Table 4: Final BPGS approved syllabus for 4 semester M.Techprogramme in Chemical and Polymer Engineering.

Total Core (C) Credits: 54, Total Elective (E) Credits: 18, Total Credits: 72

1stSemester (600 Marks)				
Theory Paper (code)		**Name**	**Credits**	**Marks**
	CP 901C	Advanced Reaction Engineering	4	100
	CP 902C	Polymer Science and Technology	4	100
	CP 903C	Heat and Mass Transfer	4	100
Dept. Elective *(Students to selectany one from the list)*	CP906E	Rubber Science and Technology	4	100
	CP907E	Colloids and Interface Science	4	100
	CP908E	Polymer Recycling and Uses	4	100
Other Elective		Elective to be taken from other department (compulsory)	4	100
Practical Papers		**Name**	**Credits**	**Marks**
	CP904C	Polymer Lab	2	50
	CP905C	Reaction Engineering Lab	2	50
2nd Semester (550 Marks)				
Theory Paper(code)		**Name**	**Credits**	**Marks**
	CP1001C	Advanced Fluid Flow & Rheology	4	100
	CP1002C	Polymer Characterization and Testing	4	100
Dept. Elective *(Students to select any two from the list)*	CP1004E	Polymer Processing	3	100
	CP1005E	Fluidization Engineering	3	100
	CP1006E	Biomaterials	3	100
Other Elective		Skill 3 (Compulsory elective offered by University)	4	100
Practical Papers		**Name**	**Credits**	**Marks**
	CP1003C	Polymer characterization Lab	2	50
3rd Semester (300 Marks) Project Identification, literature Survey and Plan of Work(Project: Phase-I)				
Paper		**Name**	**Credits**	**Marks**
	CP 1101C	Project (Literature review + Objectives+ Hypothesis + Progress Report Writing)	8	200
	CP 1102C	Progress Seminar + Viva- Voce	4	100

Approved in BFS meeting of Science, T.U. dated 6/05/2017

Dean and Chairman, BFS of Science,
Tribhuvan University.

4th Semester (400 Marks) Project Implementation (Project: Phase-II)			
Paper	Name	Credits	Marks
CP1201C	Project (Literature review+Methodology+Final Thesis	10	250
CP1202C	Comprehensive Seminar + Viva-Voce	6	150

Detailed Content of the Syllabus

1st Semester (600 Marks)

Code: CP 901C Name: Advanced Reaction Engineering Credits: 4 Marks 100

- Reactor and reactor types, modes of reactor operation: growth kinetics, batch, fed-batch and continuous operation. Productivity optimisation and cost minimisation. Reactor design: size estimation, single or multiple vessels, impeller and sparger systems. Design for containment and asceptic operation. reactor monitoring and control: instrumentation, on-line and off-line analyses, control algorithms.

- Reactor sterilization: cell death kinetics, batch and continuous systems, filter sterilization of gasses and liquids, safe and contained operation. Oxygen transfer: mass transfer, design for oxygen transfer. Mixing and power consumption: power number and impeller design, mixing time and reactor heterogeneity, effect of aeration and broth rheology. Effects of shear during operation.

- Issues in process scale-up: effects of heterogeneity and bases for scale-up. Fermentation process scale down: benefits of process scale down. Biocatalyst kinetics and properties: enzyme immobilization, kinetics of free and immobilized enzymes, Industrial lectures on impact of microbial physiology on bioreactor performance, Present and future fermentation trends, Scale-up and scale-down of industrial fermentation processes, Rapid fermentation process development, Industrial applications.

Reference books:

1. Shuler, M. L. and Kargi, F., Bioprocess Engineering Basic Concepts, Prentice Hall, Englewood Cliffs, N. J., 2002.

2. Schugerl, K. and Bellgardt, K. V., Bioreaction Engineering: Modeling and Control, Springer Verlag, Heidelberg, 2000.
3. Blanch H. W. and Clark D. S., Biochemical Engineering, Dekker, 1996.
4. Doran P., Bioprocess Engineering Principles, Academic Press, NewYork, 1995.
5. Bailey J.E., and Ollis D.F., Biochemical Engineering Fundamentals, Second Edition, McGraw Hill, New York, 1986.
6. Molecular Biology of the Cell, Third Edition, B. Alberts, D. Bray, J. Lewis, M. Raff, K. Roberts, and J. D. Watson, Garland Publishing Inc, N.Y., 1994.
7. Roger Harrison et al., Bioseparations Science and Engineering, Oxford University Press, 2003.

Code: CP 902C Name: Polymer Science and Technology Credits: 4 Marks 100

Historical development of polymers.

Basic concepts and definitions: monomer, polymer, oligomer, repeating units, structural units, degree of polymerization, molecular weight.

Classification of polymers: natural vs. synthetic, linear, branched, cross-linked, amorphous, crystalline, thermoset, thermoplastic, homopolymer, co-polymer, fiber, plastics, elastomers.

Biopolymers, natural polymer and fibers: proteins, polynucleotides, polysaccharides, naturally occurring elastomers, natural and synthetic fibers, cellulosics, non-cellulosics.

Polymerization mechanism: introduction, chain polymerization, step polymerization, ionic and coordination polymerization, ring-opening polymerization.

Thermal transition in polymer: introduction, the glass transition temperature, molecular motion and glass transition, theories of glass transition and measurement of the glass transition temperature, factors affecting glass transition temperature, the crystalline melting point and the factors affecting the crystalline melting point.

Polymer additives and reinforcements: introduction, plasticizers, fillers and reinforcements, alloys and blends, antioxidants, thermal and UV stabilizers, flame-retardants, colorants, anti-static agents.

Mechanical properties of polymers: introduction, mechanical test (stress–strain, creep, stress relaxation, dynamic mechanical and impact experiments), stress–strain behavior of polymers, deformation of solid polymers, effects of structural and environmental factors on mechanical properties, polymer fracture behavior.

Polymer degradation and the environment: thermal degradation, oxidative and UV stability, chemical and hydrolytic stability, effects of radiation, mechanodegradation, management of plastics in the environment (recycling, incineration, biodegradation).

Textbooks

1. Principles of Polymerization, G. Odian (Wiley, London, 2004)
2. Polymer Science and Technology of Plastics and Rubber, P. Ghosh, Tata McGraw Hill, New Delhi, 2000.
3. Polymer Science by Gowarikar, Johan wiley and Sons 1986.
4. Principles of Polymer Science, by Bahadur and Sastry, Narosa Publishing House 2002.
5. Textbook of Polymer Science, P. Nayak and S. Lenka, Kalyani Publishers, 1986.
6. Polymer Science and Technology by J. R. Fried, Prentice-Hall, Inc 1995.
7. Textbook of polymer Science and Engg., Anil Kumar and Gupta, tata McGraw-Hill publishing co, Ltd, 1978.
8. Plastics Materials J. A. Brydson, Butterworth Scintific, 1990.

Reference books

1. Fundamentals of Polymers: Raw Materials to Finish Products, Karak, N., PHI, New Delhi, 2009

2. Encyclopedia of Polymer Science and Engineering, Bikales, N. Overberger, C. G. Menges G., Wiley-Interscience, New York, 1989

3. Encyclopedia of Chemical Technology, Othmer, K., Wiley-Interscience, New York, 1992

Code: CP 903C Name: Heat and Mass & Transfer Credits: 4 Marks 100

Basics of heat transfer, modes of heat transfer and its defining equations, heat conduction through plane walls, hollow cylinder, hollow sphere and their three dimensional equations, combined modes of heat transfer, critical thickness of insulation, finite difference method for steady and unsteady conduction, heat transfer through extended surfaces, heat transfer through non-Newtonian fluids, concept of boundary layers, dimensionless numbers and their physical significance, free and forced convection, Boiling heat transfer, heat exchangers and its types, analogy of heat exchangers, heat exchanger design, radiation heat transfer, various radiation laws, Angle factor calculations, basics of mass transfer, diffusion, convective mass transfer, mass

transfer theories, influence of turbulence on heat and mass transfer, mass transfer coeffecients, absorption, distillation, humidification and air conditioning.

Text books

1. JP Holman: Heat Transfer, McGraw-Hill, New York.
2. Yunus A. Cengel : Heat Transfer - A Practical Approach, McGraw-Hill, New York.
3. M. NecatiOzisik: Boundary Value Problems of Heat Conduction; Dover Publications, New York.
4. P. S. Ghoshdastidar; Heat Transfer, Oxford University Press, UK.
5. Crank, J., and Park, G.S. (eds.), Diffusion in Polymers, Academic Press, New York (1968).
6. Richard G. Griskey, Mass Transfer in Polymer Systems, Springer
7. Kreith, F, Boehm R.F, Heat and Mass Transfer, CRC Press
8. Baehr HD, Stephan K, Heat and Mass Transfer, Springer

Code: CP 904C Name: Polymer Lab Credits: 2 Marks:50

1. Purification of monomers/solvent by distillation, crystallization of initiators, Free radical polymerization of MMA, MA, AA using BPO/AIBN initiators.
2. Synthesis of phenol formaldehyde (novolac and resole) resin, cross linking of phenolic resin, synthesis of poly (ethylene/terephthalate), synthesis of nylon-6,6.
3. Polymer end group analysis, determination of intrinsic viscosity and viscosity-average molecular weight of a given polymer sample, determination of number average molecular weight of a given polymer by vapor pressure osmometry, determination of molecular weight distribution by GPC.
1. Characterization of selected polymer sample by IR Spectrophotometer.
4. Determination of molecular weight & poly dispersity index (PDI) of given resin using GPC.
2. Determination of moisture content of given sample. (Quantitative analysis).

Textbooks

1. Purification of Laboratory Chemicals, Armarego, W.L.F. Chai, C.L.L., Elsevier, Burlington, 2009.

2. Experimental Methods in Polymer Science, Tanaka, T., Academic Press, Florida, 2000.

3. Experiments in Polymer Science, Collins, E.A. Bares, J. Billmeyer, Jr., F.W., (Wiley, New York, 1973)

Reference Books

1. Laboratory Preparation for Macromolecular Chemistry, MaCaffery, E.M., McGraw-Hill, New York, 1970.

2. Methods of Polymers Chemistry, Sorensen, W.R. Campbell, T.W. Preparative, Wiley, New York, 1968)

3. Polymer Chemistry: A Practical Approach, Davis, F.J., Oxford, London, 2004.

Code: CP 905C Name: Reaction Engineering Lab Credits: 2 Marks:50

Preparation and Sterilization of Industrial reactor Medium

1. Laboratory scale reactor operation and product separation
2. Growth kinetics measurement through spectrophotometer
3. Reactor based production of organic acids from synthetic medium
4. Optimization of reactor process parameters
5. Product preservation techniques

Text books

1) Biochemical Engineering and Biotechnology, Ghasem D. Najafpour, Elsevier, Amsterdam, The Netherlands
2) Bioprocess Engineering Principles, Pauline M. Doran, Academic Press, California. Elsevier India Private Limited, New Delhi
3) Bioprocess Monitoring and Control,By Marie- Noelle Pons, Hanser Publishers New York, USA
4) Biochemical Engineering By J.M. Lee, Prentice Hall, Englewood Cliffs, New Jersey
5) Biochemical Engineering, 2nd Edition, By S. Aiba, A.E. Humphrey & N.F. Millis, University of Tokyo Press, Japan
6) Biochemical Engineering Fundamentals 2nd Edition, By J.E. Bailey, D.F. Ollis, McGraw Hill Book Company, New Delhi

Detailed syllabus for electives for 1st Semester

Code: CP906E Name: Rubber Science and Technology Credits: 4 Marks: 100

Natural Rubber: source, isolation and processing of latex, various natural rubber grades and products, Chemistry of rubber and rubber additives, Compounding and vulcanization mechanism, chemistry of vulcanization, Degradation and aging of rubber, modification of rubber, theory of rubber elasticity, Rubber reinforcement, Synthetic rubbers: SBR, NBR, IR, IIR, CR, EPR, EPDM, Hypalon, floroelastomers, silicones, Thermoplastics, elastomers, structure property applications, Polyesters and ester urethane or ether-urethene rubbers, Rheometry and curometry, assessment of curing/degree of cure, rubber additives, sulpher vulcanization vs non sulpher vulcanization, cold curing, Copolymer composition determination through NMR, Details of the following rubber products: shoes, belting and hoses, cables, automobile tyres and tubes, etc.

References

1. Erman, B. Mark, J.E. Science and Technology of Rubber (Academic Press, Florida, 2005).
2. EIRI Board, Technology of Rubber & Rubber Goods Industries (Engineers India Research Institute, New Delhi, 2009).
3. Kothandaraman, B. Rubber Materials (Ane Books Pvt Ltd, New Delhi, 2008).

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Code: CP907E Name: Colloids and Interface Science Credits: 4 Marks: 100

Basic concepts of colloids and interfaces; properties of colloidal dispersions; surfactants and their properties; micelles, bilayers, vesicles and liquid crystals; surface and interfacial tension; Young−Laplace equation; Kelvin equation; contact angle; intermolecular and surface forces; DLVO theory; adsorption at interfaces; characterization of solid surfaces; applications in detergents, personal-care products, pharmaceuticals, nanotechnology, and food, textile, paint and petroleum industries.

Textbooks:

P. C. Hiemenz and R. Rajagopalan, Principles of Colloid and Surface Chemistry, Marcel Dekker, New York, 1997.
J. C. Berg, An Introduction to Interfaces and Colloids: The Bridge to Nanoscience, World Scientific, Singapore, 2010.
P. Ghosh, Colloid and Interface Science, PHI Learning, New Delhi, 2009.

Code: CP908E Name: Polymer Recycling & Uses Credits: 4 Marks: 100

Sources of plastic waste and its management, separation methods, primary & secondary recycling methods, tertiary and quaternary recycling, recycling methods of specific plastics (PVC, PET, PMMA, HDPE, LDPE, PS), characteristics and typical applications of few plastic materials.

Text Books:

1. J Leidner, Plastic Waste, Marcel Dekker
2. J Aguado& D Serrano, Feedstock Recycling of Plastic Waste, Royal Society of Chemistry
3. B Hegberg, G Brenniman, Mixed Plastic Recycling Technology, Noyes Data Corporation
4. L Mantia, Recycling of Plastic Materials, Chemtec Publishing
5. Harper, Modern Plastics Handbook, McGraw-Hill

2nd Semester (550 Marks)

Code: CP1001C Name: Advanced Fluid Flow& Rheology Credits: 4 Marks: 100

Basic Concepts and Fundamentals: Defination and properties of fluids, fluid as a continuum, Langragian and Eulerian description, Velocity and stress field, Fluid statics, Fluid Kinematics.

Governing Equations of Fluid Motion: Reynolds transport theorem, Integral and differential forms of governing equations: mass, momentum and energy conservation equations, Navier-Stokes equations, Euler's equation, Bernoulli's Equation.

Exact solutions of Navier-Stokes Equations: Couette flows, Poiseuille flows, Fully developed

flows in non-circular cross-sections, Unsteady flows, Creeping flows.

Laminar Boundary Layers: Boundary layer equations, Boundary layer thickness, Boundary layer on a flat plate, similarity solutions, Integral form of boundary layer equations, Approximate Methods, Flow separation, Entry flow into a duct.

Turbulent Flow: Introduction, Fluctuations and time-averaging, General equations of turbulent flow, Turbulent boundary layer equation, Flat plate turbulent boundary layer, Turbulent pipe flow, Prandtl mixing hypothesis, Turbulence modeling, Free turbulent flows.

Rheometry: Introduction, principles of viscometry, Rheometers and rheometrical procedures, Typical rheological behaviours, problems encountered in rheometry, Non-standard techniques: what can be done without a rheometer.

Text books

1. Morrison, F.A. 2001 *Understanding Rheology*. New York: Oxford University Press
2. Batchelor G.K, An Introduction to Fluid Dynamics, Cambridge University Press, 1983.
3. Fox W. Robert, McDonald T. Alan, Introduction to Fluid Mechanics, Fourth Edition, John Wiley & Sons, 1995.
4. Frank M. White, Fluid Mechanics, Tata McGraw-Hill, Singapore, Sixth Edition, 2008.
5. Barnes, H.A., Hutton, J.F., Walters, K.: An Introduction to Rheology. Rheology series, Vol. 3, Elsevier, 1989. F. Irgens: Compendium.
6. Bird, R.B., Armstrong, R.C. &Hassager, O. 1987 Dynamics of Polymeric Liquids. New York: John Wiley & Sons

Code: CP1002C Name: Polymer Characterization and Testing Credits: 4 Marks: 100

Characterization tests: TGA, DTA, DSC, TMA, XRD, SEM, AFM, TEM, IR, NMR, GC, GPC melt index and viscosity.

Thermal and electrical properties: Heat deflection temperature, Vicat softening temperature, thermal conductivity thermal expansion, brittleness temperature – dielectric strength dielectric constant, dissipation factor, resistance.

Mechanical properties and flammability: Tensile tests, compressive properties, impact properties, deformation, brittleness abrasion resistance hardness tests – incandescence resistance, ignition properties, oxygen index, surface burning characteristics.

Optical properties and analytical tests: Refractive index, luminous transmittance, haze, density, water absorption, moisture analysis, sieve analysis, crush and burst strength.

Testing of foam plastics and testing organizations: Foam properties, rigid and flexible foam - testing methods .

Text books

1. S. K. Nayak, S. N. Yadav, S. Mohanty, Fundamentals of Plastic Testing, Springer, 2010.

2. Vishu Shah, Hand book of Plastics Testing and Failure Analysis, 3rd Edition, John-Willey &Sons, New York, 2007.

3. B. Sivasankar, Engineering Chemistry, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2012

4. A. B. Mathur, I. S. Bharadwaj, Testing and Evaluation of Plastics, Allied Publishers Pvt. Ltd., New Delhi, 2003

5. A. Ya. Malkin, A.A. AskaDsky, V.V. Koverica Experimental methods of polymers, Mir Publishers, Moscow, 1998.

6. Iver, Mead and Riley, Hand book of Plastic test methods, Illith Publishers, New York, 1982.

Code: CP1003C Name: Polymer Characterization Credits: 2 Marks:50 lab

1. Determination of melt flow index (MFI) of given sample.
2. Curing characteristic studies of different rubbers using different compounding ingredient by rheometer.
3. Thermal analysis of polymers by DSC, TGA, DMA.
4. Study rheological properties of polymers by rheometer.
5. Determination of stress-strain profile of polymers, determination of tensile strength, modulus and elongation at break of selected thermoplastics and natural rubber, determination of impact strength, dielectric constant.

Textbooks

1. Modern Technology of Plastic & Polymer Processing Industries, NIIR Board, National Institute of Industrial Research, New Delhi, 2007)

Reference Books

1. Polymer Testing, Grellmann, W. Seidler, S. Altstadt, V., Hanser Gardner PUBNS, Cincinnati, 2007.

Detailed syllabus for electives for 2nd Semester

Code: CP1004E Name: Polymer Processing Credits: 3 Marks: 100

Basic Concept of Compounding and Processing. Classification and type of Additive for Plastics: antioxidants, light stabilizers, UV stabilizers, lubricants and relative auxiliaries, processing aids, impact modifiers, flame retardance, fillers, croslinking agents, antistatic agents, stabilizers and Plasticizers. Rheology of polymer melt. Mixing process: distributive mixing, dispersive mixing and mixing devices. Molding: injection molding, Extrusion molding, compression molding, transfer molding, reaction injection molding (RIM) , bow molding, rotational molding, film extrusion, pultrusion, calendaring, casting, coating, foaming, forming laminates. Fiber technology and processing: definition of textile terms, properties of textile fibers (electric, mechanical and fabric properties). Fiber spinning: melt spinning, dry spinning, and wet spinning. Fiber after treatments scouring, lubrication, sizing, dyeing, finishing. Elastomers technology and processing: Compounding and elastomers properties, Vulcanization: chemistry of vulcanization, sulfur vulcanization, physical aspects of vulcanization. Reinforcement, types of fillers, carbon black.

Textbooks

1. Plastics Engineering by R. J. Crawford, Pergamon Press 1989.
2. Understanding Compounding, R. H. Wildi and Maier, Hanser Publisher Inc, 1998.
3. Fundamental of Polymer processing, S. Middleman, Houghton Mifflin Company, 1997.
4. Polymer Processing Fundamentals, Osswald, A. Tim, Hanser Publishers, 1998.
5. Composite Material Handbook, M. M. Schwartz, McGraw-Hill Company, 1984.
6. Principles of Polymer Processing, Tadmor, Z. Gogos, G.G., Wiley, New York, 2006.
7. Polymer Process Engineering, Grulke, E.A., PTR Prentice Hall, Eaglewood Chiffs, New Jersey, 1994.

Reference books

3. Advances in Polymer Processing: Macro to Nano Scales, Thomas, S. Yang, W., CRC press, Boca Raton, 2007.
4. Principles of Polymer Engineering, Mccrum, N.G. Buckley, C.P Bucknell, C.P, Oxford Engineering Press, Oxford, London, 1988.

5. Rheology and Processing of Polymeric Materials: Polymer Rheology, Han, C.D., Oxford
6. University Press, New Delhi, 2006

Code: CP1005E Name: Fluidization Engineering Credits: 3 Marks: 100

Introduction to fluidization, types of fluidization, fluidized bed behaviour study, solid transport in fluidized bed, heat and mass transfer in fluidized bed, semi-fluidization principles, industrial applications of fluidization, design of fluidized bed reactor, Concept of RTD, Basic design principles for Fluidized bed reactor, use of fluidized bed reactors in polymer industries (catalytic olefin polymerization, polymerization reaction of ethylene and propylene etc.), Fluidized Bed Dryer (FBD)- Introduction, advantages and limitations of FBD, mathematical models, effect of operating parameters of FBD, design procedure of FBD,

Text Books:

1. Kunni&Levenspiel: Fluidization Engineering, Elsevier Publications,
2. W.C. Yang: Handbook of fluidization and fluid particle systems, Marcel Dekker, New York.
   J.F Davidson, D. Harrison; Fluidized Particles, Cambridge University Press, Cambridge

Code: CP1006E Name: Biomaterials Credits: 3 Marks: 100

Introduction to BiomaterialsConcept of biomaterials, need for biomaterials for uses in medicine and scientific research, basic properties, clinical significance. Disinfection and sterilisation of biomaterials. Biocompatibility, Bioceramics:Structure and Synthesis, Properties and Characterization of Biomaterials, Implants and medical devices; Deterioration of biomaterials, Naturally Occurring Polymer Biomaterials, Metalllic biomaterials and their application, Biomaterials for Tissue Engineering, Other Important Issues and Future Challenges in biomaterial engineering.

Text Books:

1. H.Boenig, Fundamentals of Plasma Chemistry and Tehnology, Technomic Publishing Co.Inc. Lancaster Basel, 1990.

1. Hench L LEthridgc E.C. Biomaterials, an interfacial approach, Academic press 1982
2. Practical Surface Analysis, 2- edition, Edited by D.Briggs, M.P.Seah, J.Wiley& Sons Ltd, 1990.
3. Biomaterials Science, An Intoduction to Materials in medicine, Eds. B. D. Ratner and A. S. Hoffman, Academic Press, New York, 1996.
4. Plasma-surface modification of biomaterials, P.K.Chua, J.Y.Chena, L.P.Wanga, N.Huang, Elsevier Science B.V, 2002.