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A.C. : 25/4/11
Item No. : 2.2.19
Annexure No. XIX

UNIVERSITY OF DELHI

SCHEME OF EXAMINATION

AND

COURSES OF READING

FOR

B.Sc. (HONS.)-POLYMER SCIENCE

I Semester Examination November 2010

II Semester Examination April 2011

III Semester Examination November 2011

IV Semester Examination April 2012

V Semester Examination November 2012

VI Semester Examination April 2013

Syllabus applicable for the students seeking admission to the B.Sc. (Hons.) in Polymer Science at University of Delhi from the academic year 2010-2011

Semester System at the Undergraduate Level

Course of Study: B. Sc. (H) Polymer Science

Semester I

- 101 Introduction to Polymer Science
- 102 Raw Materials of Polymers
- 103 Chemistry I (Minor)
- 104 Technical Writing and Communication in English
- Practical – Polymer I
- Practical –Chemistry I

Semester II

- 201 Polymer Chemistry
- 202 Unit Operations
- 203 Chemistry II (Minor)
- 204 Applications of Computers in Chemistry
- Practical –Polymer II
- Practical – Chemistry II
- Practical –Computers

Semester III

- 301 Polymer Rheology
- 302 Polymer Additives
- 303 Chemistry III (Minor)
- 304 Physics (Minor)
- Practical – Polymer III
- Practical – Chemistry III
- Practical – Physics

Semester IV

- 401 Polymer Processing & Mold Design
- 402 Polymer Testing
- 403 Organizational Behaviour (Minor)
- 404 Maths (Minor)
- Practical – Polymer IV

Semester V

- 501 Polymer Characterization
- 502 Polymer Degradation
- 503 Applied Polymer Science
- 504 Speciality Polymers
- Practical – Polymer V
- Project work*

Semester VI

- 601 Polymer Blends and Composites
- 602 Fiber Science and Rubber Technology
- 603 Polymeric Nanomaterials
- 604 Recycling & Waste Management
- Practical – Polymer VI

* Duration of project work is two months during the summer holidays between IVth and Vth semesters.

Total No. of Papers: 24; Major: 16; Minor: 6; Interdisciplinary: 2

Scheme of Examination

I[ST] SEMESTER — TOTAL MARKS: 600

Paper No.	Title	Duration (Hrs.)	Max. Marks
101	Introduction to Polymer Science	3	100
102	Raw Materials of Polymers	3	100
103	Chemistry I	3	100
104	Technical Writing and Communication in English	3	100
105	Practical – Polymer I	6	100
106	Practical – Chemistry I	6	100

II[ND] SEMESTER — TOTAL MARKS: 700

Paper No.	Title	Duration (Hrs.)	Max. Marks
201	Polymer Chemistry	3	100
202	Unit Operations	3	100
203	Chemistry II	3	100
204	Applications of Computers in Chemistry	3	100
205	Practical – Polymer II	6	100
206	Practical – Chemistry II	6	100
207	Practical – Computers	6	100

III[RD] SEMESTER — TOTAL MARKS: 700

Paper No.	Title	Duration (Hrs.)	Max. Marks
301	Polymer Rheology	3	100
302	Polymer Additives	3	100
303	Chemistry III	3	100
304	Physics	3	100
305	Practical – Polymer III	6	100
306	Practical – Chemistry III	6	100
307	Practical – Physics	6	100

IV[TH] SEMESTER — TOTAL MARKS: 500

Paper No.	Title	Duration (Hrs.)	Max. Marks
401	Polymer Processing and Mold Design	3	100
402	Polymer Testing	3	100
403	Organizational Behaviour	3	100
404	Mathematics	3	100
405	Practical – Polymer IV	6	100

V[TH] SEMESTER

TOTAL MARKS: 600

Paper No.	Title	Duration (Hrs.)	Max. Marks
501	Polymer Characterization	3	100
502	Polymer Degradation	3	100
503	Applied Polymer Science	3	100
504	Specialty Polymers	3	100
505	Practical – Polymer V	6	100
506	Project Work	-	100

VI[TH] SEMESTER

TOTAL MARKS: 500

Paper No.	Title	Duration (Hrs.)	Max. Marks
601	Polymer Blends and Composites	3	100
602	Fiber Science and Rubber Technology	3	100
603	Polymeric Nanomaterials	3	100
604	Recycling and Waste Management	3	100
605	Practical – Polymer VI	6	100
	Total		3600

* Duration of project work is two to three months during the summer holidays between IV[th] and V[th] semesters.

Total Number of Papers	: 24
Major Subject	**: 16**
Minor Subjects	**: 06**
Interdisciplinary Subjects	: 02

Ist SEMESTER

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 101: Introduction to Polymer Science

1. 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.
2. Crystal morphologies: extended chain crystals, chain folding, lamellae, and spherulites. Crystallization and crystallinity, determination of melting point and degree of crystallinity.
3. Properties of polymers (physical, thermal, flow & mechanical properties).
4. Glass transition temperature (T_g) and measurement of T_g. Factors affecting the glass transition temperature. WLF equation.
5. Polymer solution – solubility parameter, properties of dilute solutions.
6. Nature and structure of polymers – structure-property relationships. Molecular weight of polymers ($\bar{M}_n$, $\bar{M}_w$ etc.), molecular weight distribution and determination of molecular weight.

Practical – Polymer I:

- Heat deflection temperature, VICAT softening point.
- Measurement of glass transition temperature (T_g).
- To determine the melting point of crystalline polymers.
- To check the solubility of the given polymeric sample in different solvents.
- Determination of molecular weight by solution viscosity.
- Determination of molecular weight by end group analysis.
- Chemical identification of polymers
    - Unsaturation
    - Testing of functional groups (associated with polymers)

Suggested Readings:

1. Plastics Materials by J. A. Brydson, Butterworth Heinemann (1999).
2. Polymer Science and Technology of Plastic and Rubber by P. Ghosh, Tata Megraw Hill (1990).
3. Polymer Science by Gowarikar V.R., New Age International Publishers Ltd. (1986).
4. Molecular Weight Distribution in Polymer by L.H. Peebles, Wiley Interscience, N.Y. (1971).
5. Textbook of Polymer Science by Fred W. Billmeyer, Wiley, India (2007).
6. Polymer Crystillization, by Scholtz, American Chemical Society (2001).
7. Polymer Chemistry, by Seymour R. B. and Carraher, Marcel Dekker (2000).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 102: Raw Materials of Polymers

1. Oil, natural gas, coal: Capabilities and limitations.
2. General consideration of petrochemicals, an overview of petroleum refining, desalting, distillation, cracking and its types.
3. Preparation of important monomers: Formaldehyde, ethylene, vinyl acetate, vinyl chloride, ethylene oxide and ethylene glycol, acrylonitrile, glycerol, toluene diisocyanate, methyl methacrylate, isoprene, phenol, styrene, terephthalic acid, adipic acid.
4. Natural rubber from latex: Collection, concentration and stabilization of latex. Latex compounding: Vulcanizing agents, latex compounding acids, wetting, dispersing and emulsifying agents, stabilizers, thickening agents, fillers & other additives.
5. Manufacture of latex products: Spreading, casting, dipping, latex thread, latex coated coir and latex foam.

Practical - Polymer I:

1. Fractional distillation of petroleum.
2. Concentration of latex by various methods.
3. Dipping process of manufacturing.
4. Latex compounding.
5. Determination of composition of petroleum product.

Suggested Readings:

1. Chemistry and Technology of Petroleum, by Speight, CRC Press (2006).
2. Latex Technology by D. Kumar and R. Chandra, Dhanpat Publisher (2001).
3. Modern Petroleum Refining Processes, by B.K.B. Rao, Oxford and IBH (2007).
4. Introduction to Petrochemicals, by S. Maiti; Oxford & IBH Publ. Co (1992).
5. Text Book on Petrochemicals, by B.K.B. Rao, Khanna Publishers (2007).
6. Dryden's Outlines of Chemical Technology by G. Rao, Affiliated East West Press Pvt. Ltd. (1997).
7. Hand book of Rubber Technology by Smith and Martin, CBS Publishers (2007).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 103: CHEMISTRY I
Atomic Structure, Bonding, General Organic Chemistry & Aliphatic Hydrocarbons

Section A: Inorganic Chemistry-I (30 Periods)

Unit 1. Atomic Structure: *Recapitulation of: Bohr's theory and its limitations, dual behaviour of matter and radiation, de-Broglie's relation, Heisenberg Uncertainty principle. Need of a new approach to Atomic structure.*

What is Quantum mechanics? Time independent Schrodinger equation ($H\Psi = E\Psi$) and meaning of various terms in it. Significance of Ψ and Ψ_2, Schrodinger equation for hydrogen atom in Cartesian coordinates (x,y,z). Need of polar coordinates, transformation of Cartesian coordinates (x,y,z) into polar coordinates (r,θ,φ). Radial and angular parts of the hydogenic wave functions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals. (Only graphical representation), Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distances with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers m_l and m_s. Shapes of s, p and d atomic orbitals, nodal planes. Discovery of spin, spin quantum number (s) and magnetic spin quantum number (m_s).

Rules for filling electrons in various orbitals, Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

Unit 2. Chemical Bonding and Molecular Structure

Ionic Bonding :General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Lande equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent bonding :*VB Approach* :Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds. *MO Approach* : Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combination of atomic orbitals, non- bonding combination of orbitals ,MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO+. Comparison of VB and MO approaches.

Section B: Organic Chemistry-I (30 Periods)

Unit 3. Fundamentals of Organic Chemistry

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis.Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles.

Reactive Intermediates: Carbocations, Carbanions free radicals. Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Huckel's rule.

Unit 4. Stereochemistry

Conformations w.r.t. ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newman, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds) . Threo and erythro; D and L; *cis - trans* nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z Nomenclature (for upto two C=C systems).

Unit 5. Aliphatic Hydrocarbons

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure. **Alkanes:** (Upto 5 Carbons). *Preparation:* Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent.
Reactions: Free radical Substitution: Halogenation.
Alkenes: (Upto 5 Carbons) *Preparation:* Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). *Reactions:* cisaddition (alk. $KMnO_4$) and trans-addition (bromine). Addition of HX (Markownikoff's and anti-Markownikoff's addition). Hydration, Ozonolysis, oxymecuration-demercuration, hydroboration-oxidation.
Alkynes: (Upto 5 Carbons) *Preparation:* Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides, dehydrohalogenation of vicinaldihalides. *Reactions:* formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alk. $KMnO_4$.

PRACTICALS: CHEMISTRY I

Section A: Inorganic Chemistry - Volumetric Analysis

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with $KMnO_4$.
3. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
4. Estimation of Fe(II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.
5. Estimation of Cu(II) ions iodometrically using $Na_2S_2O_3$.

Section B: Organic Chemistry

1. Detection of extra elements (N,S,Cl,Br,I) in organic compounds (containing upto two extra elements)
2. Separation of mixtures by Chromatography: Measure the R_f value in each case (combination of two compounds to be given)
   (a) Identify and separate the components of a given mixture of 2 amino acids (glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography
   (b) Identify and separate the sugars present in the given mixture by paper chromatography.

Suggested Readings:

1. J. D. Lee : *A new Concise Inorganic Chemistry*, E L. B. S.
2. F. A. Cotton & G. Wilkinson : *Basic Inorganic Chemistry*, John Wiley.
3. Douglas, McDaniel and Alexader : *Concepts and Models in Inorganic Chemistry*, John Wiley.
4. James E. Huheey, *Ellen Keiter and Richard Keiter : Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Publication.
5. T. W. Graham Solomon : *Organic Chemistry, John Wiley and Sons.*
6. Peter Sykes: *A Guide Book to Mechanism in Organic Chemistry*, Orient Longman.
7. E. L. Eliel : *Stereochemistry of Carbon Compounds*, Tata McGraw Hill.
8. I. L. Finar : *Organic Chemistry* (Vol. I & II), E. L. B. S.
9. R. T. Morrison & R. N. Boyd : *Organic Chemistry*, Prentice Hall.
10. Arun Bahl and B. S. Bahl : *Advanced Organic Chemistry*, S. Chand
11. Vogel's Qualitative Inorganic Analysis, A.I. Vogel , Prentice Hall ,7th Edition.
12. Vogel's Quantitative Chemical Analysis, A.I. Vogel , Prentice Hall ,6th Edition.
13. Textbook of Practical Organic Chemistry, A.I. Vogel ,.Prentice Hall, 5th edition.
14. Practical Organic Chemistry, Mann F. G. & Saunders B. C, Orient Longman, 1960.

(4 Lect./Week)
(1 Tutorial/Week)

(Total credits -5)

PAPER 104: TECHNICAL WRITING AND COMMUNICATION IN ENGLISH

Unit 1

Communication: Language and communication, differences between speech and writing, distinct features of speech, distinct features of writing.

Unit 2

Writing Skills; Selection of topic, thesis statement, developing the thesis; introductory, developmental, transitional and concluding paragraphs, linguistic unity, coherence and cohesion, descriptive, narrative, expository and argumentative writing.

Unit 3

Technical Writing: Scientific and technical subjects; formal and informal writings; formal writings/reports, handbooks, manuals, letters, memorandum, notices, agenda, minutes; common errors to be avoided.

Suggested Readings:

1. M. Frank. Writing as thinking: *A guided process approach, Englewood Cliffs.* Prentice Hall Reagents.
2. L. Hamp-Lyons and B. Heasely: Study Writing; *A course in written English.* For academic and professional purposes, Cambridge Univ. Press.
3. R. Quirk, S. Greenbaum, G. Leech and J. Svartik: *A comprehensive grammar of the English language*, Longman, London.
4. Daniel G. Riordan & Steven A. Panley: *"Technical Report Writing Today"* - Biztaantra.
5. Daniel G. Riordan, Steven E. Pauley, Biztantra: *Technical Report Writing Today*, 8th Edition (2004).
6. *Contemporary Business Communication*, Scot Ober, Biztantra, 5th Edition (2004).

IInd SEMESTER

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 201: Polymer Chemistry

1. Criteria for polymer synthesis. Classification of polymerization processes.
2. Basic methods of polymerization and their mechanism: Addition, condensation, mass (bulk), suspension, emulsion and solution processes.
3. Concept of functionality, Carother's equation and its applications in polymerisation reactions. Polymer formation by step growth polymerization and chain growth polymerization and their kinetics. Mayo's equation, cage effect, auto-acceleration, inhibition and retardation. Kinetics of copolymerization , Zeigler-Natta catalysts.
4. Brief introduction to the preparation, structure, properties and applications of the following polymers:
   a) Polyolefins (PE,PP)
   b) Polystyrene and its copolymers
   c) Poly(vinyl chloride) and related polymers
   d) Poly(vinyl acetate) and related polymers
   e) Acrylic polymers
   f) Fluoropolymers
   g) Aliphatic polyamides
   h) Unsaturated polyester resins
   i) Phenol formaldehyde resins
   j) Polymers from amines
   k) Polyurethanes
   l) Silicones
   m) Epoxides

Practical - Polymer II:

- Preparation of thermosetting resins.
- Suspension polymerisation of styrene/MMA.
- Emulsion polymerisation of vinyl acetate, butyl acrylate.
- Bulk and solution polymerisation of methyl methacrylate/styrene.
- Preparation and testing of epoxy resins.
- Copolymerisation of styrene & MMA and determination of reactivity ratios.
- Preparation of polyvinyl alcohol.
- Preparation of polyvinyl butyral.

Suggested Readings:

1. Principles of Polymerization, by G.Odian, Wiley – Interscience (1981).
2. Plastics Materials by J. A. Brydson, Butterworth-heinemann (1999).
3. Principles of Polymer Chemistry by P.J. Flory, Asian Books Private Limited (2006).
4. Organic Chemistry of Synthetic High Polymers, by Robert W. Lenz, Interscience Publisher (1967).
5. Polymer Chemistry, by Seymour R. B. and Carraher, Marcel Dekker (2000).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 202: Unit Operations

1. Industrial stoichiometry – material balance of physical and chemical processes, energy balance.
2. Velocity distribution in flow system, interface transport, microscopic and macroscopic balances.
3. Energy transport in non isothermal systems.
4. Flow of fluids in pipes –Bernoulli's equation and calculations for pipe size and pressure drop, flow measuring instruments, various types of pumps.
5. Mechanical operations –size reduction and its equipment, filtration and types of filters.
6. Heat transfer – conduction, convection, radiation, heat exchangers.
7. Mass transfer – diffusion and its mechanism, gas absorption, various types of distillation, drying.

Practical - Polymer II:

1. Handling of jaw crusher, ball mill for crushing and grinding.
2. Distillation of various mixtures.
3. Diffusion experiments.
4. Filtration of solids from slurry.
5. Calculation of pressure drop and pipe size.

Suggested Readings:

1. Unit Operations in Chemical Engg. by Mccabe, Smith and Harriott, Mcgraw-hill Professional (2004).
2. Unit Operations in Chemical Eng. (Vol 1&2) by P. Chattopadhaya, Khanna Publishers (2003).
3. Chemical Engg. (Vol. 1 to 6) by Coulsan and Richardson, Elsevier (2010).
4. Heat and Mass Transfer by D. S. Kumar, S K Kataria & Sons Delhi (2009).
5. Introduction to Chemical Engg. by D. Banchero, Mcgraw-hill Professional (1995).
6. Solved Example in Chemical Engg. by G. K. Rao, Khanna Publishers (2002).
7. Mass Transfer Operation by Treybal, Tata Mcgraw Hill (2001).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 203: Chemistry II:

Thermodynamics, Equilibria & Functional Group Organic Chemistry

Section A: Physical Chemistry-1 **(30 Lectures)**

Unit 1. Chemical Thermodynamics

What is thermodynamics? State of a system, state variables, intensive and extensive variables, concept of heat and work, thermodynamic equilibrium, thermodynamic properties, various types of systems and processes. First Law of thermodynamics. Calculation of work (w), heat (q), changes in internal energy (?U) and enthalpy (?H) for expansion or compression of ideal gases under isothermal and adiabatic conditions for both reversible and irreversible processes. Calculation of w, q, ?U and ?H for processes involving changes in physical states. Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchhoff's equation.

Various statements of Second Law of thermodynamics, concept of entropy, Gibbs free energy and Helmholtz energy, Calculations of entropy change and free energy change for reversible and irreversible processes under isothermal and adiabatic conditions. Criteria of spontaneity. Gibbs – Helmholtz equation. Maxwell's relations. Statement of Third Law of thermodynamics and calculation of absolute entropies of substances.

Unit 2. Chemical Equilibrium

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ?G and ?G_0, Le Chatelier's principle. Relationships between K_p, K_c and K_x for reactions involving ideal gases.

Unit 3. Ionic Equilibria

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect, Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Section B: Organic Chemistry-2 **(30 Lectures)**

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Unit 4. Aromatic hydrocarbons

Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.

Reactions : (Case benzene) : Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation). (Upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (Upto 4 carbons on benzene).

Unit 5. Alkyl and Aryl Halides

Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (SN_2, SN_1 and SN_i) reactions. *Preparation:* from alkenes *and* alcohols.
Reactions: hydrolysis, nitrite & nitro formation, nitrile & iso-nitrile formation. Williamson's ether synthesis: Elimination vs substitution.
Aryl Halides *Preparation:* (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions. *Reactions (Chlorobenzene):* Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/NH_3 (or $NaNH_2/NH_3$). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

Unit 6. Alcohols, Phenols and Ethers (Upto 5 Carbons)
Alcohols: *Preparation:* Preparation of 1 3 alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.
Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. $KMnO_4$, acid. dichromate, con. HNO_3). Oppenauer oxidation
Diols: (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.
Phenols: (Phenol case) *Preparation:* Cumene hydroperoxide method, from diazonium salts. *Reactions:* Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer - Tiemann Reaction, Gattermann-Koch Reaction, Houben – Hoesch Condensation, Schotten – Baumann Reaction
Ethers (aliphatic and aromatic): Cleavage of ethers with HI.

Unit 7. Aldehydes and ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde , acetone and benzaldehyde) *Preparation:* from acid chlorides and from nitriles. *Reactions* – Reaction with HCN, ROH, $NaHSO_3$, NH_2-G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Pondorff Verley reduction.

Practical:

Section A: Physical Chemistry
Thermochemistry
1. Determination of heat capacity of calorimeter for different volumes.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
3. Determination of enthalpy of ionization of acetic acid.
4. Determination of integral enthalpy of solution of salts (KNO_3, NH_4Cl).
5. Determination of enthalpy of hydration of copper sulphate.
6. Study of the solubility of benzoic acid in water and determination of ΔH.

Section B: Organic Chemistry
1) Purification of organic compounds by crystallization (from water and alcohol) and distillation.
2) Criteria of purity: Determination of melting and boiling points.

Suggested Readings:

1. T. W. Graham Solomons : *Organic Chemistry*, John Wiley and Sons.
2. Peter Sykes : *A Guide Book to Mechanism in Organic Chemistry*, Orient Longman.
3. I.L. Finar : *Organic Chemistry* (Vol. I & II), E. L. B. S.
4. R. T. Morrison & R. N. Boyd : *Organic Chemistry*, Prentice Hall.
5. Arun Bahl and B. S. Bahl : *Advanced Organic Chemistry*, S. Chand.

6. Barrow, G. M. *Physical Chemistry* Tata McGraw-Hill (2007).
7. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).
8. Kotz, J. C., Treichel, P. M. & Townsend, J. R. *General Chemistry* Cengage Lening India Pvt. Ltd.: New Delhi (2009).
9. Mahan, B. H. *University Chemistry* 3rd Ed. Narosa (1998).
10. Petrucci, R. H. (1985) *General Chemistry* 5th Ed. Macmillan Publishing Co.:
11. New York (1985).
12. Textbook of Practical Organic Chemistry, A.I. Vogel , Prentice Hall, 5th edition.
13. Practical Organic Chemistry, Mann F. G. & Saunders B. C, Orient Longman, 1960.
14. Senior Practical Physical Chemistry, B.D.Khosla, R. Chand & Co.

(4 Lect./Week)
(4 hrs. Lab/Week)

(1 Tutorial/Week) (Total credits -7)

Paper 204: Applications of Computers in Chemistry

Theory:

Computer basics: PC hardware, operating systems, data storage and backup, networks, information technology. Basic operations using windows.

Computer programming: Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

Practical:

1. Word processing: Incorporating chemical structures into word processing documents, presentation graphics, on-line publication (www/html), multimedia animations, etc.
2. Handling numeric data: spreadsheet software (Excel), simple calculations, statistical analysis, plotting graphs using a spreadsheet (radial distribution curves for hydrogenic orbitals, gas kinetic theory, spectral data), graphical solution of equations, solving equations numerically (e.g. pH of a weak acid ignoring/ not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).
3. Numeric modelling, numerical curve fitting, numerical differentiation (e.g. handling data from potentiometric titrations), integration (e.g. entropy/enthalpy change from heat capacity data). Numerical solution of differential equations (e.g. kinetics).
4. BASIC programs for numerical differentiation and integration, finding roots (quadratic formula, iterative, Newton-Raphson method), numerical solution of differential equations.
5. Computational chemistry: Visualization of 3D structures, calculation of molecular structures and properties (e.g., conformational energies of butane, rotation of 1,3-butadiene, distribution of isomers, energies of orbitals and total energy as a function of bond angle for H_2O, Diels-Alder reaction).
6. Chemical information on the web, Chemical abstracts, Structures and properties.

Note: Software: Microsoft Office, ChemOffice

These are representative projects. The students must be encouraged to explore other projects and prepare a presentation based on their project. Internal assessment may be based on the project.

Suggested Readings:

B.Sc. (Hons.) Polymer Science

Paper.: 204

Application of computers in chemistry:

Suggested Readings:

1. Computer Fundamentals , by P.K.Sinha , IVedition ,BPH Publications.
2.Fundamental of Computers by V. Rajaraman, IV edition ,PHI Publications.
3.Let us C by Yashwant Kanetkar . III edition , Bpb Publications
4. Programing in ANSI , by E.Balgurswami, IV edition , Tata-,McGraw Hill Pvt :Ltd

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III[rd] SEMESTER

(4 Lect./Week)
(4 hrs. Lab/Week)

(1 Tutorial/Week) (Total credits -7)

Paper 301: Polymer Rheology

1. Viscosity and polymer processing, other rheological properties of fluids, shear stresses in polymer systems, non-Newtonian flow, practical melt viscosities, flow in channels, simple shear flow, melt-flow index.
2. Types of fluids and rheological models, techniques for rheological measurements by capillary, parallel plate and cone & plate viscometers. Simple elongational flow and its significance. Dynamic flow behavior, time dependent fluid responses.
3. The elastic and viscoelastic state of polymers – viscoelasticity - relationships of various approaches taken in describing the viscous and elastic properties, Maxwell model and Voigt model, Boltzmann superposition principles, dynamic mechanical testing.
4. Mixing: Types of mixing, concept and importance of master batches. Mixing of additives with the polymers, melt compounding and calendaring.
5. Types of mixers: High speed mixer, two roll mill, internal batch mixers (Banbury, Haake), single screw & twin screw extruders, flow mechanism, analysis of flow (drag, pressure and leak flow).

Practical - Polymer III:

1. Determination of melt flow index.
2. Determination of intrinsic viscosity by Ubbelohde viscometer.
3. Melt rheological properties by rheometers.
4. Measurement of resin/paint viscosity by Ford cup 4.
5. Measurement of viscosity by Brookfield Viscometer.
6. Compounding of polymers in the internal mixer and measure the torque.

Suggested Readings:

1. Introduction to Polymer Viscoelasticity by John J. Aklonis and W. J. Macknight, John Wiley & Sons (2005).
2. Polymer Science and Technology of Plastic and Rubber by P. Ghosh, Tata Megraw Hill (1990).
3. Fundamental Principles of Polymeric Materials by Stephen L. Rosen, Wiley-interscience (1993).
4. Fundamentals of Polymer Processing by Stanley and Middlemann, McGraw-Hill College (1977).
5. Melt Rheology and Its Roll in Plastic Processing by John Dealxy and Kurt F. Wissbrum, Kluwer Academic (1999).
6. Applied Rheology in Polymer Processing, by B. R. Gupta, Asian Books (2004).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 302: Polymer Additives

1. Importance of additives and their selection criteria for commercial polymers.
2. Additives for plastics and their mechanism of function:
   a) Stabilizers
   b) Fillers
   c) Plasticizers
   d) Lubricants
   e) Flame retardants
   f) Foaming agents
   g) Cross linking agents
   h) Metal deactivators
3. Additives for rubbers and their mechanism of function:
   a) Vulcanizing agents and retardants
   b) Accelerators
   c) Activators
   d) Fillers
   e) Softeners
   f) Colors and pigments
   g) Tackyfing agents
   h) Blowing agents
   i) Surface property modifiers

3. Illustration of few formulations and their compounding procedures.

Practical - Polymer III:

1. Determination of gravity of fillers.
2. Determination of bulk density of fillers.
3. Determination of pore size and net size of fillers.
4. Determination of heat stability of heat stabilizers.
5. Flash point determination of plasticizer.
6. Identification of additives.

Suggested Readings:

1. Polymer modifiers and additives, by Lutz, Marcel Dekker (2001).
2. Chemistry and Technology of Polymer Additives, by Al- Malaika, Elsevier Applied Science (1999).
3. Plastic materials, by J. Brydson, Butterworth-heinemann (1999).
4. Handbook of Rubber Technology, by Martin and Smith, Cbs Publisher (2007).
5. Polymer Science and Technology: Plastic, Rubber Blends and Composites, by P. Ghosh, Tata Mcgraw Hill (1990).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 303 – Chemistry III:

Solutions, Conductance, Electrochemistry and Functional Group Chemistry
***Section A: Physical Chemistry-2* (30 Lectures)**

Unit 1. Solutions

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions. Vapor pressure-composition and temperature composition curves of ideal and non-ideal solutions. Distillation of solutions. Lever rule. Azeotropes.

Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Immiscibility of liquids. Principle of steam distillation. Nernst distribution law and its applications, solvent extraction.

Unit 2. Phase Equilibrium

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagrams
of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, $FeCl_3$-H_2O and Na-K only).

Unit 3. Conductance

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch law of independent migration of ions. Transference number and its experimental determination using Hittorf and Moving boundary methods. Ionic mobility. Applications of conductance measurements: determination of degree of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid-base).

Unit 4. Electrochemistry

Reversible and irreversible cells. Concept of EMF of a cell. Measurement of EMF of a cell. Nernst equation and its importance. Types of electrodes. Standard electrode potential. Electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data. Calculation of equilibrium constant from EMF data. Concentration cells with transference and without transference. Liquid junction potential and salt bridge. pH determination using hydrogen electrode and quinhydrone electrode. Potentiometric titrations -qualitative treatment (acid-base and oxidation-reduction only).

Section B: Organic Chemistry-3 (30 Lectures)

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Unit 5. Carboxylic acids and their derivatives

Carboxylic acids (aliphatic and aromatic) *Preparation*: Acidic and Alkaline hydrolysis of Esters. *Reactions*: Hell – Vohlard - Zelinsky Reaction.

Carboxylic acid derivatives (aliphatic): (Upto 5 carbons) *Preparation:* Acid chlorides, Anhydrides, Esters and Amides from acids and their inter-conversion. *Reactions:* Comparative study of nucleophilicity of acyl derivatives. Reformatsky Reaction, Perkin condensation.

Unit 6. Active methylene compounds:
Preparation : Claisen ester condensation. Keto-enol tautomerism *Reactions:* Synthetic uses of ethyl acetoacetate (preparation of non-hetero molecules having up to 6 carbon).

Unit 7. Amines and Diazonium Salts
Amines (Aliphatic and Aromatic): (Upto 5 carbons)
Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction. *Reactions:* Hofmann Vs Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO_2, Schotten – Baumann Reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation.
Diazonium salts: *Preparation:* from aromatic amines. *Reactions:* conversion to benzene, phenol, dyes.

Unit 8. Carbohydrates: Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation.

Practical:

Section A: Physical Chemistry
1. pH measurements
a) Measurement of pH of different solutions, like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter.
b) Preparation of buffer solutions:
(i) Sodium acetate-acetic acid
(ii) Ammonium chloride-ammonium hydroxide
Measurement of the pH of buffer solutions and comparison of the values with theoretical values.
2. Distribution
Study of the equilibrium of one of the following reactions by the distribution method:

Section B: Organic Chemistry
Preparations: Mechanism of various reactions involved to be discussed.
Recrystallisation, determination of melting point and calculation of quantitative yields to be done.
(a) Nitration of Nitrobenzene
(b) Preparation of carboxylic acid by alkaline hydrolysis of ester/amide.
(c) Oxidation of alcohol/aldehydes/hydrocarbons to carboxylic acid
(d) Osazone from glucose/fructose
(e) Amides and anilides from carboxylic acid.
(f) Preparation of methyl orange.

Suggested Readings:

1. Barrow, G. M. *Physical Chemistry* Tata McGraw-Hill (2007).
2. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).
3.Kotz, J. C., Treichel, P. M. & Townsend, J. R. *General Chemistry* Cengage Learning India Pvt. Ltd.: New Delhi (2009).
4. Mahan, B. H. *University Chemistry* 3rd Ed. Narosa (1998).
5.Petrucci, R. H. (1985) *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
6. T. W. Graham Solomon's :*Organic Chemistry,* John Wiley and Sons.
7. R. T. Morrison & R. N. Boyd :*Organic Chemistry,* Prentice Hall.
8. I. L. Finar :*Organic Chemistry (Vol. I & II)*E. L. B. S.
9. Jerry-March :*Advanced organic Chemistry,* John Wiley & Sons
10. Peter Sykes :*A Guide Book to Mechanism in Organic Chemistry,* Orient Longman.
11. Arun Bahl and B. S. Bahl : *Advanced Organic Chemistry,* S. Chand
12. Textbook of Practical Organic Chemistry, A.I. Vogel , Prentice Hall, 5th edition.
13. Practical Organic Chemistry, Mann F. G. & Saunders B. C, Orient Longman, 1960.
14. Senior Practical Physical Chemistry, B.D.Khosla, R. Chand & Co.

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 304: Physics

Electrostatics: Electric field, potential due to a charge distribution and due to a dipole, electrical potential energy, flux, Gauss's law, electric field in a dielectric, polarization, energy stored in an electric field.

Magnetism: Magnetic field due to a current-carrying conductor, Biot Savart law, magnetic force on a current, Lorentz force, electromagnetic induction, Lenz's law, magnetic properties of matter, para- dia- and ferromagnetism, spinning of a magnetic dipole in an external magnetic field.

Fundamental laws of electromagnetism: Modification of Ampere's law, equation of continuity and displacement current, Maxwell's equations, wave equation and its plane wave solution, nature of electromagnetic waves, tranversality and polarization, propaganation of electromagnetic plane waves in dielectric media.

Electronics: Half-wave, full-wave and bridge rectifiers, ripple factor, rectification efficiency, filters (series in inductor, shunt capacitator, LC and π sections), voltage regulations, load regulation, Zener diode as voltage regulator. Characteristic curves of bipolar transistors, static and dynamic load line, biasing (fixed and self) of transistor circuit, thermal instability of bias, the black box idea of CE, CB and CC transistor circuits as two-port network, small signal active output, hybrid model of a CE transistor circuit, analysis of a small signal amplifier: its voltage and current gains, negative and positive feedback, Barkhausen's criterion for self-sustaining oscillations, LC and phase shift oscillators.

Digital electronics: Number systems (binary, BCD, octal and hexadecimal), 1's and 2's complements, Logic gates, AND, OR, NAND, NOR, XOR and NXOR, Boolean algebra (Boolean laws and simple expressions), binary adders, haf adder, half subtractor, full adder and full subtractor.

Practical: Physics

B.Sc. (Hons.) Polymer Science

Paper : 307-P

Practical Physics:

1. To study the frequency response of series and parallel LCR circuit.
2. To study the diode and transistor characteristics.
3. To draw the BH curve of iron by using a Solenoid and to determine the energy loss due to Hysteresis.
4. To measure the Resistivity of a Ge Crystal with Temperature by Four Probe Method (from room temperature to 200 °C) and to determine the Band Gap E_g for it.
5. To study the PE Hysteresis loop of a Ferroelectric Crystal.
6. To determine the Ratio of Two Capacitances by de Sauty's Bridge.
7. To determine the Dielectric Constant of a Dielectric placed inside a parallel plate
8. To determine Self Inductance of a Coil by Anderson's Bridge using AC
9. To determine Self Inductance of a Coil by Rayleigh's Method.
10. To verify and design AND, OR, NOT and XOR gates using NAND gates.

IVth SEMESTER

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 401: Polymer Processing and Mold Design

1. Extruder and die design: Extrusion process, the extrusion die, extruder and die characteristics. Classification of extrusion dies, die swell.
2. Injection moulding: Principles, the moulding cycle, the injection moulding machine, some aspects of product quality, reaction injection moulding (RIM).
3. Blow moulding: Blow moulding principles, extrusion blow moulding, injection blow moulding, stretch blow moulding, blow moulding of PET.
4. Thermoforming: Principles, types and applications.
5. Compression and transfer moulding: Introduction, thermosetting compounds, compressing moulding process, transfer moulding.
6. Miscellaneous processing methods – casting and rotational moulding.
7. Mould Making – introduction, casting, electrodeposition, cold hobbing, pressure casting, spark machining, bench fitting.
8. Feed system: Runner and gates.
9. Ejection: Ejector grid, ejector plate assembly, ejection techniques, ejection from fixed half and sprue pullers.
10. Moulding internal undercuts: Form pin, split cores, side cores, stripping internal undercuts, moulds for threaded components. Daylight moulds – general, underfeed moulds, triple daylight mould.

Practical - Polymer IV:

1. Compounding of additives in roll-mill with fillers and reinforcing agents.
2. Compression moulding
3. Injection moulding
4. Extrusion on single screw and twin screw extruders.
5. Thermoforming.
6. Casting of membrane
7. Design and draw a representative cavity and core plate
8. Develop a mould plate by electro-deposition.
9. Tool room visits.

Suggested Readings:

1. Injection mould design, by R.G.W. Pye, Affiliated East West Press Pvt. Ltd (1989).
2. Plastics: Materials & Processing by A. B. Strong, Prentice Hall (2005).
3. Injection Moulding Handbook, Dominick, V. Roato and Donald, V. Rosato, CBS Publisher (2000)
4. Polymer Processing by Morton and Jones, Chapman & Hall (2007)
5. Plastic Engg. by R. J. Crawford, Butterworth-heinemann (1998).
6. Polymer Processing Principles and Design by Baird and Collias, Wiley-Interscience (1998).
7. Plastic Processing Data Handbook by D. V. Rosato and D. V. Rosato, Springer Netherlands (2001).

4 Lect/Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 402: Polymer Testing

1. Principles and methods of standardization, statistical method of analysis. Standards: BIS standards – BIS standards of few polymers. ASTM standards – ASTM standards of few polymers. Evaluation of errors in polymer testing.
2. Mechanical properties: Thermal and mechanical analysis of polymers
   (a) Short term strengths: Tensile, flexural, impact, tear resistance, abrasion etc.
   (b) Long term strength: Creep and fatigue properties.
   (c) Thermal properties: Thermal conductivity, thermal diffusivity, specific heat capacity, linear thermal expansivity, heat distortion temperature, vicat softening point, low temperature flexibility etc.
3. Flow properties: Melt flow index, cup flow test, solution and inherent viscosity, melt viscosity etc.
4. Flammability properties: Oxygen index, critical temperature index, smoke density, flammability tests etc.
5. Optical properties: Gloss, haze, refractive index, degree of yellowness etc.
6. Permeability: Definition, permeability to gases, standard methods of measuring, 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.

Practical - Polymer IV:

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 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

Suggested Readings:

1. Handbook of Plastic Testing, Technology, by V. Shah, Wiley-Interscience (2007).
2. Polymer Testing, by W. Grellmann and S. Seinder, HANSER Publisher, 1961
3. Rubber Technology Handbook, by Martin and Smith, Smithers Rapra Technology (2009).
4. SPI Plastic Engineering Handbook, by M.L. Berins. Springer-Verlag(1991).
5. Introduction to the Mechanical Properties of Solid Polymers by Ward and Sweeney, Wiley (2004).

(4 Lect./Week)
(1 Tutorial/Week) (Total credits -5)

Paper 403: Organizational Behavior

1. **Communication:** functions of communication, the communication process: a communication model, sources of distortion, communication apprehension, communication fundamentals, direction of communication, formal vs informal networks, nonversal communications, choice of communication channel, barrier to effective communication.
2. **Principles of learning** – classical conditioning, instrumental conditioning, cognitive learning.
3. **Motivation** – what is motivation? Early theories of motivation, contemporary theories of motivation.
4. **Leadership** – what is leadership? Theories of leadership: trait theories, behavioral theories, contingency theories, recent approaches to leadership.
5. **Attitudes** – detention of anitudes, nature of attitudes; measurement of attitudes, attitude theories, factors in attitude change, attitude and behaviot, behavior and attitude.
6. **Stress and its management** – what is stress? : Understanding and its consequences; potential sources of stress; individual differences; consequences of stress, stress management.
7. **Technical communication:** report writing; seminar presentation.
8. **Performance appraisal:** Need, methods and applications.
9. **Communication:** Transaction analysis, Johari windows.
10. **Job analysis and Design:** Approaches, job rotation, job enlargement, job design models.

References:

1. Organizational Behavior (9th ed.), F. Luthans, McGraw-Hill companies Inc., 2002
2. Behavior in Organizations (8th ed.), J. Greenberg, R.A. Baron, Pearson Education Inc., 2005.
3. Organizational Behaviour Concepts, S.P. Robins, Controversies and Applications (8th ed.) 2000.

(4 Lect./Week)
(1 Tutorial/Week) (Total credits -5)

Paper – 404: Mathematics

1. Differential equations: differential equations with separable variables, series solution, numerical solutions of differential equations. Newton' laws of motion. The linear harmonic oscillator: Linear differential equations with constant coefficients.
2. Partial differential equations: separation of variables. The wave equation. Schrödinger's equation.
3. Multiple integrals. Changing variables. Vector derivative operators. Multiple integrals involving other coordinate systems (spherical polar). Maximum and minimum values of functions of several variables.
4. Stationary points, imaginary and complex numbers, complex plane, Euler's formula and polar form of complex numbers, complex conjugates, modulus of a complex number.
5. Operators: operator algebra, linear operators, eigenfunctions and eigenvalues, commutators of operators, Hermitian operators.
6. Vectors and coordinate systems: Unit vectors (application in solid state), addition and subtraction of vectors, multiplication of vectors. Vector calculus. Vectors and coordinate systems in three dimensions (Cartesian, spherical polar and their interconversion).
7. Determinants. Matrix algebra, Simultaneous equations: method of substitution and elimination, consistency and independence. Homogeneous linear equations. Simultaneous equations with more than two unknowns (e.g. spectrophotometry), Cramer's rule, matrix inversion, orthogonal and unitary matrices, matrix eigen values and eigenvectors, diagonalization of a matrix.

Suggested Readings:

1. McQuarrie, D. A. *Mathematics for Physical Chemistry* University Science Books (2008).
2. Mortimer, R. *Mathematics for Physical Chemistry*. 3rd Ed. Elsevier (2005).
3. Steiner, E. *The Chemical Maths Book* Oxford University Press (1996).
4. Yates, P. *Chemical calculations*. 2nd Ed. CRC Press (2007).

PROJECT WORK:

During the summer holidays between IVth and Vth semesters, students will undergo project work for a period of two months in any polymer industry/research labs of universities/institutions. The project report will be submitted at the end of fifth semester. Out of 100 marks, 75 marks for project work, 15 marks for the viva on the project work and 10 marks for the power point presentation of the project work will be awarded. Committee consists of 2 teachers and one outside expert will examine the project work, viva and presentation at the end of Vth semester.

Vth SEMESTER

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 501: Polymer Characterization

1. Basic principles of spectroscopy, molecular and atomic spectra, Lambert-Bear law, Frank-condon principal, electromagnetic radiation, properties of electromagnetic radiation, interaction of radiation with matter: A classical picture, uncertainty and the question of time scale.
2. Applications of spectroscopy: IR, UV, ESR, Raman, NMR and mass spectroscopy of polymers.
3. Chromatography: Thin layer chromatography, high performance liquid chromatography, gel permeation chromatography (GPC), gas chromatography
4. Applications of optical microscope, SEM, TEM and XRD in polymers.

Practical - Polymer V:

1. Verify the Lambert-Beers law.
2. Estimate the qualitative and quantitative presence of polymeric samples.
3. Analyze the thermal behavior of polymers.
4. Percentage Crystallinity of Polymeric Sample by XRD.
5. Identification of polymer components by Chromatography.
6. FTIR and Raman analysis of polymers.

Suggested Readings:

1. Instrumental method of analysis, by Willard et,al., Wadsworth Publishing Company (1988).
2. Principle of Instrumental Analysis, by Skoog et.al., Harcourt College Pub (1997).
3. Handbook of Plastic Testing, Technology, by V. Shah, Wiley-Interscience (2007).
4. Experimental Methods in Polymer Sciences, by T.Tanaka, Academic Press (1999).
5. Spectrometric identification of organic compounds. Silverstein, Robert M John Wiley(1991),
6. A complete introduction to NMR spectroscopy by Roger S .Macomber, Wiley-Interscience (2008),

4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 502: Polymer Degradation

1. Introduction to degradation. Various types of polymer degradation:
   (i) Thermal degradation
   (ii) Oxidative degradation
   (iii) Degradation by radiation
   (iv) Mechanical degradation
   (v) Chemical degradation
   (vi) Biological degradation
2. Degradation of specific polymers
   (i) Polyolefins (PE and PP)
   (ii) PVC
   (iii) Natural Rubber
   (iv) Polyamides
   (v) PMMA
   (vi) Polyimide
   (vii) Cellulose
   (viii) SBR
   (ix) Poly acrylonitrile (PAN)
   (x) Polystyrene (PS)
   (xi) PET
   (xii) PU
3. Degradation studies using DSC, TGA, DTA and DMA.

Practical - Polymer V:

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

Suggested Readings:

1. Encyclopedia of Polymer Science and Technology by W. J. Pesce and P. B. Wiley.
2. Thermal Degradation of Organic polymer, Samuel L. Madorsky, Interscience (1964).
3. Degradation and Stabilization of PVC, E. D. Owen, Elsevier Applied Science (1984).
4. Thermal Characterization of Polymeric Materials, Edith A. Turi, Academic Press (1997).
5. Handbook of Polymer Degradation by S. H. Hamid and M. B. Amin, Marcel Dekker (1992).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 503: Applied Polymer Science

1. Introduction, function and properties of adhesives, mechanical interlocking, adsorption and surface reaction. Surface topography, welling and setting, thermodynamic work of adhesion, influence of constitution on adhesion, interfacial bonding, and surface preparation of adherents. Types of adhesives (Structural, elastomeric and pseudo plastic based).
2. General information, paints composition, selection and water solubility, interface-surface treatment, properties manufacturer of paints and uses of paints.
3. Definition and importance of coating, raw materials and composition of coating, manufacture of coatings, criteria and type of coatings.
4. The technology for preparation of paints, coatings and adhesives and their use in different fields, coating operations.
5. Tyre design: Tyre mechanics, tyre friction and wear hydroplaning. Caracas design, contour shape, cord path and their characteristics. Cord tension. Load capacity of tyre. Stresses in Tyre. Tread design, Bead design, bead tension, Tyre mold design.

Practical - Polymer V:

1. Formulation of paints (Water based, solvent based).
2. Peel Test.
3. Adhesive formulation and compounding.
4. Wettability of adhesives.
5. Coating Processes (Brush coating, roller coating, dip coating, spray coating).
6. Measurement of resin/paint viscosity by Ford cup 4 and Brookfield viscometer.

Suggested Readings:

1. Outline of Paint Technology, by W M Morgen, Cbs Publisher (2000).
2. Paints, Coatings and Solvents, by Dieter Stoye, Wiley-VCH (1998).
3. Surface Coatings by Swaraj Paul, Wiley (1996).
4. Adhesion and Adhesives Technology by A. V. Pocius, Hans Carl Hanser Verlag (2002).
5. Mechanics of pneumatic Tires by Samuel K. Clark, National Bureau of Standards (1971).
6. Tyre Technology by Tom French, Taylor & Francis (1989).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 504: Speciality Polymers

1. Preparation, properties and applications of the following polymers
   - i. Polyether ether ketone resins (PEEK)
   - ii. Polyamideimide resins (PAI)
   - iii. Sulphur based polymers (Polysulphone and polyphenylene sulfide)
   - iv. Polyamide resins
   - v. Polyetherimide resins (PEI)
   - vi. Polyester resins
   - vii. Polycarbonate (PC)
   - viii. Acetal resins
   - ix. Polyphenylene oxide (PPO)
2. Functional polymers.
3. Conducting polymers: Synthesis, properties and application of polyaniline, polypyrole and polythiophene.
4. Biopolymers (Polylactic acid, polycaprolactone, starch, etc.)
5. Inorganic Polymers (Silicon and Nitrogen containing polymers)

Practical - Polymer V:

1. Conductivity testing.
2. Bio degradability and bio compatibility testing.
3. Synthesis of conducting polymers.
4. Preparation of Nylon 6, 10 by interfacial polymerisation.
5. Phenol formaldehyde (Resol/Novolac).
6. Urea-formaldehyde preparation.

Suggested Readings:

1. Plastic Materials, J. A. Brydson, Butterworth-heinemann (1999).
2. Engg. Plastics by R. W. Dyson, Blackie, Chapman and Hall, 1990
3. Engg Materials Handbook (Vol. 1 to 3) by ASTM International, USA.
4. Handbook of Biodegradable Polymer by A. J. Domb. Gordon and Breach Science Publishers (1997)
5. High Performance Polymers, their origin and development, by Seymour R. B. and Kirshenbaum G. S, Elsevier (1986).

VIth SEMESTER

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 601: Polymer Blends and Composites

Polymer blends

1. Methods of blending, the incompatibility problem, methods of compatibilization. Properties of blends (mechanical, morphological, rheology and thermal), comparison between polymer blends, copolymers, grafted copolymers and IPNs
2. Different types of polymer blends (TPE, elastomeric blends and plastic blends).Characterization of blends by various techniques.

Polymer composites

1. Introduction and classification of composites, selection criteria for polymer matrices for composites.
2. Fabrication techniques: Prepreg technology, injection and compression moulding, vacuum bag moulding, hand-lay up process, spray-up technique, filament winding process, fiber placement process, pultrusion, reaction transfer molding, laminating techniques, expansion processes, radiation processes, coating processes, fabrication processes: adhesion, cohesion and mechanical processes & FRPs.
3. Design of composite products: Basic design practice – material considerations, product considerations and design considerations.

Practical - Polymer VI:

1. Blend preparation.
2. Compatibilization of blends.
3. Effect of blend composition on distribution of additives and effect of properties
4. Preparation of laminates.
5. Preparation of composites with various fillers and various filler loading.
6. Mechanical properties of blends and composites.

Suggested Readings:

1. Polymer Blends Volume 1 & 2, by D. R. Paul and C. B. Bucknall, Wiley-Interscience (2000).
2. Polymer Blends by Lloyd M. Robeson, Hanser Gardner Pubns (2007).
3. Polymer Blends Volume 1 & 2, by D. R. Paul and Seymour Newman, Academic Press (1978).
4. Polymer Blends Handbook Vol 1 & 2 by L. A. Utracki, Kluwer Academic Pub (2003).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week) (Total credits -7)

Paper 602: Fiber Science and Rubber Technology

1. Introduction – classification and terminology of fibres, salient features of fibre forming polymers and their properties. Basic structure of a fibre. General properties of a fibre such as moisture absorption, tex, denier, tenacity, elongation at break and elastic recovery.
2. Naturally occurring fibres – Vegetable fibres, animal fibres, mineral fibres.
3. Man made and synthetic fibres – production, properties and uses of viscous rayon, cellulose acetate, nylon – 66, polyester, acrylic, carbon fibre and aramid fibres.
4. Physical properties of raw rubber and mastication.
5. Theories and phenomena of vulcanization, rheocurve of compounded rubber, mechanism of sulphur vulcanization with and without accelerators, theories of non sulphur vulcanization, properties of vulcanized rubber.
6. Natural rubber and synthetic rubber, styrene-butadiene rubber, polybutadiene rubber, ethylene propylene diene rubber, butyl rubber, nitrile rubber, neoprene, silicone rubber, fluorocarbon rubber.

Practical - Polymer VI:

1. Determination of tensile strength, modulus, elongation at break, tear strength; abrasion resistance, heat build-up resilience, hardness, flex resistance for rubber compound.
2. Effect of curing time on physical properties of NR compound.
3. Effect of mastication on intrinsic viscosity.
4. Identification of fibres through solubility tests.
5. Identification of fibres by elemental analysis.
6. Study the reaction of fibres towards heat & flame.
7. Use of plastimeter, Mooney viscometer and Rheometer.
8. Qualitative analysis of Cellulose –Polyester blends.
9. Distinguish POY & FDY polyester filament yarn based on extensibility & shrinkage behavior.
10. Fiber Testing: Twist, elongation, TEX, Denier, and count of yarn, fibre & filament.

Suggested Readings:

1. Hand book of Rubber Technology by Smith and Martin, Cbs Publisher (2007).
2. The Science and Technology of Rubber by J. E. Mark, B. Erman and F.R. Eirich, Elsevier Academic Press (2005).
3. Hand Book of Textile Fibres, Volume 1 & 2 by J. Gordon Cook, Woodhead Publishing (1984).
4. Handbook of Rubber Technology by S. Blow, Hanser Gardner (2000).
5. Understanding Textiles by Collier and Tortora, Prentice Hall (2000).
6. Physical Properties of Fibers by Morton & Hearle, CRC Press (1997).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 603: Polymeric Nanomaterials

1. Introduction to general aspects of nanostructured materials, e.g. nanocomposites, block copolymers, interaction parameter.
2. Phase behaviour morphology and phase diagrams, microphase separation transition.
3. Preparation, structure and properties of nanoreinforcing agents: eg. nanoclays, POSS, carbon nanostuctures and nanoparticles.
4. Effect of factors such as loading, dispersion and percolation, influence of size, shape and diameter of nanotubes, functionalisation of nanoparticles and nanoplatelets.
5. Structural and morphological characterization
   - Morphology of crystalline polymers.
   - Nanostructure development in semicrystalline polymer during deformation by X-ray scattering & diffraction technique.
   - Nanostructure of two component amorphous block copolymers: Effect of chain architecture.
6. Polymer nanocomposites: Technical challenges and understanding of interfacial dynamics using LJ Potential and many body problems approach.
7. Applications of polymeric nanomaterials.

Practical - Polymer VI:

1. Particle size analysis of nanofillers.
2. Preparation of polymer nanocomposites by solution & melt compounding.
3. Determination of mechanical properties.
4. Characterization of nanocomposites.
5. Determination of electrical properties.

Suggested Readings:

1. Polymer nanocomposites by J .H. Koo, McGraw-Hill (2006).
2. Polymeric Nanocomposites-Theory and Practice by S N Bhattacharya, Hanser Gardner (2008).
3. Mechanical Properties of Polymer based on Nanostructure and Morphology by G. H. Michler and F. J. Balta, CRC Press (2005).
4. Introduction to nanotechnology by- Charles Papoose and Frank J. Owens, Wiley, John & Sons (2003).
5. Nanocrystalline Materials by S.C Tjong, Elsevier Science (2006).

(4 Lect./Week)
(4 hrs. Lab/Week)
(1 Tutorial/Week)

(Total credits -7)

Paper 604: Recycling and Waste Management

1. Definition of plastic wastes and litter, basis for assessing plastic wastes, applications of plastics and their potential as sources of waste. Separation techniques (density - float sink and froth floatation methods, optical, spectroscopic, electrostatic, sorting by melting temperature, sorting by size reduction, sorting by selective dissolution and other methods).
2. Plastics waste management: 4 R's approach (reduce, reuse, recycle (mechanical and chemical), recover), recycling classification- - primary - secondary - tertiary - quaternary recycling with examples. Energy from waste – incinerators-pyrolysis, factors affecting incineration.
3. Plastics waste management: Disposal of plastic waste and litter – role of plastics in the collection of refuse; disposal process – controlled tipping, pulverization, compositing, incineration; air pollution, new developments in thermal disposal of refuse, on-site disposal methods, compacting and baling.
4. Recycling of polyolefins, PVC, PET, polystyrene, polyamides-nylon-6 and nylon-6,6, polyurethanes, mechanical process, applications of recycled materials.
5. Recycling of rubber – comparison of thermoses and thermoplastic composites, reclaiming of rubber – fuel source – pyrolysis, depolymerization of scrap rubber, tyre retreading, uses of recycled rubber – asphalt and other uses.

Practical - Polymer VI:

1. Demonstration of waste collection, sorting and separation.
2. Primary recycling of various waste collected from environment.
3. Secondary recycling of MSW by incorporating and blending the recyclable waste with virgin polymers.
4. Recycling Plant Visit.

Suggested Readings:

1. Rubber and Plastic Waste: Recycling, Reuse and Future Demand by R. Chandra and A. Adab, CBS Publisher, (2004)
2. Plastic Waste Management by Nabil Mustafa, Marcel Dekker, Inc (1993).
3. Medical, Municipal and Plastic Waste Management Handbook by NIIR Board of Consultant and Engineers, National Institute Of Industrial Research (2007).
4. Polymer Recycling by John Scheirs, John Wiley & Sons (1998).
5. Handbook of Rubber Technology by Steven Blow, Hanser Gardner (2000).
6. Recycling and Recovery of Plastics by J Ed Bandrup, Hanser Gardner (1996).