Department of Polymer Science and Engineering				
S.No.	**Course code**	**Course Title**	**Area**	**Credit**
1.	MAN-001	Mathematics-I	BSC	4
2.	PEN-101	Introduction to Polymer Science and Engineering	PCC	2
3.	CEN-105	Introduction to Environmental Studies	GSC	3
4.	HSN-001A	Communication skills (Basic)	HSSC	2
5.	HSN-001B	Communication skills (Advanced)	HSSC	2
6.	HSN-002	Ethics and Self-Awareness	HSSC	2
7.	CYN-009	Polymer Chemistry	BSC	4
8.	PEN-103	Computer Programming and Numerical Methods	ESC	4
9.	MAN-002	Mathematical Methods	BSC	4
10.	CHN-102	Material and Energy Balance	PCC	4
11.	CHN-106	Thermodynamics and Chemical Kinetics	PCC	4
12.	PEN-102	Properties of Polymers	PCC	3
13.	CYN-011	Polymer Characterization	BSC	2
14.	EEN-112	Electrical Science	ESC	4
15.	CYN-013	Polymer Chemistry Lab	BSC	2
16.	CHN-201	Heat Transfer	PCC	4
17.	CHN-211	Fluid and Fluid Particle Mechanics	PCC	4
18.	PEN-201	Polymer Engineering Thermodynamics	PCC	4
19.	PEN-203	Polymer Blends	PCC	3
20.	MIN-108	Mechanical Engineering Drawing	ESC	4
21.	CHN-212	Mass Transfer	PCC	4
22.	PEN-202	Polymer Reaction Engineering	PCC	4
23.	PEN-204	Polymer Rheology and Processing	PCC	3
24.	PEN-206	Polymer Production Engineering	PCC	3
25.	PEN-208	Elastomers Science and Engineering	PCC	3
26.	MTN-106	Materials Science	ESC	4

27.	CHN-303	Process Dynamics and Control	PCC	4
28.	PEN-301	Polymer Product Processing and Engineering	PCC	4
29.	PEN-303	Process Equipment Design	PCC	4
30.	PEN-391	Technical Communication	PCC	2
31.	PEN-302	Modeling and Simulation of Polymers	PCC	4
32.	PEN-304	Polymer Composites	PCC	3
33.	CHN-310	Process Utilities, Economics and Plant Design	PCC	3
34.	PEN-300	Industry Oriented Problem	PCC	3
Programme Elective				
39.	CHN-322	Optimization of Chemical Engineering Processes	PEC	4
40.	CHN-323	Computer Application in Chemical Engineering	PEC	4
41.	CHN-324	Computational Fluid Dynamics	PEC	4
42.	CHN-325	Process Integration	PEC	4
43.	PEN-325	Transport Phenomena in Polymeric Solutions	PEC	4
44.	PEN-401	Bio-Polymer Engineering	PEC	4
45.	PEN-402	High Performance and Special Polymers	PEC	4
46.	PEN-403	Electronic and Conducting Polymers	PEC	4
47.	PEN-404	Polymer Film Technology	PEC	4
48.	PEN-405	Polymeric Membrane Technology	PEC	4
49.	PEN-406	Advanced Polymer Composites	PEC	4
50.	PEN-407	Advanced Extrusion and Compounding	PEC	4
51.	PEN-408	Paint and Coating Engineering	PEC	4
52.	PEN-409	Polymer Fiber Technology	PEC	4
53.	PEN-410	Adhesive and Sealants Technology	PEC	4
54.	PEN-411	Rubber Product Technology	PEC	4
55.	PEN-412	Polymer Colloids	PEC	4
56.	PEN-413	Polymer Nanocomposites	PEC	4
57.	PEN-414	Advanced Process Control	PEC	4

58.	PEN-415	Polymer and Tissue Technology	PEC	4
59.	PEN-417	Polymer Degradation and Stability	PEC	4
60.	PEN-418	Polymers Recycling and Environment	PEC	4
61.	PEN-419	Polymer for Packaging Technology	PEC	4
62.	PEN-420	Polymers for Smart & Memristive Materials	PEC	4
63.	PEN-421	Applications of Polymer in Drug Delivery	PEC	4

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-001** Course Title: **Mathematics I**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory :3** **Practical:0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: BSC**

8. Pre-requisite**: None**

9. Objective: To provide essential knowledge of basic tools of Differential Calculus,Integral Calculus , Vector Calculus and Matrix Algebra for degree students.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Matrix Algebra:** Elementary operations and their use in getting the Rank, Inverse of a matrix and solution of linear simultaneous equations. Orthogonal, Symmetric, Skew-symmetric, Hermitian, Skew-Hermitian, Normal & Unitary matrices and their elementary properties. Eigen-values and Eigenvectors of a matrix, Cayley- Hamilton theorem, Diagonalization of a matrix.	**8**
2.	**Differential Calculus:** Limit, Continuity and differentiability of functions of two variables, Euler's theorem for homogeneous equations, Tangent plane and normal. Change of variables, chain rule, Jacobians, Taylor's Theorem for two variables, Error approximations. Extrema of functions of two or more variables,Lagrange's method of undetermined multipliers	**12**
3.	**Integral Calculus:** Review of curve tracing and quadric surfaces, Double and Triple integrals, Change of order of integration. Change of variables. Gamma and Beta functions. Dirichlet's integral. Applications of Multiple integrals such as surface area, volumes, centre of gravity and moment of inertia..	**12**
4.	**Vector Calculus:** Differentiation of vectors, gradient, divergence, curl and their physical meaning. Identities involving gradient, divergence and curl. Line and surface integrals. Green's, Gauss and Stroke's theorem and their applications.	**10**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	E. Kreyszig, Advanced Engineering Mathematics, 9th edition, John Wiley and Sons, Inc., U.K.	2011
2.	R.K. Jain and S.R.K. Iyenger, Advanced Engineering Mathematics, 2nd Edition, Narosa Publishing House.	2005
3.	M.D. Weir, J. Hass, F.R. Giordano, Thomas' Calculus, 11th Edition, Pearson Education.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Polymer & Process Engineering**

1. Subject Code: **PEN-101** Course Title: **Introduction to Polymer Science and Engineering**
2. Contact Hours: **L: 2** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory:2** **Practical:0**
4. Relative Weightage**: CWS :0** **PRS : 0** **MTE : 100** **ETE : 0** **PRE : 0**
5. Credits**: 2** 6. Semester**: Spring** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9 Objective: To impart introductory knowledge of polymer engineering
10. Details of Course:

S. No.	Particulars	Contact Hours
1	**Introduction:** Types of polymers; Blends; Composites; Materials and applications of polymers	1
2	**Engineering Polymers:** Types of engineering polymers; Thermoplastics; Thermosets; Elastomers; Polyolefins; Polyethylene; Polypropylene	5
3	**High Performance Polymers:** Types of high performance polymers; Polyesters; Polycarbonate; Polyamide; Polyetherimides; Poly-amide-imide; High temperature Resistant polymers; Lyotropic and thermotropic liquid crystal polymers	5
4	**Polymer Engineering**: Polymerization engineering; Polymer Processing; Additives; Polymer products; Processing; Introduction to rheology and various polymer processing techniques and equipments	6
5	**Polymeric Systems and Materials** Polymer blends; Polymer Composites; Rubbers and elastomers; Films and fibers; Bio; bio-degradable and bio-medical polymers and functional polymers	6
6	**Applications of Polymers:** Applications of polymers in commodity products as: Engineering materials in automobiles; Aerospace;	5

	Electronics; Medical and other applications; Conducting polymers	
	Total	**28**

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication
1.	H. S. Kaufman, J. J. Falcetta, "Introduction to Polymer Science & Technology"' SPE Textbook, John Wiley & Sons	2010
2	D. J. Williams, "Polymer Science & Engineering", Prentice Hall, Inc.	2010
3.	V. R. Gowariker, N. V. Vishwanathan, Jaydev Sreedhar, "Polymer Science", New Age (I)	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-105** Course Title: **Introduction to Environmental Studies**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 00**
5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **GSC**
8. Pre-requisite: **Nil**
9. Objective: To introduce fundamentals of environmental pollution and its control.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	Overview: Environment and Natural Processes; Development (Resource Utilization & Waste Generation); Environmental issues; Concept of Sustainable Development; Issues affecting future development (population, urbanization, health, water scarcity, energy, climate change, toxic chemicals, finite resources etc.); Environmental units	6
2.	Air –Water interaction: (Liquid phase-gas phase equilibrium) Henry's Law Constant with units, Dimensionless Henry's Law Constant	3
3.	Water –Soil Interaction: Carbonate System (Alkalinity and bufferi capacity); Major ions in water; Natural Organic Matter (NOMs); Water quality parameters; Physical processes (Mass Balance): Spatio-temporal variation in quality of river water, lake water, groundwater; Water quality standards	9
4.	Wetlands, water treatment and wastewater treatment .	6
5.	Air resources: Atmosphere; Air pollutants; Emissions and control of air pollutants; Atmospheric meteorology and dispersion; Transport of air (global, regional, local); A/ iratmospheric stability; Plume shape; Gaussian modeling; Air quality standards	9
6.	Land pollution and solid waste management	3
7.	Ecosystem: Structure and function; Energy flow in ecosystem; Materia flow in ecosystem; Biodiversity and ecosystem health; Bio-amplification and bio-magnification	3
8.	Hazardous Waste: Definition; Classification; Storage and management; Site remediation; Environmental Risk: assessment, and management	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Davis M .L .and Cornwell D . A .Introduction," to Environmental Engineering", McGraw Hill, New York 4/e	2008
2.	Masters G .M.,Joseph K . and Nagendran R Introduction." t o Environmental Engineering and Science", Pearson Education, New Delhi. 2/e	2007
3.	Peavy H. S,. R owe D.R. and TchobanoglousG., "Environmental Engineering", McGraw Hill, New York	1986
4.	Mines R . O. and Lackey L . W. Introduction"" to Environmental Engineering", Prentice Hall, New Yark	2009
5.	Miheicic J. R .and Zimmerman J . B . " Environmental Engineering: Fundamentals, Sustainability, Design" John Wiley and Sons, Inc.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Humanities & Social Sciences**

1. Subject Code: **HSN-001A** Course Title: **Communication Skills (Basic)**

2. Contact Hours: **L: 1** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory 2** **Practical 0**

4. Relative Weight**:** **CWS 25 PRS 00 MTE 25 ETE 50 PRE 0**

5. Credits**:** **2** 6. Semester**: Autumn/Spring** 7. Subject Area**: HSSC**

8. Pre-requisite**: Nil**

9. Objective: The course intends to build the required communication skills of the students having limited communicative abilities, so that they may communicate effectively in real-life situations

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Understanding the Basics of Communication Skills: Listening, Speaking, Reading & Writing, Scope and Importance	**01**
2.	Grammar & Composition: Time and Tense, Agreement, Active-Passive, Narration, Use of Determiners, Prepositions & Phrasal Verbs	**05**
3.	Vocabulary Building & Writing: Word-formation, Synonyms, Antonyms, Homonyms, One-word Substitutes, Idioms and Phrases, Collocations, Abbreviations of Scientific and Technical Words	**02**
4.	Introduction to Sounds (Vowels & Consonants) Organs of Speech, Place and Manner of Articulation, Stress & Intonation, Listening Comprehension (Practical Sessions in Language Laboratory)	**02**

5.	Speaking, Countering Stage-fright and Related Barriers to Communication.	**02**
6.	Reading and Comprehension: Two lessons to be identified by the department.	**02**
	Total	**14**

List of Practical:

1. Ice-breaking Exercises
2. Assignments on Time and Tense, Agreement, Active-Passive
3. Laboratory Session on Narration, Use of Determiners, Prepositions & Phrasal Verbs, Revisionary Exercises & Quiz
4. Laboratory Session on Synonyms, Antonyms, Homonyms
5. Assignments and Practice Sheets on One-word Substitutes, Idioms and Phrases, Collocations, Abbreviations of Scientific and Technical Words
6. Laboratory Session on Practice of sounds, Intonation and Stress, Listening Comprehension
7. Individual presentation, debates, Extempore & Turncoats
8. Exercises in Composition and Comprehension

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Murphy, Raymond. *Intermediate English Grammar*, New Delhi, Cambridge University Press.	**2009**
2.	Quirk, Randolph & Sidney Greenbaum. *A University Grammar of English*, New Delhi, Pearson.	**2009**
3.	McCarthy, Michael & Felicity O' Dell. *English Vocabulary in Use*, New Delhi, Cambridge University Press	**2010**
4.	Jones, Daniel. *The Pronunciation of English*, New Delhi, Universal Book Stall.	**2010**
5.	Birchfield, Susan M. *Fowler's Modern English Usage*, New Delhi, OUP.	**2004**
6.	Llyod, Susan M. *Roget's Thesaurus of English Words and Phrases.* New Delhi: Penguin.	**2010**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Humanities & Social Sciences**

1. Subject Code: **HSN-001B** Course Title: **Communication Skills (Advanced)**

2. Contact Hours: **L: 1** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory 2** **Practical 0**

4. Relative Weight**:** **CWS 25 PRS 00 MTE 25 ETE 50 PRE 0**

5. Credits**:** **2** 6. Semester**: Autumn/Spring** 7. Subject Area**: HSSC**

8. Pre-requisite**: Nil**

9. Objective: The course intends to train the learners in using both verbal and non-verbal communication effectively.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Advanced Communication Skills: Scope, Relevance, & Importance	**01**
2.	Soft Skills: Interpersonal Communication; Verbal & Non-verbal, Persuasion, Negotiation, Neuro-Linguistic Programming	**03**
3.	Communication and Media (Social and Popular), The Social and Political Context of Communication, Recent Developments and Current Debates in Media	**04**
4.	Cross-cultural and Global Issues in Communication: Race, Ethnicity, Gender & Diaspora	**03**
5.	Rhetoric and Public Communication, Audience Awareness, Emotionality	**03**
	Total	**14**

List of Experiments:

1. Discussion on the Process of Communication in Personal and Professional Life
2. Group Discussion, Case Studies and Role-Play
3. Assignments on E-mail Etiquette, Social Networking, Blog Writing, Discussions on Current Issues
4. Non-Verbal Communication in Cross-Cultural Situations, Case Studies, Group Discussions and Readings on Topics Related to Race, Ethnicity , Gender and Diaspora
5. Individual Presentations (Audience Awareness, Delivery and Content of Presentation)

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Rentz, Kathryn, Marie E. Flatley& Paula Lentz. *Lesikar's Business Communication CONNECTING IH A DIGITAL WORLD*, McGraw -Hill, Irwin	2012
2.	Bovee, Courtland L & John V. Thill. *Business Communication Today*. New Delhi, Pearson Education	2010
3.	McMurrey, David A. & Joanne Buckley. *Handbook for Technical Writing*, New Delhi, Cengage Learning.	2009
4.	Jones, Daniel. *The Pronunciation of English*, New Delhi, Universal Book Stall.	2010
5.	Allan & Barbara Pease. *The Definitive Book of Body Language*, New York, Bantam	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Humanities and Social Sciences**

1. Subject Code: **HSN-002** Course Title: **Ethics and Self-awareness**

2. Contact Hours: **L: 01** **T: 0 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 2** **Practical 0**

4.Relative Weight**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits : **2** 6. Semester**: Autumn** 7. Subject Area**: HSSC**

8. Pre-requisite**: Nil**

9. Objective: To introduce the concepts pertaining to ethical and moral reasoning and action and to develop self - awareness.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Definition of thics;E A pproaches t othics:E Psychological, Philosophical, Social.	**1**
2	**Psycho-social theories of moral development**: View of K ohlberg; Morality and Ideology, Culture and orality,M Morality i n everyday context.	**3**
3	**Ethical Concerns**: Work Ethics and Work Values, BusinessEthics, Human values in organizations.	**3**
4	**Self-Awareness**: Self Concept: Johari Window, Self and Culture, Self Knowledge, Self-Esteem; Perceived elfS-control, S elf-serving bi as, Self-presentation, Self-growth: Transactional Analysis and Life Scripts.	**4**
5.	**Self Development**: Character strengths and virtues, Emoti intelligence, Social intelligence, Positive cognitive states and processes (Self-efficacy, Empathy, Gratitude, Compassion, and Forgiveness).	**3**
	Total	**14**

11. Suggested Books:

S.No.	Name of Authors / Books / Publishers	Year of Publication
1.	Hall, Calvin S ., Lindzey, Dardner., & Cambell, B.,"Theories of Personality",Hamilton Printing Company.	1998
2.	Car Alan, "Positive Psychology: The Science of Happiness and Human Strengths", Brunner-Routledge.	2004
3.	Leary M.R., "The Curse of Self: Self-awareness, Egotism and the Quality of Human Life", Oxford University Press.	2004
4.	Louis P . P., "The M oral Life: An Introductory Reader i n Ethics and Literature", Oxford University Press.	2007
5.	Corey, G., Schneider Corey, M ., &Callanan, , P"Issues. and Ethics in the Helping Professions", Brooks/Cole.	2011
6.	Snyder, C.R., Lopez, Shane, J., &Pedrotti, J.T., "Positive Psychology" Sage, 2nd edition.	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Chemistry**

1. Subject code: **CYN-009** Course Title: **Polymer Chemistry**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **BSC**
8. Pre-requisite: **Nil**
9. Objective: To familiarize students with polymeric materials and its importance.
10. Details of the Course:

S. No.	Contents	Contact Hours
1.	**Polymeric materials:** Historical development of polymers, classification and nomenclature of polymers. Homopolymers, copolymers, block copolymers, polymer blends, inorganic polymers, and composites. Bio- and non-bio-degradable polymers. Soluble and insoluble polymers. Specialty of polymers in comparison to low molecular weight materials. Macromolecules *versus* polymers.	4
2.	**Polymer structures:** Linear, branched and cross-linked polymers. Polymer chain configuration, conformation and tacticity. Size of polymer chains and estimates of polymer chain size. Polymer chain interactions and cohesive energy density. Polymer chain polarity and its effect on physical properties of polymers–density, crystallinity and solubility.	6
3.	**Molecular weights and properties of polymers:** Molecular weight and degree of polymerization, weight average and number average molecular weight, sedimentation and viscosity average molecular weight, polydispersity and size of polymer molecule. Molecular weight dependence physical properties of polymers. Hydrodynamic radii of polymers and its relation with molecular weight of polymers. Amorphous polymers and crystalline polymers. Glass transition and melting temperatures. Degree of crystallinity and mesophase polymers.	8
4.	**Polymerization methods:** Purity and polymerizability of monomers, common initiators, inhibitors and chain transfer agents used in polymerization, bulk polymerization and auto acceleration. Solution polymerization and role of the solvent. Suspension and emulsion polymerization. Interfacial and phase transfer polymerization and its advantages. Effect of methods of polymerization on properties of the polymers.	10
5.	**Polymer reactions and mechanisms of polymerization:** Polymer chain hydrolysis, acidolysis, aminolysis and alcoholysis. Hydrogenation, addition, substitution, cyclization and chemical cross-linking reactions. Polymer chain functionality and gelation, physical and chemical degradation. Classification of polymerization reactions, free radical and ionic chain polymerization, addition and step growth polymerization, coordination polymerization, Zeigler-Natta catalysis and polymer chaintacticity.	8
6.	**Commercial polymers and their applications:** Polyethylene, high and low density polyethylene, ultrahigh molecular weight polyethylenes, polycarbonates, nylons,	6

	amino and epoxy based resins and their commercial importance, thermosetting and thermoplastic polymers and their applications.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Book/ Publisher	Year of Publication/ Reprint
1	Flory, P.J., "Principles of Polymer Chemistry", Cornell University Press, Ithaca, New York.	**1953**
2	Fried, J.R., "Polymer Science and Technology", Prentice Hall , U. K.	**2002**
3	Odean, G., Principles of Polymerization, 4th Edition, John Wiley & Sons, New Jersey	**2004**
4	Young R.J., Lovell, P.A., "Introduction to Polymers" 3rd Edition, CRC Press, Taylor and Francis Group	**2011**
5	Carraher, Jr C.E. "Introduction to Polymer Chemistry" 3rd Edition CRC Press, Taylor & Francis group.	**2012**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-103** Course Title: **Computer Programming and Numerical Methods**

2. Contact Hours: **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weightage**: CWS 15 PRS 25 MTE 20 ETE 40 PRE 0**

5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: ESC**

8. Pre-requisite**: Nil**

9. Objective: To introduce object oriented programming using C++ language and numerical analysis

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Computer Fundamentals:** Introduction to computer systems - CPU organization, ALU, registers, memory and input-output devices; Number system: binary and hexadecimal; Fixed and Floating point numbers; Errors and Approximations	**4**
2.	**Basic Programming in C++:** Concepts of algorithm & flow charts; Input/output, constants, variables, expressions and operators; Naming conventions and styles; Conditions and selection statements; Looping and control structures; File input/output, header files, string processing; Preprocessor directives such as #include, #define, #ifdef, #ifndef; Compiling and linking.	**6**
3.	**Modular Programming**: Functions (void and value returning), parameters, scope and lifetime of variables, passing by value, passing by reference, passing arguments by constant reference; Design of functions and their interfaces, recursive functions; Function overloading and default arguments; Library functions; Matters of style, naming conventions, comments	**6**
4.	**Aggregate Data-types**: Arrays and pointers; Structures; Dynamic data and pointers, dynamic arrays.	**4**
5.	**Object Oriented Programming**: Classes and Objects; Constructors and Destructors; Operator Overloading and Type Conversions; Inheritance: extending classes; Pointers; Virtual Functions; Polymorphism; Manipulating Strings; Use of Pointers in linked arrays.	**8**
6.	**Solution of Linear and Non-Linear Equation:** Direct methods	**6**

	such as Gaussian elimination and Thomas algorithm for tri-diagonal systems; Iterative methods such as Jacobi method and Gauss-Seidel method; Single variable using Bisection method and Newton-Raphson method; Application of Newton-Raphson to two variables	
7.	**Numerical Interpolation, Differentiation and Integration**: Difference tables, forward, central and backward difference interpolation; Interpolating polynomials; Differentiation formulas; Trapezoidal rule, Simpson's rule	**4**
8.	**Solution of Ordinary Differential Equations**: Initial value problems (IVPs), Euler Method and Runge-Kutta method	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Balaguruswamy, E., "Object Oriented Programming with C++", Tata McGraw Hill Education, 5th Edition.	**2011**
2.	Lafore, R., "Object Oriented Programming with C++", Pearson, 4th Edition.	**2008**
3.	Dietel, H. M. and Dietel, P. J., "C++ How to Program", Prentice Hall, 8th Edition.	**2011**
4.	Sastry, S. S., "Introductory Methods of Numerical Analysis", PHI Learning, 5th Edition.	**2012**
5.	Chapra, S. C., "Applied Numerical Methods with MATLAB for Engineers and Scientists", Tata McGraw Hill Education, 3rd Edition.	**2012**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-322** Course Title: **Optimization of Chemical Engineering Processes**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight: **CWS 25** **PRS 0** **MTE 25** **ETE 50** **PRE 0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge of optimization methods used in Chemical Engineering.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Optimization and calculus based classical optimization techniques.	**5**
2.	**One Dimensional Minimization Methods:** Elimination methods- equally spaced points method, Fibonacci method and golden section method; Interpolation methods-quadratic interpolation and cubic interpolation, Newton and quasi-Newton methods.	**6**
3.	**Linear Programming:** Graphical representation, simplex and revised simplex methods, duality and transportation problems.	**7**
4.	**Multivariable Non-Linear Programming:** Unconstrained- univariate method, Powell's method, simplex method, rotating coordinate method, steepest descent method, Fletcher Reeves method, Newton's methods Marquardt's method and variable metric (DFP and BFGS) methods; Constrained- complex method, feasible directions method, GRG method, penalty function methods and augmented Lagrange multiplier method.	**9**
5.	**Dynamic Programming:** Multistage processes- acyclic and cyclic, sub-optimization, principle of optimality and applications.	**4**

6.	**Geometric Programming (GP):** Differential calculus and Arithmetic- Geometric inequality approach to unconstrained GP; Constrained GP minimization; GP with mixed inequality constraints and Complementary GP.	**6**
7.	**Emerging Optimization Techniques:** Genetic algorithm, simulated annealing, particle swarm and ant colony optimization.	**5**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Rao S. S., ''Engineering optimization: Theory and Practice", 4th Ed., Wiley	2009
2.	Edgar T. F., Himmelblau D. M. and Lasdon L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill.	2001
3.	Ravindran A., Ragsdell K. M. and Reklaitis G. V., " Methods and Application'' 2nd Ed., Wiley	2006
4.	Venkataraman P., " Applied Optimization with MATLAB Programming'',2nd Ed., Wiley	2009
5.	Beveridge G.S.G. and Schechter R.S., " Optimization: Theory and Practice'', McGraw Hill	1970

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-323** Course Title: **Computer Applications in Chemical Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **Practical**

4. Relative Weight: **CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**:4** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide knowledge of advanced numerical methods and their applications to chemical engineering problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Review of solution methods of non linear single variable equations, polynomials (determination of quadratic factors), linear set of simultaneous equations, ill conditioned matrix, and set of nonlinear equations using Newton's and globally convergent methods	**8**
2.	Solution of homogeneous set of linear equations using eigen values and eigen vectors with application to chemical engineering problems.	**3**
3.	Review of numerical differentiation and numerical integration methods, quadratures and their applications to numerical integration.	**4**
4.	Review of single step and multiple step methods to solve initial value ordinary differential equations problems, estimation of error and its propogation in single step and multiple step methods, step size selection and adaptable step size Runga-Kutta methods, stiff ODE's and Gear's class of methods.	**8**
5.	Boundary value problems (BVP) - shooting methods for linear system, finite difference methods, regular perturbation method, method of weighted residuals and orthogonal collection methods to solve first and higher order BVP in ODE's application to chemical engineering systems, concept of finite element.	**10**
6.	Review of finite difference techniques to solve partial difference equations (PDE's), similarity transformation, method of weighted residuals, orthogonal collocation to solve PDEs with their application to chemical engineering systems.	**9**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Finlayson B. A., "Introduction to Chemical Engineering Computing", 7th Ed.., Wiley Interscience publication.	2006
2.	Gerald C. F. and Wheatly P. O.; "Applied Numerical Analysis", 7th Ed., Addison Wesley.	2003
3.	Rice R.G. and Do D. D., "Applied Mathematics for Chemical Engineers", Wiley.	1995
4.	Beers K. J., "Numerical Methods for Chemical Engineering: Applications in Matlab", Cambridge University Press.	2006
5.	Constantinides A. and Mostoufi N., "Numerical Methods for Chemical Engineers with MATLAB Applications", Prentice Hall.	1999
6.	Cutlip M. B. and Shacham M.., "Problem Solving in Chemical and Biochemical Engineering with POLYMATH, EXCELL and MATLAB", 2nd Ed., Prentice Hall.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1.Subject Code:**CHN-324** Course Title: **Computational Fluid Dynamics**

2.Contact Hours: **L: 3** **T:1** **P: 0**

3.Examination Duration (Hrs.):**Theory3** **Practical0**

4.Relative Weight:**CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5.Credits**:4** 6. Semester**: Spring** 7. Subject Area**: PEC**

8.Pre-requisite**:Nil**

9.Objectives: To provide an understanding of physical models to study hydrodynamics in engineering systems.

10.Details of Course:

S.No	Contents	Contact Hours
1.	**Basic Concepts of Fluid Flow:** Philosophy of computational fluid dynamics (CFD), review of equations governing fluid flow and heat transfer, simplified flow models such as incompressible, inviscid, potential and creeping flow, flow classification.	5
2.	**Grid Generation:** Structured and unstructured grids, choice of suitable grid, grid transformation of equations, some modern developments in grid generation in solving the engineering problems.	3
3.	**Finite Difference Method (FDM):** Discretization of ODE and PDE, approximation for first, second and mixed derivatives, implementation of boundary conditions, discretization errors, applications to the engineering problems.	15
4.	**Finite Volume Method:** Discretization methods, approximations of surface integrals and volume integrals, interpolation and differential practices, implementation of boundary conditions, application to the engineering problems.	9
5.	**Case studies:** Case studies using FDM and FVM: Flow and heat transfer in pipes and channels, square cavity flows, reacting flow, reactive flow, multiphase flow, Heat Transfer in Rotary Kiln Reactors, Fluid mixing, etc. Essence of Finite element method (FEM) .	10
	Total	42

11.Suggested Books:

S.No.	Authors / Name of Books / Publisher	Year of Publication
1.	Fletcher C.A.J. “Computational Techniques for Fluid Dynamics, Vol. 1: Fundamental and General Techniques”, Springer-Verlag.	1998
2.	Fletcher C.A.J. “Computational Techniques for Fluid Dynamics, Vol. 2: Specific Techniques for Different Flow Categories”, Springer-Verlag .	1998
3.	Anderson. J.D., “Computational Fluid Dynamics”, McGraw Hill.	1995
4.	Ghoshdastidar P.S., “Computer Simulation of Flow and Heat Transfer”, Tata McGraw Hill.	1998
5.	Patankar S.V., “Numerical Heat Transfer and Fluid Flow”, Taylor and Francis.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-325** Course Title: **Process Integration**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.):**Theory:3** **Practical:0**

4. Relative Weight: **CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**:** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the concept of pinch technology in integration of unit operations in process industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Process Integration and its Building Blocks:** Definition of Process Integration (PI), School of thoughts, Areas of application and Techniques available for PI, Onion diagram.	**6**
2.	**Pinch Technology – An Overview:** Introduction, Basic concept, How it is different than energy auditing, Role of thermodynamic laws, Problem addressed by Pinch technology.	**7**
3.	**Key Steps of Pinch Technology:** Data extraction, Targeting, Designing, Optimization-Supertargteing.	**5**
4.	**Basic Elements of Pinch Technology:** Grid diagram, Composite curve, Problem table algorithm, Grand composite curve.	**5**
5.	**Targeting of Heat Exchanger Network (HEN):** Energy targeting, Area targeting, Number of units targeting, Shell targeting, cost targeting.	**5**
6.	**Designing of HEN:** Pinch design methods, Heuristic rules, Stream splitting, Design of maximum energy recovery (MER), Design of multiple utilities and pinches, Design for threshold problem, Loops and Paths.	**6**
7.	**Heat Integration of Equipments:** Heat engine, Heat pump, Distillation column, Reactor, Evaporator, Drier, Refrigeration systems.	**4**
8.	**Heat and Power Integration:** Co-generation, Steam turbine, Gas turbine.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Kemp I. C., "Pinch Analysis and Process Integration: A user Guide on Process Integration for the Efficient Use of Energy", 2nd Ed., Butterworth-Heinemann.	2007
2.	Smith R.., "Chemical Process Design and Integration", 2nd Ed., Wiley.	2005
3.	Shenoy U. V., "Heat Exchanger Network Synthesis", Gulf Publishing Company.	1995
4.	El Halwagi M. M., "Process Integration", 7th Ed., Academic Press.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-325** Course Title: **Transport Phenomena in polymeric Solutions**

2. Contact Hours: **L: 3** **T: 1** **P:**

3. Examination Duration (Hrs.): **Theory:3** **Practical:0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective**:** To provide knowledge of Cell balances in steady/unsteady state transport processes involving momentum, energy, mass.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Review of mathematics of vectors and tensors; Use of various co-ordinate systems; Kronicker delta; Integral theorem; Differential operators; Invariants; Ordinary/partial differential equations and common solution techniques.	**04**
2.	**Fluid Mechanics (Isothermal Systems):** Shell balances and velocity distributions in laminar flow through tube, annular space and tube-flow of adjacent immiscible liquids; Interfacial boundary conditions; Flow through a slit.	**04**
3.	**Equation of Change for Isothermal Systems:** Equation of continuity; Equation of motion; Equation of mechanical energy; Equation of angular momentum; Vorticity; Stress and rate of strain tensor; Newtonian case (Navier Stokes and Euler equations); Example of flow problems: creeping flow, Hagen-Poiseuille flow and Coutte flow; Cone and plate viscometer and parallel plate torsion; Viscoelastic fluids.	**06**
4.	**Polymeric Liquids:** Analysis of behaviour of polymeric liquids; Rheometry; Non-Newtonian viscosity and the generalized Newtonian models; Elasticity and linear viscoelastic models such as Maxwell, Kelvin, Jeffreys and Burger model and their combinations; Corotationalderivaties and non-linear viscoelastic models; Molecular theories of polymeric liquids.	**04**

5.	**Energy Transport and Heat Transfer:** Energy generalized balance and heat equation; Conductivity, heat capacities, temperature and pressure dependence of conductivity; Theory of thermal conductivities.	**06**
6.	**Equations of Change for Non-isothermal Systems:** Special forms of heat equation (for internal energy and for temperature); Boussinesq equation for forced and free convection; Use of equations of change to solve steady state problems involving polymeric fluid fluxes; Boundary layer theory for non-isothermal flow; Laminar flow heating-Von Karman momentum and energy balances.	**06**
7.	**Mass Transport:** Mass transfer/molecular transport by convection; Molar fluxes; Fick's law; Maxwell-Stephan's law; Diffusion in binary liquids and gases at low density; Permeability, solubility, diffusivity of gas and solute through polymers; Shell balance and boundary conditions.	**06**
8.	**Equation of Change:** Equation of continuity for multicomponent systems; Dimensional analysis of equations of change for non-reacting binary mixtures, species continuity, constant mass density, constant molar density; Sorption of gases and vapors in polymers: rubbery polymers, glassy polymers, semi-crystalline polymers.	**06**
	Total	**42**

11. **Suggested Books:**

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Bird R.B., Stewart W.E. and Lightfoot E. N., "Transport Phenomena", McGrawhill Second Ed.	2002
2.	Mashelkar R.A., Majumdar A.S., Kamal M.R., "Transport Phenomena in Polymer Solution", Ellis Horwood Publisher	1989
3.	Deen W.M., "Analysis of Transport Phenomena", Oxford University Press. ISBN 978-0-19-508494-8.	1998
4.	Whitaker S., "Fundamental Principles of Heat Transfer", New York, Pergamon Press	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-401** Course Title: **Bio- Polymers Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory: 3** **Practical :0**

4. Relative Weightage: **CWS:25** **PRS: 0** **MTE:25** **ETE:50** **PRE: 0**

5. Credits: **4** 6. Semester: **Both** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge about biopolymers and their applications, engineering and processing.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definition, examples, applications and classification of biopolymers based on different sources; General characteristics of biopolymers; Advantages and disadvantages of biopolymers.	**5**
2.	**Synthesis and Characterization of Bio-polymers:** Structure and properties of proteins, polysaccharides, DNA, RNA,glycoproteins, proteoglycans, glycosaminoglycans.	**8**
3.	**Biodegradation of Biopolymers:** Mechanism of biodegradation; Biodegradation kinetics.	**4**
4.	**Engineering of Biopolymers:** Principles of engineering the properties of biopolymer molecules; Chemical modification; Biopolymer based composites and blends.	**8**
5.	**Biopolymer Processing:** Process technology for the production of biopolymeric nanoparticles, nanofibers, nanofilms, microfilms, 3D architecture of any shape.	**8**
6.	**Application of Biopolymers**: Application of biopolymersin tissue engineering, medical surgery, drug delivery, wound healing, packaging, automobile industry, electronics industry, household items etc.	**9**
	TOTAL	**42**

11. Suggested Books:

S. No.	Name of Books / Authors /Publisher	Year of Publication / Reprint
1.	Dumitriu S., “Polymeric Biomaterials”, Marcel Dekker.	2002
2.	Hyon S. H., “Polymeric Biomaterials”, Plennum Press.	1984
3.	Mark H. F., (Ed.) “Encyclopaedia of Polymer Science and Engineering”, John Wiley & Sons.	1989
4.	Shuiz S. and Bhirmer K., “Principles of Protein Structure”, Academic Press.	2003
5.	GuilakF., Butler D.L., Goldstein S.A. andS.A. Mooney, “Functional Tissue Engineering”, Springer-Verlag New York, 1st Edition.	2003
6.	Migonney V., “Biomaterials”, Wiley-ISTE, 1st Edition.	2014

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-402** Course Title:**High Performance and Special Polymers**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical:0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective:To impart knowledge of structure, properties, processing and manufacturing of the polymeric materials at high end applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Engineering Polymers:** Polymerization and Industrial processing, Unit operations, Catalysts, Flow Chart of Industrial Production and Structure, Properties, Applications of following Commodity/Engineering plastics –Polyolefins, Vinyl Polymers and Stryrene Polymers likePolyethylene, Polypropylene, Polyisobutylene, Poly(1-Butylene), Poly (vinyl chloride), Polystyrene,Styrene co-polymers,ABS, SAN, Polyacrlics, and others.	8
2	**Macromolecular Structure of High Performance Polymers:** Semi rigid, quasi-rigid and rigid rod macromolecules; Macromolecular chain rigidity and rotational hindrance; Effect of chain rigidity on thermal and mechanical properties of high performance polymers.	5
3	**High Performance Thermoplastics**: Structure, properties, and engineering and high-tech applications of following high performance polymers: polyamides, polyesters, polycarbonate, polyethers, poly-ether-ether-ketone, polyphenylenesulphide, polysulphones, polyphenylene-oxides	6
4	**Thermally Stable Polymers:** Structure, properties, and engineering and high-tech applications of following high performance polymers: polyesterimides, polyetherimides, polybismelimides, poly-amide-imide, pyromellitic di anhydride oxy dianiline.	6
5	**Thermotropic Liquid Crystalline Polymers:**Thermotropic liquid crystalline polymers; Structure and parameters imparting thermotropic nature; Main chain and side chain thermotropic polymers; Fibers from thermotropic polymers; Structure-property co-relations; Advanced, engineering and high tech applications.	6
6	**Lyotropic Liquid Crystalline Polymers:** Structural parameters imparting lyotropic liquid crystalline nature; Aramid and other lyotropic polymers; Fibers from lyotropic polymers; Dry-jet wet-spin processing; Structure-property co-relations; Advanced,	6

	engineering and high tech applications.	
7	**High Performance Polymers for Engineering Applications:** High performance polymers for following applications: automobile, aerospace, transportation and other engineering and high tech applications.	5
		Total 42

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication
1.	Brydson J. A., "Plastic Materials", Newnes Butterworth	1989
2.	Campbell I.M., "Introduction to Synthetic Polymers", Oxford University Press	2000
3.	Erhstein G., "Polymeric Materials", HanserGardner.	2001
4.	Baer E., Moet A. "High performance polymers", Hansen Publisher.	1991
5.	Fin J.K.,"High performance polymers", Elsevier, 2nd Edition.	2014

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-403** Course Title: **Electronic and Conducting Polymers**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.):**Theory :3** **Practical :0**

4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: Thecourse will impart knowledge of electronic and conducting polymers

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Conducting polymers, structurally different conducting polymers and their general applications	2
2.	**Conducting Polymers :** Structure, mechanism of Conduction, preparation of conducting polymers e.g. polyacetylene, polydiacetylene, polyphenylene, polypyrrole, polythiphene, polyaniline, poly(phenylenesulphide) and poly (1,6-heptadiyne); Properties and applications	9
3.	**Photoconducting Polymers**: Molecularly designed synthesis and characterization of light sensitive and photo conducting polymers and their application. **Photoresist Polymers:** Positive and negative polymer resists for lithographic process, semiconductor fabrication by LB films and spin coatings techniques	8
4.	**Polymers for Optoelectronics :** Synthesis of *Guest-Host* type and side chain liquid crystalline polymers and NLO chromophore-functionalized polymers, LASER light sensitive polymers exhibiting second harmonic and third harmonic generation ; Poling of *Guest Host* polymers; Genral optical characterization and their application	8
5.	**Piezoelectric, Pyroelectric and Ferroelectric Polymers:** Synthesis, characterization and typical application of these polymers	6

6.	**Applications:** Polymers in telecommunications, microelectronics, insulations, submarine cable insulation, polymers in optical fiber cables	9
	Total	42

11. Suggested Books:

S. No.	Name of Authors /Books /Publishers	Year of Publication
1.	Goosey M.T., "Plastic for Electronics", Elsevier, Applied Science Publishers	1985
2.	Licari J.J., "Hand book for Polymer Coatings for Electronics Chemistry, Technology and Applications", Noyes Publications	1985
3.	Mark H.F., "Encyclopedia of Polymer Science and Engineering," John Wiley and Sons	1989
4.	Nalwa H.S., Miyata S., "Nonlinear Optics of Organic Molecules and Polymers, CRC Press, Inc.	1997
5.	Skotheim T.A., Reynolds J.R. "Conjugated Polymers; Processing and Applications", CRC Press	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN- 404** Course Title: **Polymeric Film Technology**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory:3** **Practical :0**
4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**
5. Credits**: 4** 6. Semester**: Autumn/Spring** 7.Subject Area**: PEC**
8. Pre-requisite**: Nil**
9. Objective: The course will impart knowledge of polymeric films and packaging materials and their processing.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Polymers for Films and Sheets**: Structure, properties and morphology of film and sheet forming polymers.	4
2.	**Blown Film:** Principle, technologyand operation ofequipment for processing of blown film, structure and properties of blown films.	8
3.	**Melt Processed Film:** Materials, processes, equipment and machinery formelt processing offilm, effect of processing parameters on structure and properties of melt processed film applications.	8
4.	**Multi Layered Films:** Materials and equipment for multi layered films,structure, properties and applications of films multi layered films; Tetra-packs.	8
5.	**Packaging Materials:** Types of packaging, film, sheet, and boxes, laminated packaging, packaging for electronic goods, commodity materials, medicines and food products.	6
6	**Processing:** Equipment and machinery for processing of packaging materials, principle, technologyand operation ofequipment, economics of packaging; Die design for film making.	6
	Total	**42**

11. Suggested Books

S. No.	Name of Books / Authors / Publisher	Year of Publication
1.	Bryston J. H., “Plastic Films”, Longman.	2003
2.	Osswald J., “Polymer Processing Fundamentals”, Hanser Gardner.	2004
3.	Brooks D. and Giles G., (Eds), “PET Packaging Technology”, Sheffield Academic Press.	2002
4.	Lagarón J .,“Multifunctional and Nanoreinforced Polymers for Food Packaging”, Woodhead Publishing.	211
5.	Hashim A.A., “Polymer Thin Films”, InTech.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-405** Course Title: **Polymeric Membrane Technology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective**:** To provide knowledge about polymeric membranes and its application in separation processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**:Separation concepts: diffusion across a membrane, terminologies in membrane separation processes, driving forces, type of membranes.	**2**
2.	**Transport Mechanism through Membrane:**Concentration and process gradients, solution-diffusion model, concentration polarization, gel layer concentration.	**4**
3.	**Membrane Materials:** Polyethylene, polytetrafluroethylene, polypropylene, cellulose acetate, cellulose nitrite, polyacrylonitrile, polyimide, polyamide, polysulfone, polyethersulfone, blockcopolymeric materials; Bi-polar membrane materials; Inorganic membranes.	**6**
4.	**Polymeric Membrane Preparation, Testing and Applications:** Sintering, stretching, track-etching, template leaching, phase inversion techniques (diffusion-induced phase separation & thermally-induced phase separation), phase inversion membrane and interfacial polymerization; Membrane testing and morphology; Applications: Haemodialysis, beverage, food industry, water treatment and fuel cell.	**6**
5.	**Microfiltration and Ultrafiltration:** Membrane properties, concentration polarization and fouling, fouling during protein separation, crossflow and dead-end microfiltration/ultrafiltration, micellar enhanced ultrafiltration, selected application and economics.	**5**
6.	**Nanofiltration and Reverse Osmosis:** Membrane properties, osmotic pressure model, membrane fouling, design consideration, pretreatment, applications in desalination and wastewater treatment, economic consideration.	**6**
7.	**Pervaporation:** Membrane properties, process diagram, mechanism, selectivity and flux, model consideration, application (alcohol concentration, VOC and other pollutant separation).	**4**

8.	**Membrane Reactor:** Membrane separation with chemical reaction; Membrane bioreactor, catalytic membranes, equilibrium limited reaction, membrane reactor for hazardous pollutant degradation, functionalized membrane.	**5**
9.	**Membrane Application for Water/Wastewater Treatment and System Design:** Hydride processes and novel application, selected environmental applications involving for water reuse and material recovery, membrane flux, fouling and separation optimization.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Mulder M., "Basic Principles of Membrane Technology", Kluwer Academic Publisher.	1996
2.	Baker R.W., "Membrane Technology & Application", McGraw Hill.	2000
3.	Zeman L. J. and Zydney A. L., " Microfiltration and Ultrafiltration: Principle & Application", Marcel Dekker Inc.	1996
4.	Nath K., "Membrane Separation Processes", Prentice Hall of India.	2008
5.	Scott K., "Handbook of Industrial Membrane", Elsevier.	1995
6.	Schaefer A., "Nanofiltration, Principle & Application", Elsevier.	2004
7.	Drioli E. Criscuoli A. and Curcio, E., "Membrane Contactors: Fundamentals, Applications and Potentialities", Elsevier.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-406** Course Title: **Advanced Polymer Composites**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: The course will impart knowledge of advanced composites

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Concept of reinforcement in polymeric composites, introduction and overview of particulate, short and continuous fiber reinforced composites, and nano particle and nanofibre composites; aspect ratio and reinforcing efficiency of reinforcement	**2**
2.	**Advanced Particulate Polymeric Composites:** Principles of selecting a particle as reinforcement, incorporation, packing and geometry of reinforcement particles; Wollastonite, fledspar and nepheline syenite, red mud, beryllium oxide, zinc oxide, titanium oxide as particulate reinforcements; Extrusion and compounding of particulate composite by single and twin screw extruder; and processing by injection molding; semi-empirical equations for Young's modulus of particulate composites.	**8**
3.	**Advanced Short Fiber Reinforced Polymeric Composites:** Glass, aramid, and natural fibers as reinforcement; principles of selection and efficiency of short fiber as reinforcement; orientation of short fibers in a composite; isotropy and anisotropy of composites; short fiber / thermoset composites; natural fiber / polymer composites, their fiber/matrix interface and methods for improvement of fibre/matrix interfacial adhesion in them	**8**
4.	**Advanced Continuous Fiber Reinforced Thermoset Polymeric Composites:** Phenolic and polyimide as thermosetting matrix resins; silica, high silica and boron as reinforcing continuous fibers; fiber orientation in composites; unidirectional, quasi-isotropic and isotropic composites; fiber-matrix interphase and interfacial adhesion; interface improvement and use of interfacial agents, fiber surface treatment, matrix modification, and compatibilizers for improvement; Composite fabrication techniques, processes and equipment; pultrusion and and other advanced processing techniques; Statistical mechanics and semi empirical equations for tensile modulus; advanced applications.	**8**

5.	**Continuous Fiber Reinforced Thermoplastic Polymeric Composites:** Polyether-ether-ketone, polyetherimide, polyethersulfone, and other high performance thermoplastics as matrix resins, fiber/matrix adhesion, interphase , and interface improvement; fabrication techniques; equipment, processes and processing of long and continuous thermoplastic composites; limitations of processing techniques; Applications.	**7**
6.	**Nano Composites:** Fillers: Plate, equi-axed, inorganic fillers, carbon and other nano tubes. Matrices: Engineering, high tech and liquid crystal polymer matrices. Processing: Direct and solution mixing, in-situ polymerization.	**7**
7.	**Applications:** Fire resistant, high temperature, automobile, and aerospace applications.	**2**
	Total	**42**

11. Suggested Books

S. No.	**Name of Books / Authors / Publisher**	**Year of Publication**
1.	Ajayan P. M., Schadler L. S., Braun P. V., "Nanocomposite Science & Technology", Wiley-VCH.	2003
2.	De S. and White J., "Short Fiber Composites", Technomic.	2006
3.	Summerscales J. and Short D., "Fiber Reinforced Polymers", Technomic.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-407** Course Title: **Advanced Extrusion and Compounding**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/ Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To provide advanced knowledge of polymer extrusion and compounding

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Products manufactured using extruders; Fundamental principles; Different types of extruders; Extruder hardware, instrumentation and control.	03
2.	**Types of Extruders:** Single screw extruder: Basic operations, vented extruders, rubber extruders; Multi-screw extruders: Twin screw, multi-screw with more than two screws, gear pump extruder; Disk extruders; Ram extruders.	04
3.	**Extruder Hardware and Instrumentation:** Extruder drive; Thrust bearing assembly; Barrel and feed throat; Feed hopper; Extruder screw; Die assembly; Screens and screen changers; Heating and cooling systems: Electric heating, fluid hearing, extruder cooling, screw heating and cooling; Instrumentation requirements; Pressure measurements; Temperature measurements; Rotational speed; Temperature controls.	08
4.	**Twin Screw Extruders:** Twin versus single screw extruders; Intermeshing co-rotating extruders; Intermeshing counter-rotating screw extruders; Coaxial twin screw extruders; Devolatilization in twin screw extruders; Commercial twin screw extruders.	06
5.	**Extruder Screw and Die Design:** Mechanical considerations; Optimization of output; Optimizing for power consumption; Single flighted extruder screws, devolatilizing extruder screws; Multi-Flighted extruder screws, Mixing screws, Rebuilding worn screws and barrels; Die Design:Basic consideration; Film and sheet dies; Blown film dies; Profile extrusion dies; Coextrusion; Calibrators.	08
6.	**Polymer Properties and Design considerations:** Bulk polymer properties: Bulk density, coefficient of friction and particle size and shape; Thermal and melt flow properties: Thermal conductivity, specific volume and morphology, specific heat and heat of fusion, specific enthalpy, thermal diffusivity, melting point, induction time, viscoelastic behavior. Design considerations for extruding: Olefins, PVC, PS, engineering thermoplastics, blending and additive, compounding.	08
7.	**Troubleshooting:** Requirements for efficient troubleshooting; Data and tools for troubleshooting; Systematic troubleshooting: Upset	05

	versus development problems, machine related problems, polymer degradation, extrusion instabilities, air entrapment, gel problems and die flow problems.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Chris R., "Polymer Extrusion", Hanser Publications, 5th Edition, Hanser.	2014
2.	Tadmor Z. and Gogos C.G., "Principles of Polymer Processing", Wiley.	2000
3.	Lafleur P.G., Verfnes. B., "Polymer Extrusion", Wiley.	2014
4.	Hensen F., Berghaus. U., "Plastic Extrusion Technology", Hanser Publications, 2nd Edition.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-408** Course Title: **Paint and Coating Engineering**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**: 3** 6. Semester**: Autumn/ Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge about paint, paint formulation andmanufacture, surface coating methods and its applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definition and properties; Importance of paints; Classification of paints.	2
2.	**Basic Paint Ingredients:** Binders: classification and properties; Synthetic and natural binders: synthetic and natural resins, acrylics, vinyl acrylics, polyurethane, polyester, melamine resins, epoxy, oils; Solvent: types and properties; Fillers; Paints additives.	5
3.	**Formulation and Manufacturing of Paints:** Principles of paint formulation; Phenomenon of wetting, grinding and dispersion; Steps in paint manufacturing; Equipment for paint manufacturing: Ball mills, peddle mills, high speed disk disperser, double blade mixture; Problems in paint manufacturing and their solutions; Paint preservation methodology.	7
4.	**Paint Applications, Drying, Curing, and Defects:** Pretreatment and surface preparation; Application methods; Common defects and its prevention.	5
5.	**Paint Testing and Environmental Protection**: Important paint properties; Scrape adhesion test; Pull-off test; Cross cut test; Wedge-cut method for determination of film thickness (scribe and drill method); Pollution from solvent, pigment and binders; Safety measures in paint industry and pollution control.	5
6.	**Surface Coating**: Significance of coating and surface engineered materials, and application; Surface dependent	3
7.	Surface Treatment and Surface Coating Methods: Surface treatment and surface energy testing on post-treatment step; Coating methods; Gravure coating, knife over roll coating, hot melt coating, reverse roll pan, Myer bar, slot orifice, immersion/dip coating, chemical and physical vapor deposition; Electrode and electrode-less deposition, and thermal spray process.	7
8.	**Process Parameters and Engineered Surface Coating:** Influence of process parameters on surface yield and surface properties of coating: Physical and mechanical characteristics of the coating; Industrial coatings: Multi-layered coating, super hydrophilic and hydrophobic coating; Lyophilic coatings.	4

9	**Performance Testing of Coated Product:** Accelerated weathering test, salt spray and immersion resistance; Abrasion, adhesion, contact angle, hardness test; TiN coated tool, performance evaluation of CVD diamond coated tool.	**4**
	TOTAL	**42**

11. Suggested Books:

S. No.	Name of Books / Authors /Publisher	Year of Publication / Reprint
1.	Morgans W.M., "Outlines of Paint Technology",3rd Ed., .CBS Publishers.	1990
2.	Schweitzer P.A., "Paint and Coatings: Application & Corrosion Resistance", 1st Ed., CRC Press.	2005
3.	Grainger S. and Blunt J., "Engineering Coating: Design and Application" 2nd Ed., Elsevier.	1998
4.	Tracton A.A., "Coating Technology Hand Book", 3rd Ed., CRC Press.	2005
5.	Koleske J.V., "Paint and Coating Testing Manual", 15th Ed., ASTM International.	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-409** Course Title: **Polymeric Fiber Technology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/ Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: The course is intended to provide understanding about technology of polymeric fibers.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Structure, properties and morphology of fiber forming natural and synthetic polymers.	4
2.	**Processing**: Melt and solution spinning operation, general principles of fluid flow, spinning and extrusions, dry and wet spinning of fibers, spinneret size, rate of extrusion, effect of spinning on filament structure and properties; Die design.	8
3.	**Post-processing**: Post spinning, finishing, drawing and seat setting operations, effect on orientation and crystallization, heat setting and texturing, principles of setting of fibers and fabrics.	6
4.	**Characterization**: Testing of fibers: Density, birefringence, tensile, moisture regain, dyeing mechanism, color fastness.	10
5.	**Yarn synthesis:** Production of staple yarns of natural and synthetic fibers.	4
6.	**Production and Applications**: Manufacturing methods and applications of fibers based on: Polyethylene, polyamide, polypropylene, polyacrilonitrile, polyester, polylactic acid.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books /Publishers	Year of Publication
1.	Gupta V.B. and Kothari V.K. , "Manufactures Fiber Technology", Chapman and Hall.	2003
2.	Mark H.F., Atlas S.M. and Cernia E., "Man Made Fibres Science and Technology", Wiley Interscience.	1968
3.	Moncrieff R.W., " Man Made Fibres" , Haywood Books.	1975
4.	Vaidya A. A. "Production of Synthetic Fibers", Prentice Hall.	2001
5.	Deopura B. L., Alagirusamy R., Gupta B., Joshi M., "Fibrous Materials: Polyesters and Polyamides", Woodhead Publishing Ltd and CRC Press.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-410** Course Title: **Adhesives and Sealants Technology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/ Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To provide knowledge of various polymeric adhesives and sealants.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Adhesives and Sealants:** History of adhesive industry; Types of polymeric adhesives; Theory and mechanism	**7**

	of adhesion; Advantages and disadvantages of adhesive bonding over conventional joining techniques; Adhesive coating equipment's; Introduction to sealants, caulks and mastics; Advantages and disadvantages of sealant bonding over conventional joining techniques.	
2.	**Adhesive Performance and Characterization:** Description of performance properties of adhesives and their determination: Peel strength, shear strength, tack, creep and visco-elastic properties; Characterization of degree of branching, crystallinity, side-chain substitution, cross-linking, molecular weight, backing material; Identification of elastomer, tackifier, plasticizer, antioxidant and fillers.	**8**
3.	**Adhesive Types:** Properties, formulation principle, production techniques, additives and applications of adhesives: Pressure sensitive adhesives, structural adhesives, one part and multi-part adhesives, hot-melt adhesives, natural rubber adhesives, butyl and polyisobutylene adhesives, vinyl-ether adhesives, urea-formaldehyde adhesives, malamine-formaldehyde and resourcinol based adhesives.	**8**
4.	**Additives for Adhesives and Surface Preparation:** Tackifiers, cross-linkers, antioxidants, plasticizers, colorants, fillers and scents used to enhance mechanical performance, ageing characteristics, ease of use; Surface treatment procedures of substrates to improve adhesive bonding: Mechanical preparation, priming, corona treatment and chemical etching.	**6**
5.	**Specialty Adhesives:** Anaerobic adhesives, bio-adhesives, reactive adhesives and adhesives that get activated using light/UV and heat; Adhesives examples for various industries viz. electronics, wood industry, healthcare, construction, packaging, textiles, automotive, consumer, abrasives and friction material shoes, electrical, paper and aerospace.	**5**
6.	**Sealant Performance, Characterization and Applications:** Sealant types: Reactive sealants, hardening from melts, sealants based on water or solvent loss; Production processes and equipment's; Properties and formulation of sealants relevant to different application; Curing process of sealants; Characterization of sealants; Additives and its effects on sealant performance; Performance testing; Surface preparation; Specialty sealants; Sealant application in various industries; Major trends in technology and markets.	**8**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Satas D., "Handbook of Pressure Sensitive Adhesive Technology" Second Edition.	2014
2.	Taylor and Francis, "Handbook of Adhesive Technology", Second Edition, LLC.	2003
3.	Benedek I., "Pressure Sensitive Adhesive and Applications".	2004
4.	Petrie E.M., "Handbook of Adhesives and Sealants", Second edition, The McGraw-Hill Companies, Inc.	2007
5.	Flick E.W., "Handbook of Adhesives Raw Material".	1989

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-411** Course Title: **Rubber Product Technology**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory:3** **Practical :0**
4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**
5. Credits**: 4** 6. Semester**: Spring/Autumn** 7.Subject Area**: PEC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge of processing and applications of different rubbers.
10. Details of the Course:

S. No.	Contents	Contact Hours

1.	**Introduction:** Machinery used for rubber mixing-two roll mills, internal mixers and continuous mixers; Master batch preparation, blending and mixing on mills, internal mixers and continuous mixers.	**5**
2	**Machinery Used for Moulding**:Compression, transfer and injection moulding of rubbers; Flashlessmoulding, finishing of moulded articles, calculation of mould shrinkage, molding defects and its remedies; Machinery used for extrusion; Ram and screw extruders, extrusion technology, crosshead extruders and strainers.	**7**
3	**Rubber compounding:** Principles of rubber compounding; Compounding to meet processing and vulcanisate properties; Reinforcement of elastomers by fillers; Factors influencing reinforcement and mechanism of reinforcement; Compounding and manufacture of cycle tyres and tubes, solid tyres, mechanical seals, sports goods, surgical products and miscellaneous moulded, extruded and calendered rubber products.	**8**
4	**Engineering Aspect of Tyre Manufacturing Technology:** Different types of tyres: basic features and performance comparison; Components of tyres, tyre-geometry and functions; Manufacturing techniques of tyres: two wheeler, car tyres, truck tyres, OTR farm tyres and air craft tyres; Method of building bias belted, radial and tubeless tyres, green tyre treatments; Tyre curing methods; Quality control tests.	**9**
5.	**Engineering Aspect of Rubber Product Manufacturing other than Tyre:** Manufacturing techniques of conveyer belt technology, sealing ring technology, V-belt, footwear technology, hose technology, rubber coated roll, cable technology, vibration isolation and mounts.	**9**
6.	**Recent Trends in Rubber Manufacturing Technology:** Some recent trend of rubber processing technology; electron beam curing of rubber products; Computer aided rubber product design; Coated fabric technology.	**4**
	Total	**42**

11. Suggested Books

S.No.	Name of Authors /Books/Publishers	Year of

		Publication
1.	BhowmickA.K.,"Rubber Product Manufacturing Technology" CRC Press.	1994
2.	Johnson P., "Rubber Processing: An Introduction", Hanser-Gardner.	2001
3.	Morton M., "Rubber Technology", Van Norstrand-Reinhold.	1987
4.	Bhowmick A.K., "Current topic in Elastomer Research" CRC Press,	2008
5.	CiesielskiA.,"An Introduction to Rubber Technology"Rapra Technology Limited, UK	1999
6.	Blow C.M., "Rubber Technology & Manufacture"Buttenvorths, London	1982

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-412** Course Title: **Polymer Colloids**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/ Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To provide knowledge of polymer colloids

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Introduction to colloids (from blood to milk, pumice to gelatine); Polymer colloids and its applications; Colloidal	**04**

	structure due to addition of pigments, fillers and electrolytes; Colloidal structure in aqueous and non-aqueous medium.	
2.	**Polymer Emulsions:** Emulsion polymerization; Interfacial phenomena; Thermodynamic consideration and colloidal stability; Surfactants; Physical properties; Rheological properties; Film formation; Wetting; Surface modifications; Paint technology; Concentrated dispersions.	**10**
2.	**Colloidal Interaction and Stability:** Forces in colloidal system; Stability of colloidal particles and latex products; Order-disorder behavior of polymer colloids; Interface science; Janus particles.	**08**
3.	**Characterization of Colloids:** Particle size, microscopy, zonal methods, scattering methods, analysis of scattered radiation, neutron reflection, dynamic light scattering, rheological evaluation.	**10**
4.	**Advances in Polymer Colloids:** Advances in polymer latex technology, colloidal crystals-3D ordered arrays,soft particle glasses, polymeric self-assembly,nanotechnology with soft materials; colloidal biomolecules, biomaterials and biomedical applications, polymer nanocomposites, food colloids.	**10**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1.	Fitch R., "Polymer Colloids: A Comprehensive Introduction", Academic Press Inc., 1st Edition.	1997
2.	Chern C.S., "Principles and Applications of Emulsion Polymerization", Wiley.	2008
3.	Goodwin J.W., "Colloids and Interfaces with Surfactants and Polymers-An Introduction", Wiley.	2000
4.	Hamley I.W., "Introduction to Soft Matter", Wiley.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-413** Course Title: **Polymer Nanocomposites**
2. Contact Hours: L:**3** T: **1** P: **0**
3. Exam Duration (Hrs.): Theory **3** Practical **0**
4. Relative Weightage: **CWS:25 PRS: 0 MTE: 25 ETE: 50 PRE:0**
5. Credit: **4** 6.Semester: **Spring/Autumn** 7 Subject Area: **PEC**

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8. Prerequisite: **Nil**
9. Objective:To impart knowledge of preparation, processing and applications of polymer nanocomposites.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Nanocomposites and Nanofillers:** Overview of polymer nanocomposites; Classification of nanofillers: Nanoclay,	

	nanosilica, nanoparticles, carbon based nanofillers; Synthesis and properties of fillers.	**4**
2.	**Synthesis of Nanocomposites**: Direct mixing, solution mixing, in-situ polymerization, ex-situ processing; Ceramic/polymer composites; Metal/polymer nanocomposites; Modification of interfaces; Modification of nanofillers.	**6**
3.	**Thermal, Electrical and Optical Properties**: Thermal stability and flammability; Dynamic mechanical thermal properties; Glass transition; Electrical properties: resistivity, permittivity, breakdown strength; Optical properties: refractive index, transparency.	**8**
4.	**MechanicalProperties**: Stress-strain properties - tensile, modulus, elongation at break; Flexural properties; Load-carrying capability; Toughness; Impact resistance; Relaxation behavior; Wear resistance.	**7**
5.	**Morphological Properties**: Characterization of nanocomposites by XRD, TEM, AFM and FESEM.	**8**
6.	**Barrier Properties:** Permeation and diffusion models relevant to polymer nanocomposites: diffusivity, sorption.	**4**
7.	**Applications:** Applications of polymer nanocomposites in space, automobiles, defence, electronics, packaging, bio-medical engineering, filtration, coatings and cosmetic.	**5**
	Total	**42**

11. Suggested Books:

S. No.	Name of Book / Authors	Year of Publication
1.	Mai Y.W. and Yu Z.Z., "Polymer Nanocomposites", Woodhead Publishing Limited and CRC Press LLC, USA.	2006
2.	Ajayan P.M., Schadler, L.S., Braun, P.V., "Nanocomposite Science and Technology" Wiley-VCH Verlag GmbH Co. KGaA, Weinheim.	2003
3.	Nicolais L. and Carotenuto G., "Metal-Polymer Nanocomposites", Wiley Inter Science.	2005
4.	Sergeev G.B., "Nanochemistry" Elsevier	2006
5.	Ke Y.C. and Stroeve P., "Polymer-Layered Silicate and Silica Nanocomposites" Elsevier.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN- 414** Course Title: **Advanced Process Control**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/ Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective**:** To provide knowledge about advanced process control systems and their analysis.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**:Overview of dynamics of chemical processes, and control systems of simple and complex nature; Control system analysis; Importance of advanced computer control in chemical process industry with examples; Overview of dynamic process control	**5**

	and related transfer functions.	
2.	**Advanced Control Strategies:** Analysis of cascade control; Split-range control; Selective control; Override control and auctioneering control; Smith-predictor control; Multi-loop control such as combination of feedforward, feedback and inferential control; Batch process control- sequential and logic control; Real time optimization and DCS-loop analysis.	**7**
3.	**Advanced Tuning Methodologies for Traditional and Non-traditional Control:** Advanced control system design with hybrid control: PI-PD, PI-PID and I-PID; Tuning based on direct synthesis(DS), IMC, Lambda, Hagglund and Astrom, Tyreus-Luyben and integral square error techniques; Limitations of PID control; Set-point tracking; Limiting and anti-reset windup.	**4**
4.	**Computer Control Strategies:** Internal model control (IMC); Predictive control; Adaptive control; Adaptive-predictive control; Adaptive-inferential control; Supervisory control; Principles of process identification.	**7**
5.	**Multivariable Control System:** Control of system with M × N variables; Relative static and dynamic gain array; Hankel interaction index array (HIIA); Decoupling; Condition number; Niederlinski index; Resiliency; Morari resiliency index (MRI); Inverse Nyquist array; Robustness and sensitivity analysis; Doyle-Stein criterion; Uncertainty analysis; Skogestad-Morari method; Singular value decomposition; Tyreus-load-rejection criterion (TLC); BLT tuning; Multivariable DMC; Multivariable IMC; Observability and controllability analysis.	**7**
6.	**Digital Process Control System:** Control with hardware and software involving system dynamics with Z and modified Z transform-DDC; Open loop and closed loop response; Bilinear transformation and stability analysis; Nyquist criteria; Sample data control of a first order system with dead time; Design of sample data controllers.	**8**
7.	**Non-linear control:**Lyapunov analysis; Describing function technique; Use of ANN, Fuzzy logic, PSO, ABC for advanced control; Plant-wise control system design.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Bequette B.W., "Process Control – Modeling, Design and Simulation", Prentice Hall of India.	2003
2.	Coughanour D.R., 2nd Ed., "Process System Analysis and Control", McGraw Hill Publishing Inc.	1991
3.	Seborg D.E., Edgar T.F. and Mellichamp D.A., "Process Dynamics Control", 2nd Ed., John Wiley & Sons.	2008
4.	Stephanopoulos G., "Chemical Process Control- An Introduction to Theory and Practice", Prentice Hall of India.	2008
5	Richardson J.F. and Peacock D.G., "Coulson & Richardson's Chemical Engineering", Vol. 3, 3rd Ed., Butterworth -Heinemann	2006
6.	Luyben W., "Process Modeling, Simulation and Control for Chemical Engineers", 2nd Ed., McGraw-Hill Publishing Inc.	1990

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject code: **PEN-415** Course title: **Polymer and Tissue Technology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge of tissue engineering and biomaterials.

10. Details of course:

S. No.	Contents	Contact Hours
1	**Introduction:**Definition, principles and practices of tissue engineering; Tissue engineering triad;	**2**
2	**Cells, Scaffolds and Growth Factors:** Structure of cell; Cellular functions; Cell culture techniques; Different types of cells and their applications; Types and properties of scaffolds; Scaffold modifications; Growth factors: pH, temperature, chemical, electrochemical and	**7**

	mechanical stimuli;*In-vitro* and *in-vivo* environmental stimuli.	
3	**Polymers and Biomaterials for Tissue Engineering:** Definition and classification of biomaterials and polymers;Natural and synthetic polymer system; Smart polymers; Polymer blends and composites; Bioceramics; Metal based scaffold-materials;Nanomaterials; Physical, mechanical, and chemical properties of biomaterials; Biocompatibility and biodegradation;Tailoring of polymers and biomaterial properties.	**8**
4	**Scaffold Fabrication Techniques:** Solvent casting;Porogen leaching;Gas foaming; Self assembly;Electrospinning;Phase-separation;Rapid prototyping/hybrid printer;Fiber mesh and fiber bonding;Melt molding;Freeze drying; Decellulerization; Controlling pore size and porosity of the scaffold.	**7**
5	**Scaffold Characterisation and Cell Behaviour on Scaffold:**Determination of porosity, pore size, hydrophilicity, mechanical strength, roughness, toxicity, biocompatibility and biodegradability of the scaffold; Determination of shape, size, growth, proliferation and differentiation of cells.	**8**
6	**Bioreactors for Tissue Engineering:**Ideal bioreactor and its major characteristics; Fabrication of bioreactor; Scale-up possibilities for tissue engineered constructs.	**4**
7	**Regulatory and Clinical Issues:**Pre-clinical evaluation of tissue engineered constructs; Trends in food and drug administration; Ethical issues; Dealing with ethical issues.	**3**
8	**FutureAdvancements:**Overcoming present drawbacks; Dealing with ethical issues.	**3**
	TOTAL	**42**

11.Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Lanza R.P., Langer R. andVacanti J., "Principles of Tissue Engineering", Academic Press, 4th Edition.	2014
2.	GuilakF., Butler D.L., Goldstein S.A.and Mooney S.A.,"Functional Tissue Engineering", Springer-Verlag, New York, 1st Ed.	2003
3.	Migonney V., "Biomaterials", Wiley-ISTE, 1st Ed.	2014

4.	Shi D., "Biomaterials and Tissue Engineering" Springer-Verlag, New York, 1st Ed.	2004
5.	**Helsen**J. A. and**Missirlis**Y., "Biomaterials", Springer-Verlag, New York, 1st Ed.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-417** Course Title:**Polymer Degradation and Stability**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory:3** **Practical :0**
4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**
5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PEC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge onvarious factors influencing stability and degradation of polymers
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Polymer degradation by various means: Heat, oxygen, light/UV, ozone, chemical, mechanical and biological; Role of chemical structure towards degradation; Advantages and disadvantages of polymer degradation; Case studies from various industries; Polymer stabilization.	**4**

2.	**Thermo-Oxidative Degradation:** Mechanisms of thermal degradation: Radical and non-radical de-polymerization, cyclization with elimination; Mechanisms of oxidative and thermo-oxidative degradation: Auto oxidation, oxidative chain reaction, chemical changes in polymers during oxidative degradation; Effect of chemical structure on oxidation rate. Degradation during manufacturing and service; Degradation effects on product performance with case studies.	**6**
3.	**Photo-degradation:** Mechanism of photo-oxidative degradation and photo-degradation of important polymers: polyolefins, acrylates and its copolymers, methyl vinyl ketone, polystyrene, polymers with heteroatoms in main chain and condensation polymers.	**6**
4.	**Antioxidants and Stabilizers:** Mechanism of antioxidant action; Chain breaking antioxidants; Preventive antioxidants; Synergism and antagonism; Chain breaking acceptor antioxidants; Metal deactivators; UV screens and filters; Stabilization of polymers during manufacture and in service; Melt stabilization; Thermal oxidative stabilization; Polymer bound antioxidants; UV stabilizers.	**6**
5.	**Degradation in Special Environments:** Polymers under stress; Degradation in harsh environments: Nitrogen dioxide, sulfur dioxide, ablation, mechanical and ultrasonic degradation; Quantitative aspects of ultrasonic degradation and changes in molecular weight; Degradation by high energy radiation and radiation protection; hydrolytic degradation.	**6**
6.	**Degradation of Polymeric Biomaterials:** Introduction to degradation of biomaterials; Controlling degradation rate and drug release in biomaterials; Degradation through oxidation, hydrolysis, enzymolysis, photolysis, stimuli-sensitive; Immune response to degradation.	**6**
7.	**Polymer Degradation Kinetics:** Random chain scission, mid chain scission, end chain scission; Kinetics based on mode of chain scission; Kinetics of solid phase thermal degradation (pyrolysis): order of reaction, rate constant, effect of temperature, reactive gas, radical donor, catalyst on rate constant, energy of activation; Kinetics of solution degradation of polymer: rate constants, role of radical donor, Lewis acid, catalyst on rate constant; Stoichiometric carnal, molecular weight distribution, population balance of polymer chains, integro-differential equation and it's analytical solution; Optimum temperature in degradation with initiator.	**5**
8.	**Biodegradable Polymers and Polymer Recycling:** Biodegradation of polymers in soil and water; Case studies of biodegradable polymers; Recent trends in biodegradability. Limitations to polymer recycling; Case studies: Polyolefins, PET, PVC, PS, nylon, PU, polymer composites, tyres.	**3**
		Total 42

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication
1.	Hamid S. H., "Handbook of Polymer Degradation", 2nd Ed., CRC Press, Taylor and Francis Group	2000
2.	Billingham N. C., "Degradation and Stabilization of Polymers", Wiley Online Library	2013
3.	Jellenick H.H.G., "Polymer Degradation and Stability", 1st Edition, Elsevier Amsterdam, the Netherlands	1983
4.	Ranby. B. and Rabek. J. F., "Photo-degradation, Photo oxidation and photo-stabilisation of polymers", Wiley and Sons.	1975
5.	Denisov E. T. and Denisova. T. G., "Handbook of Antioxidants, Second edition, CRC Press, Taylor and Francis Group	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-418** Course Title: **Polymers Recycling and Environment**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective :To impart knowledge of adverse effects of polymers on the environment and recycling of waste polymers.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Polymer Recycling:** Disposed plastics, pollution, environmental issues related to plastic industry, plastic waste recycle.	4

2.	**Plastic Waste:** Sources ofplastic waste: municipal, industrial, agricultural and medical; Plastic waste accumulation; Separation and segregation of plastics waste: Polyethylene, polypropylene, polyvinylchloride, polystyrene, polyester, polyurethane, thermosets and thermoplastics.	7
3.	**Environmental Effects on Waste Polymers:** Stability and degradation of polymers in environment; Photo and bio degradation of plastics waste, effect of plastic degradation on environment; Weather parameters influencing lifetime of waste plastics; Polymer waste in sea and marine environment, and on hills and mountains.	6
4.	**Polymer Degradation Mechanism:**Solid phase degradation of polymers through catalytic, UV, oxidative, hydrolytic, thermal and pyrolytic processes; Polymer degradation in solution; Mechanism and kinetics of polymer degradation.	5
5.	**Waste Plastics Recycling**: Collection of plastics waste for recycling; Reuse of plastics; Processes for recycling of thermoplastics and thermosets; Recycling of plastic waste based on an individual plastic; Recycling of mixed thermoplastics and thermosets; Recycling of mixtures of both thermoplastics and thermosets.	7
6.	**Thermal Treatment of Plastics Waste:** Methods and processes; Thermal degradation, incineration and energy recovery from waste plastics: Polyethylene, polypropylene, polyvinylchloride, polystyrene, polyester; Energy requirements for plastic waste destruction.	8
7.	**Sustainability**: Life cycle of plastics; Sustainability, economy, legislation and regulations for waste polymers, future of plastics.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books /Publishers	Year of Publication
1.	Andrady A.L., "Plastics and The Environment", Wiley Interscience.	2003
2.	Bisio A.L. and XanthosM., (Eds.), "How to Manage Plastics Waste: Technology and Market Opportunities", Carl HanserVerlag.	1994
3.	Brandrup J. "Recycling and Recovery of Plastics", HanserGardner.	1996
4.	ScheirsJ. "Polymer Recycling, Science, Technology and Applications", John Wiley & Sons.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-419** Course Title: **Polymer for Packaging Technology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective:To provide knowledge about polymers used in packaging industry.

10. Details of Course:

Sl. No	Contents	Contact Hours
1.	**Introduction:**Packaging technology raw materials: Types of forms, products, applications and consumption pattern, evaluation of films; Comparison of polymer packaging withpaper, metal and glass materials.	**2**
2.	**Packaging Materials and Properties:**Major polymers used for packaging applications: Polyethylene, EVA, ionomers, HDPE, LLDPE, PP,PVC,PVDC, PS, PVOH, EVOH, nylon, polyester, polycarbonate, fluoropolymers, acrylonitrilecopolymers, thermoplastic elastomer,	**8**

	cellophane and cellulose plastics, polymer blends; Adhesives for packaging; Properties for packaging: MVTR, OTR, mechanical, thermal, optical, chemical.	
3.	**Packaging Converting Processes:** Blown film extrusion, Cast film extrusion,films co-extrusion;Coating and lamination; Manufacturing of flexible packaging; Thermoforming; Injection molding; Blow moulding: extrusion and injection blow moulding;Calendering; Foam manufacturing; Sealing methods.	**8**
4.	**Biobased Packaging:**Edible and biobased food packaging materials; Edible, polysaccharide, lipid and protein based coating; First, second and third biobased packaging materials; Permeability of thermoplastic polymers; Multilayer films; Processing; Degradation; Deteriorative reaction in foods; Enzyme reactions; Chemical reactions; Physical and biological change.	**8**
5.	**Food Packaging:** Asceptic packaging of foods; Sterilization of packaging materials; Packaging of ready-to-eat and microwavable foods; Active and intelligent packaging; Modified atmospheric packaging; Packaging of horticultural products, dairy products, cereals,snack foods and confectionary, beverages; Shelf life of foods and factors controlling shelf life; Safety and legislative aspects of packaging.	**8**
6.	**Package Printing Technologies:** Print production workflow: Typography, graphic design, artwork, prepress, printing, post press/finishing; Materials: Substrates, ink; Drying methods; Recent trends; Printing methods: Lithography, Flexography, Gravure.	**8**
	Total	**42**

11. Suggested Books:

S. No	Name of Authors/ Books/ Publisher	Year of Publication
1.	Susan E.M., Selke J., Culter D. and Ruben J. “Plastics Packaging: Properties, Processing, Applications and Regulations”, Hanser.	2004
2.	Pringer O.G. and Baner A.L. “Plastic Packaging Materials for Food: Barrier Function, Mass Transport, Quality Assurance and Legislation”, John Wiley and Sons.	2008
3.	Sina E., “Plastic Films in Food Packaging: Materials, Technology and Applications”, Elsevier.	2012
4.	Robertson G.L., “Food Packaging Principles and Practice”, Second Edition, CRC Press.	2006
5.	Nayak S.K., “Fundamental of Plastic Testing”, Springer.	2010

6.	Kipphan H., "Handbook of Print Media", Springer.	2004
7.	Johansson K., Lundberg P. and Ruberg R., "A Guide to Graphic Print Production", Wiley.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-420** Course Title: **Polymers for Smart & Memristive Materials**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective**:** To provide knowledge of synthesis, device fabrication and application of smart materials

10. Details of Course:

Sl. No	Contents	Contact Hours
1.	**Introduction:** Definition of memristiveand smart materials and their classification; Class of polymers having said properties.	**2**
2.	**Memristive Materials:** Electrical memory switching polymers;Volatile memory and non-volatile memory**:** definition and classification, I-V characteristics; Transistor; Reversibility and memory sustaining capability.	**6**

3.	**Synthesis and Characterization of Smart and Memristive Materials:** Synthetic procedure for different polymers, characterization, advantages and disadvantages; Device fabrication techniques:Detailed characterization by AFM, SEM techniques.	**8**
4.	**Memristive Devices with Different Polymeric Materials:** Organic,inorganic, metal doped organic andorganic-metallic hybrid devices;Switching and carrier transport mechanism;Shape memory polymers:Definition, classification and applications.	**8**
5.	**Smart Materials:** Definition, classification, advantages and disadvantages of electrochromic materials;Applications in e-paper, smart glass window, display;Definition, classification and applications of halochromic, pH sensitive, self-healing, piezoelectric and photochromic materials.	**8**
6.	**Device Fabrication Techniques and Characterization:** Memristive device: Sandwich and lateral device, advantages and disadvantages; Electrochromic materials: Use of supporting electrolyte in device fabrication and its importance, different types of supporting electrolytes, detailed device fabrication for other smart devices.	**6**
7.	**Real Life Applications:** Applications in memory chip, glass window, display system and others; Advantages and limitations of such devices.	**4**
	Total	**42**

11. Suggested Books:

Sl. No	**Name of Authors/ Books/ Publisher**	**Year of publication**
1.	Tu C.-H., "Electrical Switching and Memory Behaviors in Organic-based Devices", ProQuest.	2008
2.	BurghartzJ.N., "Guide to State-of-the-art Electronic Devices", John Wiley & Sons.	2013
3.	Dai L., "Intelligent Macromolecules for Smart Devices: From Materials Synthesis to Device Applications", Springer.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-421** Course Title: **Applications of Polymer in Drug Delivery**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory:3** **Practical :0**
4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**
5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PEC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge on various polymers used in drug delivery applications
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Polymers used in drug delivery,synthetic and natural polymers: cellulose, poly-ethylene glycol, poly-n-vinyl pyrilidone, PCL, PLA, PLGA, HMPA.	**04**
2.	**Conventional techniques of drug delivery:**Compression, spray, dip-coating and encapsulation, diffusion controlled systems, solvent activated system, bio-degradable system.	**04**

3.	**Responsive polymers for drug delivery:** Responsive systems based on temperature, pH and redox potential, polymer therapeutics, polymer-drug conjugates, protein-polymer conjugates	**04**
4.	**Polyelectrolytes:**polyelectrolytes,characterization of polyelectrolytes application of polyelectrolyte complexes. Soluble drug carriers, polymeric micelles, liposomes, microgel, nanogel, nanoparticles, dendrimers, examples	**06**
5.	**Current thrust in drug delivery:** Endosomolyticpolymers and macromolecules, role of poly (ethylene glycol), peptide and protein drugs, microencapsulation of polymeric drug e.g. RNA, protein; drug – polymer interactions.	**08**
6.	**Polymeric biomaterial and its stability:**Polymer stability with pH, temperature, oxido-reductive, and phagocyte effect;Adsorption of polymers from solution; Macromolecular adsorption over polymer interface; Protein adsorption; Colloid stability, Control of protein adsorption	**08**
7.	**Novel Drug Delivery Systems:** Mucosal, transdermal drug delivery system (TDDS), bio-degradable polymeric stent, parenteral implants, ophthalmic insets, micro encapsulation. intrauterinedelivery system (IUDs); Targeted drug delivery systems.	**08**
		Total 42

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication
1	Lachman L. and Lieberman H.A., "The Theory and Practice of Industrial Pharmacy", CBS publishers, India.	2005
2.	Avis K. E. and Lieberman H.A.,"Pharmaceutical dosage forms, Parenteral medications", 2 nded,Vol I,II and III, Marcel Decker	1993
3.	Tyle P., "Drug Delivery System", 1st Ed, Marcel Decker	1988
4.	JainN. K.,"Advances in controlled and novel drug delivery", 1 st Ed., CBS Publication	2001
5.	Robinson J.R. and Lee V.L. "Controlled Drug Delivery: Fundamental and Applications", Marcel Dekker, USA.	2003
6.	Radomsky M., Liu L. and Iwamoto Z., "Sustained Release Injectable Products, Interpharm Englewood, Colorado.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Chemistry**

1. Subject code: **CYN-422** Course Title: **Polymer Physics**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weightage: **CWS: 25** **PRS:0** **MTE:25** **ETE: 50** **PRE: 0**
5. Credits: **3** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: Basic Physical Chemistry Course, calculus and physics.
9. Objective: To familiarize students with the basic concepts of polymer physics.

10. Details of the Course:

S. No.	Contents	Contact Hours
1.	**Statistical Thermodynamics:** Microstates, Ensembles- microcanonical, canonical, grand-canonical, partition functions, distributions, averages, thermodynamic connection, probability distribution of fluctuations.	**6**
2.	**Chain Statics:** Characteristic dimensions of 'random coil' polymers, models for calculating the average end-to-end distance for an ensemble of statistical chains, distribution of end-to-end vectors, Worm-like chain, measurement of radius of gyration from scattering, free energy of ideal chain, scaling arguments for stretching and confinement, pair correlation for ideal chain, structure factor.	**12**
3.	**Real chains:** Excluded volume, self-avoiding walks, deforming real and ideal chains, scaling model for real chains, Flory theory, solvent quality, theta-temperature. Thermodynamics and statistical mechanics of polymer networks.	**8**
4.	**Polymer solutions:** Thermodynamics of mixing, Flory-Huggins theory**,** osmotic pressure, concentration regimes in polymer solutions, correlation length, correlation function, screening of excluded volume forces, size of a polymer in semi-dilute solutions, polymer-polymer blends and phase diagrams.	**9**
5.	**Polymer melts:** chains in melts, screening in dense polymer melts, and correlation hole.	**3**
6.	**Polymer dynamics:** Rouse model, Zimm model, Reptation	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Book/ Publisher etc.	Year of Publication/ Reprint
1.	Rubinstein M. and Colby R. C., "Polymer Physics", 1st Ed., Oxford University Press.	2003
2.	de Gennes P.G., "Scaling Concepts in Polymer Physics", 1st Ed., Cornell University Press.	1979
3.	Doi M. and Edwards S.F., "The Theory of Polymer Dynamics", Clarendon Press.	1988
4.	Flory P. J., "Principles of Polymer Chemistry", 1st Ed., Cornell University Press.	1953
5.	Strobl G. R., "The Physics of Polymers: Concepts for Understanding Their Structures and Behavior", 3rd Ed., Springer-Verlag Berlin Heidelberg.	2007
6.	Gedde U., "Polymer Physics", Reprint, Springer Netherlands.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-002** Course Title: **Mathematical Methods**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory : 3** **Practical : 0**
4. Relative Weightage**:** **CWS: 25** **PRS: 0** **MTE : 25** **ETE : 50** **PRE: 0**
5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: BSC**
8. Pre-requisite**: Nil**
9. Objective: To provide knowledge of essential mathematical tools applied in solving ordinary and partial differential equations, initial and boundary value problems.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Ordinary Differential Equations:** Solution of linear differential equations with constant coefficients. Euler-Cauchy equations, Solution of second order differential equations by changing dependent and independent variables. Method of variation of parameters, Introduction to series solution method.	**10**
2.	**Partial Differential Equations:** Formation of first and second order partial differential equations. Solution of first order partial differential equations: Lagrange`s equation, Four standard forms of non-linear first order equations .	**6**
3.	**Laplace Transform:** Laplace and inverse Laplace transform of some standard functions, Shifting theorems, Laplace transform of derivatives and integrals. Convolution theorem, Initial and final value theorem. Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function. Applications of Laplace transform.	**10**
4.	**Z - Transform:** Z – transform and inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem. Application of Z- transform to solve difference equations.	**5**
5.	**Fourier series:** Trigonometric Fourier series and its convergence. Fourier series of even and odd functions. Fourier half-range series. Parseval`s identity. Complex form of Fourier series.	**5**
6.	**Fourier Transforms:** Fourier integrals, Fourier sine and cosine integrals. Fourier transform, Fourier sine and cosine transforms and their elementary properties. Convolution theorem. Application of Fourier transforms to BVP.	**6**
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Kreyszig, E., "Advanced Engineering Mathematics", Johan Wiley & Sons	2011
2.	Jain, R. K. and Iyenger, S. R. K., "Advanced Engineering Mathematics", Narosa Publishing House	2009
3.	Amarnath, T., "An Elementary Course in Partial Differential Equations", Narosa Publishing House (II Edition)	2012
4.	Hildebrand F. B., "Methods of Applied Mathematics", Courier Dover Publications	1992
5.	Rao, K. S., "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd. (II Edition)	2010
6.	Sneddon, I. N., " Elements of Partial Differential Equations", McGraw-Hill Book Company	1988
7.	Simmons, G. F. and Krantz, S. G., Differential Equations:Theory, Technique and Practice" , Tata McGraw-Hill Edition	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-102** Course Title: **Material and Energy Balance**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory : 3** **Practical : 0**

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE : 25** **ETE: 50** **PRE: 0**

5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: PCC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge of principles of material and energy balances applied to chemical engineering systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Units and dimension in chemical engineering**,** units conversion of dimensional equations, stoichiometric and composition relations, concept of degrees of freedom and linear independence of a set of equations.	**5**
2.	**Material Balance:** Concept of material balance, open and closed systems, steady state and unsteady state, multiple component system, selection of a basis, problem solving strategy.	**4**
3.	**Material Balance without chemical Reaction for Single and Multiple Units:** Conservation of mass/atom, material balance for systems without polymer reactions involving single unit and multiple units.	**5**
4.	**Material Balance with chemical Reaction for Single and Multiple Units:** Concept of excess reactant, extent of reaction, material balance for systems with polymer reactions involving single unit and multiple units.	**6**
5.	**Recycle, Bypass, Purge and Industrial Applications:** Calculations for a cyclic processes involving recycle/ purge/ bypass, material balances involving gases, vapors, liquids and solids and use of real gas relationships, material balance involving gases, vapors, liquids & solids and uses of real gas relationships, vapor-liquid equilibrium and concepts of humidity & saturation, analysis of systems with bypass, recycle and purge, analysis of processes involving condensation, crystallization and vaporization.	**7**

6.	**Energy Balance:** Conservation of energy with reference to general energy balance with and without polymer reactions, chemical engineering problems involving reversible processes and mechanical energy balance.	**4**
7.	**Applications of Energy Balance:** Calculations of heat of change of phase (solid – liquid &liqid – vapor), heat of reaction, heat of combustion, heat of solutions and mixing, determination of temperatures for adiabatic and non-adiabatic reactions, use of psychometric and enthalpy- concentration diagrams.	**6**
8.	**Simultaneous Material and Energy Balances:** Degrees of freedom analysis for multicomponent systems, combined steady state material and energy balances for units with multiple sub-systems.	**3**
9.	**Unsteady State Material and Energy Balances:** Transient materials and energy balances involving with and without chemical reactions.	**2**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Himmelblau D.M. and Riggs J. B.," Principles and Calculations in Chemical Engineering", 8th Ed., Prentice Hall of India.	2012
2.	Felder R.M. and Rousseau R.W., "Elementary Principles of Chemical Processes", 3rd Ed.., John Wiley.	2005
3.	Bhatt B.I. and Vora S.M., "Stoichiometry", 5th Ed., Tata McGraw-Hill	2010
4.	Narayanan K.V. and Lakshmikutty B., "Stoichiometry and Process Calculations", Prentice Hall of India.	2006
5.	Hougen D.A., Watson K.M. and Ragatz R.A., "Chemical Process Principles", Part-I, 2nd Ed., CBS Publishers.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-106** Course Title: **Thermodynamics and Chemical Kinetics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**

5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To provide basic knowledge of thermodynamics and chemical kinetics to chemical engineering students.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Introduction:** Thermodynamic system, surroundings, state, process, properties, equilibrium, heat and work.	**02**
2.	**Properties of Pure Simple Compressible Substance:** P-V-T surface, P-V, T-V and T-P diagrams. Equations of state for ideal and real gases. Virial equation of state, van der Waals and Redlich-Kwong equations of state; Use of Thermodynamic tables.	**06**
3.	**First Law of Thermodynamics:** Energy balance for closed systems. Various forms of energy balance. Specific heat, internal energy, enthalpy, and specific heat of ideal gases. Application of first law to non-flow isochoric, isobaric, isothermal, and adiabatic and polytropic processes. Conservation of mass for a control volume, mass and volume flow rates, mass balance for steady flow processes, flow work, steady flow energy equation. Application to various practical systems viz. nozzles, diffusers, etc. Transient Analysis.	**05**
4.	**Second Law of Thermodynamics:** Second law, reversible and irreversible processes, Clausius and Kelvin Planck statements. Carnot cycle, Clausius inequality, entropy as a property, principle of increase of entropy. Calculation of entropy change.	**06**
5.	**Thermodynamic Cycles:** Otto, Diesel, Rankine cycles and their	**03**

	applications.	
6.	**Rate Expression and Reaction Mechanism:** Use of pseudo steady state approximation to get rate expression from mechanism, temperature-dependence of reaction rate-collision theory, transition state theory, thermodynamics and Arrhenius law.	**04**
7.	**Interpretation of Kinetic Data of Batch Reactors:** Constant volume and variable volume batch reactions, Integral and differential methods of analysis of data of uni, bi and tri-molecular irreversible reactions. Reversible reactions, homogeneously catalysed, auto-catalysed, series and parallel reactions. Estimation of rate constants and its temperature-dependence.	**08**
8.	**Solid-Catalysed Fluid Reactions:** Characterization of catalyst, Physical and chemical adsorption, various reaction steps, Langmuir-Hinshelwood kinetics.	**04**
9.	**Kinetics of Bio-Chemical Reactions:** Kinetics of enzyme catalysed reactions, substrate and product inhibition, effect of temperature and pH on enzyme catalysed reactions.	**04**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Çengel Y.A. and Boles M.A., "Thermodynamics: An Engineering Approach", 6th Ed., McGraw Hill.	2008
2.	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005
3.	Borgnakke C. and Sonntag R.E., "Fundamentals of Thermodynamics", 7th Ed., John Wiley and Sons.	2009
4.	Levenspiel O., "Chemical Reaction Engineering", 3rd Ed., John Wiley.	2000
5.	Fogler H.S., "Elements of Chemical Reaction Engg.", 4th Ed., Prentice Hall of India.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-102** Course Title: **Properties of Polymers**
2. Contact Hours: **L: 3** **T:0** **P: 2/2**
3. Examination Duration (Hrs.): **Theory:3** **Practical :0**
4. Relative Weightage**: CWS:15 PRS:25 MTE:20 ETE:40 PRE:0**
5. Credits**: 3** 6. Semester**: Spring** 7.Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge of properties of polymers, their testing and characterization
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Polymer Characterization:** Overview of properties useful forcomplete characterization of Polymers, Copolymers, – Thermal, Mechanical, Optical and Electrical, Chemical and Morphological.	**2**
2.	**Amorphous Polymers:** Free volume and free volume theory,Kinetic nature of glass transition, pressure and path dependence of polymeric glasses, Gibbs Dimarzio Theory, Factors affecting glass transition temperature, secondary sub glass transition temperature, Physical ageing, Five regions of viscoelastic behavior,	**5**
3.	**Crystalline Polymers & polymer Crystallization:** Fundamentals and thermodynamics of polymer crystallization, Structure of crystalline polymers, Structural factors affecting crystallizability and crystallinity of polymers, Spherulites, Helix Structure, Chain folding, Polymer single Crystal,	**5**
4.	**Thermal Properties and Characterization:** Operating Principles and Theory behind Characterization by Differential Scanning Calorimetry (DSC) and Thermo-gravimetric Analysis (TGA); Melting Point related Tests, Glass Transition Temperature and Factors affecting it; Testing and measurements of Heat Deflection Temperature (HDT), Vicat Softening point (VSP), Torsion Pendulum Test, Thermal	**7**

	Conductivity and Expansion, Brittleness Temperature; Measurements related to Flammability.	
5.	**Dynamic Mechanical Thermal Properties:** Damping, storage and loss modulus, dissipation factor, loss tangent, loss factor, retardation times, thermal, frequency, and force amplitude effects on dynamic properties, characterization of dynamic mechanical properties of polymers.	**6**
6.	**Mechanical Properties and Characterization:** **Tensile, Compressive and Flexural Mechanical Response of Polymers:** Stress-strain behavior, Models, Cold drawing, Strain hardening, Characterization of Tensile, Compressive & Flexural mechanical nature of polymers. Tensile and Compressive strength measurements, Fracture and Strength of Polymers, Measurements ofImpact property, Notch sensitivity and testing procedures. **Surface Mechanical Properties and Tests**- Tests and measurement related to Hardness- Durometer/Shore Hardness, Vicker Scale; Abrasion Properties & tests, Co-efficient of friction measurements; **Long-Term Mechanical Properties and measurements**- Creep, stress-relaxation and fatigue resistance, etc.	**9**
7.	**Optical and Electrical Property Characterization:** Operating Principles of Equipments and Theory behind Measurements of- Refractive Index, Specular Gloss using Gloss meter, Luminous Transmittance and Haze, Color, Birefringence, Clarity and Photo-elasticity; Surface and volume resistivity, dielectric constant, dissipation factor.	**4**
8.	**Non-Destructive Testing:** Operating Principles and Procedure ofTechniques- Ultrasonic measurements, Liquid-penetration Techniques, Magnetic particle testing, Radiography and Microwave based NDT, Thermal methods and Laser Holography.	**4**
		Total 42

11. List of Practicals :

1. Determination of T_c, T_g and T_m, of polymer (using DSC).
2. Determination of degradation profile and filler content of a polymer (using TGA).
3. Study of Mechanical Stress-strain behavior of a polymer under tension
4. Study of Mechanical Stress-strain behavior of a polymer under and compression.
5. Determination of Impact strength of a polymer by Izod method.
6. Determination of Impact strength of a polymer by Charpy method.
7. Study of Dynamic Mechanical Behavior of a Polymer

12. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication/Reprint
1.	Craver C. D. "Polymer Characterization", ACS.	1983
2.	Nayak S. K., Yadav, S. N, Mohanty, S., "Fundamentals of Plastics Testing", Springer.	2010
3.	Korschwitz J., "Polymer Characterization and Analysis", John Wiley & Sons.	1990
4.	Shiers J., "Practical Polymer Analysis", John Wiley & Sons.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemistry**

1. Subject code: **CYN-011** Course Title: **Polymer Characterization**
2. Contact Hours:**L: 3** **T:0** **P: 0**
3. Examination Duration (Hrs.): **Theory:2** **Practical :0**
4. Relative Weightage**: CWS:25 PRS:0 MTE:25 ETE:50 PRE:0**

5. Credits**: 2** 6. Semester**: Spring** 7.Subject Area**: BSC**

8. Pre-requisite**: Nil**

9. Objective: It will familiarize the students to learn methods of synthesizing different types of polymers and characterize using array of physical techniques.

10. Details of the Course:

S. No.	Contents	Contact Hours
1.	**Preliminary Survey**: Identification of polymer materials; molecular architecture; need for optical characterization, diffraction techniques, microstructure analysis.	2
2.	**Spectroscopic technique:** Interaction of electromagnetic radiation with matter; Atomic and molecular spectroscopy and instrumentation, viz., UV-visible spectroscopy, Infrared and Raman spectroscopy.	6
3.	**Nuclear magnetic resonance (NMR) spectroscopy.** Principle of magnetic resonance, experimental technique,Applications of NMR to polymers, NMR of Polymers in solid state, two dimensional NMR, NMR imaging.	4
4.	**Diffraction techniques:** Theory ofX-ray diffraction (XRD), Generation and properties of X-ray, Applications of XRD to polymer characterization; Alternate diffraction techniques viz., electron diffraction, neutron diffraction.	8
5.	**Microscopic technique:** Theoretical concepts in optical microscopy, fluorescent microscopy, scanning electron microscopy, transmission electron microscopy, atomic force microscopy, instrumentation and applications.	8
	Total	**28**

11. Suggested Books:

S.No.	Name of Authors/Book/ Publisher etc.	Year of Publication/ Reprint
1	Campbell, D., Pethrick, R.A., White J.R., "Polymer Characterization Physical Techniques", Stanley Thornes (Publishers) Ltd. 2nd Edition	2000
2	Skoog, D.A., Holler, F.J., Crouch S.R., Principles of Instrumental Analysis",6th Edition, Thomson Brooks	2006
3	West A.R., "Solid State Chemistry and its Applications" John Wiley & Sons, India	2013
4	Slayter, E.M., Slayter, H.S., "Light and Electron Microscopy" Cambridge University Press.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemistry**

1. Subject code: **CYN-013** Course Title: **Polymer Chemistry Laboratory**
2. Contact Hours: **L: 0** **T:0** **P: 4**
3. Examination Duration (Hrs.): **Theory:0** **Practical :0**
4. Relative Weightage**: CWS:0 PRS:100 MTE: 0 ETE:0 PRE:0**
5. Credits**: 2** 6. Semester**: Spring** 7.Subject Area**: BSC**
8. Pre-requisite**: Nil**
9. Objective: It will familiarize the students to learn methods of synthesizing and characterization of different types of polymers.
10. Details of the Course:

List of Practicals

1. Emulsion polymerization of styrene
2. Precipitation Polymerization of Acrylonitrile
3. Synthesis of Isotactic and Syndiotactic PMMA/ Copolymerization of MMA and Styrene (anionic, cationic, block)
4. Synthesis of Polyurethane Foams
5. Synthesis of Nylon 6,6
6. MFI of synthesized polymers
7. Synthesis of High Syndiotactic Polystyrene by Homogeneous Ziegler-Natta Catalysis
8. Characterization of the synthesized polymers by UV-Visible spectroscopy and Infrared spectroscopy
9. Determination of various molecular weight of synthesized polymers by DLS, viscosity and relate them with GPC experiment
10. Determination of Tc, Tg and Tm of polymer using DSC
11. Determination of degradation profile and filler/inter contentof/in a polymer using TGA,
12. Raman spectroscopic characterization of polymers
13. Morphological study by optical, electron microscopy and AFM
14. NMR and XRD studies of monomers and polymers

11. Suggested Books:

S.No.	Name of Authors/Book/ Publisher etc.	Year of Publication/ Reprint
1.	Campbell, D., Pethrick, R.A., White J.R., "Polymer Characterization Physical Techniques", 2nd Edition, Stanley Thornes (Publishers) Ltd.	2000
2.	Skoog, D.A., Holler, F.J., Crouch S.R., Principles of Instrumental Analysis",6th Edition, Thomson Brooks.	2006
3.	West A.R., "Solid State Chemistry and its Applications" John Wiley & Sons, India	2013
4.	Slayter, E.M., Slayter, H.S., "Light and Electron Microscopy" Cambridge University Press.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electrical Engineering**

1. Subject Code: **EEN-112** Course Title: **Electrical Science**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**

4. Relative Weight**:** **CWS: 20** **PRS: 20** **MTE: 20** **ETE: 40** **PRE: 0**

5. Credits**: 4** 6. Semester**: Both** 7. Subject Area**: ESC**

8. Pre-requisite**: Nil**

9. Objective: To introduce the students to the fundamentals of Electrical Engineering concepts of network analysis, principles of electrical machines, basics of electrical measurement and measuring instruments.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Energy Resources and Utilization:** Conventional and non-conventional energy resources; Introduction to electrical energy generation from different resources, transmission, distribution and utilization.	**5**
2.	**Network Fundamentals**: Types of Sources and elements, Kirchoff's Laws, Mesh and Node Analysis of D.C. Networks, Network Theorems: Thevenin's Theorem, Norton's Theorem, Superposition Theorem, Maximum Power Theorem, Star-Delta Transformation.	**5**
3.	**A.C. Fundamentals**: Concept of phasor, impedance and admittance; Mesh and Node analysis of AC networks; Network theorems in AC networks; Active and reactive power in AC circuits; Resonance in series AC circuits; Power factor correction.	**4**
4.	**Three-phase A.C. Circuits**: Analysis of 3-phase balanced start-delta circuits, Power in 3-phase Circuits.	**2**
5.	**Measurement of Electrical Quantities**: Measurement of Voltage, Current, and Power; Measurement of 3 phase power; Energy meters.	**5**
6.	**Single Phase Transformer**: Introduction to magnetic circuit concepts, Basic constructional features, operating principle, phasor diagram, equivalent circuit, voltage regulation; Eddy current and Hysteresis losses, efficiency; Open circuit and Short Circuit tests.	**5**

7.	**D.C. Machines**: Principle of operation, constructional features; Emf and torque equations; Types of excitation; Generator characteristics; Starting and speed control of D.C. motors.	**5**
8.	**AC Machines**: Three-phase Induction Motor - Operating principle, constructional features, torque-speed characteristics, starting and speed control; Single-phase Induction Motor - Operating principle, constructional features, torque-speed characteristics, starting methods.	**5**
9.	**Industrial Applications and Control: V**arious industrial loads, traction, heating, lighting; Concept of power electronic control of AC and DC motors.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Mukhopadhyaya P., Pant A.K., Kumar V. and Chittore D.S., "Elements of Electrical Science", M/s Nem Chand & Brothers.	1997
2.	Vincent Del Toro, "Electrical Engineering Fundamentals", Prentice Hall of India.	2002
3.	Dubey G. K., "Fundamentals of Electric Drives", 2nd Ed., Narosa Publishing House.	2007
4.	Alexander C.K., Sadiku M.N.O., "Fundamentals of Electric Circuits", McGraw Hill, 5th Edition.	2012
5.	Chapman, Stephen, J., "Electric Machinery Fundamentals", McGraw Hill Book Company.	1985
6.	Hughes Edward, "Electrical & Electronic Technology", Pearson Publishing, 8th edition.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department Chemical Engineering**

1. Subject Code: **CHN-201** Course Title: **Heat Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical: 0**

4. Relative Weight**:CWS:20** **PRS:20** **MTE :20** **ETE:40** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge about heat transfer and its processes used in Chemical Process Industries

10. Details of Course:

S. No.	Contents	Contact Hour
1.	**Introduction**: Heat transfer modes, their rate equations.	**1**
2.	**Radiation**: Mechanism of radiation and its laws, black and grey body behavior, shape factors- determination using equations and charts, relationship between shape factors, heat transfer between non-black bodies, concept of surface- and space- resistance with concept of insulated and large surfaces, use of radiation shields, radiation through absorbing and transmitting gases.	**8**
3.	**Conduction**: Use of extended surfaces, two-dimensional steady state conduction, Thermal insulation- materials for cold and hot applications and thickness calculations, introduction to transient conduction, Biot number, use of Heisler charts.	**6**
4.	**Convection**: Concept and significance of boundary layer, boundary layer similarity and analogy, convection coefficients, free and forced convection, empirical correlations- internal and external flows.	**6**
5.	**Heat Exchangers**: Types and selection, overall heat transfer coefficient, parallel and counter current flow, LMTD, F_T correction factor, analysis and design using effectiveness-NTU method.	**4**
6.	**Boiling**: Characteristics, nucleate pool- and forced convection-boiling, boiling mechanism and curve, heat transfer correlations, heat pipes.	**4**
7.	**Condensation**: Mechanism and types of condensation of vapor with and without non-condensable gases, Nusselt equation for film wise condensation on vertical surfaces and its extension to inclined and horizontal surfaces and tubes, condensation number,	**5**

	film condensation inside horizontal tube.	
8.	**Evaporator**: Classification and use of evaporators in process industries, effect of boiling point rise and hydrostatic head on evaporator performance, liquor flow sequences, calculations for multiple effect evaporator system.	**4**
9.	**Crystallization**: Mechanism, crystallization from mixed solutes, particle size distribution of crystals and parameters effecting it, some major types of crystallizers, crystallizer calculations.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books/ Publisher	Year of Publication
1.	Holman J.P., " Heat Transfer", 10th Ed., McGraw Hill	2009
2.	Bergman T.L., Lavine A.S., Incropera F.P. and DeWitt D.P., "Introduction to Heat Transfer", 6th Ed., Wiley	2011
3.	Cengel Y.A. and Ghajar A.J., "Heat and Mass Transfer: Fundamentals and Applications", 4th Ed., McGraw Hill	2010
4.	Kreith F., Manglik R.M. and Bohn M., "Principles of Heat Transfer", 7th Ed., Cengage Learning	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-211** Course Title: **Fluid and Fluid Particle Mechanics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:20 PRS:20 MTE:20 ETE:40 PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To provide knowledge of particle size analysis, size reduction, separation of particles by filtration, sedimentation and flow through porous media.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Particle Size Reduction and Analysis:**Theory of crushing and grinding, crushing and grinding equipment and their selection. Sieve analysis, size distribution, size averaging and equivalence, size estimation in sub-sieve range,	**6**
2.	**Storage of Solids :**Bins, silos, hoppers, Janseen's equation.	**2**
3.	**Fluid Handing Machinery and Flow Measurement:** Pumps; Blowers and compressors- classification, operating and performance characteristics, selection criteria and design specifications; Constant area and constant head meters; Weirs and notches.	**7**
4.	**Particle Mechanics :**Motion of particles in fluid, effect of particle shape, Stock's law, hindered settling, jigging and classification	**4**
5.	**Sedimentation and Flotation:** Gravity and centrifugal sedimentation, design of sedimentation tanks and continuous thickners, mechanism of flotation, flotation agents, coagulants and flotation equipment.	**6**
6.	**Filtration :**Flow through filter media and formation of cakes, washing and drying of cake, filter aids, selection of filtration equipment, constant rate and constant pressure filtration.	**4**
7.	**Flow Through Packed Beds :**Characteristics of packings, flow of a single fluid through a packed bed, problems of channeling and wetting, counter-current gas-liquid flow through packed beds-loading and flooding	**5**

	characteristics.	
8.	**Fluidization and Solid Conveying :** Fluidization characteristics, aggregative and particulate fluidization, voidage and minimum fluidization velocity, voidage correlations, gas-solid fluidization characteristics; Pneumatic and hydraulic transport of solids-general characteristics and flow relations	**8**
	Total	**42**

11. List of Practicals:

1. Plate and frame filter press
2. Flow through packed bed
3. Flow through fluidized bed
4. Batch Sedimentation
5. Elutration
6. Crushing and grinding experiments
7. Flow meters
8. Pumps Characteristics

12. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Backhurst J. R.and Harker J. H., "Coulson and Richardson Chemical Engineering", Vol. II", 5th Ed., Butterworth-Heinemen.	2002
2.	Brown G. G., "Unit Operations", CBS publishers.	1995
3.	Narayanan C.M. and Bhattacharya B.C., "Mechanical Operations for Chemical Engineers-Incorporating Computer Aided Analysis", Khanna publishers.	1992
4.	McCabe W. L., Smith J. C. and Harriott P., "Unit Operations of Chemical Engineering", 7th Ed., McGraw Hill.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE PROGRAM: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-201** Course Title: **Polymer Engineering Thermodynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To understand the thermodynamics to polymer.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Laws of thermodynamics, PVT behavior of fluids – Gibb's phase rule.	3
2.	**Thermodynamic Properties of Homogeneous Fluids:** Fundamental property relations, Maxwell's relations, Residual properties and their estimation, two phase systems.	4
3.	**Thermodynamic Properties of Mixtures or Solutions:** Property relationships for systems of variable composition; chemical potential, partial molar properties, fugacity and fugacity coefficients – pure species and species in a mixture, fugacity in ideal solutions, activity coefficients, excess properties.	6
4.	**Glassy, Crystalline and molten state of polymers**: States of matter, Glassy, crystalline and Molten states of polymers, Bonding and Confirmations.	5
5.	**Thermodynamics glass transition temperatures & characteristics:** Equilibrium melting temperature,melting temperature of polymer crystals**,** Factors affecting the melting temperatures, Entropy and chain flexibility, nature of glass transition, Thermodynamics of glass transition, Free volume theory.	6

6.	**Polymer chain conformations and Phase transitions:** Chain end-end distance, Conformations available to a chain, Random flight model for polymer, order of phase transitions, Feyman's method, Theory of rubber elasticity.	6
7.	**Theories for polymer solutions**: Polymer solutions, Miscible and immiscible blends, Regular solution theory, Flory- Huggins theory.	5
8.	**Thermodynamics of polymer solutions:** Theories of mixing, Solubility parameters and enthalpy of mixing, Phase behavior, Phase equilibria in polymer solutions, Critical fluctuations and spinodal decomposition, Group contribution methods for solubility parameters, Osmotic pressure- Molecular weight measurement, Viscosity of dilute solution	**7**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors**	**Year of Publication**
1	Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw Hill.	2005
2	Polymer chemistry, 2nd edition, P. C. Hiemenz and T. P. Lodge, CRC press, Boca Raton.	2007
3	Essentials of Polymer Science and Engineering, Mike Coleman, Paul Painter, DesTech Publications	2008
4	Introduction to polymer science and chemistry: A problem solving approach, ManasChanda, CRC/Taylor & Francis, Boca Raton.	2006
5	Fundamentals of polymer engineering, 2nd edition, Anil Kumar, Rakesh K. Gupta, Marcel Dekker (Taylor & Francis)	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-203** Course Title: **Polymer Blends**
2. Contact Hours: **L: 2** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory:2** **Practical :0**
4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**
5. Credits**: 3** 6. Semester**: Autumn** 7.Subject Area**: PCC**
8. Pre-requisite**: Nil**

9 Objective: To impart knowledge of principles, properties, and applications of polymer blends

10 Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Introduction to polymer solutions, polymer blends, rubber toughened plastics, interpenetrating networks, molecular composites.	2
2	**Miscibility and Phase Separation:** Polymer-polymer miscibility, thermodynamic theories of miscibility, factors governing miscibility, prediction and enhancement of miscibility; Immiscible systems and phase separation; binodal and spinodal decomposition.	5
3	**Compatibility and Compatibilization:** Immiscible and compatible systems; compatibility and compatibilization; compatibilization by block, graft and randon copolymers, compatibilization by functional polymer, compatibilization by reactive blending	5
4	**Blends of Semi-Crystalline Polymers:** Blends ofanamorphous polymer / a semi-crystalline polymer; structure and morphology of a blend of anamorphous polymer / a semi-crystalline polymer; crystallization in a blend of anamorphous polymer / a semi-crystalline polymer; blends oftwosemi-crystalline polymers, structure and morphology of a blend of twosemi-crystalline polymers; crystallization in a blend of twosemi-crystalline polymers	4
5	**Rubber Toughened Polymers**: Toughening mechanism, rubber	6

	toughening, processing, structure, properties and morphology of rubber toughened polymers.	
6	**Molecularly Reinforced Polymer Blends**: Molecular composites, self reinforced LCP blends, macromolecular nano composites, rigid polymer, flexible polymer solvent ternary systems, solution processing, melt processing, properties, applications.	**4**
7	**Interpenetrating Networks:** Introduction, processing, properties, and applications.	**2**
	Total	**28**

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication
1.	Hope P. and Folkes B.M., "Polymer Blends and Alloys", Blackie.	**1993**
2.	Paul D.R. and Sperling H.S., "Multicomponent Polymer Materials", ACS.	**2005**
3.	Paul D. R. and Newman S., "Polymer Blends", Vol-1&2 Academic Press.	**2008**
4.	Utracki L. A., "Polymer Alloys and Blends", Hanser.	**2007**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-108** Course Title: **Mechanical Engineering Drawing**

2. Contact Hours: L**: 2** T: **0** P**: 4**

3. Examination Duration (Hrs.): **Theory: 0** **Practical: 4**

4. Relative Weightage: **CWS: 0** **PRS: 25** **MTE: 25** **ETE: 0** **PRE: 50**

5. Credits: **4** 6. Semester: **Both** 7. Subject Area: **ESC**

8. Pre-requisite: **Nil**

9. Objective: The course objective is to teach the basic concepts of Mechanical Engineering Drawing to the students. The emphasis is on to improve their power imagination.

Details of Course:

S. No.	Contents	Contact Hours
1	General Instructions : Sheet Layout, Line Symbols and Groups, Preferred Scales, Technical Sketching	**1**
2	Types of projections: Reference Planes and Quadrants, Orthographic Projection	**2**
3	Projection of point and lines	**3**
4	Projection of plane figures	**2**
5	Projection of solids	**2**
6	Section of solid and development	**2**
7	Shape Description(External): Multiplanar Representation, Systems of Projection, Sketching of Orthographic Views from Pictorial Views, Conventional Practices, Precedence of Views , Precedence of Lines	**2**
8	Uniplaner Representation: Sketching of Pictorial Views (Isometric and Oblique) from Multiplaner Orthographic Views	**2**
9	Shape Description (Internal): Sectioning as an Aid to Understanding internal features, Principles of Sectioning, Types of Sections, Section Lines, Cutting Plane Lines and Conventional Practices	**3**
10	Size Description: Dimensioning, Tools of Dimensioning, Size and Position Dimensions, Unidirectional and Aligned Systems, Principle and Practices of Dimensioning,	**4**
11	Conventional Representation: Representation and	**1**

	Identification of Common Machine Elements and Features	
12	Introduction to Solid Modeling	**4**
	Total	**28**

Practical Exercises:

Topics	**Practice Classes of Two Hour Duration**
Projection of points and lines	04
Projection of plane figures	02
Projection of solids	03
Section and development	02
Sketching of Orthographic Views from Pictorial Views	04
Sketching of Pictorial Views (Isometric and Oblique) from Multiplanar Orthographic Views, Missing Lines Exercise, Missing Views Exercise	04
Sectioning Exercise	02
Dimensioning exercise	02
Identification Exercise	01
Solid Modeling, orthographic views from solid models	04

11. Suggested Books:

S.No.	**Name of Authors / Books / Publishers**	**Year of Publication/ Reprint**
1.	Technical Drawing, Giesecke, Mitchell, Spencer, Hill, Dygdon and Novak, Macmillan Publishing Company	2003
2.	Engineering Graphics, A. M. Chandra and Satish Chandra, Narosa Publishing House, New Delhi	2003
3.	Engineering Drawing and Graphics Technology, T.E. French, C.J. Vierck and R.J. Foster, McGraw-Hill Inc	1993
4.	Fundamentals of Engineering Drawing, W.J. Luzadder, J. Warren and J.M. Duff, Prentice Hall International Editions	1989
5.	SP 46:1988 Engineering Drawing Practice for Schools and Colleges, Bureau of Indian standards	-------

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-212** Course Title: **Mass Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:20 PRS:20 MTE:20 ETE:40 PRE:0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To provide basic knowledge of mass transfer operations and their application in process industries.

10. Details of Course:

S.No	Contents	Contact Hours
1	**Diffusion:** Molecular and eddy diffusivity, diffusion through stagnant gas film, equimolal and countercurrent diffusion, diffusion through solids.	**4**
2	**Interphase Mass Transfer:** Theory of interphase mass transfer, overall and individual mass transfer coefficients.	**5**
3	**Distillation:** Principles of distillation; Batch and Continuous distillation with reflux; Conditions of feed; Number of stages, stage efficiency.	**6**
4	**Solid– Liquid Extraction:** Single and multiple-stage countercurrent extraction; Calculation of number of stages by graphical and analytical procedures.	**5**
5.	**Liquid-Liquid Extraction:** Triangular diagrams; Number of Stages.	**4**
6.	**Absorption and Adsorption:** Absorption from gas mixture; Selection of solvent; Number of stages, concepts of NTU and HTU; Principles and application of adsorption	**7**
7.	**Humidification, Dehumidification and Drying:** Humidification and dehumidification operation; Cooling towers; Mechanism and rate of drying, calculation for batch and continuous drying; Industrial applications**.**	**9**
8.	**Membrane Separation:** Introduction, Principles, and application**.**	**2**
	Total	**42**

11. List of Experiments:

1. Batch Distillation
2. Liquid-liquid extraction
3. Solid-liquid extraction
4. Distillation in packed bed
5. Steam distillation
6. Diffusion of vapours in air
7. Batch dryer

12. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Treybal R.E., "Mass Transfer Operation", 3rd Ed., McGraw Hill.	1980
2.	Brown G. G., "Unit Operations", CBS Publishers.	1995
3.	McCabe W. L., Smith J. C. and Harriott P., "Unit Operations of Chemical Engineering", 7th Ed., McGraw Hill.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer Science and Engineering**

1. Subject Code: **PEN-202** Course Title: **Polymer Reaction Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:20 PRS:20 MTE:20 ETE:40 PRE:0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge of application of reactionengineering for polymer production.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Ideal Reactors:** Design equations for ideal reactors, namely batch, CSTR, plug flow, design equation for single reaction systems using batch and semi batch, CSTR, PFR and recycle reactor, auto catalytic reactions, reactor choice for single reaction	**4**
2	**Design for multiple reactions:** Parallel and series reactions, quantitative treatment of product distribution and of reactor size for different types of ideal reactors, selectivity and yield, selection of reactor for multiple reactions	**4**
3	**Non-isothermal operation and stability of reactors:** Non isothermal design of ideal reactors, hot spot in tubular reactor, auto-thermal process, steady state multiplicity, optimal temperature progression for first order reversible reaction	**4**
4	**Non-ideal flow:** Residence time distribution (RTD), role of RTD in determining reactor behavior, age distribution (E) of fluid, experimental methods for finding E, relationship between E and F curve, models for non- ideal flow-single and multi parameter models (axial dispersion, tanks in series), performance estimation of reactor using reactor models	**5**
5	**Reaction Engineering of Step Growth Polymerization:** MWD ofcondensation polymerization: ARB and $A_2 + B_2$ systems; advance stage of condensation polymerization, similarity solution step growth polymerization model	**4**
6	**Reaction Engineering of Free Radical Polymerization:** MWDof Free radical polymerization: Standard free radical polymerization; design of tubular reactors involving radical polymerization, solution of equations describing isothermal radical polymerization	**5**
7	**Reaction Engineering of Ionic, Ziggler Natta, Copolymerization:**Smith-Ewart and other models, average chain length estimation of stereoregular polymers, chain segment estimation and its distribution	**5**

8	**Bulk, Solutionand Precipitation Polymerizations:** Modeling of bulk and solution polymerization reactor, precipitation polymerization: reactor modeling to interpret MWD of industrial polymers	**5**
9	**Suspension and Emulsion Polymerization**: Suspension Polymerization: Principles, of reactor modeling and MWD estimation; Modeling of emulsion reactors, prediction of MWD and solution viscosity, examples	**6**
	Total	**42**

11. List of Practicals

i. Study of kinetics of bulk polymerization
ii. Study of kinetics of bulk polymerization in plug floe reactor
iii. Study of kinetics of bulk polymerization in CSTR
iv. Study of kinetics of emulsion polymerization in batch reactor
v. To determine the percentage conversion of monomer and molecular weight distribution of polymer in batch reactor
vi. Study of kinetics of emulsion polymerization in plugflow reactor
vii. Study of kinetics of emulsion polymerization in CSTR

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication
1.	Beisenberger J. A. and Sebastian D.H.; "Principles of Polymerization Engineering", John Wiley& Sons.	1983
2.	Odian G., "Principles of Polymerization", John Wiley & Sons.	2002
3.	Billmayer, F. W., Text Book of Polymer Science 3rd Edition, Willey Inter Science, New York	1984

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer Science and Engineering**

1. Subject Code: **PEN-204** Course Title: **Polymer Rheology & Processing**
2. Contact Hours: **L: 2** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.): **Theory:2** **Practical :0**
4. Relative Weightage**: CWS:20 PRS:20 MTE:20 ETE:40 PRE:0**
5. Credits**: 3** 6. Semester**: Spring** 7.Subject Area**: PCC**
8. Pre-requisite**:**
9. Objective: To impart knowledge of polymer processing technology and equipment.

10. Details of the Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Polymer Rheology and processing:** Introduction to various Rheological response functions, processing behavior of polymers with that of rheology	2
2.	**Basic Rheological Concepts:** Flow Classification: Steady Simple Shear Flow, Unsteady Simple Shear Flow, Extensional Flow; Non-Newtonian Flow Behavior: Newtonian Fluids, non-Newtonian Fluids, Viscoelastic Effects	3
3.	**Continuum Aspect of Rheology:** Phenomenological models to illustrate viscoelastic effects: Maxwell's Model, Voigt Model and Standard Linear Solid Model; Boltzmann's superposition theorem; Temperature dependence of Viscosity; Intrinsic viscosity of polymer solutions	5
4.	**Rheological Models:** Models for the Steady Shear Viscosity Function, Model for the Normal Stress Difference Function, Model for the Complex Viscosity Function, Model for the Dynamic Modulus Functions, Models for the Extensional Viscosity Function; Other Relationships for Shear Viscosity: Viscosity-Temperature Relationships, Viscosity-Pressure Relationship, Viscosity-Molecular Weight Relationship	7
5.	**Rheometry:** Rotational Viscometers: Cone and Plate Viscometer, Parallel-Disc Viscometer; Capillary Rheometers: Constant Plunger Speed Circular Orifice Capillary Rheometer, Constant Plunger Speed Slit Orifice Capillary Rheometer, Constant Speed Screw Extrusion Type Capillary Rheometers, Constant Pressure Circular Orifice Capillary Rheometer (Melt Flow Indexer); Extensional Viscometers: Filament Stretching Method, Extrusion Method	8
6.	**Constitutive Theories and Equations forSuspensions and rheology of complex polymeric fluid:** Importance of Suspension Rheology, Shear Viscous Flow: Effect of Shape, Concentration and Dimensions on the Particles, Effect of Size Distribution of the Particles	3
		Total 28

List of Practical:

1. Rheology of polymer by cone plate rheometer
2. Rheology of polymer by parallel plate rheometer
3. Study of Rheological behavior of Polymer gel
4. Study of rheological behavior of polymeric adhesives
5. Understanding of G', G" and tanδ parameters for polymeric materials
6. Dynamic Mechanical Analysis of Polymeric materials
7. Rheological property estimation of Rubbery materials

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	LarsonR. G.,"The Structure and Rheology of Complex Fluids", Oxford.	1998
2.	BirdR. B., ArmstrongR. C. andHassagerO., "Dynamics of Polymeric Liquids", Volume I and II, John Wiley and Sons.	1987
3.	Montgomery T. Shaw, "Introduction to Polymer Rheology", John Wiley and Sons.	2011
4	Piau J. M. and Agassant J. F., "Rheology of Polymer melt processing", Elsevier.	1996
5.	Shenoy AV, "Rheology of Filled Polymer Systems" Kluwer Academic Publishers	1999
6.	Han CD, "Rheology and Processing of Polymeric Materials" Vol-1, Oxford University Press	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer Science and Engineering**

1. Subject Code: **PEN-206** Course Title: **Polymer Production Engineering**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:15 PRS: 0 MTE:35 ETE:50 PRE:0**

5. Credits**: 3** 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**:**

9. Objective:To impart knowledge of structure, properties processing and manufacturing of polymer materials.

10 Details of Course:

S. No.	Contents	Contact Hours
Flow Diagrams, Unit Operations, Process , Economics, Industrial Production and Applications of :		
1	**Polyolefins:** Polyethylene, polypropylene	4
2	**Vinyl Polymers:** Poly (vinyl chloride)	2
3	**Styrene Polymers:** Polystyrene, ABS, SAN,	6
4	**Thermosets :**Epoxy, polyesters, polyurethanes, phenolic	7
5	**Engineering Thermoplastics:**Polyamides, polyesters, polycarbonates, polyethers,	7
6	**High Performance Thermoplastics: P**oly-ether-ether-ketone, polyphenylenesulphide, polysulphones, polyphenylene-oxides	7
6	**Polyimides:**Polyesterimides, polyetherimides, polybismelimides, poly-amide-imide	7
7	**Fibre Forming Polymers** : Aramid and polyester	2
	Total	42

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication
1.	Brydson JA, “Plastic Materials”, Newnes Butterworth	1989
2.	Campbell IM, “Introduction to Synthetic Polymers”, OxfordUniversity Press	2000
3.	Erhstein G, “Polymeric Materials”, Hanser-Gardner, Cincinnati	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer Science and Engineering**

1. Subject Code: **PEN-208** Course Title: **Elastomer Science and Engineering**

2. Contact Hours: **L: 2** **T: 0** **P: 3/2**

3. Examination Duration (Hrs.): **Theory:2** **Practical :0**

4. Relative Weightage**: CWS:15 PRS: 25 MTE:20 ETE:40 PRE:0**

5. Credits**: 3** 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**:Nil**

9. Objective: To impart knowledge of structure, properties, processing and applications of elastomers and rubbers.

10. Details of the Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definition of elastomers and requirements of polymer to be elastomer: effect of molecular weight and glass transition temperature (Tg), Interpreting the properties of elastomers	**4**
2	**Essential properties of specific elastomers**:Natural Rubber, Styrene Butadiene Rubber, Nitrile rubber, Ethylene-propylene rubbers,Polychloroprene rubber, Butyl rubber,Fluorocarbon Rubber,Polybutadiene Rubber, Polyurethane rubber, Chlorosulfonated polyethylene, Polyurethanes, silicone rubber and thermoplastic elastomers	**7**
3	**Basic rubber compound:** Definition of rubber compounding, process and principles of compounding, basic compound formula, Function of different compounding ingredients: gum rubber, curing agents, ZnO, stearic acid, fillers (black and non black), Accelerators, Antioxidants and antidegradants, Plasticizers and Miscellaneous, Compound design	**7**
4	**Vulcanization of elastomers:** Principles and theory of vulcanization, Definitions of different terms like scorch, cure/ over cure & study of curing, Different types of vulcanization systems, Sulfur and its role in vulcanization. Measurement of mooney viscosity and state of cure for rubber compound	**4**
5.	**Mastication and mixing of rubber:** Definition, objective of mixing and mastication, mixing equipments, different mixing process	**2**
6.	**Engineering aspect of rubber product manufacturing:** Tyre technology, conveyer belt technology, sealing ring technology and hose technology	**4**
	Total	**28**

List of Practicals

1. Identification of different rubbers
2. Processing of rubber in a two roll mill.
3. Processing of rubber with carbon black filler.
4. Processing of rubber with non black loading type filler.
5. Compounding of rubber with ingredients.
6. Vulcanization of rubber.
7. Mechanical properties of vulcanized rubber.

11. Suggested Books

S.No.	Name of Authors /Books/Publishers	Year of Publication
1.	Johnson P., "Rubber Processing: An Introduction", Hanser-Gardner.	2001
2.	Mark J.E., Erman B. andEirich F.R., "Science & Technology of Rubber", Elsevier.	2003
3.	Morton M., "Rubber Technology", Van Norstrand-Reinhold.	1987
4.	Bhowmick, A.K. and Stephens HL, "Handbook of elastomers" CRC Press, 2nd Edition	2000
5.	Andrew Ciesielski, "An Introduction to Rubber Technology"Rapra Technology Limited, UK	1999
6.	Blow CM, "Rubber Technology & manufacture"Buttenvorths, London	1982

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : **Department of Metallurgical and Materials Engineering**

1. Subject Code: **MTN-106** Course Title: **Materials Science**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25 PRS: 0 MTE:25 ETE:50 PRE:0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To impart basic knowledge about the Materials Science.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1	**Introduction:** Historical perspective of Materials Science. Why study properties of materials? Classification of materials. Advanced Materials, Future materials and modern materials.	2
2	**Atomic Structure, Interatomic Bonding and Structure of Crystalline Solids:** Atomic structure. Atomic bonding in solids, Crystal structures, Crystalline and non-crystalline materials. Miller indices. Anisotropic elasticity. Elastic behaviour of composites. Structure and properties of polymers. Structure and properties of ceramics.	2
3	**Imperfections in Solids:** Point defects. Theoretical yield point. Line defects and dislocations. Interfacial defects. Bulk or volume defects.	2
4	**Mechanical Properties of Metals:** Elastic deformation. Plastic deformation. Interpretation of tensile stress-strain curves**,** Yielding under multi-axial stress. Yield criteria and macroscopic aspects of plasticdeformation.	4
5	**Diffusion:** Diffusion mechanisms. Steady and non-steady state diffusion. Factors that influencediffusion.	2
6	**Dislocations and Strengthening Mechanisms:** Dislocation and plastic deformation. Mechanisms of strengthening in metals.Recovery, recrystallization and grain growth. Strengthening by second phaseparticles. Optimum distribution of particles. Lattice resistance to dislocation motion.	4
7	**Phase Diagrams:** Equilibrium phase diagrams. Particle strengthening by precipitation. Precipitationreactions. Kinetics of nucleation and growth. The iron-carbon system. Phasetransformations. Transformation rate effects and TTT diagrams. Microstructure.	3
8	**Failure:** Fracture. Ductile and brittle fracture. Fracture mechanics. Impact fracture. Ductilebrittle transition. Fatigue. Crack initiation and propagation. Crack propagation rate.Creep. Generalized creep behaviour. Stress and temperature effects	4
9	**Processing of Metals and Alloys:** Types of metals and	2

	alloys. Fabrication of metals. Thermal processing of metals. Heattreatment. Precipitation hardening.	
10	**Processing of Ceramics:** Types and applications of ceramics. Fabrication and processing of ceramics.	2
11	**Corrosion and Degradation of Materials:** Corrosion of metals. Corrosion of ceramics. Degradation of polymers	3
12	**Light microscopy:** Introduction, concept of resolution, Airy rings, numerical aperture, magnification, depth of field, depth of focus, lens defects and their corrections, principles of phase contrast – bright-field and dark-field contrast, polarized light microscopy, Quantitative microscopy, estimation of grain size, grain boundary area, relevance of light microscopy ideas to electron microscopy.	3
13	**X-ray diffractometry:** Introduction, crystal geometry, lattice directions and planes, zone axis, interplaner spacing and angle, Stereographic projection, Bragg's condition of diffraction, X-ray scattering, application of X-ray diffraction –phase identification, estimation of grain size, particle size, residual stress.	3
14	**Transmission electron microscopy (TEM):** Principle, construction and operation of TEM, Interaction of electrons with specimen, reciprocal space and lattice, diffraction from finite crystal, preparation of specimens, bright and dark field imaging, selected area diffraction, indexing of diffraction patterns	2
15	**Scanning electron microscopy (SEM):** Principle, construction and operation of SEM,study of fractured surfaces, energy and wavelength dispersive spectroscopy.	2
16	**Thermal analysis techniques:** Principles of differential scanning calorimetry (DSC), differential thermal analysis (DTA), Dilatometry, Thermogravimetric analysis (TGA).	2
	Total:	**42**

11. Suggested Books:

S. No.	Name of Authors /Books/ Publisher	Year of Publication/ Reprint
1	Chawla K.K., Composite Materials: Science and Engineering 3rd Ed., Springer	2012
2	"Composites", ASM Handbook ,Vol. 21, 10th Ed., ASM.	2001
3	W. D. Callister, Fundamentls of Materials Science and Engineering, Wiley	2011
4	Peter Hassen Material Science and Technology , Volume 5,Phase Transformation in Materials	2009
5	James F. Shackelford, Introduction to Materials Science for Engineers, 7th Edition, Pearson Prentice Hall	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Chemical Engineering**

1. Subject Code: **CHN-303** Course Title: **Process Dynamics & Control**
2. Contact Hours: **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.): **Theory: 3** **Practical:0**
4. Relative Weight**:CWS:20** **PRS: 20 MTE: 20** **ETE: 40** **PRE: 0**
5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: PCC**
8. Pre-requisite**:**Sufficient knowledge on material and energy balance and transport process
9. Objective: To acquaint the students about the dynamics and control strategies chemical process systems.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** The concept of process dynamics and control, review of Laplace transform methods, Laplace transform of disturbances and building functions, dynamic model building of simple systems.	**5**
2.	**Linear Open Loop System:** Physical examples of first order systems and their response for step, impulse and sinusoidal inputs, linearization of non linear models, response of first order system in series, examples of second order systems and their response, estimation of system parameters.	**8**
3.	**Linear Closed Loop System:** The control system and its elements, closed loop transfer functions, transient response of simple control systems, concept of stability and use of Routh – Hurwitz test for stability.	**8**
4.	**Controllers:** Modes of control action, control system and its closed-loop transfer function.	**3**
5.	**Root Locus Method :** Root locus treatment, response from root locus and its application to control system design.	**4**
6.	**Frequency Response:** Introduction to frequency response, Bode diagrams of simple systems, Bode stability criterion, control system design by frequency response, use of gain and phase margins.	**5**
7.	**Process Application :** Controller tuning rules, control of complex chemical processes and equipment, control valve sizing, introduction to real time computer control of process equipment.	**5**
8.	**Advanced Control Methods :** Introduction to state-space method, feed forward and ratio control, inferential control, control using digital computers-an introduction.	**4**
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Coughanowr D.R. and LeBlanc S. "Process System Analysis and Control", 3rd Ed., McGraw Hill.	2008
2.	Stephanopoulos G. "Chemical Process Control – An Introduction to Theory and Practice", Prentice-Hall of India.	1990
3.	Seborg D. E., Edgar T. F. and Mellichamp D. A., "Process Dynamics Control", 2nd Ed., John Wiley.	2004
4.	Bequette B. W., "Process Control – Modeling, Design and Simulation", Prentice-Hall of India.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-301** Course Title: **Polymer Processing**
2. Contact Hours: **L: 3** **T: 0** **P: 2/2**
3. Examination Duration (Hrs.): **Theory:3** **Practical :0**
4. Relative Weightage**: CWS:20 PRS:20 MTE:20 ETE:40 PRE:0**
5. Credits**: 4** 6. Semester**: Autumn** 7.Subject Area**: PCC**
8. Pre-requisite**: PEN-204**
9. Objective : To impart knowledge of polymer processing technology and equipment.
10. Details of the Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Introduction to polymer processing, quantitative aspects of polymer product processing additives and compounding – fillers, plasticizers, antioxidants, colorants, flame retardants, stabilizers compounding, mixing and compounding equipment.	6
2.	**Extrusion**: Constructional details of extruders, Plasticating Single-Screw Extruders, twin screw extruders, dies and take - off equipment, post extrusion processing, calendering, laminating, Wire-Coating Extrusion	9
3.	**Fiber Spinning**: Fiber Spinning Processes, Melt Spinning Process, Wet and dry Spinning Process, Other Fiber Spinning Processes, High-Speed Melt Spinning, Spinnability	4
4.	**Blow molding technology:** Process, principles, Machine descriptions, principles of operations, molding parameters; Optimization of processing parameters and troubleshooting; Common molding faults and their correction, Types product processing technology	4
5.	**Compression molding**: Hydraulic presses, press capacity and pressure calculations, molding process	2

6.	**Transfer molding**: Molding process, advantages, disadvantages, Resin transfer molding, Rubber transfer molding technology, type of product processing	2
7.	**Injection molding:** Working principles of injection molding machine, temperature control, injection systems, starting and shut down procedures, process variables reaction injection molding, Injection Molding of Amorphous Polymers: flow pattern and governing system equation, molecular orientation during mold filling; Injection Molding of Semicrystalline Polymers: crystallization during molding, governing system equation, morphology of injected molded semicrystalline polymers, Reaction Injection Molding	8
8.	**Miscellaneous Processing Technologies:** Principles and operations ofrotational molding, thermoforming, and foam processing machines and processing of plastic products by these processes.	**4**
9.	**Tooling & Molds** Tool making processes, die and die forming, compression molds, transfer molds, blow and extrusion dies, typical exercises in mold design and production,two plate mold, three plate mold, hot runner mold, insulated runner mold, runners, gates, mold making, mold cooling.	**3**
		Total 42

List of Practicals

1. Processing of polymer by mini mixer rheocord.
2. Handling, transportation, mixing and pumping in a single screw extruder.
3. Compounding a polymer in a single screw extruder.
4. Processing a polymer in a batch mixer.
5. Processing a polymer in an internal mixer.
6. Compounding a polymer in a twin screw extruder.
7. Processing a polymer in injection molding machine.
8. Processing a polymer in a continuous mixer.

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication
1.	Chan R., Hassen P. and Kramer E., "Processing of Polymers", Wiley-VCH	1996
2.	Griskey R., "Polymer Process Engineering", Chapman & Hall	1992
3.	Grulke E., "Introduction to Polymer Process Engineering", Printice Hall.	1993
4.	McCrum N.G., "Principles of Polymer Engineering", Oxford University Press	1988
5.	Osswald T., "Polymer Processing Fundamentals", Hanser-Gardner	1998
6.	Tadmor Z. and Gogos C.G., "Principles of Polymer Processing", Wiley.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-303** Course Title: **Process Equipment Design**
2. Contact Hours: **L: 3** **T: 0** **P: 2**
3. Examination Duration (Hrs.): **Theory:4** **Practical :0**
4. Relative Weightage**: CWS:15** **PRS:25** **MTE:20** **ETE:40** **PRE:0**
5. Credits**: 3** 6. Semester**: Autumn** 7.Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge of properties of polymers, their testing and characterization
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Shell-Tube Heat Exchangers:** Basic Design procedure for heat transfer equipment, overall heat transfer coefficient and fouling factors, shell and tube exchangers-construction details, selection algorithm, design codes, mean temperature difference, general design considerations, tube-side heat transfer co-efficient and pressure drop, shell-side heat transfer co-efficient and pressure drop, various design methods.	**9**
2.	**Condensers:** Design of condensers for single vapors, heat transfer co-efficient correlations for condensation inside and outside of tubes of the vertical and horizontal condensers, design of desuperheater-cum-condenser and condenser-cum-sub-cooler, condensation of mixtures, pressure pressure drop in condensers.	**5**
3	**Reboilers:** Vaporizers and Evaporators: Pool boiling, convective boiling, selection of reboilers and vaporizers, design of reboilers, vaporizers and evaporators, drawing of evaporators.	**5**
4.	**Extruder:** Fundamentals of Extruder design and design process parameters for single/twin and multi-screw extruder;Design of screw, barrel/shaft and die; Details of design parameters such as screw profiles and pressures, Impact of these parameters on product quality, residence time, melt temperature, torque and energy requirements; Design of different processing sections in extruder-feeding zone, compression zone, mixing, transport, cooking; Extrusion process Optimization; Screw design effects on residence time and its distribution,Screw speed effect on processing;Limitations and challenges in scale up from laboratory	**9**

	scale to production scale; Equipments available for Extrusion and Compounding	
5.	**Injection:**Fundamentals of design and design process parameters for Injection and Compression molding, Design of two plate and three plate type molds, injection, venting, runner and gates, calculation of number of cavities, hot runner mould. Computer software used in designing of molds and mold flow analysis to understand trace stress analysis in molds; Injection molding defects and how to avoid them; Design factors such as wall thickness, gate locations and gate design;	**7**
6	**Compression Molding**Compression moulds-positive, semi-positive and flash mould with horizontal and vertical flash, arrangement of loading shoes, simple two plate and three-plate moulds, split moulds; Design of Compounding elements-conveying elements, mixing elements (30deg and 90deg offset elements), extrusion elements, distributive flow elements, self-cleaning elements. Different pitches –standard, feed zone and compressing zone.	**7**
		Total 42

- **Note: This is an OPEN BOOK EXAMINATION. The students are allowed to consult IS Codes, Text Books, Reference Books and Bound Lecture notes certified by the examiner concerned.**

11. Suggested Books

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Towler G. and Sinnott R.K.., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", 2nd Ed., Butterworth-Heinemann	2012
2.	Seader J. D. and Henley E. J., "Separation Process Principles", 2nd Ed., Wiley-India	2006
3.	I.S.; 4503-1967, Indian Standard Specification for Shell and Tube Type Heat Exchangers.	1983
4.	Hewitt G.F., Shires G.L and Bott T.R., "Process Heat Transfer", Begell House	1994
5	Sidney, Lery, James F. Carly, "Plastic Extrusion Technology Handbook", 2nd Edition, Industrial Press Inc., US	1989
6	David O. Kazmer, "Injection Molding Design Engineering", Hanser Gardner Publications.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-302** Course Title: **Modelling and Simulation of Polymers**

2. Contact Hours: **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:15 PRS:25 MTE:20 ETE:40 PRE:0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective**:** To provide knowledge of procedures of molecular modeling and simulations and their applications for polymers

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Molecular Simulations:** Concept of molecular simulations and their applications; Polymer Chain Conformations:, The Gaussian Chain, Chain Conformation under an External Field; Excluded Volume Effect and Theta Condition	**3**
2	**Theory of polymericbehavior :**Bead-spring model for a polymer; Rouse theory; Hydrodynamic interactions and the Zimm model; Concentrated polymer solutions and melts;Polymer Entanglement and Tube/Reptation theory.	**5**
3	**Molecular Simulation Techniques –** RIS-Monte Carlo (RIS-MC); Rotational Metropolis-Monte Carlo (RMMC); Molecular Dynamics (MD); On Lattice and Off-Lattice Monte Carlo Simulations; Monte Carlo Simulations in Various Ensembles; Molecular Dynamics in various Ensembles.	**8**
4	**Mesoscale Modeling:** General Concept of Coarse-graining and procedure with examples and advantages;Dissipative Particle Dynamics andother Coarse-grained techniques used.	**5**
5	**Estimation of Dynamic properties through molecular simulations**– Concepts of primitive path and Tube Model; Simulation protocols for determination of dynamic properties such as Entanglement Length, Tube Diameter, Contour Length, etc.; Models for Chain Entanglement; Primitive Path Analysis through contour Length/energy	**7**

	minimization procedures.	
6	**Modeling and Simulations for understanding Elasticity and Photoelasticity (birefringence-strain) relationships of Polymer networks**: Relationships between stress-strain and birefringence-strain with examples from PET Film networks, SBS/SIS thermoplastic elastomeric networks and Poly-isoprene elastomeric networks.	**8**
7	**Scopeand applications of available molecular simulation software packages-** Employing software packages such asDLPOLY, LAMMPS, Material studio, Z-code, to solve polymer design problems, examples - Entanglement length variation with chain length, Determining characteristic static ($<R^2>$/M, etc) and dynamic properties (tube diameter (a_{pp}), entanglement/contour length, etc) of some commodity polymers such as PE, PET.	**6**
	Total	**42**

List of practicals:

i. Estimation of Tg of polymer through molecular simulations
ii. Estimation of stress strain properties through molecular simulations
iii. Estimation of contact angle of liquid drop on polymer surface
iv. Determination of static properties of polymers ($<R^2>$,$<Rg^2>$) or by RIS-MC codes
v. Determination of tube diameter and entanglement length
vi. Estimation of shear strength of an adhesive and composite
vii. Estimation of chain properties in melt using molecular dynamics software
viii. Determination of static properties of polymers ($<R^2>$,$<Rg^2>$) or by RMMC software

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1	"Understanding Molecular Simulation: From Algorithms to Applications", DaanFrenkel and Berend Smit, Academic Press: San Diego.	**1996**
2	"Principles of Polymer Chemistry", P. J. Flory, Cornell University Press, Ithaca, NY.	**1953**
3.	"Statistical Mechanics of Chain Molecules", P. J. Flory, Interscience, New York,	**1989**
4.	"Conformational Theory of Large Molecules: The Rotational Isomeric State Model in Macromolecular Systems", W. L. Mattice, and U. W. Suter, Interscience, New York.	**1994**
5.	"The Theory of Polymer Dynamics", M. Doi& S.F. Edwards.,Oxford Science Publications, Clarenden Press, Oxford	**1986**
6	"The Physics of Rubber Elasticity", L. R. G. Treloar, Clarendon Press, Oxford, 3/e, 1975.	**1975**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Polymer and Process Engineering**

1. Subject Code: **PEN-304** Course Title: **Polymer Composites**

2. Contact Hours: **L: 2** **T: 0** **P: 2**

3. Examination Duration (Hrs.): **Theory:2** **Practical :0**

4. Relative Weightage**: CWS:15 PRS:25 MTE:20 ETE:40 PRE:0**

5. Credits**: 3** 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge of structure, properties and applications of polymeric composites.

10. Details of the Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Need to reinforce polymers, particulate, short and continuous fiber reinforced composites based on thermoplastic and thermoset matrices.	**2**
2.	**Particulate Filled Polymeric Composites**: Mineral, natural, organic metallic particulate reinforcements; processing of particulate polymeric composites; particulate/polymer adhesion and its effects on structure and morphology of particulate polymeric composites; mechanics and mechanical properties, and thermal properties of particulate polymeric composites; applications of particulate polymeric composites	**6**
3	**Short Fiber Reinforced Polymeric Composites**: Synthetic, inorganic, and natural short reinforcing fibers, extrusion, compounding, processing, and injection moulding of short fiber/ polymer composite products; structure and properties of short fiber/polymer composites; semi-empirical equations and mechanics of short fiber/polymer composites; mechanical and thermal properties of short fiber/polymer composites; applications of short fiber/polymer composites in automobiles, building materials, and other engineering sectors.	**7**
4.	**Continuous Fiber Reinforced Thermoset Composites:** Epoxy, polyesters and vinyl esters as matrix polymers, and glass, aramid and carbon fibres as reinforcing fibers for continuous fibre / polymer composites; processing by wet pay up: contact molding and pressure bag molding, resin transfer molding and compression molding; properties, applications in aerospace, automobiles and engineering sectrs	**9**
5	**Other Composites:** Introduction to continuous fibre / thermoplastic composites; matrix resins and fibres for continuous fibre /	**4**

	thermoplastic composites; processing limitations for continuous fibre / thermoplastic composites; introduction to polymeric nano composites	
	Total	**28**

List of Practical

1. Extrusion & Compounding of a short-fiber / thermoplastic polymer composite by Mini Mixer / Extruder
2. Injection Moulding of Extruded short-fiber / thermoplastic polymer composite
3. Study of effect of fibre content on tensile properties of short-fiber / thermoplastic polymer composite.
4. Study of effect of fibre content on flexural properties of short-fiber / thermoplastic polymer composite.
5. Study of effect of fibre content on thermal properties of short-fiber / thermoplastic polymer composite.
6. Processing of Continuous Fibre / Thermoset Polymer Composite by Compression Moulding
7. Effect of Fibre Content on Mechanical properties of Continuous Fibre / Thermoset Polymer Composite

12. Suggested Books

S. No.	**Name of Authors / Books / Publisher**	**Year of Publication**
1.	Agarwal L.andBourtman D.J., “Analysis and Performance of Fiber Composites”, Wiley.	2000
2	Chung C., “Introduction to Composites”, Technomic, Lancaster, PA.	1998
3.	White J. and De S., “Short Fiber Composites”, Technomic, Lancaster.	1996
4.	Summerscales J. and Short D., “Fiber Reinforced Polymers”, Technomic.	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE **Department of Chemical Engineering**

1. Subject Code: **CHN-310** Course Title: **Process Utilities, Economics and Plant Design**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical :0**

4. Relative Weightage**: CWS:25** **PRS:0** **MTE:25** **ETE:50** **PRE:0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To provide knowledge of various process utilities and to equip the students with plant economics and design aspects.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Heat Transfer Media:** Utilities in process industries, primary and secondary and their importance; Classification, characteristic properties, selection criteria of heat transfer media and their industrial applications.	**8**
2.	**Steam Generation and Utilization:** Steam generation, supercritical boilers, steam handling, steam traps-classification, characteristics and selection, condensate utilization and flashing.	**3**
3.	**Water and Air:** Raw water and its characteristics, treatment and conditioning of water for use in process industries, recycling and reuse of water; Use of air in process industries for drying and instrumentation and design of air receivers.	**7**
4.	**Piping Network:** Design of pipelines and piping networks for water, steam, condensate and air.	**3**
5.	**Time Value of Money:**Interest; Compounding and discounting factors; Loan Payments; Cash flow pattern: Discrete and continuous.	**3**
6.	**Depreciation Methods andProfitability:**Methods of depreciation; Profitability methods with and without time value of money; Effect of inflation on profitability analysis; Evaluation for replacements.	**6**
7.	**Analysis of Cost Estimates:**Corporate cash flow, equipment cost curves and indices,types of capital cost estimates, methods for estimating capital investment, estimation of revenue and total product cost, gross profit and net profit.	**5**
8.	**Plant Location and Layout:** Factors for selection of plant location, site selection and preparation, plant layout and installation.	**2**
9.	**Scale-Up:** Pilot plants and models, principle of similarity,	**5**

	dimensional analysis, differential equations; Regime concept: static and dynamic; Similarity criteria and Scale-equations for important equipment.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	Goodall P. M., "The Efficient Use of Steam", Editor: Westbury House.	1980
2.	Lorch, "Handbook of Water Purification", Editor: McGraw Hill Book Company.	1981
3.	Peters M. S., Timmerhaus K. D. and West R. E., "Plant Design And Economics For Chemical Engineers", 5^{th} Ed., McGraw Hill, International Ed..	2002
4.	Couper J., "Process Engineering Economics", CRC Publisher.	2003