# FACULTY OF ENGINEERING

# SAVITIBAI PHULE PUNE UNIVERSITY

**Syllabus for the**

# M.E. (Polymer Engineering)-2017 Course

**(w. e. f. 2017-2018)**

**Savitribai Phule University, Pune**
**Structure for M.E. Polymer Engineering – 2017 Course (w.e.f. June 2017)**

**Semester I**

| Code | Subject | Teaching Scheme | Examination Scheme | | | | | Credits |
|---|---|---|---|---|---|---|---|---|
| | | Lect/ Pract | Paper | | TW | Oral/Presentation | Total | |
| | | | In Semester Assessment | End Semester Assessment | | | | |
| **509115** | Mathematical and Statistical Methods | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509116** | Principles of Management | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509117** | Advanced Polymer Technology | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509118** | Research Methodology | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509119** | Elective - I | 5 | 50 | 50 | -- | -- | 100 | 5 |
| **509120** | Lab Practice - I | 4 | -- | -- | 50 | 50 | 100 | 4 |
| **Total of First Term** | | **25** | **250** | **250** | **50** | **50** | **600** | **25** |

**Semester II**

| Code | Subject | Teaching Scheme | Examination Scheme | | | | | Credits |
|---|---|---|---|---|---|---|---|---|
| | | Lect/ Pract | Paper | | TW | Oral/Presentation | Total | |
| | | | In Semester Assessment | End Semester Assessment | | | | |
| **509121** | Polymer Processing and Testing | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509122** | Polymer Physics and Characterization | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509123** | Polymer Structure and Properties | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509124** | Elective - II | 5 | 50 | 50 | -- | -- | 100 | 4 |
| **509125** | Lab Practice - II | 4 | -- | -- | 50 | 50 | 100 | 5 |
| **509126** | Seminar -I | 4 | -- | -- | 50 | 50 | 100 | 4 |
| **Total of Second Term** | | **25** | **200** | **200** | **100** | **100** | **600** | **25** |

**Semester III**

| Code | Subject | Teaching Scheme | Examination Scheme | | | | | Credits |
|---|---|---|---|---|---|---|---|---|
| | | Lect/ Pract | Paper | | TW | Oral/Presentation | Total | |
| | | | In Semester Assessment | End Semester Assessment | | | | |
| **509127** | Polymer Rheology | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509128** | Transport Phenomenon in Polymers | 4 | 50 | 50 | -- | -- | 100 | 4 |
| **509129** | Elective - III | 5 | 50 | 50 | -- | -- | 100 | 5 |
| **509130** | Seminar -II | 4 | -- | -- | 50 | 50 | 100 | 4 |
| **509131** | Project Work Stage - I | 8 | -- | -- | 50 | 50 | 100 | 8 |
| **Total of Third Term** | | **25** | **150** | **150** | **100** | **100** | **500** | **25** |

**Semester IV**

| Code | Subject | Teaching Scheme | Examination Scheme | | | | | Credits |
|---|---|---|---|---|---|---|---|---|
| | | Lect/ Pract | Paper | | TW | Oral/Presentation | Total | |
| | | | In Semester Assessment | End Semester Assessment | | | | |
| **509132** | Seminar -III | 5 | -- | -- | 50 | 50 | 100 | 5 |
| **509133** | Project Work Stage - II | 20 | -- | -- | 150 | 50 | 200 | 20 |
| **Total of Fourth Term** | | **25** | **150** | **150** | **200** | **100** | **300** | **25** |

* The term work and oral/presentation of Project Stage I and II and laboratory practice I and II should be assessed jointly by the pair of internal and external examiners along with the oral examination of the same.

**Note:** Institute must submit the list of candidates, guide and project details (title, area, problem definition, abstract - clearly indicating objectives and scope, sponsorship details, if any) to the university within month of commencement of third semester. The guide must be approved/qualified full time teacher of the Institute. A guide can accept/enroll at the most 8 students per year.

**List of Electives**

| **Elective I** | **Elective II** | **Elective III** | |
|---|---|---|---|
| a. Polymer Reaction Engineering | a. Mold and Die Design | a. Polymer Product Design | -- |
| b. Composite Technology | b. Elastomer Technology | b. Specialty Polymer Materials | -- |
| c. Paints And Adhesives | c. Packaging Technology | c. Polymer and Environment | -- |
| **Non-credit course (Mandatory)** | | | |
| **Term I, Sem I** | **Term I, Sem II** | **Term II, Sem I** | **Term II, Sem II** |
| Yoga and Meditation | Human Rights and World Peace | Cyber Security /Information security | Industrial Safety and Equipment Maintenance |

**Note:**

1. Contact Hours for the calculation of load of Faculty Member:

**Seminar:** 1 Hr. / week, **Project:** 2 Hr. / week.

2. The term work and Oral/Presentation of Project Stage I and II and Laboratory Practice I and II should be assessed jointly by the pair of internal and external examiners along with the oral examination of the same.

## GUIDELINES

## LAB PRACTICE I & II

The laboratory work will be based on completion of assignments confined to the courses of that semester.

## SEMINAR

The student shall deliver the seminar on a topic approved by authorities.

**Seminar I:** Shall be on state of the art topic of student's own choice approved by an authority. The student shall submit the duly certified seminar report in standard format, for satisfactory completion of the work by the concerned Guide and Head of the department/Institute.

**Seminar II:** shall be on the topic relevant to latest trends in the field of Polymer engineering, preferably on the topic of specialization based on the electives selected by him/her approved by authority. The student shall submit the seminar report in standard format, duly certified for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

**Seminar III:** shall preferably an extension of **seminar II.** The student shall submit the duly certified seminar report in standard format, for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

## PROJECT WORK

1) The project work shall be based on the knowledge acquired by the student during the coursework and preferably it should meet and contribute towards the needs of the society. The project aims to provide an opportunity of designing and building complete system or subsystems based on area where the student likes to acquire specialized skills.

2) Colleges should display the **list of recognized/approved PG teachers/guides** which will help the students to choose the guides for their projects. This will help avoid subsequent complications and delay in the process.

## PROJECT WORK STAGE – I

Project work Stage - I is an integral part of the project work. In this, the student shall complete the partial work of the project which will consist of problem statement, literature review, project overview, Methodology, scheme of implementation (Mathematical Model/SRS/UML/ERD/block diagram/ PERT chart, etc.) and Layout & Design of the Set-up. As a part of the progress report of Project work Stage-I, the candidate shall deliver a presentation on the advancement in Technology pertaining to the selected dissertation topic. The student shall submit the duly certified progress report of Project work Stage-I in the standard format for satisfactory completion of the work by the concerned Guide and Head of the Department/Institute.

## PROJECT WORK STAGE – II

1) In Project Work Stage – II, the student shall complete the remaining part of the project which will consist of the fabrication of set up required for the project, work station, conducting experiments and taking results, analysis & validation of results and conclusions.

2) The student shall prepare the duly certified final report of project work in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

**Note:**

1) Institute must submit the list of candidates, guide and project details (title, area, problem definition, and abstract - clearly indicating objectives and scope, sponsorship details, if any) to the University within month of commencement of third semester. The guide must be approved/qualified full time teacher of the Institute. A guide can accept/enroll at the most 8 students per year.
2) It is compulsory that every dissertation should be scanned by plagiarism software approved by University and a true copy of a generated report be accompanied with the dissertation report at the time of submission to the University.
3) It is mandatory to publish at least one research paper either in reputed conference or peer reviewed academic journals (National or International)

**ME (Polymer Engineering)**

**509115: Mathematical and Statistical Methods**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 4** |

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**Objectives:**

1. To understand various topics like rheology, polymer engineering processes through various equations like finite differential method etc.

2. To get insight in various Chemical Engineering Processes using advanced Numerical and Statistical Methods.

3. To understand research papers on relevant topics involving advanced Mathematics.

4. To provide adequate background of Mathematics to deal with Chemical Engineering Problems.

**Matrix & Linear Algebra**

Revision of basic concepts in Matrix algebra

Methods to solve sparse matrices, TDMA Algorithm

Solution of Linear and Non Linear system of equations

Solution of Eigen-value problems

**Transformation**

Discrete functions and their properties

Z - transforms and their properties

Relation between Discrete and Fourier transforms.

**Advanced Numerical Methods**

Brief review of various numerical methods
Numerical Integration, Gauss Quadrature Formulae

Finite Difference methods for solution of field problems, Grid generation

Solution of IVP/BVP (ODE/PDE) with / without free, moving or periodic boundaries.
Solution of stiff/coupled equations

Finite Element and Finite Volume methods in Heat and Mass Transfer Problems

**Variational Calculus**

Orthogonal collocation method

Method of Weighted Residuals

**Advanced Statistical Methods**

Hypothesis Testing

Design of experiments and Model discrimination

Markov Process

**References:**


1. Advanced Mathematical Methods for Scientists and Engineers, Bender, C.H. and Orszag S.A., McGraw Hill (1978)

2. Probability and statistics for Engineers, Miller and Ereund, 5th Ed., Prentice Hall of India

3. Mathematics for Scientists and Engineers, Scolicoff

4. Nonlinear Analysis in Chemical Engg, Finlayson, B.A., McGraw Hill (1980)

5. Modeling with Differential Equations in Chemical Engineering, Walas S.M. Butterworth

   - Heinemann (1991)

6. Toguchi Method, explained practical steps to robust design, Bignchi T. P. Prentice Hall, (1993)

7. Taguchi Techniques for Quality Engineering Rosj Phillip J., McGraw-Hill Publishing Co.; 2nd Revised edition (1 Oct 1995)

8. Heat Transfer, Benjamin Gebhart, Tata McGraw Hill, (1971).

**ME (Polymer Engineering)**

**509116: Principles of Management**

| | |
|---|---|
| **Teaching Scheme** | **Examination Scheme** |
| **Lectures: 4 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 4** |

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**Objectives:**

1. To develop entrepreneurship skills amongst the student.
2. To make the students understand organizational structure.
3. To train the students through various management skills.
4. To teach the students the working of R & D in industry.

**Management Science**

Introduction, management, administration and organization concept, definitions of management, functions of management, authority and responsibility, units of command and direction.

**Business organization**

Different forms of organizations, their formation and working, localization of industry specialization, different organization structure, the line organization, the functional organization, the line and staff organization.

**Plant layout**

Factors governing plant location, objectives of a good plant layout, process layout, product and combination layout.

**Work study**

Work measurement, time study and motion economy, flow process chart, two handed process chart, flow diagram, sim charts, strings, diagrams, Therbligs

**Personnel management**

Man power planning, sources of recruitment-selection and training, job evaluation, merit rating, performance, appraisal, wage administration and systems of wage payments, incentives, motivations, industrial fatigue, trade unions – ind ustrial relations.

**Financial management**

Capital structure, fixed capital, working capital, sources of finance and financing institutes, prime costs, overhead costs, allocation of overheads, depreciation.

**Stores and purchase organization**

Inspection, inventory of materials, quality control

**Marketing**

Difference between sales and marketing, marketing mix – product, price, place and promotion, market segmentation - targeting and positioning, consumer behavior, product lifecycle, new

product – introduction, branding, product labeling and packaging, advertising, direct marketing and sales promotion, types of channel and physical distribution, pricing, rate of pricing, price setting methods and strategies.

**Costing**
Types of cost, standard costing, marginal costing, break even analysis components of balance sheet, profit and loss account, sources and utilization of funds, key profitability ratio's such as debt to equally ratio, ROI etc.

**Operation research**
Transportation, assignment, sequencing, game theory, queuing theory, inventory control, economic batch calculations – deterministic & proba bilistic models, PERT-CPM

**Research and development in polymer industry**
Introduction, proposal preparation and motivative efforts, initiation of research and development program, concept of creativity, group approach to idea generation, conditions for successful growth of creative ideas to realization, quality of research personnel and staff selection, organizational and special problems of research and development, conducting a research and development project, scheduling, monitoring, and decision-making for cost effectiveness, accountability and responsibility.

**Technology Management**
Technology strategy, technology forecasting, choice and objectives of technological forecasting, technology road mapping, and technology project portfolio (projects under development) and technology portfolio (technologies in use). The integrated planning, design, optimization, operation and control of technological products, processes and services, diffusion of innovations theory, Capability Maturity Model

**References:**


1. Financial management, R.P. Rastogi, 9th edition.
2. Cost accounting, Sexena and Vashistha
3. Financial management, Prasanna Chandra
4. Marketing management by Philip Kotler, Keller, Koshy and Jha – Pearson Publication, Prentice Hall Publication, 12th edition.
5. Services marketing by Groonroos – Wieley Public ation
6. Global marketing management by Keegon – Prentic e Hill Publication
7. Consumer relationship management by Zikmund – W iley Publication
8. Marketing management by Rajan Sexena – Tata McG raw - Hill Publication
9. Marketing management by Namakumari and Ramaswamy – McMillan Publication
10. Marketing management by Dholakiya – Mc Millan Publication
11. Plant Design and Economics for Chemical Engineers, Peters, Timmer hous, MacGraw-Hill.
12. Chemical Process Economics, Hapel J., Jordan D.G.
13. Cost Accounting, B.K. Bhar, Academic Publishers, Calcutta.

14. Mechanical Estimating and Costing, Kanappan D., Augustine A.G. MacGraw-Hill, New Delhi.
13. Manufacturing Cost Engineering Handbook, E.M. Malstrom, Marcel DekkerInc New York, 1984.
14. Operation Research, Prentice Hall India, Taha H.A., 6th edition 2002.
15. Principles and Application, PERT & EPM, Srinath I.S., East West Press, 1975.
16. Operation Research, Sharma S.D., KNRN & Company, 1973.
17. Operation Research, Gupta Premkumar & Hira D.S., S. Chand Company, 2001.
18. Operation Research, Patel R.C. & Dave N.R., Mangalani A.K., C. Jamanadas & Company, 1995.
19 Kropsu-Vehkapera, H., Haapasalo, H. & Rusanen, J-P. (2009). "Analysis of Technology Management Functions in Finnish High Tech Companies". The Open Management Journal **2**: 1–10.
20. Principles of Management by Philip Kotler, TEE Publication.
21. Industrial Engineering and Management by TR Banga.

**ME (Polymer Engineering)**

**509117: Advanced Polymer Technology**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 4** |

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**Objectives:**

1. To equip students with basic knowledge of polymer synthesis that will help them to develop new materials.
2. To impart the awareness of recent advances in polymer material synthesis.
3. To introduce the students with current research interest and novel concepts at National and International level.
4. To teach the students to understand and evaluate new high-performance and specialty application materials.

**Polymerization:** Probability and statistics- statistics of linear polycondensation, statistics of chain polymerization, branching and gelation. Kinetics of chain growth copolymerization. Copolymer sequence distribution. Chain microstructure and its characterization by spectroscopy. Order and morphology of polymers. Thermal aspects of- crystallization, crystalline melting temperature and glass transition temperature. Polymer solutions and blends- entropy of mixing, enthalpy of mixing, F-H equation, cohesive energy density, phase behavior, dilute solutions.

**Advanced polymerization mechanisms**: Metathesis polymerization, ring opening metathesis polymerization (ROMP), ring forming polymers, living cationic polymerization, living radical polymerization, NMP, ATRP, RAFT and other new methods, electrochemical polymerizations, metal catalyzed olefin polymerization, click polymerization, phase transfer polymerization, group transfer polymerization, cyclopolymerisation, oxidative polymerization, dispersion polymerization, mini-dispersion polymerization.

**Advanced polymer materials and applications:** Liquid crystalline polymers, electro-active polymers, polymers for photoresists, fluorinated polymers, chiral polymers, biopolymers, polymers in lithography, fluoropolymers, polymer electrolytes and gel electrolytes, hydrophilic polymers, ionic polymers, hydrogels and stimuli sensitive hydrogels, functional polymers: photoconductive polymers, elecroconductive polymers, piezoelectric polymers, light sensitive polymers, ion exchange resins, polymeric reagents, polymers as catalysts, polymers as substrates, polymer thin films, photoresponsive polymers and materials.

**Specialty-application polymers:** Silicones and other inorganic polymers: silicones, polyphosphazenes, polythiazyl. Heat and fire resistant polymers: polybenzimidazole, polybenzoxazole, polybenzthiazole, Rubbers: silicones, epichlorohydrin, fluroelastomers, polysulphides, polyurethane, acrylic rubbers, silane-containing polymers.

**Polymer reactions and synthesis:** Polymer supported reactions, surface functionalization of polymers, graft copolymerization, approaches to making comb and graft architectures, grafting onto existing polymer surfaces, surface engineering using graft copolymers, oxidative coupling branched and dendritic polymers and its synthesis, new developments in telechelic polymers, microbial synthesis of polymers, biodegradable polymers, polymers from renewable resources

**Introduction to self assembly and supramolecular chemistry:** Concept of self-asssembly - from primary structure to complex structure, types of self assembly and non-covalent interactions, macromolecular systems via secondary bonding, use of H-bonding and ionic charge to build structures, self assembled polymers, supramoleculer and metallosupramoleculer polymers and their applications.

**References:**


1. Comprehensive supramoleculer Chemistry, Pergamon, vol 1-10, 1999
2. Core concepts in supramoleculer chemistry and nano-chemistry, J W Steed, 1st Edition, Wiley
3. Paul C. Hiemenz and Timothy C. Lodge, Polymer Chemistry: The Basic Concepts, 2nd ed.
4. Odian, George. Principles of Polymerization. 4th ed. Hoboken, NJ: Wiley-Interscience, 2004
5. Polymer Chemistry: An Introduction, 3rd ed. (Seymour, Raymond B.; Carraher, Charles E., Jr.)
6. Polymer Handbook, 2 Volumes Set, J. Brandrup, E. H. Immergut and E. A. Grulke
7. Coca, Simion, and Krzystof Matyjaszewski. "Block Copolymers by Transformation of 'Living' Carbocationic into 'Living' Radical Polymerization." Macromolecules 30 (1997): 2808-2810.
8. Polymer Chemistry an Introduction, Oxford University Press, M.P.Stevens, 1991.
9. Essentials of polymer science and engineering, P C Painter, M M Coleman, DEStech publications, Inc., USA.
10. Principles of Polymerization, Wiley eastern, George Odian, 1991
11. Polymer Science, New age international (P) Ltd. Publishers, V.R. Gowarikar, Pearson publication, 2003.
12. Text book of Polymer Science, Wiley Eastern, F.W. Billmeyer Jr, 2003.
13. Polymer Molecular Weight – Vol. I and II, Slade Jr.
14. Self-Assembly and Nanotechnology Systems: Design, Characterization, and Applications, Yoon S Lee, John Wiley & Sons, Inc., 2012
15. Supramolecular Chemistry, Jonathan W. Steed, Jerry L. Atwood, John Wiley & Sons, 2009
16. Specialty Polymers: Materials and Applications, Faiz Mohammad, I. K. International Pvt Ltd, 2007

**ME (Polymer Engineering)**
**509118: Research Methodology**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 4** |

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**Objectives:**

1. To understand the process through which the researcher has to go through.
2. The course will help to reduce the mistakes one makes in the way of doing Research.
3. To improve one's built-in aptitude for research.

**Introduction**
Research methodology: Definition of scientific and technical research, Objectives of research Types of research, Various steps in research process, Problem formulation, Literature search and information management, Research plan, Mathematical tools for analysis, Developing a research question-choice of a problem, Literature review: surveying, synthesizing, critical analysis, reading materials, reviewing, rethinking, critical evaluation, interpretation, Research purposes, Ethics in research – APA Ethics code.

**Quantitative methods for problem solving**
Statistical modeling and analysis, Time series analysis probability distributions, Fundamentals of statistical analysis and inference, Multivariate methods, Concepts of correlation and regression, Fundamentals of time series analysis and spectral analysis, Error analysis, Applications of spectral analysis, Evaluation of results.

**Design of Experiments:**
a) Objectives, strategies, Factorial experimental design, Designing engineering experiments, basic principles - replication, randomization, blocking, Guidelines for design of experiments.
b) Single Factor Experiment: Hypothesis testing, Analysis of Variance components (ANOVA) for fixed effect model; Total, treatment and error of squares, Degrees of freedom, Confidence interval; ANOVA for random effects model, Estimation of variance components, Model adequacy checking.
c) Two factor Factorial Design, Basic definitions and principles, main effect and interaction, response surface and contour plots, General arrangement for a two - factor factorial design; Models - Effects, means and regression, Hypothesis testing.

**Tabular and graphical description of data**
Tables and graphs of frequency data of one variable, Tables and graphs that show the relationship between two variables, Relation between frequency distributions and other graphs, Preparing data for analysis.

**Soft Computing**

Computer and its role in research, Use of statistical software SPSS, GRETL etc. in research. Introduction to evolutionary algorithms - Fundamentals of Genetic algorithms, Simulated Annealing, Neural Network based optimization, Optimization of fuzzy systems.

**Structure and Components of Research Report and Presentation**
Types of report, Layout of research report, Mechanism of writing a research report, Referencing in academic writing, Research report preparation: abstract, description of instruments and materials, experimental procedures, description of results, discussion of results, conclusions. Citation methods: Foot Note, Text Note, End Note and Bibliography. Writing a blogSpot, Article, Essay, Research Paper, Research Project, Legislation Drafting, Judgment Writing, Thesis, Dissertation, Book, Reviews - Book Review; Case Review. Presentation: Scientific and technical presentations, Planning the presentation (formulation of objectives, analysis of audience), Preparing the presentation, Presentation delivery techniques, Organizing the presentation forum.

**Introduction to Intellectual Property Rights:** Nature of Intellectual Property: Patents, Designs, Trademarks and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. Recent Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Softwares etc. Traditional knowledge Case Studies, IPR and IITs.

***Exercise:*** *One Minor Research Proposal preparation in a proper format following above guidelines should be made compulsory to every student as a compulsory Assignment.*

**Text Books**


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


**Reference Books**


1. Donald R. Cooper, Pamela S. Schindler, Business Research Methods, 8/e, Tata McGraw-Hill Co. Ltd., 2006.
2. Fuzzy Logic with Engg Applications, Timothy J.Ross, Wiley Publications, 2nd Ed[d]
3. Simulated Annealing: Theory and Applications (Mathematics and Its Applications, by P.J. van Laarhoven & E.H. Aarts[e]
4. Genetic Algorithms in Search, Optimization, and Machine Learning by David E. Goldberg.
5. Beach,D.P. and T.K.E. Alvager, 1992, Handbook for Scientific and Technical Research, Prentice-Hall, Englewood Cliffs, N.J.
6. Day,R.A., 1988, How to Write and Published Scientific Paper, Oryx Press, Phoenix, AZ, 1988
7. Hautala, P.C., 1989, Technical and Managerial Communication, Univ. of Idaho Press, Moscow, ID
8. Halbert, “Resisting Intellectual Property”, Tay lor & Francis Ltd ,2007
9. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New”

**ME (Polymer Engineering)**

**509119 [Elective I] (a): Polymer Reaction Engineering**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objective:**

1. To understand the distinguishing features and challenges involved in polymer manufacturing processes as compared to monomer manufacturing processes.
2. To make student to learn the kinetics of various processes.
3. To make student understand the intricate designing aspects of reactors and trouble shooting.

**Introduction to Polymerization Processes,** Microstructural features of polymers and their effect on properties, Classes of polymerizations, Polymerization techniques & polymerization reactors. Important aspects of polymers, polymerization reaction engineering as compared with monomers and their reaction engineering, the effect of mixing on kinetics and MWD.

**Coordination Polymerization,** Polyolefin types: microstructural classification and analytical Techniques, Catalysts for olefin polymerization, Polymerization kinetics for single- and multiple-site catalysts, Inter- and intra-particle mass and heat transfer resistances, Industrial olefin polymerization reactors, Metallocene polyolefins reactor.

**Free-Radical Polymerization: Homogeneous Systems,** Free-radical polymers: properties and applications, FRP mechanisms and kinetics, Controlled radical polymerization, Polymer reaction engineering aspects, Overview of Free-Radical Polymerization: Heterogeneous Systems.

**Suspension and emulsion polymerization,** Smith-Ewart Model, Emulsion polymerization reactors, Inverse emulsion polymerization, Mini-emulsion polymerization, Micro-emulsion polymerization, Dispersion polymerization.

**Step-Growth Polymerization,** Polymerization kinetics and modeling, Industrial step-growth products, processes and modeling,

**Diffusion controlled polymerization**, Tromsdorff effect in Free Radical Polymerization, Models of Tromsdorff effect. Extension of these models to step growth polymerizations at high conversions, Interfacial polymerizations in immiscible monomers case.

**Design fundaments of reactors** for tailor making polymers, Control of Polymerization Reactors, Characterization of the control problem, Classical polymerization reaction control problems, On-line monitoring, Risk parameter assessment, Calculation of the control action and control schemes, Industrial reactors: VK tube reactor, polystyrene manufacture, fluidized bed HDPE reactor, PET reactor.

**References:**


1. Polymerization Process Modeling, Neil A. Datson, Rafael Galvan, Robert L. Laurence, Mathew Tirrel, 1996 VCH Publishers .
2. Control of Polymerization Reactors, F.Joseph Schork, Pradeep B. Deshpande & Kenneth W. Leffew, Marcel Dekker 1993.
3. Polymer Reaction Engineering, Edited by José M.Asua, Blackwell Publishing.
4. Reaction Engineering of Step Growth Polymerization, Gupta S. & Anilkumar, Plenum Press, New York 1987.
5. Encyclopedia of Polymer Science & Engg. 2nd Edition.
6. Polymer Reactor Engg. - McGreavy, Blackie Academic & Professional,Chapman & Hall, 1994.

**ME (Polymer Engineering)**

**509119 [Elective I] (b): Composite Technology**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objectives:**

1. To make students aware of various basic requirements like matrix, reinforcing fillers and additives etc. in composite manufacture.
2. To make students understand the mechanics of composites.
3. To impart the knowledge of various standard methods in testing and trouble shooting of composites.
4. To make students learn various advanced techniques of composite manufacture.

**Introduction,** Study of different types of matrix materials, thermoplastic and thermosetting, study of various reinforcements – long, shot fibers , particulate fillers, flakes. Review of processing techniques like hand layup, filament winding, resin transfer molding and pultrusion. Natural fiber reinforced composites, Effect of processing parameters on properties,

**Extrusion of Thermosets,** Pultrusion, application of pultruded products. Advantages and limitations of process.

**Macromechanics,** Macromechanical behavior of a lamina : Stress strain relations for anisotropic materials, Engineering constants for orthotropic materials, Restrictions on elastic constants, Invariant properties of an orthotropic lamina, Biaxial strength theories for an orthotropic lamina, Maximum stress theory, Maximum strain theory, Tsai- Hill theory, Tsai-Wu tensor theory.

**Micromechanical behavior of a lamina,** Mechanics of materials approach to stiffness, Elasticity approach to stiffness, Particulate composites Mechanics of materials approach to strength

**Macromechanical behavior of a laminate,** Classical lamination theory ,Symmetric laminates, Antisymmetric laminates, Nonsymmetric laminates, Inversion of stiffness equations, cross-ply laminate stiffnesses, Theoretical and experimental cross-ply laminate stiffness, Angle-ply liminate stiffnesses, Theoretical and experimental angle-ply laminate stiffnesses, Strength of laminates, Interlaminar stresses, Design of laminates

**Bending, buckling, and vibration of laminated plates,** Governing equations for bending, buckling, and vibration, Deflection of simply supported laminated plates under distributed lateral load, Buckling of simply supported laminated plates under in-plane load

**Mechanical** and physical properties of composites, test methods for composites, trouble shooting in composite manufacture processes, structural applications of composites.

**References:**


1. Fibre-glass Reinforced Plastics, N. P. Cheremisinoff (Ed), Noyce Pub. 1988.
2. Fibre Reinforced composites, P. K. Malik, Marcel Deckar, 1988.
3. Design Data for Reinforced Plastics, N. L. Hancex, R. M. Mayer, Chapman Hall,1994
4. Reinforced Plastics: Properties and Applications, Raymond Seymour , The Materials Information Society, 1991.
5. Handbook of Composites, George Lubin, Stan T. Peters, Chapman & Hall, 1998.
6. Handbook of Composite Reinforcements, By Stuart M. Lee, John Wiley & Sons,1992.
7. Handbook of Composite Fabrication, edited by Gü neri Akovali, iSmithers Rapra Publishing, 2001.
8. 3D Fibre Reinforced Polymer Composites, By L. Tong, A.P. Mouritz, M. Bannister, Elsevier, 2002.
9. Mechanics of Composite Materials, Second Edition, By Autar K. Kaw, CRC Press, 2010.
10. Composite materials in Maritime Structures, R. A. Shenoi, J. F. Wellicome, Vol- I and II, Cambridge University Press,1993.
11. Mechanics of Composite Material, Robert Jones, McGraw Hill company, second edition,1999.

**ME (Polymer Engineering)**

**509119 [Elective I] (c): Paints and Adhesives**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objectives:**

1. To give the broad view of coatings, their types, formulation and various areas of application.
2. To emphasize on eco-friendly paints and green technology.
3. To study the evaluation techniques in-depth in paint manufacture and quality control.
4. To equip the students with in-depth knowledge for their careers in relevant industry.

**Brief review of paints:** Raw materials, various resins viz. – alkyl, polye ster, amino, phenolic, polyurethane, epoxy, silicone, acrylic etc., Paint manufacture, formulating principles, architectural coating, industrial coating, automotive coatings, lacquers, varnish, powder-coatings, water based coatings, printing inks.

**Eco-friendly coatings:** Aspects of environmental pollution (volatile organic compounds, VOC and its calculation as per BIS and ASTM. VOC and hazardous air pollutants, HAP) with reference to conventional coatings & organic solvents, water as a substitute for organic solvents, merits & demerits of water as a solvent, water borne/based/thinnable/reducible coatings, aqueous dispersions vs. non aqueous dispersions, alternative ways of making ecofriendly coatings; high solids coatings, radiation curable coatings, powder coatings, electrodepositable coatings. considerations for influence of solvents, temperature, pigments, additives, cross-linkers etc.

**Radiation curable coatings:** Types of radiations, UV curing, fundamentals of photopolymerisation, photoinitiators, photo sensitizers, oligomers, monomers, problems associated with radiation cure systems, electron beam curing: EB generators, factors affecting EB generation and curing, uses / areas of application of EB curing and other curing systems.

**Paint Evaluation:** Evaluation of Physical Properties of Paints/Varnishes and Lacquers, Density Bulking value by wt/ litre cup, Non volatile matter, fineness of grind by Hegman Gauge, viscosity by Brookfield, bubble tube and cone & plate Viscometer, Application of films by Automatic Film Applicator and Bar Applicator, Determination of Wet Film and Dry Film Thickness, Drying Time, Surface Roughness by Surface Profile Gauge

**Evaluation of Optical Properties of Coating Films**, Opacity by Digital Opacity Meter, Hiding Power by Black & White Cryptometer, Gloss by Digital Glossometer, Color by Color Matching Cabinet, Analysis of Colour by Color Spectrophotometer, Distinction of Image by DOI Meter.

**Evaluation of Mechanical Properties of Coating Films**, Scratch Hardness by Automatic Scratch Hardness Tester, Pencil Hardness by Pencil Hardness Tester, Hardness by Pendulum

Hardness Tester, Adhesion by Pull off Adhesion Tester, Adhesion by Cross Cut Adhesion Tester, Mechanical Strength by Cupping Tester, Flexibility by Conical & Cylindrical Mandrel Tester, Impact Resistance by Tubular Impact Tester. Abrasion Resistance by Wet Abrasion Tester & Taber Abrasion Tester, Bond Strength of Coatings by Digital Bond/Heat Seal Strength tester.

**Evaluation of Electrical Resistance Properties of Coating Films**, Electrical Strength of Coatings by Digital Voltage Breakdown Tester, Resistivity of Paints by Paint Resistivity Meter, Pinhole Testing by Holiday Detector (Pinhole Tester)

**Evaluation of Chemical Resistance Properties of Coating Films**, Salt Spray Test using Salt Spray Cabinet, Corrosion Resistance by Digital Corrosion Cabinet, Exterior Durability by Accelerated UV Weathering Cabinet

**Modern Instrumentation techniques in Paint and Coatings**: Chromatographic Techniques : Theory practice and application of paper chromatography, thin layer chromatography (TLC), Gas liquid chromatography (GLC) High pressure (Performance) liquid chromatography (HPLC) in coating industry for the analysis of oils, resins, solvents and plasticizers. Microscopy in coatings and coating ingredient: Microscopical examination of pigments paints and paint films. Scanning electron microscopy (SEM): Principle and practice.

**Brief introduction to:** Infra Red (IR) spectroscopy : Theory, instrumentation, qualitative analysis, monitoring chemical changes in coating materials, internal reflection spectroscopy, Fourier transform infra red (FTIR) and quantitative analysis. Near Infrared (NIR) Spectroscopy. Nuclear magnetic resonance (NMR) spectroscopy: nuclear spin MNMR equation, relaxation, The NMR instrument, chemical shift, spin-spin coupling, application of NMR to coatings and polymers. X-ray analysis: analysis based on X-ray diffraction and X-ray emission, use of DSC (Differential Scanning Calorimetry) and TGA (Thermo Gravimetric Analysis) in characterization of coatings.

Computer Application in Paint Industry: Resin/polymer design, product formulation and costing, color matching, raw material and formula file data bases for non technical applications, future trends.

**Nano Coatings:** Definition of Nano Coatings- nano sized dried film structure OR nano ingredients, How it works, Advantages of Nano coatings, End application of Nano coatings, Future Trends.

**Environmental, Health and Safety Practices in Coating Industry**: What is MSDS of Paint, Safe Storage, Handling of Paint raw materials, Safe and Ergonomic layout in Paint production Industry, Paint packing –Importance of good paint p acking, Use of Personal Protective Equipments in Paint manufacturing and application Industry, Environmental Impact assessment during Paint Production and Paint Application

**Guidelines for good adhesion various theories of adhesion:** Diffusion, electrostatics, mechanical interlocking, merits and demerits of adhesive, joint. Equilibrium contact angle,

spreading prepare, work of cohesion and adhesion thermodynamics of coating spreading surface tension and surface energy critical surface tension.
**Types of adhesives** classification chemistry of epoxy, acrylic, elastomer modified, PU adhesives, pressure sensitive adhesives, hot melt adhesives solvent and emulsion based adhesives formulations of various adhesives health and safety aspects in adhesives industry.

**Surface characteristics** of various surfaces and pretreatments, mechanical testing of adhesives, properties of adhesives such as tack, viscosity cure time, etc.

**References:**


1. Organic coating Technology, Vol. I & I H.F. Payne.
2. Paints and Surface coatings, Lambourne (new), second edition, Woodhead Publication House, 2004
3. Oil Colour Chem. Association, Surface Coatings, Vol. I & II.
4. Paint Technology Manuals, Vol. I to VI. Chapman And Hall, 1974.
5. Encyclopedia of Chemical Technology, Vol. I page no. 445 – 446, Kirk and Othmer, Fourth Edition.
6. Encyclopedia of Chemical Technology Vol. VI page no. 669 – 760, Vol. XVII page no. 1049 – 1082, Kirk and Othmer, Fourth Edition
7. Oil & Colour Chemists Association, Surface coatings Vol. I, Chapman & Hall, 1984.
8. Oil & Colour Chemists Association, Surface coatings Vol. II, Chapman & Hall, 1984.
9. Surface Engineering Fundamentals of coatings, Datta P.K. & Gray J.S. Vol. I London. Royal Society of London, 1993.
10. Surface Engineering Fundamentals of coatings, Datta P.K. & Gray J.S. Vol. II London. Royal Society of London, 1993.
11. Surface Engineering Fundamentals of coatings, Datta P.K. & Gray J.S. Vol.III London. Royal Society of London, 1993.

**ME (Polymer Engineering)**

**509120: Laboratory Practice – I**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **Term Work: 50 Marks** |
| | **Oral/Presentation: 50 Marks** |
| | **Credits: 4** |

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**Objective:**

1. After performing the listed experiments the students will be able to
    a) Synthesize the polymer
    b) Test/characterize the polymer material
    c) Process and make an article, and
    d) Use rheology based software.

Each student should ' **perform'** at least **10** experiments from the list given below and submit the journal which will form the term-work for the subject.

**Important: The students are required to preserve the samples, compounded materials, test specimens, tested specimens, 'original' result pape rs such as charts, graphs, data sheets soft copies of modeling and analysis etc. and should be submitted alongwith the journal for evaluation, failing which the TW will not be granted.**

**Lab Practice I :**
The laboratory work will be based on completion of assignments confined to the courses of that semester.

The assessment will be done jointly by the pair of internal and external examiners along with the oral examination of the same.

1. To determine the tensile strength at break and/or yield and/or % elongation of dumbbell shaped specimens of various polymers according to ASTM standards.
2. Compounding, molding and testing of PVC.
3. Injection molding of PET with different mould temperatures and studying properties of moldings.
4. Blown film extrusion and studying effects of changing processing parameters on the properties of the film.
5. Thermoforming at different temperatures and studying product properties such as shrinkage on heating and environment stress cracking of products.
6. Use of Flow Analysis software for balanced filling of an injection mould cavity.
7. To determine the vicat softening temperature.

8. Use of Flow Analysis software for studying cooling and warpage.
9. Modeling a cavity and deciding gate location using Flow Analysis software.
10. Study of volume & surface resistivity.
11. To find out environmental stress crack resistance for polyethylene samples.
12. To determine the izod impact strength for various polymer.
13. Compounding of PP with fillers and rheological characterization of compound.
14. To determine the heat deflection temperature.
15. Experiments based on use of Modeling and Flow Analysis software.
16. Copolymerization of styrene with MMA and its dependence on type of initiator and its characterization.

**Important instructions:**

1. Five experiments out of experiment no 1 to 7 are compulsory.
2. Each experiment is to be supported with compulsory assignment which should be the part of the journal.
3. Assignments / 'theory practical's are to be strictly avoided as laboratory practice experiments.

**ME (Polymer Engineering)**

## Semester II

### 509121: Polymer Processing and Testing

| Teaching Scheme | Examination Scheme |
|---|---|
| Lectures: 4 Hrs/Week | In Semester Assessment: 50 Marks |
| | End Semester Assessment: 50 Marks |
| | Credits: 4 |

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**Objective:**

1. To understand polymer testing related to short term as well as long term mechanical properties.
2. To study thermal as well as electrical properties.
3. To have in-depth understanding of fundamental polymer processing operations.
4. To equip the students with in-depth knowledge for their careers in relevant industry.

**Basic Concept**: Plastic Additives and Compounding: Various additives and their purpose (e.g. antioxidants, plasticizers, antistatic agents, blowing agents etc.), Principle of mixing and mixers, types.

**Extrusion**
Basic operation and analysis, solids conveying, drag induced conveying, melting mechanism, power consumption in metering zone. Overall extruder performance. Design of extrusion screws, modeling of extrusion process and computer simulation. Overall working of single screw and twin screw extruders.

**Polymer Devolatilization**
Basic analysis of the process, functional design considerations, screw geometry and design Devolatilization in single screw and twin screw extruders and their design.

**Extruded products**
Such as films, pipes, profiles, coating, foamed products, design of sizing systems, haul off systems, cooling and / or chilling units, winders, auxiliary equipments used, measurement and control of parameters. Types of dies used for the production of extruded products. Analysis of the flow through the dies. Manufacture of flat films, co extruded films, oriented films, drawing and stretching units.

**Reactive extrusion and resident time distribution (RTD)**
Process details, basic principles, equipment used, effective residence time and residence time distribution (RTD), point measurements: characterization of melting and mixing time with the RTD, applications.

**Extrusion blow molding**

Types of blow molding techniques, flow analysis in the die, wall thickness control, parison swell, parison sag. Continuous and intermittent blow molding CAE of blow molding operation.

**Thermoforming**
Types, various techniques, materials, heat transfer analysis of the process, effect of plugs on article thickness, continuous heating of a thin moving sheet. CAE in thermoforming.

**Injection molding**
Role of rheology in injection molding, melt flow in feed system, flow in mould cavity, mould filling. Control of politicizing and injection process.

**Reaction injection molding**
Overall molding cycle, metering system for components, mixing head design, mould construction, materials used and their applications.

Other Processing techniques: Calendering and milling, compression and transfer molding, casting, rotational molding, fabrication, decoration of polymers.

**Introduction to Testing**
Importance of Testing, Concept of Statistics, Quality Control, Standards and Standard Organizations, Preparations of test Samples and Conditioning, ASTM standards.

**Mechanical Properties**
Short term and long term mechanical properties, their significance and importance. Determination of Short term stress-strain properties such as Tensile strength, elongation at break, tensile modulus, compression, flexural etc. Different types of Impact tests: Determination of impact tests for different polymeric materials. Study of creep, relaxation, set and fatigue.

**Non destructive testing of finished and semi-finished products**
Such as ultrasonic testing, acoustic emission or stress wave emission, radiography, optical methods, etc.

**Electrical Properties**
Their importance and significance, effect of temperature and humidity on electric properties. Different types of electrical properties such as: Determination of dielectric strength, surface and volume resistance. Power factor and permittivity. Tracking resistance, arc resistance

**Thermal Properties**
Determination of heat deflection temperature (HDT) Determination of vicat softening point VST) Determination of melting point and softening point for different polymers

**Environmental Resistance Properties**
Effect of liquids and chemicals. Study of weathering resistance. Study of weathering property. Study of fire resistance.

**Barrier Properties**

Their significance and importance. Study of Barrier properties. Testing of plastics products such as sheet, films, laminates, and coated fabrics, plastic pipes/ fittings, tanks, buckets, dustbins, window frames, fiber reinforced plastics for mechanical, environmental resistance, etc.

**References:**


1. Handbook of Plastics Test Method, R.B. Brown, George Godwin Limited, 1981.
2. Handbook of Plastic Testing Technology, Brown and Vishnu Shah, A. Wiley, Inter science Publication, 2007

3. Handbook of Plastics Test Methods, G.V. Eves, J.A. Mead, M.M. Riky.
4. Volume 8 of ASTM Standards, BIS Standards.
5. Polymer Extrusion, Chris Rauwendal SPE, Hanser Publishers.
6. Polymer Missing and Extrusion Technology – Nich olas Cheremisinoff, Marcel Dekker 1987
7. Modeling Of Polymer Processing, Isayav, Hanser Publishers, 1991.
8. Plastics Waste Management, Mustafa.
9. Plastics Extrusion Technology – Hanser SPE, 199 6
10. Thermoforming – J.L. Throne, Hanser Publishers 1987
11. Blow Molding Handbook – Rosato, Hanser Publish ers 1987
12. Mixing and Compounding of Polymers: Theory and Practice, Ica Manas-Zloczower, Hanser Verlag, 2009.
13. Extrusion of Polymers: Theory and Practice, Chan I. Chung, Hanser Verlag, 01-Apr-2000
14. Rotational Molding of Plastics – R. J. Crawfor d, Research Studies Press Ltd.
15. Engineering with Polymers - Powell.

**ME (Polymer Engineering)**

**509122: Polymer Physics and Characterization**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 4** |

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**Objectives:**

1. To impart fundamental knowledge of polymers through the basic concepts of polymer physics.
2. To study various physical properties of polymers.
3. To make students aware of various characterization techniques.

**Statistical properties** of polymer chain, conformation of polymers, the ideal chain, fundamental properties of Guassian chain, coil-helix transition, hydration of polymer chain. Classical theory of gelation, thermodynamics of rubber elasticity, structure of polymer networks.

**Solution properties** – molecular configurations in solutions, solubilit y parameter, light scattering measurements, phase diagrams, viscosity of polymer solutions, thermodynamics of polymer solutions and melts, solubility parameter, theta solvents.

**Solid state properties** – Thermo-mechanical properties, DMA creep, ultimat e properties, thermal relaxations. Optical, electrical and mechanical properties. Surface properties, contact angle measurements.

**Thermal analysis** by DTA, DSC. Use of DSC for determination of kinetics of crystallization. TGA, TMA. Pyrolysis techniques, polymer degradation. Dynamic viscoelasticity measurements for characterization of different relaxations. Molecular motions responsible for different relaxations. WLF equation and predicting transition temperature.

**Dielectric measurements**, conductivity, resistivity.
Separation techniques – GPC, HPLC, mol. wt and mol. wt distribution measurements. X – ray studies for polymers.

**Microstructure evaluation** by scanning electron and optical microscopes. Structure evaluation by FTIR, NMR, C-13 NMR, UV. Elemental analysis – qu alitative and quantitative.

**References:**


1. Introduction to Physical Polymer Sciences, L.H. Sperling, J. Wiley N.Y,1993.
2. Molecular Motions in High Polymers, R.T. Crompton, Pergmon Press N.Y., 1989.
3. Analysis of Polymers, T.R. Crompton Pergmon Press N.Y., 1989.
4. Mechanical Properties Of High Polymers, I.M. Ward, John Wiley, 1979.

**ME (Polymer Engineering)**

**509123: Polymer Structure and Properties**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 4** |

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**Objective:**

1. To understand the various aspects of relation between polymer structure and properties.
2. To study the aspect of crystallinity in polymers.
3. To impart the knowledge about polymer morphology.
4. To understand the relation between polymer structure, morphology and various processing techniques.

**Effect of following factors** on various properties like mechanical, thermal, electrical, barrier and rheological properties. Chemical composition and types of bonds; in the structure. Influence forces and molecular flexibility.

**Study of spherulites**, factors affecting their growth and thus effect on properties. Effect of orientation and crystallinity on polymer properties. Orientation of amorphous and crystalline zones and study of its effects on properties. Difference between orientation and crystallinity. Crystallization kinetics.

**Structural requirements** of polymers for formation of films, fibers and multiphase systems. Molecular Weight, Molecular Weight distribution and structural parameters required. Morphology and behavior of multiphase systems and composite materials on structure and properties.

**Different transitions** in polymer and effect of molecular and sub-molecular factors on transitions. Effect of different transitions on various properties like mechanical, electrical, optical etc. Effect of Molecular weight, crosslinking, filler, additives and blending on these transitions and the methods to measure this effect.

**Structure and morphology** developed during processing techniques like injection, blow molding, rotational molding etc. Molecular structure required for above processing techniques. Effect of various processing parameters on properties of polymers and correlation with structure and morphology.

**Thermodynamics and kinetic** forces affecting polymer properties. Effect of chemical groups of adhesion.

**Structure property relation in advance polymeric material**: Polymer-clay nanocomposites, polymer composites with carbon nanotubes, synergism in polymer hybrid composites, gas barrier properties, dendrimers and hyperbranched polymers and their blends.

**References:**


1. Polymer Structure, Properties and Applications, R.D. Deanin,1972
2. Introduction to Polymer Crystallization, Allan Sharples, St. Martin's Press, N.Y., 1966.
3. Macromolecular Physics, Berhard Wunderlich, Academic Press, N.Y.
4. Properties and Structure of Polymers, A.V. Tobolsky, John Wiley and Sons, New York, 1960.
5. Structure and Properties of Polymers, H.V. Boenig, J.Wiley and Sons, N.Y., 1973.
6. Handbook of Plastic Testing Technology, Brown and Vishu Shah, A. Wiley, Inter science Publication,1984
7. Handbook of Plastics Test Methods, G.V. Eves, J.A. Mead, M.M. Riky,second edition,1981
8. Introduction to Physical Polymer Science by L.H. Sperling,John Wiley,2001.
9. Commercial Polymer Blends, Utraci L.A.,Chapman Hall,1998.

**ME (Polymer Engineering)**

**509124 [Elective II] (a): Mold and Die Design**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objective:**

1. To study of various types of moulds and understand their construction and working.
2. To understand design aspects of various types of moulds.
3. To impart knowledge about various dies, their working and designing aspects.
4. To equip the students with in-depth knowledge for their careers in relevant industry.

**Introduction:** A brief introduction to various methods of polymer processing, equipments and methods used for mould making, materials for mould making, mould fabrication techniques like spark erosion, milling, polishing procedure, elementary principles of design, costing of moulds and their maintenance

**Injection moulds:** Study of general arrangement of components of two plates and three plate injection molds. Single and multi-cavity mould, design of feed system, cooling and ejection system, venting, degating devices, Study of constructional features and design of molds for components with internal and external undercuts, types of sprues and gates, runner, stack moulds.

**Compression and transfer moulds:** Compression mould requirements, construction mould insert design, transfer moulds, different designs.

**Design of blow molds,** extrusion blow molds, injection blow moulds, thermoforming moulds, rotational molding tools.

**Miscellaneous types of moulds**, moulds for processing reaction resins, moulds for forming of expandable polystyrene.

**Study of constructional features and design of molds** for components with internal threads.

**Study of general arrangement of components** of compression molds and transfer molds. Design of ejection system, feed system.

**Hot runner moulds,** their general arrangement, design of hot runner block, types of secondary nozzles. Heating systems used, Design of stack molds.

**Extrusion die design**: Basic considerations in die design, melt fracture, entry geometry, die retraction, streamlining of extrusion dies. Typical extrusion dies: straight through dies, cross head dies, offset dies, wire covering crosshead, constructional features in tubular films dies, flat film dies, pipe dies, blown film dies, sheet dies and profile dies, dies for solid sections, dies for multicolour and multi-material and mechanically driven dies.

**References:**


1. Injection Mould Design, R.C.W. Pye, EWP Press, 2000.
2. How to make Injection Moulds, Menges, Hanser Publication 1993.
3. Extrusion Dies, Walter Michaeli, Hanser, 1992
4. Dies for Plastics Extrusion, M.V. Joshi.

**ME (Polymer Engineering)**

**509124 [Elective II] (b): Elastomer Technology**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objective:**

1. To study the details pertaining to raw materials and formulations.
2. To study the aspects of processing, testing and applications.
3. To equip the students with in-depth knowledge for their careers in relevant industry.

**Introduction:** Natural rubber from latex, various processes involved in isolation of natural rubber,

**Basic concepts:** Rubber Elasticity: Physics of raw and vulcanized rubber. Kinetic and thermodynamics theory of rubber elasticity. Stress strain relationships for vulcanized rubber. Molecular basis for material to act as a rubber. Stages in raw rubber and latex rubber technology such as mastication, mixing, compounding and vulcanization.

**Study of various additives** like peptizers, antioxidants, accelerators, activators, fillers, carbon black reinforcement, chords and fabrics, blowing agents, colorants, Processing aids like tackifiers, plasticizers, softeners, extender oils, their function, level of addition and stage of addition.

**Characterization** of compounds, rheological behavior of compounds, properties influenced by compounding ingredients.

**Processing and fabrication methods** of rubbers: extrusion, calendaring and injection molding. Manufacturing techniques for products such as tyres, belts, hoses, foot-wears, cellular products and cables. Manufacture of latex based products such as dipped goods, foams and threads. Manufacture of latex products: by impregnation and spreading process, casting impregnation, dipping process (e. g. Surgical gloves, balloons, fabric gloves), latex coatings, latex cement and adhesives, latex thread and coir, latex foam. Designing engineering elastomers.

**Testing of rubber products:** Study of major elastomeric materials like natural rubber SBR, NBR, IIR, CR, BR, with respect to synthesis, compounding considerations, cure characteristics.

Study of thermoplastic elastomers with respect to compounding, properties and applications.

**Vulcanization of rubbers:** Vulcanization by sulphur and by other methods. Chemical reactions, factors affecting rate of vulcanization. Determination of cure rate of rubbers. Testing and analysis of raw rubber, compounds and vulcanizates. Testing finished rubber products, test methods and fundamentals.

Synthesis, structure, characterization and properties of diene homopolymer rubbers, diene based copolymer rubbers viz. styrene –butadiene, nitrile etc. , polychloroprenes.

**References:**


1. Science and Technology of Rubbers, J. E. Mark, B. Ermas, F. R. Eirich, Academic Press 1994
2. Rubber Processing Technology, Materials and Principles, J. L white, Hanser Publishers 1995
3. W. Hofmann “Rubber Technology Handbook, Hanser Publishers 1989
4. Rubber Technology and Manufacture C. M. Blow, C. Hepburn, Butterworth Publishers 1985.
5. Thermoplastics Elastomers, N. R. Legge, G. Holden, H. E. Schroedar Hanser Publishers 1987.
6. Rubber Technology Handbook, C. Hoffman, Hanser Pub. 1989.
7. Synthetic Rubbers: Chemistry and Technology, D.C. Blackley, Applied Science Publisher,1983.
8. Elastomer Technology Handbook, Nicholas P. Cheremisinoff, CRC Press, 1993

**ME (Polymer Engineering)**

**509124 [Elective II] (c): Packaging Technology**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objective:**

1. To introduce the students with most exploited area in polymer application - packaging.
2. To impart the students with various aspects such as package design, materials selection, adhesives used protection factor and packaging as a marketing tool etc.
3. To study the printing aspect of packaging material.

**Introduction – Packaging Material**

Historical background, Basic concepts – Physical an d Physico-chemical such as colligative properties, gas laws, surface tension, dialysis, diffusion, energy measurements, etc. Package – components, separation, clearance, support, positioning, cushioning, weight distribution, suspension and closures. Paper – Specialty papers, paper board and corrugated / solid boards Glass – Containers Plastics – Rigid, semi-rigid and flexible Metals – Black plate, GI, tinplate, TFS and aluminium Wood and plywood Textiles ad jute Celluloses and laminates

**Ancillary Materials and Packaging**

Packaging Characteristics. Physical characteristics of the product – physical state, weight, centre of gravity, symmetry, fragility, rigidity, surface finish, etc. Physico-chemical characteristics – susceptibility to water, water vapour, gases, odour, heat, light – mechanism of spoilage. Principles of Corrosion and its prevention. Compatibility – permissible plasticizers in plastics and coating media, their migration to food – can li ning compounds and lacquers for containers for fruit and vegetables, fish, meat and other products. Package design – factors influencing design / product-package relationship.

**Adhesives**

Theory and principles of adhesion and factors affecting board strength. Different types of adhesives – vegetable, animal, inorganic and synthe tic. Adhesive tapes – gum tapes, pressure sensitive tapes, their manufacture and applications.

**Cushioning**

Physical concepts in cushioning, energy, impact load and concept of shock as complex of deceleration and impulse time. Prevention of shock damage to articles by various means and their measurement. Types of cushioning materials and properties – space fillers-cork, paper shavings, wood-wool, saw dust, coir dust, paddy straw and dry grass. Resilient materials – rubberized hair, rubberized coir, polystyrene and polystyrene and polyurethane foams, springs, metal shock mounts, etc.: Non-resilient system – ri gid foams, honeycomb, etc. Reinforcements – straps – steel, plastic, rayon-based, - wires, bail ing hoops etc. Stitching methods - bags, paper and textiles, corrugated board boxes and stitching appliances. Seals and closures. Lining compounds and lacquers for tin containers. Labels and labeling including instant labels. Ink jet printing and bar coding.

**Printing**

Printing techniques, gravure, flexography, ink jet printing for coding, marking applications, surface design and sales appeal, graphic and surface design, printing inks, bar coding. Reinforcements on distribution packages, corrosion prevention in packaging, principles of corrosion and its impact on packaging. Adhesives tapes, their manufacture, properties and limitations BOPP pressure sensitive tapes Cushion design, prevention of shock damage to articles by various means and measurement of shock, cushioning materials and their applications, plastic corrugated board. Containerization, containerization and multimodal transport system, containerization concept, intermodal containers – i ts impact on packaging. Packaging of accessories and spares – skin, blister and shrink p ackaging, stretch wrapping systems, strip packaging, blister packaging. Form – fill – seal ma chine (systems), developments in packaging of stand – up pouches, blow molding machines, high flow PEs – a new trend in injection mold containers.

**Packaging of processed food products**, dehydrated, ready to use foods, packaging of meat, fish and poultry, packaging of fresh foods, packaging of dairy products, packaging of biscuits, bread and confectionery, packaging of fruit juices, aseptic packaging – sterilization of packaging materials, using aseptic system, aseptic packaging, sterilization by irradiation, radiation sterilization – process norms, guidelines and appli cations, packaging of horticultural crops. specifications and performance requirements of fiberboard boxes, packaging quality control, testing methods for evaluation of transport packages. For packaging materials – physical, physico – chemical, resistance to light, insect and mould/fungus. For packaged goods – Unit package: compatibility studies, shelf-life studies –with reference to flexible, rigid packs, different types of seals, closures etc. Bulk packages – Evalu ation of transport – worthiness of filled packages – physical and climatic hazards. Standards for packaging material – rigid, non – rigid and ancillary material. Standards for export packages – labeling and marketing regulation. Packaging quality control criteria. Sampling, variables and attributes, Implication of ISO – 9000. Eco Packaging and regulation.

**Packaging management**, package design an important marketing tool, systems approach to packaging, systems packaging, scientific packaging and loss prevention, packaging needs for export, basic concepts in standardization, packaging standardization and physical distribution, standards – basic concepts, packaging materials, ri gid and ancillary material and export packaging, packaging economics maximizing the container utility in relation to the product, packaging cost, cost reduction in packaging, inventory control, value analysis and value engineering, packaging laws, consumer protection in food packaging, marketing and labeling, eco-friendly packaging for exports.

**References:**


1. Food packaging and preservation, Edited by M. Mathlouthi.
2. Foods and Packaging Materials-Chemical Interactions Edited by Faul Actarmann.
3. Food Packaging Technology Hand Book, By NIIR.
4. Package Engineering, Honlon J F, McGraw Hill,1984
5. Packaging Handbook, Intel,1992.
6. Packaging With Plastics, Bruins Paul F, Gordon and Breach,1974.
7. Plastics Packaging, Turtle Ivor, Pira,1990.
8. Active Packaging for food application by Aaron L. Brodel. , Eugene R. Strupinstes, Lauri R. Kline.
9. Advances in Plastic Packaging Technology, by John Briston.
10. Plastic Films by J.H. Briston.
11. Hand Book on Modern Packaging Industries, by NIIT.

**ME (Polymer Engineering)**
**509125: Laboratory Practice - II**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **Term Work: 50 Marks** |
| | **Oral/Presentation: 50 Marks** |
| | **Credits: 4** |

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**Objective:**

1. After performing the listed experiments the students will be able to
    a) Synthesize the polymer
    b) Test/characterize the polymer material
    c) Process/fabricate and make an article, and
    d) Handle / operate the equipments.

Each student should ' **perform'** at least 10 experiments form the list given below and submit the journal which will form the term – work for the sub ject.

**Important: The students are required to preserve the samples, compounded materials, test specimens, tested specimens, 'original' result pape rs such as charts, graphs, data sheets soft copies of modeling and analysis etc. and should be submitted alongwith the journal for evaluation failing which the TW will not be granted.**

**Lab Practice II:**
The laboratory work will be based on completion of assignments confined to the courses of that semester.

The assessment will be done jointly by the pair of internal and external examiners along with the oral examination of the same.

1. Study of G.P.C. to determine MW and MWD of polymer and analysis of a result sheet obtained from GPC instrument.
2. Study of IR and FTIR for characterization of the structure of the polymers and interpretation of an IR spectrum obtained from the instrument.
3. Preparation of thermoplastic reinforced composites using various reinforcing materials/matrix compositions and their comparison.
4. Study of optical microscopy and interpretation of an optical micrograph.
5. Study of scanning electron microscopy and interpretation of a SEM photograph of actual self-prepared sample.
6. Study of differential scanning calorimetry to determine various thermal behaviors of polymers and its interpretation.
7. Study of dynamic mechanical analysis of polymers and interpretation of a typical graph obtained on DMA instrument.

8. Interpretation and analysis of a DSC scan taken for crystallization, isothermal crystallization.
9. Determination of intrinsic viscosity and viscosity average molecular weight of polystyrene / polyamide – 6 / polypropylene.
10. Study of X-Ray scattering and X-Ray diffraction methods to determine crystallinity and orientation in polymers and analysis of an X-Ray diffraction pattern.
11. Preparation & characterization by actual testing of laminates single layered configurations of isotropic, orthotropic lamina.
12. Preparation and characterization of laminates by actual testing of symmetric laminates or anti-symmetric laminates.
13. Preparation & characterization laminates by actual test of non-symmetric laminates.
14. Preparation of Natural Fiber Reinforced Thermoset Composites.
15. Synthesis of a graft copolymer.

**Important instructions:**

1. Five experiments out of experiment no 1 to 7 are compulsory.
2. Each experiment is to be supported with compulsory assignment which should be the part of the journal.
3. Assignments / 'theory practical's are to be strictly y avoided as laboratory practice experiments.

**ME (Polymer Engineering)**

**509126: Seminar – I**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **Term Work: 50 Marks** |
| | **Oral/Presentation: 50 Marks** |
| | **Credits: 4** |

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**Objective:**

1. To make the student aware of recent advances in the area of polymer science and engineering.
2. To train the student to carry out literature survey to collect the technical information.
3. To develop the oral and written presentation skills amongst the students.
4. To develop technical writing skills through report preparation.

**SEMINAR:**

The student shall deliver the seminar on a topic approved by authorities.

**Seminar I :** Shall be on state of the art topic of student's own choice approved by an authority. The student shall submit the duly certified seminar report in standard format, for satisfactory completion of the work by the concerned Guide and head of the department/institute.

**Important instructions:**

1. Seminar is to be presented using power point presentation.
2. Seminar report is to be submitted in soft and hard copy to the department.
3. The attendance record (signatures) of the audience must be attached and maintained with the report, clearly mentioning "Attendance Record f or the ME Seminar Presentation" with Date and Topic of presentation.

**ME (Polymer Engineering)**

## Semester III

**509127: Polymer Rheology**

| Teaching Scheme | Examination Scheme |
|---|---|
| Lectures: 4 Hrs/Week | In Semester Assessment: 50 Marks |
| | End Semester Assessment: 50 Marks |
| | Credits: 4 |

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**Objective**

1. To understand the study of flow & determination of polymeric melt while being sheared through various flow profiles during processing.
2. To study various parameters that affect the flow behavior in polymer melt.
3. Detailed study of various rheometers.
4. To equip the students with in-depth knowledge for their careers in relevant industry.

**Introduction to Rheological Principals**

Classifications of fluids, Newtonian and Non-Newtonian fluids, time independent and time-dependent fluids, elastic viscous fluids. Tensor notation system to fluid flow, Shear viscosity, tensile viscosity, effect of temperature & pressure on viscosity. Normal stresses, storage & loss modulus, types of polymeric fluids and Weissenburg effect. Elastic effect, extrudate swell, extrudate distortion, melt fracture. Creep, creep compliance, stress relaxation, isochroous stress strain plot.

**Mechanical and Rheological Properties**

Mechanical properties, Definitions – Poisson's rati o, bulk modulus, shear modulus etc, Elastic properties of material – stress strain characterist ics, stiffness, tensile strength, yielding in polymers etc, Rubber elasticity, Polymer melt rheology, viscoelsticity.

**Melt Flow Analysis**

Laminar flow thru circular c/s, annulus, slit, parallel plates, irregular profiles. Flow analysis using rheological models like power law, Ellis model. Turbulent flow analysis, turbulence dampling. Rheological models for extensional viscosity. Transition between laminar & turbulent flow, Ryan Johnson criteria. Applications of Ryan Johnson criteria. Viscoelasticity behavior Stress relaxation, relaxation modulus, creep compliance dynamic modulus, dynamic compliance, dynamic viscosity, Mechanical models – Maxwell mode l, Voigt – kelvin model, Zener model, Boltzmann Principle of Superposition.

Time-temperature correspondence, time-temperature superposition, WLF equation, Glass-transition and theories of glass transition - free volume theory, thermodynamic theory and kinetic theory. Molecular theories – Reuse theory, Doi – Ed ward theory, Curtis – Bird model. Introduction to-non linear viscoelasticity.

**Rheometry Study of rotation**

Rheometry & surface Rheometer. Basic concept of constant stress & constant strain, Different types of Rheometers – Oscillatory Cone and plate Rh eometer, Concentric cylinder, parallel disk Rheometer, concentric rotating disk Rheometer, controlled stress rotational Rheometer, Torque Rheometers – Extruder type, sliding plate Rheometer s, sliding cylinder Rheometer.

**Parameters influencing polymer Rheology**

Effect of temperature, activation energy, effect of on viscosity, effect of molecular wt & distribution on viscosity, molecular at dependence of zero shear viscosity, effect of slinking, crystallinity branching, copolymerization, effect of fillers, fiber filled polymer melts, effect of plasticizers, shear rate dependence of viscosity. Rheology of multiphase systems, rheology of immaculate polymer blends, phase separated block & graft copolymers. Rheology of extrusion, injection molding, calendaring, Principles of rheology as applied to extrusion die design, calculations of pressure drop, etc.

**Composite rheology:**

Solid in liquid suspension, fiber suspension, dilute fiber suspension, semi-concentrated fiber suspension, concentrated suspension, gas containing melts and foams.

**References:**


1. Rheology of filled polymer systems by Aroon V. Shenoy; Klyunner Academic Publishers, 1996.
2. Polymer Advances in polymer chemical physics Yu. g. Yan ov sky and Yu. A. Bisistov.
3. The Mesoscopic theory of polymer dynamics Valadimir N. Pokrovski; Klower academic publishers.
4. Polymer & composite rheology by Rakesh K. Gupta.
5. Polymer Melt Rheology; F.N. Cogswell, George Good Ltd. John Wiley, 1981
6. Applied Rheology in Polymer Processing B.R. Gupta, Asian book, 2003.
7. Introduction to Polymer Viscoelasticity John J. Aklonis and W.J. Mackmight John Wiley & Sons.,1983
8. Melt Rheology & its Role in Plastics processing theory & applications John M. Dealy, Kurt F. Wissburn, Chapman & Hall, 1995.
9. Polymer and Composite Rheology, Second Edition, CRC Press, 2000.
10. Flow Properties of Polymer Melts, Brydson, JA, Godwin, London,1981.
11. Rheology, Principles, measurements and applications, Christopher W. Macosko, Wiley-VCH, 1994.
12. Vectors, Tensors and the Basic Equations of fluid mechanics, R. Aris, Courier Dover Publications, 1989.

**ME (Polymer Engineering)**

**509128: Transport Phenomenon in Polymers**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 4** |

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**Objectives:**

1. To make students aware of mass transport concepts in polymeric materials.
2. To impart basic knowledge of transport phenomena in polymers.
3. To make students aware of energy transport concepts in polymeric materials.
4. To study the transport phenomena in polymeric liquids.

**Tensor algebra and calculus**
Summary of relevance to transport phenomena in polymers, Curl and Divergence.

**Kinematics of fluid flow and deformation**

Complete overview, stability of flow.

**Stress in fluids and solids**

Body and surface forces, Cauchy's principles, Stress, strain and vorticity tensors, Local balance lows - spatial / material forms

**Momentum transport**

Flow phenomena in Polymeric liquids, Non - Newtonian viscous and elastic effects. Applications of differential balances to momentum transfer. Complete solutions and special cases. Complete coverage of special topics in Non - Newtonian fluid mechanics with case studies. Mixing: Residence time distribution.

**Mass transport**

Brief introduction to - Foundation Diffusion, convection and Dispersion Axial, Radial, Diffusion through polymers Mechanism and theories of diffusion through polymers. Different diffusion coefficient. Permeation through polymers. Permeability of polymers and factors affecting it. Diffusion through gas, liquid and solid films (Multi component ). Models for diffusion through polymer films containing impermeable domains of various shapes. Applications of diffusion to barrier packing, controlled release and membranes and ion exchange resins etc.

Solid liquid extraction: liquid extraction one stage wise contact, multistage current extraction, continuous counter-multistage extraction, continuous counter-current extraction with reflux equipments used in liquid-liquid extraction, Distillation: vapour phase equiliibria, enthalpy concentration diagrams, rectification-binery systems. Multistage tray tower design: multistage (tray) tower method of McCabe and Thiele: Physical adsorption.

**Energy transport**

Foundations conduction, convection and viscous dissipation. Brief introduction to - applications of differential balances to energy transfer. Complete solution and special cases like viscous heating and chemical reactions. Applications of integral averaging techniques to energy transfer, Heat and mass transfer in polymeric systems, boundary layer flow with and without heat transfer, heat and mass transfer with and without phase change.

**References:**


1. Transport Phenomena, Bird, Stewart and Lightfoot (1960), Wiley.

2. Momentum, Energy And Mass Transfer In Continua, Slattery John. C. (1972), McGraw Hill.

3. Mechanics Of Non - Newtonian Fluids, Schowalter William R. (1978), Pergamon

4. Diffusion Mass Transfer In Fluid Systems, Cussler, Cambridge (1998) 2nd Edition
5. Welty J R, Wicks C W, Wilson R E, Fundamentals of Momentum, heat transfer, John Wiley & Sons.

**ME (Polymer Engineering)**
**509129 [Elective III] (a): Polymer Product Design**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objectives:**

1. To study various basic concepts in product design
2. To study the design aspect of various specialized products and profiles.
3. To impart the students with the knowledge of modeling and computer simulation.
4. To study the influencing factors such as material selection, processing techniques, design feature etc on product design.

**Product Design:** Procedure and steps, Flowchart in product design. Structural foam product design, Mechanical properties, Short term and long term properties. Relaxation, Recovery of plastics, Maxwell model, Kelvin model, Zener model for visco-elastic deformation. Design methods using deformation data, Pseudo - Elastic design methods for plastics, load bearing products, Stress concentration, Intensity factor, Fracture behavior of plastics, Energy approach to fracture. Creep failure of plastics, Fatigue, Impact behavior of plastics.

**Properties of plastic influencing design**, choice of plastic material, design features that influence performance. Limitations of plastic molded parts based on various processing techniques such as injection, compression and transfer molding etc. Performance limitation in service and environment exposure. An outline of testing and quality control.

Parallel Engineering approach to product design.

**Design of extruded products** like pipes, profiles for various applications, blow molded products, thermoformed product, and rotational molded products like storage tanks.

**Assembly of Parts:** Various techniques of assembly like-mechanical fasteners, welding of thermoplastics, press fit and snap fit assemblies adhesive bonding.

**Computer Aided Engineering:** Study of development of flow analysis software: Study of filling phase, Study of packing phase, Study of cooling, Study of shrinkage, Study of warpage

**Finite element analysis** for product design, modeling and meshing for computer simulation.

**References:**


1. Plastics Product Design, Beck, Van Nosrand Reinhold Publishers, 1980.
2. Flow Analysis Of Injection Moulds, Peter Kennedy, Hanser Publishers 1995.
3. Plastics Materials Properties and Applications, A.W. Birley, M.J. Scott
4. Designing With Plastics and Composites, D.V. Rosato, Van Nostrand.
5. Advanced Polymeric Materials: Structure Property Relationships, By Gabriel O. Shonaike, Suresh G. Advani, CRC Press, 2003.

**ME (Polymer Engineering)**
**509129 [Elective III] (b): Specialty Polymer Materials**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objectives:**

1. To study the various emerging areas of polymer science and engineering.
2. To study and explore the innovative applications of specialty polymers.
3. To update the students with the recent advances in materials development.

**Liquid crystalline polymers:** Introduction, structural requirements to exhibit liquid crystallinity, thermotropic and lyotropic liquid crystals, various phases, study of phase transitions, synthesis of Kevlar and other LC polymers, liquid crystallinity through polymer modifications, self reinforced composites, characterization techniques such as XRD, optical microscopy, DSC etc, applications of LCs in novel areas.

**Polymers with electrical and electromeric properties:** Conducting polymers, conduction mechanism, polyacetylenes, polyparaphenylenes, polypyrroles, Organometallic polymers, photoconducting polymers, polymers in non-linear optics, Piezoelectric, pyroelectric and ferroelectric properties: polyvinylidene fluoride, polyvinylidene fluoride – trifluoroetylene copolymers. Recent advances and applications.

**High temperature and fire resistant polymers:** Introduction, need of thermally resistant polymers, improving low performance polymers for high temperature use, polymers for low fire hazards, Study of polymers like fluoro polymers, aromatic polymers, polyethers, polyphenylene sulphides, polysulphones, polyesters, polyamides, polyketones, polyimides.

**Membranes:** Cellulosics, polysulphones, PPS, polyacrylates and polyhyadrizes, methods, of manufacture, casting and applications. Polyurethanes membranes and IPNS. Reverse osmosis. Applications of membranes in various fields.

**Ionic polymers:** Ionic crosslinking, ion-exchange, hydrophilicity, ionomers based on polyethylene, polystyrene, polytetrafluoroethylene, elastomeric ionomers, aromatioc polymers, polyelectrolytes, polymers with integral ions- halatotelechelic polymers (HTP's), polyethyleneimine (PEI), polyelectrolytic complexes, ion exchange materials. Biological and inorganic ionic polymers.

**Bio polymers:** Biopolymers and Biodegradable Polymers, Polymers in medicines, drug carriers and controlled drug release, polymers in human body, Biodegradable polymers: polylactic acid (PLA), starch-based polymers, synthetic biodegradable polymers, such as aromatic aliphatic co-polyesters, and polyhydroxyalkanoates (PHA). Examples of Pharmaceutical Polymers: Vinyl

Polymers, Cellulose Ethers, Polyesters, Silicones, Polysaccharides and Related Polymers, Miscellaneous Polymers, carbon nanotubes for biomedical applications.

**Hydrophilic polymers:** Synthetic polymers: polymer hydrogels, polyacrylamide hydrophilic polymers, polyvinyl alcohols, polyvinyl pyrrolidone, Natural polymers: carbohydrates and proteins, Semi-synthetic polymers.

**Polymer nanocomposites:** Introduction, An Overview of Nanoparticles, Selecting Resin Matrix and Nanoparticles for Applications, Processing of Nanomaterials, Characterization of Polymer Nanomaterials, Properties of Polymer Nanostructured Materials, Polymer Nanostructured Materials for High-Temperature Applications, Current Status, Trends and Future

**References:**


1. Handbook of Thermoplastics, Olagoke Olabisi, MARCEL, DEKKER INC.
2. Polymers for High Technology, Electronics And Photonics, M.J. Bowden and S.R. Turner, American Chemical Society 1987.
3. High Modulus Polymer, A. Zachariades and R.S. Porter, Decker Publication,1988.
4. Powder Coating – Chemistry and Technology, T.A. Miser J. Wiley NY 1991
5. Polymers For Space Research, C.L. Segal, F.N. Kelly, Marcel Dekker NY
6. Carbon Nanotubes for Biomedical Applications Author: Klingeler, Rüdiger; Sim, Robert B. (Eds.), Chem Tech Publishing.
7. Pharmaceutical Applications of Polymers for Drug Delivery Author: Professor David Jones, Chem Tech Publishing.
8. Engineering polymers, R.W. Dyson Chapman Hall NY 1990
9. Polymer Nanocomposites, Processing, Characterization, and Applications, Joseph H. Koo, Mc Graw Hill.
10. Biopolymers, edited by Alexander Steinbüchel, Insti tute of Microbiology, University of Münster, 2004 by WILEY-VCH

**ME (Polymer Engineering)**

**509129 [Elective III] (c): Polymer and Environment**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 5 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **End Semester Assessment: 50 Marks** |
| | **Credits: 5** |

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**Objective:**

1. The present syllabus will make students aware of present day scenario of polymers and its interaction with the environment.
2. To study the various additives and hazardous chemicals used in polymer industry.
3. Environmental factors affecting polymer stability and vice a versa.
4. Study of recycling and waste management.

**Contribution of plastics in modern society**, polymers: boon or bane, polymers as a replacement to traditional natural resources, biodegradability, various degradation mechanisms, significance of nonbiodegradability, myths and reality. Vital role of polymers in healthcare and safety. Role of plastics in clean and hygienic packaging, plastic materials for national security, contribution of plastics in automobiles and agriculture, energy conservation due to plastics.

**Life cycle assessment**, carbon foot print, control and monitoring pollution, green chemistry, new methods of production of polymers, new feedstock alternative to petroleum, alternative technologies for ecofriendly plastics, OECD, ASTM standards of composting.

**Additives and stabilizers in polymers:** single stabilizers to complex systems, phosphate stabilizers in polymers, polymer processing additives, UV absorbers, hazardous chemicals in polymer industry and their handling.

**Polymer degradation:** Degradation mechanism, polymer oxidation and antioxidant action, biodegradation in polymers, environmental degradation of polymers, wavelength sensitivity of polymers, lifetime prediction of plastics, behavior of polymers in fire: assessment of combustion behavior, improvement of polymer stability in fire, weathering of polymers, protection of polymer from photooxidation, exploitation of polymer degradation.

**Biopolymers and Biodegradable Polymers:** Aromatic constituents occurring in plants and natural environments or as fossil resources, Natural rubber and Gutta Percha, Comparison to synthetic rubbers, Biodegradation of natural rubber and synthetic rubber, Biotechnological versus chemical recycling, Polyesters: Synthesized by organisms: Polyhydroxyalkanoates (PHA), Non-storage PHAs, Poly(malic acid), Medical and pharmaceutical applications, Polysaccharides, Alginates, Cellulose, Chitin, Chitosan, Dextran, Pectin, Starch, etc. Polyamides and complex proteinaceous materials synthesized by organisms, Poly( ..-D-glutamate), Cyanophycin, modifications of proteins, Silk proteins, Adhesive proteins, Protein composites, Wool, Collagens and gelatins. Special applications in the areas like electronics, aerospace, medicine and pharmacy, food, packaging, construction engineering, etc.

**Recycling and waste management:** Separation processes in waste minimization, Toxic material handling and management, Plastic waste management, three R's, reduce, recycling, reuse and recover. Combustion and incineration processes, Polymer Recycling, Disposal of waste plastic, Energy and feedstock recovery through recycling, Polymers and energy, Future of degradable polymers.

**References:**


1. Handbook of polymer degradation, Sec Ed. S Halim Hamid, Marcel Dekker Inc, NY
2. Interaction of Polymers with Polluted Atmospheres, Smithers Information Ltd, September 2009.
3. The Chemistry of Polymers, John W. Nicholson, RSC Publishing
4. Biopolymers, edited by Alexander Steinbüchel, Insti tute of Microbiology, University of Münster, 2004 by WILEY-VCH
5. Plastics for environment and sustainable development, ICPE, CIPET, Chennai.

**ME (Polymer Engineering)**

**509130: Seminar – II**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **Term Work: 50 Marks** |
| | **Oral/Presentation: 50 Marks** |
| | **Credits: 4** |

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**Objective:**

1. To make the student aware of recent advances in the area of polymer science and engineering.
2. To train the student to carry out literature survey to collect the technical information.
3. To develop the oral and written presentation skills amongst the students.
4. To develop technical writing skills through report preparation.

**Seminar II :** Shall be on the topic relevant to latest trends in the field of concerned branch, preferably on the topic of specialization based on the electives selected by him/her approved by authority. The student shall submit the seminar report in standard format, duly certified for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

**Important instructions:**

1. Seminar is to be presented using power point presentation.
2. Seminar report is to be submitted in soft and hard copy to the department.
3. The attendance record (signatures) of the audience must be attached and maintained with the report, clearly mentioning "Attendance Rec ord for the ME Seminar Presentation" with Date and Topic of presentation.

**ME (Polymer Engineering)**

**5091231: Project Work Stage I**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 8 Hrs/Week** | **Term Work: 50 Marks** |
| | **Oral/Presentation: 50 Marks** |
| | **Credits: 8** |

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**Objective:**

1. The student should be able to choose and evaluate the problem based on current interest of research at national and international level.
2. To train the student to acquire the technical data.
3. To develop analyzing ability amongst the students.
4. To train the students to make use of available resources and to procure the resources to carry out his/her project work.
5. To initiate and orient the students with R & D skills.
6. To give the students the exposure of recent advances at national and international level.

**PROJECT WORK**:

The project work shall be based on the knowledge acquired by the student during the coursework and preferably it should meet and contribute towards the needs of the society. The project aims to provide an opportunity of designing and building complete system or subsystems based on area where the student likes to acquire specialized skills.

**Project Work Stage – I**

Project work Stage – I is an integral part of the p roject work. In this, the student shall complete the partial work of the project which will consist of problem statement, literature review, project overview, scheme of implementation (Mathematical Model/SRS/UML/ERD/block diagram/ PERT chart, etc.) and Layout & Design of the Set-up. As a part of the progress report of Project work Stage-I, the candidate shall deliver a presentation on the advancement in Technology pertaining to the selected dissertation topic. The student shall submit the duly certified progress report of Project work Stage-I in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

The assessment will be done jointly by the pair of internal and external examiners along with the oral/presentation examination of the same.

**Important instructions:**

1. The ME candidate is required to work on Original Topic.
2. It should not be the repetition earlier reported work.
3. The student is required to carry out broad literature survey in the area of work.
4. The justification for selection of project topic and originality of the topic is to be mentioned in the Project Report.
5. The student will make presentation of his project work for assessment purpose.
6. All supporting documents, samples, products, soft copies to be preserved and presented at the time of examination.

**ME (Polymer Engineering)**
## Semester IV

**509130: Seminar – III**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 4 Hrs/Week** | **Term Work: 50 Marks** |
| | **Oral/Presentation: 50 Marks** |
| | **Credits: 4** |

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**Objective:**

5. To make the student aware of recent advances in the area of polymer science and engineering.
6. To train the student to carry out literature survey to collect the technical information.
7. To develop the oral and written presentation skills amongst the students.
8. To develop technical writing skills through report preparation.

**Seminar III:** Shall preferably an extension of **seminar II.** The student shall submit the duly certified seminar report in standard format, for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

**Important instructions:**

1. Seminar is to be presented using power point presentation.
2. Seminar report is to be submitted in soft and hard copy to the department.
3. The attendance record (signatures) of the audience must be attached and maintained with the report, clearly mentioning “Attendance Rec ord for the ME Seminar Presentation” with Date and Topic of presentation.

**ME (Polymer Engineering)**

**509133: Project Work Stage II**

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 20 Hrs/Week** | **Term Work: 150 Marks** |
| | **Oral/Presentation: 50 Marks** |
| | **Credits: 20** |

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**Objective:**

1. The student should be able to choose and evaluate the problem based on current interest of research at national and international level.
2. To train the student to acquire the technical data.
3. To develop analyzing ability amongst the students.
4. To train the students to make use of available resources and to procure the resources to carry out his/her project work.
5. To initiate and orient the students with R & D skills.
6. To give the students the exposure of recent advances at national and international level.

**Project Work Stage - II**

In Project Work Stage – II, the student shall compl ete the remaining part of the project which will consist of the fabrication of set up required for the project, work station, conducting experiments and taking results, analysis & **validation of results and conclusions**. The student shall prepare the duly certified final report of project work in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.

It is mandatory for every student that his Project Outcomes (results and conclusion) are 'validated' in the form of minimum one Publication (published or accepted) in a refereed and peer reviewed journal of international repute till the date he/she appears for the Project Work Stage II examination. (Communicated papers will not be considered as publication)

The assessment will be done jointly by the pair of internal and external examiners along with the oral examination of the same.

**Important instructions:**

1) The ME candidate is required to work on Original Topic.
2) It should not be the repetition earlier reported work.
3) The student is required to carry out broad literature survey in the area of work.

4) The justification for selection of project topic and originality of the topic is to be mentioned in the Project Report.
5) The student will make presentation of his project work for assessment purpose.
6) The project report is to be submitted in Standard Hard Bound format.

7) It is mandatory for the candidate to participate and present his work at any (national/international) conference/seminar or publish his/her work in any (national/international) journal during the tenure till oral exam is conducted. (In some cases paper accepted (before the date of oral examination) for presentation or publication in conference or journal will be considered.
8) All supporting documents to be maintained.

**ME (Polymer Engineering)**

# Non Credit Course (mandatory)

***Note: Refer R-2.7 for Examination Rules of "Rules a nd Regulations for M.E. Programs under faculty of Engineering effective from June 2013". Non-credit c ourses are mandatory for the grant of the term and shall be completed by the students as a self study under the guidance of PG teacher either by referring to the Hand books, Journal/Conference papers (at least 25 in number), open source software, tools and in addition may be by organizing educational visits to the technological/professional centers in the subject, if any. Each student is required to produce in own words, one 10 pages innovative, technical paper to be submitted as a part of the semester course work of non-credit courses.***

## Term I, Sem I: Yoga and Meditation

| **Teaching Scheme** | **Examination Scheme** |
|---|---|
| **Lectures: 2 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **Credits: 2** |

Yoga: Sukshma (subtle) yoga techniques, Difference between physical exercises and yogasans, Impact of yogasans on human body, benefits of yogasans, Patanjali yoga sutras, technique of different yogasans like, Trikonasan, Ardhachandrasan, Padmasan, Akarnadhanurasan, Ardhamatsendrasan, Vajrasan, Pachhimottasan, Bhujangasan, Shalbhasan, Dhanurasan, Naukasan, Makrasan, Pawanmuktasan, Halasan, Sarvangasan, Shavasan, Suryanamaskar( Sun Salutation), Yoga and Food.

Meditation: Breathing technique, Pranayama, Benefits of pranayama, Prcautions for pranayama, Kumbhak, Bandh(Locks), Chakras, Mudra, Technique of pranayama,Anulom- VilomPranayam, UjjayiPranayam, BhramariPranayam, BhastrikaPranayam, AgnisarPranayam, KapalbhatiPranayam, Meditation(Dhyan).

**References Books:**


1. Light on Yoga: by B.K.S. Iyengar, Harper Collins Publishers India
2. Light on Pranayama: by B.K.S. Iyengar, Harper Collins Publishers India
3. Yoga for Dummies by Georg Feuerstein and larry Payne, Wiley India publishing
4. Yoga, Pilates, Meditation & Stress Relief By Parragon Books Ltd
5. The Yoga Sutrasby Patanjali, Swami Satchidananda, Integral Yoga Publications
6. Meditation - Science and Practice by N. C. Panda, Publisher: D. K. Printworld


**Other Source:**


7. http://www.artofliving.org/in-en/yoga
8. http://www.artofliving.org/in-en/yoga/sri-sri-yoga/sukshma-yoga-relaxation
9. http://www.yogsansthan.org/
10. http://www.yogapoint.com/
11. http://www.divyayoga.com/
12. http://www.yogaville.org/about-us/swami-satchidananda/
13. www.yogaVision.net
14. http://www.swamij.com/

## ME (Polymer Engineering)

### Term I , Sem II: Human Rights and World Peace

| Teaching Scheme | Examination Scheme |
|---|---|
| Lectures: 3 Hrs/Week | In Semester Assessment: 50 Marks |
| | Credits: 3 |

**Human Rights – Concept, Development, Evolution**
- Philosophical, Sociological and Political debates, Benchmarks of Human Rights Movement.

**Human Rights and the Indian Constitution**
- Constitutional framework, - Fundamental Rights & Duties, - Directive Principles of State Policy, - Welfare State & Welfare Schemes

**Human Rights & State Mechanisms**
- Police & Human Rights, - Judiciary & Human Rights, - Prisons & Human Rights, - National and State Human Rights Commissions

**Human Rights of the Different Sections** and contemporary issues
- Unorganized Sector, Right to Environment, particularly Industrial sectors of Civil Engineering and Mechanical Engineering, Globalization and Human Rights, - Right to Development,

**Citizens' Role and Civil Society**
- Social Movements and Non-Governmental Organizations, Public Interest Litigation, Role of Non Government organizations in implementation of Human rights, Right to Information.

**Human Rights and the international scene** –Primary Information with reference to Engineering Industry, UN Documents, International Mechanisms (UN & Regional), International Criminal Court,

**World Peace:**
Peace; Meaning, Nature , philosophy of peace, Theories of Peace: Democratic peace theory, Active Peace theory, Game Theory, Religious Beliefs and Peace theories: Buddhism, Islam, Christianity, Hinduism, Economic equality, Social Justice, and Social Values.

Durable Peace: Challenges and Methods, Methods for Conflict Resolutions, Global Conflict and Peace Initiatives, Religious Philosophy and Conflict Resolution, Globalization and Growing Conflict, Globalization, Civil Society and World Peace, Gandhian Understanding of Peace.

**References:**


1. Study material on UNESCO,UNICEF web site
2. HUMAN RIGHTS IN INDIA A MAPPING, Usha Ramanathan: free download from http://www.ielrc.org/content/w0103.pdf
3. Introduction to International Humanitarian Law **by** Curtis F. J. Doebbler - CD Publishing**,** 2005.
4. Freedom of Information**,**by Toby Mendel - UNESCO **,** 2008

**ME (Polymer Engineering)**

**Term II, Sem I: Cyber Security/Information security**

**Teaching Scheme**
**Lectures: 3 Hrs/Week**

**Examination Scheme**
**In Semester Assessment: 50 Marks**
**Credits: 3**

**Security principles, threats and attack techniques**

• Introduction to security • Information security • Security triad: Confidential, Integrity, Availability • Focus of control • Security threats and attacks • Security management

**Authentication and access control**

• Identification • Authentication • Authentication by passwords • Protecting passwords • Access control structures • Types of access control

**Lattice and reference monitors**

• Security levels and categories • Lattice diagram • Reference monitors • Security kernel • Hardware security features • Protecting memory

**Security models**

• Bell-LaPadula • Biba • Non-deducibility • Non-int erference • Other models

**Cryptography**

• Cryptographic mechanisms • Digital signatures • E ncryption • Certificates

**Authentication in distributed systems**

• Key establishments and authentication • Kerberos • Public key infrastructures • Single sign-on

**Network security**

• Protocol design principles • ISO architecture • I P security • SSL/TLS • Firewalls • Intrusion detection

**Unix security and Windows security**

• Subjects, objects and access control • General se curity principles • Access components • Access decisions • Administration and management issues

**Software security and database security**

• Memory management • Data and code • Relational da tabases • Access control in databases
• Statistical database security

**Java Security, Mobile Security**

• GSM security • Wireless LAN security

**Protection measures**

• Business risk analysis • Prevention, detection an d response • Information classifications • Security evaluation

**Reference Books:**

1) Bakshi P M and Sri R K, Cyber and E-commerce Laws, Bharat Publishing House, 1st Edn, 2002
2) Syed shakil Ahmed, Rajiv Raheja, A handbook on Information technology: Cyber law and ECommerce, Capital Law House, 2004
3) Rodney D Ryder, Business Process Outsourcing, Date Protection and Information Security, Wadhwa & Co., 1st Edn, 2001
4) Vakul Sharma, Information Technology Law and Practice, Delhi Law House, 3rd Edn, 2011

5) Lipton, K., Cyberspace Law Cases and Materials, 2nd edition. Aspen Publishers. NY: New York, 2006
6) Michael E Whitman and Herbert J Mattord, Principles of Information Security, Vikas Publishing House, New Delhi, 2003
7) Micki Krause, Harold F. Tipton, Handbook of Information Security Management, Vol 1-3 CRC Press LLC, 2004.
8) Michael E Whitman and Herbert J Mattord, Principles of Information Security, Vikas Publishing House, New Delhi, 2003

**ME (Polymer Engineering)**

**Term II, Sem II: Industrial Safety and Equipment Maintenance**
**(Skill Development)**

| | |
|---|---|
| **Teaching Scheme** | **Examination Scheme** |
| **Lectures: 2 Hrs/Week** | **In Semester Assessment: 50 Marks** |
| | **Credits: 2** |

**Machine Operation and Guarding :**
Principles in machine guarding. Ergonomics of machine guarding. Type of guards, their design and selection. Guarding of different types of machinery including special, paper, rubber and printing machinery, machine, tools etc. Built-in-safety devices, maintenance and repairs of guards, incidental safety devices and tools. Safety in the use of Machines : Safety in the use of 1) power presses (all types), 2) shearing, 3) bending, 4) rolling, 5) drawing, 6) turning, 7) boring, 8) milling, shaping, 9) planning broaching, planting, 10) grinding, 11) CNCS. Need for selection and care of cutting tools. Preventive maintenance, periodic checks for safe operation. Associated hazards and their prevention

**Material Handling and Storage of Materials :**
Kinetics of manual handling. Maximum loads that could be carried. Lifting and carrying of objects of different shapes, size and weight. Safe use of accessories for manual handling Storage of materials. Safety in stacking and unstacking, floor loading conditions. Layout condition for safety in storage, ergonomics of manual handling and storage. Lifting machinery, lifts and hoists; safety aspects in design and construction, testing, use and care, signaling, inspection and maintenance. Safety in design and construction, operation, inspection and maintenance of industrial trucks, lifting tackles and loose gears, conveyors. Safety features, safe locations, testing, inspection and maintenance of lifting tackles,safe working load for all mechanical material handling equipment. The competent persons in relation to safety legislation – duties and responsibilities.

**Hand Tools and Power Tools :** Main causes of accidents, prevention and control of accidents. Centralised and personal tool issues System. Purchase, storage and supply of tools. Inspection, maintenance and repair of tools. Detectable causes of tool failures. Tempering, safe end in and dressing of certain tool**.** Safe use of various types of hand tools used for metal cutting,

**Electrical Hazards**
Hazards of electrical energy. Safe limits of amperages, voltages. Safe distance from lines. Capacity and protection of conductor. Joints and connections. Means of cutting off power. Overload and short circuit protection. No load protection. Earth fault protection. Earth insulation and continuity tests. Earthing Standards. Protection against sure and voltage fluctuation.

Hazards arising out of 'borrowed' neutrals. Othersprecautions. Types of protection for electrical equipment in hazardous atmosphere. Electrical area classification. Criteria in their selection, installation, maintains and use. Safety Check list for buying new machinery for the Plant Classification of Hazardous materials. Safety in chemical industry, Criteria for sitting and layout

of Chemical and Petrochemical Plants Plant Area classification. Instrumentation for safe plant operations. Hazard in Unit Processes and Unit Operations, Control, precautions and prevention, specific safety measures for certain chemical industry like fertiliser, insecticide, pesticides-choler-alkali, explosives, polymer plants. Sampling technique for toxic and flammables, pharmaceuticals, petro-chemical etc. 3.1 Precautions in the process and operations involving explosives, flammables, toxic substances, dusts, gases, vapour cloud formations and combating.

Transportation of Hazardous material .Safety Precautions for transporting hazardous / toxic / flammable /explosive/ radioactive substances by all modes.

Colour coding identification of contents. Safety Precautions for working on pipelines, safe entry procedures to confined spaces including reaction vessels. Safe procedure of start up and shut down procedures. Safety in preventive and emergency maintenance operations.

**Fire & Explosion :**
Chemistry of fire, Factors contributing towards fire, Classification of fires. Common causes of industrial fires. Determination of fire load.. Design of building plant, exists, etc. for fire safety and Fire resistance of building materials. Prevention of fire. Portable extinguishers. Hydrant system, sprinkler system, introduction to. Carbon-di-oxide systems. Foam extinguisher system. Dry chemical Extinguishing systems Halon replacement of firefighting products. Fire detection and alarms system. Special safety precautionary measures for control of fire and explosion in handling / processing flammable liquids, gases, vapors, mists and dusts etc. BLEVE (Boiling liquids expanding vapor Explosion , Vapor Cloud Explosion) including pesticides. Fire emergency action plan. Deflagration and detonation.

**References:**


1. Accident Prevention Manual for Industrial Operations National Safety Council, 444, North Michigan Avenue, Chicago, I 11 – 60611
2. Safety code for Scaffolds and Ladders, (Part II) – Ladders IS : 3696 , (Part II) - 1966
3. Safety in Construction Work : Scaffolding H.M.S.O London, 1977.