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.