multistage Counter Current Leaching, Equipments for Leaching.	06
4	**Adsorption and Ion Exchange:** Introduction to Adsorption, Types of Adsorption, Adsorption Isotherms, Single Stage Adsorption, Multistage Cross Current Adsorption, Multistage Counter Current Adsorption, Equipments for Adsorption, Ion Exchange Equilibria, Ion Exchange Equipments	06
5	**Crystallization:** Solubility curve, Super saturation, Method of obtaining super saturation, Effect of heat of size and growth of crystal, Rate of Crystal growth and Ls law of crystal growth, Material and energy balance for crystallizers, Crystallization equipment-description.	04
6	**Membrane separation Technique:** Need of membrane separation and its advantages, classification of membrane separation process, Various membrane configurations. Various membrane and their applications, Ultra filtration, Nano filtration. Reverse osmosis, Pervaporation. Membrane distillation.	06

Note:

Minimum one assignment on each module should be given at regular intervals. The term work assessment will be based on quality of assignments, attendance in the theory class / tutorials, performance, punctuality and orals at the time of submission.

References

1. Treybal R.E., Mass transfer operation, 3rd ed., McGraw Hill New York, 1980.
2. McCabe W.L. and Smith J.C., Unit operation in chemical engineering, 5th ed., McGraw Hill New York 1993.
3. Geankoplis C.J., Transport processed and unit operations, Prentice Hall , New Delhi 1997.
4. Coulson J.M., Richardson J.F., Backhurst J.R. and Harker J.H. , Coulson and Richardson chemical engineering, vol 1, Butterworth Heinman, New Delhi, 2000.
5. Coulson J.M. Richardson J.F. Backhurst J.R.and Harker J.H. Coulson and Richardosn chemical engineering, vol 2, Asian book pvt ltd, New Delhi, 2000.
6. R.K.Sinnot (Ed) Coulson and Richardson chemical engineering, vol 6, Butterworth Heinman, New Delhi, 2000.

Course Code	Course Name	Credits
CHC603	Heat Transfer Operations – II (HTO-II)	4.0

Prerequisites

Mathematics, Heat Transfer Operations – I.

Course Objectives

Student should able to design shell and tube heat exchangers - condenser, reboilers, evaporators, etc. Student should able to design furnace. Students should know how heat exchanger design software work.

Course Outcomes

Detail syllabus

Module	Contents	No. of hrs
1	**Shell and Tube Heat Exchanger Design for Liquids:** TEMA standards, Stream Analysis Method, Bell-Delaware method. Effect of fouling, and over-design.	12
2	**Plate type heat exchangers(PHE):** Design methods, gasket selection, limitations and advantages PHE	06
3	**Condensers:** Shell and tube condensers – horizontal, vertical. Barometric condensers. Effect of non-condensible. Engineering problems and troubleshooting.	06
4	**Reboiler:** Design – Kettle type reboiler, horizontal thermosyphon reboiler, vertical thermosyphon reboiler. Engineering problems and trouble shooting.	06
5	**Furnace Design:** Radiant section, convection section. Box type furnace. Methods of Lobo and Evans. Method of Wilson, Lobo and Hottel.	08
6	Introduction to Heat exchanger design using softwares e.g. HETRAN, HTRI, TEAMS, etc	02

Note:

It is suggested to arrange tutorials along with practicals of subject code CHL609 to facilitate design and simulations of different exchangers. Students need to take one mini project which should include full scale design of Shell and tube heat exchanger for different process conditions. Minimum six tutorials should be considered for term work.

References

1. Serth, Robert W., Process Heat Transfer Principles and Applications, Elsevier Science & Technology Books, 2007.

2. Kern, D. Q., Process Heat Transfer, McGraw Hill, 1965.

3. Holman, J.P., Heat Transfer, McGraw Hill, 6th Ed., 1986.
4. Standards of Tubular Exchanger Manufacturers Association (TEMA), 8th Ed., New York, 1999.
5. R.K.Sinnot (Ed) Coulson and Richardson chemical engineering, vol 6, Butterworth Heinman, New Delhi, 2000.
6. Bell, K. J., Muller, A.C., Wolverine Engineering Data Book -II, Wolverine Tube Inc., 2001.
7. Rajiv Mukherjee, Effectively Design Shell-and-Tube Heat Exchangers, Chemical Engineering Progress, February 1998.
8. James O. Maloney (Ed), Perry's Chemical Engineers Handbook, Section 11, 8th Ed., McGraw Hill, 2008.
9. Gas Processors Suppliers Association, Engineering Data Book, Section 8 & 9, 12th Ed.,Oklahoma,s 2004.

Course Code	Course Name	Credits
CHC604	Chemical Reaction Engineering – II (CRE-II)	4.0

Prerequisites

Students should know basic Chemistry pertaining to Chemical Reactions, Chemical formula etc. They are required to be aware of Chemical processes and unit operations used for the manufacturing of chemical products. Simple to complex numerical methods of solving one and two dimensional Mathematical equations.

Course Objectives

- Development of Kinetic model for Heterogeneous reactions giving emphasis on various types of reactions like non catalytic, catalytic, liquid liquid reaction, liquid gas reactions in isothermal, adiabatic or non isothermal conditions.
- Development of design strategy for Heterogeneous reactions considering different types of reactors for example fixed bed tubular reactor, fluidized bed reactor, packed bed reactors etc.Reactor design for reactions operating under isothermal, adiabatic or non-isothermal conditions.
- Studying the real reactors considering residence time distribution in various reactors and obtaining actual design parameters.

Course Outcomes

Students will be able to apply the knowledge they have gained to find the model equation and use this model to design the reactors used for heterogeneous reactions taking place in isothermal or non isothermal conditions.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** Kinetics and mechanism of various Heterogeneous reactions and design consideration of reactors used during different operating conditions. **Catalytic heterogeneous reactions:** Properties of solid catalysts, Physical adsorption and Chemisorption, Surface area and pore size distribution, Langmuir-Hinshelwood model, General mechanism of solid catalysed fluid phase reactions. Special cases when (a) Film resistance controls. (b) Surface phenomenon controls. (c) Surface reaction controls (d) Pore diffusion controls. Intrinsic kinetics and various cases of adsorption and reaction stage controls. Concept of effectiveness factor of catalyst and its dependence on catalyst properties and kinetic parameters.	09
2	**Design of solid catalysed fluid phase reactors:** Phenomenon observed in operation of packed, fluid bed, slurry and such reactors. Product distribution in multiple and complex reaction. Thermal Effects, phenomena of stability, instability and run away and its analysis. Strategies for stable operation of reactors. Design consideration of fluid-solid catalytic reactors, including Fluid bed reactors.	03

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Module	Contents	No. of hrs
3	**Non-Catalytic heterogeneous reactions:** General mechanism of reaction.,Various models. Specific cases with respect:(a) Film diffusion controlling. (b) Ash diffusion controlling. (c) Chemical reaction controlling. **Design of reactors for non-catalytic reactors:** Experimental reactors for heterogeneous Reactions, Non-Catalytic Fluid Solid Reactions in Flow Reactors, Application to design of continues solid flow reactors; various design considerations, Application of fluid bed reactors and their design consideration, heat transfer effects.	12
4	**Kinetics of fluid-fluid reactions:** Reaction with mass transfer, The rate equation pertaining to fast to very slow reactions. **Applications to design:** Design of gas-liquid, liquid-liquid and gas-liquid-solid reactors – Heterogeneous reactors, Bubble heterogeneous reactors, co-current and counter-current flow packed bed reactors.	09
5	**Non-ideal flow reactors:** Concept of residence time distribution(RTD), Measurement and characteristics of RTD, RTD in Ideal batch reactors, Plug flow reactor and CSTR. Zero Parameter Model – Segregation and Maximum mixedness model. One parameter model – Tank in series model and Dispersion Model, Recycle Model. Multi parameter models, Effect of dispersion on conversion for general irreversible reaction case, Diagnostic methods of analysis of flow patterns in reactors, Role of micro and macro mixing and segregation in ideal (MFR, PFR) and non ideal reaction cases.	06

References

1. Smith J. M., Chemical Reaction Engineering, 3 ed., Tata McGraw Hill, 1980.
2. Levenspiel O., Chemical Reaction Engineering, John Wiley & Sons, 3 ed., 1999.
3. Laidler, K.J., Chemical Kinetics, Tata McGraw Hill, 1997.
4. Hill C.G., Chemical Reaction Engineering.
5. Walas, Reaction Kinetics for Chemical Engineers, Mcgraw Hill, 1959.
6. Fogler, H.S. Elements of Chemical Reaction Engineering, 4 ed.,PHI, 2008.
7. Doraiswamy & Sharma, Heterogeneous Reaction, Vol. 1 & 2, John Wiley, 1984.
8. Walas, Chemical Reaction Engineering – Hand Book of Solved problems, Gordon & Breach, 1995

Course Code	Course Name	Credits
CHC605	Plant Engineering	4.0

Prerequisites

Knowledge of Process Calculations, Thermodynamics and Fluid flow.

Course Objectives

- At the end of the course the students should understand the knowledge of industrial safety, plant utilities and statistical analysis of results.
- They should able to understand industrial accidents and hygiene, hazards and risk analysis.
- They should able to understand various types of steam generators,its performance.
- They should be able to understand various properties of compressed air, air drying methods, study different types of compressors and humidification and dehumidification operations.
- They should be able to understand the Principles of refrigeration, study different refrigeration systems and refrigerants and their importance.
- They should understand how to select vacuum system and to carry out various operations under vacuum, and knowledge of various types of vents and flares.
- They should learn about statistical analysis of experimental results.

Course Outcomes

- Students will demonstrate the knowledge of industrial safety, utilities and statistical analysis.
- Students will know different types industrial accident, industrial hygiene and risk analysis.
- Students will know how to make efficient use of steam and boilers in chemical industries.
- Students will have deep knowledge of working various compressors and humidification and dehumidification operations.
- Students will be able to find refrigeration effect for different refrigeration systems.
- Students will have knowledge of vacuum systems and vacuum operations, venting and flaring.
- Students will be able carry out statistical analysis of experimental results.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction to safety:** Introduction, safety programs. **Accidents:** Nature of accidents, process of accidents. **Industrial hygiene:** Phases of industrial hygiene projects.Material safety data sheet. **Fire:** Fire triangle, Flammability characteristics of liquids and gases,Minimum oxygen concentration, Ignition energy, Autoignition, Autoxidation, Adiabatic compression, Ignition sources, Sprays and mists, Prevention methods. **Explosion:** Detoriation, Deflagration, Confined explosion, VCE, BLEVE, Blast damage, Missile damage, Prevention methods.	06

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Module	Contents	No. of hrs
2	**Relief systems, Hazards and risk assessment:** **Relief:** Concept, Location of relief, Types, Relief systems. Deflagration venting for dust and vapour explosion. Venting for fires. **Hazards identification:** Hazards Check-list, Hazards Surveys, HAZOP, HAZON. **Risk assessment:** Event trees, Fault trees. Accident investigation: Accident investigation process, AIDS for diagnosis, recommendations.	06
3	**Steam generators:** Steam generators,classification of boilers, boiler mountings and accessories. Performance of steam generators. Distribution of steam in plant. Efficient use of steam.	09
4	**Air:** Compressed air from blower, compressor. Air drying system for instrument air and plant air. Humidification and dehumidification of air.	08
5	**Refrigeration:** Principles of refrigeration. Refrigeration system like compression refrigeration, absorption refrigeration, chilled water system, air conditioning. Types of refrigerants and their importance.	08
6	**Vacuum systems, Venting and flaring:** Different types of vacuum systems. Types of vents and flares.	08
7	**Statistical analysis of results:** Data tabulation and graphical representation. Standard deviation and standard error. Degree of freedom. Analysis of variance (ANOVA).Linear regression analysis.	07

References

1. Crowl, D. A. and Louvar, J. P.; Chemical Process Safety: Fundamentals with Applications; Prentice Hall, Englewood
2. Khurmi, R. S. and Gupta, J. K. A textbook of thermal Engineering, S. Chand.
3. Rajput, R.K.A textbook of Power Plant Engineering. Laxmi Publications (P) Ltd., Navi Mumbai.
4. Ashoutosh Panday; Plant Utilities; Vipul Prakashan, Mumbai
5. Kothari, C. R. and Garg, Gaurav (2014). Research Methodology: Methods and Techniques, Third edition, New age international publishers, New Dehli.

Course Code	Course Name	Credits
CHE606	Elective – I : Operations Research	4.0

Prerequisites

Linear Algebra, Computer Programming

Course Objectives

- To understand Linear Programming and its applications to OR models.
- To understand and solve network models in OR.
- To understand Game theory and its applications.
- To study and design Queuing systems.

Course Outcomes

- The student will be able to solve typical OR models using linear integer and dynamic programming techniques.
- The student will be able to model and solve network flow problems in OR.
- The student will be able to make decisions under various scenarios.
- The student will be able to design Queuing Systems.

Detail syllabus

Module	Contents	No. of hrs
1	**Linear Programming:** Introduction, Graphical Method of Solution, Simplex, Two-Phase Method, Duality, Dual Simplex, Revised Simplex, Sensitivity Analysis	10
2	**Transportation Models:** Examples of Transportation Models, The Transportation Algorithm, The Assignment Model, The Transshipment Model	06
3	**Network Models:** Scope and Definition of Network Models, Minimal Spanning Tree Algorithm, Shortest Route Problem, Maximal Flow Model, CPM and PERT, Minimum-Cost Capacitated Flow Problem	10
4	**Integer and Dynamic Programming:** Branch and Bound Method, Travelling Salesman Problem, Introduction to Dynamic Programming, Forward and Backward Recursion, Selected Applications,	06
5	**Deterministic Inventory Models:** Classic EOQ Model, EOQ with Price Breaks, Multi-item EOQ with Storage Limitation, Dynamic EOQ Models, No-Setup Model, Setup Model	06

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Module	Contents	No. of hrs
6	**Decision Analysis and Game Theory:** Decision Making under Certainty, Decision Making under Risk Decision Under Uncertainty, Game Theory	06
7	**Queuing Systems:** Elements of a Queuing Model, Role of Exponential Distribution, Pure Birth and Death Models, Generalized Poisson Queuing Model, Measures of Performance	06

References

1. Hamdy A. Taha, Operations Research, 8 Ed., Prentice Hall India.
2. Thomas Edgar, Optimization of Chemical Processes, David M.Himmelbleau,2 Ed., John Wiley.

Course Code	Course/Subject Name	Credits
CHE606	Elective – I: Advanced Material	4.0

Prerequisites

Mechanical, Electrical, Magnetic and Optical behaviour of material Iron- Carbon system and alloy, deformation and failure in metals Polymer alloys, ceramics, FRP composites polymer and their Properties Corrosion and choice of materials

Course Objectives

To understand various advanced material such as conducting polymer, high temperature polymer, stainless steel material, composites, ceramics etc. To understand properties and engineering applications of above material. To understand fabrication methods of above materials.

Course Outcomes

Student will identify various types of advance material in polymer, ceramics, & composites. Understand the properties of various polymeric, ceramic and metallic materials and their application in various fields. Student will have knowledge of different types of composite material, their properties and application Understand the fabrication of various composite material. Student will have knowledge of types of nanotube and nanosensor their application. Understand the thin film coating methods and their application in various fields.

Detail syllabus

Module	Contents	No. of hrs
1	**Advanced Metallic Material**: Stainless steels: Types, properties of stainless steel, corrosion resistance and selection of stainless steel, failure of stainless steel. High Temperature Alloys: Properties and types. Titanium Alloys and Cobalt - Chromium Alloys: composition, properties and applications, Nitinol as Shape memory alloy and its application	07
2	**Advanced Polymeric Material:** Structure, preparation and application of various conducting polymers, high temperature polymers and liquid crystal polymers, Biomedical application of polymers such as hydrogels, polyethylene, polyurethanes, polyamides and silicone rubber.	05
3	**Ceramic Material:** Properties of ceramic material, classification of ceramic material, ceramic crystal structures. Behaviour of ceramic material: dielectric, semiconductor, ferroelectric, magnetic, mechanical behaviour, Preparation and application of ceramic material: Alumina, partially stabilized zirconia, Sialon, Silicon Nitride, Silica Carbide Processing of ceramics.	06

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Module	Contents	No. of hrs
4	**Composite Materials:** Necessity of composite material, classification of composite material, types of matrix and reinforcement, Reinforcement mechanism, choosing material for matrix and reinforcement **Fiber Reinforcement Plastic Processing:** Open moulding and closed moulding, Carbon Composites: fabrication and properties	07
5	**Metal Composites:** Advantages of metal composite over metal, types of reinforcement and matrix fabrication types, various fabrication process, mechanical behavior and properties **Ceramic Composites:** matrices and reinforcement, mechanical properties, fabrication methods.	08
6	**Carbon Nanotube**:Synthesis, properties and applications. **Nanoshells:** Types properties and applications. **Nanosensors:** Assembly methods, nanosensors based on optical, quantum size, electrochemical and physical properties. **Thin film coatings:** Physical and chemical vapour deposition coatings, hardfacing, thermal spraying, diffusion process, useful material for appearance, corrosion and wear.	06

References

1. B. K. Agrawal, Introduction to Engineering Material, Tata McGraw Hill Education Pvt. Ltd, 2012.
2. A. K Bhargava, Engineering Material: Polymer, Ceramic and Composites, PHI learning Pvt. Ltd, 2010.
3. Dr. H K Shivanand, B.V. Babu Kiran, Composite Material, Asian Books Private Limited, 2010.
4. T. Pradeep, Nano: The Essential, Tata McGraw Hill Education Pvt. Ltd, 2010.
5. William Smith, Structure and Properties of Engineering Alloy, 2nd Edition, McGraw Hill International Book.
6. William Smith, Javad Hasemi, Ravi Prakash, Material Science and Engineering, Tata McGraw Hill Education company Ltd ,2006
7. Kenneth G. Budinski , Michael K. Budinski, Engineering Materials Properties and Selection, 8th Edition, Prentice Hall.
8. Bowden M.J & Tumber S.R., Polymer of high Technology, Electronic and Photonics, ACS symposium series, ACS , 1987
9. Dyson R.W., Engineering. Polymers, Chapman and Hall, First Edition, 1990
10. Chawala K.K., Composites materials, science and Engineering, 3rd Edition
11. Sujata V. Bhat, Biomaterial, Narosa Publication Pvt. Ltd.

Course Code	Course/Subject Name	Credits
CHE606	Elective – I: Computational Fluid Dynamics	4.0

Prerequisites

Linear Algerbra, Partial Differential Equations, Scilab

Course Objectives

- To understand the formulation of CFD problems
- To discretize the problems
- To solve the set of equations in simple cases using Scilab routines.
- To understand and use software in CFD.

Course Outcomes

- The student will be able to obtain flow profiles for some simple applications using Scilab.
- The student will be able to use appropriate software for solving realistic problems.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** Advantages of Computational Fluid Dynamics, Typical Practical Applications,Equation Structure, Overview of CFD	02
2	**Preliminary Computational Techniques:** Discretisation, Approximation to Derivatives, Accuracy of the Discretisation Process, Wave Representation, Finite Difference Method	04
3	**Theoretical Background:** Convergence, Consistency, Stability, Solution Accuracy, Computational Efficiency	06
4	**Weighted Residual Methods:** General Formulation, Finite Volume Method, Finite Element Method and Interpolation, Finite Element Method and the Sturm-Liouville Equation	08
5	**Steady Problems:** Nonlinear Steady Problems, Newtons Method, Direct Linear Method, Thomas Algorithm	06
6	**One-dimensional Diffusion Equation:** Explicit Methods, Implicit Methods, Boundary and Initial Conditions, Method of Lines	08
7	**Multidimensional Diffusion Equation:** Two-Dimensional Diffusion Equation, Multidimensional Splitting Schemes, Splitting Schemes and the Finite Element Method, Neumann Boundary Conditions	08

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Module	Contents	No. of hrs
8	**Linear Convection-Dominated Problems:** One-Dimensional Linear Convection Equation, Numerical Dissipation and Dispersion, Steady Convection-Diffusion Equation, One-Dimensional Transport Equation, Two-Dimensional Transport Equation	10

References

1. C.A.J. Fletcher, Computational Techniques for Fluid Dynamics 1, Springer-Verlag Berlin Heidelberg GmbH.
2. John D. Anderson, Computational Fluid Dynamics, McGraw Hill Education Private Limited.

Course Code	Course Name	Credits
CHL607	Chemical Engg Lab (MTO-II)	1.5

Concept for experiments

The laboratory work shall consist of a record of minimum eight experiments performed during the term.The design of experiments should cover all concepts (such as Distillation, liquid-liquid extraction, Adsorption, leaching, Crysatllisation & Membarne separation etc) mentioned in the syllabus. Each and every experiment should conclusively demostrate / verify the theory.

The students should be able to explain variations (if any) between observed and expected results based on technical knowledge. Each experimental report should contain a discussion of the results obtained.

Course Code	Course Name	Credits
CHL608	Chemical Engg Lab (CRE-II)	1.5

Concept for experiments

Minimum 8 experiments need to be performed by the students on following concepts.

- Void Volume, Porosity & Solid density of catalyst particle.
- Solid fluid Heterogeneous non-catalytic reaction.
- RTD study in CSTR.
- RTD study in packed column.
- RTD study in PFR.
- Semi-batch reactor
- Adiabatic batch reactor.
- Heterogeneous catalytic esterification reaction between alcohol and acetic acid using acid catalyst.

Course Code	Course Name	Credits
CHL609	Chemical Engg Lab (HTO-II)	1.0

Concept for experiments

Experiments should be based on Design and simulation of Shell and Tube heat exchangers like liquid-liquid and gas-liquid heat exchange without phase change, condensers, reboilers, etc. Minimum six simulations need to be performed using simulators like HETRAN/HTRI/TEAMS, etc.

UNIVERSITY OF MUMBAI

Revised Syllabus
Program – **Bachelor of Engineering**
Course – **Chemical Engineering**
(Final Year – Sem VII and VIII)

under
Faculty of Technology
(As per Credit Based Semester and Grading System from 2014-15)

General Guidelines

Tutorials

- The number of tutorial batches can be decided based on facilities available in the institution.
- Tutorials can be creative assignments in the form of models, charts, projects, etc.

Term Work

- Term work will be an evaluation of the tutorial work done over the entire semester.
- It is suggested that each tutorial be graded immediately and an average be taken at the end.
- A minimum of ten tutorials will form the basis for final evaluation.

Theory Examination

- In general all theory examinations will be of 3 hours duration.
- Question paper will comprise of total six questions, each of 20 Marks.
- Only four questions need to be solved.
- Question one will be compulsory and based on maximum part of the syllabus.

Note: In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus as far as possible.

Practical Examination

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments.

Project & Seminar Guidelines

- Project Groups: Students can form group with minimum 2(Two) and not more than 4(Four)
- The load for projects may be calculated as below,

  Sem VII: $\frac{1}{2}$hr for teacher per group.

  Sem VIII: 1 hr for teacher per group.
- Maximum of four groups can be allotted to a faculty.
- Seminar topics will be the consensus of the project guide and the students. Each student will work on a unique topic.
- The load for seminar will be calculated as one hour per week irrespective of the number of students.
- Students should spend considerable time in applying all the concepts studied, into the project. Hence, eight hours each were allotted in Project A,B and three hours for Seminar to the students.

University of Mumbai

Scheme for BE: Semester-VII

Subject Code	Subject Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHC701	Process Equipment Design	03	–	01	3.0	–	1.0	4.0
CHC702	Process Engineering	03	–	01	3.0	–	1.0	4.0
CHC703	Process Dynamics & Control	03	–	01	3.0	–	1.0	4.0
CHE704	Elective – II	04	–	–	4.0	–	–	4.0
CHP705	Project – A	–	–	08	–	–	3.0	3.0
CHS706	Seminar	–	–	03	–	–	3.0	3.0
CHL707	Chemical Engg Lab (PED)	–	03	–	–	1.5	–	1.5
CHL708	Chemical Engg Lab (PDC)	–	03	–	–	1.5	–	1.5
	Total	13	06	14	13.0	3.0	9.0	25.0

Examination Scheme

Subject Code	Subject Name	Examination Scheme							
		Theory marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Avg. of Test 1 and Test 2					
CHC701	Process Equipment Design	20	20	20	80	25	–	–	125
CHC702	Process Engineering	20	20	20	80	25	–	–	125
CHC703	Process Dynamics & Control	20	20	20	80	25	–	–	125
CHE704	Elective – II	20	20	20	80	–	–	–	100
CHP705	Project – A	–	–	–	–	50	–	100	150
CHS706	Seminar	–	–	–	–	25	–	50	75
CHL707	Chemical Engg Lab (PED)	–	–	–	–	–	–	25	25
CHL708	Chemical Engg Lab (PDC)	–	–	–	–	–	25	–	25
			Total	80	320	150	25	175	750

Elective Streams(CHE704)

Sem.	**Management Stream**	**Technology Stream**	**Process System Engineering Stream**
VII	High Performance Leadership	• Polymer Technology • Petroleum Refining Technology	• Advanced Process Control

Course Code	Course Name	Credits
CHC701	Process Equipment Design	4.0

Prerequisites

Fundamentals of units. Elementary theory of engineering mechanics. Engineering drawing. Knowledge of Heat Transfer, Mass Transfer, Mechanical Operations and Mechanical Equipment Design.

Course Objectives

- To understand the basics for design as per the codes & standards for the mechanical design of equipments used in the process industry.
- Selection of material of construction and stress analysis by determining values of stresses arising out of different loading conditions.

Course Outcomes

- Student will demonstrate ability to carry out complete chemical engineering project.
- Students will demonstrate ability to design process equipments as heat exchanger, distillation column, high pressure vessels etc.

Detail syllabus

Module	Contents	No. of hrs
1	**INTRODUCTION:** The organisation of a chemical engineering project. Flow sheet presentation i) Block diagram ii) Pictorial representation iii) Presentation of stream flowrates. iv) Information to be included. v) Plant layout. The P & I diagram i) Symbols and layout. ii) Basic symbols. Computer Aided Design Softwares. Material safety data sheet.	03
2	**HEAT EXCHANGERS:** Introduction. Codes and Standards for heat exchangers. Material of construction. Design of shell and tube heat exchanger (U-tube and fixed tube) as per IS: 4503 & TEMA standards i.e. shell, tube, tube sheets, channel and channel cover, flanged joints. Complete fabrication drawing for designed heat exchanger to a recommended scale. Design of standard vertical evaporator with design of calendria and tube, flange, evaporator drum & heads.	12
3	**DESIGN OF TALL COLUMNS:** Stresses in column shell. Shell thickness determination at various heights. Elastic stability under compression stresses. Complete fabrication drawing for designed column to a recommended scale.	08

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Module	Contents	No. of hrs
4	**HIGH PRESSURE VESSELS:** Stress analysis for thick walled cylinders. Theories of elastic failure. Prestressing of thick walled vessels. Design of monoblock high pressure vessels. Multilayer high pressure vessel design and construction. Materials of construction for high pressure vessels.	12
5	**INTRODUCTION TO DESIGN OF CRYSTALLIZERS, FILTERS AND DRYERS:** Design considerations for Crystallizers, filters, absorption column, extractor and dryers (No numerical problems).	03
6	**PIPING DESIGN AND LAYOUT:** Pipe sizing for gases and liquids. Piping for high temperature. Piping layout and its factors under consideration. Design of buried and overhead pipeline.	02

TUTORIALS:

- Design procedure or example based on heat exchanger.
- Design procedure or example based on short tube vertical evaporator.
- Design procedure or example based on distillation column.
- Design procedure or example based on monoblock high pressure vessel.
- Design procedure or example based on multilayer high pressure vessel.

References

1. Process Equipment Design- Vessel Design by E. Brownell and Edwin, H. Young, John Wiley, New York 1963.
2. Chemical Engineering Vol 6-Design by J.M. Coulson, J.F.Richardson and P.K Sinnot, Pregamon press, International edition 1989.
3. Introduction to Chemical Equipment Design- Mechanical Aspects by B.C Bhattacharya, CBS Publications.
4. Process Equipment Design by M.V. Joshi, Macmillan India.

Course Code	Course Name	Credits
CHC702	Process Engineering	4.0

Prerequisites

- The students should have knowledge of Heat transfer and Mass Transfer to carry out Mass and Energy balance around process.
- They should be aware about basic principles of economics to evaluate cost and profit of process.
- They should be familiar with process and mechanical design of Process equipments.
- They should be familiar with various types of plant utilities.

Course Objectives

- To provide training to solve problems relevant to the general practice of chemical engineering and design
- To provide students experience in conducting and in planning experiments in the modern engineering laboratory including interfacing experiments with computers as well as interpreting the significance of resulting data and properly reporting results in well written technical reports.
- To provide experience in the process of original chemical engineering design in the areas of equipment design, process design and plant design through the process of formulating a design solution to a perceived need and then executing the design and evaluating its performance including economic considerations and societal impacts if any, along with other related constraints, and culminating in both written and oral presentation of results.
- To provide students familiarity with professional issues in chemical engineering including ethics, issues related to the global economy and to emerging technologies ,and fostering of important job related skills such as improved oral and written communications and experience in working in teams at a number of levels.

Course Outcomes

- The graduates are expected to have ability to apply knowledge of mathematics, science and engineering.
- The graduates are expected to have ability to design a system, a component, or a process to meet the desired needs within realistic constraints such as economic, environmental, social, ethical, health and safety, manufacturability and sustainability.
- The graduates are expected to possess ability to function on multi disciplinary teams.
- The graduates are expected to possess ability to identify, formulate and solve engineering problems.
- The graduates are expected to have an understanding of professional and ethical responsibility.
- The graduates are expected to engage themselves in lifelong learning.
- The graduates are expected to posses ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Detail syllabus

Module	Contents	No. of hrs
1	**An Overview of Process Engineering:** Process engineering and Chemical Engineering, Basic functions of Process Engineering: understanding and transferring licensor's know-how, development of P&ID, equipment selection and specifications, input to other engineering disciplines. Activities of Process engineering: Material and Energy balance, gathering data, establishing design basis, P&I diagram, control strategy, equipment specifications, deciding requirements of interlock shut down arrangement, piping requirement, civil and electrical requirements, acquiring knowledge of codes and standards, statutory requirements, safety study, preparing operating manuals, commissioning, interaction with other engineering disciplines, interaction with external agencies	01
2	**Preliminary Process Selection:** Economic evaluation of process: fixed and variable costs. Analysis of environmental concerns of process: rules & regulations of pollution control board, handling hazardous materials, etc. Safety analysis of process, Analysis of control structure of process, Flexibility analysis of process	01
3	**Selection of Process Steps:** Various types of diagrams to represent the process: block diagram, process flow diagram(PFD) , process and instrumentation diagram (P&ID), utilities line diagram. Basic steps in PFD synthesis: gathering information, representing alternatives, criteria for assessing preliminary design. PFD: objective, way of presentation, essential constituents (equipment symbols, numbers, names, process stream flow lines, utility designation, operating conditions, etc), optional constituents (energy exchange rates, physical properties of streams, etc) Way of presenting major equipments in PFD: vessels, heat exchangers, pumps, compressors, distillation columns, process lines, instruments, Common characteristics of PFD	02

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Module	Contents	No. of hrs
4	**Flowsheet Synthesis Based on Design Heuristics:** Input information to the process for flow sheet synthesis: reactions, side reactions, maximum yield, catalyst deactivation rate, production rate, product purity, raw material, process constraints, plant & site data, cost data, physical properties. Level 1 decision in flow sheet synthesis: batch v/s continuous process (production rates, market forces, operational problems, single unit for multiple operations). Level 2 decision in flow sheet synthesis: input output structure of flow sheet (feed purification, recover or recycle reversible by-products, gas recycle & purge stream, reactants not to recover or recycle, number of output streams). Level 3 decision in flow sheet synthesis: Recycle structure of flow sheet (number of reactor systems, recycle streams, excess reactants, heat effects & equilibrium limitations, reversible by-products, reactor heat effects). Level 4 decision in flow sheet synthesis: separation system for process (phase of reactor effluent and separation system, vapor recovery system (VRS), liquid recovery system (LRS), types of VRS and LRS. Level 5 decision in flow sheet synthesis: heat integration in flow sheet. Reactor trains: options & selection criteria, CSTR, PFR, reactors similar to CSTR, application of different reactor geometries and associated heuristics.	06
5	**Mass & Energy Balances around Major Equipments in Flow Sheet:** Physico-chemical specification of each process stream in flow sheet. Detailed mass and energy balance around major equipments in flow sheet using thumb rules: reactors, mixers, splitters, flash columns, distillation columns, absorption column, stripping column, evaporator, dryer	07

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Module	Contents	No. of hrs
6	**Sizing and Costing of Major Equipments in Flow Sheet:** Sizing of equipments using short cut designing methods and design heuristics: reactors, heat exchangers, distillation columns, pumps, compressors, evaporators. Costing of equipments: evaluation of updated bare module cost of above process equipments using Guthries costing modules	08
7	**Utility Selection for Process:** Plant utilities: concept, Major types of plant utilities: heating utilities, cooling utilities, compressed air, nitrogen, vacuum, water, electricity. Heating utilities and their operating T & P ranges: steam, pressurized hot water, thermal fluids dowtherm A, E, inorganic salt mixtures, mineral oils, silicon compounds. Cooling utilities and their operating T & P ranges: cooling tower water, chilled water, chilled brine system. Utility Hook-ups. Evaluating minimum utility requirement for process using pinch analysis	05
8	**Control Strategy for Process**: To suggest control strategies for various process parameters to be controlled. Degree of Freedom analysis for suggested controlled strategy. Alternate control strategies for various process parameters	03
9	**Safety and Hazard Analysis for Process:** Major types of accidents in chemical industries: fire, explosion, toxic release. Fire: probability of occurrence, potential for fatalities and economic losses, fuel-oxidants-ignition source for fire to occur, fire triangle, types of fire. Explosion: probability of occurrence, potential for fatalities and economic losses, types of explosion Toxic release: probability of occurrence, potential for fatalities and economic losses, entry route-entry organ-method of control, various models to analyse toxic release. Multiple Redundancy System: Risk assessment and its different methods – event tree analysis, fault tree analysis, quantitative risk analysis, layer of protection analysis, HAZOP	03

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Module	Contents	No. of hrs
10	**Basic Chemical Processes:** Common Features and Preliminary Process System (PPS) for Basic Chemical Processes: Nitration, Chlorination, Oxidation, Sulfonation, Liquid Phase Catalytic Reduction	04

References

1. Systematic Methods Of Chemical Process Design, Loren T Biegler, Grossman E.I., Westberg, A.W. Prentice Hall Intl ed., 1997

2. Conceptual Design of Chemical Processes, J.M.Douglas, McGraw Hill International Editions, 1988

3. Chemical Process Equipment: selection & design, Walas, S.M., Butterworth, London, 1980

4. Strategy of Process Engineering, John D.F.Rudd & C.C. Watson, Wiley & Sons International, 1968

5. Process Design Principles: synthesis analysis & evaluation, Sieder, W.D., Seader J.D. & Lewin D.R., John Wiley & Sons, 1998.

6. Analysis, Synthesis, and Design of Chemical Processes, Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz, PHI Learning Private Limited, New Delhi, 2011

7. Introduction to Process Engineering and Design, S B Thakore, B I Bhatt, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2011

Course Code	Course Name	Credits
CHC703	Process Dynamics & Control	4.0

Prerequisites

Linear Algebra, Differential Equations, Laplace Transforms.

Course Objectives

- To understand dynamic behaviour of process systems and equipments.
- To understand frequency response of dynamic systems.
- To understand and analyse stability charecteristics of dynamic systems.
- To design controllers.

Course Outcomes

- The student will be able to model dynamical systems and study their responses in Time ,Laplace and Frequency domains.
- The student will be able to design stable controllers, for important chemical processes

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction To Process Control:** Typical Control Problems, A Blending Process Example, Control Strategies, Hierarchy of Control Activities, An Overview of Control System Design.	04
2	**Dynamic Models of Processes:** The Rationale for Dynamic Process Models, General Modelling Principles, Degrees of Freedom Analysis, Typical Dynamic Models.	06
3	**Transfer Function Models:** Transfer Functions of Typical Systems, First and Second Order Systems, Properties of Transfer Functions, Transfer Functions of Systems in Series, Time Delay Processes, Linearisation of Non-linear Systems, State Space and Transfer Function Matrix Models.	03
4	**Dynamic Behaviour of Processes:** Standard Process inputs, Response of First Order Processes, Response of Second Order Processes, REsponse of Integrating Processes.	06
5	**Development of Empirical Models From Process Data:** Fitting First and Second Order Models Using Step Tests, Development of Discrete Time Dynamic Models, Identifying Discrete Time Models From Experimental Data.	04

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Module	Contents	No. of hrs
6	**Feedback and Feedforward Control:** Basic Control Modes, Features of PID and On-off Control, Conntrol Valve Characteristics, Response of Feedback Control Systems, Digital Verions of PID Controllers.	02
7	**Closed-Loop Response and Stability:** Closed-Loop Transfer Functions, Closed-Loop Response, Stability, Root Locus.	04
8	**Controller Design and Tuning:** Performance Criteria, Model-Based Design Methods, Controller Tuning, Controllers with Two Degrees of Freedom, On-Line Tuning.	04
9	**Control Strategies:** Degrees of Freedom Analysis, Selection of Variables, Typical Applications.	02
10	**Frequency Response:** Frequency Response of Typical Systems, Bode Stability Criterion, Nyquist Stability Criterion, Gain and Phase Margins.	05

References

1. Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, Francis J. Doyle III, Process Dynamics and Control,3 Ed., John Wiley & Sons (Asia) Pvt. Ltd., New Delhi.

2. William L. Luyben, Process Modeling Simulation and Control For Chemical Engineers,2nd Ed., Mc-Graw Hill Publishing Co.

3. Stephanopoulos, Chemical Process Control, PHI Learning Pvt. Ltd.

Course Code	Course Name	Credits
CHE704	Elective – II : High Performance Leadership	4.0

Prerequisites

This course is designed to enhance your leadership to improve your ability to lead with purpose, to communicate effectively, and to work well with others. The course will be a combination of learning about leadership through the review of literature. Students will further develop and apply various skills and techniques deemed to be essential for successful leadership in organizations. The course also explores leadership challenges and opportunities in relation to individual and team performance.

Course Objectives

- To become aware of strengths and weaknesses in one's leadership behaviour.
- Analyse the numerous approaches of leadership development and critically evaluate how they may be applied in practice.
- To understand how the most successful leaders are able to influence followers through effective communication of well-reasoned ideas, proposals and values.
- To systematically train and improve one's leadership effectiveness.

Course Outcomes

- Improve one's self leadership skills through effective emotion regulation and emotional intelligence.
- Apply concepts of leadership and effective communication to individuals, groups, and organizations

Detail syllabus

Module	Contents	No. of hrs
1	**Leadership:** Theories of Leadership, Leadership Styles and Leadership, Leadership Skills, Objectives for personal development.	05
2	**Leadership Skills:** Leadership Skills and Leadership, Developing competencies, The Business Related Inventory of Personality (strengths and weaknesses), Changing behaviour in critical situations.	07
3	**Team work & Positive thinking:** Team work & Team building, Positive thinking Martin Seligmans theory of Learned, Helplessness, Learned Optimism Lessons through Literature Positive thinking, Attitudes, Beliefs, Lateral Thinking.	07

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Module	Contents	No. of hrs
4	**Interpersonal skills:** Interpersonal skills Conversation, Feedback, Feed forward, Transformational Leadership: analysis and consequences from the 360° feedback Interpersonal skills, Delegation, Humour, Trust, Expectations, Values, Status, Compatibility.	06
5	**Effective Leadership Communication:** Principles of effective communication: authenticity, clarity, credibility, and empathy. Persuasion including body language, posture, facial expressions, gestures, creating a personal relationship (message-audience-speaker), Impact speech: effective and convincing lines of argument.	08
6	**Conflict Management:** Types of conflicts, Coping strategies and Conflict Management Styles. Creative problem Solving Techniques.	06

References

1. Jeff Grimshaw & Gregg Baron, Leadership Without Excuses : How to Create Accountability and High-Performance, Tata McGraw - Hill Education, 1st Ed., 2010.

2. Harrison Owen, Wave Rider: Leadership for High Performance in a Self-organizing World, Berrett-koehler Publishers, 2008.

3. Daniel Goleman, Richard E. Boyatzis, Annie McKee, Primal Leadership: Realizing the Power of Emotional Intelligence, Harvard Business Review Press, 2002.

4. John Baldoni, Great Communication Secrets of Great Leaders, Primento Digital Publication, 2012.

5. Paul Glen, Leading Geeks: How To Manage And Lead The People Who Deliver Technology, Wiley Publication, 2002.

6. Shel Holtz, Corporate Conversations : A Guide To Crafting Effective And Appropriate Internal Communications, Phi Learning Pvt Ltd, 1st Ed., 2007.

7. Garber, J. and Seligman, M.E.P., Human Helplessness: Theory and Applications, New York Academic Press.,1980.

8. Bass, Bernard. M., The Bass Handbook of Leadership, Theory, Research & Managerial Applications, 4th edition, New York, 2008

Course Code	Course Name	Credits
CHE704	Elective – II: Polymer Technology	4.0

Prerequisites

Chemistry, physics, Chemical reaction engineering.

Course Objectives

- To understand thermodynamics of polymer structure.
- To select polymerization reactor for a polymer product.
- To characterize polymers and state polymer additives, blends and composites.

Course Outcomes

At the end of the course students will be able to

- Understand thermodynamics of polymer structure.
- Select polymerization reactor for a polymer product.
- Characterize polymers and state polymer additives, blends and composites.

Detail syllabus

Module	Contents	No. of hrs
1	**INTRODUCTION:** Introduction and Classification of Polymers. Thermosets, Factors influencing the polymer properties, Glass Transition Temperature Monomers used for polymer synthesis, Thermoplastics, Linear Branch, Cross Linked Polymers. **ADDITION AND CONDENSATION POLYMERISATION:** Mechanism, kinetics, synthesis and reactions.	06
2	**NATURAL POLYMERS:** Chemical & Physical structure, properties, source, important chemical modifications, applications of polymers such as cellulose, lignin, starch, rosin, shellac, latexes, vegetable oils and gums, proteins etc. **POLYMERIZATION TECHNIQUES:** Bulk polymerization, Solution polymerization, Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits Comparison of the various processes Advantages and disadvantages.	12

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Module	Contents	No. of hrs
3	**MOLECULAR WEIGHT AND MOLECULAR WEIGHT DISTRIBUTION:** Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers. **CO-POLYMERIZATION:** Basic concept, Technical significance, steady state assumptions in free radical copolymerization, The copolymer equation, Instantaneous molar composition of copolymer formed; Monomer reactivity ratios; Significance and method of determination, Types of copolymers.	08
4	**POLYMERIZATION REACTOR:** Polymerization reactors types and mode of operation, Polymerization reactor design, control of polymerization, Post polymerization unit operations and unit processes Polymer Degradation.	06
5	**POLYMER PROCESSING:** High Performance and Specialty Polymers, Polymer additives, compounding. Fillers plastisizers lubricants colourants UV stabilizers, fire retardants, antioxidants, Different moulding methods of polymers. Injection moulding , blow moulding, thermoforming, film blowing etc.	08
6	**MANUFACTURING PROCESSES:** Manufacturing of typical polymers with flow-sheet diagrams properties & application: PE, PP, PS, Polyesters, Nylons, ABS, PC. Manufacturing of thermoset polymers such as Phenolic resins.	12

References

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, 2000.

2. Premamoy Ghosh, Polymer Science and Technology, 3rd Edition, Tata Mc. Graw-Hill Publishing Company, New Delhi, 2010.

3. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.

4. Gowarikar V.R. et.al., Polymer Science Wiley Eastern 1984.

5. Ghosh P, Polymer Science & Technology of Plastics & Rubbers Tata McGraw Hill, 1990.

6. Encyclopedia of Polymer Science & Engineering., Wiley 1988.

7. Rosen S.L. Fundamental Principles of Polymeric materials, 2nd e.d., John Wiley & Sons Inc, 1993.

8. McCrum N.G et.al. ,Principles of Polymer Engineering , 2nd ed., Oxford Sciences, 1997.

9. Bhatnagar M.S., a Textbook of Polymers Vol.I & Vol.II, S.Chand & Co. Ltd.,New Delhi, 2004.

Course Code	Course Name	Credits
CHE704	Elective – II: Petroleum Refining Technology	4.0

Prerequisites

Knowledge about Formation and origin of petroleum, composition and testing methods,Basic treatment Techniques.

Course Objectives

- To understand petroleum refinery products, its evaluation techniques, and treatment techniques.
- To understand various cracking processes, and its applications in chemical industries.

Course Outcomes

Students will be able to understand petroleum refinery products, its evaluation techniques, and treatment techniques,various cracking processes, and its applications in chemical industries.

Detail syllabus

Module	Contents	No. of hrs
1	**Origin formation and composition of petroleum:** Origin theory, Reserves and deposits of world. Types of crude and Indian crude types. Exploration Reserves.	06
2	**Refinery products and feedstock:** Overall refinery flow.Low boiling products. Gasoline Specifications. **Fuels:** Jet fuels, automotive diesel fuels. Oils:-Heating Oils, Residual fuel Oils, Crude Oil properties, Composition of petroleum, Crude suitable for asphalt manufacture. Crude distillation curves. Distillation characteristics. Petrochemical Feedstock.	10
3	**Fractionation of Petroleum:** Dehydration and desalting of crude, Heating of Crude Pipe still Heaters. Multi-component Fractionation of Petroleum including pump-around and side-stripping.Blending of gasoline. Over lead corrosion in distillation unit.	12
4	**Treatment Techniques and product specifications:** Fraction impurities treatment of gasoline, Treatment of kerosene, Treatment of Lubes. Wax and purification.	08
5	**Catalytic Cracking and thermal process:** Fluidised bed catalytic cracking, Catalytic reforming, Coking, Hydrogen Process Hydro cracking, Hydrodesulphurization, Hydro-Treatment. Alkalyation process, Isomerisation Proccess, Polymer gasoline.	10

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Module	Contents	No. of hrs
6	**Asphalt Technology:** Source of Asphalt. Air Blowing of Bitumen up-gradation of heavy crude.Brief review about bio-refinery	06

References

1. B.K Bhaskara Rao, Modern Petroleum Refining Process .
2. W.L Nelson, Petroleum Refinery Engineering 4th ed, McGraw Hill.
3. Petroleum Chemistry and Refining Edited by James G. Speight,Taylor and Francies .
4. Chemical Process Industries, Austin, G.T Shreves.
5. Encyclopedia of chemical processing and design by john J. McKhetta; Marcel Deckker, Inc.
6. Chemial Weakly for supply and demand figures and current prices and price trends.

Course Code	Course Name	Credits
CHE704	Elective – II: Advanced Process Control	4.0

Prerequisites

Linear Algebra, Differential Equations, Difference Equations, Laplace Transforms.

Course Objectives

- To understand dynamics of MIMO processes.
- To understand Batch Process Control.
- To understand Model Predictive Control.
- To design digital controllers.

Course Outcomes

- The student will be able to analyse multi-loop and multi-variable control systems.
- The student will be able to design batch controllers.
- The student will be able to design MIMO controllers.
- The student will be able to design Model Predictive Controllers.

Detail syllabus

Module	Contents	No. of hrs
1	**Advanced SISO Control Strategies:** Cascade Control, Time Delay Compensation, Inferential Control, Selective Control/Override Systems, Nonlinear Control Systems, Adaptive control Systems	06
2	**Digital Sampling Filtering and Control:** Sampling and Signal Reconstruction, Signal Processing and Data Filtering, z-Transform Analysis for Digital Control, Tuning of Digital PID Controllers, Direct Synthesis for Design of Digital Controllers, Minimum Variance Control	08
3	**Multiloop and Multivariable Control:** Process and Control Loop Interactions, Pairing of Control and Manipulated Variables, Singular Value Analysis, Tuning of Multi-loop PID Control Systems, Decoupling and Multivariable Strategies, Strategies for Reducing Control Loop Interactions	06
4	Model Predictive Control: Overview of Model Predictive Control, Predictions for SISO Models, Predictions for MIMO Models, Model Predictive Control Calculations, Set Point Calculations, Selection of Design and Tuning Parameters, Implementation of MPC	08

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Module	Contents	No. of hrs
5	**Batch Process Control:** Batch Control Systems, Sequential and Logic Control, Control During The Batch, Run-to-Run Control	06
6	**Introduction To Plantwide Control:** Plantwide Control Issues, Hypothetical Plant for Plantwide Control Studies, Internal Feedback of Material and Energy, Interaction of Plant and Control System Design	06
7	**Plantwide Control System Design:** Procedures for the Design of Plantwide Control Systems. A Systematic Procedure for Plantwide Control System Design. **Case Study:** The Reactor/Flash Unit Plant, Effect of Control Structure on Closed Loop Performance	06
8	**Optimal Control:** Introduction to Optimal Control, Batch Process Optimisation	06

References

1. Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, Francis J. Doyle III, Process Dynamics and Control, 3 Ed., John Wiley & Sons (Asia) Pvt. Ltd., New Delhi.

2. William L. Luyben, Process Modeling Simulation and Control For Chemical Engineers,2 Ed., McGraw Hill Publishing Co.

3. Stephanopoulos, Chemical Process Control, PHI Learning Pvt. Ltd.

Course Code	Course Name	Credits
CHP705	Project – A	3.0

Details

- Project Groups: Students can form groups with minimum 2(Two) and not more than 4(Four).
- The load for projects may be calculated proportional to the number of groups, not exceeding two hours per week.
- Each teacher should have ideally a maximum of three groups and only in exceptional cases four groups can be allotted to the faculty.
- Students should spend considerable time in applying all the concepts studied, into the project. Hence, eight hours each were allotted in Project A,B to the students.

Course Code	Course Name	Credits
CHS706	Seminar	3.0

Details

- Seminar topics will be the consensus of the project guide and the students. Each student will work on a unique topic.
- The load for seminar will be calculated as one hour per week irrespective of the number of students.

Course Code	Course Name	Credits
CHL707	Chemical Engg Lab (PED)	1.5

Concepts for experiments:

Includes drawing sheets based on

- Process flow diagram and piping and instrument diagram.
- Fabrication drawing of problem based on heat exchanger.
- Fabrication drawing of problem based on short tube vertical evaporator.
- Fabrication drawing of problem based on distillation column.
- Fabrication drawing of problem based on monoblock high pressure vessel.
- Fabrication drawing of problem based on multilayer high pressure vessel.

Course Code	Course Name	Credits
CHL708	Chemical Engg Lab (PDC)	1.5

Concepts for experiments:

Objective for experiments

- To correlate the theoretical understanding of the dynamics of systems with actual observations.
- To calculate system parameters from observed data.
- To validate system models.
- To study closed-loop behaviour of control systems

At least eight experiments should be carried out in this lab course based on the following concepts:

- Dynamic behaviour of typical first and second-order systems.
- Dynamic behaviour of systems in series.
- Response of closed loop systems with different control configurations.
- Tuning of Controllers.

University of Mumbai

Scheme for BE: Semester-VIII

Subject Code	Subject Name	Teaching Scheme			Credit Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
CHC801	Modelling, Simulation & Optimization (MSO)	03	–	01	3.0	–	1.0	4.0
CHC802	Project Engineering & Entrepreneurship Management	03	–	01	3.0	–	1.0	4.0
CHC803	Environmental Engineering (EE)	04	–	–	4.0	–	–	4.0
CHC804	Energy System Design	03	–	01	3.0	–	1.0	4.0
CHE805	Elective – III	04	–	–	4.0	–	–	4.0
CHP806	Project – B	–	–	08	–	–	6.0	6.0
CHL807	Chemical Engineering Lab (EE)	–	02	–	–	1.0	–	1.0
CHL808	Chemical Engg Lab (MSO)	–	02	–	–	1.0	–	1.0
	Total	17	04	11	17.0	2.0	9.0	28.0

Examination Scheme

Subject Code	Subject Name	Examination Scheme							
		Theory marks				Term Work	Pract.	Oral	Total
		Internal Assessment			End Sem. Exam				
		Test 1	Test 2	Avg. of Test 1 and Test 2					
CHC801	Modelling, Simulation & Optimization (MSO)	20	20	20	80	25	–	–	125
CHC802	Project Engineering & Entrepreneurship Management	20	20	20	80	25	–	–	125
CHC803	Environmental Engineering (EE)	20	20	20	80	–	–	–	100
CHC804	Energy System Design	20	20	20	80	25	–	–	125
CHE805	Elective – III	20	20	20	80	–	–	–	100
CHP806	Project – B	–	–	–	–	50	–	100	150
CHL807	Chemical Engineering Lab (EE)	–	–	–	–	–	25	–	25
CHL808	Chemical Engg Lab (MSO)	–	–	–	–	–	25	25	50
			Total	100	400	125	50	120	800

Elective Streams(CHE805)

Sem.	Management Stream	Technology Stream	Process System Engineering Stream
VII	Production Management	• Advanced Separation Technology • Biotechnology • Nanotechnology	• Advanced Process Simulation • Advanced Transport Phenomenon

Course Code	Course Name	Credits
CHC801	Modelling, Simulation & Optimization (MSO)	4.0

Prerequisites

Linear Algebra Process Calculations Computer Programming

Course Objectives

- To understand writing and solving linear balance equations for single units as well as complete flowsheets.
- To understand writing and solving systems of non-linear equations for single and multiple units.
- To understand simulation of complete flowsheets.
- To understand optimization of single and multiple units.

Course Outcomes

- The student will be able to write and solve linear and non-linear mass and energy balance equations for individual as well as multiple units.
- The student will be able to carry out sequential and equation oriented simulation of complete flowsheets.
- The student will be able to optimize typical chemical processes.

Detail syllabus

Module	Contents	No. of hrs
1	**Mass and Energy Balances:** Introduction, Developing Unit Models for Linear Mass Balances, Linear Mass Balances, Setting Temperature or Pressure Levels from Mass Balances, Energy Balances.	10
2	**Unit Equation Models:** Introduction, Thermodynamic Options for Process Simulation, Flash Calculation, Distillation Calculations, Other Unit Operations.	10
3	**Simulation:** Introduction, Process Simulation Modes, Methods for Solving Systems of NLE, Recycle Partitioning and Tearing, Simulation Examples.	10
4	**Process Flowsheet Optimization:** Introduction, Constrained Non-Linear Programming, SQP, EO based Process Optimization.	10

References

1. Lorenz T. Beigler, Ignacio E.Grossman, Arthur W. Westburg, Systematic Methods of Chemical Process Design, Prentice Hall

2. Thomas Edgar, David M. Himmelbleau, Optimization of Chemical Processes, 2nd Ed., John Wiley.

Course Code	Course Name	Credits
CHC802	Project Engineering & Entrepreneurship Management	4.0

Prerequisites

- Employment and Corporate Skills.
- Operation Research
- High Performance Leadership.

Course Objectives

- Project management demands the judicious mix of science, arts and technology, so the objective is to project the scientific aspects of project management.
- To amidst real life constraints for the benefit of the individual, project and society.
- To learn entrepreneurship for the improvement of technology, product and the society for the economical growth.

Course Outcomes

- To prepare students for an exciting, challenging and rewarding managerial career.
- To insight students in identifying opportunities, creating and starting a venture, financing and managing the venture.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** Definition of project, project management, project life cycle, project types, Project over runs, Role, responsibilities demands on project manager.	04
2	**Project initiation:** Feasibility reports of various types project selection criteria, project licensing, Basic and detailed engineering, Guarantees, Liabilities, Risk insurance, types of estimates.	06

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Module	Contents	No. of hrs
3	**Project clearances:** Various laws & regulations, List of various clearances, Intellectual property rights, Patents, need for clearances and influences on project, management, LOI. **Project organization:** Various forms of pure project, matrix and mixed type. Project team, responsibilities of various members. **Project planning:** WBS, responsibility charts, contracts, types, role of contractor, sub-contractor consultant, selection criteria and appointment procedure	08
4	**Project Scheduling and execution:** CPM and PERT, GANTT charts, LOB , Resource allocation, ABC and VED Analysis , Economic Order Quantity (EOQ), CAT vs RAT. (Numericals included)	08
5	**Project monitoring and control:** Time and cost control tools and techniques, fund flow control, Project quality control, Importance of environmental and safety aspects. **Project termination:** Commissioning, start up, stabilization, close out.	06
6	**Entrepreneurship:** Definition of entrepreneurship, Concept of entrepreneur and entrepreneurship, Characteristics, aspects of entrepreneurship, factors affecting entrepreneurship. Classification and types of entrepreneurship based on business, technology, motivation, growth and stages of development.	06

References

1. Choudhary, S., Project Management.
2. Joy, P. K., Total Project Management.
3. Jack Meredith and Samuel, Project management a Managerial approach.
4. Vasant Desai, Dynamics of entrepreneurial development and management.

Course Code	Course/Subject Name	Credits
CHC803	Environmental Engineering (EE)	4.0

Prerequisites

Basic concepts of Fluid Flow Operations, Solid Fluid Mechanical Operations, Mass Transfer Operations and Chemical Reaction Engg.

Course Objectives

- Students should be able to understand the scope of subjects in Chemical Industry.
- Students should learn to apply the Environmental Engineering concepts to control and management of various types of pollutants.

Course Outcomes

Students should be able to apply the Environmental Engineering concepts to control and management of various types of pollutants.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** Environmental pollution, Importance of environmental pollution control, Concept of ecological balance, Role of environmental engineer, Hydrological & nutrient cycles, Environmental Legislation & Regulations, Industrial pollution emissions & Indian standards, Water (prevention & control of pollution) act, Air (prevention & control of pollution) act.	06
2	**Water Pollution:** Classification, sources and effect of water pollutant on human being and ecology, Sampling, measurement and standards of water quality, Determination of organic matters: DO, BOD, COD, TOC. **Determination of inorganic substances:** nitrogen, phosphorus, trace elements, alkalinity. **Physical characteristics:** suspended solids, dissolved solids, colour and odour, Bacteriological measurements.	08

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Module	Contents	No. of hrs
3	**Waste Water Treatment:** **Primary treatment:** pretreatment, settling tanks and their sizing. **Secondary treatment:** micro-organisms growth kinetics, aerobic biological treatment, activated sludge process, evaluation of bio-kinetic parameters, trickling filters, sludge treatment and disposal. **Tertiary treatment:** advanced methods for removal of nutrients, suspended and dissolved solids, Advanced biological systems, Chemical oxidation, Recovery of materials from process effluents.	12
4	**Air Pollution:** Air pollutants, sources and effect on man and environment, acid rain, smog, greenhouse effect, Ozone depletion, global warming, Temperature lapse rate and stability, Plume behaviour, Dispersion of air pollutants, Gaussian plume model, Estimation of plume rise, Air pollution sampling and measurement, Analysis of air pollutants.	08
5	**Air Pollution Control Methods and Equipment:** Source correction methods for air pollution control, Cleaning of gaseous effluents, Particulate emission control, Equipment, system and processes for. . . – **Particulate pollutants:** gravity settler, cyclones, filters, ESP, scrubbers etc. – **Gaseous pollutants:** scrubbing, absorption, adsorption, catalytic conversion.	12
6	**Solid Waste Management:** Solid waste including plastic, nuclear and hazardous waste management.	03
7	**Noise Pollution:** Noise pollution: measurement and control, effect on man and environment.	03

References

1. Rao, C.S., Environmental Pollution Control Engineering, New Age International (P) Limited.

2. Peavy, H. S., Rowe, D.R., Tchobanoglous, G., Environmental Engineering, McGraw-Hill Book Company Limited

3. Metcalf et al., Waste Water Treatment, Disposal & Reuse, Tata McGraw Hill Publishing Company Limited.

4. Mahajan, S.P., Pollution Control in Process Industries, Tata McGraw Hill Publishing Company Limited.

Course Code	Course/Subject Name	Credits
CHC804	Energy System Design	4.0

Prerequisites

- The students should have knowledge of Heat transfer to carry out Energy balance and Heat Exchanger Networking.
- They should be aware about basic principles of economics to evaluate cost and profit of energy efficient operations/modifications/techniques.
- They should be familiar with various types of plant utilities.
- They should be familiar with basic Industrial systems/operations like, HVAC, Lighting, Steam, Refrigeration, etc.

Course Objectives

- To provide training to solve problems relevant to the energy conservation.
- To provide students the knowledge in planning conducting energy audit, energy survey, and evaluate energy conservation opportunities.
- To provide knowledge to design and evaluate energy efficient technologies such as heat exchanger networks, multiple effect evaporators, co-generation, etc.

Course Outcomes

- The graduates are expected to have ability to design a energy system to meet the desired needs within realistic constraints such as economic, environmental, social, ethical, health and safety, manufacturability and sustainability.
- The graduates are expected to possess ability to function on multi disciplinary teams, identify, formulate and solve engineering problems.
- The graduates are expected to have an understanding of professional and ethical responsibility.
- The graduates are expected to posses ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Detail syllabus

Module	Contents	No. of hrs

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Module	Contents	No. of hrs
1	**Global Energy Scenario:** Broad classification of energy sources: primary, secondary, commercial, non-commercial, renewable, non-renewable. Global primary energy reserves and energy consumption, Ratio of energy demand to GDP: significance. Indian energy scenario: w.r.t above points. Energy policies, regulations, consumption and production, installed capacity, energy intensive sectors in India. Energy management:aim, key principles, steps to be taken to improve energy efficiency of systems. Energy conservation act (India). Energy and environment, Causes of high energy intensity and energy demand in developing countries: technological, managerial, economic, structural causes	02
2	**Energy Audit:** Definition, need and steps of energy audit. **Energy audit methodology:** interview with key facility personal, facility tour, document review, facility inspection, staff interviews, utility analysis, identifying energy conservation opportunities/measures, economic analysis, preparing audit report, review and recommendations. **Types of energy audit:** preliminary (walk-through) audit, general (mini) audit, investment grade (maxi/detailed) audit. **Energy profiles:** energy profile by use, cost, function. **Energy sub-audits:** envelope, functional, process, transportation and utility audit. Instrumentation part of energy audit: equipments for measuring light intensity, electrical performance, temperature, pressure, humidity, performance of combustion system and HVAC system during energy audit; energy auditors tool box and its contents. **Preparing for energy audit visit:** to study the facility in view of energy use data, energy rate structure, physical and operational data. **Safety considerations during energy audit:** related to electrical, respiratory, hearing, etc. **Post audit analysis:** identifying ECOs, evaluate feasibility of ECOs with help of simple pay back period analysis, preparing summarized energy audit report	04
3	**Energy Efficient Technologies:** Basic energy consuming systems in chemical industries and energy efficient modifications in those systems: lighting system; motors, belt and drives system; fans and pumps system; compressed air system; steam system; refrigeration system; material handling system; hydraulic system; drying system. Examples of energy efficient technologies: pressure swing adsorption purification; ethylene by thermal cracking.	03

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Module	Contents	No. of hrs
4	**Energy Integration in The Process Industries:** Energy integration in process: concept. Pinch analysis: evaluation of minimum utility requirement by temperature interval method and composite curve method. Design of heat exchanger network (HEN) for process system: minimum approach temperature difference (ΔT_{min}); Linnhoff rules for HEN design; pinch decomposition diagram; concept of minimum number of heat exchangers ($NH_{x,min}$); design of HEN with $NH_{x,min}$ using breaking loop method and stream splitting method. Concept of Threshold approach temperature difference (ΔT_{thresh}) and Optimum approach temperature difference (ΔT_{opt}) during HEN. Determining annualized cost of HEN	10
5	**Heat Integration in Process Units:** Multiple effect evaporators (MEE): types forward feed, backward feed, parallel feed; advantage of MEE over single effect evaporator in terms of energy saving. Effect of process variables on evaporator operation: feed temperature, operating pressure, steam pressure, Boiling point rise. Heat integration of Multiple effect evaporators (MEE) with background process. Heat integration MEE with and without vapour re-compression: mechanical vapour re-compression, thermal vapour re-compression. **Distillation column:** heat integration in distillation column – multiple effect distillation, heat pumping, vapour re-compression, Reboiler flashing. Different arrangements of heat integration of columns with background process.	12
6	**Co-generation:** Introduction and basic concepts related to co-generation: advantages of co-generation over conventional power plants; basic terms related to co-generation like, process heat, process returns, net heat to process, heat to power ratio, prime mover, etc. Basic thermodynamic cycles supporting working of co-generation plant: Brayton cycle, Rankine cycle. Basic types of co-generation systems: topping cycle, bottoming cycle, combined cycle. Different types of co-generation power plants: steam turbine system, gas turbine system, combined gas steam turbine system, diesel engine system. Distributed generation (DG) co-generation technologies: reciprocating engine system, micro turbines, fuel cells, photovoltaic cells, Co-generation design procedure, Applications of co-generation	06

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Module	Contents	No. of hrs
7	**Waste Heat Recovery (WHR):** Classification and applications of WHR: waste heat sources, quality of waste heat and its application; high temperature WHR, medium temperature WHR, low temperature WHR . Benefits of WHR: direct and indirect benefits. Different techniques used for WHR / Commercial devices used for WHR: recuperators, radiation/convective hybrid recuperator, ceramic recuperator, regenerator, heat wheel, heat pipe, waste heat boiler, economizer, heat pumps	03

References

1. Seider W. D., and Seader J. D. and Lewin D. R., Process Design Principles, John Wiley and Sons Inc., 1988.
2. Douglas J. M. .Conceptual Design of Chemical Process., McGraw Hill Book Co.,1988.
3. G. D. Rai, Non-Conventional Energy Sources, Khanna Publishers.
4. Larmine James, .Fuel Cells Explained., John Wiley and Sons, 2000.
5. Kreith F., .Principles of Solar Energy., McGraw Hill Book Co., 1978.
6. Freris L. L., .Wind Energy Conversion System., Prentice Hall, 1990.
7. Wayne C. Turner, Steve Doty (Ed.), Energy Management Hand Book., John Wiley and Sons, 2000
8. Biegler L. T., Grossman E. I. and Westerberg A. W., .Systematic Methods of Chemical Process Design., Prentice Hall International Ltd., 1997.
9. P K Nag, Power Plant Engineering, The McGraw-Hill Publishing Company Limited.
10. H.M.Robert, J.H.Collins, Handbook of Energy Conservation-Volume 1, CBS Publishers & Distributors.
11. Robin Smith, Chemical Process Design and Integration, Wiley India, 2005.
12. Serth, Robert W., Process Heat Transfer Principles and Applications, Elsevier Science & Technology Books, 2007.

Course Code	Course/Subject Name	Credits
CHE805	Elective – III: Total Quality Management	4.0

Prerequisites

Course Objectives

- To acquaint with the significance and features of TQM philosophy
- To familiarize with various quality tools and their uses in problem solving.
- To appraise on the modern productivity improvement approaches and their interface with TQM
- To familiarize with various quality standards, quality auditing and certification methodologies.
- To give and an insight into the ongoing global trends in quality approach and practices with specific forms to the customer relationship.

Course Outcomes

Learner will be able to:

- Appreciate the importance of quality and its dimensions in striving for excellence.
- Understand the conscious compromise between cost and quality.
- Develop competency in the selection and use of appropriate quality tools in various manufacturing and service functions.
- Integrate quality approaches for productivity improvement.
- Acquire knowledge base and develop skills for conducting quality audits.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** Definition of Quality, principles and dimensions of TQM. Quality in manufacturing and service segments. Approach in implementation of TQM, barriers in implementation. Cost of quality – prevention, appraisal and failure costs, hidden costs, trade-off between quality and cost.	06
2	**Planning for quality and Quality improvement:** **Planning for quality:** Need for quality policies and objectives. Significance of top management commitment, strategic planning for quality. **Quality improvement:** Management of controllable defects, operator controllable defects, sporadic and chronic problems of quality, Pareto's principle. **Bench marking:** Definition and significance, data collection for bench marking and its use.	08

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Module	Contents	No. of hrs
3	**Customer relations:** Customers, user and consumers, product awareness, types of customers, customer perception and expectations. Quality feedback and redressal. **Basic principles of reliability:** quality and reliability, product life cycle, trade-off between maintainability.	05
4	**Vendor relations:** Vendor as a partner, vendor selection, vendor evaluation. Push-Pull view of supply chain and cycle view of chain management.	05
5	**SQC Tool:** Histograms, Pie charts, Scatter diagrams, Cause and effect diagram. Statistical Process Control: **Process variability:** Variables and process variation, measures of accuracy and centring, precision or spread, normal distribution. **Process Control:** Control charts for variables ($\bar{X}$-chart, R-chart, σ-chart) and attributes (np-charts, p-chart, c-charts, U-charts). **Process capability:** OC curve, acceptance sampling, single and double sampling – producer's and consumer's risk.	14
6	**Quality System:** **Quality standards:** • ISO 9001:2000 Quality management system. • ISO 14001:2004 Environmental management system. • ISO 27001:2005 Information security management system. **Quality assurance:** Nature of assurance, reports on quality, measuring performance, internal audit, surveillance audit, quality certification methodology and implications. **Productivity improvement tools/Approaches/Techniques:** Principles of Six-Sigma, approaches like JIT, Lean manufacturing zero defect concept, KANBAN, QFD, FMEA, Basics of DOE and Shainin concepts of quality. Productivity improvement techniques like 5S, POKAYOKE, SMED, KAIZEN and Concurrent Engineering.	14

Note: Seminar/Case study presentation with report by individual or in groups comprising of not more than **three** students should be considered for tutorials.

References

1. Juran, J. M., Gryana, F. M., Quality planning and analysis, TMH.
2. Bester Fidd, D. H., et.al., Total quality management, Prentice Hall.
3. Erossbly, Pillip b., Quality is free, Mentor/New Americal Library.

4. Ishikawa, K., What is total quality control? The Japanese way, Prentice Hall.
5. Fergenbaum, Armand V., Total quality control.
6. Logothetis, N., Managing for total quality, Prentice Hall.
7. Aurora, K. C., Total Quality Management, S. K. Kataria and Sons.
8. Haldar, U. K., Total Quality Management, Dhanpatrai and Co.

Course Code	Course Name	Credits
CHE805	Elective – III: Advanced Separation Technology	4.0

Prerequisites

Basic knowledge regarding fundamental separation processes and its applications in chemical industries.

Course Objectives

The students completing this course are expected to understand the various separation principles like Adsorption process, the types and designs. Foam fractionation process with equipments and application in waste water treatment. Liquid chromatography – types and separation and of enzymes using it. Types of membranes, membrane characterization, membrane material, membrane molecules, membrane applications in biotechnology.

Course Outcomes

- The graduates are expected to have ability to apply knowledge of mathematics, science and engineering
- The graduates are expected to have ability to design a system, a component, or a process to meet the desired needs within realistic constraints such as economic, environmental, social, ethical, health and safety, manufacturability and sustainability
- The graduates are expected to possess ability to identify, formulate and solve engineering problems
- The graduates are expected to posses ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Detail syllabus

Module	Contents	No. of hrs
1	**Adsorption Process:** Modern absorbent such as Activated carbon, molecular sieves of various types, Activated Alumina. Their characteristics and applications. Regeneration & Activation of absorbents. Thermal & pressure swing process. Fixed bed, Moving bed, stimulated moving bed and other processing schemes. Design of adsorption process for separation and purification. Industrial Examples	13
2	**Foam Fractionation Process:** Foam Formation, coalescence, collapse and drainage phenomena Adsorption properties of foams. Modes of operation of foam fraction equipment. Principal of froth flotation, properties of foam relevant to the flotation equipment. Application of froth flotation to mineral processing, protein and enzyme separation, waste water treatment.	13

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Module	Contents	No. of hrs
3	**Liquid Chromatographic Process:** Basic concept of chromatography, phenomena and characterization. Various chromatography options. Typical Chromatographic separation systems for preparative chromatography. Equipment characteristics of solids, their selection for various applications. Column design and filling. Applications of chromatography in separation of enzymes and proteins. Industrial Examples	13
4	**Membrane process:** Introduction to the membrane process,definition of membrane, importance, process. **Characterization of membranes:** Characterization of porous membranes, characterization of ionic membranes, characterization of non-ionic membranes.Preparation of synthetic membranes. Preparation of phase inversion membranes. Preparation techniques for immersion precipitation, preparation techniques for composite membranes, influence of various parameters on membrane morphology, preparation of inorganic membranes.Transport process in membrane driving force, transport through porous membranes, transport through non- porous membranes and transport in ion-exchange membranes.Polarization phenomenon and fouling concentration polarization, characteristic flux behaviour in pressure driven membrane preparation, various models, temperature polarization, membrane fouling, methods to reduce fouling. Modules and process design plate, and frame, spiral wound, tubular, capillary, hollow fibre modules and their comparison, system design.	13

References

1. Ruthven, D.M., Principal Adsorption & Adsorption Process, Wiley,1984.
2. Lemlich, R., Adsorptive Bubble Separation Techniques, Academic Press,1972.
3. Coulson, Richardson, Chemical Engineering, Vol.3, Pergamon.
4. Terybal, R.E, Mass Transfer Operations, McGraw Hill.
5. Ruthven, Faruqh, Knalbal, Pressure Swing Adsorption, VCH, 1994.
6. Snyder, Kirl, Introduction To Liquid Chromatography, 2 ed., 1979.
7. Scott RTW, Liquid Chromatography Column Theory, Wiley, 1992.
8. Marcel Mulder, Basic Concepts Of Membrane Technology, Kluwer Academic Publishers (1997).
9. E.J. Hoffman, Membrane Separation Technology, Gulf Professional Publishing.
10. Nath, Membrane Separation Process, Prentice Hall of India.

11. Membrane Handbook - Editors W.S. Winston Ho, K.K. Sirkar, Van Nostrand Reinhold Publication.

Course Code	Course Name	Credits
CHE805	Elective – III: Biotechnology	4.0

Prerequisites

Knowledge of biology, chemistry, chemical engineering

Course Objectives

- At the end of the course the students should understand the basic concept of biotechnology. They should be able to classify micro-organisms, understand cell structure and basic metabolism.
- They should be able to understand basic knowledge about biological polymers.
- They should be able to understand basic knowledge about enzyme technology.
- They should understand role of biotechnology in medical field and industrial genetics.
- They should know importance of biotechnology in agricultural, food and beverage industries, environment, energy and chemical industries.
- They should understand to how to recover biological products.

Course Outcomes

- Students will demonstrate the knowledge of biotechnology in various fields.
- Students will know cell and metabolism.
- Students will have deep knowledge of biological polymers.
- Students will have deep knowledge of enzymes.
- Students will able to know about other uses of biotechnology in medical field and industrial genetics.
- Students will be able to understand how biotechnology helps in agricultural, food and beverage industry, chemical industries, environment and energy sectors.
- Students will be able to understand how biological products are recovered.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** Traditional and modern applications of biotechnology. Classification of micro-organisms. Structure of cells, types of cells. Basic metabolism of cells. Growth media. Microbial growth kinetics.	08
2	**Biological polymers:** Lipids, Proteins, Amino acids, Nucleic acids, Carbohydrates, Macro-nutrients and micro-nutrients.	06

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Module	Contents	No. of hrs
3	**Enzyme Technology:** Nomenclature and classification of enzymes. Enzyme kinetics. Immobilization of enzymes. Industrial applications of enzymes.	06
4	**Biotechnology in health care and genetics:** Pharmaceuticals and bio-pharmaceuticals, antibiotics, vaccines and monoclonal antibodies, gene therapy. Industrial genetics, protoplast and cell fusion technologies, genetic engineering, Introduction to Bio-informatics. Potential lab biohazards of genetic engineering. Bioethics.	06
5	**Applications of biotechnology:** Biotechnology in agriculture, food and beverage industries, chemical industries, environment and energy sectors.	08
6	**Product recovery operations:** Dialysis, Reverse osmosis, ultrafiltration, microfiltration, chromatography, electrophoresis, elecrodialysis, crystallization and drying.	06

References

1. Shuller M.L. and F. Kargi. 1992. Bioprocess Engineering, Prentice-Hall, Englewood Cliffs, NJ.
2. Bailey. J.E. and Ollis D.F. 1986, Biochemical Engineering Fundamentals, 2 nd Edition, McGraw-Hill, NewYork.
3. Kumar H.D., Modern Concepts of Biotechnology, Vikas Publishing House Pvt. Ltd.
4. Gupta P.K., Elements of Biotechnology, Rastogi Publications
5. Inamdar , Biochemical Engineering, Prentice Hall of India.

Course Code	Course Name	Credits
CHE805	Elective – III: Nanotechnology	4.0

Prerequisites

Basic concept of electron, atom, ions, molecules & molecular rearrangements, Basic knowledge of fluid flow, thermodynamics and heat transfer, Various types of material and metals, Basic knowledge of particle size measurement, Students are expected to have an understanding of basic chemical and physical concepts.

Course Objectives

- Understand the basic scientific concepts nanoscience and nanotechnology.
- Understand the properties of materials and biomaterials at the atomic/molecular level and the scaling laws governing these properties.
- To facilitate skills transfer from another relevant area of engineering or science and technology to the study of nanotechnology.
- Understand what nanotechnology is about and how to use it.

Course Outcomes

- Understand the essential concepts used in nanotechnology.
- Appreciate the development of modern nanotechnology.
- Understand the application of nanotechnology in major scientific fields.
- Understand the challenges nanotechnology poses to our environment.
- Gain knowledge of structure, properties, manufacturing and applications of silicon and carbon materials.
- Gain knowledge of fabrication methods in nanotechnology and characterization methods in nanotechnology.

Detail syllabus

Module	Contents	No. of hrs
1	**Fundamentals of Science behind Nanotechnology:** Electron , Atom and Ions, Molecules, Metals, Biosystems, Molecular Recognisation, Electrical Conduction and Ohms Law ,Quantum Mechanics and Quantum Ideas,Optics	05
2	**Fullerenes:** Combustion Flame Synthesis, Crystal Formation, Sintering, Organic Synthesis Method Super Critical Oligomerization, Solar Process, Electric Arc Process.	05

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Module	Contents	No. of hrs
3	**Carbon NanoTubes (CNT):** Synthesis of CNT, Electric Arc Discharge Process, Laser Ablation Process, CVD, HIPCO Process, Surface Mediated growth of Vertically Aligned Tubes, Physical Properties of CNTs, Morphology of CNT.	06
4	**Nanostructuring Methods:** Vacuum Synthesis, Gas Evaporation Tech, Condensed Phase Synthesis, Sol Gel Processing, Polymer Thin Film, Atomic Lithography, Electro deposition, Plasma Compaction. **Characterization of Nanostructures:** Transmission Electron Microscope, Scanning Electron Microscope, Microwave Spectroscopy, Raman Microscopy, X ray Diffraction.	10
5	**Calculations in Nanotechnology:** Particle Size Distribution, Particle Size & Measurement Methods, Fluid Particle Dynamics, Particle Collection Mechanisms, Particle Collection Efficiency.	09
6	**NanoBiology:** Interaction between Biomolecules & Nanoparticle Surface, Influence of Electrostatic Interactions in the binding of Proteins with Nanoparticles, The Electronic effects of bimolecule - Nanoparticle Interaction, Different Types of Inorganic materials used for the synthesis of Hybrid Nano-bio assemblies, Application.	05

Note: A minimum of 08 Tutorials involving a report based on literature survey and an oral presentation to the class on topic from any one Tutorial during tutorial session is envisaged. In addition numerical problems on various topics as included above. The performance of the students should be evaluated based on report and presentations.

References

1. Nano-structuring Operations in Nanoscale Science and Engineering- Kal Ranganathan Sharma, McGraw-Hill Companies

2. Nanotechnology: Basic Calculations for Engineers and Scientists - Louis Theodore, A John Willy & Sons

3. Nanotechnology: A Gentle Introduction to the Next Big Idea-By Mark Ratner, Daniel Ratner

4. Nano-The Essentials, Understanding Nanoscience and Nanotechnology, T. Pradeep

5. Introduction to Nanotechnology- Charles P. Poole, Jr. and Frank J. Owens, John Wiley & Sons, 2003

6. Nanotechnology: Basic and Emerging technologies, - Michael Wilson, Chapman & Hall
7. Principal of Nanotechnology-Molecular Based Study of Condensed Matter in Small Systems, - G .Ali Mansoori
8. Nanotechnology Assessment and Prospective - Schmid et al., Springer

Course Code	Course Name	Credits
CHE805	Elective – III: Advanced Process Simulation	4.0

Prerequisites

Process Calculations, Simulation and Optimization, Computer Programming.

Course Objectives

To understand the tools of process integration.

Course Outcomes

The student will be able to design integrated processes.

Detail syllabus

Module	Contents	No. of hrs
1	**Introduction:** Introduction to Process Integration, Alternative Processes, Process Synthesis, Process Analysis, Process Integration.	02
2	**Overall Mass Targeting:** Targeting for Minimum Discharge of Waste, Targeting for Minimum Fresh Material Utilities, Mass-Integration Strategies for Attaining Targets.	04
3	**Graphical Techniques for Direct-Recycle Strategies:** Introduction, Source-Sink Mapping Diagram and Lever-Arm Rule, Selection of Sources, Sinks, and Recycle Routes, Direct REcycle Targets Through Material Recycle Pinch Diagram, Multi-component Source-Sink Mapping Diagram.	08
4	**Synthesis of Mass Exchange Networks (A Graphical Approach):** Design of Individual Mass Exchangers, Cost Optimization of Mass Exchangers, Synthesis of Mass Exchange Networks, Mass Exchange Pinch Diagram, Screening of Multiple External MSAs.	08
5	**Mass Integration Strategies:** Low/No Cost Strategies, Most Changes in Operating Conditions and Process Variables, medium-Cost Strategies and Main Technology Changes.	06
6	**Algebraic Approach to Targeting Direct Recycle:** Algebraic Targeting Approach, Algebraic Targeting Procedure, The Composition Interval Diagram, Table of Exchangeable Loads, Mass Exchange Cascade Diagram, Example of Cleaning of Aqueous Waste.	06

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Module	Contents	No. of hrs
7	Recycle Strategies Using Property Integration Contents: Property Based Material Recycle Pinch Diagram, Process Modification, Clustering Techniques for Multiple Properties, Cluster Based Source Sink Mapping, Design Rules, Multiplicity, Clusters and Mass Fractions, Examples.	10
8	**Mathematical Approach:** Problem Statement and Representation, Formulation of Optimization Models, Interaction between Direct Recycle and the Process, Synthesis of MENs.	08

References

1. Mahmoud M. El-Halwagi, Process Integration, Academic Press

Course Code	Course/Subject Name	Credits
CHE805	Elective – III: Advanced Transport Phenomenon	4.0

Prerequisites

Continuity equation, equation motion covered in Fluid Mechanics, Diffusion and absorption from Mass Transfer and Conduction, convection and radiation from Heat Transfer. Knowledge of numerical methods to solve ODE and PDE.

Course Objectives

- Students will get in depth knowledge of momentum, heat and mass transport.
- Applications of fundamental subjects learned, towards chemical engineering problems.
- Students will learn the modelling of engineering operations and structured approach towards engineering problems.

Course Outcomes

- Students will get useful base from which to start for analysing given chemical engineering problem.
- Students will able to apply conservation principles, along with the flux expressions from mass and heat transfer to frame a model for any chemical engineering problem.
- By applying boundary conditions students can approach to structured solution to a given chemical engineering problem.

Detail syllabus

Module	Contents	No. of hrs
1	Differential equations of heat transfer (Conduction), mass transfer (molecular diffusion) with application like CVD reactors.	06
2	**Shell balance :** velocity distribution in laminar flow, temperature distribution in solids and laminar flow, concentration distributions in solids and in laminar flow.	08
3	Convective momentum transport in boundary layer. Convective heat transport in boundary layer. Convective Mass transport in boundary layer. Formulation of differential equations for wetted wall column, thin film evaporator (only model formulation, solution not expected).	10
4	Simplification of continuity equation and equation of motion in Cartesian, cylindrical and spherical coordinates for different steady state engineering problems e.g. flow through trough, pipes and ducts, conical sections, etc for Newtonian and Power law fluids.	10

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Module	Contents	No. of hrs
5	Simplification of equation of energy with and without viscous dissipation for steady state chemical engineering problems. Applications should be limited to Newtonian and Power law fluids. Simplification of continuity equation for multicomponent system with applications to chemical engineering problems like absorption, absorption with reaction, adsorption, diffusion, extraction, etc.	10
6	Unsteady state microscopic balances with and without generation: laminar flow in a tube, conduction with/without heat generation, gas absorption in liquid droplets with/without reaction. Solution to partial differential equations developed in earlier modules using various numerical methods like finite element method, Crank-Nicholson method, Laplace equation. Emphasis should be given to write the computer programs and analysis of simulated values using SciLab/MATLAB for home/class assignments.	08

References

1. Bird, R.B., W.E. Stewart and E.N. Lightfoot, Transport Phenomena, Wiley, New York, 2nd ed., 2002.
2. Welty, James R., Wicks, C. E., Wilson, R. E., Rorrer, Gregory L., Fundamental of Momentum, Heat, and Mass Transfer, Wiley India (P.) Ltd., 5th ed., 2008.
3. Ismail Tosun, Modelling in Transport Phenomena A Conceptual Approach, ELSEVIER SCIENCE B.V, Amsterdam, 2002.
4. Slattery, J.C., Advanced Transport Phenomena, Cambridge University Press, Cambridge, 1999.
5. Brodkey, R.S. and H.C. Hershey, 1988, Transport Phenomena: A Unified Approach, McGraw-Hill, New York.
6. Fahien, R.W., 1983, Fundamentals of Transport Phenomena, McGraw-Hill, New York.
7. Santosh K. Gupta, Numerical Methods for Engineers, New Age Publishers, 2nd ed., 2010.
8. L. Gary Leal, Advanced Transport Phenomena, Cambridge University Press, Cambridge, 2007.
9. Richard G. Griskey, Transport Phenomena and Unit Operations: A Combined Approach, John Wiley & Sons, Inc., New York, 2002.
10. Yang, Cao, Chung, and Morris, Applied Numerical Methods Using MATLAB, John Wiley & Sons, Inc., New York, 2005.

11. G. R. Liu, S. S. Quek, The Finite Element Method: A Practical Course, Butterworth-Heinemann, Oxford, 2003.

Course Code	Course Name	Credits
CHP806	Project – B	6.0

Details

- Project Groups: Students can form groups with minimum 2(Two) and not more than 4(Four).
- The load for projects may be calculated proportional to the number of groups, not exceeding two hours per week.
- Each teacher should have ideally a maximum of three groups and only in exceptional cases four groups can be allotted to the faculty.
- Students should spend considerable time in applying all the concepts studied, into the project. Hence, eight hours each were allotted in Project A,B to the students.

Course Code	Course/Subject Name	Credits
CHL807	Chemical Engineering Lab (EE)	1.0

Concepts for experiments:

Students should be able to apply the Environmental Engineering concepts to control and management of various types of pollutants. A minimum of eight experiments must be performed on following concepts,

- Physical characterization (TDS /turbidity measurement) of waste water.
- Chemical characterization (chloride ion, sulphate ion etc.) of waste water.
- Determination of organic matters (dissolved oxygen) in waste water.
- Sampling measurement and standard of water quality (determination of BOD).
- Sampling measurement and standard of water quality (determination of COD).
- Determination of toxic matters (phenol, chromium etc.) in waste water.
- Determination of inorganic matters (heavy metal) in waste water.
- Measurement of particulate matter in air.
- Measurement of gaseous pollutant (any one) in air.
- Measurement of various types of residues or solids in the given sample.
- Measurement of sound level.

Course Code	Course/Subject Name	Credits
CHL808	Chemical Engg Lab (MSO)	1.5

Concepts for experiments:

The following are suggestions for experiments using using any available computing software:

- Simulation of multi-component flash calculations in ideal and non-ideal systems.
- Simulation of Pipe and pump network flows.
- Simulation of operation of batch, semi-batch and continuous reactors.
- Simulation of unit operations.
- Simulation of flowsheet calculations.
- Optimization of chemical processes.