UNIVERSITY OF KERALA

B. TECH. DEGREE COURSE

(2013 SCHEME)

SYLLABUS FOR

V SEMESTER

BIOTECHNOLOGY & BIOCHEMICAL ENGINEERING

SCHEME -2013

V SEMESTER
BIOTECHNOLOGY & BIOCHEMICAL ENGINEERING (B)

Course No	Name of subject	Credits	Weekly load, hours			C A Marks	Exam Duration Hrs	U E Max Marks	Total Marks
			L	T	D/P				
13.501	Engineering Mathematics IV (BCHMPSU))	4	3	1	-	50	3	100	150
13.502	Mass Transfer Operations (B)	4	3	1	-	50	3	100	150
13.503	Enzyme Engineering & Technology (B)	3	2	1	-	50	3	100	150
13.504	Principles of Heat Transfer in Bioprocesses (B)	4	3	1	-	50	3	100	150
13.505	Thermodynamics of Bioprocesses (B)	4	3	1	-	50	3	100	150
13.506	Genetic Engineering (B)	4	3	1	-	50	3	100	150
13.507	Molecular Biology laboratory (B)	3	-	-	3	50	3	100	150
13.508	Bioprocess Engineering Lab (B)	3	-	-	3	50	3	100	150
	Total	**29**	**17**	**6**	**6**	**400**		**800**	**1200**

13.501 ENGINEERING MATHEMATICS - IV (BCHMPSU)

Teaching Scheme: 3(L) - 1(T) - 0(P)   **Credits**: 4

Course Objective:

- *To provide a basic understanding of random variables and probability distributions.*

- *Mathematical programming techniques are introduced as a part of this course. These techniques are concerned with the allotment of available resources so as to minimize cost or maximize profit subject to prescribed restrictions.*

Module – I

Random Variables -Discrete and continuous random variables and their probability distributions-Probability distribution (density) functions - Distribution functions - mean and variance-simple problems-
Binomial distribution, Poisson distribution, Poisson approximation to Binomial, Uniform distribution, Exponential Distribution, Normal distribution - mean and variance of the above distributions(derivations except for normal distribution) - Computing probabilities using the above distributions.

Module – II

Curve fitting - Principle of least squares - Fitting a straight line – Fitting a parabola-Linear correlation and regression - Karl Pearson's coefficient of correlation - Sampling distributions - Standard error –Estimation - Interval estimation of population mean and proportions(small and large samples)- Testing of hypothesis - Hypothesis concerning mean - Equality of means - Hypothesis concerning proportions- Equality of proportions.

Module – III

Linear programming - Formation of LPP - General linear programming problem - Slack and surplus variables - Standard form - Solution of LPP - Basic solution - Basic feasible solution - Degenerate and non-degenerate solutions - Optimal solution - Solution by simplex method - Artificial variables - Big-M method.

Module – IV

Duality in LPP - Properties of primal and dual optimal solutions - solution using duality-Transportation problem and Assignment problem.

References:

1. Veerarajan, T., *Probability, Statistics and Random Processes,* 3/e, Tata McGraw Hill, 2002.

2. Papoulis A. and S. U. Pillai, *Probability, Random Variables and Stochastic Processes*, 3/e, Tata McGraw Hill, 2002.

3. Koneru S. R., *Engineering Mathematics*, 2/e, Universities Press (India) Pvt. Ltd., 2012.

4. Bali N. P. and M. Goyal, *Engineering Mathematics*, 7/e, Laxmi Publications, India, 2012.

5. Kreyszig E., *Advanced Engineering Mathematics*, 9/e, Wiley India, 2013.

6. Swarup, K., P. K. Gupta and Manmohan, *Operations Research*, 6/e, Sulthan Chand and Sons, 1978.

7. Sharma S. D. and H. Sharma, *Operations Research: Theory, Methods and Applications*, 13/e, Kedar Nath and Ram Nath, 1972.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours   Maximum Total Marks: 100

The question paper shall consist of 2 parts.

Part A (20 marks) - Five Short answer questions of 4 marks each. All questions are compulsory. There should be at least one question from each module and not more than two questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

After successful completion of this course, the students will be familiar with the large scale applications of linear programming techniques which require only a few minutes on the computer. Also they will be familiar with the concepts of probability distributions which are essential in transportation engineering.

13.502 MASS TRANSFER OPERATIONS (B)

Teaching Scheme: 3(L) - 1(T) - 0(P)   **Credits**: 3

Course objectives:

The course offers a prefatory on the second major class of unit operations involved in process engineering, namely mass transfer. The fundamental theory and applications of mass transfer shall be explicated, with adequate emphasis on relevant case-studies and numerical exercises.

Module – I

Introduction to Mass Transfer and Diffusion : Molecular diffusion in liquids and gases -Fick's Law for Molecular Diffusion - - Steady state diffusion under stagnant and laminar flow conditions - Pseudo steady state diffusion - Diffusion through a varying cross sectional area - Molecular diffusion in Biological solutions and gels -Diffusivity measurements and prediction - multicomponent diffusion.

Principles of Unsteady state and Convective Mass Transfer- Convective mass transfer coefficients - theories of diffusion in turbulent flow, mass, heat and momentum transfer analogies. Derivation of Mass Transfer coefficients in Laminar flow – Mass Transfer for flow inside pipes - Mass Transfer for flow outside solid surfaces - Diffusion of gases in porous solids and capillaries - Interface mass transfer, diffusion in solids. Equipment for gas-liquid operations, tray towers, venturi scrubbers, wetted wall towers, spray towers and spray chambers, baffle towers and packed columns.

Gas absorption: Absorption conditions of equilibrium between liquid and gas, The Henry's law - the mechanism of absorption and desorption between phases - Single stage Equilibrium contact - Counter current Multiple stage contact - Analytical Equations for Counter current stage contact (The Kremser Equations) - interphase mass transfer, liquid and gas side resistance. Design of absorbers - Liquid phase hold up - Pressure drop - Loading, flooding in packed towers. Absorption of one component, overall coefficients, dilute solution. Non-isothermal operations. Multicomponent absorption: Absorption with chemical reaction.

Module – II

Basic concepts of Distillation: Vapour - Liquid equilibrium pressure - temperature - concentration - phase diagram - isothermal and isobaric equilibrium - Relative Volatility - Raoult's law - ideal solutions deviations from ideality - Minimum and maximum boiling azeotropes - Partially miscible liquids distillation - Insoluble liquids(Steam distillation) -

Enthalpy - concentration diagrams - Treatment of multicomponent systems-Different distillation Methods : Flash Vapourisation of binary mixture - Simple distillation of binary mixtures Vacuum distillation - Continuous rectification methods - brief discussion on general characteristics of tray and packed tower - Azeotropic and extractive distillation, low pressure distillation and molecular distillation.

Multistage Tray tower Design : Material and enthalpy balance of a fractionator - Ponchon and Savarit and McCabe - Thiele Method -Enriching section with total condenser and reflux below the bubble point - partial condenser - Stripping section. Complete fractionation- Feed below bubble point - Feed tray location - Effects of reflux ratio - total reflux - minimum reflux Optimum reflux. Reboiler arrangements - use of open steam - Use of multiple feeds - effect of heat loss - Introduction of feed and its influence on operating lines - q-lines and location of tray -

Fractionation of azeotropic and partially miscible binary mixtures - Tray efficiencies. Continuous Contact Equipment: Concepts of transfer units - HTU and NTU - and height of the enriching section and stripping section - Graphical methods.

Module – III

Liquid- liquid extraction: Terminologies - application of ternary liquid equilibrium - representation in equilateral triangular co-ordinate of different type systems - Effect of temperature - Representation of ternary equilibrium data in rectangular co-ordinates on total and solvent free bases, equilibria of multicomponent systems - Criteria for selection of solvent. Design of stage wise extractors: Mixers -settlers - Sieve tray tower single - stage extraction - graphical method of determining composition, flow rates.

Multistage cross current extraction with practically miscible and immiscible solvents, graphical method of determining number of stages. Continuous countercurrent multistage extraction - graphical method of determining number of stages - composition and minimum solvent on total and solvent free basis – Counter current extraction with insoluble solvents - continuous counter current extraction with reflux - Graphical solution in total and solvent free basis - total reflux minimum reflux ratio. Constructional & hydrodynamic aspects of stagewise extractors.

Design of differential continuous contact extractors. Common characteristics of differential extractors. Types of extractors and their brief description - Design of differential contact tower extractors – Two resistance theory - Overall transfer Coefficient and corresponding HTU and NTU for insoluble liquids and dilute solutions - Hydro dynamics of differential contact extractors- selection of extractors.

Solid Liquid Extraction: Description of leaching operations and technologies - Applications of leaching - Preparation of solid - Methods of Operation and classification of equipment - Solid - Liquid Equilibrium in leaching - methods of representation on total and inert free basis – Counter current leaching - material balance and graphical solution.

Module – IV

Adsorption: Description of adsorption processes and their application - Types of adsorption - nature of adsorbents - adsorption equilibria - adsorption hysterisis - Isotherms for adsorption of single components and mixtures - Effect of temperature and pressure - Freundlich equation. Stagewise adsorption : Contact filtration of liquids - single and multistage crosscurrent adsorption - Multistage Countercurrent adsorption - Agitated vessels for solid - liquid adsorption – Multi stage fluidised bed adsorber for recovery of Vapour - Continuous Contact Adsorption : Steady state moving bed adsorber - Countercurrent adsorption of one component - Adsorption of two components - Unsteady state fixed bed adsorber - adsorption wave - break through curves and rates of adsorption.

Ion Exchange: Principles of ion exchange techniques and application - Ion exchange Equilibira - Rate of ion exchange.

References
1. Treybal R.E., *Mass Transfer Operations*, 3/e, McGraw Hill, 1981.
2. McCabe W.L., J.C. Smith and P. Harriott, *Unit Operations of Chemical Engineering*, 6/e, McGraw Hill, 2001.
3. Dutta B.K., *Principles of mass transfer and separation processes*, Prentice Hall of India, 2007.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours   Maximum Total Marks: 100

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from modules I and II, and two questions each from modules III and IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Note: *Part B questions should have at least 60 % numerical problems. There could be numerical problems in part A also.*

Course outcome:

Upon successful completion of this course, the students shall become familiar with the principles and applications of mass transfer in diverse bioprocess situations. This knowledge shall equip them to design mass transfer equipments, suiting diverse process needs.

13.503 ENZYME ENGINEERING AND TECHNOLOGY (B)

Teaching Scheme: 2(L) - 1(T) - 0(P)   **Credits**: 3

Course objectives:

This course provides an insight into the realm of biocatalytic reaction engineering, with prime emphasis on enzymes. The reaction kinetics, together with the technological and engineering principles underlying general enzymatic processes shall be explicated, such as to enable the design, development and analysis of enzyme- based bioprocess systems.

Module – I

Introduction: Enzymes as biocatalysts- Chemical nature of enzymes- role of coenzymes – comparison of enzymes with chemical catalysts- nomenclature and classification- Oxidoreductases, Transferases, Hydrolases, Lyases, Isomerases, Ligases- specificity of enzyme action- types of substrate specificity- theories of Enzyme substrate complex formation- Fischer's template theory, Koshland's theory, Substrate strain theory -action of enzymes- proximity effect and orbital steering- mechanism of enzyme catalysis- theories of reaction rates- collision theory, transition state theory. Extremozymes- nontraditional enzymes- Abzymes, Ribozymes.

Kinetics of enzymatic reactions: Mechanistic models for simple enzyme kinetics-rapid equilibrium and quasi steady state assumptions- determination of rate parameters for Michaelis- Menten type Kinetics- double reciprocal plot, Eadie- Hofstee plot, Hanes-Woolf plot, batch kinetics – specific activity of enzymes- Models for complex enzyme kinetics-allostery (cooperative binding), Inhibited enzyme kinetics-reversible and irreversible inhibition- kinetics of reversible enzyme inhibition- competitive, non-competitive, uncompetitive inhibition- substrate inhibition kinetics- effects of pH, temperature, pressure and ionic strength on enzyme activity- enzyme half life – enzyme deactivation models and kinetics- bisubstrate reactions- ternary complex model, Ping- Pong mechanism.

Module – II

Enzyme preparation and use: Sources of enzymes- screening for novel enzymes-media for enzyme production- preparation of enzymes- cell lysis, liquid/solid separation, nucleic acid removal, purification, concentration, finishing- safety and regulatory aspects of enzyme use- industrial applications of enzymes in solution-applications of hydrolytic enzymes (esterases, carbohydrases etc.) and non hydrolytic enzymes (fumarase, glucose isomerase, glucose oxidase etc.) - Medical applications.

Preparation and kinetics of immobilized enzymes: Mechanical forces acting on enzymes-strategies for enzyme stabilization- economic argument of immobilization-methods of

immobilization- industrial processes employing immobilized enzymes-medical and analytical applications of immobilized enzymes.

Module – III

Kinetics of immobilized enzymes: Effects of solute partition and solute diffusion- analysis of diffusional effects in porous supports- effects of external mass transfer resistance-effectiveness factor- analysis of intraparticle diffusion and reaction-Thiele modulus-Simultaneous film and intraparticle mass transfer resistances- Biot number-effects of inhibitors, temperature and pH on Immobilized enzyme catalytic activity and deactivation.

Design and analysis of enzyme reactors: Ideal reactor operation-batch and continuous operation of a mixed reactor for enzyme reaction- chemostat with immobilized cells-continuous operation a PFR for enzyme reaction- novel reactors- stirred tank batch reactor, membrane reactor, packed bed reactor, continuous flow stirred tank reactors, fluidized bed reactor- design equations- factors influencing productivity and conversion effectiveness.

Module – IV

Enzyme Biosensors: Use of enzymes in analysis- beneficial features and components of Biosensors- Biosensor types- Calorimetric biosensors, Potentiometric biosensors, Amperometric biosensors, Optical biosensors, Piezo-electric biosensors, Immunosensors.

Recent advances: Enzymatic reactions in biphasic liquid systems- stabilization, equilibria, kinetics and applications- Practical applications of enzymes in reverse- use of proteases in peptide synthesis-use of glycosidases in synthetic reactions- interesterification of lipids-artificial enzymes (Synzymes) - applications of genetic engineering techniques to enzyme technology (Enzyme engineering)- poly functional enzymes- solvent engineering.

References:

1. Shuler M. L. and F. Kargi, *Bioprocess engineering- Basic concepts,* Prentice Hall of India, 2002
2. James. E. Bailey, David. F. Ollis, *Biochemical Engineering Fundamentals,* McGraw Hill, 1986
3. Chaplin M. F. and C. Bucke, *Enzyme Technology,* Oxford University Press, 1990.
4. Palmer T., *Enzymes: Biochemistry, Biotechnology and Clinical Chemistry,* Affiliated East West Press, 2007.
5. Price N. C. and Stevens L., *Fundamentals of Enzymology*: *The Cell and Molecular Biology of Catalytic Proteins,* Oxford University Press, 1999.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)
30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours   Maximum Total Marks: 100

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from modules I and II, and two questions each from modules III and IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

> ***Note:*** *Part B questions should have at least 50 % numerical problems. There could be numerical problems in part A also.*

Course Outcome:

Upon successful completion of this course, the students would have assimilated the basic principles and applications of enzyme reaction engineering. This knowledge shall serve the purpose of choosing suitable enzymes for given bioprocess applications, with adequate emphasis on the engineering principles underlying the design of reaction systems based on enzyme catalysis.

13.504 PRINCIPLES OF HEAT TRANSFER IN BIOPROCESSES (B)

Teaching Scheme: 3(L) - 1(T) - 0(P)   **Credits**: 4

Course objectives:

The course offers a prefatory on the third major class of unit operations involved in process engineering, namely heat transfer. The fundamental theory and applications of heat transfer shall be explicated, with adequate emphasis on relevant case-studies and numerical exercises.

Module – I

INTRODUCTION: Importance of heat transfer in bioprocessing industries, various applications and principle and mechanism of the different modes of heat transfer *Viz.* Conduction, Convection and Radiation.

CONDUCTION: General heat conduction equation in rectangular geometry, Laplace equation, Poisson equation, heat diffusion equation, different boundary conditions applied in heat transfer problems, formulation of heat transfer problems using different boundary conditions with and without generation of heat at steady state and unsteady state for rectangular, cylindrical and spherical geometries at steady and unsteady states. Fourier's law, thermal conductivity of materials, Steady state unidirectional heat flow through single and multiple layer slabs, cylinders and spheres with constant and variable thermal conductivities. Numerical problems.

Solution of steady state one dimensional heat conduction with heat generation in slabs, cylinders, spheres. Numerical problems.

Unsteady state conduction: Elementary treatment of unsteady state heat conduction-Lumped capacity analysis. Biot Modulus, Fourier number and their significance. Numerical problems. Chilling and freezing of food and biological materials. Unsteady state thermal processing and sterilization of biological materials. General principles of thermal/heat sterilization, sterilization of medium using High Temperature Short Time (HTST) methods. Design of Continuous sterilizers.

INSULATION AND EXTENDED SURFACES: Properties of insulation materials, Types of insulation, Critical and Optimum thickness of insulation. An overview of Fins and their different variants (detailed heat transfer analysis is not desired).

Module – II

CONVECTION: Boundary layer concept, thermal and velocity boundary layer and the relationship between the two. Film concept of heat transfer, Individual and overall heat transfer coefficient, LMTD, LMTD correction factor. Dimensional numbers - Dimensional analysis, Buckingham's pi theorem, Empirical correlation for forced and natural convection for internal and external flows (flows over flat plates, cylinders and spheres)- Numerical problems. A brief introduction of the analogy between momentum and heat transfer –

Reynolds, Colburn and Prandtl analogies, their merits and demerits (Deriving the analogy expressions from the basic concepts is not desired. Only analogy expressions and their significance are required).

RADIATION: Properties and definitions, Absorptivity, Reflectivity, Emissive power and intensity of radiation, Black body radiation, Gray body radiation, Stefan – Boltzman law, Wien's displacement law, Kirchoffs law, View factors, Radiation between surfaces:- two black bodies, two infinite parallel grey planes, one small grey body enclosed in another black body. A brief overview of radiation involving gases and vapours.

Module – III

HEAT TRANSFER WITH PHASE CHANGE: Boiling heat transfer: Types of boiling, factors affecting boiling heat transfer coefficient, dimensionless variables, Pool boiling curve, Correlations for determining boiling heat transfer coefficient- Rohsenow correlation, Critical heat flux- Zuber correlation and minimum heat flux- numerical problems. Elementary treatment of flow boiling with its different regimes. Numerical problems.

Condensation – Types of condensation, Nusselt's equation (Derivation is required), correlations for determination of condensing coefficients for film condensation on single cylinders (horizontal and vertical orientations), spheres and banks of tubes- Numerical problems.

Module – IV

HEAT TRANSFER EQUIPMENT: Detailed classification of heat exchangers based on different modes, Types of shell and tube heat exchangers, their constructional details indicating the function of various components. Condenser – types of condensers, Use of Wilson's plot, Elementary design as to the determination of area, length and number of tubes for shell and tube heat exchanger and condensers.-Numerical problems. A brief overview of Effectiveness-NTU method of analysis of heat exchangers (Derivation of expressions for effectiveness is not required). Use of effectiveness-NTU plots- Numerical problems

Use of plate-heat exchangers for biological fluids. Construction and basic design of plate heat exchangers with the correlations used for the design.

EVAPORATORS: Types of evaporators, performance of tubular evaporator – Evaporator capacity, Evaporator economy, Material and energy balance in single effect evaporators. Multiple effect evaporators – Methods of feeding, Effect of liquid head and boiling point elevation. Factors to be considered in the selection of evaporators, Calculations on single effect evaporators alone are desired. - Numerical problems. Vapor recompression evaporation evaporators- Numerical problems.

References:

1. Ozizik M. N., *Heat Transfer - A Basic Approach,* McGraw Hill, 1985.
2. Dutta B. K., *Heat Transfer- Principles and Applications*, Prentice Hall of India, 2000.
3. Holman J. P., *Heat Transfer*, McGraw Hill, 1992.

4. Geankopolis C J, *Transport Processes and Separation Process Principles*, Prentice Hall of India, 4th Edition, Eastern Economy Edition, 2004.

5. Incropera F. P. and D. P. DeWitt, *Introduction to Heat Transfer,* 2/e, John Wiley, 1996.

6. Kern D. Q., *Process Heat Transfer*, McGraw Hill, 1997.

7. Coulson J. M. and J. F. Richardson, *Chemical Engineering,* Vol. 1, Pergamon Press, 1999.

8. Johnson A. T, Biological *Process Engineering: An Analogical Approach to Fluid Flow, Heat Transfer and Mass Transfer Applied to Biological Systems*, Wiley, 1998.

9. Shah K. and D. P.Sekulic, *Fundamentals of Heat Exchanger Design,* John Wiley, 2003.

10. Kothandaraman C. P. and S. Subramanyan, *Heat and Mass Transfer Data Book,* New Age International, 2008.

Internal Continuous Assessment *(Maximum Marks-50)*

> *50% - Tests (minimum 2)*
> *30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.*
> *20% - Regularity in the class*

University Examination Pattern:

> *Examination duration: 3 hours   Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from modules I and II, and two questions each from modules III and IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

> **Note:** *Part B questions should have at least 60 % numerical problems. There could be numerical problems in part A also.*
>
> *Reference **No. 10** indicated in the group of references given above is allowed in the examination hall, which may be mentioned along with the directions to be provided on the facing sheet of the question paper. Steam tables are also permitted in the examination hall. No other charts, tables and codes are permitted in the Examination hall. Necessary relevant data shall be given along with the question paper by the question paper setter.*

Course Outcome:

> *Upon successful completion of this course, the students shall become familiar with the principles and applications of heat transfer in diverse bioprocess situations. This knowledge shall equip them to design heat transfer equipments, suiting diverse process needs.*

13.505 THERMODYNAMICS OF BIOPROCESSES (B)

Teaching Scheme: 3(L) - 1(T) - 0(P)   **Credits**: 4

Course Objectives:

This course is aimed at providing a complete insight into the basic theory of thermodynamics and its implications in process engineering. Concepts shall be built on the backdrop of the thermodynamics module offered as part of basic Biochemical engineering and Biotechnology course, during first year.

Module – I

Review of basic terminology, laws of thermodynamics, volumetric and thermodynamic properties of pure fluids (*described in detailed during an earlier course on Basic Biochemical Engineering and Biotechnology offered in semester 1 & 2*)

(**Note:** *The above topics shall be discussed in brief only, with the objective of preparing the students for the advanced course in thermodynamics*. No questions on the same shall be asked for the university examination)

Applications of the laws of thermodynamics to flow processes: Duct flow of compressible fluids, pipe flow, flow through nozzles, throttling process; turbines (expanders), compression processes- Compressors, pumps, ejectors.

Production of power from heat: Steam power plant- Rankine cycle, Regenerative cycle; Internal combustion engines- Otto engine, Diesel engine, Gas- turbine engine.

Refrigeration and liquefaction: The Carnot refrigerator, the vapor compression cycle, choice of refrigerant, absorption refrigeration, heat pumps. Liquefaction processes- Linde process, Claude process.

Module – II

Heat effects accompanying chemical reactions: standard heat of reaction, combustion and formation- Hess's law of constant heat summation. Heat of reaction at constant pressure and volume. Effect of temperature on standard heat of reaction- temperature of reaction – simple numerical examples.

Solution Thermodynamics: Partial molar properties: Physical meaning of partial molar properties, partial molar properties and properties of solution, determination of partial molar properties. Chemical potential: Effect of temperature and pressure on chemical potential. Fugacity in solutions: Fugacity in gaseous solutions, Lewis Randal rule, fugacities in liquid solutions, ideal solutions and Raoult's law. Henry's law and dilute solutions: Ideal behaviour and real solutions, Henry's law and gas solubility. Activity in solutions: Activity coefficients, Effect of pressure and temperature on activity coefficients Gibbs-Duhem equation, property changes of mixing: activity and property changes of mixing, property

changes of mixing for ideal solutions, excess properties: excess Gibbs free energy. Numerical problems.

Module – III

Phase Equilibria: Criteria of phase equilibria, criterion of stability: phase equilibria in single and multi-component systems, phase rule for non-reacting systems, Duhem's theorem, Vapour-Liquid Equilibria, VLE in ideal and Non-ideal solutions, Non-Ideal solutions: azeotropes, VLE at low pressures, VLE at high pressures, Consistency test for VLE data, calculation of activity coefficients using Gibbs-Duhem equation, Liquid-Liquid equilibrium diagrams, Liquid phase reactions, heterogeneous reaction equilibrium, solid-solid equilibria. Numerical examples.

Module – IV

Chemical Reaction Equilibria: Equilibrium criteria for homogeneous chemical reactions; evaluation of equilibrium constant; effect of temperature and pressure on equilibrium constant; other factors affecting equilibrium constant. Calculation of equilibrium conversion and yields for single and multiple reactions. Evaluation of equilibrium for liquid phase reactions. Heterogeneous reaction equillibria involving biological reactions, phase rule for reacting systems. Numerical examples.

References:

1. Smith J. M., H.C. VanNess and M. M. Abbot, *Chemical Engineering Thermodynamics*. 6/e, McGraw Hill, 2001.

2. Narayanan K. V., *A Text Book of Chemical Engineering Thermodynamics,* Prentice Hall India, 2001.

3. Sandler S. I., *Chemical and Engineering Thermodynamics*, John Wiley, 1989.

4. Koretsky M. D., *Engineering and Chemical Thermodynamics,* John Wiley, 2004.

5. Jones J. B. and G. A. Hawkins, *Engineering Thermodynamics*, John Wiley, 1985.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)
30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours   Maximum Total Marks: 100

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from modules I and II, and two questions each from modules III and IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Note: *Part B questions should have at least 50 % numerical problems. There could be numerical problems in part A also.*

Course outcome:

Upon successful course completion, the students shall familiarize themselves with the key concepts in thermodynamics and its applications in process engineering. Concepts built herein shall be vital in the design of bioprocess systems, particularly separation equipments which operate based on heat and mass transfer principles.

13.506 GENETIC ENGINEERING (B)

Teaching Scheme: 3(L) - 1(T) - 0(P)   **Credits**: 4

Course Objectives:

This course aims at providing an advanced introduction to the field of genetic engineering, which constitutes the most popular realm of Biotechnological application. The concepts developed herein shall form the basis for developing a zest for gene cloning to suit diverse applications of human benefit.

Module – I

Introduction and basic concepts: DNA Structure and properties; Restriction Enzymes; DNA ligase, Klenow enzyme, T4 DNA polymerase, Polynucleotide kinase, Alkaline phosphatase; Cohesive and blunt end ligation; Linkers; Adaptors; Homopolymeric tailing; Labeling of DNA: Nick translation, Random priming, Radioactive and nonradioactive probes, Hybridization techniques: Northern, Southern and Colony hybridization, Fluorescence in situ hybridization; Chromatin Immunoprecipitation; DNA-Protein Interactions-Electromobility shift assay; DNAaseI footprinting; Methyl interference assay**.**

Cloning Vectors: Plasmids; Bacteriophages; M13 mp vectors; PUC19 and Bluescript vectors, Phagemids; Lambda vectors; Insertion and Replacement vectors; EMBL; Cosmids; Artificial chromosome vectors (YACs; BACs); Animal Virus derived vectors-SV-40; vaccinia/bacculo and retroviral vectors; Expression vectors; pMal; GST; Pet based vectors; Protein purification; His-tag; GST-tag; MBP-tag etc.; Intein-based vectors; Inclusion bodies; Methodologies to reduce formation of inclusion bodies; Baculovirus and Pichia vector system, Plant based vectors, Ti and Ri as vectors, Yeast vectors, Shuttle vectors.

Module – II

Cloning Methodologies: Insertion of Foreign DNA into Host Cells; Transformation; Construction of libraries; Isolation of mRNA and total RNA; cDNA and genomic libraries; cDNA and genomic cloning; Expression cloning; Jumping and hopping libraries; Southwestern and Farwestern cloning; Protein-protein interactive cloning and Yeast two hybrid system; Phage display; Principles in maximizing gene expression.

Module – III

PCR and Its Applications: Primer design; Fidelity of thermostable enzymes; DNA polymerases; Types of PCR – multiplex, nested, reverse transcriptase, real time PCR, touchdown PCR, hot start PCR, colony PCR, cloning of PCR products; T-vectors; Proof reading enzymes; PCR in gene recombination; Deletion; addition; Overlap extension; and

SOEing; Site specific mutagenesis; PCR in molecular diagnostics; Viral and bacterial detection; PCR based mutagenesis, Mutation detection: SSCP, DGGE, RFLP, Oligo Ligation Assay (OLA), MCC (Mismatch Chemical Cleavage, ASA (Allele-Specific Amplification), PTT (Protein Truncation Test).

Module – IV

Sequencing methods; Enzymatic DNA sequencing; Chemical sequencing of DNA; Automated DNA sequencing; RNA sequencing; Chemical Synthesis of oligonucleotides; Introduction of DNA into mammalian cells; Transfection techniques; Gene silencing techniques; Introduction to siRNA; siRNA technology; Micro RNA; Construction of siRNA vectors; Principle and application of gene silencing; Gene knockouts and Gene Therapy; Creation of knockout mice; Disease model; Somatic and germ-line therapy- in vivo and ex-vivo; Suicide gene therapy; Gene replacement; Gene targeting; Transgenics; cDNA and intragenic arrays; Differential gene expression and protein array.

References:

1. Primrose S. B., Twyman R. M. and R. W. Old, *Principles of Gene Manipulation*, 6/e, S.B. University Press, 2001.

2. Sambrook J. and D. W. Russel, *Molecular Cloning: A Laboratory Manual, Vol 1, Cold Spring Harbour Laboratory (CSHL),* 2001.

3. Brown T. A., *Genomes*, 3/e, Garland Science, 2006.

4. Desmond S.T. and Nicholl, *Introduction to Genetic Engineering,* Cambridge University Press, 2004.

5. Joshi P., *Genetic Engineering and its applications,* Agrobios, India, 2004.

6. Minglani G. S., *Advanced Genetics,* Narosa Publishing House, 2003.

7. Hawley S. R. and M. Y. Walker, *Advanced Genetic Analysis-Finding Meaning in a Genome,* Blackwell Publishing Co., 2004.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours   Maximum Total Marks: 100

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from modules I and II, and two questions each from modules III and IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

Upon successful completion of this course, the students shall become familiar with the basic principles, techniques and applications of gene cloning. The concepts developed herein shall enable the student at applying the principles of genetic engineering in various domains of human benefit.

13.507 MOLECULAR BIOLOGY LAB (B)

Teaching Scheme: 0(L) - 0(T) - 3(P)   **Credits**: 3

Course Objectives:

This course aims at imparting hands- on training on various laboratory techniques in molecular biology and genetic engineering. The skills acquired herein shall enable the student to develop customized protocols for gene isolation and manipulation for meeting various bioprocess needs.

Compulsory experiments:

1. Isolation of plant genomic DNA (CTAB method)
2. Agarose gel electrophoresis of DNA and detection/visualization using Ethidium Bromide.
3. Analysis of protein by gel electrophoresis under denaturing conditions. (SDS –PAGE)
4. Isolation of plasmid DNA from *E.Coli* by alkaline lysis method.
5. Purification of plasmid DNA by column chromatography and CsCl/ EtBr Density gradient centrifugation.
6. Digestion of bacteriophage lambda DNA using a restriction enzyme.
7. Preparation and transformation of competent cells of *E.coli*.
   - Transformation of plasmids and recombinant DNA into *E.coli* by Calcium chloride method and characterization of the transformants obtained.
   - Preparation and storage of competent *E.Coli* cells.
8. Ligation of DNA fragments
   - Ligation of plasmid DNA with λ DNA restriction fragments
   - Electrophoresis of ligation samples

Demonstration experiments *(Based on availability of required facilities):*

1. Preparative Isolation of low copy number plasmid DNA from *E.coli* by potassium acetate method
2. Isolation of High copy number plasmid using 'Mini screen' method.
3. Restriction mapping- determination of positions of restriction sites in the plasmid DNA used in restriction digestion.
4. Isolation of chromosomal DNA from *E.coli*
5. Isolation of total RNA from *E.Coli* and determination of concentration and purity of RNA.
6. Southern transfer of DNA from Agarose gels onto nitrocellulose or Nylon membrane.
7. Detection of nucleic acids by non- radioactive methods (hybridization with non-radioactive labeled probes).

8. Demonstration of in Vitro synthesis of specific DNA fragments with Polymerase chain reaction (PCR)
   - In vitro amplification of Double stranded DNA
   - Gel purification of PCR product
9. DNA sequencing by dideoxy method and determination of DNA sequence by reading from autoradiogram.
10. Oligonucleotide directed mutagenesis (Kunkel method)

References:

1. Sambrook J. and D. W. Russell, *Molecular Cloning – A Laboratory Manual,* Cold Spring Harbor Laboratory Press, 2001.
2. Schmauder H. P., *Methods in Biotechnology,* Taylor and Francis, 2003.

Internal Continuous Assessment *(Maximum Marks-50)*

40% - Test
40% - Class work and Record
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours   Maximum Total Marks: 100

80% - Procedure, conducting experiment, results, tabulation and inference
20% - Viva voce

Candidate shall submit the fair record for endorsement by the external examiner.

Course Outcome:

Upon successful completion of this course, the students shall acquire basic skills for isolation, characterization and manipulation of the genetic material for meeting various bioprocess objectives of human benefit.

13.508 BIOPROCESS ENGINEERING LAB (B)

Teaching Scheme: 0(L) - 0(T) - 3(P)   **Credits**: 3

Course Objectives:

This course aims at providing the students requisite hands- on experience on the key engineering aspects of industrial bioprocesses. Processes based on microbes and enzymes as biocatalysts shall be examined practically, while describing the real-life industrial applications of each.

List of Experiments:

1. Demonstration of various bioreactor configurations, parts and integrated process control systems.

2. Screening of process variables- single dimensional search: Plackett-Burman design practice

3. Determination of Thermal Death Point (TDP) and Thermal Death Time (TDT) of microorganisms for design of a sterilizer.

4. Microbial cell growth kinetics: Growth of microorganisms, estimation of Monod parameters and temperature effect on growth-estimation of energy of activation and Arrhenius Constant for microorganisms.

5. Determination of volumetric mass-transfer coefficient (KLa) by dynamic method and sulphite oxidation method.

6. Preparation and characterization of immobilized cell systems

7. Determination of kinetic constants in free and immobilized cell systems- Evaluation of Effectiveness factor and Thiele modulus

8. Isolation of high yielding microbial strains for the production of commercially important enzymes.

9. Production of commercially important enzymes from microbial sources.

10. Standardization of medium composition for the optimum production of enzymes.

11. Determination of enzyme activity and specific activity.

12. Partial purification of isolated enzymes.

13. Characterization of enzymes-Effect of pH, temperature and inhibitors on enzyme activity etc.

14. Molecular weight determination of enzyme by Gel filtration method.

15. Method of checking the purity of the enzyme -SDS-PAGE

16. Immobilization of enzymes –Different Techniques such as adsorption, entrapment, encapsulation and crosslinking.

17. Strain improvement techniques- physical, chemical and genetic manipulation methods.

18. Development of enzyme assay methods.

19. Formulation of enzyme stability.

References:

1. Eisenthal R. and M. J. Dansen, *Enzyme Assays –A Practical Approach*, IRL Press, Oxford University Press, 1993.

2. Lee J. M., *Biochemical Engineering*, Prentice Hall, 1992, (Washington State University, http://jmlee.org, eBook Version 2.32, 2009.

Internal Continuous Assessment *(Maximum Marks-50)*

40% - Test
40% - Class work and Record
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours   Maximum Total Marks: 100

80% - Procedure, conducting experiment, results, tabulation and inference
20% - Viva voce

Candidate shall submit the fair record for endorsement by the external examiner.

Course Outcome:

Upon successful completion of this course, the students shall be acquainted with the practical aspects of industrial bioprocessing, with adequate familiarity on the underlying engineering principles. This knowledge shall enable them to deal with real- life industrial bioprocess situations with substantial ease.