

# *Doctor of Philosophy (PhD) Curriculum*



***School of Chemical Technology***

***Kalinga Institute of Industrial Technology***

***(Deemed to be University)***

***Bhubaneswar-751024***

## Subjects available for PhD Programme

| Course Code | Course Name                                     | Credit |
|-------------|---|--------|
| CTR1001     | Research Methodology                            | 4      |
| CTR1002     | Numerical Methods in Chemical Engineering       | 4      |
|             | <b>Fundamental Electives</b>                    |        |
| CTR2001     | Colloids and Surface Chemistry                  | 4      |
| CTR2002     | Advanced Technique of Chemical Analysis         | 4      |
| CTR2003     | Fundamentals of Materials Science               | 4      |
|             | <b>Professional Electives</b>                   |        |
| CTR3001     | Mineral Processing and Extractive Metallurgy-I  | 4      |
| CTR3002     | Mineral Processing and Extractive Metallurgy-II | 4      |
| CTR3003     | Environmental Science & Technology              | 4      |
| CTR3004     | Nanotechnology                                  | 4      |
| CTR3005     | Biochemical Engineering-I                       | 4      |
| CTR3006     | Biochemical Engineering-II                      | 4      |
| CTR3007     | Polymer Technology-I                            | 4      |
| CTR3008     | Polymer Technology-II                           | 4      |

Candidates admitted with ME/MTech degree will have to complete 1 compulsory course (Research Methodology) and 2 elective courses. Candidates admitted with BE/BTech/MSc degree will need to complete 2 compulsory courses (Research Methodology and Numerical Methods in Chemical Engineering) and 4 elective courses.

# Detailed Syllabus

## CTR1001 Research Methodology

### *Unit-I: Philosophy and Culture of Research*

#### *A. Philosophy:*

- i) Introduction to philosophy of knowledge; various aspects of research methodology; Methodological Approaches; the analytical approach; Methodological procedures with integrated approaches.
- ii) Types of Research; Introduction to Qualitative & Quantitative Research- Need for Qualitative & Quantitative Research, Grounded Theory Approach, Case Studies in Qualitative Research, The Challenges of Reliability and Validity in Qualitative Research.
- iii) General concept of research in Chemical Engineering and Technology, Genesis of interdisciplinary research (process chemistry and engineering), problem solving approach, role of industries in deciding the relevant research problems, Role of mentoring, Proposal writing, Significance of R & D in solving industrial and/or societal issues, applying grants to funding agencies including industries, Concept of translational research and technical-incubators
- iv) Optimization techniques and design of experiments (DOE)

#### *B. Research and Writing:*

- i) Language of chemical Literature, Review, Developing the objectives, preparing the Research Design including industrial need, regulatory mandates, Ethical issues.
- ii) Methodology to write a technical paper/short communication/research proposal/monograph, and abstract writing; Preparation of the Report or Presentation of Results-Formal write ups of conclusion reached, IPR, research-ethics and Chemical hazardous and safety, Documentation & Bibliography

#### *C. Presentation Tool:*

- i) Introduction to Presentation tools, features and functions; Creating presentations, customizing presentation, tools used (Microsoft power point, open office, XIs); Creating a poster and poster presentation.
- ii) Computational tools used in chemical engineering, simulation and modeling software

### **Text Books:**

- 1) Research Methodology: Methods and Techniques, Second Edition, New Age International publishers by C.R. Kothari
- 2) Optimization in Chemical Engineering, S. Dutta, Cambridge University Press
- 3) Shreve's Chemical Process Industries book, R. Norris Shreve

### *Unit-II: Research Objective and Formulation*

A. Research objective and specification, Motivation of research, need, critical thinking and creativity, Fundamental research question, Research approach, Research Hypothesis.

B. Research Problem, Criteria for Selecting and formulating a research Problem; role of industries in designing the research problem, writing and Evaluating Research Problem, Review

the Environment or Context of the Research Problem, explore the Nature, and Define the Variable Relationships, the Consequences of Alternative Courses of Action.

**Text Book :**

- 1) Social Research Methods, 4th Edition by Alan Bryman, Oxford Text Books
- 2) Introduction to Chemical Engineering Processes

***Unit-III: Data Analysis for Research***

- A. Basic statistical methods through the use of linear model theory and regression.
- B. Analysis through one-end two-sample t-tests, multiple linear regression, analysis of variance, regression diagnostics , model-building techniques, random effects models, and mixed models.
- C. Need of Quantitative analysis in Research Methodology, Data collection, Univariate & Bi-variate data analysis and application to various projects.
- D. Use of Internet & digital Resources in data mining, Role of primary literature and survey in designing and optimizing a research problem.

**Text Book:**

1. Textbooks on Qualitative Research and Methods/ Methodology: Toward a Praxis of Method: Wolff-Michael Roth
2. Text Book on Research Methodology: Methods and Techniques C.R.Kothari and Gaurav Garg

***Unit-IV: Computer Fundamentals***

Unit-1: Introduction

Overview of computer organization, Data representation: Number systems, character representation codes, Binary, hex, octal codes and their inter conversions. Binary arithmetic, Floating point arithmetic, signed and unsigned numbers, Data Storage: Primary and Secondary storage, Operating Systems such as DOS, Windows, UNIX etc.

Unit-2: Introduction to Programming

Concept of algorithms, Flow charts, Example of Algorithms, Concept of sequentially following up the steps of an algorithm, Notion of program, programmability and programming languages, Structure of programs, Object codes, compiler, Introduction to the Editing tools such as vi or MS-VC editors, Concepts of the finite storage, bits, bytes, kilo, mega and gigabytes, Concepts of character representation, Introduction to database, MS SQL, Introduction to HTML

Unit-3: C programming: Basics of C and C++ programming

**Text Books**

- 1) Computer Fundamentals and Programming in C, Pradip Dey and Manas Ghosh, Oxford University Press
- 2) Fundamentals of Computers, V. Rajaraman, N. Adabala, PHI

### ***Unit-V: Intellectual Property Rights and Ethics***

A. Intellectual Property: the philosophy of property, what is Intellectual Property, Patent, Trademark, Industrial Design, Geographical Indication, Copyright and Related Rights. Research Incentives.

B. Plagiarism: Definition, Plagiarism and consequences, IPR Violation, Google Copy-Paste, Syndrome, Plagiarism and IPR Violation Detection.

C. Tools for Detecting Plagiarism, Integrating Search Application Programmers Interface (API), Advanced Plagiarism Detection, Reusing research paper, collaborative work and copyright

D. Research Ethics: Definition and importance, ethical guidelines, examples, case study, other resources and guidelines for authorship, peer review, research misconduct, and conflicts of interest. Data management and stress management.

E. IPR Laws: Rights of Patent; Patent Infringement, remedies for infringement for patent rights; Indian Patent Act 1970 and TRIPS; Major changes in Indian Patent system as post TRIPS effect; Draft of National Intellectual Property Policy; 2003 and 2005 amendments Content of Patent specification and procedure for patent; (a) Obtaining patent, (b) Geographical Indication, (c) WTO, Detailed Information on Patenting Biological Products, Cartagena Protocol. Intellectual property Law. Plant Genetic resources: Patenting of biological material; Plant Breeder's Right (PBR) and Farmer's right. The Business of IPR and its influence on national and international economy. Brand building and value creation through IPR. Convention on Biodiversity; Budapest treaty; Case Studies on Patents- Basmati, Neem, Haldi. Emerging issues in IPR recent case studies on cancer drugs Novartis and Cadilla cases in India.

**Safety:** Principles, Risks, Regulatory agencies, Health and Safety Practices, Applying Chemical and Process safety Principles, Emergency Procedures

#### **Text Book:**

- 1) Information Ethics: Privacy and Intellectual Property by Lee A Freeman and A Graham Peace, International Science Publishing
- 2) Intellectual Property Rights in a Network World: Theory and Practice, Lee A Freeman, International Science Publishing.

### **CTR1002 Numerical Methods in Chemical Engineering**

#### **Unit-1**

Solution of differential equations in series with reference to Bessel and Legendre equations, elementary properties of Bessel and Legendre functions. Solution of differential equations by numerical methods, Picard's method, Euler's method, Runge-Kutta method, Milne's method. Solution of difference equation with constant coefficients.

#### **Unit-2**

Formation and classification of partial differential equations, first order linear equations, standard forms of non linear equations, Charpit's method, homogeneous linear equations with

constant coefficients. Different methods for parabolic equations, hyperbolic equations and elliptic equations. Solution of partial differential equations of engineering interest by method of separation of variables.

#### Unit-3

Z-transforms: Introduction, standard Z-transforms, properties of z-transforms, initial value and final value theorems, Inverse – Z-transforms, Inverse Z-transforms by power series method, partial fractions method and integral method, application to difference equations.

#### Unit-4:

Approximation and round of errors, Truncation error and Taylor's series , Roots of equation: The bisection method, the false-position method, fixed point iteration, the Newton-Raphson method, Muller's method, Linear algebraic equation: LU decomposition, the matrix inverse, Gauss-Seidel method, Interpolation: Newton divided difference interpolation, Lagrange Interpolation, Newton's forward and backward interpolation, Numerical integration: The trapezoidal rule, The Simpson's rules, Gauss quadrature Ordinary differential equation: Euler's method, Improvement of Euler's method, Runge-Kutta methods

#### **Text Books**

- 1) Advanced Engineering Mathematics, Erwin Kreyszig, John-Wiely
- 2) Advanced Engineering Mathematics S. R. K. Iyengar, R. K. Jain, Narosa
- 3) Mathematical Methods in Chemical Engineering Arvind Verma, M. Morbidelli, Oxford

#### **CTR2001 Colloids and Surface Chemistry**

##### Unit-1 Introduction

General introduction of colloids, interfaces, surfactants, and micellization.; Intermolecular forces, Van der Waals forces (Keesom, Debye, and London interactions), Colloidal systems and colloidal stability (van der Waals attraction and potential energy curves), Brownian motion and Brownian flocculation, Surface and interfacial tension and surface free energy, Gibbs equation, Theory of surface tension and contact angle, and wetting. Thermodynamics of interfaces, micelle and mixed micellar formation, Electrical phenomena at interfaces (Electrokinetic phenomena, Electrical double layer), Emulsion and microemulsion, Application: General applications, Enhanced petroleum recovery, super hydrophobic and self cleaning surfaces, novel fabrication of nanostructured particles. Brief idea about measurement of surface tension, Contact angle, Zetapotential, Particle size.

##### Unit-2 Particulate Science & Technology

Study of particles: Definition of a particle, Qualities of particles; The industrial revolutions: explosion of particle related advances (from advanced mining techniques to abrasives, cutting tools, and mass production of chemicals and agricultural products). Modern scientific advances in paints and coatings and other particles in various base solvents, Particles in fluids; Composite materials, the design and manipulation of matter on the nanoscale and into nanostructures; Particle Science as an enabling technology to create new energy sources, clean our air and water

and build stronger and lighter materials, Advances in particle sciences in particular in the area of human healthcare.

### **Text Books**

- 1) P. C. Hiemenz, and R. Rajagopalan, Principle of colloid and surface chemistry, 3rd edition, MerceL Dekher, N. Y. 1997.
- 2) J. K. Beddow, Particulate Science and Technology.

### **CTR2002 Advanced Technique of Chemical Analysis**

Unit-1: Spectroscopic techniques

UV-visible spectroscopy: Energy levels and selection rules, Woodward-Fieser and Fieser-Kuhn rules, Influence of substituent, ring size and strain on spectral characteristics, Solvent Effect

FT-IR spectroscopy: Fundamental vibrations, characteristic regions of the spectrum (fingerprint and functional group regions), influence of substituents, ring size, hydrogen bonding, vibrational coupling and field effect on frequency, determination of stereochemistry by IR technique

NMR spectroscopy: Magnetic nuclei with special reference to  $^1\text{H}$  and  $^{13}\text{C}$  nuclei, Chemical shift and shielding/deshielding, factors affecting chemical shift, relaxation processes, chemical and magnetic non-equivalence, local diamagnetic shielding and magnetic anisotropy,  $^1\text{H}$  and  $^{13}\text{C}$  NMR scales

Mass Spectrometry: Ionization methods, SIMS, FAB, CA, MALDI, PD, Field Desorption Electrospray Ionization, Fragmentation patterns-nitrogen and ring rules, McLafferty rearrangement and its applications

Unit-2: Structural Elucidation Using Spectroscopic Techniques

Identification of structures of unknown organic compounds based on the data from UV-Vis, IR,  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR spectroscopy (HRMS data or Molar mass or molecular formula may be given)

### **Text Books**

- 1) Inorganic quantitative analysis, A.I. Vogel, Logmans ELBS
- 2) W. Kemp, Organic Spectroscopy, 2nd Edn., Macmillan, 1987
- 3) R.M. Silverstein, G.C. Bassler, T.C. Morrill, Spectroscopic Identification of Organic Compounds, 5th Edn., Wiley, 1991
- 4) Spectroscopy of Organic Compounds, P. S. Kalsi

### **CTR2003 Fundamentals of Materials Science**

Unit-1: Introduction: Classification of Materials, Engineering applications of materials

Unit-2: Structure of Materials

Structures of Metals and Ceramics: Fundamental concepts, unit cells, metallic crystal structures, ceramic crystal structures, crystallographic directions and planes, single crystals and polycrystalline materials, closed pack crystal structures, imperfection and defects in solids

Unit-3: Electrical Properties of Materials

Dielectric Materials: Microscopic Displacement of atoms and molecules in an external dc electric field, Polarization and dielectric constant, Temperature dependence, Dielectric Breakdown, Ferro electric material Piezoelectrics, Pyroelectrics, Dielectric Materials as electrical insulators,

Unit-4: Magnetic Properties of Materials

Dia, Para and Ferro magnetic materials, Theory of magnetism, Ferromagnetic materials or Ferrites, Comparison of magnetic behaviour and magnetic parameters of Dia, Para and Ferro magnetic materials

Unit-5: Optical Properties of Materials

Scattering, Refraction, Theory of Refraction and absorption, Atomic Theory of optical properties, Lasers, Optical fibres – Principle, structure, application of optical fiber

### **Text Books**

- 1) Elements of Materials Science and Engineering, L. H. Van Vlack, Pearson India
- 2) Fundamentals of Materials Science and Engineering, W. D. Callister, John Wiley & Sons
- 3) Materials Science and Engineering, V. Raghvan, PHI Learning

### **CTR3001 Mineral Processing and Extractive Metallurgy-I**

Unit-1: Introduction and scope of mineral processing

Introduction and scope of mineral processing in extractive metallurgy, Mineral resources of India and worldwide for basic metals like Iron, Copper, Aluminium, Zinc etc., Physical and chemical characteristics of industrial minerals, Terminology in mineral processing, Economics of ore processing

Unit-2: Liberation, comminution, sizing and classification

Liberation and its significance, Comminution and sizing, Laws of Comminution, Crushing and Grinding- types and equipment, Washing, Sorting and hand-picking, Laboratory and industrial screening- equipment, screen efficiency, Classifier-mechanical and hydraulic, sizing and sorting Classifiers

Unit-3: Minerals separation processes

Gravity Separation, particle settling rate, design and operations of jigging, shaking concentrators, flowing film concentrators, dense media separation; Froth flotation (Solid-Liquid Separation): design and operation of thickeners, flocculation, filters; Flotation: principle of flotation, contact angle and its measurements, application of physico-chemical principles in flotation, equipments such as Jameson Cell, Flotation Columns etc, circuits and kinetics, Magnetic, tribo-electric, eddy current, electrostatic separation methods; use of microwave and ultrasound technology in mineral and particulate system



Unit-4: Simplified beneficiation Flow Sheets of coal and ores of metals

Beneficiation flow sheets of coal and simple ores of copper, zinc and Iron with reference to Indian deposits

#### **Text Books**

- 1) Mineral processing technology: an introduction to the practical aspects of ore treatment and mineral recovery, Barry Alan Wills, Pergamon Press
- 2) Principles Of Extractive Metallurgy, A Ghosh H S Ray
- 3) Extraction of Non-ferrous Metals, H. S. Ray and K. P. Abraham, East West Press
- 4) Mineral Processing Technology, S K Jain, CBS Publisher

#### **CTR3002 Mineral Processing and Extractive Metallurgy-II**

Unit-1: Extractive metallurgy- a process of separation

Commercial production of metals, classification of processes, process design and analysis

Unit-2: Basics of pyrometallurgical processes

Unit operations for preliminary treatment of ores, unit operations for pyrometallurgical extraction with examples of ferrous and non-ferrous (copper and zinc) metals, iron and steel making – principles, role structure and properties of slags, metallurgical coke, blast furnace, direct reduction processes, primary and secondary steel making, stainless steel making

Unit-3: Principles of electro and hydrometallurgy

Basics concepts of electrolysis, electrolysis in aqueous solutions, electrolysis of fused salts, Advantages and limitations of hydrometallurgy, leaching: kinetics, pressure leaching, bioleaching, electrochemical mechanism in leaching, Purification of leach liquor: solvent extraction, selective precipitation and stripping, Eh-pH diagrams

#### **Text Books**

- 1) Principles Of Extractive Metallurgy, A Ghosh H S Ray
- 2) Extraction of Non-ferrous Metals, H. S. Ray and K. P. Abraham, East West Press
- 3) Mineral Processing Technology, S K Jain, CBS Publisher

#### **CT3003 Environmental Science and Technology**

Unit-1: Air Pollution and its control

Definitions of concentration of pollutants, classification of pollutants, primary and secondary pollutants with examples, sources of pollutants, Natural Processes and Anthropogenic processes, photochemical smog, Sampling and measurements of Pollutants, Air Pollution control

Unit-2: Water Pollution & waste water treatment

Water quality standards, discharge standards, types of pollutants, physical, biological, and chemical examination techniques, Coagulation and flocculation, filtration (sand, gravity, fluidized sand etc.), clarification (clarifier design, Lamella clarifier etc.), Biological treatment, Activated Sludge Process, trickling filters, types of aerators and their efficiency of oxygen transfer, tertiary Treatment Processes: Membrane processes, Adsorption and ion exchange, Root

Zone, chlorination, ozonation, Chemical treatment: Chemical oxidation, wet air oxidation, incineration

Unit-3: Treatment of solid and hazardous wastes: Toxics, nuclear, land fill, Introduction to SHE analysis, Life cycle analysis (LCA), ISO 14000, Environmental Audit/ Statutory Regulations

Unit-4 Safety engineering

Industrial hygiene and safety aspects related to toxicity, noise, pressure, temperature, vibrations, radiations, etc. Explosions including dust, vapour cloud, and mist explosions, Hazard identification, assessment and safety audit including ETA, FTA and Dow fire and explosion index, HAZOP, HAZAN and consequence analysis, Safety aspects related to (i) transport handling and storage of flammable liquids and gases and toxic materials (ii) Process equipment including piping (fire, static electricity, pressure, temperature, etc.) Safety aspects at process development and design stage, Reliability engineering, Hazard mitigation systems, Emergency planning

### **Text Books**

- 1) Wastewater Engineering, Metcalf and Eddy
- 2) Industrial and Pollution Engineering, Cavaseno, VinCene N.T.
- 3) Environmental Pollution Control Engineering, Rao C.S.
- 4) Environmental Engineering, Peavy H. S.
- 5) Chemical Process Safety Fundamentals and Applications, Crawl D.A., Louver J.F.

### **BT3004 Nanotechnology**

Unit-1: The Science of Nanotechnology

Nanotechnology: Definition of nano scale with reference to biosystems, Scope (Overview of current industry applications) and future prospects (Engineering principles for nanotechnology materials and applications), Physics of nano-structure - Quantum Size effect - optical properties, Semiconductor (magnetic, organic, and doped nanoparticles), Synthesis of bio-metric materials (Quantum dot, thin film etc) – Characterization techniques - Role of surfaces in nanotechnology devices – Nano fabrication nanotubes, nano-probes - biosensor.

Unit-2: Techniques in Nanotechnology

Nanomaterials: Polymers, Carbon Nanotubes, Nanowires, Nanocrystals, and Quantum Dots, Synthesis of nanomaterials, Top-down and bottom-up approach, Analytical Techniques of nanotechnology: XRD, SEM, TEM, AFM

Unit-3: Nanotechnology for a Sustainable Environment

Water Pollution abatement, Nanotechnology and Safer Drinking Water, Nanofilters, Reverse Osmosis, Groundwater Cleanup, Cleaning Up Organic Pollutants Using Nanotechnology, Air Pollution control using nanotechnology, Nanotechnology for clean energy generation

Unit-4: Nano-biotechnology

Nanotechnology in Biomedical and Life Sciences: Criteria for suitability of nanostructures for biological applications, Present and future of nanotechnology applications in: a) Molecular biology, b) Medicine

Unit-5: Economical and ethical aspects of nanotechnology

**Text Books**

- 1) Nanoscience: Nanobiotechnology and Nanobiology, Patrick Boisseau, Philippe Houdy, Marcel Lahmani, Springer
- 2) Nanobiotechnology: Nanotechnology, Biochemistry, Bionanotechnology, Biotechnology, Biomolecule, Biosensors, Photonics, Biophysics

**BT3005 Biochemical Engineering-I**

Unit-1: Introduction

Introduction to Biochemical process industries: Industrial alcohols, anti biotic, enzymes, vitamins, single cell process

Unit-2: Microbial Biochemistry

Structural differences between different microbial cell types and cellular organelles; Biochemical/Microscopic/ Molecular methods used to differentiate between archae, eubacteria and eukaryotes; Cell wall of prokaryotes; Outer membrane of Gram –ve bacteria and control of its synthesis; Potential targets for drug design.

Unit-3: Principles of enzyme catalysis

Proteins as enzymes; Michaelis-Menten kinetics; Kinetics and Statistics; Inhibition; Effect of pH and

temperature; Enzymology; Immobilized enzymes: methods, mass transfer considerations; Industrial enzymes

Unit-4: Bioenergetics and Catabolic Pathways

Oxidation-reduction reactions; Electron carriers and cellular metabolism; High energy compounds and their role in microbial fermentations; Enzymes as catalysts; Cellular metabolites and interconnectivity in biochemical pathways; Respiration and Electron Transport

**Text Books**

- 1) R. Dutta, Fundamentals of Biochemical Engineering, Springer, 2008
- 2) Lehninger Principles of Biochemistry by Nelson & Cox, W H Freeman and Co. 2007
- 3) Pauline Doran, Bioprocess Engineering Principles, Elsevier
- 4) Michael Shuler and Fikret Kargi, Bioprocess Engineering: Basic Concepts, Prentice Hall

**BT3006 Biochemical Engineering-II**

Unit-1: Fermentation

Introduction to solid and submerged fermentation, Different types of industrial fermenters, Designing of industrial fermenters, Applications of fermentation: Fermentation Pathways for Industrial Products, Biochemical pathways of metabolic reactions to utilize carbon sources and formation of different metabolites by microorganisms, Fermentation economics: Cost-benefit analysis, and business plan development.

## Unit-2: Bioreactors

Bioreactor configurations, stirred tank reactor, bubble column reactor, mist bioreactor, airlift reactor, stirred and air-driven reactors, packed bed, fluidized bed, photo-bioreactor, wave bioreactor, Practical considerations for bioreactor construction: Aseptic operation, Fermenter inoculation & sampling, Construction materials, Sparger design, Ideal reactor operations: Batch operation of a mixed reactor, fed-batch operation of a mixed reactor, continuous operation of a mixed reactor, operational considerations for immobilized systems.

## Unit-3: Downstream processing

Filtration: Filter Aids (membrane filter and depth filter), filtration equipments (plate filters and rotary-drum vacuum filters), filtration theory, micro-filters and ultra filtration systems for separation of cells and fermentation medium, Centrifugation: Basic theory, centrifuge equipments (tubular-bowl, disc-stack bowl, ultracentrifuge), Cell Disruption: Basics, Manton-Gaulin homogenization; The Ideal-Stage Concept, Two-Phase Liquid Extraction, Adsorption, Adsorption operations, Equilibrium relationships for adsorption, Fixed-Bed adsorbers, Performance characteristics of fixed-bed adsorbers, Breakthrough curve.

Unit 4: Bioprocess engineering in food and beverage industries (case studies: manufacturing of bread/fruit juices), Bio-fuel technology (case studies: production of bio-gas), Environmental remediation (case studies: bio-sorption of heavy metals), Bio-mineral processing (case studies: bio-leaching of copper)

## Text Books

- 1) Principle of Fermentation Technology, Peter F Stanbury, Allan Whitaker & Stephen J Hall
- 2) Pauline Doran, Bioprocess Engineering Principles, Elsevier
- 3) Michael Shuler and Fikret Kargi, Bioprocess Engineering: Basic Concepts, Prentice Hall

## BT3007 Polymer Technology-I

### Unit-1 Techniques of polymerization

Bulk, solution, suspension, emulsion, plasma etc, Different initiating systems such as free radical polymerization, redox, cationic & anionic polymerization (different terms such as living polymers, inifers, telechelics), Their kinetics & control over structure of polymer, Condensation polymerization, different catalysts used case studies of condensation polymerization, Carothers equation, Comparison of these systems with advantages & disadvantages, Copolymerization, reactivity ratios & kinetics of copolymerization (copolymer composition equation), Different advanced catalyst systems: Ziegler Natta catalyst & metallocene catalysts & their role in polyolefins, ATRP etc

### Unit-2 Thermoplastic Polymer Technology

Polyethylenes; modified polyethylenes, Polypropylene and copolymer of PP, modified Polyolefins like crosslinked & filled polyolefins, Polyisobutylene & polyolefin elastomers etc, Engineering Polymers Polyesters such as PET, PBT, PTT, Polycarbonates, Polyacetal etc,

Styrenic polymers - Polystyrene, HIPS, SAN, ABS, important copolymers of styrene maleic anhydride and styrene acrylics copolymers, toughening mechanism of impact modified plastics, Polymamides- Nylon 6, Nylon 6,6, Nylon 11, aromatic polyamide such as Kevlar, Acrylic polymers & copolymers, Polyacrylamide, PMMA, ASA, Polyacrylonitrile, Polyvinyl chloride & its copolymers, Poly vinyl acetate, Polyvinyl alcohol, Modified cellulose

Unit-3 Technology of Thermoset Resins

Polyester Resins- unsaturated polyesters resins: Raw material: poly-basic acids, polyfunctional glycols. Curing of resins through unsaturation of the resin/polymer backbone, Curing systems, catalysts and accelerators, Polyester based composites & their recipes, Water reducible polyesters, high solid polyesters/ polyesters for powder coatings Moulding compositions, DMC, SMC, fibre and film forming compositions

Phenolics: Basic components of the polymer. Different kinds of phenols and their derivatives, different kinds of aldehydes used, Novolacs and Resol: effect of the ratio of phenol to aldehyde on the nature and the property of the polymer, Theory of resinification and effect of pH on the reaction mechanism and the reaction product, Curing of phenolics

Amino resins: Basic raw materials used like urea/melamine/ aniline/ formaldehyde, Synthesis of UF and MF resins. Theory of resinification and effect of pH on the reaction mechanism and the reaction product

### **Text Books**

- 1) Polymer Science, Gowariker, Johan wiley and Sons 1986
- 2) Text book of polymer Science, Billmeyer, John Wiley and Sons 1984
- 3) Polymer Science and Technology by J. R. Fried, Prentice-Hall, Inc 1995
- 4) Fundamentals of Polymer Processing, S. Middleman, Houghton Mifflin Company
- 5) Textbook of Polymer Science and Engg Anilkumar and Gupta, tata McGraw-Hill

### **BT3008 Polymer Technology-II**

Unit-1 Pigments & additives for Polymers

Properties required in a pigment and extender, Pigment dispersion basics, Inorganic pigments such as titanium dioxide, zinc oxide, carbon black, chromate pigments, molybdate orange, chrome green, ultramarine blue, iron blue, cadmium red, pearlescent and other effect pigments, corrosion inhibiting pigments, such as zinc phosphate, zinc and barium chromate pigments, ceramic pigments, metal flake pigments, extenders, Theory of color formation in organic compounds, effect of auxiliary groups on the shade and hue of the pigment (Bathochromic and hyper chromic shift)

Manufacture of Carbon black different grades such as furnace & channel black

Unit-2 Compounding and Polymer Processing

Basic Concept of Compounding and Processing; Concept of Master batches, Classification and type of Additive for Plastics: Antioxidants, Light stabilizers, UV stabilizers, Lubricants and

relative auxiliaries, Processing aids , Impact modifiers, Flame retardance, antistatic agents.PVC stabilizers and Plasticizer

Processing Techniques: Basic of varies processing techniques such as a) One-dimensional process is like Coating and Adhesives, b) Extruders: single screw and twin screw extruders, Film blowing, coextrusion of multilayred films, Fiber spinning, Pipe extrusion, Extrusion of profiles, coextrusion of pipes, Extrusion of cable material, extrusion of sheet, Calendaring, Thermoforming, c) Molding: Injection molding Blow molding, Compression molding, Injection stretch blow molding, Resin transfer molding, Gas and water assisted injection molding and other three dimensional molding.

#### Unit-3 Design and Fabrication of Moulds

Compression moulds: Positive, semi-positive and flash mould with horizontal and vertical flash, arrangement of loading shoes, simple two plate and three-plate moulds, split moulds, Injection moulds : Two plate and three plates types, injection, venting, runner and gates, calculation of number of cavities, hot runner mould, Computer softwares used in designing of molds & mold flow analysis, Transfer moulds: Principles of integral pot, auxiliary ram and separated pot mould, calculation of number of cavities, Extrusion dies: extrusion of simple shapes tubing, cable covering and sheeting dies, Mould fabrication : steels for moulding tools and their treatment include processes used for mould fabrication, finishing processes, Heating systems for plates and moulds, measurement and control of temperature of moulds and dies, simple blow mould, Introduction to computer aided design and software design aspects for moulds and dies

#### Unit-4 Evaluation and Testing of Plastics & Polymers

Thermal properties of polymers, Structural evaluation of polymers, Molecular weight determination, Viscosity of polymer solutions and polymers, Electrical properties, Mechanical properties, Environmental resistance, Optical properties, Fire test, Adhesion test

#### **Text Books**

- 1) Plastic mould engineering handbook by Du Boi's and I. Pribble.
- 2) Plastic moulds and Dies Laszlo Sors.
- 3) Fundamentals of Polymer Processing, S. Middleman, Houghton Mifflin Company
- 4) Handbook of Plastics Analysis, H. Lobo and J. V. Bonilla, Marcel Dekker