TRIPURA UNIVERSITY

MASTER OF TECHNOLOGY (M.TECH.)

IN

CHEMICAL & POLYMER ENGINEERING

CURRICULUM STRUCTURE

FIRST & THIRD SEMESTER: JULY-DEC

SECOND & FOURTH SEMESTER: JAN-JUNE

Tripura University (A Central University)

Suryamaninagar, Agartala, Tripura West-799022

Programme Educational Objectives

The department of Chemical and Polymer Engineering is one of the new teaching departments/schools included under the XII Five Years Plan sanctioned by UGC. This department started functioning in the month of August 2016. The department is offering a 4-semester M.Tech programme with an intake capacity of 15 students with an objective of providing and promoting teaching, industrial consultancy and R&D in the frontier areas of Chemical and Polymer Engineering practice. The course curriculum has been designed taking into consideration the recent developments in the wide areas of chemical and polymer engineering. The Department aims to meet the growing need for well-qualified chemical engineers who will meet the expanding industry's requirements in design, manufacturing, marketing and entrepreneurial segments thereby helping in Nation Building.

Keeping in views the entire scientific and technological development of the student through covering almost all the courses, the M. Tech. in Chemical and Polymer Engineering programme has been designed. The present programme aims to train the students to acquire high level theoretical and experimental knowledge in the direction of technology through learning the designed courses with high quality and significance. However, the main objectives of the programmes are as follows:

- To impart education and training in the fields of Chemical & Polymer Engineering to make the students capable enough to address some of the United Nation's Sustainable Development Goals (UN SDG's) through sustainable and novel research soultions.
- To prepare the students to outshine in academics and research in different motifs of Chemical & Polymer Engineering.
- To train the students with good theoretical and practical knowledge so as to comprehend, analyze, design, and create novel products and solutions for the real life problems.
- To inspire and motivate the students to take laboratory based innovations to the market through various entreprenaaurial development activities.
- To acquire high end industry centric skills in the field of Chemical & Polymer Engineering.
- To provide the knowledge of various new techniques by which the students can lead the cutting edge technologies
- To prepare the competent technologists at national and international level
- To provide students with an academic environment aware of excellence, leadership, written ethical codes and guidelines, and the life-long learning needed for a successful professional career
- To prepare the students with excellent communication skills, capable of communicating effectively in various context, thus sharing new knowledge with other researchers from other institutions, universities and also industrialists
- To develop gender –neutral attitudes and practices; respect for all races, nations, religions, culture, languages and traditions

- To coach students in professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, and an ability to relate the taught subjects to address environmental issues.
- To provide the ideas about environment sustainability and pollution control through exemplary and practical educations
- To impart knowledge of various simulation softwares used in the field of Chemical & Polymer Engineering.
- To prepare Professional Engineer with ethical, social and moral values.

Programme Outcomes

PO1: Knowledge about Technology: Graduates will have an advanced knowledge of fundamental areas of chemical &polymer engineering, such as Heat & Mass Transfer, Advanced Reaction Engineering, Polymer Science & Technology, Rubber Science & Technology etc. and henceforth will be able to solve chemical and polymer engineering problems.

PO2: Planning Abilities: Graduates will be able to communicate ideas, demonstrate efficient planning including time management, resource management and organization skills, reason critically and exercise independence of mind and thought in conducting research.

PO3: Problem analysis ability: Graduates will be able to apply scientific attitude to analyze the society problems and to apply information systematically for the solution. They will have a holistic approach in solving problems and designing systems by applying professional engineering judgment, particularly where there is technical uncertainty and determine process feasibility and viability of the chemical & polymeric processes with respect to economic aspects, environmental safety and social aspects etc.

PO4: Modern Tool usage: Graduates will be able to handle new techniques and advanced tools like DSC, FTIR, FESEM, UVSpectrophotometer etc.

PO5: Leadership Skills: Graduates will be able to have leadership skills with high regard for ethical values and social responsibility through the effective use of flexible CBCS based courses making them elegible to take management related courses.

PO6: Professional Identity: Graduates will be able to show professional identity as competent technologists at national and international level

PO7: Technology and society: Graduates will develop an understanding of how to undertake research, design & development in cutting edge areas, inculcating ethical practices with independent intellectual skill, courage, integrity and sensitive to the social aspects of society.

PO8: Communication: Graduates will possess effective communication skills, teamwork skills, multidisciplinary approach, and an ability to relate their course subjects to address environmental issues.

PO9: Environment and sustainability: Understanding about environment sustainability and pollution control through laboratory practices

PO10: Life-long learning & progression:The graduates will possess the knowledge of contemporary issues and ability to engage in life-long learning of new innovative technologies in chemical/polymer and allied fields and pursue advanced studies.

Curriculum Structure
M.Tech. in Chemical & Polymer Engineering

Total Core (C) Credits: 60, Total Elective (E) Credits: 20, Total Credits: 80

M.Tech. First (1st) Semester – 600 Marks (C credits: 16; E credits: 8)							
Theory Papers (Code)	**Paper Name**	**Credit Distribution**			**Total Credit**	**Marks**	**Remarks**
		L	**T**	**P**			
CP 901C	Advanced Reaction Engineering	4	0	0	4	100	C: Core Course
CP 902C	Polymer Science and Technology	4	0	0	4	100	
CP 903C	Heat and Mass Transfer	4	0	0	4	100	
CP 906E	Rubber Science and Technology	4	0	0	4	100	E: Elective Course (students to select anyone from the list)
CP 907E	Colloids and Interface Science	4	0	0	4	100	
CP 909E	Polymer Composites	4	0	0	4	100	
Elective from another department	-	4	0	0	4	100	Mandatory course for M.Tech. students
Practical Papers (Code)	**Paper Name**	**Credit Distribution**			**Total Credit**	**Marks**	**Remarks**
CP 904C	Polymer Lab	0	0	2	2	50	
CP 905C	Reaction Engineering Lab	0	0	2	2	50	
SUB TOTAL		**20**	**0**	**4**	**24**	**600**	
M.Tech. Second (2nd) Semester – 600 Marks (C credits: 12; E credits: 12)							
Theory Papers (Code)	**Paper Name**	**Credit Distribution**			**Total Credit**	**Marks**	**Remarks**
		L	**T**	**P**			
CP 1002C	Polymer Characterization and Testing	4	0	0	4	100	C: Core Course
CP 1004C	Fluidization Engineering	4	0	0	4	100	
CP 1004E	Polymer Processing	4	0	0	4	100	
CP 1007E	Advanced Fluid Flow Rheology	4	0	0	4	100	E: Elective Course (students to select anyone from the list
CP 1008E	Membrane Science and Technology	4	0	0	4	100	
Offered by University centrally	Computer Skill-III	4	0	0	4	100	Mandatory course for M.Tech. students
Practical Papers (Code)	**Paper Name**	**Credit Distribution**			**Total Credit**	**Marks**	**Remarks**
CP 1003C	Polymer Characterization Lab	0	0	2	2	50	

Theory Papers (Code)	Paper Name	Credit Distribution			Total Credit	Marks	Remarks
		L	T	P			
CP 1005C	Fluidization Engineering lab	0	0	2	2	50	
SUB TOTAL		**20**	**0**	**4**	**24**	**600**	
M.Tech. Third (3rd) Semester – 400 Marks (C credits: 16)							
Theory Papers (Code)	**Paper Name**	**Credit Distribution**			**Total Credit**	**Marks**	**Remarks**
		L	**T**	**P**			
CP 1103C	Research Methodology	4	0	0	4	100	
CP 1104C	Project Part-I	0	0	12	12	300	Semester project progress report (150 marks), seminar, and Viva-Voce (150 marks)
SUB TOTAL		**4**	**0**	**12**	**16**	**400**	
M.Tech. Fourth (4th) Semester – 400 Marks (C credits: 16)							
Theory Papers (Code)	**Paper Name**	**Credit Distribution**			**Total Credit**	**Marks**	**Remarks**
		L	**T**	**P**			
CP 1203C	Project Part-II	0	0	16	16	400	M.Tech. final thesis (200 marks), Comprehensive seminar and Viva-Voce (200 marks)
SUB TOTAL		**0**	**0**	**16**	**16**	**400**	
AGGREGATE (Entire Duration of M.Tech.)		**44**	**0**	**36**	**80**	**2000**	

*** L - Lecture hrs/week T - Tutorial hrs/week P-Project/Practical/Lab/All other non-classroom academic activities, etc. hrs/week C - Credit Points of the Course E- Elective Points of the Course**

Evaluation Scheme for Theory Courses:

Internal Exam	End Semester Exam	Total
30 marks	70 Marks	100 Marks

*For laboratory and all non classroom activities (project, dissertation, presentation seminar, viva voce etc.), the Internal and End-semester assessment breakup shall not exist. Students will be graded on the total marks allocated to the respective project/presentation seminar/presentation etc.

LEARNING OUTCOMES
M.Tech. 1st Semester

Course Code	Name of the Course	Credit Distribution			Total Credit	Marks
		L	T	P		
CP 901C	**Advanced Reaction Engineering**	**4**	**0**	**0**	**4**	**100**

At the end of the course student will be able to:

1. Understand and analyze the various steady and unsteady reactors
2. Design experiments involving chemical reactors, and analyzing and interpreting data
3. Develop the performance equations and solve problems
4. Scale up of the reactors suiting industrial needs
5. Incorporate catalysts and non catalysts in industrial and non-industrial problems
6. Understand mechanism and mathematical modeling of different types of polymerization reactors
7. Understand and solve problems related to flow through porous media and gas soild fluid beds

Course Contents:

Kinetics of Homogenous reactions: Introduction and overview of reaction engineering, the kinetics of homogenous reactions, kinetic models

Stoichiometry and introduction to batch reactors: Stoichiometric considerations for constant and variable volume batch systems, analysis of batch reactor kinetic data, integral and differential method of analysis of batch data

Design for single reactors: Introduction and ideal batch reactor design, ideal mixed flow reactor design, ideal plug flow reactor design, recycle reactor design, reactor size comparisons

Reactor design for multiple reactions: Design for parallel reactors, design for series reactors

Non-ideal reactor design: Non-ideal reactors and Residence Time Distribution, RTD measurements, reactor modeling, Solid Non-Catalytic Reactions, The shrinking Core Model, Case of Pseudo steady-state hypothesis & ash diffusion control

Advanced reactor processes and fundamentals: Design for polymerization reactors, reaction through porous media, application to gas-solid reactions in fluid beds.

Recommended Books:

1. H. Scot Folger: Elements of Chemical reaction engineering Prentice Hall, second edition. 1986.
2. J.M. Smith: Chemical Engineering Kinetics, McGraw Hill, Third Edition, 1981.

3. O Levenspiel: Chemical Reaction Engineering, Wiley 1997.

CP 902C	Polymer Science and Technology	4	0	0	4	100

At the end of the course student will be able to:

1. Establish the understanding of fundamental principles of Polymer Science directly and provide a broad background on polymer science and technology.
2. Furnishes knowledge and understanding of polymer chemical structures, their physical properties, processing methods and ultimate applications.
3. Imparts the awareness of recent advances in polymer material synthesis, current research interest, and novel concepts in polymer technology.
4. Enhances the ability to identify suitable polymer(s) for a given application.
5. Better understanding of the properties of a polymer by relating them to its structure.

Course Contents:

Basic concepts and definitions: monomer, polymer, oligomer, repeating units, structural units, degree of polymerization, molecular weight.

Classification of polymers: natural vs. synthetic, linear, branched, cross-linked, amorphous, crystalline, thermoset, thermoplastic, homopolymer, co-polymer, fiber, plastics, elastomers.

Biopolymers, natural polymers, and fibers: proteins, polynucleotides, polysaccharides, naturally Occurring elastomers, natural and synthetic fibers, cellulosic, non-cellulosic.

Polymerization mechanism: introduction, chain polymerization, step polymerization, ionic and coordination polymerization, ring-opening polymerization.

Thermal transition in polymer: introduction, the glass transition temperature, molecular motion and glass transition, theories of glass transition and measurement of the glass transition temperature, factors affecting glass transition temperature, the crystalline melting point and the factors affecting the crystalline melting point.

Polymer additives and reinforcements: introduction, plasticizers, fillers, and reinforcements, alloys and blends, antioxidants, thermal and UV stabilizers, flame-retardants, colorants, antistatic agents.

Mechanical properties of polymers: introduction, mechanical test (stress–strain, creep, stress relaxation, dynamic mechanical, and impact experiments), stress–strain behavior of polymers, deformation of solid polymers, effects of structural and environmental factors on mechanical properties, polymer fracture behavior.

Polymer degradation and the environment: thermal degradation, oxidative and UV stability, chemical and hydrolytic stability, effects of radiation, mechanodegradation, management of plastics in the environment (recycling, incineration, biodegradation).

Recommended Books:

1. Principles of Polymerization, G. Odian (Wiley, London, 2004)
2. Polymer Science and Technology of Plastics and Rubber, P. Ghosh, Tata McGraw Hill, NewDelhi, 2000.
3. Principles of Polymer Science, by Bahadur and Sastry, Narosa Publishing House 2002.
4. Textbook of Polymer Science, P. Nayak, and S. Lenka, Kalyani Publishers, 1986.
5. Polymer Science and Technology by J. R. Fried, Prentice-Hall, Inc 1995.
6. Textbook of Polymer Science and Engg., Anil Kumar and Gupta, Tata McGraw-Hill Publishing co, Ltd, 1978.
7. Plastics Materials J. A. Brydson, Butterworth Scientific, 1990.

CP 903C	Heat and Mass Transfer	4	0	0	4	100

At the end of the course student will be able to:

1. Understand the basic modes of heat and mass transfer.
2. Apply principles of heat and mass transfer to predict transfer coefficients
3. Analyze working of various heat transfer equipment
4. Ability to design and analyze the performance of heat exchangers and evaporators
5. Design heat and mass transfer equipment.
6. Ability to design and analyze reactor heating and cooling systems
7. Students will learn about the diffusional mass transfer
8. Operation of mass transfer equipments will be understood

Course Contents:

Basics of heat transfer, modes of heat transfer and its defining equations, heat conduction through plane walls, hollow cylinder, hollow sphere and their three dimensional equations, combined modes of heat transfer, critical thickness of insulation, finite difference method for steady and unsteady conduction, heat transfer through extended surfaces, heat transfer through non-Newtonian fluids, concept of boundary layers, dimensionless numbers and their physical significance, free and forced convection, Boiling heat transfer, heat exchangers and its types, analogy of heat exchangers, heat exchanger design, radiation heat transfer, various radiation laws, Angle factor calculations, basics of mass transfer, diffusion, convective mass transfer, mass transfer theories, influence of turbulence on heat and mass transfer, mass transfer coefficients, absorption, distillation, humidification and air conditioning.

Recommended Books:

1. JP Holman: Heat Transfer, McGraw-Hill, New York.
2. Yunus A. Cengel: Heat Transfer - A Practical Approach, McGraw-Hill, New York.
3. M. NecatiOzisik: Boundary Value Problems of Heat Conduction; Dover Publications, New York.

4. P. S. Ghoshdastidar; Heat Transfer, Oxford University Press, UK.
5. Crank, J., and Park, G.S. (eds.), Diffusion in Polymers, Academic Press, New York (1968).
6. Richard G. Griskey, Mass Transfer in Polymer Systems, Springer.
7. Kreith, F, Boehm R.F, Heat and Mass Transfer, CRC Press.
8. Baehr HD, Stephan K, Heat and Mass Transfer, Springer

CP 906E	**Rubber Science and Technology**	**4**	**0**	**0**	**4**	**100**

At the end of the course student will be able to:

1. Acquaint with rubber trees, their availability, latex extraction, and latex purification methods.
2. Couse will enhance the knowledge of various kinds of rubbers and their properties
3. Students will be familiarized with rubber vulcanization, rubber compounding, and different rubber processing methods.
4. A better understanding of rubber testing equipment and methods.

Course Contents:

Natural Rubber: source, isolation, and processing of latex, various natural rubber grades and products, Chemistry of rubber and rubber additives, Compounding and Vulcanization mechanism, the chemistry of Vulcanization, Degradation and aging of rubber, modification of rubber, theory of rubber elasticity, Rubber reinforcement.

Synthetic rubbers: SBR, NBR, IR, IIR, CR, EPR, EPDM, Hypalon, floroelastomers, silicones, Thermoplastics, elastomers, structure-property applications, Polyesters and ester urethane or ether-urethane rubbers, Rheometry and curometry, assessment of curing/degree of cure, rubber additives, Sulphur vulcanization vs. non-Sulphur Vulcanization, cold curing, Copolymer composition determination through NMR.

Manufacturing of tyres and tubes: tyres manufacturing and compounding, basic design and reinforcing systems, testing and analysis.

Other rubber products: shoes, belting and hoses, cables, and tubes, etc.

Recommended Books:

1. Erman, B. Mark, J.E. Science, and Technology of Rubber (Academic Press, Florida, 2005).

2. EIRI Board, Technology of Rubber & Rubber Goods Industries (Engineers India Research
Institute, New Delhi, 2009).
3. Kothandaraman, B. Rubber Materials (Ane Books Pvt Ltd, New Delhi, 2008).
4. M. Morton, Rubber Technology, Van Nostrand Reinhold, 1987.

CP 907E	**Colloids and Interface Science**	**4**	**0**	**0**	**4**	**100**

At the end of the course student will be able to:

1. Understand the fundamental aspects of colloidal suspensions, surface tension, wetting, surfactant adsorption, selfassembly, and interparticle interactions, as well as the importance of these phenomena to consumer, industrial, and biomedical applications.
2. Students will gain familiarity with current literature via reading and analysis of journal articles targeted in a research area picked by the student; this exercise may culminate in a final project.

<u>Course Contents:</u>

Basic concepts of colloids and interfaces; properties of colloidal dispersions; surfactants and their properties; micelles, bilayers, vesicles and liquid crystals; surface and interfacial tension; Young-Laplace equation; Kelvin equation; contact angle; intermolecular and surface forces; DLVO theory; adsorption at interfaces; characterization of solid surfaces; applications in detergents, nanotechnology, and petroleum and polymer industries.

Recommended Books:

1. P. C. Hiemenz and R. Rajagopalan, Principles of Colloid and Surface Chemistry, Marcel Dekker,
New York, 1997.
2. J. C. Berg, An Introduction to Interfaces and Colloids: The Bridge to Nanoscience, World Scientific, Singapore, 2010.
3. P. Ghosh, Colloid and Interface Science, PHI Learning, New Delhi, 2009.

CP 909E	**Polymer Composites**	**4**	**0**	**0**	**4**	**100**

At the end of the course:

1. Students will be familiarized with different polymer-matrix composites, their applications, and reinforcement mechanisms.

2. A better understanding of the significance of composites as an essential class of materials for various applications.
3. Enhance the knowledge on manufacturing and testing methods of composites.
4. Students will be able to predict the appropriate characterization methods for different classes of composites.

Course Contents:

Introduction: advantages and characteristics of composites. Classification: particulate, fibrous, laminated, and hybrid composites. Additives for Composites: Catalysts, Accelerators, Coupling Agents, Fillers, Toughening Agents.

Composite matrix materials: classification and matrix resins (unsaturated polyester, vinyl ester, epoxy, phenol formaldehyde, urea formaldehyde, melamine formaldehyde resin, their properties and applications.

Reinforcement materials: glass fibers, woven and non-woven fabrics, boron fibers, carbon fibers, aramid fibers, natural fibers. Their impact and properties.

Processing, testing, and applications of composites. Smart polymers, composites materials, and structures. Applications of smart materials.

Recommended Books:

1. Advanced Polymer composites, Jang, ASM International, USA, 1994.
2. Experimental Characterization of advanced composite materials, Donald F. Adams, Leif Carlsson A Carlsson, R. Byron Pipes, Third Edition, CRC Press, 2002.
3. Handbook of Composites, George Lubin, Stanley T. Peters, Chapman & Hall, 1998.
4. Polymer Composites, M.C. Gupta and A.P. Gupta, New Age International Publishers, 2007.
5. Composite Materials: Processing, fabrication, and applications, Mel M. Schwartz, Prentice Hall PTR, 1997.

CP 904C	**Polymer Lab**	**0**	**0**	**2**	**2**	**50**

At the end of the course:

1. Students will understand and synthesize polymers using techniques such as free radical, emulsion, suspension polymerization, etc.
2. They will be able to correlate the structure-property relationship of polymers and their specific applications.

Course Contents:

- Purification of monomers/solvent by distillation, crystallization of initiators, Free radical Polymerization of MMA, MA, AA using BPO/AIBN initiators.
- Synthesis of phenol-formaldehyde (novolac and resole) resin, cross-linking of Phenolic resin, synthesis of poly (ethylene/terephthalate), synthesis of nylon-6,6.
- Polymer end group analysis, determination of intrinsic viscosity and viscosity-average the molecular weight of a given polymer sample, determination of number average the molecular weight of a given polymer by vapor pressure osmometry, determination of molecular weight distribution by GPC.
- Characterization of selected polymer sample by IR Spectrophotometer.
- Determination of molecular weight & polydispersity index (PDI) of given resin using GPC.
- Determination of moisture content of given sample. (Quantitative analysis).

Recommended Books:

1. Purification of Laboratory Chemicals, Armarego, W.L.F. Chai, C.L.L., Elsevier, Burlington,2009.
2. Experimental Methods in Polymer Science, Tanaka, T., Academic Press, Florida, 2000.
3. Experiments in Polymer Science, Collins, E.A. Bares, J. Billmeyer, Jr., F.W., (Wiley, NewYork, 1973).
4. Laboratory Preparation for Macromolecular Chemistry, McCaffery, E.M., McGraw-Hill, New York, 1970.
5. Methods of Polymers Chemistry, Sorensen, W.R. Campbell, T.W. Preparative, Wiley, NewYork, 1968).
6. Polymer Chemistry: A Practical Approach, Davis, F.J., Oxford, London, 2004.

CP 905C	Reaction Engineering Lab	0	0	2	2	50

At the end of the course student.

1. Demonstrate understanding of the basic concepts involved in data collection from lab scale reactors
2. Develop rate laws for homogenous reactions.
3. Understand the kinetics involved.
4. Determine optimal reactor configurations and operating policies for systems involving single reaction.
5. Understand to represent flow in real vessels for scale up.

Course Contents:

1. Interpretationofbatchreactordata.
2. Tostudythekineticsof the liquid-phaseirreversiblereactioninabatchreactor.
3. Tostudythekineticsof the liquid-phasereversiblereactionin a batchreactor.

4. ConversationinCSTR.
5. ConversationinPFR.

Recommended Books:

1. Biochemical Engineering and Biotechnology, Ghasem D. Najafpour, Elsevier, Amsterdam, The Netherlands.
2. Bioprocess Engineering Principles, Pauline M. Doran, Academic Press, California. Elsevier India Private Limited, New Delhi.
3. Bioprocess Monitoring and Control,By Marie- Noelle Pons, Hanser Publishers New York, USA.
4. Biochemical Engineering By J.M. Lee, Prentice Hall, Englewood Cliffs, New Jersey.
5. Biochemical Engineering, 2nd Edition, By S. Aiba, A.E. Humphrey & N.F. Millis, University of Tokyo Press, Japan.
6. Biochemical Engineering Fundamentals 2nd Edition, By J.E. Bailey, D.F. Ollis, McGraw Hill Book Company, New Delhi.

SUB TOTAL	20	0	4	24	600

M.Tech. 2ndSemester

Course Code	Name of the Course	Credit Distribution			Total Credit	Marks
		L	T	P		
CP 1002C	Polymer Characterization and Testing	4	0	0	4	100

At the end of the course:

1. Students will be familiarized with different polymer characterized techniques such as DSC, TGA, SEM, FTIR, NMR, etc.
2. They will be able to identify a polymer structure and their other properties such as optical, morphological, chemical, mechanical properties, etc.
3. Understanding and importance of sample preparation methods and sample handling.
4. It will enhance the ability to analyze the data obtained from the characterization techniques.

Course Contents:

Introduction: Polymer solution thermodynamics, molecular weight, weight distribution, molecular dimensions end group analysis, osmometry, light scattering, viscometry, and gel permeation chromatography.Infra-red, UV-Vis, Raman spectroscopy techniques and nuclear magnetic resonance (NMR).

Microscopy techniques: optical, scanning electron microscope (SEM) and transmission electron microscope (TEM).

Scattering Techniques: X-Ray diffraction, small angle light scattering.

Thermal analysis: differential scanning calorimetry (DSC), differential thermal analysis (DTA), thermogravimetric analysis (TGA).

Mechanical analysis: tensile, compressive, impact, flexural etc., testing. Dynamic mechanical analysis (DMA), rheometer.

Particle size analysis: laser diffraction, dynamic light scattering, image particle analysis, acoustic spectroscopy.

Recommended Books:

1. Introduction to polymers, Young & Lovell, Nelson Thrones.
2. Thermal analysis of polymer materials, Wunderlich, springer.
3. Handbook of plastic technology, Allen & Baker, CBS publication.
4. Handbook of Plastics Testing and Failure Analysis, Vishu Shah, 3rd Edition, John-Willey &Sons, New York, 2007.
5. Testing and Evaluation of Plastics, A. B. Mathur, I. S. Bharadwaj, Allied Publishers Pvt. Ltd., New Delhi, 2003.
6. Handbook of Plastic test methods, Iver, Mead and Riley, Illith Publishers, New York, 1982.

CP 1004C	Fluidization Engineering	4	0	0	4	100

At the end of the course studentwill be able to:

1. Understand the fluidization phenomena and operational regimes.
2. Design various types of gas distributors for fluidized beds and determine effectiveness of gas mixing at the bottom region.
3. Analyze fluidized bed behavior with respect to various hydrodynamic bed properties.
4. Develop and solve mathematical models of the fluidized bed.

<u>Course Contents:</u>

Introduction to fluidization, types of fluidization, fluidized bed behavior study, solid transport in fluidized bed, heat and mass transfer in fluidized bed, semi-fluidization principles, industrialapplications of fluidization, design of fluidized bed reactor, Concept of RTD, Basic designprinciples for Fluidized bed reactor, use of fluidized bed reactors in polymer industries (catalyticolefin polymerization, polymerization reaction of ethylene and propylene etc.), FluidizedBedDryer (FBD)- Introduction, advantages and limitations of FBD, mathematical models, effect ofoperating parameters of FBD, design procedure of FBD.

Recommended Books:

1. Kunni&Levenspiel: Fluidization Engineering, Elsevier Publications.
2. W.C. Yang: Handbook of fluidization and fluid particle systems, Marcel Dekker, New York.
3. J. F. Davidson, D. Harrison; Fluidized Particles, Cambridge University Press, Cambridge.

CP 1004E	Polymer Processing	4	0	0	4	100

At the end of the course:

1. Students will learn about the polymer processing methods and the effect of rheology in the polymer processing of various polymers.
2. Understanding of molding extrusion processes along with different screws and flow analysis involved in this process.
3. The process variables & their importance and understanding the concept of thermoset injection molding & reaction injection molding.
4. The concepts of thermoforming process, its types, process variable involved, etc.
5. The subject also imparts knowledge of post-molding operations like printing and other decorative methods.

<u>Course Contents:</u>

Introduction of processing of thermoplastics, thermosets, and rubbers. Principle and theories of polymer processing.

Basic Concept of Compounding and Processing. Classification and type of Additive for Plastics: antioxidants, light stabilizers, UV stabilizers, lubricants and relative auxiliaries, processing aids,impact modifiers, flame retardance, fillers, crosslinking agents, antistatic agents, stabilizers and Plasticizers. Rheology of the polymer melt. Mixing process: distributive mixing, dispersive mixing,
and mixing devices.

Extrusion: single and twin-screw extruders and their working principles. Calendering and milling.

Molding: injection molding, extrusion molding, compression molding, transfer molding, reaction injection molding (RIM), blow molding, rotational molding.

Fiber technology and processing: definition of textile terms, properties of textile fibers (electric,mechanical and fabric properties). Fiber spinning: melt spinning, dry spinning, and wetspinning. Fiber after treatments scouring, lubrication, sizing, dyeing, finishing.

Elastomers technology and processing: Compounding and elastomers properties, Vulcanization: chemistry of Vulcanization, sulfur vulcanization, physical aspects of Vulcanization. Reinforcement, types of fillers, carbon black.

Recommended Books:

1. Plastics Engineering by R. J. Crawford Pergamon Press 1989.
2. Understanding Compounding, R. H. Wildi, and Maier, Hanser Publisher Inc, 1998.
3. Fundamental of Polymer processing, S. Middleman, Houghton Mifflin Company, 1997.
4. Polymer Processing Fundamentals, Osswald, A. Tim, Hanser Publishers, 1998.
5. Principles of Polymer Processing, Tadmor, Z. Gogos, G.G., Wiley, New York, 2006.
6. Polymer Process Engineering, Grulke, E.A., PTR Prentice-Hall, Eaglewood Chiffs, New Jersey, 1994.
7. Advances in Polymer Processing: Macro to Nano Scales, Thomas, S. Yang, W., CRC press,
   Boca Raton, 2007.
8. Principles of Polymer Engineering, Mccrum, N.G. Buckley, C.P Bucknell, C.P, Oxford Engineering Press, Oxford, London, 1988.
9. Rheology and Processing of Polymeric Materials: Polymer Rheology, Han, C.D., Oxford.

CP 1007E	Advanced Fluid Flow Rheology	4	0	0	4	100

At the end of the course student will be able to:

1. Understand the fundamental underlying fluid mechanical principles and application of those principles to solve real life problems
2. Derive some of the governing equations
3. Have a strong fundamental understanding of the basic principles of Fluid Mechanics and will be able to apply the basic principles to analyze fluid mechanical systems.
4. Understand the rheology of fluids and some of its underlying characterization techniques.

<u>Course Contents:</u>

Basic Concepts and Fundamentals: Definition and properties of fluids, fluid as a continuum, Langragian and Eulerian description, Velocity and stress field, Fluid statics, Fluid Kinematics. Study of Newtonian and Non-Newtonian fluids.

Governing Equations of Fluid Motion: Reynolds transport theorem, Integral and differential forms of governing equations: mass, momentum and energy conservation equations, NavierStokes equations, Euler's equation, Bernoulli's Equation.

Exact solutions of Navier-Stokes Equations: Couette flows, Poiseuille flows, Fully developed flows in non-circular cross-sections, Unsteady flows, Creeping flows.

Laminar Boundary Layers: Boundary layer equations, Boundary layer thickness, Boundary layer on a flat plate, similarity solutions, Integral form of boundary layer equations, Approximate Methods, Flow separation, Entry flow into a duct. Turbulent Flow: Introduction, Fluctuations and time-averaging, General equations of turbulent flow, Turbulent boundary layer equation, Flat plate turbulent boundary layer, Turbulent pipe flow, Prandtl mixing hypothesis, Turbulence modeling, Free turbulent flows.

Rheometry: Introduction, principles of viscometry, Rheometers and rheometrical procedures,Typical rheological behaviors, problems encountered in rheometry, Non-standard techniques:what can be done without a rheometer.

Recommended Books:

1. Morrison, F.A. 2001 *Understanding Rheology*. New York: Oxford University Press.
2. Batchelor G.K, An Introduction to Fluid Dynamics, Cambridge University Press, 1983.
3. Fox W. Robert, McDonald T. Alan, Introduction to Fluid Mechanics, Fourth Edition, John Wiley & Sons, 1995.
4. Frank M. White, Fluid Mechanics, Tata McGraw-Hill, Singapore, Sixth Edition, 2008.
5. Barnes, H.A., Hutton, J.F., Walters, K.: An Introduction to Rheology. Rheology series, Vol.
   3, Elsevier, 1989. F. Irgens: Compendium.
6. Bird, R.B., Armstrong, R.C. &Hassager, O. 1987 Dynamics of Polymeric Liquids. New York: John Wiley & Sons.

CP 1008E	Membrane Science and Technology	4	0	0	4	100

At the end of the course student will be able to:

1. Know the different types of organic and inorganic membranes along with their properties and preparation methods
2. Understand application of different models for the calculation of membrane flux, extent of separation, and concentration polarization for various membrane systems etc.
3. Characterize membranes using various analytical and non analytical techniques
4. Explore various advancement of membrane techniques to solve environmental problems.

Course Contents:

Overview and membrane materials: Separation processes, membrane development, membrane definition & types, membrane processes & classifications, Advantages, Disadvantages and Classifications of membranes, Polymer basics & polymers used in membrane preparation and their properties.

Membrane material properties: Materials for membrane preparation, associated advantages and disadvantages, membrane modules & selection, flow types

Membrane preparation methods: Preparation of synthetic membrane, phase inversion membranes, composite membranes, inorganic membranes, porous and non-porous membranes

Various membrane filtration technologies: Transport through porous and non-porous membranes, concept of osmosis & reverse osmosis, understanding MF/UF/NF/RO processes, advantages & disadvantages for membrane processes, advanced membrane separation processes, problems and solutions based on membrane processes

Membrane characterization: Concepts of membrane characterization, advanced membrane characterization concepts using various analytical and sophisticated techniques such as SEM/FESEM, BET, FTIR etc.

Recommended Books:

1. M. H. Mulder, Basic Principles of Membrane Technology,Springer, 2004
2. B. K. Dutta, Mass Transfer and Separation Processes, PHI,2007.
3. K. Nath, Membrane Separation Processes, PHI, 2008.

CP 1003C	**Polymer Characterization Lab**	**0**	**0**	**2**	**2**	**50**

At the end of the course:

1. Students will learn analysis of the thermal properties of the polymers using DSC, TGA, and other thermal techniques.
2. Morphology of polymers using microscopic techniques such as SEM, TEN, etc.
3. Hand-on experience on other polymer characterization techniques.

Course Contents:

- Determination of melt flow index (MFI) of given sample.
- Curing characteristic studies of different rubbers using different compounding ingredients byRheometer.

- Thermal analysis of polymers by DSC, TGA, DMA.
- Study rheological properties of polymers by rheometer.
- Determination of stress-strain profile of polymers, determination of tensile strength, modulus and elongation at break of selected thermoplastics and natural rubber, determination of impact strength, dielectric constant.

Recommended Books:

1. Modern Technology of Plastic & Polymer Processing Industries, NIIR Board, National Institute of Industrial Research, New Delhi, 2007).
2. Polymer Testing, Grellmann, W. Seidler, S. Altstadt, V., Hanser Gardner PUBNS, Cincinnati, 2007.

CP 1005C	**Fluidization Engineering lab**	**0**	**0**	**2**	**2**	**50**

At the end of the course student will be able to:

1. Know the handling of gas-soild lab scale based fluidized bed reactors
2. Evaluate the observable hydrodynamic behaviour of gas-solid fluidized beds
3. Gain experience in the scaling up of fluidized bed reactors.

Course Contents:

- Comparison of pressure drop profile for a Packed Bed and fluidized bed
- Experiment on fluidization techniques and determination of (a) Minimum fluidization velocity; (b) Pressure drop profile
- Visualization of different types of fluidization.
- Estimating the fluidization index

Recommended Books:

1. Fluidization Engineering, 2nd ed. by D Kunii and O Leven spiel, Butterworth Heinemann.
2. Handbook of Fluidization and Fluid-Particle Systems by W C Yang, CRC Press.
3. Fluidization by M Leva, McGraw-Hill.
4. Fluidization by J F Davidson and D Harrison, Academic Press.

SUB TOTAL	**20**	**0**	**4**	**24**	**600**

M.Tech. 3rd Semester

Course Code	Name of the Course	Credit Distribution			Total Credit	Marks
		L	T	P		
CP 1103C	**Research Methodology**	**4**	**0**	**0**	**4**	**100**

At the end of the course:

1. Students will understand the processes by which the Research has been conducted.
2. It will help in minimizing the mistakes commonly made during the Research.
3. Create a positive attitude towards Research.

Course Contents:

Experimental in chemical and polymer research: laboratory formalities, instruments handling and maintenance, laboratory safety, and troubleshooting; Materials Science research: development of a research idea, methods to perform experiments, data collections, errors in data collections, interpretation of results, and related discussions, reproducibility of data.

Preparation of research reports/manuscript: authorship, graphical abstract, introduction, experimental/computational methods, results and discussion,conclusions.

Few important sections in Chemical and Polymer research: acknowledgment, conflict of interest, copyright, ethics of research and publications; Patents; Post-publication: citation of an article, the researcher's profile, communication with scientist, and collaboration.

Recommended Books:

1. C.R. Kothari, Research Methodology Methods and Techniques, 2/e, Vishwa Prakashan, 2006.
2. Donald H.McBurney, Research Methods, 5th Edition, Thomson Learning, ISBN:81- 315-0047-0,2006.

CP 1104C	**Project Part-I**	**0**	**0**	**12**	**12**	**300**
SUB TOTAL		**4**	**0**	**12**	**16**	**400**

M.Tech. 4th Semester

Course Code	Name of the Course	Credit Distribution			Total Credit	Marks
		L	T	P		
CP 1203C	Project Part-II	0	0	16	16	400
SUB TOTAL		**0**	**0**	**16**	**16**	**400**

	L	T	P	Total Credit	Marks
AGGREGATE (Entire Duration of M.Tech.)	**44**	**0**	**36**	**80**	**2000**