M.Tech. - Chemical Engineering

Curriculum and Syllabus

Operative for the students admitted in 2013 and onwards

M.TECH. Chemical Engineering

Course Structure and Scheme of Evaluation (Semester – wise)

[The total minimum number of credits = 61]

Course Structure and Scheme of Evaluation (Semester - wise)

Code	Name of the subject	Hours per week L T P	Credits
SEMESTER I			
CL 601	Advanced Process Control	2 1 0	3
CL 603	Process Modelling & Simulation	2 1 0	3
CL 605	Chemical Reactor Analysis & Design	2 1 0	3
	Elective I	3 0 0	3
	Elective II	3 0 0	3
	Elective III	3 0 0	3
CL 607	Chemical Engineering Lab	0 0 4	2
	Total Credits in Semester I		**20**
SEMESTER II			
CL 602	Advances in Fluidization Engg.	3 0 0	3
CL 604	Chemical Process Design	3 0 2	4
CL 606	Advanced Transport Phenomena	3 1 0	4
	Elective – IV	3 0 0	3
	Elective – V	3 0 0	3
	Elective – VI	3 0 0	3
Total Credits in Semester II			**20**
SEMESTER – 3			
CL 647	PROJECT WORK	12	12
Total Credits in Semester III			**12**
SEMESTER – 4			
CL 648	PROJECT WORK	12	12
Total Credits in Semester IV			**12**
Total Credits in the Course			**64**

M. Tech. DEGREE

(Chemical Engineering)

List of Core Subjects:

SEMESTER - I		
S.No.	**Code No.**	**Title**
1.	CL 601	Advanced Process Control
2.	CL 603	Process Modeling & Simulation
3.	CL 605	Chemical Reactor Analysis & Design
SEMESTER - II		
4.	CL 602	Advances in Fluidization Engg.
5.	CL 604	Chemical Process Design
6.	CL 606	Advanced Transport Phenomena

List of Elective Subjects:

S.No.	Code No.	Title
1	**CL 610**	Computational Techniques in Engineering
2	**CL 611**	New Separation Techniques
3	**CL 612**	Nano Technology
4	**CL 613**	Scale - up Methods
5	**CL 614**	Industrial Safety And Risk Management
6	**CL 615**	Bioprocess Engineering
7	**CL 616**	Polymer Dynamics
8	**CL 617**	Multiphase flow
9	**CL 618**	Ecology for Engineers
10	**CL 619**	Fuel Cell Technology
11	**CL 620**	Pinch Analysis and Heat Exchange Network Design
12	**CL 621**	Industrial Energy Systems
13	**CL 622**	Industrial Waste Management
14	**CL 623**	Computational Fluid Dynamics
15	**CL 624**	Process Optimization
16	**CL 625**	Design and Analysis of Experiments
17	**CL 626**	Advanced Food Process Engineering
18	**CL 627**	Bio-refinery Engineering
19	**CL 628**	Air Pollution Control Equipment Design
20	**CL 629**	Global Chemical Sustainability
21	**CL 630**	Energy Systems Modeling and Planning
		Any other PG elective

Syllabus for Each Subject from Next Page onwards

CL 601 ADVANCED PROCESS CONTROL

OBJECTIVE:
Expose students to the advanced control methods used in industries and research. This course prepares the student to take up such challenges in his profession.
OUTCOMES:
Upon completing the course, the student should have understood
- controller tuning
- type of controller that can be used for specific problems in chemical industry
- design of controllers for interacting multivariable systems
- design of digital control systems

Review of Systems: Review of first and higher order systems, closed and open loop response. Response to step, impulse and sinusoidal disturbances. Transient response. Block diagrams.

Stability Analysis: Frequency response, design of control system, controller tuning and process identification. Zigler-Nichols and Cohen-Coon tuning methods, Bode and Nyquist stability criterion. Process identification.

Special Control Techniques: Advanced control techniques, cascade, ratio, feed forward, adaptive control, Smith predictor, internal model control.

Multivariable Control Analysis: Introduction to state-space methods, , Control degrees of freedom analysis and analysis, Interaction, Bristol arrays, Niederlinski index - design of controllers, Tuning of multivariable controllers.

Sample Data Controllers: Basic review of Z transforms, Response of discrete systems to various inputs. Open and closed loop response to step, impulse and sinusoidal inputs, closed loop response of discrete systems. Design of digital controllers. Introduction to PLC and DCS.

TEXT BOOKS:

1. *D.R. Coughanour, 'Process Systems analysis and Control', McGraw-Hill, 2nd Edition, 1991.*
2. *D.E. Seborg, T.F. Edger, and D.A. Millichamp, 'Process Dynamics and Control', John Wiley and Sons, 2nd Edition, 2004.*

REFERENCES:

1 *B.A.Ogunnaike and W.H.Ray, "Process Dynamics, Modelling and Control", Oxford Press, 1994.*
2 *W.L.Luyben, 'Process Modelling Simulation and Control for Chemical Engineers', McGraw Hill, 2nd Edition, 1990.*
3 *B.W. Bequette, 'Process Control: Modeling, Design and Simulation', PHI, 2006.*
4 *S. Bhanot, 'Process Control: Principles and Applications', Oxford University Press, 2008.*

CL 603 PROCESS MODELLING AND SIMULATION

OBJECTIVES:
To give an overview of various methods of process modeling, different computational techniques for simulation. The focus shall be on the techniques themselves, rather than specific applications so that the student can take up modeling and simulation challenges in his profession.

OUTCOMES:
Upon completing the course, the student should have understood

- Development of process models based on conservation principles and process data
- Computational techniques to solve the process models
- How to use simulation tools such as MATLAB/SCILAB

Introduction to process modeling - a systematic approach to model building, classification of models. Conservation principles, thermodynamic principles of process systems.

Development of steady state and dynamic lumped and distributed parameter models based on first principles. Analysis of ill-conditioned systems. Models with stiff differential equations.

Development of grey box models. Empirical model building. Statistical model calibration and validation. Examples. Introduction to population balance models, multi-scale modeling.

Solution strategies for lumped parameter models and stiff differential equations. Solution methods for initial value and boundary value problems. Euler's method. R-K methods, shooting method, finite difference methods – predictor corrector methods.

Solution strategies for distributed parameter models. Solving parabolic, elliptic and hyperbolic partial differential equations. Introduction to finite element and finite volume methods.

Solving the problems using *MATLAB/SCILAB.*

TEXT BOOKS:

1. *K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press, 2001.*
2. *W.L. Luyben, "Process Modeling, Simulation and Control for Chemical Engineers", 2nd Edn., McGraw Hill Book Co., New York, 1990.*
3. *Singiresu S. Rao, "Applied Numerical Methods for Engineers and Scientists" Prentice Hall, Upper Saddle River, NJ, 2001*

REFERENCES:

1. *Bruce A. Finlayson, Introduction to Chemical Engineering Computing, Wiley, 2010.*
2. *W. F. Ramirez, "Computational Methods for Process Simulation", 2nd ed., Butterworths, 1997.*
3. *Amiya K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall of India, 2nd Edition, 2011*
4. *Laurene V. Fausett, Applied Numerical Analysis using MATLAB, Second edition, Pearson, 2009*

CL 605 CHEMICAL REACTOR ANALYSIS AND DESIGN

OBJECTIVES:

To understand basics of heterogeneous catalytic and non-catalytic reactor design

OUTCOME:

Through knowledge on catalyst physical properties and catalyst characterisation Awareness on kinetics of catalytic and non-catalytic chemical reaction, Students familiar with the design of catalytic and non-catalytic reactor

Analysis of Noncatalytic fluid solid reaction: Kinetics of non-catalytic fluid-particle reactions, various models, application to design.

Catalyst preparation and characterization: Catalysis - Nature of catalyses, methods of evaluation of catalysis, factors affecting the choice of catalysts, promoters, inhibitors, and supports, catalyst specifications, preparation and characterization of catalysts, surface area measurement by BET method, pore size distribution, catalyst, poison, mechanism and kinetics of catalyst, deactivation.

Physical adsorption and chemical adsorption: Fluid-fluid reactions different regimes, identification reaction regime, application to design. Physical absorption with chemical reaction, simultaneous absorption of two reacting cases consecutive reversible reactions between gas and liquid, irreversible reactions, estimation of effective interfacial area in absorption equipment.

Reaction kinetics, accounting porous nature of catalyst: Heterogeneous catalytic reactions - effectiveness factor, internal and external transport processes, non-isothermal reacting systems, uniqueness and multiplicity of steady states, stability analysis.

Modeling of chemical reactors: Modeling of multiphase reactors - Fixed, fluidized, trickle bed, and slurry reactors.

TEXT BOOKS:

1. *O. Levenspiel, "Chemical Reaction Engineering", 3rd Edn., Wiley Eastern, New York, 1999.*
2. *J .M. Smith, "Chemical Kinetics", 3rd Edn., McGraw Hill, New York, 1981.*
3. *H.Scott Fogler, "Elements of Chemical Reaction Engineering",4th Edn., Prentice Hall of India Ltd.,2008.*

REFERENCES:

1. *J.J. Carberry "Chemical and Catalytic Reaction Engineering", McGraw Hill, New York, 1976.*
2. *R. Aris, "Elementary Chemical Reactor Analysis", Prentice Hall, 1969.*
3. *G.F. Froment, K.B. Bischoff, "Chemical Reactor Analysis and Design", 2nd ed., John Wiley, New York, 1990.*

CL 602 ADVANCES IN FLUIDIZATION ENGINEERING

COURSE OBJECTIVES:

Fluidization finds extensive application today in Process Industry and also in combustion. Objective of this course is to make the student aware of fundamentals of Fluidization and understand the design aspects of fluidized bed systems.

OUTCOME:

The student at the end of the course will be in a position to design a fluidized bed system for different applications.

Applications of fluidized beds: Introduction, Industrial application of fluidized beds, Physical operations and reactions.

Fluidization and analysis of different phases: Gross behavior of fluidized beds. Bubbles in dense beds. The emulsion phase in dense bubbling beds. Flow pattern of gas through fluidized beds.

Heat and Mass transfer in fluidized bed systems: Mass and heat transfer between fluid and solid. Gas conversion in bubbling beds. Heat transfer between fluidized bed and surfaces.

Elutriation and entrainment: TD and also distribution of solid in a fluidized bed. Circulation systems.

Design of fluidized bed systems: design of fluidization columns for physical operations, catalytic and non- catalytic reactions, three phase fluidization.

CA: 2 Tests each for 20 marks + Assignment/seminar for 10 marks
50 marks for end semester examination.

TEXT BOOK:

1. *Diazo Kunji and O. Levenspiel, "Fluidization Engg". 2nd Ed., Butterworth Heinemann, 1991.*

REFERENCE:

1. *J. F. Davidson and Harrison, "Fluidization", 10th Ed, Academic Press, London, 1994.*
2. *Jackson, R., "The Dynamics of Fluidized Particles," Cambridge University Press, New York (2000).*
3. *Fan, L.-S. and C. Zhu, Principles of Gas-Solid Flows, Cambridge University Press, New York (1998).*

CL 604 CHEMICAL PROCESS DESIGN

OBJECTIVES: To understand advances in the design of Chemical process equipment

OUTCOME:

Students will have awareness on advances in process engineering design of many process equipments, Students will be exposed to process integration approach to before proceeding for design any process Equipments, Students will have awareness on use of Aspen plus for simulation different process

Design and sizing of Shell and Tube Heat exchangers with types and arrangements of fluids, plate type heat exchanger, Condensers -vertical and Horizontal.

Design and sizing of Single and Multiple effect Evaporators-Short tube, long tube etc.

Design of storage tank and supports: horizontal storage tank, Design of Saddle, Skirt, and Lug supports

Design of Reaction vessel with and without cooling coil, Normal and High Pressure vessel, Design and sizing of mass transfer equipments: Design of distillation column, Multi-component distillation with reboiler, Absorption tower both plate as well as packed type, cooling tower and extraction columns

Design and sizing of drier, and Crystallizer.

Design and sizing of phase separation equipment- filter press, Centrifuge, Cyclone (Hydro as well as air).

All the above design should be taught in a process Integration approach with special the material and energy conservation

Aspen Plus lab type course: Property method and model descriptions, Property calculation method and Routes, Petroleum component characterization method Property parameter estimation and simulation of different process equipments using Software

TEXT BOOKS:

1. *K.Q.Kern Process Heat transfer, McGraw-Hill,1965*
2. *Coulson and Richardson Chemical Engineering Vol.VI, Pergamon Press,1983*
3. *S.B.Thakore and B.I.Bhatt Introduction to Process Engineering and Design, McGraw-Hill, 2009*
4. *Couper, "Chemical process equipment design*

REFERENCES:

1. *Perry Chemical Engineer's Hand book by Perry, McGraw-Hill,2009*
2. *McCabe and Smith Unit operation of Chemical Engineering, McGraw-Hill, 2008*
3. *Christie John Geankopolis Transport process and Separation Process, Fourth Edition, PHI, 2004.*
4. *Aspen Manual*

CL 606 ADVANCED TRANSPORT PHENOMENA

PREREQUISITE: UG Courses on momentum, heat and mass transfer, CRE, PDEs, ODEs

OBJECTIVE: The course will accustom the students with import topics in advanced transport phenomena (momentum, heat and mass transport). The Focus will be to develop physical understanding of principles discussed and with emphasis on chemical engineering applications. In addition to the text, the student will be exposed to classic and current literature in the field.

OUTCOME: Ability to set up and solve differential momentum, heat, and mass balances for 1-D steady state problems and quasi-steady-state problems occurring in laminar and turbulent flows in terms of vector and tensor fluxes. Formulate conservation statements in heat, mass, and momentum at multiscales from microscopic to macroscopic in both steady and unsteady modes. Analyze advanced transport problems in heat, mass, and momentum, both macroscopic and microscopic formulate simultaneous energy and mass balances in chemical processes.

Momentum Transport:
Introduction to concepts and definitions, Newtonian and non-Newtonian Fluid Models, Review of Shell balance method and Equations of changes for fluid flow problems (Flow over flat plate, though pipes, packed bed and fluidized beds)
Turbulent Flow - Equation of changes, phenomenological theories, Turbulent flow in closed conduits and analysis of different velocity distributions, Boundary layer theory: Equation of changes, Blasius Exact solution method, von karman Integral momentum method, Boundary layer separation.

Energy Transport:
Application of Shell balance and Equations of changes for temperature distributions in heat flow problems Steady state conduction, Combination of heat transfer resistance,
Different method of analysis for Multidimensional Steady and Unsteady state heat conduction, Convection heat transfer co-efficient, Heat transfer during Laminar and Turbulent flow in closed conduits-,

Mass Transport
Application of Shell balance method and Equations of changes for mass transfer problems, Concentration distributions for isothermal and non-isothermal mixtures, Multi component systems, with more than one one independent variable and in turbulent flow

Convective mass transfer and correlation, interphase mass transfer, Macroscopic balance for multi component system, Mass transfer with chemical reactions,

Dimensional analysis in fluid dynamics, convection heat transfer, Boiling and Condensation heat transfer, Heat transfer in Liquid metals, Empirical correlation for high Prandtl Number of fluids, Analogy between momentum and heat transfer,

TEXT BOOKS:

R. Byron Bird, Warren E. Stewart and Edwin N. Lightfoot, "Transport Phenomena", Revised second Edition, John Wiley & Sons, 2007

REFERENCES:

1. JamesWelty, Charles E. Wicks and Wilson, Gregory L Rorrer, "Fundamentals of Momentum, Heat and Mass transfer", 5th Edition, 2008.
2. C. O.Bennet and J. O. Meyers, "Momemtum, Heat and Mass transfer" McGraw Hill, 1995.
3. J.P. Holman, "Heat Transfer", 8th Edition, McGraw Hill, New York, 1997
4. H. Schlichting, Boundary-Layer Theory, 7th edition, McGraw-Hill, Inc,

CL 610 COMPUTATIONAL TECHNIQUES IN ENGINEERING

Objective: To explain the different computational techniques for solving chemical engineering problems.
Outcome: After completion of the course, the student is expected to know design and analysis of experiments. Finite differences based solutions. Numerical methods.

Design and analysis of experiments: Treatment and interpretation on engineering data: Curve fitting, Non-linear least square regression. Interpolation: Newton's Forward/Backward interpolation formula, Lagrange's interpolation formula and experiments their application. Tests of significance, Analysis of variance.

Formulation of physical problems: Mathematical statement of the problem, Representation of problems, Formulation on Socuene extraction in single & multiple stages, Radial heat transfer through a cylindrical conductor, salt accumulation in stirred tank.

Numerical solution of linear & nonlinear algebraic equations: Linear systems of equations, solutions by Creamer's Rule, Matrix methods, Gaussian, Gauss-Jordan, Jacobean, Gauss-Seidel and Relation methods. Non-linear equations: Bisection, Regula-falsi, Secant and Newton- Raphson methods.

Numerical solution of ordinary differential equations: Ordinary differential equations: Runge-Kutta, Euler's and Milne's predictor corrector methods. Solution of boundary value problems.

Finite differences: Finite differences, Partial differential equations, Solutions of elliptic, parabolic, and hyperbolic types of equations.

TEXT BOOKS:

1. *S. K. Gupta, "Numerical Techniques for Engineers", Wiley Eastern, 1995.*
2. *M.K. Jain, S.R.K. Iyengar and R. K. Jain, "Numerical Methods for Scientific and Engineering Computations", 1992.*

REFERENCE:

1. *H.S. Mickley, T.K. Sherwood and C.E. Reid, "Applied Mathematics in Chemical Engineering", II Edn., Tata McGraw Hill, New Delhi, 1978.*

CL 611 NEW SEPARATION TECHNIQUES

Objective : To learn the principle and technical concept of advanced separation processes.

Outcome:

Create awareness among students with new and unconventional separation processes, Acquire sufficient knowledge in energy intensive processes for separation of components, Students will be equipped with the applications in Down-streaming processes

General Review: Mechanisms: Separation factors and its dependence on process variables, classification and characterization, thermodynamic analysis and energy utilization, kinetics and mass transport. Theory of cascades and its application in single and multistage operation for binary and multi component separations.

Membrane Separations: Types and choice of membranes, their merits, commercial, pilot plant polarization of membrane processes and laboratory membrane permeators, dialysis, reverse osmosis, ultra filtration, Concentration and economics of membrane operations, Design controlling factors.

Separation by Sorption Techniques: Types and choice of adsorbents, chromatographic techniques, Types, Retention theory mechanism, Design controlling factors ion exchange chromatography equipment and commercial processes, recent advances and economics.

Ionic Separations: Controlling factors, applications, Theory mechanism and - equipments for electrophoresis, dielectrophoresis and electro dialysis - commercial applications - Design considerations.

Thermal Separation: Thermal diffusion: Basic rate law, phenomenological theories of thermal diffusion for gas and liquid mixtures, Equipments design and applications. Zone melting: Equilibrium diagrams, Controlling factors, Apparatus and applications.

Other Techniques: Adductive crystallization molecular addition compounds, Clathrate compounds and adducts, Equipments, Applications, Economics and commercial processes. Foam Separation: Surface adsorption, Nature of foams, Apparatus, Applications, and Controlling factors. .

TEXT BOOKS:

1. H.M. Schoen, "New Chemical Engineering Separation Techniques”, Wiley Interscience, New York, 1972.

2. C.J. King, "Separation Processes", Tata McGraw Hill, New Delhi, 1982.

3. B. Sivasankar, “Bioseparations – Principles and Techniques”, Prentice Hall of India Pvt. Ltd, New Delhi, 2005.

4. “Membrane Separation processes”, Kaushik Nath, PHI ,2008.

REFERENCES:

1. R.E. Lacey and S. Loeb, “Industrial Processing with Membranes,” Wiley–Inter sciences, New York, 1972.

2. Ronald W.Roussel, Hand book of Separation Process Technology, John Wiley, New York, *1987.*

3. H.R.C. Pratt, “Counter-Current Separation Processes,” Elsevier, Amsterdam, 1967.

4. “Separation process Principles”, J.D. Seader, Ernest J.Henley and D. Keith Roper , 3rd edition, John Wiley & Sons Australia, Limited, 2010.

CL 612 NANO TECHNOLOGY

Objective:

Outcome:

Supramolecular Chemistry: Definition and examples of the main intermolecular forces used in supramolecular chemistry. Self-assembly processes in organic systems. Main supramolecular structures.

Physical Chemistry of Nanomaterials: Students will be exposed to the very basics of nanomaterials; a series of nanomaterials that exhibit unique properties will be introduced.

Methods of Synthesis of Nanometerials. Equipment and processes needed to fabricate nano devices and structures such as bio-chips, power devices, and opto-electronic structures. Bottom-up (building from molecular level) and top-down (breakdown of microcrystalline materials) approaches.

Biologically-Inspired nanotechnology basic biological concepts and principles that may lead to the development of technologies for nano engineering systems. Coverage will be given to how life has evolved sophisticatedly; molecular nanoscale engineered devices, and discuss how these nanoscale biotechnologies are far more elaborate in their functions than most products made by humans.

Instrumentation for nanoscale characterization. Instrumentation required for characterization of properties on the nanometer scale. The measurable properties and resolution limits of each technique, with an emphasis on measurements in the nanometer range.

TEXT BOOKS:

1. *Supramolecular Chemistry by Jean-Marie Lehn, Wiley VCH, 1995*
2. *Supramolecular Chemistry by Jonathan Steed & Jerry Atwood, John Wiley & Sons, 2004*
3. *Intermolecular and Surface Forces by Jacob Israelachvil, Academic Press, London, 1992.*

CL 613 SCALE -UP METHODS

Objective: To understand different scale up methods in chemical engineering

Outcome: After completion of the course, the students should be able to understand scale up of reactors, unit operations equipment, heat transfer equipment and mixing equipment.

Principals of Similarity, Pilot Plants & Models: Introduction to scale-up methods, pilot plants, models and principles of similarity. Industrial applications.

Dimensional Analysis and Scale-Up Criterion: Dimensional analysis, regime concept, similarity criterion and scale up methods used in chemical engineering.

Scale-Up of Mixing and Heat Transfer Equipment: Typical problems in scale-up of mixing equipment and heat transfer equipment

Scale-Up of Chemical Reactors: Kinetics, reactor development & scale-up techniques for chemical reactors.

Scale-Up of Distillation Column & Packed Towers: Scale-up of distillation columns and packed towers for continuous and batch processes

TEXT BOOKS:

1. *Johnstone and Thring," Pilot Plants Models and Scale-up methods in Chemical Engg.", McGraw Hill, New York, 1962.*

2 Marko Zlokarnik, "Dimensional Analysis and Scale-up in Chemical Engg.", Springer Verlag, Berlin, Germany, 1986.

REFERENCE:

1. *Donald G.Jordan, "Chemical Process Development" (Part 1 and 2), Interscience Publishers, 1988.*

CL 614 INDUSTRIAL SAFETY AND RISK MANAGEMENT

Aim: The course is aimed at making the student to understand the principles of industrial safety and procedures to be followed in chemical industries.

Objectives: On completion of the course, the students are expected to be familiar with accident prevention techniques, hazard analysis techniques and legislations pertaining to safety in chemical industries.

Hazards: Chemical hazards classification. Radiation hazards and control of exposure to radiation. Fire hazards. Types of fire and prevention methods. Mechanical hazards. Electrical hazards. Construction hazards.

Psychology and Hygiene: Industrial psychology. Industrial hygiene. Nature and types of work places. Housekeeping. site selection and plant layout. Industrial lighting and ventilation. Industrial noise.

Occupational diseases and control: Occupational diseases and prevention methods. Safe housekeeping. Instrumentation and control for safe operation. Pressure, Temperature and Level controllers. Personal protective equipments.

Management and Risk Analysis: Safety organization – safety committee – safety education and training. Types of safety analysis. Case studies pertaining to chemical industries.

Legislations and economics: Factory Act. ESI Act, Environmental Act. Workmen - compensation Act. Provisions under various acts. Economics of safety. Financial costs to individual, family, organization and society. Budgeting for safety

TEXT BOOKS:

1. *H.H. Fawcett & W. S .Wood, "Safety and Accident Prevention in Chemical Operation", 2nd Ed, Wiley Interscience, 1982.*

REFERENCES:

1. *Guide for Safety in the Chemical laboratory Second edition 1977, Manufacturing Chemists Association. Van Nostrand Reinhold Company, New York.*
2. *Industrial Safety and Laws, 1993, by Indian School of Labour Education, Madras.*

CL 615 BIOPROCESS ENGINEERING

Objectives: To understand the principles, stoichiometry, kinetics, modeling and instrumentation of biological processes employed in industrial fermentation

Outcome: To have theoretical knowledge on enzyme kinetics, modeling, monitoring and control of bioreactors

Introduction: Fermentation Processes General requirements of fermentation processes- An overview of aerobic and anaerobic fermentation processes and their application in industry - Medium requirements for fermentation processes - examples of simple and complex media Design and usage of commercial media for industrial fermentation. Sterilization: Thermal death kinetics of micro-organisms - Batch and Continuous Heat-Sterilization of liquid Media- Filter Sterilization of Liquid Media and Air.

Enzyme Technology, Microbial Metabolism :Enzymes: Classification and properties-Applied enzyme catalysis - Kinetics of enzyme catalytic reactions-Metabolic pathways - Protein synthesis in cells.

Stoichiometry And Kinetics Of Substrate Utilization And Biomass And Product Formation: Stoichiometry of microbial growth, Substrate utilization and product formation-Batch and Continuous culture, Fed batch culture

Bioreactor And Product Recovery Operations:Operating considerations for bioreactors for suspension and immobilised cultures, Selection, scale-up, operation of bioreactors-Mass Transfer in heterogeneous biochemical reaction systems; Oxygen transfer in submerged fermentation processes; oxygen uptake rates and determination of oxygen transfer rates and coefficients; role of aeration and agitation in oxygen transfer. Heat transfer processes in Biological systems. Recovery and purification of products.

Introduction To Instrumenation And Process Control In Bioprocesses: Measurement of physical and chemical parameters in bioreactors- Monitoring and control of dissolved oxygen, pH, impeller speed and temperature in a stirred tank fermenter.

TEXT BOOKS:

1. *M.L. Shuler and F. Kargi, "Bio-process Engineering", 2nd Edition, Prentice Hall of India, New Delhi. 2002.*
2. *J.E. Bailey and D.F. Ollis," Biochemical Engineering Fundamentals", 2nd Edn., McGraw Hill, Publishing Co. New York., 1985.*

REFERENCE:

1. *P.Stanbury, A. Whitakar and S.J.Hall, "Principles of Fermentation Technology" 2nd Edn., Elsevier-Pergamon Press, 1995.*

CL 616 POLYMER DYNAMICS

Pre Requisites: The students should have idea on basics of polymerization processes and types of polymerization.

Objective :

To provide an opportunity for post graduate students to develop skills, strategies and methods necessary to understand the basic principles dynamics of polymers in solution through various models.

Outcome:

At the conclusion of this course the successful student should be able to
Understand flow behavior of polymer melts and solutions.
Describe polymer dynamics in dilute and semi-dilute solutions
Review and Distinguish between the models for polymer solutions.

Course Content:

Polymer Melts and Solution: Description Viscosity of Polymer Melts and Solution: Viscosity of Concentrated Solutions and Melts, Effect of Branching on Viscosity, Elasticity and Visco-elasticity, Maxwell Model for Visco-elasticity, Flow phenomena in polymeric liquids, Brownian Motion, Smoluchowski and Langevin Equation, Autocorrelation and Cross-Correlation functions, Response Function, Fluctuation Dissipation Theorem, Interacting Brownian Particles, Oseen Tensor, microscopic basis of visco elasticity.

Dilute Solutions: Elastic Dumbell Model and bead-rod-spring model for polymer chain, the Rouse and Zimm Models

Visco-elasticity and Birefringence. Semidilute and Concentrated Solutions and melts: Effective Medium Theory, Entanglement Effect, Tube Model and Reptation Model, Network theories, Linear Visco-elasticity, Stress Relaxation, Non-Linear Visco-elasticity, Dynamics of Rigid Rodlike Polymers.

TEXT BOOKS/REFERENCES:

1. *Theory of Polymer Dynamics, M. Doi and S. F. Edwards, Clarendon Press, Oxford, 1986.*
2. *Dynamics of Polymeric Liquids, 2nd Edition vols. 1 & 2, R. B. Bird, R. C. Armstrong, O. Hassager, John Wiley and Sons, NY, 1987.*
3. *Structure and Rheology of Complex Fluids, R. G. Larson, Oxford University Press, 1999.*

CL 617 MULTIPHASE FLOW

Prerequisite: UG Courses on Fluid flow, heat and mass transfer

Objective: The course will give a general introduction to the underlying concepts of multiphase flows and different approaches to model such flows under different conditions. The course opens with real life examples of such flow and its importance in process industries with multiphase contactors.

Outcome:
Analyze, characterize the multiphase systems and appreciate the role of structure in multiphase flows and the role it plays in obtaining engineering solutions
Understand the assumptions may be made to simplify multiphase flows and when they might be employed
Model a wide variety of multiphase flows
Understand the limitations of modeling multiphase flows
Obtain answers to engineering problems involving multiphase flows

Two phase flow: Gas/Liquid and Liquid/liquid systems: Flow patterns in pipes, analysis of two phase flow situations,

Prediction of holdup and pressure drop or volume fraction, Bubble size in pipe flow, Lockchart-Martinelli parameters, Bubble column and its design aspects, Minimum carryover velocity. holdup ratios, pressure drop and transport velocities and their prediction.

Flow patterns - identification and classification - flow pattern maps and transition - momentum and energy balance - homogeneous and separated flow models -correlations for use with homogeneous and separated flow models - void fraction and slip ratio correlations - influence of pressure gradient - empirical treatment of two phase flow - drift flux model - correlations for bubble, slug and annular flows

Introduction to three phase flow, Dynamics of gas-solid liquid contactors (agitated vessels, packed bed, fluidized bed, pneumatic conveying, bubble column, trickle beds), Flow regimes, pressure drop, holdup, distributions, mass and heat transfer, reactions, Applications of these contactors

Measurement techniques in multiphase flow: Conventional and novel measurement techniques for multiphase systems (Laser Doppler anemometry, Particle Image Velocimetry)

TEXT BOOKS/REFERENCES:

1. Clift, R., Weber, M.E. and Grace, J.R., Bubbles, Drops, and Particles, Academic Press, New York, 1978.
2. Y. T. Shah, Gas-Liquid-Solid reactors design, McGraw Hill Inc, 1979
3. Fan, L. S. and Zhu, C., Principles of Gas-solid Flows, Cambridge University Press, 1998
4. Govier, G. W. and Aziz. K., “The Flow of Complex Mixture in Pipes”, Van Nostrand Reinhold, New York, 1972.
5. Wallis, G.B., “One Dimensional Two Phase Flow”, McGraw Hill Book Co., New York, 1969.
6. Crowe, C. T., Sommerfeld, M. and Tsuji, Y., Multiphase Flows with Droplets and Particles, CRC Press, 1998
7. Kleinstreuer, C., Two-phase Flow: Theory and Applications, Taylor & Francis, 2003
   Rhodes, M., Introduction to Particle Technology, John Wiley & Sons, New York. 1998.

CL 618 ECOLOGY FOR ENGINEERS

Prerequisites
Basic university-level knowledge in environmental engineering or environmental science

Aim
The course aims at giving substantial and functional knowledge on ecology, ecosystem services and provision of raw materials from biological systems to the industry in a society adapting towards sustainability.

Learning outcome (after completion of this course, the student should be able to)
- Describe fundamental ecological principles
- Identify and describe the major biomes of the world
- Explain how the productivity of biological systems and ecosystem services affect and are affected by activities in society
- Explain how industry could be transformed to enable sustainable use of natural capital
- Describe valuation of nature from different ethical perspectives

Content
Ecological principles
Biomes
Biological diversity
Ecosystem services
Sustaining biological resources for society's consumption
Valuation of nature and ecosystem services

Organisation
Lectures
Seminars
Field trips
Projects and exercises

Books:
Living in the Environment. G. Tyler Miller, Jr, Scott E. Spoolman. International Student Edition.Seventeenth edition. Brooks/Cole
Millennium Ecosystem Assessment Reports (http://www.maweb.org/en/Index.aspx)
Supplementary material, student reports, handouts from lectures and exercises

CL 619 FUEL CELL TECHNOLOGY

OBJECTIVES

To understand about fuel cells, their working principle, Types, Design and performance analysis.

OUTCOME

After completing the course, student should have learnt

Basics and working principles of the Fuel cell technology.

Selection the suitable materials for electrode, catalyst, membrane for the fuel cells.

The mass transfer process such as pressure drop and velocity distribution in single cell as well as stack.

Design and stack making process for real field applications.

Course content

Basic principles, classifications, heat of reactions, enthalpy of formation of substances, Gibbs free energy of substances, Efficiency, power, heat due to entropy change and internal ohmic heating.

Nernst equation and open circuit potential, pressure and temperature effect - Stoichiometric coefficients and reactants utilization - Mass flow rate calculation - voltage and current in parallel and serial connection – Over potentials and polarizations - Activation polarization - Tafel equation and exchange current density –

Ionic conductivity, catalysts, Temperature and humidification effect, electro-osmotic Drag effect.

PEM Fuel Cell components: Anode and Cathode materials, catalysts, membrane, Fuels for fuel cells.

PEM Fuel cell stacks - Rate of mass transfer of reactants and products - water management – current collections and gas removal- Bipolar plates- flow distribution – Heat and water removal from the stack.

Fuel cell systems analyze: Energy systems, power- Train or Drive-Train Analysis – PEMFC powered Bus- Flow Sheet and conceptual Design-Detailed Engineering Designs

TEXT BOOKS:

1. *Fuel Cell Systems Explained, James Larminie and Andrew Dicks, 2nd Edition, John Wiley & Sons Inc., 2000.*
2. *PEM Fuel Cells Theory and Practice, Frano Barbir, Elsevier Academic Press,2005.*
3. *Fuel Cell Technology Handbook, Gregor Hoogers, SAE International, 2003.*

REFERENCES:

1. *Fuel Cell Principles and Applications, B Viswanathan and M Aulice Scibioh, Universities Press, 2006.*

CL 620 PINCH ANALYSIS & HEAT EXCHANGER NETWORK DESIGN

Pre-requisites: Basics of Heat Transfer, Mathematics, Process Design
Course Objectives: Understanding on Pinch concept, Application to Process Heat Exchange Networking, Identification of Energy Minimization in the Process, Retrofitting Concepts and Setting up Targets for Energy Minimization.
Course Outcome:
After the course, you are able to appreciate the pinch concept and process thermodynamics, able to identify minimum energy targets, identification of different choices and constraint during heat exchange networking, strategies for retrofitting existing process plant, integration of energy demands of multiple processes.
Course Content:
Thermodynamical review of the process, Pinch Concept, significance of pinch, pinch in grid representation, Threshold problems, capital cost implication of the pinch.

Targeting: Heat exchanger networks, energy targeting, area targeting, unit targeting, shell targeting, cost targeting, super targeting, continuous targeting.

Pinch Methodology: Problem representation, temperature enthalpy diagram, simple match matrix. Heat content diagram, Temperature interval diagram.

Pinch Design and Optimization: Networks for maximum energy recovery, Pinch design method, Flexibility criteria of the pinch, cp table, the tick of heuristic, case studies, optimization of heat exchanger network optimality for a minimum area network, Sensitivity analysis.
Energy and Resource Analysis of various processes, Batch process, flexible process, distillation process, evaporation process, reaction process, process using mass separating agent. Heat pipes and Heat pumps,

TEXT BOOKS:

1. *V. UdayShenoy" Heat Exchanger network synthesis" Gulf Publishing Co, USA, 1995*
2. *D.W. Linnhoff et al., "User Guide on Process Integration for the efficient use of Energy", Institution of   Chemical Engineers, U.K., 1994.*

REFERENCES:

1. *James M. Douglas "Conceptual Design of Chemical Process", McGraw Hill, New York, 1988.*
2. *Anil Kumar, "Chemical Process Synthesis and Engineering Design", Tata McGraw Hill New Delhi, 1977.*

CL 621 INDUSTRIAL ENERGY SYSTEMS

Prerequisites

Engineering thermodynamics, heat transfer, energy technology (including heat exchanger theory).

Aim

The aim of the course is to train students to use process integration methods and tools necessary for identifying and designing efficient industrial process energy system solutions that contribute to sustainable development. Besides understanding technical and economic issues, students will also achieve understanding of the impact of industrial process energy usage on the greenhouse effect, and the role that industrial energy systems can play with respect to meeting greenhouse gas emissions reduction targets. The course addresses use of methods to identify the cost-optimal mix of different process heating technologies to satisfy a given process steam demand. One important aspect is how future energy policy instruments will influence these optimal solutions. Technical systems encountered in the course include heat exchanger networks, boilers, heat pumps, combined heat and power systems, and thermal separation units.

Learning outcome

After completion of this course, the student should be able to

- describe the different technologies and heat distribution configurations that are commonly used for heating industrial processes, and explain the differences between these technologies and configurations
- calculate energy conversion performance characteristics for process utility boilers, heat pumps, and combined heat and power (CHP) units based on steam turbine or gas turbine cycles, for given energy conversion process parameters, and given industrial process heat load characteristics
- for a given value of minimum acceptable temperature difference for heat exchanging, determine the pinch temperature and the minimum heating and cooling requirements for a given industrial process, as well as a target value for the heat exchanger network surface area and investment cost (supertargeting)
- analyse the impact of choice of minimum temperature difference for heat exchanging on the above characteristics
- design a heat exchanger network for maximum heat recovery for a given process (both new processes, and retrofit of existing processes)
- identify opportunities for integration of high-efficiency energy conversion technologies (heat pumps and combined heat and power units) and energy-intensive thermal separation operations (distillation, evaporation) at an industrial process site
- evaluate the process integration measures listed above with respect to energy efficiency, greenhouse gas emissions and economic performance
- identify the cost-optimal mix of technologies for satisfying an industrial process heat demand, accounting for current and possible future energy

market conditions, including costs associated with emissions of greenhouse gases

Content

The course contains the following parts:

Introduction to industrial process energy systems: concepts, heat balances, heat distribution systems; local heating vs central heating systems; illustrating example from the pulping industry

Energy conversion technologies in industrial energy systems: overview of technologies and engineering thermodynamics for process utility boilers, heat pumps, steam turbine combined heat and power (CHP) and gas turbine CHP. Energy conversion performance of such systems for given energy conversion process parameters, and given industrial process heat load characteristics

Process integration: Basics of process integration methodologies with emphasis on pinch analysis (Pinch temperature, minimum process heating and cooling requirements, composite curves and grand composite curves, targeting for minimum number of heat exchanger units, and heat exchanger surface area costs). Design of heat exchanger networks for maximum heat recovery.Process integration principles for high-efficiency energy conversion technologies (heat pumps and combined heat and power units) and energy-intensive thermal separation operations (distillation, evaporation).Energy efficiency and economic performance evaluation of process integration measures.Process integration methodologies for retrofit applications in existing industrial energy systems.

Economics of energy conversion in industrial energy systems: characteristics of heat pumps and combined heat and power (CHP) units (performance, investment costs). Influence of operating conditions on performance. Optimization of size and various design parameters based on process integration principles. Methodology for identifying the cost-optimal mix of technologies for satisfying a process heat demand, accounting for heat load variation over the course of the year

Greenhouse gas emissions consequences of energy efficiency measures in industry.Greenhouse gas emissions from industrial energy systems. Optimisation of industrial energy systems considering future costs associated with greenhouse gas emissions.

Organisation

The course includes about 15 lectures, 2 guest lectures, 7 exercise projects, and one industrial laboratory session (Energy system analysis of a regional waste-to-energy plant)

Textbooks:

Heat and Power Technology, on sale at CREMONA (Chalmers student litterature bookstore).

CL 622 INDUSTRIAL WASTE MANAGEMENT

Aim

The purpose of this course is to train the students in different waste management techniques. A special emphasis will be on techniques for transformation of waste materials into products that can be beneficially utilized. The ultimate goal should, of course, be that no waste is formed in industry or society. But in the foreseeable future, activities in the industry and society will produce waste. An important step towards a sustainable society is a proper waste management with the goal of utilizing the waste material in best possible way.

Learning outcome (after completion of this course, the student should be able to)

Describe and discuss the following topics:
-Waste management overview and definitions
-Material recycling
--Metals
--Polymeric material
--Treatment of liquid waste streams - mechanical, biological and chemical methods; industrial and municipal cases; anaerobic digestion; production of bio-gas; dewatering and drying
--Solid waste - separation, incineration, composting and landfilling; treatment and use of ash-products
--Radioactive waste
--Emerging technologies

Water Pollutants, Effects, Monitoring and Quality standards: Pollution of water and soil, effect of pollutants on environment and health, monitoring water pollution, water pollution laws and minimum national standards, monitoring, compliance with standards, Latest norms for effluent treatment.

Water Pollution Sources, Analysis and Methods of control: Water pollution sources and classification of water pollutants - Wastewater sampling and analysis. Treatment of water-pollution: BOD, COD of wastewater and its reduction – Fundamentals of Anaerobic digestion and Aerobic digestion.

Wastewater Treatment Plant Design: Physical unit operations: Screening, Flow equalization, sedimentation etc., Chemical Unit Processes: chemical precipitation, dis-infection, colour removal by adsorption Biological unit processes: Aerobic suspended - growth treatment processes, aerobic attached-growth treatment processes, anaerobic suspended - growth treatment processes, anaerobic attached-growth treatment processes.

Advanced Wastewater and Water Treatment: Carbon adsorption - Ion exchange - Membrane processes - Nutrient (nitrogen and phosphorus) removal - Design of plant for treatment and disposal of sludge

Solids Waste and Landfill Management: Sources and classification - methods of solid waste disposal - Composting (natural) - Accelerated composting with industrial sludge - Landfill technology - Methods adopted for municipal solid waste - Toxic-waste management, Incineration of industrial waste, Design aspects, economics.

Hazardous Waste Management and Risk Assessment: Types of hazardous Wastes-Health effects - Nuclear fission and radioactive waste treatment and disposal methods. Risk assessment

TEXT BOOKS:

1. C.S. Rao, "Environmental Pollution Control Engineering", Wiley 2nd Edition, New Age International Publishers, 2006.

2. S.P. Mahajan, "Pollution Control in Process Industries", Tata McGraw Hill, New Delhi, 1985

REFERENCES:

1. P. Sincero and G.A. Sincero, Environmental Engineering: A Design Approach Prentice Hall of India pvt Ltd, N.Delhi.1996

2. Tchbanoglous and F.L. Burton, Metcalf and Eddy's Wastewater Treatment-Disposal And Reuse (Third Ed.), TMH publishing Co Ltd, N. Delhi. (1996)

CL 623 COMPUTATIONAL FLUID DYNAMICS

Aim

The course gives an introduction into advanced modeling using Computational Fluid Dynamics (CFD), which has become a indispensible tool for many engineers. The focus is on modeling the interaction between convection, diffusion, heat conduction and chemical reactions for single phase and multiphase flows. The focus is to teach how to do CFD analysis correctly but not how to write your own CFD code. The student is given hands-on experience of drawing, meshing and simulation. One important objective is to give the students a critical attitude to both identify the possibilities and the limitations in advanced simulation programs. After completing the course the student will be able to select appropriate models and perform advanced simulations in accordance with best practice guidelines.

Learning outcome (after completion of this course, the student should be able to)

Hands-on experience with a commercial CFD program
Formulate problems that can be solved with a CFD program
Critically evaluate simulation results
Communicate the results in oral and written form

Conservation Laws of Fluid Motion and Boundary Conditions: Governing equations of fluid flow and heat transfer, Equations of state, Navier-Stokes equations for a Newtonian fluid, Classification of physical behaviour, Classification of fluid flow equations, Auxiliary conditions for viscous fluid flow equations

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

The Finite Volume Method for Diffusion Problems: Introduction, one-dimensional steady state diffusion, two-dimensional diffusion problems, three-dimensional diffusion problems, discretised equations for diffusion problems

The Finite Volume Method for Convection-Diffusion Problems: Steady one-dimensional convection and diffusion, The central differencing scheme, Properties of discretisation schemes-Conservativeness, Boundedness, Transportiveness, Assessment of the central differencing scheme for convection-diffusion problems, The upwind differencing scheme, The hybrid differencing scheme, The power-law scheme, Higher order differencing schemes for convection-diffusion, Quadratic upwind differencing scheme

The Finite Volume Method for Unsteady Flows and Implementation of Boundary Conditions: One-dimensional unsteady heat conduction, Discretisation of transient convection-diffusion equation, Solution procedures for unsteady flow calculations, Implementation of Inlet, outlet and wall boundary conditions, constant pressure boundary condition.

TEXT BOOKS:

1. *H. K. Versteeg and W. Malalasekera, An introduction to computational fluid dynamics: the finite volume method , Longman scientific & technical publishers, 2007*
2. *John D. Anderson, Computational fluid dynamics: The Basics with Applications McGraw-Hill, .New York, 1995.*

REFERENCE BOOKS:

1. *Vivek V. Ranade, Computational flow modeling for chemical reactor engineering Academic Press, San Diego, 2002*

CL 624 PROCESS OPTIMIZATION

Objective:

To understand the concepts and origin of the different optimization methods.

To get a broad picture of the various applications of optimization methods used in Chemical Engineering.

Optimizes the different methods in industry for design and production of products, both economically and efficiently.

Learning Outcome:

After completion of this course, the student should be able to

Apply the knowledge of optimization and optimum design and an overview of optimization methods.

Optimization has been applied in many fields of science, including engineering, economics and logistics, where optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives.

Implement the theory and applications of optimization techniques in a comprehensive manner for solving linear and non-linear, geometric, dynamic, integer and stochastic programming techniques.

Identify, formulate and solve a practical engineering problem of their interest by applying or modifying an optimization technique.

Content:

General: Functions of single and multiple variables - optimality criteria, direct and indirect search methods. Linearization: Constraint optimality criteria, transformation methods based on linearization. Transportation problems.

Quadratic and Geometric Programming: Quadratic and geometric programming problems, calculus of variations.

Optimality Criteria & Optimal Control Problems: Euler-Lagrange optimality criteria, Pontryagin's maximum principle, optimal control problems. Numerical methods.

Artificial Intelligence in Optimization: Introduction to Artificial Intelligence in optimization.

TEXT BOOK:

1. *T.F. Edgar and D.M. Himmelblau," Optimization Techniques for Chemical Engineers", McGraw-Hill, New York, 1985.*
2. *S.S.Rao, "Engineering Optimization Theory and Practice", Third edition, New Age International Publishers, India.*

REFERENCE:

1. *K. Deo, "Optimization Techniques", Wiley Eastern, 1995.*
2. *R.Panneerselvam, "Operation Research", Second edition, PHI Learning private Ltd, New Delhi, India.*
3. *Prem Kumar Gupta and D.S.Hira, "Problems in Operations Research (Principles and Solutions)", S.Chand and company Ltd. New Delhi, India.*

CL 625 DESIGN AND ANALYSIS OF EXPERIMENTS

Prerequisites
Fundamental statistics
Objectives: The aim of the course to give competences in the field of applied statistical methods for work concerning planning and analysis of experiments, regression analysis, optimization of processes and multivariate analysis.
Outcome:

- Plan experiments according to a proper and correct design plan.
- Analyse and evaluate experimental results (statistically), according to chosen experimental design (ANOVA, regression models).
- Control and properly use fundamentals such as hypothesis testing, degrees of freedom, ANOVA, fractional design and other design methods/techniques and so on.
- Know the fundamentals of multivariate analysis and chemometric methods (PCA and PLS) with simple applications.

Content

- Statistics
- Simple Comparative Experiments
- Experiments of a single factor, analysis of variance.
- Randomized blocks
- Latin squares
- The 2k factor design
- Blocking and confounding
- Two level fractional Factorial design.
- Three level and mixed level factorial and fractional factorial design.
- Fitting regression methods. LS method.
- Robust parameter design
- Experiment with random factors.
- Nested design
- Response surfaces, EVOP.
- Multivariate data analysis

Organisation
The course contains lectures mixed with calculation examples showing practical applications of basic theories. The assignments and calculation are based on realistic industrial examples taken from literature and research projects. The projects are problem based with active learning activities. This part has been a very successful part in terms of life-long learning for the students and highly appreciated among students for many years.

Textbook:
Douglas C. Montgomery: Design and Analysis of Experiments, Wiley, 6th Edition

CL 626 ADVANCED FOOD PROCESS ENGINEERING

Objectives: To understand various methods of food processing.

Outcome: After completion of the course, the students should be able to understand unit operations in food processing, separation and mixing and food biotechnology.

Food Process Engineering - Fundamentals: Raw material and the process-Geometric, Functional and Growth properties of the raw material, Mechanization and the raw material, cleaning - contaminants in food raw materials, function of cleaning and cleaning methods, sorting and Grading of Foods.

Unit Operations in Food Processing: Fluid flow, thermal process calculations, refrigeration, evaporation and dehydration operations to food processing. Heat processing of foods - modes of heat transfer involved in heat processing of foods.

Food Canning Technology: Fundamentals of food canning technology, Heat sterilization of canned food, containers - metal, glass and flexible packaging, Canning procedures for fruits, vegetables, meats, poultry and marine produces.

Separation And Mixing Process In Food Industries: Conversion operations. Size reduction and screening of solids mixing and emulsification, filtration and membrane separation, centrifugation, crystallization, extraction.

Food Biotechnology: Food Biotechnology. Dairy and cereal products. Beverages and food ingredients. High fructose corn syrup. Single cell protein.

TEXT BOOK:

1. *R.T. Toledo, "Fundamentals of Food Process Engineering", AVI Publishing Co., New York, 1980.*

REFERENCES:

1. *J.M. Jackson & B.M. Shinn, "Fundamentals of Food Canning Technology", AVI Publishing Co., New York, 1978.*
2. *J.G. Bernnan, J. R .Butters, N.D. Cowell & A. E. V. Lilley, "Food Engineering Operations", 2nd Edn., Applied Science, New York, 1976.*

CL 627 BIOREFINERY ENGINEERING

Prerequisites: Basic course in organic chemistry, Unit operations in Chemical engineering

Aim

Within the next 50 years we will se a gradual transition from an oilbased society to a bio-based society. In this transition there will be a necessity to find new process routes to produce some of the materials used today as well as new materials that can replace some of the materials normally used today. The aim of this course is to give basic knowledge needed to understand how biomaterial can be used and how different biorefinery concepts can be developed based on both environmental and economical criteria.

Learning outcome (after completion of this course, the student should be able to)

After this course the students should have knowledge in: The chemical composition of the most common sources of biomaterial; methods of extracting components; the most important chemical reactions; the most common processes for extracting components and post treatment of extracted materials.

Content

The course will shed light upon some general questions such as what type of biomaterial that are available, how these can be used as well as important reactions and how biomaterial can be processed. The course can be divided in the following parts:

Part I An overview: what biomaterial and biorefinery are; common types of biomaterial and where those can be found; finally, some common process routes will also be discussed

Part II This part will be dedicated to some basic items: the chemical composition and the structure of biomaterial will be discussed. Also some important reactions with different constitutes in biomaterial is treated. A special emphasis will be on the most abundant biomaterial, the wood material.

Part III Process concepts: In this part different process concepts will be learned. Both hot methods (e.g. gasification) and wet methods (eg. pulping and ethanol production) will be treated.

Part IV Post treatment of components from biomaterial: In this part, examples of post treatment routes to products are discussed.

Textbooks:

CL 628 AIR POLLUTION CONTROL EQUIPMENT DESIGN

Objectives: To understand various methods of design of air pollution control equipment

Outcome: The students should be able to design equipment based on the application of air pollution treatment.

Air Pollutant Sources, Effects and Clean Air Acts: Pollution of air: Sources and effects of air pollutants on physical environment and living systems, Monitoring air pollution, Air pollution Laws and Minimum national standards.

Air Pollutant Formation, Dipersion, Analysis: Formation of pollutants through large-scale combustion of fossil fuels, mineral processing, automobiles in urban areas and at source minimisation of release - Meteorological aspects of air pollutant dispersion. Chemical reactions in a contaminated atmosphere, urban air pollution, acid rain Air sampling and measurement, Analysis of air pollutants

Air Pollution Control Methods for Particulates Removal: Control Methods - Source Correction methods - Particulate emission control: Dry techniques industrial dust collectors, cyclone and multiclone separators, bag filters, electrostatic precipitators, relative merits and demerits, choice of equipments, design aspects economics. Wet techniques wet dust collection, wet cyclone, empty scrubber, column (packed) scrubber, ventury scrubber, suitability, merits and demerits, design aspects and economics.

Control of Specific Gaseous Pollutants: Cleaning of Gaseous effluents - Control of sulphur dioxide emission by various methods - Control of nitrogen oxides in combustion products - Control of release of carbon monoxide and hydrocarbons to the atmosphere.

Noise Pollution and Control: Sound pressure, Power and Intensity - Measures of Noise- Outdoor noise propagation- Indoor Noise propagation- Noise Control

TEXT BOOKS:

1. *Y.B.G. Verma, H. Brauer," Air Pollution Control Equipments", Springer, Verlag Berlin, 1981.*
2. *M.N. Rao and H.V.N. Rao, "Air Pollution", Tata McGraw Hill, New Delhi, 1993.*

REFERENCES:

1. *Rao C.S. "Environmental Pollution Control Engineering," 2nd Edition, New Age International Publishers, 2006.*
2. *A. P. Sincero and G.A. Sincero Environmental Engineering: A Design Approach, Prentice Hall of India pvt Ltd, N.Delhi.1996*

CL 629 GLOBAL CHEMICAL SUSTAINABILITY

Prerequisites

Basic university-level knowledge in environmental engineering or environmental science

Objectives: This course provides the students with an understanding of the effects on sustainability of the actions of an engineer and means to identify appropriate changes.

Outcome: -Give an overview of the function and state of the natural systems in the world, with more detailed explanations for issues relating to chemistry and chemicals

-Explain how the human society, in particular chemical and chemical engineering industry, affects and depends on natural systems

-Describe international and regional work on environment and sustainable development on governmental and non-governmental level

-Identify appropriate tools and strategies for sustainable development in society, in particular industry

-Analyze sectors of society, in particular chemical and chemical engineering industry, and formulate appropriate strategies for sustainable development

-Describe the importance of including different stakeholders and perspectives in discussions on sustainable technology development

The course also includes experiences of using skills from earlier courses, e.g.

- -Oral and written presentation
- -Working in team
- -Project work
- -Critical review

Content:

The course deals with incentives for sustainable development in chemical and chemical engineering industry and with tools and strategies to achieve it. The course describes how natural systems function and the connections to the social and economic dimensions. It also describes how efforts are made to solve sustainability problems on regional and global arenas, and the major sustainability challenges in industry and tools and methods to facilitate a move in the desired direction. The course is broad but has a particular focus on process industry related issues, on chemistry and chemicals, on international and global concerns and efforts, and on the environmental dimension of sustainable development.

Organisation

The course offers learning opportunities through a variety of different activities. In exercises and lectures, students are encouraged to share their own experiences with the rest of the class and with the teachers. The multi-cultural environment in the class with students from all over the world and from different engineering specializations is regarded as an asset and will be utilized as much as possible in the course.

References:

1. G. Tyler Miller, Jr, Scott E. Spoolman(2008). Living in the Environment , International Student Edition, Sixteenth edition, Brooks/Cole
2. Handouts from lectures and exercises or dedicated texts.
3. Student project reports.

CL 630 Energy Systems Modelling and Planning

Prerequisites
Engineering thermodynamics, energy conversion, energy technology, numerical methods.
Aim
The aim of the course is to give the student insight into the complexity of energy systems and to provide the student with practical tools to solve energy system analytical problems. The course is based on real problems combining technical, environmental and economical parameters. It is focussed on local, regional and national energy systems. The application of reference energy systems, load curves and environmental policy instruments is central in the course.
Learning outcome (after completion of this course, the student should be able to)

- analyse energy systems using simulation and optimisation modelling tools;
- construct and use load duration curves based on chronological load data;
- select and define appropriate reference energy systems;
- apply system analytical tools;
- understand the interaction between energy conversion technology, environmental impact and economic performance;
- understand the interaction between different parts of the energy system;
- understand how energy policy instruments affect energy system investment decisions;
- apply systems thinking to energy problems;
- understand marginal effects;
- define and calculate the overall efficiency of a given energy system.

Content
The course includes basic energy systems elements such as, - energy economics - system analysis tools, energy systems modelling and optimisation tools such as, - linear programming - simulation models policy instruments - market based - traditional, local and regional energy systems - district heating systems, - energy and the environment, - system aspects for bioenergy technologies, - the Nordic energy system.
Organisation
The course includes lectures as well as hand in assignments. Presence at the introduction to the assignments and at the discussion/presentation of each assignment are compulsory.
Textbooks:
Articles and e-book chapters available at the course home page and at the Chalmers library.