INDEX

FACULTY OF SCIENCE
(POLYMER SCIENCE)
SEMESTER – II

B.SC. (Hons.) Polymer Science

DISCIPLINE SPECIFIC CORE COURSE – 4: CHEMISTRY AND ENGINEERING OF POLYMER REACTIONS (CEPR)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
CHEMISTRY AND ENGINEERING OF POLYMER REACTIONS (CEPR)	4	3	0	1	12th with PCM	--

Learning Objectives

The Learning Objectives of this course are as follows:

- To learn about the different polymerizations
- To study kinetics of chain growth and step growth polymerization
- To understand general concepts, principles, kinetics and methodology of polymerization

Learning outcomes

The Learning Outcomes of this course are as follows:

- Know about overview of aspects of polymer engineering
- Understand essential fundamentals and chemistry of the polymerization processes.
- Learn about various terms such as reaction initiation, propagation and termination

SYLLABUS OF DSC-4

UNIT – I (2 Weeks)

INTRODUCTION

Introduction to polymerization process, control of polymer synthesis; thermodynamic and kinetic control, diffusion control, polymer end chain control & control strategies, Introduction to reactor design, Interpretation of batch reactor data; design equations for ideal reactors, namely batch, CSTR, plug flow, design equation for single reaction systems using batch and semi batch, CSTR, PFR, Multiple reactor system; reactor in series and parallel, preference of type of reactor used

UNIT – II (3 Weeks)

RADICAL CHAIN POLYMERIZATION

Introduction, thermodynamic and kinetic aspect of radical chain polymerization, rate of polymerization, kinetic chain length, Mayo's equation, cage efficiency, selection criteria of initiators, ceiling temperature, Tromsdorff effect, inhibition and retardation Ziegler-Natta catalyst and stereoregular polymerizations, Radical chain copolymerization (reactivity ratio, copolymer equations)

UNIT – III (2 Weeks)

REDOX & OTHER INITIATIONS

Initiation in aqueous media, initiation in non-aqueous media, rate of redox polymerization, photochemical initiation, rate of photo-polymerization, initiation by ionizing radiation, electrolytic polymerization, plasma polymerization.

UNIT – IV (3 Weeks)

IONIC CHAIN & CONTROLLED POLYMERIZATIONS

Classification of ionic species, effect of solvents, initiation, propagation and termination in ionic polymerization, cationic polymerization, anionic polymerization, introduction of Atom Transfer Radical Polymerization (ATRP), Reversible Addition-Fragmentation Chain Transfer Polymerization (RAFT) and Nitroxide mediated polymerization (NMP)

UNIT – V (3 Weeks)

STEP GROWTH POLYMERIZATION

Reaction engineering of step growth polymerization: basic properties & examples of commercially important polymers, reactivity of functional groups kinetics of step polymerization, self-catalyzed & external catalysis of polymerization, molecular weight distribution in linear & nonlinear polymerization, effect of non-equivalence of functional groups, equilibrium considerations,

UNIT – VI (2 Weeks)

POLYMERIZATION TECHNIQUES

Bulk, solution, precipitation, suspension & emulsion polymerization.

Practical component-

- To prepare polystyrene/poly(methyl methacrylate) by bulk polymerization and determine the rate of polymerization.
- To study the effect of reaction temperature on free radical polymerization of styrene/MMA.
- To study the effect on initiator concentration of free radical polymerization of styrene/MMA.
- Redox initiated polymerization of MMA & investigate the effect of viscosity on polymerization kinetics
- Redox polymerization of acrylamide
- To investigate Trommsdorff effect in bulk polymerization of MMA
- Solution polymerization of methyl methacrylate/styrene.
- Suspension polymerization of styrene/MMA.
- Emulsion polymerization of styrene/ methyl methacrylate.
- Preparation of Poly (vinyl butyral).

Essential/recommended readings

- Odian, G., (2004) Principles of Polymerization, Wiley-interscience.
- Billmeyer F.A., (2011) Textbook of Polymer Science, John-Wiley & Sons.
- Seymour R.B., Carraher C.E., (2003) Polymer Chemistry, Marcel Dekker.
- Flory P.J., (2007) Principles of Polymer Chemistry, Asian Books Private Limited.
- Levenspiel, O. (1998). Chemical reaction engineering. John Wiley & Sons.

Suggestive readings

- Brydson J.A., (2016) Plastics Materials, Butterworth Heinemann, 8th Edition.
- Lenz, R. W. (1967). Organic chemistry of synthetic high polymers.
- Gowarikar V.R., (2019) Polymer Science, New Age International Publishers Ltd, 3rd Edition

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 5: POLYMER RHEOLOGY (PR)

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
POLYMER RHEOLOGY (PR)	4	3	0	1	12th with PCM	---

Learning Objectives

The Learning Objectives of this course are as follows:

- To enhance fundamental knowledge of flow behaviour of polymer melts
- To understand the concept of mixing of polymers

Learning outcomes

The Learning Outcomes of this course are as follows:

- Apply the knowledge of measurement of viscosity in handling of rheological instruments
- Interpret rheology of polymer melts by mechanical models

SYLLABUS OF DSC- 5

UNIT – I (4 Weeks)

RHEOLOGICAL PRINCIPLES

Viscosity and polymer processing, rheological properties of fluids, shear stress in polymers, Newtonian & non-Newtonian flow, polymer melt viscosities (ideal molten chains, microscopic studies of melts), flow in channels, simple shear flow, melt-flow index, Weissenberg effect, die swell, melt fracture, creep & creep compliance, stress relaxation, isochronous stress-strain curves

UNIT – II (5 Weeks)

MELT FLOW ANALYSIS

Types of fluid & rheological models, rheological measurements by capillary, parallel plate and cone & plate viscometers, simple elongational flow and its significance, dynamic flow behavior, time dependent fluid behavior

UNIT – III (3 Weeks)

RHEOLOGICAL MODELS

The elastic and viscoelastic state of polymers – viscoelasticity, viscoelastic models: Maxwell model, Voigt-Kelvin model, Boltzmann superposition principle, dynamic mechanical testing

UNIT – IV (3 Weeks)

MIXING OF POLYMERS

Types of mixing, concept and importance of master batches, mixing of additives with the polymers, melt compounding

Practical component-

- Determination of melt flow index of a polymer such as PP, PS, LDPE etc.
- Determination of intrinsic viscosity by Ubbelohde viscometer.
- Determination of rheological properties of polymer melts by rheometers.
- Measurement of resin/paint viscosity by Ford cup 4.
- Measurement of dynamic viscosity by Brookfield Viscometer.
- Compounding of polymers and investigation of their rheological behavior.
- Industry/R&D organization visit.

Essential/recommended readings

- Gupta B.R., (2004) Applied Rheology in Polymer Processing, Asian Books.
- Rosen S.L., (2012) Fundamental Principles of Polymeric Materials, Wiley-Interscience.
- Ghosh P., (2010) Polymer Science and Technology of Plastic and Rubber, Tata McGraw Hill.
- Aklonis J., Macknight W.J., (2005) Introduction to Polymer Viscoelasticity, John Wiley & Sons
- Middleman, S. (1968). Flow of high polymers; continuum and molecular rheology.

Suggestive readings

- Bird R.B., Armstrong R.C., Hassager O., (1977) Dynamics of Polymeric Liquids (volume 1), John Wiley & Sons, New York.
- Shaw M.T., (2012) Introduction to Polymer Rheology, John Wiley & Sons.
- Dealy, J. M., & Wissbrun, K. F. (2012). Melt rheology and its role in plastics processing: theory and applications. Springer Science & Business Media.
- Hiemenz, P. C., & Lodge, T. P. (2007). Polymer chemistry. CRC press.

DISCIPLINE SPECIFIC CORE COURSE – 6: POLYMER TECHNOLOGY(PT)

Credit distribution, Eligibility and Pre-requisites of the Course

Course title &	Credits	Credit distribution of the	Eligibility	Pre-

Code		course			criteria	requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
POLYMER TECHNOLOGY(PT)	4	3	0	1	12th with PCM	-

Learning Objectives

The Learning Objectives of this course are as follows:

- To learn about the production, properties and applications of thermoset and thermoplastic polymers
- To learn about the chemistry and manufacturing of flexible and rigid polyurethane foams
- To understand the modification of unsaturated polymers

Learning outcomes

The Learning Outcomes of this course are as follows:

- Learn preparation of thermoplastic polymers
- Learn preparation of thermosetting polymers
- Apply the knowledge of polymer synthesis to obtain polymers with desired properties

SYLLABUS OF DSC-6

UNIT – I (9 Weeks)

THERMOPLASTIC POLYMERS

Manufacturing process, properties and applications of the following polymers:

- Polyethylene (LDPE,LLDPE,VLDPE, HDPE)
- Polypropylene and related copolymers
- Polystyrene ABS, HIPS and related copolymers
- Poly (vinyl chloride) and related copolymers
- Poly (vinyl acetate) and related polymers
- Acrylic polymers (PMMA,PEA, PAA, PAN, Polyacrylamide)
- Aliphatic polyamides (Nylon 6, Nylon 66, Nylon 6,10)
- Polyester (PET, PBT)

UNIT – II (6 Weeks)

Manufacturing process, curing, properties, and applications of the following polymers:

- Unsaturated polyester resins
- Phenol formaldehyde resins (resols and novolacs)
- Urea and melamine formaldehyde resins
- Epoxides
- Polyurethanes (Flexible & Rigid foams)

Practical component-

- Preparation of PMMA bone cement.

- Preparation and testing of epoxy resins
- Preparation of Nylon 6,10 by interfacial polymerization
- Preparation of phenolic resin for adhesive applications.
- Preparation of unsaturated polyester resin and determination of molecular weight by acid value/hydroxyl value.
- Synthesis of copolymer of styrene & maleic anhydride, and styrene & MMA and determination of reactivity ratios.
- To prepare melamine formaldehyde product viz. crockery etc.
- Synthesis of Polyurethane Foams
- Preparation of sodium polyacrylate salt and poly(acrylic acid) from polyacrylamide.

Essential/recommended readings

- Brydson J.A., (2016) Plastics Materials, Butterworth Heinemann, 8th Edition.
- Mittal Vikas, (2011) High Performance Polymers and Engineering Plastics, Wiley.
- Seymour R.B., Carraher C.E., (2003) Polymer Chemistry, Marcel Dekker.
- Billmeyer F.A., (2011) Textbook of Polymer Science, John-Wiley & Sons.
- Gowarikar V.R., (2019) Polymer Science, New Age International Publishers Ltd, 3rd Edition

Suggestive readings

- Flory P.J., (2007) Principles of Polymer Chemistry, Asian Books Private Limited.
- Mark J.E. Erman B., Eirich F.R., (2005) The Science and Technology of Rubber, Elsevier Academic Press.
- Sperling, L. H. (2005). Introduction to physical polymer science. John Wiley & Sons.
- Crompton R.T., (1989) Molecular Motions in High Polymers, Pergamon Press N.Y.
- Crompton T.R., (1989) Analysis of Polymers, Pergamon Press N.Y.
- Treloar, L. R. G. (1983). Mechanical Properties of Solid Polymers, IM Ward, John Wiley & Sons Ltd, Chichester.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENTS

GENERIC ELECTIVES (GE-4): BIOMEDICAL APPLICATIONS OF POLYMERS(BAP)

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
BIOMEDICAL APPLICATIONS OF POLYMERS(BAP)	4	2	0	2	12th with PBC/PCM	---

Learning Objectives

The Learning Objectives of this course are as follows:

- To acquire knowledge of biopolymer and biodegradation
- To gain knowledge of applications and testing of biopolymers

Learning outcomes

The Learning Outcomes of this course are as follows:

- Understand the basic concepts and requirement of biomaterials and biocompatibility
- Apply the knowledge of various biomaterials for a desired bio-application

SYLLABUS OF GE-4

UNIT – I (3 Weeks)

BASICS OF BIOMATERIALS

Concept of biocompatibility and biodegradability, responsiveness, estimations of degradation and biocompatibility, Important biomaterials: hydrogel, fibres, bio-ceramics, bio-elastomers and membranes

UNIT – II (2 Weeks)

POLYMERS AS BIOMATERIALS

Polyester and polysaccharides, natural gums, biodegradable polymers, polymers and hydrogels

UNIT – III (5 Weeks)

BIOMATERIALS FOR ORGAN TRANSPLANTS AND TISSUE ENGINEERING

Properties and applications of polymers for organ transplant e.g. dental cement, orthopedic, skin, artificial kidney etc., basic concepts of tissue engineering, Important polymers for tissue engineering: cellulose, chitosan and alginates

UNIT – IV (5 Weeks)

DRUG DELIVERY AND WOUND CARE

Introduction to drug delivery, polymers in controlled drug delivery, dressing strips, polymer drug vessels, core shell and nanogels, polymers for antimicrobial activity, bio-conjugates

Practical component-

- Evaluate the biocompatibility of polymeric samples.
- Determination of the degradation behavior of polymers such as thermal, hydrolytic degradation etc.
- Preparation of membranes and measurement of absorption behavior.
- Preparation and characterization of dental cement.
- Preparation of a hydrogel and its characterization.
- Determination of tensile strength of biopolymers.
- Determine the swelling rate of biopolymers
- Preparation of nanogel and find its water absorption
- preparation and characterization of membrane for skin transplant

Essential/recommended readings

- Tiwari A., Tiwari A., (2013) Nanomaterials in drug delivery, Imaging and Tissue Engineering, Wiley.
- Pilla S., (2011) Handbook of Bioplastics and Biocomposites Engineering Applications, Wiley.
- Ratner, Buddy D., Allan S. Hoffman, Frederick J. Schoen, and Jack E. Lemons. "Biomaterials science: an introduction to materials in medicine." San Diego, California (2004): 162-4.
- Park, J. B., & Bronzino, J. D. (2002). Biomaterials: principles and applications. crc press.

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Suggestive readings

- Ratner D., Hoffman A.S., (1996) An Introduction to Materials in Medicine, Academic Press.
- Saltzman W.M., (2001) Drug delivery–Engineering principles for drug therapy, Oxford University Press.
- Kalia S., Averous L., (2011) Biopolymers: Biomedical and Environmental Applications, John Wiley & Sons.

GENERIC ELECTIVES (GE-5): POLYMERS FOR PACKAGING (PP)

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
POLYMERS FOR PACKAGING (PP)	4	2	0	2	12th with PBC/PCM	---

Learning Objectives

The Learning Objectives of this course are as follows:

- To learn about the basic necessities and importance of packaging
- To acquire knowledge of various types of packaging materials

Learning outcomes

The Learning Outcomes of this course are as follows:

- Apprehend the basic concepts of packaging and its utilization for desired applications
- Assess the quality of packaging material and packaged product

SYLLABUS OF GE-5

UNIT – I (3 Weeks)

PACKAGING SYSTEMS

Types of packaging systems: box, bottle, tetra, pouch, shrink, vacuum, gas, controlled atmosphere packaging (CAP), modified atmosphere packaging (MAP), and aseptic packaging

UNIT – II (4 Weeks)

POLYMERS IN PACKAGING

Properties and applications: LLDPE, LDPE, HDPE, HMHDPE, PP, PVC, nylons, polyester, polycarbonate, PS, EPS, PLA, PVA and Starch

UNIT – III (4 Weeks)

PACKAGING PROCESS TECHNIQUES

Preparation of packaging materials by thermoforming, co-extrusion, extrusion-stretch blow molding, injection molding, BOPP films

UNIT – IV (4 Weeks)

TESTING OF POLYMER PACKAGING MATERIAL

Bursting strength, tensile strength, tear strength, puncture test, impact test (Drop, falling dart), permeability test (water vapour, oxygen), biodegradability, sealing strength

Practical component-

- To identify packaging materials with the help of FT-IR, DSC, TGA etc.
- Determination of physico-mechanical properties (density, burst strength, tensile strength, tear strength, puncture test strength, impact strength etc).
- Determination of water vapor transmission rate of packaging material.
- To test sealing strength integrity of packaging materials.
- To check biodegradability of packaging material.
- Preparation biodegradable packaging film
- Determination of water vapor transmission rate of packaging material.
- To test seal strength integrity of packaging materials.
- To check biodegradability of packaging material.
- To determine compatibility of film.

Essential/recommended readings

- Robertson G.L., (2005) Food Packaging Principles and Practice, CRC press.
- Paine F.A. and Paine H.Y., (1992) A Handbook of Food Packaging, Blackie Academic and Professional.
- Sharma S., Aggarwal M., Sharma D., (2019), Food Frontiers, New Delhi Publisher
- N. C. Saha, M. Garg, S. Dey Sadhu, A. K. Ghosh(2022) Food Packaging-Materials, Techniques and Environmental Issues" by published by Springer.
- Garg, M., Meena, P.L., Sadhu, S.D., Alam, T. (2019). Food Packaging: A Practical Guide : Viba Press Pvt. Ltd.

Suggestive readings

- Robertson G.L., (2012) Food Packaging–Principles and Practice, CRC Press.
- Coles R, McDowell D., Kirwan M.J., (2003) Food Packaging Technology, Blackwell.
- Sukhareva L.A., Yakolev V.S., Legonkova O.A., (2008) Polymers for packaging materials for preservation of foodstuffs, VSP.

GENERIC ELECTIVES (GE-6): POLYMERS FOR ELECTRICAL AND ELECTRONIC APPLICATIONS (PEEA)

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
POLYMERS FOR ELECTRICAL AND ELECTRONIC APPLICATIONS	4	2	0	2	12th with PBC/PCM	----

(PEEA)						

Learning Objectives

The Learning Objectives of this course are as follows:

- To learn about basic concepts of polymer electrical and electronic properties
- To gain knowledge of electrical and electronics applications of polymers

Learning outcomes

The Learning Outcomes of this course are as follows:

- Synthesize a conducting polymer for a specific application
- Apply the knowledge of properties of polymers required for electrical and electronics applications

SYLLABUS OF GE-6

UNIT – I (4 Weeks)

INTRODUCTION TO POLYMERS

Petro polymers, conducting polymers, biopolymers, composites, Band diagram, processing of polymers, doping (chemical and ion), advantages and disadvantages of conducting polymers, limitations

UNIT – II (4 Weeks)

PREPARATION OF CONDUCTING POLYMERS

Synthetic methods: chemical, electrochemical, photochemical etc. (polyaniline, polypyrrole, polythiophene, polyacetylene, etc.), methods to enhance the processability of conducting polymers

UNIT – III (4 Weeks)

PROPERTIES

Dielectric strength, dielectric loss, charge storage capacity, electrical conductivity, heat capacity, magnetism, hysteresis loop, shape memory, mechanical properties, EMI shielding

UNIT – III (3 Weeks)

ELECTRONIC APPLICATIONS

Semiconducting organic materials, polymer based electronic devices, organic field effect transistor, organic transistors, plastic solar cell, light emitting diode, supercapacitor, sensors etc.

Practical component-

- Preparation of conducting polyaniline and measurement of their conductivity.
- Preparation of polypyrrole and measurement of their conductivity.
- Preparation of polythiophene and measurement of their surface resistivity.
- Preparation and testing of conducting polymers for sensor applications.
- Measurement of multilayer insulation of a thin film.
- Measurement of dielectric strength of a polymer film.
- Measurement of mechanical properties of insulating cable
- Preparation polymer sample and analyzed its dielectric strength

- Preparation of a conducting polymer nanocomposites.
- Preparation polymeric semiconductor

Essential/recommended readings

- Skotheim T.A., Elsenbaumer R.L., Reynolds J.R., (1998) Handbook of conducting polymers, Vol. 1 and Vol. 2, Marcel Dekker.
- Nalwa H.S., (1977) Organic Conductive Molecules and Polymers, John Wiley & Sons.
- Bredas J.L., Silbey R., (1991) Conjugated Polymers: The Novel Science and Technology of Highly Conducting and Nonlinear Optically Active Materials, Kluwer Academic Publishers.
- Bikales M., Menges O.B., (1986) Encyclopedia of Polymer science and Engineering, Second Edition, Vol.5, John Wiley & Sons.

Suggestive readings

- Lyons M.E.O., (1994) Electroactive polymers, Plenum Press.
- Margolis J., (1993) Conducting Polymers and Plastics, Chapman & Hall.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Nomenclature of certificate/diploma/degrees:

- ✓ After securing 44 credits (from semester I and II), by completing one year of study of the UG Programme with Political Science as a single core discipline, if a student exits after following due procedure, he or she shall be awarded **Undergraduate Certificate in Polymer Science.**

- ✓ After securing 88 credits (from semester I, II, III & IV), by completing two years of study of the UG Programme with Political Science as a single core discipline, if a student exits after following due procedure, he or she shall be awarded **Diploma in Polymer Science.**

- ✓ After securing 132 credits (from semester I to VI), by completing three years of study of the UG Programme with Political Science as a single core discipline, if a student exits after following due procedure, he or she shall be awarded **Bachelor of Science (Honours) in Polymer Science.**

- ✓ After securing 176 credits (from semester I to VIII), by completing four years of study of the UG Programme with Political Science as a single core discipline and writes dissertation, the student shall be awarded **Bachelor of Science (Honours with Research) in Polymer Science.**

- ✓ After securing 176 credits (from semester I to VIII), by completing four years of study of the UG Programme with Political Science as a single core discipline and engages in Academic Project/Entrepreneurship, the student shall be awarded **Bachelor of Science (Honours with Academic Project/Entrepreneurship) in Polymer Science.**