Bhaskaracharya College of Applied Sciences
(University of Delhi)
Sector2, Phase-I, Dwarka
New Delhi - 110075

Dated : 24/05/2019

NOTICE

Suggestions and feedback are invited for draft syllabus of B.Sc.(H) Polymer Science on/ before May 31, 2019 at the email: **polymersciencebcas@gmail.com**

This is for information to all.

24/5/19.

PRINCIPAL

Principal
Bhaskaracharya College of Applied Sciences
(University of Delhi)
Sector-2, Phase-I, Dwarka, New Delhi-75

Draft Syllabus of B.Sc.(H) Polymer Science approved in committee of courses held on May 24, 2019

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Introduction:

The Choice Based Credit System (CBCS) opens up various prospects to a student to choose courses from the syllabus comprising Core, Elective and Skill based courses. It offers a flexible course structure ensuring that each student gets a strong base in the subject and thorough knowledge. The learning outcome based curriculum framework will provide students with a clear vision to make a wise choice regarding the course they wish to study. This will make the students more competent to fulfill present day needs of acquiring knowledge to achieve their goal through higher studies or employment and research.

Programme Duration and Design:

The B.Sc. (Hons) Polymer Science course is a six semester course to be taught in three academic years. The curriculum of this course is designed to engage students in theory, practicals, discussions and presentations in addition to conventional teaching-learning process. Students will be encouraged to carry out short projects and industrial training. As a part of the curriculum industrial and R & D lab visits will also be organized. Students will also be motivated to participate in seminars, conferences and workshops. Each theory paper consists of 100 marks out of which 25 marks are kept for internal assessment (class test, presentation, group discussion, quiz, assignment etc.) and a practical paper will be of 50 marks of which 25 marks will be internally assessed.

Programme Structure

The programme offers Core Courses and Elective Courses. The Core papers are all compulsory in nature. There are three types of Elective Courses – Discipline Specific Elective (DSE), Generic Elective (GE), Skill Enhancement Courses (SEC). In addition there are two mandatory Ability Enhancement Courses (AEC) (English/MIL Communication or EVS). The Core, DSE and GE papers are of six credits each; while the SEC and AEC are of four credits each.

To graduate in B.Sc. (Hons) Polymer Science, the student requires to study fourteen Core papers, four Discipline Specific Elective papers, four Generic Elective papers, two Skill Enhancement papers and two Ability Enhancement papers.

The distribution of papers is as follows: two Core Courses each, in Semesters I and II, three Core Courses each in Semesters III and IV and two Core Courses each in Semesters V and VI. The programme offers several Discipline-Specific Electives, of which the student will study two in each of the Semesters V and VI.

Various Generic Elective papers are floated for the students of B.Sc. (Hons) Polymer Science Programme by other Departments of the College and each student will have the option to select one GE course each in Semesters I, II, III, and IV. The Department of Polymer Science offers ten GE courses to students of other disciplines (refer to * on page 4).

Students will study one Skill Enhancement Course in Semesters III and IV.

B.Sc. (H) POLYMER SCIENCE PROGRAMME STRUCTURE AND COURSE DISTRIBUTION

Semester	Core Course (14)	Ability Enhancement Course (AEC) (2)	Skill Enhc. Course (SEC)(2)	Discipline Specific Elective (DSE) (4)	Generic Elective (GE) (4)
I	Introduction to Polymer Science	English/MIL Communication or EVS			GE-1
	Raw Materials of Polymers				
II	Polymer Technology	English/MIL Communication or EVS			GE-2
	Unit Operations				
III	Polymer Rheology		SEC -1		GE-3
	Polymer Additives				
	Polymer Degradation				
IV	Polymer Processing & Mold Design		SEC -2		GE-4
	Polymer Testing				
	Recycling and Waste Management				
V	Polymer Characterization			DSE-1	
	Specialty Polymers			DSE-2	
VI	Polymer Blends and Composites			DSE -3	
	Fibre Science and Rubber Technology			DSE-4	

COURSES OFFERED UNDER B.Sc. (H) POLYMER SCIENCE PROGRAMME (CBCS)

CORE COURSES –14 (six credits each) – Each course has 4 Periods/week for Theory, 4 Periods/week for Practical

SEMESTER	COURSE CODE	NAME OF THE COURSE	CREDITS T=Theory Credits P=Practical Credits
I	C-101	Introduction to Polymer Science	T=4 P=2
	C-102	Raw Materials of Polymers	T=4 P=2
II	C-201	Polymer Technology	T=4 P=2
	C-202	Unit Operations	T=4 P=2
III	C-301	Polymer Rheology	T=4 P=2
	C-302	Polymer Additives	T=4 P=2
	C-303	Polymer Degradation	T=4 P=2
IV	C-401	Polymer Processing & Mold Design	T=4 P=2
	C-402	Polymer Testing	T=4 P=2
	C-403	Recycling and Waste Management	T=4 P=2
V	C-501	Polymer Characterization	T=4 P=2
	C-502	Specialty Polymers	T=4 P=2
VI	C-601	Polymer Blends and Composites	T=4 P=2
	C-602	Fibre Science and Rubber Technology	T=4 P=2
			Credits: 14× 6 = 84

DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE) – 4 (six credits each, refer to ** on page 5)
Each course has 4 Periods/week for Theory, 4 Periods/week for Practical

SEMESTER	COURSE CODE	NAME OF THE COURSE	CREDITS T=Theory Credits P=Practical Credits
V, VI	DSE: Paper 1	Conducting Polymer	T=4 P=2
	DSE: Paper 2	Fibre Manufacturing Technology	T=4 P=2
	DSE: Paper 3	Paints, Coatings and adhesive	T=4 P=2
	DSE: Paper 4	Polymeric Nanomaterials	T=4 P=2
	DSE: Paper 5	Tyre Technology	T=4 P=2
	DSE: Paper 6	Packaging Technology	T=4 P=2
	DSE: Paper 7	Fabrication of Polymeric products	T=4 P=2
	DSE: Paper 8	Polymer in Biomedical Applications	T=4 P=2

	DSE: Paper 9	Dissertation	P=6
			Credits: 4 × 6 = 24

GENERIC ELECTIVES COURSES (GE)– 4(six credits each) –Offered by other Departments
Each course has 4 Periods/week for Theory, 4 Periods/week for Practical

SEMESTER	COURSE CODE	NAME OF THE COURSE	CREDITS T=Theory Credits P=Practical Credits
I		GE 1	6
II		GE 2	6
III		GE 3	6
IV		GE 4	6
			Credits: 4 × 6 = 24

SKILL ENHANCEMENT ELECTIVE COURSES (SEC) – 2 (four credits each, refer to * on page 5)**

SEMESTER	COURSE CODE	NAME OF THE COURSE	CREDITS T=Theory Credits P=Practical Credits
III-IV	SEC: Paper 1	Biopolymers	T=2 P=2
	SEC: Paper 2	Estimation of Polymers and Polymeric Compounds	T=2 P=2
	SEC: Paper 3	Wire and Cable Technology	T=2 P=2
	SEC: Paper 4	Footwear Technology	T=2 P=2
			Credits: 2 × 4 = 08

ABILITY ENHANCEMENT COURSES (AEC) – 2 (4 credits each)

SEMESTER	COURSE CODE	NAME OF THE COURSE	CREDITS T=Theory Credits P=Practical Credits
I-II	AECC1	English/MIL Communication or EVS	T = 4
	AECC2	English/MIL Communication or EVS	T = 4
			Credits: 2 × 4 = 08
TOTAL CREDITS = 148			

***Generic Elective Papers (GE) (Minor-Polymer Science) (any four) for other Departments/Disciplines: (Credit: 06 each – 4T + 2P)**

GE: Paper 1- Basics of Polymer Science
GE: Paper 2- Chemistry of Polymers
GE: Paper 3- Polymer Testing and Characterization
GE: Paper 4- Polymer Modifiers and Waste Management
GE: Paper 5- Product Manufacturing and Processing
GE: Paper 6- Material Sciences
GE: Paper 7- Biomedical Applications of Polymers

GE: Paper 8- Fibres and Rubbers
GE: Paper 9- Polymers in Packaging
GE: Paper 10 - Polymers for electrical and electronic applications

****Discipline Specific Elective Courses: (Credit: 06 each) (4 courses to be selected)-DSE 1-4**

DSE 1 & DSE 2: Any two of the following

DSE: Paper 1- Conducting Polymers

DSE: Paper 2- Fibre Manufacturing Technology

DSE: Paper 3- Paints, Coatings and adhesive

DSE: Paper 4- Polymeric Nanomaterials

DSE 3 & DSE 4: Choose any two of the following

DSE: Paper 5- Tyre Technology

DSE: Paper 6- Packaging Technology

DSE: Paper 7- Fabrication of Polymeric products

DSE: Paper 8- Polymer in Biomedical Applications

DSE: Paper 9- Dissertation

*(Wherever wet lab experiments are not possible the principles and concepts can be demonstrated through any other material or medium including videos/virtual labs etc.)

The college will offer four DSE papers in semester V (DSE: Paper 1-4) and five DSE papers in semester VI (DSE: Paper 5-9). Out of which two papers in each semester i.e., V & VI are to be selected. (refer to **Discipline Specific Elective Courses at page no. 5). Students may also opt for a dissertation as a DSE course in Semester VI. It will be a six credit course. The number of students who will be allowed to opt for this paper will vary depending upon the infrastructural facilities and may vary each year. The college may announce the number of seats for project work well in advance and choose students for the same. It will involve experimental work under the supervision of a faculty member and will involve twelve hours of work per week. The project will be evaluated by internal and external examiners and the report should be sent to examiners in advance (prior to the day of examination).

*****Skill Enhancement Courses** - emphasis is given to **Hands on Exercises** in the following disciplines:

SEC: Paper 1	Biopolymers
SEC: Paper 2	Estimation of Polymers and Polymeric Compounds
SEC: Paper 3	Wire and Cable Technology
SEC: Paper 4	Footwear Technology

Learning Outcome based approach to Curriculum Planning

Nature of Programme

B.Sc.(H) Polymer Science is interdisciplinary undergraduate course. The students with PCM background are eligible to take admission in the course

>> Aims of Bachelor's degree programme in (CBCS) B.SC. (HONS) POLYMER SCIENCE

The Learning Outcomes-based Curriculum Framework (LOCF) for the B.Sc. (Hons) degree in Polymer Science offers a broad structural outline which can address to the current curricular requirements with ample scope to include modifications in content. The inherent flexibility in the context permits each student to choose their preferences depending on their individual capacity. The uniformity in core design ensures smooth transfer across universities in the country. The B.Sc. (Honours) Polymer Science programme covers a wide range of basic and applied courses as well as courses of interdisciplinary nature. While the core papers build a strong base in the student, the contents of electives and skill enhancement courses help them explore their eligibility and suitability to pursue studies in these areas.

Graduate Attributes in Subject

>> Disciplinary knowledge

- Though a student pursuing an undergraduate degree in a science discipline is inherently curiosity driven, has the ability to observe and integrate rationally, a student graduating with an honours degree in polymer science is distinguished by the following additional attributes:
- **Thorough knowledge of the discipline:** Graduates with in-depth knowledge in the field of polymer engineering science and technology applicable for successful career in Polymers.
- **Laboratory skills and techniques:** A graduate in polymer science is expected to be capable of handling all basic synthesis, processing, testing and analytical techniques and precise in operating the same.
- **Digital literacy:** Increasing use of instruments having interface with computers and use of computers in laboratory work creates this attribute. A student with degree in polymer science should have the knowledge and skill in computers in a variety of situations- data analysis, computing as well as information retrieval, presentations, technical writing and library use.
- **Awareness of ethical issues:** Graduates with integrity and strong ethical values who are members and contribute to professional society.
- **Safety and environmental concerns:** Does the student know the importance of working with safety awareness in laboratory? Actively seeks information about health hazards and environmental safety of chemicals that are used in the laboratories and follows standard protocols for their safe disposal recycling.
- Research oriented: Graduates who contribute towards research and professional Development and who are entrepreneurial engineers

Qualification Description

- Development of a clear understanding of the basic concepts of Polymer Science and creating an awareness of the emerging areas of the field
- Improving the ability to read, understand and discuss scholarly articles and

research papers of Polymer Science and related areas.

- Learning laboratory skills, enabling the accurate design of an experiment and systematic collection of experimental data and its interpretation
- Demonstration of strong oral and written communication skills inculcating the ability to present studies in the field of Polymer Science using the concepts and knowledge acquired.
- Demonstration of the ability to work effectively and productively, independently or as part of a team

The qualification description for B.Sc. (Hons) programme in Polymer science includes:

- Creation of a clear understanding of machineries and tools related to manufacturing, processing, quality assurance and testing of chemicals and polymers.
- To develop creative and innovative abilities of students by incorporating Academia – industrial interactions, project activities as important component of curriculum.
- Enabling graduates to become entrepreneurs.

Programme Learning Outcome in course

The B.Sc. (Hons) programme in Polymer science is designed to nurture the in depth knowledge in students with the core concepts and principles. Undergraduate students pursuing this programme undergo through laboratory training to develop quantitative and qualitative skills. This provides vast scope for critical thinking, team work and exposes students to techniques useful for applied areas of scientific study.

- **Knowledge:** Students acquire theoretical knowledge and understanding of the fundamental concepts, principles and processes in main branches of polymer science namely, basics of Polymers science, processing and applications, and biopolymer science. Width results from the choice of electives that students are offered.
- **Laboratory Skills:** During the course students develop laboratory skills as a much valued learning outcome of this programme. Quantitative techniques gained through hands on training opens choice of joining the industrial laboratory work force.
- **Communication:** In today's world communication is a highly desirable attribute to possess. Opportunities to enhance students' ability to write methodical, logical and precise reports are inherent to the structure of the programme. Techniques that effectively communicate scientific chemical content to large audiences are acquired through oral and poster presentations and regular laboratory report writing.
- **Research skills**

Teaching – Learning Process

B.Sc. (Hons) Polymer science programme is a three-year degree programme designed to train the students with a thorough theoretical background and practical training in all aspects of polymer science. This is an interdisciplinary course and includes fundamental as well as in-depth knowledge of the course. Along with the above Core Courses there are Discipline Specific Elective Courses, Generic Elective Courses and

Ability Enhancement Courses which address the need of the hour.
These courses are delivered through classroom, laboratory work, projects, case studies and industry visits in a challenging, engaging, and inclusive manner that accommodates a variety of learning styles and tools (PowerPoint presentations, audio visual resources, e-resources, seminars, workshops).
The laboratory training complements the theory learned in the classroom and includes synthesis of polymers, processing, testing and applications with modern instruments, computational data analysis, modelling and laboratory safety procedures.

Teaching-Learning Process
In addition to traditional teaching procedures, presentations, demonstrations, group discussions, research lab/industrial visits, models etc.

Assessment Methods

The assessment of students' performance in polymer science will assessed over the duration of the program by many different methods. A variety of assessment methodology within the domain of polymer science will be used. Learning outcomes will be assessed using the following direct measures:

Theory:

1. Internal assessment (class test, presentations, assignments, Group Discussion, attendance, Literature surveys etc. 25 Marks
2. Written examinations 75 marks

Practical: 50marks

1. Internal assessment (continuous evaluation, viva-voice, attendance) 25 Marks
2. Practical Exam - Observation of practical skills, Experimental design planning, Execution of experiments, Computerized adaptive testing, Case study, Portfolios on industrial visits undertaken etc. 25 Marks

INTRODUCTION TO POLYMER SCIENCE (31141101) CORE COURSE - (CC) CREDIT: 6

Course Objective:

1. The basic concepts related to crystalline and amorphous structure of polymers are introduced to students.
2. The brief idea of molecular weight determination, polymer solubility will be introduced.

CORE PAPER: C-101: INTRODUCTION TO POLYMER SCIENCE
CREDITS: THEORY-4, PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

- Understand basic concepts of crystalline and amorphous states of polymers
- Learn structure-property relationship of polymers.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Introduction to Polymers 15 Lectures
Introduction and history of polymeric materials, classification of polymers, configuration and conformation of polymers, nature of molecular interaction in polymers, cumulative interaction, entanglement, random chain model and RMS end-to-end distance. Various structures of copolymers such as linear branched and cross-linked copolymers and their types.

Unit 2: Polymer Crystals 6
Crystal morphologies, Extended chain crystals, chain folding, lamellae, and spherulites. Crystallization and crystallinity, determination of melting point and degree of crystallinity

Unit 3: Properties of polymers 15
Physical properties, Stress–strain behavior, Introduction to flow & mechanical properties (Tensile, Flexural, Impact, Fatigue, Hardness, Creep, Abrasion.

Unit 4: Polymer Molecular weight 10
Nature and structure of polymers – structure-property relationships. Molecular weight of polymers (Mn, Mw etc.), polydespersity, molecular weight distribution and determination of molecular weight by viscosity, end group analsyis, cryoscopy, ebulliometry, osmometry, light scattering & ultracentrifugation method

Unit 5: Solution Properties of Polymers 10
Polymer solutions, solubility parameter, solution viscosity, Thermodynamics of polymer solutions

Unit 6: Glass transition behaviour of Polymers 4
Glass transition temperature (Tg) and measurement of Tg. Factors affecting the glass transition temperature, WLF equation.

PRACTICALS:
1. Determination of heat deflection temperature, VICAT softening point.
2. Measurement of glass transition temperature (Tg).
3. To determine the melting point of crystalline polymers.
4. To check the solubility of the given polymeric sample in different solvents.
5. Determination of molecular weight by solution viscosity.
6. Determination of molecular weight by end group analysis.
7. Chemical identification of polymers- • Unsaturation • Testing of functional groups (associated with polymers).

References:
1. Brydson J.A., 1999, Plastics Materials, Butterworth Heinemann.
2. Ghosh P., 2010, Polymer Science and Technology: Plastics, Rubbers, Blends and Composites Tata McGraw Hill
3. Gowarikar V. R., 2010, Polymer Science, New Age International Publishers Ltd.
4. Billmeyer F.W., 2007, Textbook of Polymer Science,Wiley, India.

5. Shah V., 1998, Handbook of Plastics Testing Technology, Wiley interscience
6. Seymour R. B. and Carraher C.E., 2000, Polymer Chemistry, Marcel Dekker.

Additional Resources:
1. Schultz, 2001 Polymer Crystallization, American Chemical Society.

Teaching learning process:
Presentation/Quiz/Visits

Assessment methods:
As per DU norms

Keywords:
End to end Distance, Lamellae, Glass Transition Temperature, Molecular Weight Distribution, Viscosity Average Molecular Weight

RAW MATERIALS OF POLYMERS
(31141102)
CORE COURSE - (CC) CREDIT: 6

Course Objective:
1. Understanding resources of Polymers
2. Synthetic and natural polymers Latex Product manufacturing

CORE PAPER: C-102: RAW MATERIALS OF POLYMERS
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to
- get the idea about both synthetic and natural resources of polymers
- discuss the commercial techniques used in monomer production and latex product manufacturing.

THEORY:
CONTENT (TOTAL PERIODS: 60)

Unit 1: Introduction to crude oil and it's refining 10
Petroleum Oil, natural gas, coal: Capabilities and limitations. General consideration of petrochemicals, an overview of petroleum refining, desalting, distillation, cracking and its types

Unit 2: Synthesis of monomers from Petrochemicals 20
Formaldehyde, ethylene, vinyl acetate, vinyl chloride, ethylene oxide and ethylene glycol, acrylonitrile, glycerol, toluene di-isocyanate, methyl methacrylate, isoprene, phenol, styrene, terephthalic acid, adipic acid.

Unit 3: Latex 10

Natural rubber latex: collection process, composition, concentration and stabilization of latex.

Unit 4: Latex additives and it's compounding 10

Vulcanizing agents, fillers, coagulating agent, wetting, dispersing and emulsifying agents, stabilizers, thickening agents and other additives. A few compounding formulations for product manufacturing.

Unit 5: Latex Product Manufacturing Techniques 10

Spreading, casting, dipping, latex thread, latex coated coir and latex foam.

PRACTICALS:

1. Fractional distillation of crude oil.
2. To calculate Dry Rubber Content of Latex.
3. To determine the coagulation strength of latex.
4. Preparation of balloon by dipping process
5. Latex compounding for various products.

References:

1. Kumar D. and Chandra R., 2001, Latex Technology, DhanpatRai& Co
2. B.K.B. Rao, 2007, Text book on Petrochemicals, Khanna Publishers.

Additional Resources:

1. B.K.B. Rao, 2007, Modern Petroleum Refining Processes, Oxford and IBH
2. Maiti S., 2002, Introduction to Petrochemicals, Oxford & IBH Publ. Co.
3. Speight, 2006, Chemistry and Technology of Petroleum, CRC Press.
4. Smith and Martin, 2007, Hand book of Rubber Technology, CBS Publishers.

Teaching Learning Process:

Power point presentation, discussion, demonstration, quiz

Assessment Methods:

As per University of Delhi Rules

Keywords:

Monomer synthesis, latex, product manufacturing, petroleum

POLYMER TECHNOLOGY
(31141201)
Core Course - (CC) Credit: 6

Course Objective:

1. The course will help in understanding basic concept of polymer and its synthesis.
2. To study various polymerization methods and their kinetics.
3. To learn properties and applications of polymers

CORE PAPER: C-201: POLYMER TECHNOLOGY

CREDITS: THEORY-4 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

- understand the basic concepts of polymers chemistry and polymerization process
- comprehend thermoplastics and thermosetting polymers including their synthesis, properties and applications.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Introduction 10
Criteria for polymer synthesis, nomenclature, addition and condensation polymerization, chain growth and step polymerization, polymerization techniques: mass (bulk), suspension, emulsion and solution processes.

Unit2: Kinetics of polymerization 10
Concept of functionality, Carother's equation and its applications in polymerization reactions.Kinetics of step growth polymerization and chain growth polymerization. Cage effect, Ionic Polymerization, effect of gegen ions and solvent on ionic polymerization, Mayo's equation, auto-acceleration, inhibition and retardation.Co-polymerization, reactivity ratios. Zeigler-Natta catalyst and coordination polymerization

Unit 3: Thermoplastic Polymers 15
Brief introduction to preparation, structure, properties and applications of the following polymers: Polyolefins (PE, PP), Polystyrene and its copolymers, Poly (vinyl chloride) and related polymers, Poly (vinyl acetate) and related polymers

Unit 4: Thermosetting Polymers 15
Brief introduction to preparation, structure, properties and applications of the following polymers:Unsaturated polyester resins, Phenol formaldehyde resins,Polymers from amines, Polyurethane, Silicones, Epoxides

Unit 5: Engineering polymers 15
Brief introduction to preparation, structure, properties and applications of the following polymers: Acrylic polymers, Fluoropolymers, Aliphatic polyamides, saturated polyesters

PRACTICALS:
1. Suspension polymerization of Styrene/MMA.
2. Preparation of UF/PF/MF resins.
3. Preparation and testing of Diglycidyl ether of bis phenol-A (DGEBA).
4. Bulk and solution polymerization of Methyl Methacrylate/Styrene.
5. Emulsion polymerization of Styrene/ Methyl Methacrylate.
6. Copolymerization of styrene & MMA and determination of reactivity ratios.
7. Preparation of Poly (vinyl butyral).

References:
1. Odian, G., 2004, Principles of Polymerization, Wiley – Interscience.

2. Brydson, J. A., 1999, Plastics Materials, Butterworth-Heinemann.
3. Seymour R. B. Carraher, C. E., 2003, Polymer Chemistry, Marcel Dekker.

Additional Resources:
1. Billmeyer F.A., 2011, Text book of Polymer Science, John-Wiley and Sons.
2. Flory P. J. Principles of Polymer Chemistry, Asian Books Private Limited.

Teaching learning process:
Quiz/Presentation/Demonstration/Industrial Visits

Assessment methods:
As per DU norms

Keywords:
Polymer chemistry, polymerization, Thermoplastics, Thermosetting Polymers

UNIT OPERATIONS
(31141202)
CORE COURSE - (CC) CREDIT: 6

Course Objective:
1. This paper introduces the idea of unit operations and its importance in industrial processes.
2. Basic learning and designing a process for industrial applications.

CORE PAPER: C-202: UNIT OPERATIONS
CREDITS: THEORY-4 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

- help students in understanding basic concepts of unit operations and their importance in polymer industries
- learn the analogy of mass transfer and energy transfer in various operations.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Introduction to unit operations 5
Unit Operations: Concept and Requirement, Material and Energy Balances. Energy transport in non-isothermal systems.

Unit 2: Fluid dynamics 15
Velocity distribution in flow system, Reynolds number, interfaces transport. Flow of fluids in pipes –Continuity equation, Bernoulli's equation and calculations for pipe size and pressure drop, flow measuring instruments: manometers and measurement of flow and pressure, flow meters, Principles and construction of Venturimeter, Orificemeter, various types of pumps.

Unit 3: Mechanical Operations 10
Size reduction and its equipment (Ball mill, Jack crusher, End and Edge Roller Mill), Filtration: Theory of filtration, filter aids, filter media, industrial filters including filter press, rotary filter, edge filter, etc., factors affecting filtration.

Unit 4. Heat Transfer 15

Conduction (Fourier Law, Reynolds number), convection, radiation, heat exchangers (Tube Shell, Shell plate).

Unit 5: Mass Transfer Mechanism 15

Mass transfer: Diffusion and its mechanism, factors effecting diffusion, gas absorption (Henry's Law, Langmuir Absorption Isotherm, BET equation), various types of distillation, drying.

PRACTICALS:

1. Handling of jaw crusher, ball mill for crushing and grinding.
2. Distillation of various liquid mixtures.
3. Diffusion experiments.
4. Filtration of solids from slurry.
5. Calculation of pressure drop and pipe size.
6. Heat Transfer through different materials.
7. Study of different adsorption isotherm.

References:

1. Mccabe, Smith and Harriott, 2004, Unit Operations in Chemical Engg., McGraw-Hill Professional.
2. Chattopadhaya P., 2003, Unit Operations in Chemical Engg. (Vol 1&2), Khanna Publishers.
3. Coulsan and Richardson, 2010, Chemical Engg. (Vol. 1 to 6), Elsevier.
4. Kumar D. S., 2009, Heat and Mass Transfer, S K Kataria& Sons Delhi.
5. Rao G. K., 2002, Solved Example in Chemical Engg.,Khanna Publishers.
6. Treybal R., 2012, Mass Transfer Operations, Tata McGraw Hill.

Teaching Learning Process:

Demonstrations/Group Discussion/ Presentations

Assessment Methods:

Assignment/Quiz, Class Test

Keywords:

Mass Transfer, Energy Transfer, Distillation, Reynolds Number

SEMESTER-III

POLYMER RHEOLOGY (31141301)
CORE PAPER: C-301:
TOTAL CREDITS: 6 (THEORY-4, PRACTICAL -2)
(Total Lectures: Theory- 60, Practicals-60)

Course Objective:

1. To enhance fundamental knowledge of polymer rheology including basic principles of flow behavior, rheological models and equipments
2. To understand the concept of mixing of polymers

Course Learning Outcomes: After studying this paper, students will be able to

- enhance fundamental knowledge of polymer rheology including basic principles of flow behavior, rheological models and equipments
- understand the concept of mixing of polymers

CONTENTS

Unit 1: Rheological Principles 10

Viscosity and polymer processing, rheological properties of fluids, shear stress in polymers, Newtonian & Non-Newtonian flow, polymer melt viscosities, 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 2: Melt Flow Analysis 15

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 3: Rheological principals and models 15

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

Unit 4: Mixing of polymers 10

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

Unit 5: Type of mixers 10

Two roll mill, high speed mixer, internal batch mixer (Kneader, Banbury &Haake), single screw & twin screw extruders, flow mechanism, analysis of flow (drag, pressure and leak flow).

PRACTICALS:

1. Determination of melt flow index of polymers
2. Determination of intrinsic viscosity by Ubbelohde viscometer.
3. Determination of rheological properties of polymer melts by rheometers.
4. Measurement of resin/paint viscosity by Ford cup 4.
5. Measurement of dynamic viscosity by Brookfield Viscometer.
6. Compounding of polymers and investigation of their rheological behavior.
7. Industry/R&D organization visit

References:

1. Gupta B. R., 2004, Applied Rheology in Polymer Processing, Asian Books.
2. Aklonis J. andMacknight W. J., 2005, Introduction to Polymer Viscoelasticity, John Wiley & Sons

Additional Resources:

1. Ghosh P., 2010, Polymer Science and Technology of Plastic and Rubber, Tata McGraw Hill.
2. Rosen S.L., 2012, Fundamental Principles of Polymeric Materials, Wiley-Interscience.
3. Dealy J. M. and Wissbrum K.F., 1999, Melt Rheology and Its Role in Plastic Processing, Springer.
4. Bird R.B., Armstrong R. C., Hassager O., 1977, Dynamics of polymeric liquids (volume 1),John Wiley & Sons, New York.
5.Shaw Montgomery T., 2012, Introduction to polymer rheology, John Wiley and sons Inc.

Teaching learning process:

Quiz, Projects (winter and summer), presentations, surprise test

Assessment methods:

Assignments and Class Tests as per University of Delhi norms

Keywords:

Boltzmann superposition, Weissenberg effect, Rheological Principles, drag, pressure and leak flow

POLYMER ADDITIVES (31141302)
CORE COURSE - (CC) CREDIT: 6

Course Objective:

1. To introduce the basics of polymer additives and their significance
2. To learn the different additives and representative formulations.

CORE PAPER: C-302: POLYMER ADDITIVES

CREDITS: THEORY-4, PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. To learn about the selection criteria and importance of additives used inpolymers.
2. To develop fundamental understanding of different additives used in processing of plastics andrubbers.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Introduction to additivesandcompounding 10
Importance of additives and theirs election criteria for commercial polymers and technical requirements of additives, limitation of polymers, master batch and compounding techniques

Unit2: Colourants 10
Dyes and pigments, Coloring properties, Inorganic and organic Pigments: Titanium dioxide, Zinc oxide, Carbonblacks, Metal oxide pigments, Chromium and Cadmium pigments, Organic dyes Ultra marine blueetc.

Unit 3: Additivesforrubbers 10
Vulcanizing agents (sulphur, peroxide and metal oxide), accelerators, plasticizers, luibricants, retarders (pre-vulcanizedinhibitor), activators, stabilizers (UV, antioxidants, thermal), softners, fillers, tackifying agents, blowing agents, surface property modifiers etc.

Unit 4: Additives for plastics 10
Plasticizers (phthalate, polymeric, hydrocarbon oil, vegetable oil etc.), fillers, foaming agents, blowing agents, stabilizers (UV, heat, antioxidants and light), metal deactivator etc.

Unit 5: Additives for special needs 10
Flame retardants (halogen based, metal oxides, hydrated salts etc), Impact modifier, lubricants, dry bonding agent and antistatic agents.

Unit 6: Casestudy 10
Compounding techniques with illustration of few formulations like:

i. Rigid PVCpipes
ii. Clear bags and flexiblefilms
iii. Acrylic sheet and displayboard
iv. Rubbersole
v. Air waterhose
vi. Conveyorbelt

PRACTICALS:

1. Determination of gravity of fillers.
2. Determination of bulk density of fillers and master batch
3. Determination of pore size and net size offillers.

4. Determination of heat stability of heatstabilizers.
5. Measurement of flash point ofplasticizer.
6. Identification of additives usingchromatography.
7. Determination the plasticizer and filler content in plasticsmaterials.
8. Evaluate the bleeding and blooming properties of anadditive.

References:

1. Lutz, 2001, Polymer Modifiers and Additives, Marcel Dekker.
2. Al – Malaika, Golovoy S., A and Wilkie (Eds), 1999, Chemistry and
3. Technology of Polymer Additives, Black well Science Ltd, Oxford.
4. Brydson J., 1999, Plastic Materials, Butterworth-Heinemann.
5. Martin and Smith, 2007, Handbook of Rubber Technology, volume 2, CBS Publisher.
6. Zweifel H., Amos S. E., 2001, Plastics Additives Handbook, Hanser.

Additional Resources:

1. MasciaL., 1974, The Role of Additives in Plastics, Edward Arnold Publishers Ltd., U.K.
2. Murphy J., Additives for Plastics Handbook, 2nd Edition, Elsevier Advanced Technology, Oxford.
3. Gachter and Mullar, 1987, Plastics Additive Handbook, HanserPublishers.
4. Gerard J. F., 2001, Fillers and Filled Polymers, Wiley-VCH verlagGmbH

Teaching Learning Process:
Class roomlectures, Group discussion, Demonstration

Assessment Methods:
Both theory and practical as per university guidelines

Keywords:
Compounding techniques, Fillers, Plasticizer, formulation

POLYMER DEGRADATION
(31141303)
CORE COURSE - (CC) CREDIT: 6

Course Objective:
1. Learning the usage of polymers Importance of degradation

CORE PAPER: C-303: POLYMER DEGRADATION
CREDITS: THEORY-4, PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to
- learn the chemistry behind the degradation
- learn about the handling of various polymers without affecting theproperties
- evaluate degradation by various methods.

THEORY:
CONTENT (TOTAL PERIODS: 60)

Unit 1: Concept of Degradation 15

Introduction to degradation, Classification of degradation based on

a) Pattern of Degradation:

i) Random Degradation

ii) Side Chain Degradation

iii) Chain End Degradation

b) Cause of Degradation (Mechanism, Factors affecting Thermal Degradation, Example)

i) Thermal degradation
ii) Oxidative degradation
iii) Degradation by radiation
iv) Mechanical degradation
v) Chemical degradation
vi) Biological degradation

Unit 2: Degradation of a fewThermoplastics 25

Different types of degradation patterns with mechanism:

i) Polyolefins (PE and PP)
ii) PVC
iii) Polyamides
iv) PMMA
v) Cellulose
vi) Polyacrylonitrile (PAN)
vii) Polystyrene (PS)
viii) PET

Unit 3: Degradationofelastomers 10

i) PU
ii) NaturalRubber
iii) SBR

Unit4: Quatitative and Qualitative Evaluation of Degradation 10

Degradation studies using DSC, TGA, Viscosity, chromatography and FTIR.

PRACTICALS:

1. Biodegradation of polymers.
2. Mechanical degradation of polymers and its effect on properties.
3. Thermal Degradation of polymer under various conditions.
4. Thermal analysis by DSC/ TGA.
5. Photo-degradation of PVC.
6. Chemical Degradation of condensation polymers.
7. Environmental stress cracking resistance of polymers.

References:

1. Pesce W.J and P.B., 2007,Wiley, Encyclopedia of Polymer Science and Technology.
2. Turi E. A., 1997, Thermal Characterization of Polymeric Materials, AcademicPress.

Additional Resources:

1. Hamid S. H. and Amin,M. B., 1992 Marcel Dekker, , Handbook of PolymerDegradation.
2. Ehrenstein G. W, Riedel G. and Trawiel P., 2004 Hanser, Thermal analysis ofplastics.

Teaching Learning Process:
Presentation, discussion, quiz

Assessment Methods:
As per University of Delhi norms

Keywords
Thermoplastic, elastomer, degradation, stability

POLYMERPROCESSING&MOLDDESIGN
(31141401)
CORE COURSE - (CC) CREDIT: 6

Course Objective:
1. To introduce the various processing techniques ofpolymers.
2. To train the students with different mold and die making techniques and theirparts.

CORE PAPER:C-401:POLYMERPROCESSINGANDMOULDDESIGN
CREDITS: THEORY-4,PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

- enrich knowledge about various design criteria for polymer, mould &die.
- develop the fundamental knowledge in the area of polymer processing including basic principles and all shaping operations used in the polymer Industry.

THEORY

Unit 1: Extrusion and die 10
Extrusion process, the extrusion die, Classification of extrusion dies-sheet die, flat film and blown film dies, pipe and tubing die, profile extrusion dies, coextrusion dies and Die defect.

Unit 2: Injection, blow, Compression and transfer moulding 13
Principles,the injection moulding cycle, the injection moulding machine, some aspects

of product quality, reaction injection moulding (RIM), Blow moulding, extrusion blow moulding, injection blow moulding, stretch blow moulding, blow moulding of PET, compressing moulding process, transfer moulding, thermosettingcompounds

Unit 3: Thermoforming, casting and rotational moulding 10
Principles, types and applications

Unit 4: Mould designing and making 10
Materials election for mould and die, mold making processes: casting, electro deposition, cold hobbing, pressure casting, spark machining, bench fitting, defects and remedy. Feed system: runner, gates and coolingunit.

Unit 5: Ejection system 7
Ejector grid, ejector plate assembly, ejection techniques, ejection from fixed half and sprue pullers,

Unit 6: Moulding with under cuts 10
Form pin, split cores, side cores, stripping internal undercuts, moulds for threaded components. Day light moulds–general, under feed moulds, double & triple day light mould

PRACTICALS:
1. Compounding of PVC and rubbers in two roll-mill with fillers and reinforcing agents.
2. Preparation of polymeric sheet/ specimen by compression, tansfer and injection moulding.
3. Process a plastic from extruder and determine the different properties like production rate, residence time etc.
4. Prepare a polymer film/ membrane by solution casting methods.
5. Preparation of thermo formed polymeric product.
6. Demonstrate the software used in mould and die design (Auto CAD, solid works, etc.)
7. Tool room/industrial visit and to design well labelled mold from clay/POP/resin etc.

References:
1. Pye R.G.W., 2000, Injection mould design, Affiliated East West Press Pvt.Ltd.
2. Strong A. B., 2005, Plastics: Materials & Processing, Prentice Hall.
3. Rosato D.V. and Rosato D.V., 2000, Injection Moulding Handbook, CBS Publisher.

Additional Resources:
1. Morton and Jones, 2007, Polymer Processing, Chapman &Hall.
2. Crawford R. J., 1998, Plastic Engg,Butterworth-Heinemann.
3. Rees H, 1995, Mould Engineering, HanserPublisher

Teaching Learning Process:
Class room lectures, Group discussion, visit and demonstration

Assessment Methods:

Theory and practical as per university guidelines

Keywords:
Processing techniques, Die Designing, Mould making, Defects

POLYMER TESTING
(31141402)
CORE COURSE - (CC) CREDIT: 6

Course Objective:
1. Understanding the basics of polymertesting
2. Learning the basics and application of different testing methods like thermal, mechanical, optical etc,

CORE PAPER: C-402: POLYMER TESTING
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to
- gain the knowledge of the testing and standards of thepolymers.

1. This paper also trains the mechanical, thermal, optical, electrical testing ofpolymers.

THEORY

Unit 1: Basic and testing standards 10
Principles and methods of standardization, preparation of sample, Different standards: BIS and ASTM standards testing methods,Evaluationof errors in polymer testing, correction of errors.

Unit 2: Thermal and mechanical analysis of polymers 15
(a) Short term strengths: Tensile, Flexural, Impact, Tear resistance, Abrasionetc.
(b) Long term strengths: Creep and fatigue properties.
(c) Thermal properties: Thermal stability, Thermal conductivity, thermal diffusivity, specific heat capacity, linear thermal expansion, heat distortion temperature, vicat softening point, low temperature flexibilityetc.

Unit 3: Flow properties 5
Melt flow index, cup flow test, solution and inherent viscosity, melt viscosity etc.

Unit 4: Flammability properties 5
Burning behavior, flammability tests, UL-94, Oxygen index, critical temperature index, smoke density.

Unit5: Optical and electrical properties 15
Different optical properties (reflection, refraction, diffraction etc), color matching, Refractive index, Gloss, haze, degree of yellowness etc. Dielectric Strength, Surface and volume resistivity, Breakdown voltage, Arcresistance

Unit 6: Gas barrier and environmental assessment 10

Definitions, permeability to gases, standard methods of measuring the permeability of gases, other methods of measuring permeability. Environment resistance – cause of deterioration of polymer by weathering, assessment of deterioration, natural weathering, artificial weathering. Chemical resistance

PRACTICALS:

1. Determine the melt flow index of LLDPE, PP etc.
2. Evaluate limiting oxygen index (LOI)/ UL-94 of plastic sample: PVC, PE, PP etc.
3. Determination the Heat Distortion Temperature,Vicat softening temperature and thermal stability of polymer film.
4. Measurement of abrasion resistance and dielectric strength of polymersheets.
5. Determination the coefficient of friction and izod Impact strength of PVC and PP samples.
6. Determination of environment stress cracking resistance of PE/PPfilms.
7. Determination of Shore Hardness and rockwell hardness ofplastics.

References:

1. Shah V.,2007, Handbook of Plastic Testing & Technology,Wiley-Interscience.
2. Martin and Smith, 2009, Rubber Technology Handbook. RapraTechnology.
3. Hylton D., 2004, Understanding Plastic Testing, Hanserpublication

Additional Resources:

1. Berins M. L., 1991, SPI Plastic Engineering Handbook,Springer-Verlag.
2. WardI.M.andSweeneyJ.,2004,AnIntroductiontotheMechanicalPropertiesofSolidPolymers,Wiley.
3. Grellmann W., Seidler S., 2013, Polymer Testing, Hanserpublication.

Teaching Learning Process:

Class roomlectures, Groupdiscussion, Demonstrations

Assessment Methods:

Both practical and theory as per university guideline

Keywords:

Standards Mechanical testing, Thermal testing, Environmental stress crack assessment

RECYCLING AND WASTE MANAGEMENT
(31141403)
CORE COURSE - (CC) CREDIT: 6

Course Objective:

1. Students will learn about waste management
2. Students will develop the concept of plasticrecycling

3. Students will learn about various waste disposal and treatmentmethods

CORE PAPER: C-403: RECYCLING AND WASTE MANAGEMENT
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

- understand the problems associated with polymer waste management.
- Get an idea about thevariouswastemanagementtechniquesavailableforpolymer
- Learn variousenvironmentalconcernsrelatedtoplasticwasteandmethodsofhandlingthem

THEORY:
CONTENT (TOTAL PERIODS:60)

Unit 1: Introduction towastemanagement 10
Definitionofplasticwastesandlitter,basisforassessingplasticwastes,applicationsofplasticsandtheirpotentialassourcesofwaste.Sorting techniques and it's classification (density - float sink and froth floatation methods, selective dissolution, optical, spectroscopic, sorting by melting temperature, TriboelectricSeperatoretc.).

Unit 2: Classification ofWasteManagement 10
Thermoplastic waste management: 4 R's approach (reduce, reuse, recycle, recover), recycling classification - primary, secondary, tertiary, quaternary recycling with examples (mechanical, chemical and thermal processes)

Unit3:Disposalandwastetreatmenttechniques 15
Controlled tipping, pulverization, composting, incinerators, pyrolysis, gasification, on-site disposal methods, compacting and baling

Unit 4:Plasticrecycling 15
Recycling of Polyolefins, PVC, PET, Polystyrene, Polyamides (Nylon-6 and Nylon-6,6) etc.

Unit 5: Waste managementofThermoset 10
Recycling of Thermosets, reclaiming of rubber, tyre retreading, uses of recycled rubber

PRACTICALS:

1. Primary recycling of various waste collected fromenvironment.
2. SecondaryrecyclingofMSWbyincorporatingandblendingtherecyclablewastewithvirginpolymers.
3. To study Composting ofnatural/Biopolymers.
4. Separation of polymer mixture by Sink FlotationTechnique.
5. Separation of Polymer mixture by Selective dissolutiontechnique.

References:

1. ChandraR.andAdabA.,2004,RubberandPlasticWaste:Recycling,ReuseandFutureDemand,CBSPublisher.
2. NIIRBoardofConsultantandEngineers,2007,Medical,MunicipalandPlasticWasteManagementHandbook,NationalInstituteofIndustrial Research.

Additional Resources:

1. Scheirs J., 1998, Polymer Recycling, John Wiley &Sons.
2. Blow S., 2000, Handbook of Rubber Technology, HanserGardner.
3. Bandrup J.E., 1996, Recycling and Recovery of Plastics, HanserGardner.
4. Goodship V., 2007, Introduction to plastics recycling,Rapra.

Teaching Learning Process:
Power point presentation, Discussion,demonstrations

Assessment Methods:
As per University of Delhi Rule

Keywords:
Recycling, WasteManagement, Plastics, Rubber

POLYMER CHARACTERIZATION
(31141501)
CORE COURSE - (CC) CREDIT: 6

Course Objective:

1. Understanding the basics of polymercharacterization.
2. Learningtheprincipleandapplicationsofdifferentrelevanttechniquesinpolymercharacterization.

CORE PAPER:C-501:POLYMERCHARACTERIZATION
CREDITS: THEORY-4, PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. This course will provide adequate knowledge of characterization techniques of thepolymers.
2. Thispaperalsohelpstolearnthedeterminationofstructure,purity,morphology,stabilityandmolecularweightofapolymers.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit1:Introduction 10
Basicprincipleofspectroscopy,molecularandatomicspectra,Lambert-Beer'slaw,Frank-condonprinciple,electromagneticradiationandit's properties, interaction of radiation with matter, statistical method ofanalysis.

Unit2: Spectroscopic techniques 10
Principlesandapplicationsinstructuraldeterminationofpolymers
(functionalgroup,tacticity,molecularstructure,purity,unsaturationetc.): Infra-

redspectroscopy,UV-Visspectroscopy,ElectronSpinResonance,Raman,NuclearMagneticResonancespectrometer.

Unit 3: Chromatography techniques in Polymer 10
Thinlayerchromatography,highperformanceliquidchromatography,gelpermeationchromatography(GPC),gaschromatographyandsize exclusionchromatography.

Unit 4: Microscopic andX-Raytechniques 10
Optical microscopy, Electron micrtoscopy (SEM, TEM, AFM) and XRD: Basics and applications (size, morphology, crystallinty etc.) in polymers characterization.

Unit 5: Thermal and mechanical characterization 10
Thermalgravimetricanalysis (TGA),DifferentialThermalAnaysis(DTA),DifferentialScanningCalorimeter(DSC),DynamicMechanical Analyser (DMA)andThermalMechanicalAnalyser(TMA):PrincipleandApplicationsinpolymercharacterization.

Unit6:Molecularmassandmassspectroscopy 10
GasChromatography-massspectrometer(GC-MS),MALDI-TOF,ESI-MSandmethodsfordeterminationofmolecularmass (principlesand applications in polymercharacterization)

PRACTICALS:

1. To Verify Lambert-Beer's law by UV-Vis.spectrophotometer.
2. Calculate % amount of Inorganic and organic ingredient in polymericcompound.
3. Analyze the thermal behavior ofpolymers.
4. Determine the molecular weight of a polymer.
5. Calculate Percentage Crystallinity of Polymeric Sample by XRD,DSC.
6. Identification of additives in a processed polymer byChromatography.
7. FTIR, NMR and Raman analysis ofpolymers.

References:

1. Willard H.H., Merrit L.L., Dean J.A. 1988. Instrumental method of analysis, WadsworthPublishing Company
2. Skoog D.A, 1997, Principle of Instrumental Analysis, Harcourt College Pub.
3. Shah V., 2007, Handbook of Plastic Testing, Technology, Wiley-Interscience.

Additional Resources:

1. Tanaka, T., 1999, Experimental Methods in Polymer Sciences, AcademicPress.
2. Silverstein,RobertM.,1991,Spectrometricidentificationoforganiccompounds, JohnWiley.
3. MacomberRogerS,2008,AcompleteintroductiontoNMRspectroscopy, Wiley-Interscience.

Teaching Learning Process:
Class roomlectures, Groupdiscussion Demonstration

Assessment Methods:
Theory and practical as per university guidelines

Keywords:
Polymer, analysis Spectroscopy Chromatography Microscope

SPECIALTY POLYMERS (31141502)
CORE COURSE - (CC) CREDIT:6

Course Objective:

1. Tostudybasicconceptsofspecialtypolymersincludingtemperature&fireresistanthigh performancepolymers,biopolymersandconducting polymers.
2. To learn synthesis and application of specialty polymers.

CORE PAPER: C-502: SPECIALITY POLYMERS
CREDITS: THEORY-4 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. The course will help students to understand basic concepts of specialty polymers & their structure property relationship and their applications

THEORY
CONTENTS (TOTAL PERIODS:60)

Unit 1: Preparation, properties and applications ofspecialtypolymers:25
IntroductiontoEngineering/Specialitypolymers,hightemperatureandfireresistantpolymers, preparation,propertiesandapplicationsofthe followingpolymers:

i. Polycarbonate(PC)
ii. Poly(ether ether ketone) (PEEK) and Poly(ether-ketone)(PEK)
iii. Sulphur based polymers (Polysulphone and polyphenylenesulfide)
iv. Polyamide, Polyamideimide resins (PAI) and Polyimideresins
v. Polyacetals
vi. Polyphenylene oxide(PPO)
vii. Silicones, fluoropolymersandpolyphsophazenes
viii. High performance thermosetting resins such as epoxides, polyesters, polybenzoxazineetc.

Unit 2.Conductingpolymers10
Synthesis, properties and applications of polyaniline, polypyrrole ,polythiophene and poly(p-phenylenevinylene)

Unit3: Biopolymers10
Basicconceptsofbiopolymers/biodegradablepolymers(Polylacticacid,polycaprolactone,starch,etc.),hydrogels,smarthydrogelsandtheir applications

Unit 4 Recent advances inspecialitypolymers10
High performance polymer blends and nanocomposites,

Unit 5

PRACTICALS:

1. Synthesis of conducting polymers.
2. Synthesis of heat resistant polymers
3. To determine conductivity of polymericsample.
4. Preparation of Nylon 6, 10 by interfacialpolymerization.
5. Investigationofperformancepropertiesofspecialtypolymerssuchasthermalstability,fireresistance

References:

1. BrydsonJ.A.,1999,PlasticMaterials,Butterworth-heinemann.
2. DysonR.W.,1990,Engg.Plastics,Blackie,ChapmanandHall.

Additional Resources:

1. Domb.A.J.,1997,HandbookofBiodegradablePolymer,GordonandBreachSciencePublishers.
2. SeymourR.B.and,KirshenbaumG.S.,1986,HighPerformancePolymers,theiroriginanddevelopment,Springer.

Teaching Learning Process:
Quiz/Demonstration/Visits

AssessmentMethods:
As per DU Norms (Assignment/Presentation and tests)

Keywords:
Temperature/Fire Resistant Polymers, High performance polymers, Conducting polymers

POLYMER BLENDS AND COMPOSITES
(31141601)
CORE COURSE - (CC) CREDIT:6

Course Objective:
1. Understanding of blends and composites
2. To study the preparation and application of blends and composites

CORE PAPER: C-601: POLYMER BLENDS AND COMPOSITES
CREDITS: THEORY-4; PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to
1. Students will learn about the theoretical concept of Blends and Composites
2. This paper will help students to gain knowledge about the preparation and properties of Blends and Composites

THEORY:
CONTENT (TOTAL PERIODS: 60)

Unit 1: Basic Concept of Blends 15

Definition of Blends. Types of Blends (Plastic-plastic, rubber-rubber and plastic-rubber blends), Differences between copolymer, and IPNs,Blends and alloys, Composites, Concept of miscibility, Concept of free energy of mixing, Phase equilibria, Flory-Huggins Theory, spinodal andcritical phase, Gibb's phase rule

Unit 2: Preparation and Properties of Blends 10

Methods of blending, Compatibilizers, Methods of compatibilization, Factors effecting miscibility of polymer blends, Composition and properties(rheology, morphology, mechanical and thermal)

Unit 3: Characterization Techniques of Blends 10

IR, microscopy (TEM, SEM and optical), TGA, DSC, DMA, Viscosity, Refractive Index

Unit 4: Polymer Composites 10

Definition; Classification of composites;dispersed phase: (Reinforcing fillers, non-reinforcing fillers), and (Particulate matter, fibrous structure and platelet structures), Continuous Phase: Thermoset matrix, thermoplastic matrix and high-performance resins,Mechanism of reinforcement, various factors effecting reinforcements

Unit 5: Design and fabrication of composites 15

Fabrication techniques: Prepreg technology, injection and compression moulding, vacuum bag moulding, hand-lay-up process, spray-uptechnique, filament winding process, fibre placement process, pultrusion, reaction transfer molding, laminating techniques, expansionprocesses, fabrication processes: adhesion, cohesion and mechanical processes & FRPs.

Design of a few polymer composite application,: Basic design practice – material considerations, product considerations and designconsiderations, Rule of Mixture

PRACTICALS:

1. To prepare polymer blends by melt, solution and latex blending.
2. To find out Compatibility of blends.
3. Preparation of laminates.
4. Preparation of composites with various fillers and various filler loading.
5. Fabrication of composite by various techniques.
6. Characterization (Thermal and mechanical) of blends and composites.

References:

1. Paul D. R. and Bucknall C. B., 2000, Polymer Blends Volume 1 & 2, Wiley-Interscience.
2. Robeson Lloyd M., 2007, Polymer Blends, Hanser Gardner Pubns

Additional Resources:

1. Paul D. R., Newman S., 1978, Polymer Blends Volume 1 & 2, Academic Press.
2. Utracki L. A., 2003, Polymer Blends Handbook Vol 1 & 2 by, Kluwer Academic Pub.
3. Bhowmick A.K and De S.K 1990, Thermoplastic Elastomers from Rubber-Plastic Blends, Ellis Horwood Publishers Ltd., UK.
4. Bhowmick A.K and McIntyre D., 1989, Polymer and Composite Characterization" –

Special issue of J. Macromolecular Science, Chemistry,
Eds., Marcel Dekker, Inc., USA.

Teaching Learning Process:
Power point presentation, discussion, demonstration

Assessment Methods:
As per university of delhi rules

Keywords:
Blends, composites, compatibility, design

FIBRE SCIENCE AND RUBBER TECHNOLOGY
(31141602)
CORE COURSE - (CC) CREDIT: 6

Course Objective:
1. To study the basic concepts of fibres, natural and synthetic fibres
2. To study the concept of vulcanization and properties of rubber

CORE PAPER: C-602: FIBRE SCIENCE AND RUBBER TECHNOLOGY
CREDITS: THEORY-4 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to
1. The students will get brief idea of fibres (natural and synthetic) including their classification, structure and properties.
2. The students will also get a brief introduction to natural and synthetic rubbers including their classification, structure and properties.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Introduction to fibres 10
Introduction, classification, structure and general properties of a fibre such as moisture absorption, tex, denier, tenacity, elongation at break, elastic recovery etc.

Unit 2: Natural fibres 10
Brief introduction to structure, properties and application of naturally occurring fibres – Vegetable fibres, animal fibres and mineral fibres

Unit 3: Synthetic fibres 10
Structure, properties and applications of synthetic fibres: viscous rayon, cellulose acetate, nylon 6, nylon – 66, polyester, acrylic, carbon fibre and aramid fibres.

Unit 4: Rubbers: Preparation, Properties and applications 15

Natural rubber and synthetic rubber (styrene-butadiene rubber, polybutadiene rubber, ethylene propylene diene rubber, butyl rubber, nitrile rubber, neoprene, silicone rubber, fluorocarbon rubber)

Unit 5: Vulcanization of rubber 15

Theory and mechanism of sulfur and non sulphur vulcanization (with and without accelerators), rheocurve of compounded rubber, properties of vulcanized rubber

PRACTICALS:

1. Determination of tensile strength, modulus, elongation at break, tear strength, abrasion resistance, heat build-up, resilience, hardness, flex resistance for rubber compounds.
2. Determination of curing time and physical properties of rubber compounds.
3. Identification of fibres through elemental analysis.
4. Analysis of reaction of fibres towards heat & flame.
5. To determine mooney viscosity using Mooney viscometer.
6. To determine physical properties of fibres: tex, tenacity, denier, moisture content, densityetc.
7. R & D visit.

References:

1. Smith and Martin, 2007, Hand Book of Rubber Technology, CBS Publisher.
2. Mark J. E., Erman B. and Eirich F. R., 2005, The Science and Technology of Rubber, Elsevier Academic Press.
3. Cook J. G., Volume 1 (1984) and & Volume 2, 2009, Hand Book of Textile Fibres, Woodhead Publishing.
4. Blow S., 2000, Hand Book of Rubber Technology, Hanser Gardner.
5. Morton &Hearle, 2008, Physical Properties of Fibres, CRC Press.

Additional Resources:

1. Collier and Tortora,2009, Understanding Textiles, Prentice Hall.

Teaching learning process:
Demonstration/Visits/Presentations

Assessment methods:
As per DU norms

Keywords:
Natural and synthetic fibres, Vulcanization

CONDUCTINGPOLYMERS
(31147901)
DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT:6

Course Objective:

1. To introduce the basics of conductingpolymers
2. Teach the different synthetic methods, properties and applications of conductingpolymers.

DSE: PAPER 1: CONDUCTING POLYMERS
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. Students will get the idea about different conductingpolymers
2. This paper also discusses the different properties and applications of conductingpolymers.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit1:Basicaspectsofconductingpolymers: 10
Historical back ground, Band structure, Band alignment, Conduction mechanism, Theory of electrical conduction in conducting polymers.

Unit 2: Synthesis ofconductingpolymers 10
Chemicalandelectrochemicalpolymerizationsofpolyaniline,polypyrrole,polythiopheneetc, dopinganditseffectsonpropertiesofconducting polymers.

Unit 3: Properties of conducting polymers 10
Electrical Properties, resistance, impedance, capacitance, magnetic properties and optical properties.

Unit 4: Blends of Conducting Polymers 10
Blendsofconductingpolymers,nanoblends,blendsofpolyaniline,polyanilinederivativesandtheirblends,comparisonofthemorphological and conductivity characteristics of polyaniline blends, blends of polythiophene andpolypyrrole.

Unit 5: Composites 10
Compositesofconductingpolymers,conductingpolymersbasedbiocomposite,propertiesandapplicationsofconductingpolymerComposites, Bio-components matrices and effect ofreinforcements.

Unit 6: Applications 10
Electronicdevices,Sensors,Rechargeablebatteries,Solarcells,Lightemittingdevices,Biomedicaldevices,bio-system,organtransplant, artificial mussels and EMI shieldingetc.

PRACTICALS:

1. Synthesis of conducting polymers such as polyaniline, polypyrrole, polythiophene etc,
2. Prepare film/ sheet of conductingpolymers
3. Evaluate the mechanical properties of conducting polymerfilms/sheet.
4. Determine the thermal properties of conductingpolymers
5. Measures the electrical conductivity and resistance of conducting polymer films/ sheet.

References:

1. ChandrasekharP.,1999,ConductingPolymers,fundamentalsandapplications:Apracti calapproach,Springer.
2. NalwaH.S.,1997,HandbookofOrganicConductiveMoleculesandPolymers:Conduct ivepolymers:synthesisandelectricalproperties, Wiley.
3. SkotheimT.A.,ElsenbaumerR.L.,ReynoldsJ.R.,2007,HandbookofConductingPoly mers,CRCPress.

Additional Resources:

1. Fernandez O. T., 2015, Conducting Polymers, Royal Society ofChemistry.
2. Almeida L. C. (Ed), 2013, Conducting Polymers: Synthesis, Properties &Applications

Teaching Learning Process:
Class roomlectures, Groupdiscussion, Demonstration

Assessment Methods:
Theory and practical as University guidelines

Keywords:
Conducting polymers, Synthetic methods, Conduction mechanism and applications

FIBREMANUFACTURINGTECHNOLOGY
(31147902)
DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT: 6

Course Objective;

1. Tohelpstudentsunderstandbasicconceptsofspinningincludingmeltandsolutionspinn ing. To study various parameters effectingspinning.
2. To study effect of drawing and heat setting of fibre structure and properties.

DSE: PAPER 2: FIBRE MANUFACTURING TECHNOLOGY
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes

1. Basicconceptsofspinningincludingmeltspinningandsolutionspinning Effectofdrawingandheatsettingonfibrestructureandproperties.
2. Various factors effecting spinning and spinning variables

CONTENTS (TOTAL PERIODS: 60)

Unit1: Introductiontofibres 5
Manmade fibres: definition of made fibres, brief history of manmade fibres, relative merits and demerits of manmade and natural fibres.

Unit 2: Fundamentals of Spinning and Rheological properties of fibreformingmaterials25
Spinnabilityoffluidsandhydrodynamicstability**,**Introductiontopolymerviscoelasticity,stres srelaxation,polymerentanglements,Shearflow inacapillary,factorsaffectingshearviscosityofpolymerfluids,Elongationalflow,Elongationa lviscosity,Flowinstabilitiesinpolymerfluids

Basicconceptofmeltspinning,dryspinninganddryjetwetspinningprocess.Differentcompone ntsofspinningprocess,i.e.,extruder,gear pump, filters, manifold, spinning head, quenching chamber, winders. Variables of spinning.Quenching/solidification techniques.Factors influencingselectionofaparticularprocessforfibreformation,Variousparameterseffectingfib rebreakageandfibrestructure.
Conceptofdrawingandheatsettingoffibres,neckdrawing.Effectofdrawingandheatsettingcon ditionsonthestructureandpropertiesof fibre. Spin finishapplication

Unit3:Meltspinning10Melt spinning process, Crystallization in spin line, stress induced crystallization,Melt spinning of PP, polyester and nylon-6 and -66. Effect of process parameters on structure and properties of melt spun filament. Characteristic features of PET and polyamide spinning.

Unit4:Solution dryspinning:
10Dryspinningofcelluloseacetate.Acetylationofcellulose.Dopepreparatio nandspinningofcellulosediacetateandtriacetate.Dryspinningof acrylic. Significance and types of co-monomers used during polymerization ofacrylic.

Unit5:Solutionwetspinning10WetspinningofAcrylic,Wetspinningofviscoserayon,formati onofstructureinviscose.Influenceofvariousadditivesandtemperatureofthe regeneration bath and their influence on the process and properties of viscoserayon.

PRACTICALS:
1. Melt spinning ofPolypropylene
2. Melt spinning of Nylon 6/66.
3. Solution spinning of Acrylicfibre.
4. Drawing and heat seating ofFibres.
5. Effect of drawing and heat setting on properties offibres.
6. Chemical modifications offibres

References:

1. Gupta V. B., and Kothari V. K., 1997, Manufactured Fibre Technology, 1st Ed., Chapman and Hall,London.
2. NPTEL course material on Manufactured fibreTechnology
3. Macintyre J. E., 2003, Synthetic Fibres, Wood Head Fibre Science Series,UK.
4. KothariV.K.,2000,TextileFibres:DevelopmentsandInnovations,IAFLPublications,Ne wDelhi.

Additional Resources:

1. VaidyaA.A.,1988,ProductionofSyntheticFibres,1stEd.,PrenticeHallofIndia,NewD elhi.

Teaching Learning Process:
Demonstration/Industrial visit/ Presentation

Assessment Methods:

As per DU Norms

Keywords:
Melt Spinning, Dope, Drawing, Heat Setting, Extruder

PAINTS, COATINGS AND ADHESIVE
(31147903)
DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT: 6

Course Objective:
1. Understanding of basics of paint, coatings and adhesives
2. Students will be able to perform quality assessment of the same
3. Students will gain knowledge in formulating different types of paints, coatings and adhesives

DSE: PAPER 3- PAINTS, COATINGS AND ADHESIVES
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. Apprehend the basic concept of raw material and manufacturing of Paints, Coatings andAdhesives and their applications.
2. Students will be able to assess the quality of Paints, Coatings and Adhesives.
3. Students will understand the challenges and future scope in the field of Paints, Coatings and Adhesives.

THEORY
CONTENT (TOTAL PERIODS:60)

Unit 1: Introduction to Paints, Coatings and Adhesives

15General information about Paints, paint composition, Types of Paint,Function and properties of adhesives, Types of adhesives (Structural, elastomeric and pseudo plastic). Definition and importance of coating, composition of coating

Unit 2: Raw materials of Paints, Coatings and Adhesives

15Pigments (Natural and synthetic), Binders (natural and synthetic: thermoset and thermoplastic) Solvents, thinners, Dryers, drying oils etc.

Unit 3: Surface Treatment

10Surface preparation (Plastic, Metal, Wood and cemented), Heat treatment, Corona Discharge treatment, Flame treatment, MechanicalTreatment Types and preparations of adhesive, adsorption and surface reaction. Surface topography, wetting and setting, interfacial bonding

Unit 4: Preparation Paints, Coatings and Adhesives

10Formulations, Selection and water solubility, manufacturing and uses of paints, coatings (Manufacture, criteria and type), adhesive(Manufacturing of Structural and Elastomeric),Manufacturing Equipments: High-Speed Mixers, Mill (Vertical, Horizontal, Continuous, Sand Mill and Ball Mill)

Unit 5: Coating Operations

10Coating operations: Brush, Roller , both side roller, Spray(Manual/Airless/Air guns), Dip coating (Advantages & Limitations), Flow Coating

PRACTICALS:

1. Formulation of paints (water and solvent based).
2. To find out adhesive strength by Peel Test method.
3. Adhesive formulation and compounding.
4. Measurement of Wettability of adhesives.
5. Measurement of resin/paint viscosity by Ford cup 4 and Brookfield viscometer.
6. Colour Matching of Paints films
7. To find out Tape Adhesion of Coatings
8. To Tested Film Hardness of Coating Adhesive film
9. Measurement of Impact Resistance of Paints films
10. To find out Salt Spray Testing of paints
11. Find out Humidity Testing of paints

References:

1. Morgan W. M., 2000, Outline of Paint Technology, CBS Publisher.
2. Stoye D., 2008, Paints, Coatings and Solvents, Wiley-VCH.

Additional Resources:

1. Pocius A. V., Carl H., 2002, Adhesion and Adhesives Technology, Hanser-Verlag.
2. Ryntz R. A., Yaneff P. V., Marcel Dekker, 2003, Coatings of polymers and plastics.
3. Mittal K.L., 2003, Adhesion aspects of polymer coatings, VSP.
5. Talbert R., 2008, Paints technology Handbook, CRC Press.

Teaching Learning Process

Power point presentation, discussion, quiz, demonstration

Assessment Methods

As per University of Delhi Rules

Keywords

Paints,adhesives, coatings

POLYMERIC NANOMATERIALS
(31147904)
DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT:6

Course Objective:

1. To make students understand the basic concepts of nanomaterials and polymer nanocomposites.
2. To learn the effect of shape, size, dispersion and percolation of nanomaterials on polymer nanocomposites.
3. Preparation, characterization and applications of polymer nanocomposites.

DSE: PAPER 4: POLYMERIC NANOMATERIALS

CREDITS: THEORY-4 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. The course will help students to understand what are polymeric nanomaterials and how arethey prepared ?
2. The students will be able to learn the effect of various factors influencing properties of polymeric nanomaterials.
3. The students will be able to explore various areas in which nanomaterials find applications on the basis of their morphological, mechanicaland thermal properties.

THEORY
CONTENT (TOTAL PERIODS: 60)

Unit 1: Introduction 10
Introduction to general aspects of nanostructured materials, e.g. nanocomposites, block copolymers, interaction parameter, phase behaviourmorphology and phase diagrams, microphase separation transition

Unit 2: Nano-reinforcing Agents
15Preparation, structure and properties of nano-reinforcing agents: 1 D, 2 D and 3 Dnanomaterialseg. nanoparticles, nanotubes, nanoclays,POSS, carbon nanostructures (CNTS, graphene).

Unit 3**.**Factors affecting properties of nanomaterials 10
Factors governing properties of nanocomposites such as loading, dispersion and percolation, influence of size, shape and diameter ofnanoparticles nanotubes, functionalization of nanomaterials.

Unit 4:Structural and morphological characterization
15Morphology of crystalline polymers., X-ray scattering & diffraction technique analysis of Nanostructure developed in semicrystalline polymersduring deformation, Nanostructure of two component amorphous block copolymers, effect of chain architecture.

Unit 5: Polymer Nanocomposites 10

Basic concepts, preparation, characterization and applications of polymer nanocomposites. Technical challenges and understanding ofinterfacial dynamics using LJ Potential and many body problems approach

PRACTICALS:
1. Particle size analysis of nanomaterials (nanoparticles).
2. Preparation of polymer nanocomposites by solution casting & melt compounding.
3. Determination of mechanical properties of nanocomposites.
4. Characterization (morphology and thermal) of nanocomposites by optical microscope, SEM, TEM, DSC, DMA, TGA etc.
5. Determination of electrical properties of nanocomposites.
6. Photocatalysis/self-cleaning (contact angle/rolling angle measurements)

References:
1. Koo J. H., 2010, Polymer Nanocomposites, McGraw-Hill.
2. Bhattacharya S. N., 2008, Polymeric Nanocomposites-Theory and Practice, Hanser Gardner.
3. Michler G. H. and Balta F. J., 2005, Mechanical Properties of Polymer based on Nanostructure and Morphology, CRC Press.
4. Owens F. J. and Papoose C., 2003, Introduction to Nanotechnology, Wiley, John & Sons.

Additional Resources:
1. Tjong S. C., 2006, Nanocrystalline Materials, Elsevier Science.

Teaching Learning Process:
Demonstration/ Quiz/presentation/ R & D Lab visits

Assessment Methods:
As per DU norms (Includes Tests, Assignments/Quiz/Presentation)

Keywords:
Nanomaterials, Polymer nanocomposites, LJ Potential

TYRE TECHNOLOGY
(31147905)
DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT: 6

Course Objective:
1. Developing the knowledge of manufacturing techniques of various tires
2. Understanding of different types of tires and their components

DSE: PAPER 5- TIRE TECHNOLOGY
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. To learn the basic concept of manufacturing technology of tire.
2. Designing and compounding of various tire components
3. Testing and quality assessment of tire

THEORY

CONTENT (TOTAL PERIODS: 60)

Unit 1: Introduction and Tire Technology 10

Classification: Based on construction (pneumatic, radial, bias, cross ply, tube, tubeless, solid); Based on application (Scooter, Motorcycle, OHT,TBR/PCR, Airplane Tire etc). Tire components and its functions (Tread, Bead, Ply, Belt, Inner liner IL, Sidewall, Tubeless IL, Tube, Bladder), Tire performances (Rolling resistance, traction, mileage, wear, fatigue, load withstandability, etc.). Tire terminology (Tire indexing, Aspect ratio, etc), high performance radial tires.

Unit 2: Tire manufacturing 15

Mixing (Mixing instruments: banbury, two roll mill, kneader, internal mixers), Processing (extrusion, calendaring, bead winding), Building (building drum), Curing (moulding machines etc), mould sign,

Unit 3: Tire design 15

Compound design (selection of chemical ingredients); Process design (process parameters correlating with properties); Product design (constructions). Latest advances in materials and technologies.

Unit 4. Tire mechanics 10

Cornering Properties of Tires, Slip Angle, Cornering Force, Aligning Torque Tractive (Braking) effect and Longitudinal Slip (Skid). Camber and Camber Thrust, Performance on wet surfaces, Riding comfort

Unit 5: Tire testing 10

Tire Testing: Endurance, groove crack test, plunger test, Traction: dry, wet and snow, Air permeation,noise test, rolling resistance, Drivability,Road test, wet braking test, Fuel economy test. Tread to ply pull out, bead seating test etc.

PRACTICALS:

1. Rubber material identification
2. Rubber mixing and moulding
3. To test mechanical and physical properties of vulcanized rubber:
4. To perform air aging properties of rubber and rubber to fabric ply.
5. To determine bonding strength of rubber to fabric.
6. To calculate abrasion losses of tire tread.
7. To calculate rebound resilience
8. Tire indexing and cut section analysis
9. Compression set

References:

1. Clark S. K., 1971, Mechanics of Pneumatic Tires, National Bureau of Standards, Monograph, US Govt. printing office
2. French T., 1989, Tyre Technology, Adam Hilger, New York.

Additional Resources:

1. Ford T. L. and Charles F. S., 1988, Heavy Duty Truck TIRE Engineering SAE's 34th L. Ray Buckingdale Lecture, SP729.
2. Gent A.N. and Walter J.D., 2006, The Pneumatic TIRE , U.S. Department of Transportation, National Highway Traffic Safety Administration.
3. Mark J.E., Erman B., Eirich F.R., 2005, The Science and Technology of Rubber, Elsevier.
4. Koutny F., Zling, 2007, Geometry and Mechanics of PnumaticTIRE, CZE.

Teaching Learning Process
Power Point Presentation,Discussion, Quiz, Industry Visits

Assessment Methods:
As per DU nomes

Keywords:
Manufacturing, tire, testing

PACKAGING TECHNOLOGY
(31147906)
DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT:6

Course Objective:
1. Students will learn the basic necessities and importance of packaging.
2. This paper will help students to choose the correct polymer for different types of material packaging.

DSE: PAPER 6- PACKAGING TECHNOLOGY
CREDITS:THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

- Apprehend the basic concept of packaging and their utilization from application point of view.
- assess the quality of packaging material and packaged product

THEORY
CONTENT (TOTAL PERIODS:60)
Unit 1: Introduction and Material 10
Importance, scope of packaging (India and Global), packaging materials: types, properties, advantages and disadvantages.

Unit 2: Packaging Systems 15

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

Unit 3: Polymers in Packaging 15

Properties and Applications: LLDPE, LDPE, HDPE, HMHDPE, PP, PVC, Nylon, Polyester, Polycarbonate, PS, EPS etc.

Unit 4: Packaging process techniques 10

Thermoforming in packaging, co-extrusion, extrusion-stretch blow molding, injection molding, LDPE, BOPP films.

Unit 5: Testing of polymer packaging material 10

Bursting strength, Tensile strength, Tear strength, Puncture test, Impact test (Drop, falling dart), permeability Test (Water vapour, Oxygen),Biodegradability, Sealing strength

PRACTICALS:

1. To Identify packaging materials with the help of FT-IR, DSC, TGA etc.
2. Determination of physico-mechanical properties (density, bursting strength, tensile strength, tearing strength, drop test strength, puncturetest strength, impact strength etc).
3. Determination of water vapor transmission rate of packaging material
4. To test sealing strength integrity of packaging materials
5. To check biodegradibility of packaging material

References:

1. Gordon L. Robertson, 2005, Food Packaging Principles and Practice, CRC press.
2. Paine F. A. and Paine H. Y., Blackie, 1992, A Handbook of Food Packaging, Academic and Professional

Additional Resources:

1. Robertson G. L., 2012, Food Packaging – Principles and Practice, CRC Press Taylor and Francis Group.
2. Coles R, McDowell D., Kirwan M. J., Blackwell , 2003, Food Packaging Technology.
3. Robertson G. L., 2012, Food Packaging – Principles and Practice, CRC Press Taylor and Francis Group.
4. L. A. Sukhareva, V. S. Yakolev, O. A. Legonkova, 2008, Polymers for packaging materials for preservation of food stuffs.

Teaching Learning Process:

Power point presentation,Demonstraions, Discussions, Videos

Assessment Methods:

As per University of Delhi norms

Keywords:
Packaging Materials, Polymer Testing, Packaging Systems, Polymer Processing

FABRICATIONOFPOLYMERICPRODUCTS (31147907) DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT: 6

Course Objective:

1. To make students aware of the polymer processingtechniques.
2. To learn about the handling of processingtechniques

DSE:PAPER7: FABRICATIONOFPOLYMERICPRODUCTS CREDITS:
THEORY-4, PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. Topreparethestudentsforunderstandingofvariouspolymerprocessingoperationsfrom processcontrolandprocessingequipmentpoint ofview.
2. Tounderstandthebasicconceptsofcellularplastics,joiningofplastics,laminatesandinjection moldingetc.
3. Togivetheknowledgeofpostmoldingoperationslikeprintingandotherdecorativemethods.

THEORY:
CONTENT (TOTAL PERIODS: 60)

Unit 1:FRPLaminates: 10
Introduction,FRPprocessingmethods,centrifugalcasting,matcheddiemoldinglaminates,high pressurelaminatingprocess,typesof machinery,impregnationsystems– decorativeandindustriallaminates,continuoushighpressurelaminatingprocess,applications.

Unit 2:CellularPlastics 10
Processtocreatefoaminresins,mechanicalfoaming,chemicalfoaming,physicalfoaming,processestoshapeandsolidifyfoams,lowpressure foam molding, high pressure foam molding, RIM extrusion foaming, casting foams, steam chest molding, structural foam molding and applications.

Unit 3: Machinery and JoiningofPlastics 10
Machiningmethodseg.cutting,drilling,blending,filling,etc. Principles: Joining, cohesion,adhesion; Cementing: solvent, DOP; Welding: vibration, hot plate, ultrasonic; Adhesive bonding

Unit 4: PostMoldingOperations 15
Printing and decoration of molded items - films, pipes, sheets, etc. hotstamping,padprinting,screenprinting,rotogravureprinting,heatsealing,ultrasonicwelding,limitationsofpostmouldingoperations– theiradvantages.

Unit 5: AdvancedProcessingTechniques15

Non-Conventional Injection Moulding: Gasinjectionmoulding– types,processmodeling,gasdissolution,gasfingering,unstablegaspenetration Water injection moulding, classification of different water injectors, injection foam moulding-types Microcellularinjectionfoammoulding,nucleationandpressureprofilesduringfilling Powder metal injection moulding - process and steps involved. Microinjection moulding-types and process details, reactive injection moulding.

PRACTICALS:

1. To Prepare open and closed cellfoam
2. To prepare laminates such as epoxy, polyester and epoxy-polyestertype.
3. To Prepare PMMA sheet using bulkpolymerizations.
4. To Join polymer products bymolding.
5. To repair polymer products by different processingtechniques.
6. Post curing of peroxide curerubber.
7. To prepare PMMA sheet with in-situpolymerization

References:

1. SatarD.,1986,PlasticsFinishingandDecoration,VanNostrandReinholdcompany,NewYork.
2. Margolis James M., 1986, Decorating Plastics, Hanser Publishers, NewYork.
3. Astrom B. T., 1995, Manufacturing of polymer Composites, Chapman and Hall,London.
4. RosatoDonal V. and Rosato Dominick V., 1990, Plastics Processing Data Book, Van Nostrand Reinhold, NewYork.

Additional Resources:

1. Strong A. B., 1996, Plastics: Materials and Processing by, Practice- Hall, NewJersey.
2. Watson M.N., 1988, Joining Plastics in Production by, the Welding Institute,Cambridge.
3. Gupta B.R., 2005, Applied Rheology in Polymer Processing, Asian Book Pvt. Ltd,(1^{st}edition).
4. KamalMusaR,IsayevAvraaamI,LiuShih-Jung,2009,InjectionMoulding-Technologyandfundamental,SerieseditorJamesLWhite, Hanser Publishers,Munich.
5. Mckelvy J., 1962, Polymer Processing, John Wiley, NewYork.
6. MiddlemanS.,1977,FundamentalsofPolymerProcessing,,McGraw-Hill.
7. EldenR.A.,SwanA.D.,1971,calendaringofplastics,LondonIliffebooks.

Teaching Learning Process:
Discussion, presentation Quiz

Assessment Methods:
As per University of Delhi noms

Keywords
Lamination, extrusion, injection molding

POLYMER IN BIOMEDICAL APPLICATIONS
(31147908)

DISCIPLINE SPECIFIC ELECTIVE - (DSE) CREDIT: 6

Course Objective:

1. Understanding of Biopolymer and Biodegradation
2. Application and testing of Biopolymers

DSE: PAPER 8: POLYMERS IN BIOMEDICAL APPLICATION
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. This paper will enable students to understand the basic concepts and requirement of Biomaterials and Biocompatibility
2. Students will also understand the requirement of various biomaterials for any particular bio-application.

THEORY
CONTENT (TOTAL PERIOD 60)

Unit 1: Basics of Biomaterials 10

Concept of biocompatibility and Biodegradability, responsiveness, estimations of degradation and biocompatibility, Important Biomaterials:Hydrogel, fibres, bio-ceramics, bio-elastomers and membrane.

Unit 2: Properties of biomaterials 10

Mechanical (elasticity, yield stress, ductility, toughness, tensile strength, fatigue, hardness), tribological (friction, wear, lubricity), morphology
and texture, porosity, adsorption, physical properties, electrical properties, optical properties, magnetic properties, thermal properties, chemicaland biological properties.

Unit 3: Polymers as Biomaterials 10

Sources, Properties and Applications: Polyamides, Lipids, Polyesters and Carbohydrates, Natural Gums, polyurethanes, Polylactic acid, Alginates

Unit 4: Biomaterials for Organ Transplants 20

Properties and uses of polymers for organ transplant e.g. dental cement, orthopedic, skin, artificial kidney etc., basic concept of tissueengineering, uses of cellulose, chitosan and alginate.

Unit 5: Drug Delivery 10

Introduction to drug delivery, polymers in controlled drug delivery, dressing strips, polymer drug vessels, core shell and nanogels

PRACTICALS:

1. Evaluate the biocompatibility of polymeric samples.
2. Determination of the degradation behavior of polymers such as thermal, hydrolytic etc.

3. Prepare membranes and measure absorption behavior.
4. Preparation and characterization of dental cement.
5. Prepare a hydrogel and characterization.
6. Determine the mechanical strengths of polymers.

References:

1. A. Tiwari and A. Tiwari, 2013, Nanomaterials in drug delivery, Imaging and Tissue Engineering, Wiley.
2. Pilla, 2011, Handbook of Bioplastics and Biocomposites Engineering Applications, Wiley.

Additional Resources:

1. B. D. Ratner and A. S. Hoffman, 1996, An Intoduction to Materials in medicine, Eds. Academic Press, New York.
2. Saltzman W. M., 2001, Drug delivery – Engineering principles for drug therapy, Oxford University Press, USA.
3. S. Kalia and L. Averous, 2011, Biopolymers: Biomedical and Environmental Applications by John Wiley & Sons.

Teaching Learning Process:
Demonstration, discussion, power point presentation

Assessment Methods:
As per University of Delhi rule

Keywords:
Biomaterials,properties, application

BIOPOLYMERS
(31143901)
SKILL-ENHANCEMENT ELECTIVE COURSE - (SEC) CREDIT: 4

Course Objective:

1. Students will learn basic structure, function, properties and features of biopolymers.
2. The different properties and applications of biopolymers will be also introduced.

SEC: PAPER 1: BIOPOLYMERS
CREDITS: THEORY-2, PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. This course will impart detailed knowledge of the structure, function, properties and use of biopolymers.
2. This paper also introduces the basics of different biopolymers along with their applications.

THEORY
CONTENTS (TOTAL PERIODS: 30)

Unit 1: Basics to biopolymers 5
Significance, classifications of biopolymers, Properties and applications

Unit 2: Representative biopolymers 10

Derivatives of industrial interest of different biopolymers: Starch, cellulose, chitosan, gelatine, keratin, fatty acids, lipids, aliphatic polyesters
(PLA, PHB) and cellulose

Unit 3: Characterization 5
Evaluation of biodegradability, molecular weight, functionality, biocompatibility, mechanical strength and transition temperatures

Unit 4: Processing 5
Processing of Biopolymers: composite formation, blending and solvent casting.

Unit 5: Applications 5
Application of biopolymers in packaging, biomedical testing and devices, Agriculture: soil conditioning and micro-nutrient delivery.

Unit 6: Case study
Biopolymer based film as substitute of polythene
Soil conditioning by biopolymers

Biopolymer in controlled drug delivery

PRACTICALS:

1. Determine the monomers and molecular weight of biopolymers.
2. Develop a bio degradable film by solution casting of biopolymers.
3. Estimate the bio degradability by soil burial test.
4. Evaluate the mechanical strength (swelling index, porosity, hardness and tensile) of a film.
5. Estimate the water vapour transmission rate of a film.

References:

1. Byrom D., Biomaterials –novel materials from biological sources, Stockton press.
2. Bastioli C., 1987, Hand Book of Biodegradable polymers, Rapra Tech.
3. Niaounakis M., 2015, Biopolymers: Processing and Products 1st Edition, Elsevier Inc.

Additional Resources:

1. Johnson R. M., Mwaikambo L. Y. and Tucker N., 2003, Biopolymers, Rapra Technology.
2. Pilla S., 2011, Hand Book of Bioplastics&Biocomposites for Engineering Applications, Wiley.
3. Alexander S., 2003, Biopolymers,Vol. 1 Wiley.

Teaching Learning Process:
Class room lectures, Group discussion, Demonstration

Assessment Methods:
As university guidelines

Keywords:
Biopolymer, Biodegradability, Processing and modification, Application

ESTIMATION OF POLYMERS AND POLYMERIC COMPOUNDS (31143902)
SKILL-ENHANCEMENT ELECTIVE COURSE - (SEC) CREDIT: 4

Course Objective:

1. To introduce the estimation and characterization of polymers and polymeric products.
2. To trained about the different characterization techniques and their applications.

SEC: PAPER 2: ESTIMATION OF POLYMERS AND POLYMERIC COMPOUNDS
CREDITS: THEORY-2, LAB-2

Course Learning Outcomes: After studying this paper, students will be able to

1. This course will provide detailed knowledge about estimation of the properties, structure and constituents of polymers.
2. This paper also discusses the basics of different methods used in estimation of different properties of a polymer

THEORY
CONTENTS (TOTAL PERIODS: 30)

Unit 1: Basic of polymer analysis 5
Quantitative and qualitative estimation of the monomer, fillers, plasticizers, initiators, inhibitors, antioxidants and heat stabilizers etc used in polymer industries.

Unit 2: Physical testing 5
Determination physical properties such softening point, melting point, viscosity, refractive index, specific gravity, swelling index, melt flow index and of polymer materials.

Unit 3: Spectroscopic and morphology 5
Chemical composition, Functional group, crystallinity and morphology (surface and bulk) by suitable methods (IR, XRD SEM etc).

Unit 4: Thermal 5
Stability, Conductivity, heat deformation temperature, glass transition temperature and heat capacity,

Unit 5: Mechanical 5
Tensile strength, Elongation, Degradation, Flexural and Hardness of polymers

Unit 6: Standardization of different polymer products 5
Estimation of polymer products for: Iodine value, Carbon black content, Freesulfur content, Total inorganic content, Silica content. Hydroxyl values, acid value, flash point, etc.

PRACTICALS:

1. Determine the plasticizer content in processed specimen.
2. Estimate the swelling index of a polymeric hydrogel.
3. Identify the functional group in a polymer.
4. Determine tensile strength of a polymer sample.
5. Find out the iodine and acid value of polymer product.

References:

1. Shah V., 2007, Handbook of Plastic Testing & Technology, Wiley-Interscience.
2. Forrest M. J., 2001, Rubber Analysis: Polymers, Compounds and Products. Rapra Tech. Ltd.
3. Loadman M. J., 2012, Analysis of Rubber and Rubber-like Polymers. Springer.

Additional Resources:

1. Seidel A.(Eds), 2008, Characterization and Analysis of Polymers, Wiley.
2. Chalmers J. M., Meier R. J.(Eds) , 2008, Molecular Characterization and Analysis of Polymers Elsevier.

Teaching Learning Process:
Class room lectures, Group discussion, Demonstration

Assessment Methods:
Practical and theory as per university guidelines

Keywords:
Basic principle of analysis, Physical testing, Structural and morphology estimation

WIRE AND CABLE TECHNOLOGY
(31143903)
SKILL-ENHANCEMENT ELECTIVE COURSE - (SEC) CREDIT: 4

Course Objective:

1. To give brief introduction to materials used as cables.
2. Brief introduction to the properties of cables: insulation, thermal and mechanical properties

SEC: PAPER 3: WIRE AND CABLE TECHNOLOGY
CREDITS: THEORY-2 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. This course will help students to understand the basic concepts of conductors, semiconductors and insulators.
2. The properties and applications of materials for cables application

THEORY
CONTENTS (TOTAL PERIODS: 30)

Unit 1: Introduction

5Introduction to Insulators, semiconductors and conductors, classification of wire and cables (eg. Electric, telecommunication etc.), cable characteristics.

Unit 2: Properties of cable insulating materials: 8

i) Electrical: Volume and surface resistivity, break down voltage, dielectric constant, dielectric loss

ii) Thermal: Heat resistance, permissible temperature, effect of overloading on the life of an electrical appliances and thermal conductivity

iii) Chemical: Solubility, chemical resistance, weatherability

iv) Mechanical and physical: Mechanical strength, porosity, density, brittleness.

Unit 3: Properties of Cable material 7

Factors affecting the electrical, thermal, chemical and mechanical properties of cable insulating materials, selection of cable insulating materials

Unit 4: Properties and applications of polymeric materials used for cable insulation and sheathing 10

Chlorinated polyethylene (CM), Chlorosulfonated polyethylene (CSM), HDPE, LDPE, PVC, NBR, PTFE, EPDM, EVA.

References:

1. Cousins K., 2000, Polymers for wire and cables- changes within an industry, SmithersRapra Publishing.
2. Black R. M., 1983, The History of Electric wire and Cables, Peter Peregrinus Ltd.
3. Smith and Martin, 2007, Hand book of Rubber Technology, CBS Publishers.

Teaching Learning Process:
Presentations/Visits

Assessment Methods:
As per DU Norms

Keywords:
Cables, Conductors, Insulators

FOOTWEAR TECHNOLOGY
(31143904)
SKILL-ENHANCEMENT ELECTIVE COURSE - (SEC) CREDIT: 4

Course Objective:

1. The course will impart the basic concepts of raw material and manufacturing of Footwear.
2. This course will help students to understand applications of polymers in Footwear.

SEC PAPER 4: FOOTWEAR TECHNOLOGY
CREDITS: THEORY-2 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. To give basic understanding of various type of polymers used in footwear, Footwear manufacturing and Technology.

THEORY
CONTENT (TOTAL PERIODS: 60)

Unit: 1 Shoes Soles 7

Soling requirements, soling materials, compounding and processing. Individual soling compounding: PVC, thermoplastic rubber, polyurethane, ethylene vinyl acetate, etc.

Unit: 2 Shoes Adhesive 8

Soling adhesives and their types, adhesion principle and selection criteria, Heel covering; sole attaching, neoprene. PU, hot melt and liquid curing adhesives, adhesion problems. Coated fabrics: PVC, PU coated fabric.

Unit: 3 Soles Materials 7

Molded and pre fabricated units, individual solings–rubbers, vulcanized rubbers, nylons, polyesters, PVC, thermoplastic rubbers, PU, EVA.

Unit: 4 Processing Technology 8

Injection moulding, sponge moulding, direct molded shoes, thermoplastic moulding, polyurethane injection moulding, insert moulding, HF flow moulding.

References:

1. Smith and Martin, 2007, Hand Book of Rubber Technology, CBS Publisher.
2. Harvey A. J., 1982, Footwear Materials & Process Technology, Shoe Trades Publishers.

3. Cohn, W. E., 1969, Modern Footwear Materials & Process, Fairchild Publicatins.

Additional Resources:

1. Enkatappaiah, B., 1997, Introduction to Modern Footwear Technology, Sita Publishers.

Teaching Learning Process:
Industry Visit/Presentations/Demonstrations

Assessment Methods:
As per DU Norms

Keywords:
Footwear Manufacturing, Footwear Technology

BASICS OF POLYMER SCIENCE
(31145901)
GENERIC ELECTIVE - (GE) CREDIT:6

Course Objective:

1. To give brief introduction to polymers and their properties
2. 2. The course will also help students to learn about the role of polymer structure on properties such as physical, mechanical and solution properties

GE: PAPER 1 - BASICS OF POLYMER SCIENCE
CREDITS: THEORY-4 PRACTICAL-2
Course Learning Outcomes: After studying this paper, students will be able to

1. Students will get brief idea of polymer physical states.
2. The course will help to understand significance of thermal transitions and molecular weight on various properties of polymers.

THEORY
CONTENTS (TOTAL PERIODS: 60

Unit: 1 Introduction to Polymers 15
Introduction and classification of polymers, configuration and conformation of polymers, nature of molecular interaction in polymers, cumulative interaction, entanglement, random chain model and RMS end-to-end distance, various structures of copolymers such as linear branched and cross-linked copolymers

Unit: 2 Polymer Crystal 10
Crystal morphologies, Extended chain crystals, chain folding, lamellae, and spherulites. Crystallization and crystallinity, determination of crystallinity

Unit: 3 Properties of polymers 15

Physical properties, Stress–strain behavior, Introduction to flow & mechanical properties (Tensile , Flexural, Impact, Fatigue , Hardness, Creep, Abrasion , Glass transition temperature (*T*g) and its measurement of *T*g. Factors affecting the glass transition temperature.

Unit: 4 Molecular weight of polymers 10

Nature and structure of polymers – structure-property relationships. Molecular weight of polymers (*M*n, *M*w etc.), polydespersity, molecular weight distribution and determination of molecular weight by viscosity, end group analysis, cryoscopy, ebulliometry, light scattering & ultracentrifugation methods

Unit: 5 Solution Properties of Polymers 10

Polymer solutions, solubility parameter, solution viscosity, polymer solubility, Thermodynamics of polymer solutions properties.

PRACTICALS:

1. Determination of heat deflection temperature, VICAT softening point.
2. To determine the melting point of crystalline polymers.
3. To check the solubility of the given polymeric sample in different solvents.
4. Determination of molecular weight by solution viscosity/end group analysis.
5. Chemical identification of polymers: Functional groups (associated with polymers).

References:

1. Brydson J.A., 1999, Plastics Materials, Butterworth Heinemann.
2. Ghosh P., 2010, Polymer Science and Technology: Plastics, Rubbers, Blends and Composites Tata McGraw Hill.
3. Gowarikar V. R., 2010, Polymer Science, New Age International Publishers Ltd.
4. Billmeyer F.W., 2007,Textbook of Polymer Science,Wiley, India.
5. Shah V., 1998, Handbook of Plastics Testing Technology, Wiley interscience publications.
6. Seymour R. B. and Carraher C.E., 2000, Polymer Chemistry, Marcel Dekker.

Additional Resources:

1. Schultz, 2001, Polymer Crystallization, American Chemical Society.

Teaching Learning Process:
Demonstrations/Presentations

Assessment Methods:
As per DU Norms

Keywords:
Crystallization, glass transition temperature, Molecular weight determination, polymer solubility

CHEMISTRY OF POLYMERS
(31145902)
GENERIC ELECTIVE - (GE) CREDIT: 6

Course Objective:

1. The course will help in understanding basic concept of polymerization and kinetics.
2. To give brief introduction of preparation, properties and applications of thermoplastics and thermosetting polymers

GE: PAPER 2 - CHEMISTRY OF POLYMERS

CREDITS: THEORY-4 PRACTICAL-2

Course Learning Outcomes

1. To give understanding of basic concepts of chemistry, of polymers , polymerization behaviour of monomers
2. Brief introduction to thermoplastics and thermosetting polymers including their synthesis, properties and applications.

THEORY

CONTENTS (TOTAL PERIODS:60)

Unit 1: IntroductiontoPolymerization 10Criteria for polymer synthesis, nomenclature, addition and condensation polymerization, chain growth and step polymerization, polymerization techniques: mass (bulk), suspension, emulsion and solution processes

Unit 2: Kinetics of polymerization 10

Concept of functionality, Carother's equation and its applications in polymerization reactions, Kinetics of step growth polymerization and chain growth polymerization, Mayo's equation, auto-acceleration, inhibition and retardation. Co-polymerization, reactivity ratios, Zeigler-Natta catalysts and polymerization

Unit 3: Thermoplastic Polymers 15

Brief introduction to the preparation, structure, properties and applications of the following polymers:

a) Polyolefins (PE,PP)
b) Polystyrene and related polymers
c) Poly(vinyl chloride)
d) Poly(vinyl acetate) and related polymers

Unit 4: Thermosetting Polymers 15

Brief introduction to the preparation, structure, properties and applications of the following polymers:

a) U
nsaturated polyesters
b) Phenol formaldehyde resins
c) Polymers from amines
d) Polyurethanes (Foams)

e) Epoxides

Unit: 5 Engineering polymers 15

Brief introduction to structure, properties and applications of polymers: acrylic polymers, fluoropolymers and aliphatic polyamides

PRACTICALS:

1. Suspension polymerization of Styrene/MMA.
2. Preparation and testing of UF/PF
3. Preparation and testing of Diglycidyl ether of bis phenol-A (DGEBA).
4. Bulk polymerization of Methyl Methacrylate/Styrene.
5. Solution polymerization of Methyl Methacrylate/Styrene.
6. Emulsion polymerization of Styrene/ Methyl Methacrylate.
7. Copolymerization of styrene & MMA.
8. Preparation of Poly (vinyl butyral).

References:

1. Odian, G., 2004, Principles of Polymerization, Wiley – Interscience.
2. Brydson, J. A., 1999, Plastics Materials, Butterworth-Heinemann.
3. Flory P. J. Principles of Polymer Chemistry, Asian Books Private Limited.
4. Billmeyer F.A., 2011, Text book of Polymer Science, John-Wiley and Sons.
5. Seymour R. B. Carraher, C. E., 2003, Polymer Chemistry, Marcel Dekker

Teaching Learning Process:
Demonstrations/Discussions/Presentations

Assessment Methods:
As per DU norms

Keywords:
Polymerization, Polymers chemistry, Polymerization Kinetics, Thermoplastics, Thermosetting Polymers

POLYMER TESTING AND CHARACTERIZATION
(31145903)
GENERIC ELECTIVE - (GE) CREDIT: 6

Course Objective:

1. To introduce the testing and characterization of the polymers.
2. Teach the different characterization and testing method with their applications.

GE: PAPER 3 - Polymer Testing and Characterization
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. Students will get the idea about both testing and characterization of polymers
2. This paper also discusses the commercial techniques involved in testing and characterizations.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Introduction 10

Basic principal, Lambert bears law, accuracy, precision, errors and analysis, calibration of results and different standards like BIS, ASTM.

Unit 2: Thermal and mechanical analysis 10

Stress- strain curve, measurement of Tensile, Flexural Impact, tear and abrasion resistance of polymeric materials, Creep and fatigue properties, Thermal conductivity, thermal diffusivity, specific heat capacity, linear thermal expansion, heat distortion temperature, vicat softening point and thermal stability.

Unit 3: Flow and Optical properties 10

Melt flow index, cup flow test, Viscosity, Gloss, haze, refractive index, degree of yellowness etc.

Unit 4: Spectroscopy 10

NMR, IR, ESR, UV and Mass spectroscopy: Principle and application in polymer characterization.

Unit 5: Electrical and magnetic properties 10

Dielectric strength, Surface and Bulk resistance, conductance, Diamagnetism and Para magnetism

Unit 6: Stability and Burning behaviour 10

Environmental stress crack resistance, Dynamic and static weathering, Burning behaviour, Limiting oxygen index, UL-94 and smoke density

PRACTICALS:

1. Measure the M.F.I of polymers.
2. Determination the LOI & Smoke density of polymeric samples.
3. Determination the H.D.T and Vicat softening temperature.
4. Measurement of abrasion resistance and burning behavior of polymer samples.
5. Determination the coefficient of friction and Izod impact of polymer sample.
6. Determination of environment stress cracking resistance of PE/PP
7. Determination of Hardness of plastics

References:

1. Shah V., 2007, Handbook of Plastic Testing, Technology, Wiley-Interscience.
2. Grellmann W. and Seinder S., 1961, Polymer Testing, Hanser Publisher.
3. Martin and Smith, 2009, Rubber Technology Handbook, SmithersRapra Technology.

Additional Resources:

1. Berins M. L., 1991, SPI Plastic Engineering Handbook, Springer-Verlag.
2. Ward and Sweeney, 2004, Introduction to the Mechanical Properties of Solid Polymers, Wiley.

Teaching Learning Process:

Class room lectures, Group discussion, Demonstration

Assessment Methods:

Theory and practical as per university guidelines

Keywords:

Standards, Spectroscopy, Mechanical testing

POLYMER MODIFIERS AND WASTE MANAGEMENT (31145904) GENERIC ELECTIVE - (GE) CREDIT: 6

Course Objective:

1. Better understanding of Additives
2. Understanding the importance and methods of polymer waste management

GE: PAPER 4 - POLYMER MODIFIERS AND WASTE MANAGEMENT

CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. This paper will help students to improve their understanding about the usage and importance of different polymeric modifiers
2. Students will also understand the importance and various processes of polymer waste management from environmental safety concern.

THEORY

CONTENT (TOTAL PERIODS:60)

Unit 1: Introduction to Polymer Additives 5

Importance of additives and their selection criteria for commercial polymers

Unit 2: Additives for Plastics and Rubbers and Their Functions 30

Stabilizers, Fillers, Plasticizers and Lubricants, Flame retardants, Vulcanizing agents and retardants, Accelerators, Activators, Softeners, Colors and pigments etc.

Unit 3: Product Design 5

Illustration of few formulations and their compounding procedures

Unit 4: Basics of waste management 10

Definition of Waste and litter, 4 R's approach (reduce, reuse, recycle (mechanical and chemical), recover), recycling classification- - primary - secondary - tertiary - quaternary recycling with examples.

Unit 5: Waste Disposal Techniques 10

Role of plastics in the collection of refuse; Sorting of mixed plastic waste, disposal processes– controlled tipping, pulverization, compositing, incineration; compacting and baling.

PRACTICALS:

1. Effect of fillers on physical and mechanical properties of plastics and rubbers
2. Determination of bulk density and surface property of fillers.
3. Identification of additives.
4. Secondary recycling of MSW by incorporating and blending the recyclable waste with virgin polymers.
5. Sorting of mixed plastics
6. Designing of rubber and plastic products

References:

1. Lutz, Marcel Dekker, 2001, Polymer modifiers and additives.
2. Al- Malaika, 1999, Chemistry and Technology of Polymer Additives, Elsevier

Additional Resources:

1. Brydson J., 1999, Plastic materials, Butterworth-heinemann, Elsvier.
2. Martin and Smith, 2007, Handbook of Rubber Technology, CBS Publisher.
3. Ghosh P., 1990, Polymer Science and Technology: Plastic, Rubber Blends and Composites, Tata Mcgraw Hill
4. Chandra R. and Adab A., 2004, Rubber and Plastic Waste: Recycling, Reuse and Future Demand, CBS Publisher.

Teaching Learning Process:

Power Point Presentation, Demonstartion, Discussion and Quiz

Assessment Methods
As per University of Delhi Rules

Keywords
Polymer Additives,Product Designing, Waste Management, Waste Disposal Techniques

PRODUCT MANUFACTURING AND PROCESSING
(31145905)
GENERIC ELECTIVE - (GE) CREDIT: 6

Course Objective:

1. Introduce the manufacturing process of polymers and polymeric products.
2. Teach the different manufacturing technique and quality control.

GE: Paper 5- Product Manufacturing and Processing
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. Students will get the idea about products manufacturing from polymers and plastics.
2. This paper also introduces different commercial techniques involved product manufacturing.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Extruder 10
Principle, Dies, different types of extruder, feeding and process monitoring

Unit 2: Injection moulding 15 Principles, the moulding cycle, the injection moulding machine, some aspects of product quality. Reaction injection moulding (RIM)

Unit 3: Blow moulding 10Blow moulding principles, extrusion blow moulding, injection blow moulding, stretch blow moulding, blow moulding of PET.

Unit 4: Thermoforming 15 Principles, types and applications, Compression and transfer moulding: Introduction, thermosetting compounds, compressing moulding process, transfer moulding.

Unit 5: Miscellaneous processing methods 10
Casting, rotational moulding etc

PRACTICALS:
1. Compounding of additives in roll-mill with fillers and reinforcing agents.
2. Make a sheet by Compression moulding
3. Prepare a tensile specimen by Injection moulding
4. Extrusion on single screw and twin screw extruders.
5. Make a product by Thermoforming.
6. Casting of a polymer membrane

References:

1. Strong A. B., 2005, Plastics: Materials & Processing, Prentice Hall.
2. Rosato D. V. and Rosato D. V.,2000, Injection Moulding Handbook, CBS Publisher.
3. Morton and Jones, 2007, Polymer Processing,Chapman& Hall.

Additional Resources:

1. Crawford R. J., 1998, Plastic Engg. Butterworth-heinemann.
2. Baird and Collias, 1998, Polymer Processing Principles and Design, Wiley- Interscience.
3. Rosato D. V. and Rosato D. V., 2001, Plastic Processing Data Handbook, SpringerNetherlands.

Teaching Learning Process:
Class room lectures, Group discussion, Demonstration

Assessment Methods:
Theory and Practical as per University Guidelines

Keywords:
Processing, Extruder, Injection and Blow moulding

MATERIALS SCIENCE
(31145906)
GENERIC ELECTIVE - (GE) CREDIT:6

Course Objective:
1. To introduce the basics of materials science.
2. Teach the different types materials, their properties and applications.

GE: Paper 6 - MATERIALS SCIENCE
CREDITS: THEORY-4, Practical-2
Course Learning Outcomes: After studying this paper, students will be able to

1. This course will provide detailed knowledge of the structure, function, properties of different materials.
2. This paper also helps to learn the different types of materials such as polymer, metal, alloys and composites.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Basic of materials structure 15
Amorphous and crystalline structure, unit cells and space lattices, x-ray diffraction of crystal structures, miller indices of planes and directions, packing geometry in metallic, covalent and ionic solids.single and polycrystalline materials. Imperfections in crystalline solids Magnetism, intrinsic and extrinsic semiconductors, dielectric properties, absorption and transmission of electromagnetic radiation in solid.

Unit 2: Solutions 5
Ideal and real solutions, solubility limit, phase rule, phase diagrams, solid solution, intermediate phases, intermetallic compounds,

Unit 3: Advanced Materials 10
Smart materials, exhibiting ferroelectric, piezoelectric, optoelectric, semiconducting behavior, lasers and optical fibres, photoconductivity and superconductivity, nanomaterials – synthesis, properties and applications, biomaterials, superalloys, shape memory alloys.

Unit 4: Polymers 10
Classification, polymerization, structure and properties, additives for polymer products, processing and applications

Unit 5: Ceramic and composite materials 10
Ceramics: Structure, properties, processing and applications of traditional and advanced ceramics. Composites, classifications, properties and applications of various composites

Unit 6: Metal and alloys 10
Solid solutions, solubility limit, intermediate phases, intermetallic compounds, iron-iron carbide phase diagram, heat treatment of steels, cold, hot working of metals, recovery, recrystallization and grain growth. Microstructure, properties and applications of ferrous, non-ferrous alloys and polymer alloy.

PRACTICALS:

1. To check hardness of composite materials s by Rockwell hardness tester.
2. To determine % composition of metals, fillers etc.

3. To determine magnetic properties of materials.
4. To determine mechanical properties(strength, modulus) of materials.
5. Preparation of advanced polymer composite material for different applications(packaging and biomedical).
6. To prepare safety glass and evaluate its properties.

References:

1. Shackelford J. F., 2010, Materials Science And engineering Handbook, Third Edition CRC Press, New York.
2. Mittemeijer E. J., 2011, Fundamentals of Materials Science: The Microstructure–Property Relationship Using Metals as Model Systems, Springer.
3. Sedha R.S., Khurmi R.S.,2004, Materials Science, S. Chand India

Additional Resources:

1. Kakani S. L. and Kakani A., 2006, Material Science, New Age International.
2. Yao J., Zhou Z., Zhou H., 2019, Highway Engineering Composite Material and Its Application, Springer.

Teaching Learning Process:

Class room lectures, Group discussion, Demonstration

Assessment Methods:

Both theory and practical as university guidelines

Keywords:

Structure, Polymers, Advanced materials, Metal and Alloys

BIOMEDICAL APPLICATIONS OF POLYMERS
(31145907)
GENERIC ELECTIVE - (GE) CREDIT: 6

Course Objective:

1. To make students understand the basic concept of Biopolymers.
2. Use of polymers for drug delivery and wound care.

GE: PAPER 7 - BIOMEDICAL APPLICATIONS OF POLYMERS

CREDITS: THEORY- 4, PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. This paper will enable students to understand the basic concepts and requirement of biomaterials and biocompatibility.
2. Students will also understand the use of polymeric materials for any particular bio-application.

THEORY

CONTENTS (TOTAL PERIODS: 60)

Unit: 1 Basics of Biomaterials 10

Concept of biocompatibility and Biodegradability, responsiveness, estimations of degradation and biocompatibility, Important Biomaterials: hydrogel, fibres, bio-ceramics, bio-elastomers and membranes.

Unit: 2 Properties of biomaterials 10

Mechanical (elasticity, yield stress, ductility, toughness, strength, fatigue, hardness), tribological (friction, wear, lubricity), morphology and texture, porosity, adsorption, physical properties, electrical properties, optical properties, magnetic properties, thermal properties, chemical and biological properties.

Unit 3: Polymers as Biomaterials 10

Polyster and Polysaccharides, Natural Gums, Biodegradablepolymers, polymers and Hydrogels.

Unit: 4 Biomaterials for Organ Transplants and Tissue Engineering 20

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

Unit: 5 Drug Delivery and Wound Care 10

Introduction to drug delivery, polymers in controlled drug delivery, dressing strips, polymer drug vessels, core shell and nanogels, Antimicrobial polymers, Bio-conjugates

PRACTICALS:

1. Evaluate the biocompatibility of polymeric samples.
2. Determination of the degradation behaviour of polymers such as thermal, hydrolytic etc.
3. Preparation of membranes and measurement of absorption behaviour.
4. Preparation and characterization of dental cement.
5. Preparation of a hydrogel and its characterization.
6. Determination of tensile strength of biopolymers.

References:

1. A. Tiwari and A. Tiwari, 2013, Nanomaterials in drug delivery, Imaging and Tissue Engineering, Wiley.
2. S. Pilla, 2011, Handbook of Bioplastics and Biocomposites Engineering Applications, Wiley.

Additional Resources:

1. D. Ratner and A. S. Hoffman, 1996, An Intoduction to Materials in medicine, Eds. Academic Press, New York.
2. Saltzman W. M., 2001, Drug delivery – Engineering principles for drug therapy, Oxford University Press, USA.
3. Kalia and L. Averous, 2011, Biopolymers: Biomedical and Environmental Applications by John Wiley & Sons.

Teaching Learning Process:

Demonstration, discussion, power point presentation

Assessment Methods:
As per University of Delhi rule

Keywords:
Biopolymers, Drug Delivery, Physio-Chemical Properties of Biomaterials

FIBRES AND RUBBERS
(31145908)
GENERIC ELECTIVE - (GE) CREDIT: 6

Course Objective:

1. To give brief introduction of: Fibres and rubbers, Classification of fibres including natural and synthetic fibres.
2. Basic concept of vulcanization and properties of vulcanized rubbers.

GE: PAPER 8 - FIBRE AND RUBBERS
CREDITS: THEORY-4 PRACTICAL-2

Course Learning Outcomes: After studying this paper, students will be able to

1. The course will help students to understand basic concept of fibres, their classification as natural and synthetic fibres.
2. The brief introduction of rubbers, vulcanization and properties of vulcanized rubber.

THEORY
CONTENTS (TOTAL PERIODS: 60)

Unit 1: Introduction 5

Basic concepts, classification and terminology of fibres, salient features of fibre forming polymers and their properties. Basic structure of a fibre, properties of a fibre such as moisture absorption, tex, denier, tenacity, elongation at break and elastic recovery.

Unit 2: Natural fires 10

Natural occurring fibres – Plant/Végétable fibres, animal fibres, mineral fibres

Unit 3: Synthetic Fibres 15

Man made and synthetic fibres–properties and uses of viscous rayon, cellulose acetate, nylon – 66, polyester, acrylic, carbon fibres and aramid fibres.

Unit 4: Vulcanization 15

Rubber and mastication, vulcanization, rheocurve of compounded rubber, mechanism of sulphur vulcanization with and without accelerators, theories of non sulphur vulcanization, properties of vulcanized rubber

Unit 5: Engineering polymers 15

Natural rubber and synthetic rubber, styrene-butadiene rubber, polybutadiene rubber, ethylene propylene diene rubber, butyl rubber, nitrile rubber, neoprene, silicone rubber, fluorocarbon rubber

PRACTICALS:

1. Determination of tensile strength, modulus, elongation at break, tear strength, abrasion resistance, heat build-up resilience, hardness, flex resistance for rubber compounds.
2. Determination of curing time on physical properties of NR compound.
3. Identification of fibres through solubility tests.
4. Identification of fibres by chemical methods
5. Analysis of reaction of fibres towards heat & flame.
6. To determine viscosity using Mooney viscometer.
7. Qualitative analysis of Cellulose –Polyester blends.
8. Distinguish POY & FDY polyester filament yarn based on extensibility & shrinkage behavior.
9. Determination of Twist, elongation, TEX, Tenacity, Denier, and count of yarn, fibre& filament.

References:

1. Smith and Martin, 2007, Hand Book of Rubber Technology, CBS Publisher.
2. Mark J. E. Erman, B, Eirich, F. R., 2005, The Science and Technology of Rubber, Elsevier Academic Press.
3. Cook J. G., 2009, Hand Book of Textile Fibres, Woodhead Publishing Volume 2.
4. Blow S., 2000, Hand Book of Rubber Technology, Hanser Gardner.
5. Collier and Tortora, 2009, Understanding Textiles, Prentice Hall.
6. Morton & Hearle, 2008, Physical Properties of Fibres, CRC Press.

Teaching Learning Process:

Presentation/Demonstration/Visits

Assessment Methods:

As per DU Norms

Keywords:

Fibres, Rubbers

GE: PAPER 9- **POLYMERS IN PACKAGING (31145909)**

CREDITS: 6 **(**THEORY-4, PRACTICAL -2)

CONTENT (TOTAL PERIODS: THEORY-60, PRACTICAL -60)

Course Objective:

1. Students will learn the basic necessities and importance of packaging.
2. This paper will help students to choose the correct polymer for different types of

material packaging.

Course Learning Outcomes: After studying this paper, students will be able to

1. Apprehend the basic concept of packaging and their utilization from application point of view.
2. Students will be capable of assessing the quality of packaging material and packaged product

THEORY

Unit 1: Introduction and Material 10

Importance, scope of packaging (India and Global), packaging materials: types, properties, advantages and disadvantages.

Unit 2: Packaging Systems 15

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

Unit 3: Polymers in Packaging 15

Properties and Applications: LLDPE, LDPE, HDPE, HMHDPE, PP, PVC, Nylon, Polyester, Polycarbonate, PS, EPS, PLA, PVA and Starch etc.

Unit 4: Packaging process techniques 10

Thermoforming in packaging, co-extrusion, extrusion-stretch blow moulding, injection molding, LDPE, BOPP films.

Unit 5: Testing of polymer packaging material 10

Bursting strength, Tensile strength, Tear strength, Puncture test, Impact test (Drop, falling dart), permeability Test (Water vapour, Oxygen), Biodegradability, Sealing strength

PRACTICALS:

1. To Identify packaging materials with the help of FT-IR, DSC, TGA etc.
2. Determination of physico-mechanical properties (density, bursting strength, tensile strength, tearing strength, drop test strength, puncture test strength, impact strength etc).
3. Determination of water vapor transmission rate of packaging material
4. To test sealing strength integrity of packaging materials
5. To check biodegradability of packaging material

References:

1. Gordon L. Robertson, 2005, Food Packaging Principles and Practice, CRC press.
2. Paine F. A. and Paine H. Y., Blackie, 1992, A Handbook of Food Packaging, Academic and Professional

Additional Resources:

1. Robertson G. L., 2012, Food Packaging – Principles and Practice, CRC Press Taylor and Francis Group.
2. Coles R, McDowell D., Kirwan M. J., Blackwell, 2003, Food Packaging Technology.
3. L. A. Sukhareva, V. S. Yakolev, O. A. Legonkova, 2008, Polymers for packaging materials for preservation of food stuffs.

Teaching Learning Process:
Power point presentation, Demonstrations, Discussions, Videos

Assessment Methods:
As per University of Delhi norms

Keywords:
Packaging Materials, Polymer Testing, Packaging Systems, Polymer Processing

POLYMERS FOR ELECTRICAL AND ELECTRONIC APPLICATIONS
(31145910)
Generic Elective - (GE) Credit:6

Course Objective:

1. Students will learn about applications of polymers in electrical, electronics, space and automobiles.
2. This paper will present an understanding of conducting polymer in solar cell application.

GE: PAPER 10- POLYMERS FOR ELECTRICAL AND ELECTRONIC APPLICATIONS
CREDITS: THEORY-4, PRACTICAL -2

Course Learning Outcomes: After studying this paper, students will be able to

1. Understand different properties of polymers in the field of automobiles, space, electrical and electronics.

THEORY:
CONTENT (TOTAL PERIODS: 60)

Unit 1: Introduction to polymers 10
Classification of polymers: Petro polymers, conducting polymers, biopolymers, synthetic methods for polymers, composites, processing of polymers, doping (chemical and ion). limitations,

Unit 2: Properties 15

Dielectric strength, dielectric loss, Band diagram, charge storage capacity, electrically conductivity, heat capacity, magnetism and mechanical properties, EMI shielding, Advantages and disadvantages of conducting polymers, methods to enhance the processability of conducting polymers.

Unit 4: Electronic applications 10

Semiconducting organic materials, Polymer based electronic devices, Organic field effect transistor, Organic transistors, plastic solar cell, light emitting diode, super capacitor, Sensors etc.

PRACTICALS:

1. Multilayer insulation (MLI) of spacecraft as thin films for space application.
2. Electric insulation cable for domestic supply.
3. Polymer and clay nanocomposite for automobile body part
4. Conducting polymer nanocomposite for sensing applications

References:

1. T.A. Skotheim, R.L. Elsenbaumer, J.R. Reynolds, *Hand book of conducting polymers*, 2 ed. Marcel Dekker, New York, vol.**1-2**., (1998).
2. H.S. Naiwa, *organic conductive molecules and polymers*, John Wiley and sons; vol. **2**, England (1977).
3. J. L. Bredas, R. Silbey, Conjugated polymers, kluwer, Dordrecht, (1991).
4. *Encyclopaedia of Polymer science and Engineering, second edition*, Vol.5, Mark Bikales over Berger Menges John Wiley and Sons Inc. (1986).
5. M.E.O.Lyons, *Electroactive polymers*, Ed; Plenum Press; New York, PP 1-65, (1994).
6. J. Margolis, *Conducting Polymers and Plastics*, Chapman and Hal, London 1993

Teaching Learning Process:

Power point presentation, Demonstrations, Discussions, Videos

Assessment Methods:

As per University of Delhi norms

Keywords

Electrical applications, polyaniline, polypyrrole, EMI shielding, Shape Memory Polymers