BRANCH-BIOTECHNOLOGY

Specialization: Biotechnology

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Advanced Biochemical Engineering	4-0	4	100	50	-	-	-
Specialization Core-2 Applied Bioinformatics	4-0	4	100	50	-	-	-
Elective-I (Specialization related) 1. Plant biotechnology 2.Animal biotechnology 3. Genomics & Proteomics 4.Computational Biology	4-0	4	100	50	-	-	-
Elective-II (Departmental related) 1. Environmental Biotechnology 2. Advanced Microbiology & Immunology 3. Nanobiotechnology 4. Pharmaceutical Biotechnology	4-0	4	100	50	-	-	-
Elective-III (from any Department) 1.Techniques in Genetic Engineering 2. Bioreactor Design & Optimization 3.IPR, Bioethics & Biosafety 4.Process Control & Instrumentation	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the Department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

ADVANCED BIOCHEMICAL ENGINEERING

Module-I

Concept of ideal reactors based on flow characteristics, design of ideal reactors using material and energy balance equations. Single reactors, with ideal flow condition, comparison of volumes of plug flow reactor and chemostat. Multiple reactors-methods to show how total volume is affected in multiple reactors. Searching for mechanism – Arrhenius equation – Batch reactor analysis for kinetics (synchronous growth and its application in product production).

Module-II

Growth Kinetics: Batch growth quantifying cell concentration, growth profiles and kinetics in batch culture, fed batch growth, continuous growth and their growth kinetic quantification, chemostat growth, semi-continuous / exponential feeding strategy. Maximizing the yield of intermediate product in series reactions.

Module-III

Design principles – Non isothermal reactions and pressure effects; Non-ideal flow in bioreactors-reasons for non-ideality, concept of RTD studies, characterization of non-ideality using RTD studies, various distribution functions, conversions using tracer studies. Diagnosing the ills of non-ideal bioreactors, various models of non-ideal flow.

Module-IV

Design and analysis of bioreactors-stability and analysis of bioreactors, biomass production and effect of dilution rate. Design and operation of various bioreactors, viz CSTF, fed batch systems, air-lift bioreactors, fluidized bed bioreactors. Scale up of bioreactors. Criteria for selection of bioreactors.

APPLIED BIOINFORMATICS

Module-I

Sequence-alignment methodologies: Sequence databases; Similarity matrices; Pairwise alignment: Features of dynamic Programming, alignment by Bayesian Statistical Methods, multiple sequence alignment: local multiple sequence alignment: MEME, PSSM, HMM (algorithms and applications) Progressive methods for global multiple sequence alignment: CLUSTALW, PILEUP, T-COFFEE; Statistical significance of alignment results;

Module-II

Pattern analysis in sequences and Phylogenetic tree construction methods: Motif representation, Markov models; .Distance Based methods: clustering based methods, optimality based methods: Fitsch -Margoliash and Minimum evolution methods, Neighbour joining and related neighbour methods Character Based methods: Maximum parsimony methods, Maximum likely hood method, genetic algorithmand Phylogenetic tree evaluation: Boot strap analysis; dendrogram and applications

Module-III

Structure-Prediction of Biomolecules with applications in Bioinformatics: Structure classification of proteins (SCOP, CATH); Secondary structure prediction of various protein categories (e.g. transmembrane proteins and helical proteins), RNA secondary structure prediction methods.

Module-IV

Patterns, motifs and Profiles in sequences: Derivation and search methods; Derived Databases of patterns, motifs and profiles e.g.Prosite, Blocks, Prints-S, Pfam; Overview of tertiary structure prediction methods; algorithms for modelling protein folding; algorithms for 3D structure prediction with representative examples Protein structure prediction by comparative modelling approaches (homology modelling and fold recognition); ab initio structure prediction methods.

PLANT BIOTECHNOLOGY

Module-I

Plant Genomics and Molecular Mapping: Introduction Genome mapping; Identification of candidate genes using: genetic information (positional cloning); biochemical and expression analysis (microarray analysis, proteomics, metabolomics); Characterization and functional analysis of candidate genes using: transformation, mutant populations, knockout systems; Heterologous expression systems. Structural and Functional genomics; application of sequence based and structure-based approaches to assignment of gene function. Molecular marker and its type (RFLP, RAPD, AFLP, SSR, STS, EST, SNP); Constructing molecular maps; Molecular tagging and mapping of genes/traits; Marker assisted selection of qualitative and quantitative traits. Construction of genetic and physical map; Gene mapping and cloning; QTL mapping and cloning; Nucleic acid and Protein arrays: basic principles, instrumentation and applications in plant genomics, Identification of disease genes.

Module-II

The Gene transfer Techniques for the production of Transgenic: Overview of different gene transfer methods, plant vectors for transformation, transgene analysis and expression. Indirect Gene transfer Methods: structural features of Ti plasmid, mechanism of gene transfer to plants Integration of T-DNA into plant genome, Molecular events in Agrobacterium mediated gene transfer.

Module-III

Direct gene transfer methods: Particle bombardment mediated transformation, Mechanism, Particle gun design, parameter for effective transformation; silicon carbide fibre mediated transformation and alternative methods. Reporter genes, Selectable and scorable markers, binary and Co-integrative vectors, Removal of marker genes, Applications and limitations of Agrobacterium gene transfer, Concept of marker free transgenic plants. Plastid engineering: Introduction, importance, scope and technique.

Module-IV

Crop Improvement and Agro-industrial biotechnology: Genetic Engineering for Herbicide resistance; Genetic Engineering for Biotic and Abiotic Stress Resistance/Tolerance; Genetic engineering for Improvement of crop yield and quality: Protein, lipids, carbohydrates, vitamins & mineral nutrients; Applications in Agro-industry: Microbes in agriculture , Production and utilization of essential amino acids, chemicals from micro-algae. Agro-waste utilization; Mycorrhiza in agriculture and forestry.

ANIMAL BIOTECHNOLOGY

Module- I

Animal cell culture: Basic concepts animal cell culture; Cell culture media and reagents; Animal cell, tissue and organ cultures; Primary culture, secondary culture; Continuous cell lines; Suspension cultures; Somatic cell cloning and hybridization; Transfection and transformation of cells; Commercial scale production of animal cells; Stem cells and their application; Application of animal cell culture for in vitro testing of drugs; Testing of toxicity of environmental pollutants in cell culture; Application of cell culture technology in production of human and animal vaccines and pharmaceutical proteins.

Module-II

Animal health Biotechnology: Introduction to the concept of vaccines; Conventional methods of vaccine production; Recombinant approaches to vaccine production; Hybridoma technology; Phage display technology for production of antibodies; Antigen-antibody based diagnostic assays including radioimmunoassay and enzyme immunoassays; Immunoblotting; Nucleic acid based diagnostic methods including nucleic acid probe hybridization; Restriction endonuclease analysis; PCR, Real time PCR; Nucleic acid sequencing; Commercial scale production of diagnostic antigens and antisera; Animal disease diagnostic kits; Probiotics. Structure of sperms and ovum; Cryopreservation of sperms and ova of livestock; Artificial insemination; Super ovulation; in vitro fertilization; Culture of embryos; Cryopreservation of embryos; Embryo transfer; Embryo-splitting; Embryo sexing; Micromanipulation of animal embryos; Transgenic animal technology and its different applications; Ethical, social and moral issues related to cloning.

Module-III

Animal genomics: Introduction to different breeds of cattle, buffalo, sheep, goats, pigs, camels, horses, canines and poultry; Genetic characterization of livestock breeds; Marker assisted breeding of livestock and poultry; Introduction to animal genomics; Different methods for characterization of animal genomes, SNP, STR, QTLS, RFLP, RAPD, proteomics, metabolomics; Genetic basis for disease resistance; Gene knock out technology and animal models for human genetic disorders.

Module-IV

DNA Forensics**:** Immunological and nucleic acid based methods for identification of animal species; Detection of adulteration in meat using DNA based methods; Detection of food/feed adulteration with animal protein; Identification of wild animal species using DNA based methods using different parts including bones, hair, blood, skin and other parts confiscated by anti-poaching agencies; Human forensics; Microbial forensics; Bioterror agents; Biocrimes and Bioterrorism.

GENOMICS & PROTEOMICS

Module I

Introduction Structural organization of genome in Prokaryotes and Eukaryotes; Organelle DNAmitochondrial, chloroplast; DNA sequencing principles and translation to large scale projects; Recognition of coding and non-coding sequences and gene annotation; Tools for genome analysis-RFLP, DNA fingerprinting, RAPD, PCR, Linkage and Pedigree analysis-physical and genetic mapping.

Module II

Genome sequencing projects Microbes, plants and animals; Accessing and retrieving genome project information from web; Comparative genomics, Identification and classification using molecular markers-16S rRNA typing/sequencing, EST's and SNP's.

Module III

Proteomics Protein analysis (includes measurement of concentration, amino acid composition, Nterminal sequencing); 2-D electrophoresis of proteins; Microscale solution isoelectric focusing; Peptide fingerprinting; LC/MS-MS for identification of proteins and modified proteins; MALDITOF; SAGE and Differential display proteomics, Protein-protein interactions, Yeast two hybrid system.

Module IV

Pharmacogenetics High throughput screening in genome for drug discovery identification of gene targets, Pharmacogenetics and drug development. Functional genomics and proteomics Analysis of microarray data; Protein and peptide microarray-based technology; PCRdirected protein in situ arrays; Structural proteomics

Texts/References:

1. Voet D, Voet JG & Pratt CW, Fundamentals of Biochemistry, 2nd Edition. Wiley 2006

2. Brown TA, Genomes, 3rd Edition. Garland Science 2006

3. Campbell AM &Heyer LJ, Discovering Genomics, Proteomics and Bioinformatics, 2nd Edition. Benjamin Cummings 2007

4. Primrose S &Twyman R, Principles of Gene Manipulation and Genomics, 7th Edition, Blackwell, 2006.

5. Glick BR & Pasternak JJ, Molecular Biotechnology, 3rd Edition, ASM Press, 1998.

COMPUTATIONAL BIOLOGY

Module- I

Biological Databases: Primary and Secondary Databases; GenBank, EMBL, DDBJ, Swissprot, MIPS, PIR, TIGR, Hovergen, TAIR, PlasmoDB, ECDC, Protein and Nucleic Acid Sequences databases. Search Algorithms: Scoring Matrices and their use; Computational complexities; Analysis of Merits and demerits; Sequence pattern; Pattern databases; PROSITE, PRINTS, Markov chains and Markov models; Viterbi algorithm; Baum- Welch algorithm; FASTA and BLAST Algorithm; Needleman-Wusch& Smith-Waterman algorithms

Module- II

Structure and Analysis: Representation of molecular structures; External and internal co-ordinates; Concept of free energy of molecules; Introduction to various force fields; Molecular energy minimization techniques; Monte Carlo and Molecular Dynamics simulation Molecular structure Determination: Principle of X-ray crystallography and NMR spectroscopy; 2D Protein Data bank and Nucleic Acid Data bank; Storage and Dissemination of molecular structures

Module- III

Modelling & Drug design: Homology modelling; Threading; Structure prediction; Structure-structure comparison of macromolecules; Simulated docking; Drug design; molecular dynamics simulation, Docking methods, Drug design Process, drug like Property of a molecule, target identification, Drug design process for a known and unknown target. 2D and 3D QSAR; Ligand databases.

ENVIRONMENTAL BIOTECHNOLOGY

Module- I

Introduction: Environment; Basic concepts; Resources; Eco system: plants, animals, microbes; Ecosystem management; Renewable resources; Sustainability; Microbiology of degradation and decay; Role of Biotech in environmental protection; Control and management of biological processes Alternate source of energy: Biomass as source of energy; Bioreactors; Rural biotechnology; Bio composting; Bio fertilizers; Vermiculture; Organic farming; Bio mineralization; Biofuels; Bioethanol and bio hydrogen; Energy management and safety

Module-II

Pollution: Environmental pollution; Source of pollution; Hydrocarbons, substituted hydro carbons; Oil pollution; Surfactants; Pesticides; Measurement of pollution; Water pollution; Biofilm; Soil pollution; Radioactive pollution; Radiation; Ozone depletion; Greenhouse effect; Impact of pollutants; Measurement techniques; Pollution of milk and aquatic animals Pollution Control, remediation and management: Waste water collection; control and management; Waste water treatment; Sewage treatment through chemical,

Module-III

Microbial and biotech techniques; Anaerobic processes; Anaerobic filters; Anaerobic sludge blanket reactors; Bioremediation of organic pollutants and odorous compounds; Use of bacteria, fungi, plants, enzymes, and GE organisms; Plasmid borne metabolic treatment; Bio augmentation; Bioremediation of contaminated soils and waste land; Bioremediation of contaminated ground water; Macrophysics in water treatment; Phytoremediation of soil metals; Treatment for waste water from dairy, distillery, tannery, sugar and antibiotic industries; Solid waste management.

Module-IV

Environment and health in respect to genetics: Gene and environment; Effect of carbon and other nanoparticles upon health; Gene mutation; Genetic testing; Genetic sensors; Environmental pollution and children; Human biomonitoring Metagenomics, environmental genomics. Bioprospecting, Bio microelectronics and Nano-biotechnology. Metabolic pathways for biodegradation of hydrocarbon compounds and other organic pollutants. Microbial interaction with metals and radionuclides, mechanisms. Nitrate and phosphate removal.

ADVANCED MICROBIOLOGY AND IMMUNOLOGY

Module-I

Microbial Diversity & Systematics: Classical and modern methods and concepts; Domain and Kingdom concepts in classification of microorganisms; Criteria for classification; Classification of Bacteria according to Bergey's manual; Molecular methods such as Denaturing Gradient Gel Electrophoresis (DGGE), Temperature Gradient Gel Electrophoresis (TGGE), Amplified rDNA Restriction Analysis and Terminal Restriction Fragment Length Polymorphism (T-RFLP) in assessing microbial diversity; 16S rDNA sequencing and Ribosomal Database Project.

Module-II

Microbial processes and its optimization: Microbial growth and its kinetics, Models of growth kinetics; Microbial processes-production, optimization, screening, strain improvement, factors affecting downstream processing and recovery; Representative examples of ethanol, organic acids, antibiotics etc. Enzyme Technology-production, recovery, stability and formulation of bacterial and fungal enzymes-amylase, protease, penicillin acylase, glucose isomerase; Immobilised Enzyme and Cell based biotransformation of steroids, antibiotics, alkaloids, Enzyme based and cell based biosensor.

Module-III

Advanced Immunology: Fundamental concepts of Immune system; components of innate and acquired immunity; phagocytosis; complement system; MHC – structure, genetic organization; HLA typing; graft versus host reaction; Antigens – immunogens, hapten, adjuvant, carrier. Molecular basis of immune responses: Primary and secondary immune response; kinetics of immune response; Immunoglobulins – class, subclass and structure

Module-IV

Ig superfamily; affinity, avidity, allotype, isotype, idiotype; Antibody genes and antibody diversity. Immunological techniques: RIA, ELISA, Western blotting, ELISPOT assay, Immunofluorescence, flow cytometry and immunoelectron microscopy, lymphoprofileration assay, mixed lymphocyte reaction, cell cytotoxicity assays, microarrays, transgenic mice, gene knock outs.

NANOBIOTECHNOLOGY

Module I

Introduction and scope of Nano Biotechnology, comparison of Biotechnology to Nano biotechnology, Nanobiomacines: Negligible gravity and intertia, atomic granularity, thermal motion, water environment and their importance in nanobiomachines. The role of proteins, amino acids, nucleic acids, lipids and polysaccharides in modern biomaterials. Overview of natural Bionanomachines; Thymidylate synthetize, ATP synthetize, Actin and myosin, opsin, Antibodies and collagen.

Module II

Synthesis of Biomolecules: Recombinant Technology, Site-directed mutagenesis, Fusion Proteins. Quantum Dot structures and their integration with biological structures. Tools of Analysis: X-Ray crystallography, NMR spectroscopy, Electron microscopy and Atomic force microscopy. Molecular modelling tools: Graphic visualization, structure and functional prediction, Protein folding prediction and the homology modelling, Docking simulation and Computer assisted molecular design.

Module III

Structural principles of Nano biotechnology raw materials: Factors governing biomolecular structure and stability, Protein folding; Self-assembly, Self-organization, Molecular recognition and Flexibility of biomaterials. Functional principles of Nano biotechnology: Information driven Nano assembly, Energetics, Role of enzymes in chemical transformation, allosteric motion and covalent modification in protein activity regulation, Structure and functional properties of Biomaterials, Bimolecular motors: ATP Synthetase and flagellar motors, Traffic across membranes: Potassium channels, ABC Transporters and Bacteriorhodopsin, Bimolecular sensing, Self-replication, Machine-Phase Bio nanotechnology.

Module IV

Fields of Application: Designer proteins, Peptide nucleic acids, Nanomedicine, Drug delivery, DNA computing, Molecular design using biological selection, Harnessing molecular motors, Artificial life, Hybrid materials, Biosensors, Future of Bio nanotechnology.

Text books:

1. David S Goodsell,Bio nanotechnology, John Wiley & Sons, 2004.

2. Greco Ralph S, Nanoscale Technology in Biological Systems, CRC Press, 2005.

PHARMACEUTICAL BIOTECHNOLOGY

Module- I

Introduction History of pharmacy; the pharmaceutical industry & development of drugs; Economics and regulatory aspects; Quality management; GMP. Drug kinetics and biopharmaceutics Mechanism of drug absorption, distribution, metabolism and excretion – factors affecting the ADME process; Bioequivalence; Pharmacokinetics.

Module- II

Principles of drug manufacture Liquid dosage forms – solutions, suspensions and emulsions; Topical applications – ointments, creams, suppositories; Solid dosage forms – powders, granules, capsules, tablets, coating of tablets; Aerosols; Preservation; Packing techniques. Advances in drug delivery Advanced drug delivery systems – controlled release; Transdermal, Liposomes and drug targeting.

Module-III

Biopharmaceuticals Understanding principles of pharmacology, pharmacodynamics; Study of a few classes of therapeutics like Recombinant therapeutics, Monoclonal Antibodies, Vaccines, Gene therapy, Antibiotics and Hormones.

Module-IV

Immunogenicity of biopharmaceuticals: Immunogenicity; Factors contributing to immunogenicity (product related factors, host- related factors), Consequence of immunogenicity to biopharmaceuticals; Measurement of immunogenicity. Case studies: Erythropoietin, Insulin, Somatotropin, Interleukin-2, Interferon Granulocyte macrophage-CSF, DNase, Factor VIIa, Factor IX, Factor VIII, Activated protein C, Tissue plasminogen activator, Monoclonal antibodies etc.

TECHNIQUES IN GENETIC ENGINEERING

(Will be uploaded soon)

BIOREACTOR DESIGN AND OPTIMIZATION

Module- I

Principles and concepts Recapitulation of the principles of Kinetics for chemical and Bio-chemical Reactions. Fundamentals of homogeneous reactions for batch / semi-batch, plug low reactor (PFR), continuous stirred rank reactors (CSTR), fluidized bed reactor bubble column, air lift fermenter etc., stirred tank/mixed reactors.Adiabatic and programmed reactors. Unconventional bioreactors: Hollow fibre reactor, membrane reactor, perfusion reactor for animal and plant cell culture.

Module- II

Bioreactor Analysis Analysis of ideal bioreactors: Fed-Batch reactors, Enzyme catalyzed reactions in CSTRs, CSTR reactors with Recycle and Wall growth, Ideal Plug- Flow Tubular reactor. Analysis of Non-ideal Reactor Analysis: Concept of ideal and non-ideal reactor; residence time distribution; models of non-ideal reactors – plug flow reactor for microbial processes; Mass transfer in biochemical processes; Multiphase bioreactors – packed bed with immobilized enzymes or microbial cells; three – phase fluidized bed trickling bed reactor; Design and analysis of the above reactor systems; Gas liquid reactors, Reactor stability.

Module- III

Bioreactor Design considerations: oxygen transfer, heat transfer, rheology, mixing. Scale up and scale down concepts. Bioprocess control and computer coupled bioreactors; Growth and product formation by recombinant cells. Mechanical fittings in a bioreactor: vessel, agitation system materials, welds, finish, valves, piping and valves for biotechnology, special requirements of utilities and cleaning of production plants.

Module- IV

Instrumentation and control of bioprocesses: Physical and chemical sensors, online sensors for cell properties, off-line analytical methods; Biosensors. Bioreactor design calculations.

Text Books

1. Levenspiel, O., Chemical Reaction Engineering, Wiley Eastern Ltd.

2. Bailey &Olis, Biochemical Engg. Fundamentals, MGH. 1990

3. Atkinson, B., Biological Reactors, pion Ltd., London, 1974. Coulson, Richardson, Sinnott, An introduction to chemical engineering design, Pergamon Press. Lydersen, D'Elia, Nelson, Bioprocess engineering: Systems and equipment.

IPR, BIOETHICS & BIOSAFETY

Module-I

BIOTECHNOLOGY AND SOCIETY: Introduction to science, technology and society, issues of access- Case studies/experiences from developing and developed countries. Ownership, monopoly, traditional knowledge, biodiversity, benefit sharing, biological spots, environmental sustainability, Food and agricultural organization, biotechnology in international relations, globalization and development divide. Public acceptance issues for biotechnology: Biotechnology and hunger: Challenges for the Indian Biotechnological research and industries.

Module-II

BIOETHICS: Principles of bioethics: Legality, morality and ethics, autonomy, human rights, beneficence, privacy, justice, equity etc. The expanding scope of ethics from biomedical practice to biotechnology, bioethics vs. business ethics, ethical dimensions of IPR, technology transfer and other global biotech issues. BIOSAFETY CONCEPTS AND ISSUES Ethical conflicts in biotechnology - interference with nature, fear of unknown, unequal distribution of risks and benefits of biotechnology, Rational vs. subjective perceptions of risks and benefits, relationship between risk, hazard, exposure and safeguards, Biotechnology and biosafety concerns at the level of individuals, institutions, society, region,

Module-III

BIOSAFETY IN THE LABORATORY

Laboratory associated infections and other hazards, assessment of biological hazards and levels of biosafety, prudent biosafety practices in the laboratory/ institution. Experimental protocol approvals, levels of containment. REGULATIONS Biosafety assessment procedures in India and abroad. International dimensions in biosafety, HACCP, bioterrorism and convention on biological weapons. Social and ethical implications of biological weapons. Biosafety regulations and national and international guidelines with regard to recombinant DNA technology. Guidelines for research in transgenic plants. Good manufacturing practice and Good lab practices (GMP and GLP). National and international regulations for food and pharma products.

Module-IV

ECOLOGICAL & FOOD SAFETY the GM-food debate and biosafety assessment procedures for biotech foods & related products, including transgenic food crops, case studies of relevance. Eco-friendly case studies. AGRI & PHARMA SECTOR Plant breeder's rights. Legal implications, Biodiversity and farmers rights. Biosafety assessment of pharmaceutical products such as drugs/vaccines etc. Biosafety issues in Clinical Trials.

Texts/References:

1. BAREACT, Indian Patent ACT 1970 Acts & Rules, Universal Law Publishing Co.Pvt Ltd., 2007.

2. Kankanala C., Gentic patent Law and Strategy, 1st Edition, Manupatra Information Solution Pvt Ltd. 2007.

3. Important Links

www.w3.org/IPR

www.wipo.int/portal/index.html.en

www.ipr.co.uk/IP_conventions/ptent_cooperation_treaty.html

www.patentoffice.nic.in

www.iprlawindia.org/-31k-Cached – Similar page

www.cbd.int/biosafety/background.shtml

PROCESS CONTROL & INSTRUMENTATION

Module I

Mercurythermometer, step function, impulse function, sinusoidal function, step response, impulse response, sinusoidal response, liquid level system, mixing process, RC circuit, Linearization, non-interacting & interacting systems, High order & second order systems. Transportations lag.

Module II

The control system – basics, development of block diagram, control valve, controller, P-control, PI – control, PD – control, PID control. Overall transfer function for single loop systems, for change in set point, for change in load. Overall transfer function for multiloop control systems. Concept of stability, stability criterion. Routh test for stability.

Module III

The Bode stability criterion, Ziegler-Nicholas controller settings, Cascade control, feed forward control. Ratio control, Smith predictor. Internal model control, controller tuning, Ziegler – Nicholas rules, Cohen and Coon rules, process identification, control valve, vlve sizing, valve characteristics, valve positioner.

TEXT BOOKS:

1. 'Process Systems analysis and Control', D.R. Coughanour, McGraw-Hill, 2nd Edition, 1991.

2. 'Process Dynamics and Control', D.E. Seborg, T.F. Edger, and D.A. Millichamp, John Wiley and Sons, 2nd Edition, 2004.

REFERENCES:

1. 'Principle and Practice of Automatic Process Control', C.A. Smith and A.B. Corripio, 3rd ed., John Wiley and Sons, 2005.

2. 'Process Modelling Simulation and Control for Chemical Engineers', W.L .Luyben, McGraw Hill, 2nd Edition, 1990.

3. 'Chemical Process Control – Theory and Practice', Stephanopoulous, Prentice Hall of India Ltd., .1984.