## The Undergraduate Curriculum

The annual system of study is followed in the department._The following is the curriculum of the department for the four years of study.

| FIRST YEAR | | | 1st Semester Hours/Week | | | 2nd Semester Hours/Week | | |
|---|---|---|---|---|---|---|---|---|
| **Code** | **Subject** | **Units** | **Theo.** | **Tuto.** | **Lab.** | **Theo.** | **Tuto.** | **Lab** |
| GE 121 | Mathematics | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 122 | Organic Chemistry | 8 | 3 | - | 3 | 3 | - | 3 |
| Chem.E. 123 | Analytical and Inorganic Chemistry | 8 | 3 | - | 3 | 3 | - | 3 |
| Chem.E. 131 | Engineering Drawing | 2 | - | - | 3 | - | - | 3 |
| Chem.E. 141 | Chemical Engineering Principles-I | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 124 | Computer Programming | 6 | 2 | - | 2 | 2 | - | 2 |
| GE 111 | English Language | 4 | 2 | - | - | 2 | - | - |
| GS 112 | Human Rights | 2 | 1 | 1 | - | 1 | 1 | - |
| GE 103 | Work shop | 1 | - | - | 3 | - | - | - |
| **Total** | | **42** | **15** | **3** | **14** | **15** | **3** | **11** |
| **Total hours per week** | | | **32** | | | **29** | | |

| SECOND YEAR | | | 1st Semester Hours/Week | | | 2nd Semester Hours/Week | | |
|---|---|---|---|---|---|---|---|---|
| **Code** | **Subject** | **Units** | **Theo.** | **Tuto.** | **Lab.** | **Theo.** | **Tuto.** | **Lab** |
| GE. 221 | Mathematics | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 241 | Fluid Flow | 5 | 2 | 1 | - | 2 | 1 | 2 |
| Chem.E. 242 | Physical Chemistry | 8 | 3 | 1 | 3 | 3 | 1 | 3 |
| Chem.E. 243 | Env. Pollution and Indust. Safety | 4 | 2 | - | - | 2 | - | - |
| Chem.E. 244 | Chemical Engineering Principles-II | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 222 | Computer Programming | 6 | 2 | - | 2 | 2 | - | 2 |
| Chem.E. 232 | Properties and Strength of Materials | 7 | 3 | - | 3 | 3 | - | - |
| Chem.E. 233 | Statistics and Eng. Economics | 4 | 2 | - | - | 2 | - | - |
| GS 211 | Freedom and Democracy | 2 | 1 | 1 | - | 1 | 1 | - |
| **Total** | | **44** | **19** | **5** | **8** | **19** | **5** | **7** |
| **Total hours per week** | | | **32** | | | **31** | | |

| THIRD YEAR | | | 1st Semester Hours/Week | | | 2nd Semester Hours/Week | | |
|---|---|---|---|---|---|---|---|---|
| **Code** | **Subject** | **Units** | **Theo.** | **Tuto.** | **Lab.** | **Theo.** | **Tuto.** | **Lab** |
| Chem.E. 331 | Engineering Analysis | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 341 | Chemical Eng. Thermodynamics | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 342 | Mass Transfer | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 343 | Heat Transfer | 5 | 2 | 1 | - | 2 | 1 | 3 |
| Chem.E. 344 | Chemical Industries | 4 | 2 | - | - | 2 | - | - |
| Chem.E. 345 | Reactor Design | 4 | 2 | 1 | - | 2 | 1 | - |
| Chem.E. 321 | Optimization and Numerical Methods | 5 | 2 | - | 3 | 2 | - | - |
| Chem.E. 322 | Industrial Management | 4 | 2 | - | - | 2 | - | - |
| - | Summer Training (4 weeks) | - | - | - | - | - | - | - |
| **Total** | | **34** | **16** | **5** | **3** | **16** | **5** | **3** |
| **Total hours per week** | | | **24** | | | **24** | | |

| FOURTH YEAR | | | 1st Semester Hours/Week | | | 2nd Semester Hours/Week | | |
|---|---|---|---|---|---|---|---|---|
| **Code** | **Subject** | **Units** | **Theo.** | **Tuto.** | **Lab.** | **Theo.** | **Tuto.** | **Lab** |
| Chem.E. 441 | Unit Operations | 5 | 2 | 1 | 3 | 2 | 1 | - |
| Chem.E. 442 | Petrochemical Industries | 4 | 2 | - | - | 2 | - | - |
| Chem.E. 443 | Petroleum Refining | 5 | 2 | 1 | - | 2 | 1 | 3 |
| Chem.E. 444 | Equipment Design | 2 | 1 | 2 | - | 1 | 2 | - |
| Chem.E. 445 | Process Control | 5 | 2 | 1 | - | 2 | 1 | 3 |
| Chem.E. 446 | Engineering Project | 4 | 1 | - | 3 | 1 | - | 3 |
| Chem.E. 431 | Computer Application | 6 | 2 | - | 2 | 2 | - | 2 |
| **Total** | | **31** | **12** | **5** | **8** | **12** | **5** | **11** |
| **Total hours per week** | | | **25** | | | **28** | | |

## The Syllabus

The following is the syllabus of the subjects in the department curriculum.

## FIRST YEAR

### GE 121 Mathematics

General review, Functions, Inequalities, Composite numbers, Function differentiation, Implicit differentiation and application of derivatives, Graph of maxima and minima, Limits, l'Hopital's rule, Trigonometric functions, Hyperbolic functions, Integration, Transcendental function, Improper integrals, Differential equations, Determinates and matrices.

### Chem.E 122 Organic Chemistry

Hydrocarbons, aliphatic, ring, olifenes, acytelines, aromatics, Orbital, Thermal cracking process, hydrogenation, reduction, Special reactions: oxidation and combustion, addition, substititution, nitration, Sulphonation, halogenation, polymerization,Halides, Alcohols and phenols, Ethers, Aldehydes and ketones, Carboxylic acids, esters, amino-acids, amides, Amines and some.

### Chem.E 123 Analytical & Inorganic Chemistry

Stoichiometric calculations, chemical coefficient, molarity, normality, titration, density, Equilibrium in the acids and bases, pH, graphs of titration, Indicators of bases and acids, Equilibrium in precipitation, solubility, partial precipitation, Analysis using oxidation and reduction, electromotive force, use of the half cell potentials, Nernest eq., Measure of concentration by potential of the cell. Selected Inorganic materials and reactions.

### Chem.E 131 Engineering Drawing

Introduction to the drawing tools and how to use them, Composition of the engineering drawings, Lettering, numbers, dimensions, Projection, Sectioning, Isometric drawing.

### Chem.E 141 Principles of Chemical Engineering (I)

Engineering calculations, units, dimensions, basis, Temperature and pressure, Conversion, yield, selectivity, purge, percent of completion in chemical reactions, Material balance with and without chemical reaction, Recycle, Gases, vapors, liquids and solids, Ideal gas, mixture of ideal gases, Vapor pressure, Mixture of gas and saturated vapor, Partial saturation and humidity, Energy balance, Calculation of thermal content.

### Chem.E 124 Programming

Definition of the computer; components, method of operation, Files, definition, types, coding, explanation of the dose system and its internal and external orders, Introduction to the Windows system, Program: how to start , printing, shut down, delete of the disk, arrangement of the icons, run, help, Word, Statistical program Excel, Presentation program Power point, Internet.

### GE 111 English Language

### GS 112 Human Rights

### GE 103 Workshop Technology

## SECOND YEAR

### GE 221 Mathematics

Conic sections, polar coordinates, Hyperbolic functions, Vectors, equation of plane, Partial differentiation, functions with more than one

variable, Multiple integrals, inverse integral, change of multiple integral to polar coordinates, Series, Differential equations, variable separable, homogeneous, linear, general solution by D-operator.

### Chem.E 241 Fluid Flow

Introduction, non-dimensional analysis, Static fluids, pressure of fluids, force applied by a fluid, immerged bodies, Types of flow, Bernoulli's eq., Reynolds number, friction factor and pressure drop, flow in open channels, Pumps, pump efficiency, Flow and pressure measurements, Fluid flow in the presence of solid particles.

### Chem.E 242 Physical Chemistry

1st law of thermodynamics, 2nd and third laws of thermodynamics, Gibbs free energy, Chemical equilibrium, Chemical reactions, Rate of reaction equations, Phase equilibria in ideal solutions, Phase equilibria in non-ideal solutions, Electrochemical equilibrium, Surface thermodynamics, Experimental gas kinetics, Liquid kinetics, Viscosity of liquids , Electrical conductance, Electrolytes.

### Chem.E 243 Environmental Pollution and Industrial Safety

Water pollution, Specific measurement of water, COD, BOD, Supply and treatment of water, purification of water, Salt removal, treatment of heavy water of city, treatment of industrial water, Air pollution, Specific air measurements, Suspended particles, Gases, effect on human health, Industrial safety, Safety terms in equipments, Dangers, Effect of radioactive materials, Chemical effects, Biological effects, Storage of chemicals, Industrial safety, fires and their causes, Fire alarm systems, Fires of fine solid particles.

### Chem.E 244 Chemical Engineering Principles (II)

Material balance of unsteady state with and without chemical reactions, Relations of real gases, van der Waal's equation, critical states and compressibility, mixtures of non –ideal gases, Energy balance, heat capacity, latent heat of vaporization, Energy balance with chemical reactions, Heat of Solutions and mixtures, enthalpy change for mixtures, enthalpy diagram, concentration, humidity chart, Flow sheets, material and energy balance for complete projects.

### Chem.E 222 Computer Programming

Introduction to visual basics, Explorer project window, properties, events, Project, project saving, applications, Files and projects, List, structure, coding of the list, Chatting boxes, mail boxes, ready box, file boxes, font boxes, color boxes, printing box, Basic statements in the visual basics, mathematical and logical statements, Decision statements, if statement, Go statement, complicated if statement, Statements of state, transformation function, IFF function, Loop statements.

### Chem.E 232 Properties & Strength of Materials

Strength of materials definitions, Simple stress, Shear stress, Stress in cylinders, Simple strain, Thermal stress, deformation in beams , Equations of stress and momentum in beams,. Curves of stress and momentum in beams.

Crystalline structure, Phase diagram, Alloys of copper, aluminum and iron, Plastics (polymers), Properties and uses of polyethylene, Ceramics, Electrochemical cells, crystalline deformations, Corrosion and its control, Practical: tests of the resistance of materials to friction, crystalline structure of metals.

### Chem.E 233 Statistics and Eng. Economics

Statistics: Statistical operations and frequency tables, Graphs, Central limit theorem, Measures of differences, Theory of probabilities, Distributions, confidence interval, normal distribution, two-sided, Poisson, Tests (Z, t, F, X2).

Economics: Estimation of cost of industrial projects, Factors affecting the production cost and investment, Capital investment, Cost index, Profit and cost of investment, Depreciation, Optimum design, Cost of the mass and heat transfer equipments.

### GS 211 Freedom and Democracy

## THIRD YEAR

### Chem.E 331 Engineering Analysis

1st order differential equations, 2nd order differential equations, Frobineous method, Error, Gamma, Beta, and Bell functions, Partial differential equations, Laplace transform, Mathematical modeling, Finite differences (application on chemical engineering systems) with multiple steps.

## Chem.E 341 Chemical Engineering Thermodynamics

Basic definitions, 1st law of thermodynamics for open and closed systems under steady and unsteady flow, Reversible process, Heat capacity, relations of temperature, pressure and volume with critical point, ideal gas behavior, Maxwell's relations, throttling process, 2nd law of Thermodynamics, heat engine, Carnot cycle, entropy and the 2nd law, lost work, entropy calculations, Freezing system and heat pump, Systems with varying concentrations, fugacity and its calculation, Vapor-liquid equilibrium.

## Chem.E 342 Mass Transfer Operations

Diffusion, Mass transfer theories, mass transfer coefficients, Absorption of gases, Extraction (liquid-liquid), Leaching (solid-liquid), Distillation: continuous, , batch distillation, multi-component distillation, Humidification and cooling and drying towers, steps of drying, Evaporation: types of evaporators, single and multiple effect evaporators.

## Chem.E 343 Heat Transfer

Heat transfer by conduction, convection and radiation, heat conductance, One-dimensional steady state conduction, Radial systems (cylinder and sphere), Overall heat transfer coefficient, Critical thickness of the insulator, Fins, Unsteady state conduction, Thermal boundary layer for laminar and turbulent flow, Analogy between fluid friction and heat transfer, Heat exchangers, Heat transfer by radiation.

## Chem.E 344 Chemical Industries

Treatment of industrial water. Prevention and removal of scales, Industrial carbon, Gases (carbon doxide, ammonia, nitrogen, helium, oxygen), Sulphur and its compounds, Nitogen, carbon dioxide, ammonia, nitrogen, helium and oxygen compounds, phosphoric acid, fertilizers, urea, nitric acid, Soap and detergents, Magnesium compounds, Ceramic industries, Cement, Glass industry, Paper and cellulose, Sugar industry, Fermentation industries, Fats and vegetable oils, Pharmaceutical industry.

## Chem.E 345 Reactor Design

Thermodynamic of chemical reactions, Reaction kinetics, rate of reaction equation, Ideal reactors, Operation of reactors at different temperatures, Design of single reaction reactors, Recycle reactor, Self catalytic reactor, Introduction to design of reactors with heterogeneous

reactions, analysis of the reactor (solid-fluid), height of the reactor unit, activity of catalyst.

### Chem.E 321 Optimization and numerical methods

Error estimation, Roots of equations (Fixed point iteration, Newton-Raphson, Bisection, False-position, Application), Solving set of linear equations (Jacobi / Gauss-siedel iteration, Elimination methods, Cramers / Matrix-inverse methods, Applications), Solving set of non-linear equations ( Newton / fixed point iteration method), Solving differential equations D.E, ordinary ( Euler, Modified Euler, Runge-Kutta), higher order and system of differential equations (Runge-Kutta), Applications to D.E, Numerical Integration ( Trapezoidal, Simpsons 1/3-3/8 rule), Interpolation ( linear, lagrange, Newton-Gregory, Stirling), Unconstrained single variable optimization (Bisecting, Fibonacci, Golden section search and Newton method, Applications), Constrained multi-variable optimization (linear programming, simplex, non-linear programming, G.R.G.S, Applications).

### Chem.E 322 Industrial Management

Linear programming, Graphical method, Standard form, simplex method, Big M technique, Two phase method, Algebric method, Special cases of linear programming, Dual form, Dual simplex method, Sensetivity analysis by graphical method, Postoptimally analysis by simplex method, Transport problem, Network assignments.

## FOURTH YEAR

### Chem.E 441 Unit Operations

Transfer of heat, mass and momentum, Reynolds analogy, Boundary layer theory, Non Newtonian fluids, Mixing, Fluid flow through packed columns, Fluidization, Filtration, Flow of particles through fluids, Sedimentation, Centrifuge, Practical: sedimentation, screening, cooling towers, drying, Reynolds anology, gas-solid and liquid-solid fluidization, pressure drop through packed towers, filtration, free falling velocity.

### Chem.E 442 Petrochemical Industries

Production of the basic materials for the petrochemical industry (olefins and aromatics), Petrochemicals from methane, Ethylene derivatives, Propylene derivatives, High molecular weight olefins derivatives,

Petrochemicals in benzol and xylenes, Polymers production techniques, Thermoplastic, Thermoset, Industrial fibers, Industrial rubber.

### Chem.E 443 Petroleum Refining

Crude oils, Chemical composition, Physical and chemical characteristics, Thermal processes, Catalytic processes, Conventional chemical treatment of refinery products, Lubricating oils, Production of different types of fuels and oil products (gas oil, solvents, car and aero plane gasoline, jet fuel, kerosene, diesel, asphalt, wax), Practical: density, flash point, viscosity, aniline point, sulphur content, water content, carbon content, salt content.

### Chem.E 444 Equipment Design

Flow sheet of process design, types of flow sheets and symbols, block diagram, piping system and control systems, utility flow sheet, units layout, project evaluation and survey, land selection, cost estimation, Pumps and piping systems, pipe fittings, valves, steam traps, selection of metal type of pipes, Vessels and tanks, design of vertical columns, design of pressure vessel, foundation, Plate and packed columns, , losses in pressure in columns, Mechanical design. Heat exchangers, Mass transfer equipments; absorption or extraction columns, Heat and mass transfer equipments, distillation column, absorption, heat exchanger.

### Chem.E 445 Process Dynamics and Control

1st order response, time delay, steady state coefficient, final value theorem, 2nd order system, Closed loop systems, transfer function and flow diagram, Air control valve, Control system, discontinuous, proportional, integral, differential, Optimum control by Zegler-Nickes method, Stability, Routh's method, Frequency response (Bode and Niquist diagram), Measuring devices of temperature, pressure, concentration and fluid flow.

### Chem.E 446 Engineering Project

Each student will be assigned a problem (either individually or as part of a group), and expected to submit a complete design report which includes market research, process selection and design, economic evaluation, unit operations and equipment details, a full design of three units of the plant and all the supporting drawings.

### Chem.E 431 Computer Application

Introduction to MatLab, Array building, Arithmetic functions, Numerical method functions, 2D plotting, Function discovery, EOS for pure compounds and mixtures, Degrees of freedom, VLE calculations, Adiabatic flame temperature, CRE and Chemical reactors, Material balances with recycle streams, Simulation of mass transfer equipments, Simulating processes, 3D plotting, Fluid flow in two and three dimensions, Process control simulink, Introduction to ChemCad, New job, Selecting Engineering units, Selecting process equipments, Putting and connecting systems, Selecting components and thermodynamic options, Defining feed streams, Equipment parameters, Running the simulation, Result review, Generating the PFD, Equipment sizing and cost estimation, Introduction to Hysys 3.1.

## Postgraduate Curriculum

## M.Sc. Courses;

| | Code | Subject | Hours | Units |
|---|---|---|---|---|
| 1st Semester | Chem.E 500 | Heat Transfer | 3 | 3 |
| | Chem.E 501 | Fluid Flow | 3 | 3 |
| | Chem.E 502 | Catalyst | 3 | 3 |
| | Chem.E 503 | Process Modeling. | 3 | 3 |
| | GE 504 | English Language. | 2 | 1 |
| | Total | | 14 | 13 |
| 2nd Semester | Chem.E 505 | Mass Transfer | 3 | 3 |
| | Chem.E 506 | Reactor Design | 3 | 3 |
| | Chem.E 507 | Corrosion | 3 | 3 |
| | Chem.E 508 | Thermodynamics. | 3 | 3 |
| | GE 504 | English Language. | 2 | 1 |
| | Total | | 14 | 13 |

### Chem.E 500 Heat Transfer

Thermal conductivity, Temperature distribution in solids, Temperature distribution in laminar flow, The equation of energy, the equation of motion, Application of Equation of change, Dimensional

analysis, Unsteady heat conduction in solids, Steady two dimensional heat transfer, Boundary layer theory, Temperature distribution in turbulent flow, Interphase transport in no isothermal system.

**Chem.E 501 Fluid Flow**

Viscosity and the mechanism of momentum transport, Velocity distribution in laminar flow, The equation of change for Isothermal systems, Velocity distribution with more than one variable, Velocity distribution in turbulent flow, Interphase transport in isothermal systems, Macroscopic balances for isothermal systems.

**Chem.E 502 Catalyst**

Catalytic functions, Catalytic materials, Balanced structure of catalytic pellets, Catalytic design and development, Catalyst preparation, Catalyst characterization ( Bulk properties, Particle properties, Surface properties), Catalyst deactivation.

**Chem.E 503 Process Modeling**.

Fundamental laws, Continuity equations, Energy equations, Equation of motion, Transport equations, Equation of state, Equilibrium, Chemical Kinetics, Examples of Mathematical Models of chemical engineering systems ( CSTR'S with variable holdups, Nonisothermal CSTR, Single component vaporizer, Multicomponent flash drum, Batch reactor, Mass Transfer with Chemical reaction, Ideal binary distillation column, Multicomponent nonideal distillation column, Application

**GE 504 English Language**.

**Chem.E 505 Mass Transfer**

Diffusivity and the mechanism of mass transfer. Concentration distribution in solids and laminar flows. Equation of change for a multicomponent system. Concentration distributions with more than one independent variable. Concentration distributions in turbulent flow. Inter-phase transport in non-isothermal mixtures. Macroscopic balances for multi-component systems. Other mechanisms for mass transport.

**Chem.E 506 Reactor Design.**

Plug flow reactor, Laminar and turbulent flow reactors, Isothermal and adiabatic reactors, Fixed bed reactors, Fluidized bed reactors, Design of reactors, Plug flow model, diffusion model, stage model.

### Chem.E 507 Corrosion

Corrosion and Society, Enabling theory for aqueous corrosion, Theory for aqueous corrosion (part 1), (part2), (part3), (part4), (part6), Cathodic protection.

### Chem.E 508 Thermodynamics

Thermodynamic properties of fluids, Flow processes, Conversion of heat into work, Refrigeration and liquefaction, Thermodynamics of variable composition ideal and non ideal behavior, Analysis of convergent pressure, Analysis of Nozzles, Behavior of multicomponent systems, Surfaces, Vapor-Liquid-Solid interfaces, Phase Equilibria at low to moderate pressures, Solutions, VLE from equations of state, Process analysis, Nucleation.

## Ph.D. Courses;

| | Code | Subject | Hours | Units |
|---|---|---|---|---|
| 1st Semester | Chem.E 600 | Mass Transfer | 3 | 3 |
| | Chem.E 601 | Interfacial Phenomena | 3 | 3 |
| | Chem.E 602 | Advanced Corrosion | 3 | 3 |
| | Chem.E 603 | Air Pollution. | 3 | 3 |
| | GE 504 | English Language. | 1 | 1 |
| | Total | | 14 | 13 |
| 2nd Semester | Chem.E 604 | Two Phase Flow | 3 | 3 |
| | Chem.E 605 | Nanoscale Energy Transport | 3 | 3 |
| | Chem.E 606 | Combustion Technology | 3 | 3 |
| | Chem.E 607 | Advanced Reactor Design | 3 | 3 |
| | GE 504 | English Language. | 2 | 1 |
| | Total | | 14 | 13 |

### Chem.E 600 Mass Transfer

Stochastic mathematics and applications in mass transfer. Review of recent published articles in mass transfer: Types of diffusion, Mass transfer coefficient, Interfacial area, Distillation, Absorption, Liquid extraction, Adsorption, Liquid membrane, Reaction Kinetics, Osmosis,

Nanotechnology, Cooling by direct solar energy (absorption and adsorption refrigeration).

### Chem.E 601 Interfacial Phenomena

Physics of Surfaces, Electrostatic Phenomena, Properties of Monolayer, Reactions at liquid surfaces, Mass Transfer across interfaces, Disperse Systems and Adhesion.

### Chem.E 602 Advanced Corrosion

Thermodynamic and Electrode Potential, Pourbaix Diagrams, Kinetics of Activation polarization, Kinetics of Concentration polarization.

### Chem.E 603 Air Pollution

Industrial ventilation, Settling chamber, Cyclone, Electrostatic precipitation, Scrubber, Adsorption.

### Chem.E 604 Two Phase Flow

Introduction, Flow patterns, Basic equations, Two Phase flow models, Separated flow model, Application of flow models ( bubble flow, slug flow, annular flow, drop flow).

### Chem.E 605 Nanoscale Energy Transport

Introduction, Simple kinetic theory, Schrodinger equation, Quantum wells, Rigid rotors, Electronic energy levels in crystals, Phonon energy levels in crystals, Reciprocal lattice, Energy spectrum in Nanostructures, Specific heat of molecules, Effects of Nanostructures on energy storage, Electromagnetic waves, Acoustic waves, Laudauer formalism, Transport in carbon Nanotubes.

### Chem.E 606 Fuel Technology

Solid fuels (Definitions, Coal origin, Classification, Contents, Combustion calculations, solid fuels made from coal, Caloric value of coal), Liquid fuels (Definitions, Petroleum oils, treatment and distillation, Cracking, Reforming, Diesel fuels, Gasolines, Kerosines, Combustion of fuel oils ), Gaseous fuels ( Classification, Natural gas, Synthesis of methane, Combustion calculations.

### Chem.E 607 Advanced Reactor Design

Introduction, Ideal reactors, Non-ideal flow, Compartment model, Dispersion model, Tanks in series model, Convection model for laminar

flow, Earliness of mixing, segregation and RTD, Heterogeneous reactions, Solid catalyzed reactions, Packed bed catalytic reactor, Non catalytic fluid particle reactions, Kinetics and design.