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 PART A: Pressure Vessel Subjected to Internal Pressure. 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