SYLLABUS
OF
M.TECH. CHEMICAL ENGINEERING
(Effective from 2005-2006 & onwards)

Approved by
Board of Studies
on
December 23 & 24, 2004
Faculty of Engineering & Technology
On
27-11-2006

(Incorporating New Numbering System)

BANARAS HINDU UNIVERSITY
DEPARTMENT OF CHEMICAL ENGINEERING & TECHNOLOGY
INSTITUTE OF TECHNOLOGY
Varanasi 221005
M. TECH. IN CHEMICAL ENGINEERING

Course Structure

**SEMESTER – I**

<table>
<thead>
<tr>
<th>Course number</th>
<th>Subject</th>
<th>Contact hrs/week</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CH5101</td>
<td>Transport Phenomena</td>
<td>3</td>
<td>3</td>
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<tr>
<td>CH5102</td>
<td>Process Dynamics and Control</td>
<td>3</td>
<td>3</td>
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<tr>
<td>CH5103</td>
<td>Chemical Reactor Analysis</td>
<td>3</td>
<td>3</td>
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<tr>
<td>CH*</td>
<td>Elective – I (Departmental Course)</td>
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<td>CH*</td>
<td>Elective – II (Departmental Course)</td>
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<td>CH5301</td>
<td>Chemical Engineering Laboratory</td>
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**SEMESTER – II**

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<tr>
<td>CH</td>
<td>Open Elective (From Other Departments)</td>
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<tr>
<td>CH**</td>
<td>Elective III (Departmental Course)</td>
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<td>CH**</td>
<td>Elective IV (Departmental Course)</td>
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<tr>
<td>CH**</td>
<td>Elective V (Departmental Course)</td>
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<tr>
<td>CH**</td>
<td>Elective VI (Departmental Course)</td>
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<td>CH5401</td>
<td>Project</td>
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<tr>
<td>CH5402</td>
<td>Seminar</td>
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**SEMESTER – III**

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<tbody>
<tr>
<td>CH6301</td>
<td>Seminar on Dissertation</td>
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<tr>
<td>CH6302</td>
<td>Dissertation - Interim Evaluation</td>
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**SEMESTER – IV**

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<tbody>
<tr>
<td>CH6401</td>
<td>Dissertation - Open Defence</td>
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<tr>
<td>CH6402</td>
<td>Dissertation - Evaluation</td>
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|               | **COURSE TOTAL**                  | **38**           | **60**  |
List of Electives

- Elective – I and II (Departmental course)

Any two from the following:

CH5104: Process Optimization
CH5105: Biotransport Processes
CH5106: Artificial Intelligence in Chemical Engineering
CH5107: Membrane Separation Processes
CH5108: Interfacial and Colloidal Phenomena
CH5109: Multi Component Separation

- Open Elective

List of courses will be announced in the beginning of semester.

- Elective – III, IV, V and VI (Departmental course)

Any four from the following:

CH5201: Chemical Process Design
CH5202: Process Plant Simulation
CH5203: Transport Phenomena in Polymer Processing
CH5204: Advanced in Fluidization Engineering
CH5205: Statistical and Non-Equilibrium Thermodynamics
CH5206: Air Pollution Control Technology
CH5207: Water Pollution Control Technology
CH5208: Advanced Fertilizer Processing
CH5209: Design and Development of Heterogeneous Catalysts
CH5210: Renewable Energy Technology
CH5211: Reliability and Risk Analysis in Process Industries
CH5212: Non-Newtonian Flow and Heat Transfer
CH5213: Fuel Cell Technology

Note: The topic of dissertation for each student shall be allotted in the second semester.
Courses of Study

CH5101: Transport Phenomena  (Credits: 3)

Development of momentum mass and energy balance equations; Equations of change for isothermal systems; Velocity distributions in flow systems; Interphase transport; Microscopic and macroscopic balance.

Theories of turbulence- phenomenological and statistical; Turbulent transfer processes in single and multiphase systems; Temperature distribution in turbulent flow; Concentration fluctuation and time smoothed concentration; Turbulent mixing with first and second order reactions.

Boundary layer theory; Steady state transport in boundary layers; Taylor dispersion in laminar tube flow.

Interphase transport in non-isothermal systems.

Equation of change for entropy; Application of generalized Maxwell – Stephan’s equations; Mass transport across selectively permeable membrane and porous media.

CH5102: Process Dynamics and Control  (Credits: 3)

Dynamic modeling of complex processes by applying fundamental laws; Empirical modeling – graphical methods for first order plus dead time and second order (over and under ) damped processes; Computer based process parameter estimation techniques.

Introduction to non-linear, open-loop unstable, dead-time, integrating and non-minimum phase processes, and their control.

Advanced control strategies: Controller design for cascade control, feed-forward control, Smith predictor scheme, and inferential control.

Adaptive control: MRAC and STR; Control configuration; Analysis and applications.

Model based control: Internal model control; Dynamic matrix control; Model predictive control.

Multivariable control: State-space representation; Transfer function matrix; RGA and its application; Stability and interaction analysis; Design of decouplers.

Digital control: Hardware and software requirements; Introduction to DDC, DCS, supervisory (optimizing), and hierarchical control; z-and modified z-transformation and their inverse; Sampling, aliasing, and ringing; Controller design and implementation.

An introduction to plant-wise control and on-line (real-time) optimization of plant.

Case studies.

CH5103: Chemical Reactor Analysis  (Credits: 3)

 Behaviour of chemical reactors: Residence time distribution; Segregated and non-segregated flow models; Order and segregation; Effect of non-segregated mixing upon yield and selectivity; Non-isothermal reactor performance; Uniqueness of the steady state.

Conservation equations for reactors: Transport coefficients; Determination of dispersion coefficients; Homogeneous reactor design; Semibatch reactor; Transient behaviour.

Gas – liquid and liquid - liquid reaction system: Gas-liquid reaction models; Regime identification; Multi-phase reactor models; Multiplicity of steady states; Selectivity and yield.
Fluid – solid noncatalytic reaction system: Models; Kinetics; Non-isothermal reactions; Reactor design; Liquid-solid reactions – Ion exchange.

Analysis and design of heterogeneous catalytic reactors: Fixed bed reactor; Peclet number for heat and mass transfer; Adiabatic fixed bed reactor; Non-isothermal non-adiabatic fixed bed reactor; Fluidized bed reactor; Slurry reactor, Trickle bed reactor; Reactor suffering catalyst deactivation; Decay affected selectivity.

Reactor stability and optimization.

Scale up of reactors.

**CH5104: Process Optimization  (Credits: 3)**

Introduction to optimisation; Formulation of objective function; Basic concepts-functions, regions, necessary and sufficient conditions for an extremum of an unconstrained function.

One dimensional Search: Scanning and bracketing; Newton, quasi-Newton and secant methods; Region elimination method; Polynomial approximation methods.

Unconstrained multivariable optimization: Direct methods-random search, grid search, univariate search, simplex method, conjugate search direction and Powell’s method; Indirect method-gradient and conjugate gradient methods, Newton’s method, movement in search direction, secant method.

Linear programming: Basic concepts in linear programming; Graphical solution; Simplex method; Standard LP form; Obtaining first feasible solution; Sensitivity analysis.

Non linear programming: Lagrange multiplier method; Quadratic programming; Penalty function and augmented Lagrangian methods; Successive quadratic programming; Optimization of dynamic processes.

Optimization of staged and discrete processes: Dynamic programming; Integer and mixed integer programming.

Non traditional optimisation techniques: Simulated annealing; Genetic algorithms; Differential evolution.

Application of optimisation in the design of separation process, chemical reactor and large scale process plant.

**CH5105: Biotransport Processes  (Credits: 3)**

Principles of transport phenomena involved in the analysis of selected physiological processes and the design of artificial internal organs and extracorporeal devices.

Reviews of pertinent physiological principles; Rheology of blood; Convective and diffusive mass transport in blood and tissues; Mass transport characteristics of biological and synthetic membrane processes; Artificial organs including artificial kidney, pancreas, liver, and cardiopulmonary assist devices.

**CH5106: Artificial Intelligence in Chemical Engineering  (Credits: 3)**

Artificial intelligence: History and implications; Definition and scope; Role in chemical engineering. Knowledge: Knowledge representation; Heuristic knowledge; Rule-based knowledge; Decision trees; Object oriented programming.
Artificial neural networks: Types; Training methods; Uses; Data fitting; Pattern recognition; Classification; Process optimization.
Data mining: Windowing techniques; Wavelet transforms- noise, filtering, pattern recognition.
Uncertainty: Fuzzy logic- definition; possibility theory; fuzzy numbers and fuzzy arithmetic; Membership functions; Fuzzy control
Evolutionary methods of optimization: Genetic algorithm; Simulated annealing.
Expert Systems: Knowledge based systems; Fuzzy expert systems; Building an expert systems.
Applications of AI in Chemical Processes: Abnormal situation management; Process control; Correlating thermodynamic property.
Fault diagnosis.

CH5107: Membrane Separation Processes  (Credits: 3)
Principles, characteristic, and classification of membrane separation processes; Membrane materials, structures, and preparation techniques; Membrane modules; Plant configurations.
Membrane characterization: Pore size and pore distribution; Bubble point test; Challenge test; Factors affecting retentivity, concentration polarization, gel polarization, fouling, cleaning and regeneration of membranes.
Mechanisms of separation: Porous membranes, dense membranes, and liquid membranes.
Membrane separation models: Irreversible thermodynamics; Capillary flow theory; Solution diffusion model; Viscous flow models; Models for separation of gas (vapour) mixtures;
Science and technology of microfiltration, reverse osmosis, ultrafiltration, nanofiltration, dialysis and electrodialysis, pervaporation, liquid membrane permeation, gas permeation.
Membrane reactors: Polymeric, ceramic, metal and bio-membrane.

CH5108: Interfacial and Colloidal Phenomena(Credits: 3)
Thermodynamics of interfaces: Gibbs dividing surface; Interfacial tension; Gibbs adsorption isotherm; Young-Laplace equation; Wetting and contact angle; Thin fluid films; Combination of van der Waals forces, double layer potential etc. to disjoin pressure.
Fluid statics and dynamics of interfaces and thin films; Equilibrium shapes of menisci; Drop formation; Stability of thin films; Wetting of solids; Coating flows and fluid displacement in pores.
Application of colloidal systems; Foams, emulsions, oil recovery and other special topics.

CH5109: Multicomponent Separation  (Credits: 3)
Fundamentals, characteristic and classification of separation processes; Selection of feasible separation process; Thermodynamics of separations; Factors affecting product purity.
Approximate process for multicomponent, multistage operations: Fenske-Underwood-Gilliland method; Kremscr group method.
Equilibrium based methods for multicomponent absorption, stripping, distillation and extraction: Theoretical model for an equilibrium stage; General strategy of mathematical solution; Equilibrium tearing procedure; Tridiagonal matrix algorithm; Inside-out method.
Enhanced distillation; Homogeneous and heterogeneous azeotropic distillation; Reactive distillation.
Rate based models for distillation: Thermodynamics properties and transport expressions; Methods for estimating transport coefficient and interfacial area; Vapour and liquid flow pattern.
Methods of calculations: Chem Sep program; RATEFRAC program.
Batch distillation, batch stripping and complex batch distillation.
Pressure swing adsorption; Supercritical fluid extraction

**CH5301: Chemical Engineering Laboratory**  (Credits: 2)

Selected laboratory experiments in unit operations, unit processes, chemical reaction engineering, thermodynamics, instrumental methods of analysis and supervised individual assignments

**CH5201: Chemical Process Design**  (Credits: 3)

Process design and development; General design consideration; Hierarchy of chemical process design; Nature of process synthesis and analysis; Developing a conceptual design and flow sheet synthesis.
Synthesis of reaction-separation systems; Distillation sequencing; Energy targets. Heat integration of reactors, distillation columns, evaporators and driers; Process change for improved heat integration.
Heat and mass exchange networks and network design.

**CH5202: Process Plant Simulation**  (Credits: 3)

Computer aided analysis of chemical process systems; Classification and development of mathematical models to various chemical engineering systems; decomposition of networks; Tearing algorithms; Numerical methods of convergence promotion and solving chemical engineering problems; Specific purpose simulation; Dynamic process plant simulation; Case study problems using professional software packages.

**CH5203: Transport Phenomena in Polymer Processing**  (Credits: 3)

Rheology of polymer melts and polymer solutions and their characterisation; Flow of polymer melts and polymer solutions in simple geometry; Linear viscoelastic models; Co-rotational derivatives and non-linear viscoelastic models; Experimental techniques of determining the viscoelastic properties.
Mixing: Residence time distribution; Temperature distribution; Heat and mass transfer in polymer systems; Boundary layer flow with and without heat transfer; Heat and mass transfer with and without phase change; Stability of flows.

**CH5204: Advanced in Fluidization Engineering** (Credits: 3)

Hydrodynamics of fluidised beds-static and flowing.
Heat and mass transfer modelling of non reacting and reacting systems in fluidised beds.
Catalytic and non catalytic reaction models: Ideal models; Residence time distribution and contact time distribution models; Two phase models; Hydrodynamic flow models such as bubbling bed model, countercurrent back mixing model, bubble assemblage model.
Fluid catalytic cracking, combustion and gasification, and miscellaneous processes in fluidised beds.
CH5205: Statistical and Non-Equilibrium Thermodynamics  (Credits: 3)

Ensemble; Most probable distribution; Canonical, grand canonical and microcanonical ensemble partition functions; Derivation of thermodynamic variables from partition functions; Statistical explanation of second and third laws of thermodynamics; Quantum statistics; Applications of Maxwell Boltzmann, Fermi-Dirac, and Bose-Einstein Statistics; Thermodynamic properties of perfect gas; Einstein and Debye theory of crystalline solids; Langmuir and BET isotherms of adsorption of gas on lattice structure.

Non–equilibrium thermodynamics: Maxwell distribution; Mean free path and collision frequency; Introductory transport theory; Boltzmann transport equation; Two particle collisions; Boltzmann H-theorem; Conservation laws; Zero order approximation and its application; First order approximation and applications; Introduction to Chapman-Enskog approximation of distribution function.

Irreversible thermodynamics: Conjugate fluxes and driving forces; Onsager reciprocal relation; Simultaneous heat and mass transfer problems; Multicomponent mass transfer problems; Heat transfer in anisotropic media; Formulation of the problem for a single reaction; Affinity of a reaction; Application in more than one reactions.

CH5206: Air Pollution Control Technology  (Credits: 3)

Brief review of industrial, municipal, and natural pollution sources. Physicochemical processes governing the dynamics of pollutants from point, non-point, line, and area sources; Generation, transport and decay of air pollutants; Sampling and monitoring methods. Strategies and methods for removal of gaseous pollutants and particulates from process exhaust streams; Air pollution abatement technology; Detail design of particulates and gaseous emission control equipment; Air pollution indices; Air pollution survey; Costs of air pollution control.

Air pollution legislation and regulations. Case studies of a few industrial pollution control systems.

CH5207: Water Pollution Control Technology  (Credits: 3)

Wastewater characteristics; Wastewater treatment objectives, methods, and implementation considerations. Principles of physical, chemical, and biological processes, that form the basis for wastewater and liquid hazardous waste treatment, such as chemical, biological, and thermal oxidation, carbon adsorption, ion-exchange, membrane processes, air and steam stripping, and chemical precipitation. Design of facilities for physical and chemical treatment; Design of facilities for treatment and disposal of sludge; Effluent disposal. Water pollution legislation and regulation. Schemes for treatment of some typical industrial wastes – pulp and paper, sugar, distillery, dairy, fertilizer, refinery etc.

CH5208: Advanced Fertiliser Processing  (Credits: 3)

Introduction The development of fertiliser industries.
Ammonia: Latest developments in production technology; Design aspects of primary reformer; Purge gas recovery unit based on cryogenic as well as membrane technology; Modifications for improving plant efficiency, capacity and reliability; Role of catalysts.

Urea: Description of various processes for urea production; Economic evaluation and energy requirement; advances in reactor, prilling and granulation technologies.

Technologies of production of nitric acid, ammonium nitrate, calcium ammonium nitrate, phosphoric acid, selected phosphatic fertilisers, multi-nutrient fertilisers.

Environmental issues: Pollution of air, water and soil; waste disposal; Emission monitoring; Decommissioning of old plants

**CH5209: Design and Development of Heterogeneous Catalysts  (Credits: 3)**

Structure of solid surfaces; Chemisorption and physiosorption; Thermodynamics and kinetics of surface processes; Principles of heterogeneous catalysis; Preparation, characterization and classification; Structure and activity; Lattice imperfection; Geometric and electronic factors

Prepartion and characterization of catalysts.

Kinetics of heterogeneous reactions.

Physical, chemical and mathematical description of catalyst deactivation; Deactivation by fouling, poisoning and sintering.

Deactivation and regeneration of catalyst pellets.

Deactivation and regeneration of fixed beds.

Dynamics of polyfunctional catalysts.

Electrocatalysis and photocatalysis.

Mechanism and kinetics of some typical heterogeneous catalytic reactions.

Applications in fertilizer, petroleum, petrochemical industries and pollution control.

**CH5210: Renewable Energy Technology  (Credits: 3)**

Principles of renewable energy: Fundamentals; Scientific principles, technical implications, and social implications.


Solar heating devices: Solar water heaters; Sheltered and unsheltered heaters; Systems with separate storage; Selective surfaces; Solar ponds, Solar concentrators and other devices.

Principles of photovoltaic generation of electricity; Silicon cell; Photon absorption; Cell efficiency; Solar cell construction; Types and usage of photovoltaic systems.

Bio-fuels: Bio-fuel classification; Combustion, pyrolysis, gasification and other thermo-chemical processes; Production of alcohol and biogas.

Bio-diesel: Fundamentals; Transesterification of vegetable oils for biodiesel production; Characterization of biodiesel; Economics, current trends and future prospects in usage of biodiesel.

Hydrogen energy: Hydrogen energy system and analysis; Hydrogen infrastructure; Safety, codes and standards

Hydrogen production: Electrolysis; Thermochemical; Hydrogen from fossil fuel, biomass and renewable sources of energy.

Hydrogen storage: Carbon storage materials; Metal hydrides and chemical hydrides; Cryogenic hydrogen storage.

Hydrogen fuel cells.
CH5211: Reliability and Risk Analysis in Process Industry  (Credits: 3)

Basic statistical principles: Introduction to probability theory and statistical distribution; Introduction to Bayesian analysis.
System reliability: Reliability concepts; Failure rate; Hazard rate; Fault tree and even tree analysis; Block diagrams and network models; Introduction to Markov models and its application to system reliability calculations.
Maintainability: Renewal theory; Modelling of maintenance policies; Planned, conditioned based and reliability centred maintenance.
Availability: Concept, models and simulation tools.
Reliability prediction: Structural reliability theory; Modelling and component reliability estimation; Criticality analysis.
Reliability in design: Design materials; Environment and usage factors; Failure processes; Damage growth and determination mechanisms; Accelerated testing; Bayesian estimation; Reliability growth; Inspection and condition monitoring in failure rate and risk reduction.
Risk analysis and safety engineering: Review of industrial accidents; Human factors and accident causation; Human reliability analysis and role in industrial man-machine systems; CIMAH regulations and preparation of safety cases; Outline of formal safety assessment methods; Introduction to HAZOPS in hazard analysis.
Fire and explosions risk analysis: Fire/ explosion protection systems; Plant layout; Fire and blast walls; Temporary refuges; Emergency management.

CH5212: Non-Newtonian Flow and Heat Transfer  (Credits: 3)

Constitutive equations of various Non-Newtonian fluids; Problems related to development of constitutive equations; Evaluation of relevant physical properties.
Laminar and turbulent flows in conduits; Packed and fluidised beds, Flow around submerged objects. Viscoelastic effects; Mixing and agitation.
Temperature distribution and heat transfer in laminar and turbulent flows.
Boundary layer flows with and without heat transfer.

CH5213: Fuel Cell Technology  (Credits: 3)

Fundamentals and classification of fuel cells; Thermodynamic efficiency.
Electromotive force of fuel cells: Standard electrode potentials; Effect of concentration; Nernst equation.
Rate of electrode processes: Types of polarization; Surface reactions; Oxygen electrodes; Hydrogen electrodes; Overall performance.
Low temperature fuel cells: Hydrogen–oxygen fuel cells– alkaline and polymeric membrane types; Active catalyst and its dispersion; Heat and mass transfer; Construction and design; Limiting problems; Low temperature fuel cells of other types – methanol fuel cell, hydrocarbon fuel cell.
High temperature fuel cells: Advantages; Molten electrolyte fuel cell; Solid electrolyte fuel cell; Construction.
Air depolarised cells; Biochemical fuel cells; Regenerative cells; Micro fuel cells.
Fuel cell operation: Supply of fuel; Electrical arrangement; Removal of products; Materials for battery construction; Production and purification of fuels.
Application of fuel cell systems: Large scale power generation; Power plant for vehicles; Domestic power; Fuel cells in space.
Fuel cell economics; Future trends in fuel cells.

**CH5401: Project**  (Credits: 2)

The project is aimed at training the students in literature search and critical appraisal of the same. The project may also involve some analytical and/ or experimental work. In a few cases the project may also involve a sophisticated design work. Each student will submit a report on his/ her project. The project report is expected to show clarity of thought and expression, critical appraisal of the existing literature and analytical and/ or experimental or design skill.

**CH5402: Seminar**  (Credits: 1)

Each student will make formal presentations with respect to his/ her independent study or research.

**CH6301: Seminar on Dissertation**  (Credits: 5)

Each student will deliver a seminar on the objective, literature review, methodology and work carried out during the semester on his/ her dissertation topic.

**CH6302: Dissertation – Interim Evaluation**  (Credits: 5)

Each student shall submit three copies of the report containing the work carried out on his/ her dissertation topic during the semester for evaluation by the examiners.

**CH6401: Dissertation – Open Defence**  (Credits: 5)

On completion of dissertation work, each student will deliver a seminar to defend his/ her work.

**CH6402: Dissertation – Evaluation**  (Credits: 10)

Each student will submit three copies of the dissertation for evaluation and award. It must incorporate results of investigation on an assigned problem in chemical engineering or allied discipline involving experimental and/ or theoretical work.