VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

SCHEME OF TEACHING AND EXAMINATION FOR

M.TECH. CHEMICAL ENGG.

I Semester **CREDIT BASED**

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Practical / Field Work / Assignment/ Tutorials		I.A.	Exam		
16HCE11	APPLIED MATHEMATICS IN CHEMICAL ENGINEERING	4	--	3	20	80	100	4
16HCE12	ADVANCED THERMODYNAMICS	4	--	3	20	80	100	4
16HCE13	TRANSPORT PHENOMENA	4	--	3	20	80	100	4
16HCE14	CHEMICAL EQUIPMENT DESIGN	4	--	3	20	80	100	4
16HCE15X	ELECTIVE – I	3	--	3	20	80	100	3
16HCE16	LAB COMPONENT	--	3	3	20	80	100	2
16HCE17	SEMINAR	--	3	--	100	--	100	1
		19	6	18	220	480	700	22

ELECTIVE – I: 16HCE151- AIR POLLUTION CONTROL AND DESIGN OF EQUIPMENT
16HCE152 -COMPUTATIONAL FLUID DYNAMICS
16HCE153 -MODERN SEPARATION TECHNIQUES
16HCE154- FUEL CELL TECHNOLOGY

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M.TECH. CHEMICAL ENGG.

II Semester **CREDIT BASED**

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Practical / Field Work / Assignment/ Tutorials		I.A.	Exam		
16HCE21	PLANT WIDE CONTROL OF CHEMICAL PROCESSES	4	--	3	20	80	100	4
16HCE22	RESEARCH METHODOLOGY AND INDUSTRIAL SAFETY	4	--	3	20	80	100	4
16HCE23	CATALYTIC REACTION ENGINEERING	4	--	3	20	80	100	4
16HCE24	WASTE MANAGEMENT TECHNIQUES	4	--	3	20	80	100	4
16HCE25X	ELECTIVE-II	3	--	3	20	80	100	3
16HCE26	LAB COMPONENT	--	3	3	20	80	100	2
16HCE27	SEMINAR	--	3	--	100	--	100	1
	Total	19	6	18	220	480	700	22

Elective – II: 16HCE251- ENZYME ENGINEERING, 16HCE252- INTERFACIAL ENGINEERING
16HCE253- GASIFICATION TECHNOLOGY, 16HCE254- FOOD PROCESSING AND ENGINEERING

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

SCHEME OF TEACHING AND EXAMINATION FOR

M.TECH. CHEMICAL ENGG.

III Semester: INTERNSHIP **CREDIT BASED**

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Practical / Field Work / Assignment/ Tutorials		I.A.	Exam		
16HCE31	Seminar / Presentation on Internship (After 8 weeks from the date of commencement)	--	--	--	25	--	25	20
16HCE32	Report on Internship	--	--	--	25	--	25	
16HCE33	Evaluation and Viva-Voce of Internship	--	--	--	-	50	50	
16CH34	Project Phase-I	--	--	-	50	--	50	1
TOTAL		--	--	--	100	50	150	21

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

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M.TECH. CHEMICAL ENGG.

IV Semester: **CREDIT BASED**

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Practical / Field Work / Assignment/ Tutorials		I.A.	Exam		
16HCE41	BIOINSTRUMENTATION AND BIOSENSORS	4	--	3	20	80	100	4
16HCE42X	Elective-III	3	--	3	20	80	100	3
16HCE43	Project Phase-II	--	6	--	50	--	50	3
16HCE44	Evaluation of Project and Viva-voce	--	--		100	100	200	10
	TOTAL	7	--	6	190	260	450	20

ELECTIVE III: 16HCE421 FERMENTATION ENGINEERING, 16HCE-422 TOTAL QUALITY MANAGEMENT
16 HCE423 CHEMICAL PROCESS OPTIMIZATION 16HCE 424 PHARMACEUTICALTECHNOLOGY

NOTE:

1. Project Phase – I: 6 weeks duration shall be carried out between II and III Semesters. Candidates in consultation with the guides shall Carry out literature survey / visit to Industries to finalize the topic of dissertation.
2. Project Phase – II: 16 weeks duration during 4th Semester. Evaluation shall be done by a committee constituted comprising of HOD as Chairman, Guide and senior faculty of the department.
3. Project Evaluation: Evaluation shall be taken up at the end of 4th Semester. Project work evaluation and viva-voce examination shall be Conducted.
   a. Internal examiner shall carry out the evaluation for 100 marks.
   b. External examiner shall carry out the evaluation for 100 marks.
   c. The average of marks allotted by the internal and external examiner shall be the final marks of the project evaluation.
   d. Viva-Voce examination of Project work shall be conducted jointly by Internal and External examiner for 100 marks.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
SYLLABUS OF TEACHING AND EXAMINATION

APPLIED MATHEMATICS IN CHEMICAL ENGINEERING
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 1

Subject Code	:	16HCE11	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:
Students will
1. Be familiar with the Numerical Methods and differential techniques.
2. Learn how to find probability, sampling and design of experiments.
3. Be able to study about mathematical frame work for different assertions and is essential in every decision making process.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
PROBABILITY AND SAMPLING THEORY: Definitions, Conditional probability, Probability Distributions- Bernoulli, Binomial, Poisson, uniform, exponential, normal and gamma. Random samples, central limit theorem, X^2, t and F distributions. Estimation-point estimation, unbiasedness and consistency. Hypothesis testing-types of errors, significance level, Test concerning single mean, single variance and two means and two variance. Goodness of fit test.	10	L1, L2, L5
Module 2		
DESIGN AND ANALYSIS OF EXPERIMENTS: Treatment and interpretation on engineering data: Curvefitting, Non-linear least square regression. Interpolation: Newton's Forward/Backward interpolation formula, Lagrange's interpolation formula and experiments, their application.	10	L1, L3, L4
Module 3		
NUMERICAL SOLUTION OF LINEAR & NONLINEAR ALGEBRAIC EQUATIONS: Linear systems of equations, solutions by Creamer's Rule, Matrix methods, Gaussian, Gauss-Jordan, Jacobean, Gauss-Seidel and Relation methods. Formulation of linear and non-linear first and second order ordinary differential equations, higher order linear, differential equations for systems involving momentum, heat and mass transfer with and without chemical reactions and their analytical solutions.	10	L1, L3, L5

Module 4		
NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS: Ordinary differential equations: Runge-Kutta, Euler's and Milne's predictor corrector methods. Solution of boundary value problems.	10	L1, L3, L5
Module 5		
PARTIAL DIFFERENTIAL EQUATIONS: Solutions of elliptic, parabolic, and hyperbolic types of equations by Finite differences method.	10	L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Come out with the good knowledge of Advanced Numerical Methods and Statistical Techniques and they will be able to implement these techniques whenever required in their further studies.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life - long Learning

TEXT BOOKS:

1. H.S. Mickley, T. K. Sherwood and C.E. Reid, "**Applied Mathematics in ChemicalEngineering"**,II Tata McGraw Edn., Hill, New Delhi, 1978.
2. Jain M.K., **Numerical Solution of differential equations,** Wiley Eastern, 1987

REFERENCE BOOKS:

1. M. K. Jain, S.R.K. Iyengar and R. K. Jain, "**Numerical Methods for Scientific and Engineering Computations"**, 1992.
2. Sheldon M. Ross, **Introduction to Probability and Statistics for Engineers and Scientists,** John Wiley, 1989.
3. Smith G.D., **Numerical Solution of partial differential equations,** Oxford University Press, 1978

ADVANCED THERMODYNAMICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 1

Subject Code	:	16HCE12	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Apply the concepts of thermodynamics like fugacity, VLE, CRE, and statistical Thermodynamics.
2. Study the laws of thermodynamics and their applications.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
REVIEW OF FIRST & SECOND LAW OF THERMODYNAMICS: Applications solution thermodynamics – partial molar properties – Ideal & non ideal solutions -fugacity and it's coefficient.	10	L1, L2, L3
Module 2		
VLE: Determination of fugacity coefficient -Gibbs Duhem equation – azeotropic separation techniques –VLE Correlation techniques – Van Laar, Margules, Wilson, NRTL and other types of correlation equation applications -High pressure VLE – Partially miscible systems.	10	L1, L2, L4
Module 3		
CHEMICAL REACTION EQUILIBRIA: Industrial chemical reaction equilibria -homogeneous and heterogeneous systems - Effect of pressure and temperature – Complex reactions – liquid phase, vapor phase reactions.	10	L1, L3, L4
Module 4		
THIRD LAW OF THERMODYNAMICS: Verification of third law, Applications and evaluation.	10	L2, L4, L5
Module 5		
STATISTICAL THERMODYNAMICS: Energy levels, Boltzmann Distribution Law and Partition functions	10	L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Understand and apply the laws of thermodynamics to analyze various cases.
2. Evaluate VLE and CRE data for research studies.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving

TEXT BOOKS:

1. Jefferson W. Tester, Michael Modell, **Thermodynamics and Its Applications,** 3rd Edition, 1997.
2. J.M. Smith and Van Ness H.C, **Introduction to Chemical Engineering, Thermodynamics"-** ,McGraw Hill, 5th edition 1996.

REFERENCE BOOKS:

1. J.M. Smith and Van Ness H.C, **Introduction to Chemical Engineering Thermodynamics"-** ,McGraw Hill, 5th edition 1996.

TRANSPORT PHENOMENA

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 1

Subject Code	:	16HCE13	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Be able to analyze various transport processes with understanding of solution approximation methods and their limitations.
2. Will accustom momentum, heat and mass transport situations.
3. Will develop physical understanding of principles discussed and with emphasis on chemical engineering applications.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
BASIC CONCEPTS: Newtonian fluids, Non Newtonian Fluids, Analogies between Momentum, Heat and Mass Transport, Rheological behavior of fluids, Differential balance equations for heat, mass and momentum.	10	L1, L2, L5
Module 2		
MOMENTUM TRANSPORT (LAMINAR FLOW): Steady state Shell momentum balances, Boundary conditions applicable to momentum transport problems(flow over flat plate, flow through circular tube and annulus)	10	L1, L2, L4
Module 3		
INTERPHASE AND MULTIPHASE MOMENTUM TRANSFER: Friction factor (qualitative treatment only), Introduction to velocity distributions in Turbulent flow(Fluctuations and Time smooth Quantities) and Equation of Change for Isothermal system(Equation of Continuity and Motion), Macroscopic Balance for Isothermal Systems (Mass, Momentum and Mechanical Energy Balance). Formation of bubbles and drops and their size distribution, Solid-fluid systems - forces acting on stagnant and moving solids.	10	L1, L2, L6
Module 4		
ENERGY TRANSPORT: **Convection:** Heat Transfer coefficient, Free and Forced convection, film type and drop wise condensation and equations for heat transfer coefficients for both, Heat transfer in boiling liquids.	10	L1, L2, L4, L5

Radiation: The spectrum of electromagnetic radiation, absorption and emission at solid surfaces, Planck's distribution law, Wein's displacement law and Stefan- Boltzmann law, Lambart's cosine law, heat exchange by radiation between two black surface elements.		
Module 5		
MASS TRANSPORT: Fick's law of diffusion, Diffusion with homogeneous and heterogeneous chemical reaction, convective mass transfer co-efficient, theories of ordinary diffusion in liquids	10	L1, L2, L4

Course outcomes:

After studying this course, students will be able to:

1. To understand the chemical and physical transport processes and their mechanism.
2. To do heat, mass and momentum transfer analysis.
3. To analyze industrial problems along with relevant approximations and boundary conditions.
4. To develop steady and time dependent solutions along with their limitations.
5. To set up and solve differential momentum, heat, and mass balances for 1-D steady state problems and quasi-steady-state problems occurring in laminar and turbulent flows in terms of vector and tensor fluxes.
6. Formulate conservation statements in heat, mass, and momentum at multiscales from microscopic to macroscopic in both steady and unsteady modes.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Collaborative and multidisciplinary work

TEXT BOOKS:

1. Bird R.B., W.E. Stewart and E.N. Lightfoot, **Transport Phenomena**, John Wiley and Sons,Academic Press, 1994
2. B. M Suryavashi and L. R Dongre, **Transport phenomena**, Niraliprakashann, 4th edition.

REFERENCE BOOKS:

1. Welty, J.R., C.E. Wicks and R.E. Wilson, **Fundamental of Momentum, Heat and Mass Transfer,** John Wiley and Sons, 4th Edn., John Wiley, 2000.
2. Sissom L.E. and D.R.Pitts, **Elements of Transport Phenomena**, McGraw Hill, New York, 1972.
3. Brodkey R.S. and H.C.Hershey, **Transport Phenomena, A United Approach** McGraw Hill, 1988
4. Warren L. Mccabe, Julian C. Smith, Peter Harriott, Unit **Operations of Chemical Engineering**. Mcgraw-hill, 7th Edition

CHEMICAL EQUIPMENT DESIGN

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 1

Subject Code	:	16HCE14	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Understand advances and types in the design of Chemical process equipments.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Detailed Engineering Process & Mechanical Design aspects and sketching (The sketch shall include sectional front view, full Top/side view) of the following: 1. Double pipe Heat Exchanger. 2. Shell and Tube Exchanger. 3. Horizontal and Vertical Condensers 4. Evaporator Single Effect 5. Bubble Cap Distillation Column 6. Absorption column	50	L1, L2, L3, L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Have awareness on advances in process engineering design of many process equipments relating to heat and mass transfer.
2. Will be exposed to process integration approach to before carrying out design any process Equipments.

Question Paper Pattern:

This question paper will have two questions. Each full question consists of 100 marks. The students will have to answer 1full question. Use of IS code books relevant to above designs and Perry's Chemical Engineers Handbook is permitted for examination.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life - long Learning

TEXT BOOKS:

1. Robert E Treybal, **Mass Transfer operations,** 3rd edition, McGraw Hill, 1981.
2. K A Gavhane – **Mass Transfer,** Niraliprakashann.

REFERENCE BOOKS:

1. Kern D.Q., **Process Heat Transfer**, McGraw Hill, 18th Reprint, 2008.
2. Coulson and Richardson, **Chemical Engineering,** Volume 6, Butterworth Heinemann, 1990.
3. B I. Bhat & Thakore, **Process design**, McGraw Hill
4. BIS 4503 – **Code for shell and tube heat exchangers**
5. Perry and Green, **Chemical Engineering Handbook**, 8th Edition, McGrawHill, 2008.

ELECTIVE-I
AIR POLLUTION CONTROL AND DESIGN OF EQUIPMENT
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 1

Subject Code	:	16HCE151	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will
1. Focus on classification of air pollutants, water pollutants and solid waste - causes, effects and control methods, need of environmental Legislation.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
INTRODUCTION: Definition and concentrations, classification and properties of air pollutants, emission sources-natural and anthropogenic sources, effects of air pollution on flora and fauna, human health and materials. **AIR POLLUTION LAWS AND STANDARDS:** Meteorological aspects of air pollution dispersion- Temperature lapse rates and stability, wind velocity and turbulence, plume behavior, dispersion of air pollutants, solutions to atmospheric dispersion equation, the Gaussian plume model.	8	L1, L2, L3
Module 2		
AIR POLLUTION SAMPLING AND MEASUREMENTS: Types of pollution sampling and measurements, ambient air sampling, Collection of gaseous air pollutants, collection of Particulate pollutants, stack sampling, analysis of air pollutants like sulphur dioxide, nitrogen oxide, carbon monoxide, oxidants and ozone, hydrocarbon, particulate matter.	8	L1, L2, L4
Module 3		
AIR POLLUTION CONTROL METHODS AND DESIGN OF EQUIPMENTS: Control methods, source correction methods, cleaning of gaseous effluents, design of stacks and industrial ventilation systems.	8	L1, L2, L5
Module 4		
PARTICULATE EMISSION CONTROL: Selection of particulate collector, design of gravitational settling chambers, cyclone separators, bag house filters, electrostatic precipitators, wet scrubbers.	8	L1, L2, L5, L6

Module 5		
CONTROL OF GASEOUS EMISSIONS: Absorption by liquids, adsorption by solids, combustion. Air pollution control in specific industries, control of sulphur dioxide, nitrogen dioxides, carbon monoxides and hydrocarbon emissions. Acid rain, green house effects, important air pollution episodes.	8	L1, L2, L5

Course outcomes:

After studying this course, students will be able to:

1. Adopt the preventive measures for the control of air pollutants,
2. To understand the control measures of pollutants emitted from different industries.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life - long Learning

TEXT BOOKS:

1. Mudakavi J.R, **Principles and Practices of Air Pollution Control and Analysis,** I.K. International Publishing Home Pvt. Ltd., New Delhi, 2010.

REFERENCE BOOKS:

1. Martin Crawford, **Pollution control theory,** McGraw Hill, NY, 1976
2. Joe Ledbetter, **Air Pollution Part A&B,** Marcel Dekker, NY, 1972.
3. Cheremissinoff N, **Air Pollution Control,** Design Hand Book, Part I and II, Marcel Dekker, NY, 1977.

ELECTIVE-I
COMPUTATIONAL FLUID DYNAMICS
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 1

Subject Code	:	16HCE152	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will

1. Learn advanced modeling using Computational Fluid Dynamics (CFD), which has become an indispensible tool for many engineers.
2. Learn to carry out CFD analysis correctly.
3. Get hands-on experience of drawing, meshing and simulation.
4. Identify the possibilities and the limitations in advanced simulation programs.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
Introduction to CFD, Flow fields. Finite difference and finite element methods. Various numerical techniques for CFD.	8	L1, L2, L3
Module 2		
Conservation laws of fluid motion and boundary conditions. (Governing equations of fluid flow and heat transfer. Differential and integral forms of the transport equations.) Navier-Stokes equations), Turbulence Modeling.	8	L1, L2, L4
Module 3		
One- and two- dimensional steady & amp; transient conduction - Steady one-dimensional convection and diffusion - Solution methodology: upwind scheme, exponential scheme, hybrid scheme, power law scheme – Explicit, Implicit, Crank-Nicolson schemes –Stability criterion.	8	L2, L3, L5
Module 4		
Representation of the pressure gradient term and continuity equation – Staggered grid - Momentum equations – Pressure and velocity corrections - Pressure correction equation - SIMPLE algorithm - Boundary conditions for the pressure correction method.	8	L2, L3, L4
Module 5		
About the CFD software for different applications and construction of geometry and Discretions using available commercial CFD solvers. (Tutorials) Creating and meshing a basic geometry. Any 5 Basic problems (eg. Basic flow studies in pipe modeling a mixing elbow (2-D). Modeling a three-pipe intersection (3-D). Modeling flow in a tank, modeling a combustion chamber (3-D).)	8	L3, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Develop commercial CFD program.
2. Select appropriate models and perform advanced simulations in accordance with best practice guidelines.
3. Formulate problems that can be solved with a CFD program.
4. Critically evaluate simulation results and communicate the results in oral and written form.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life - long Learning
5. Collaborative and Multidisciplinary Work

TEXT BOOKS:

1. Anderson, J.D., **Computational Fluid Dynamics: The Basics with Application,** McGraw-Hill Co. Inc.
2. Anderson, D.A., Tannehill, J.C. and Pletcher, R.H., **Computational Fluid Mechanics and Heat Transfer**, Hemisphere Publishing Corporation.

REFERENCE BOOKS:

1. Patankar, S.V., **Numerical Heat Transfer and Fluid Flow**, Hemisphere Publishing Corporation.
2. Ferziger, J.H. and Peric, M., **Computational Methods for Fluid Dynamics**, Springer.
3. Versteeg, H.K. and Malalasekera, W., **An Introduction to Computational Fluid Dynamics: The Finite Volume Method**, Prentice-Hall Inc.

MODERN SEPARATION TECHNIQUES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 1

Subject Code	:	16HCE153	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:

Students will

1. Learn the principle and technical concept of advanced separation processes.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
INTRODUCTION: Review of conventional processes, Recent advances in separation techniques based on size, surface properties, ionic properties and other special characteristics of substances, Process concept, Theory and equipment used in cross flow filtration, cross flow electro filtration, dual functional filter, Surface based solid -liquid separations involving a second liquid, Sirofloc filter.	8	L1, L2, L4
Module 2		
MEMBRANE SEPARATIONS: Types and choice of membranes, Plate and frame, tubular, spiral wound and hollow fibre membrane and their relative merits, Commercial, pilot plant and laboratory membrane permeators involving dialysis, reverse osmosis, Nano filtration, ultra filtration, Micro filtration and Donnan dialysis, Economics of membrane operations, Ceramic membranes.	8	L1, L2, L3
Module 3		
SUPERCRITICAL FLUID EXTRACTION: Concept, modeling, design aspects and applications **SEPARATION BY ADSORPTION TECHNIQUES:** Mechanism, Types and choice of adsorbents, Normal adsorption techniques, Affinity chromatography and immuno chromatography. Types of equipment and commercial processes, recent advances and process economics.	8	L3, L4, L6
Module 4		
IONIC SEPARATIONS: Controlling factors, Applications, Types of equipment employed for electrophoresis, Dielectrophoresis, Ion exchange chromatography and electro dialysis, Commercial Processes.	8	L2, L3, L4

Module 5		
MISCELLANEOUS SEPARATION TECHNIQUES: Separations involving Lyophilization, Pervaporation and permeation techniques for solids, liquids and gases. Industrial viability and examples, Zone melting, Adductive crystallization, Oil spill Management, Industrial effluent treatment by modern techniques.	8	L3, L4, L5

Course outcomes:

After studying this course, students will be able to:

1. Acquire sufficient knowledge in principles and working for separation of components.
2. Get clear idea of new and unconventional separation processes.
3. Equip with the applications in Upstream and Down-streaming processes.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life - long Learning
5. Collaborative and Multidisciplinary Work

TEXT BOOKS:

1. King, C.J, **Separation Processes**, Tata McGraw Hill Publishing Co., Ltd., 1982.
2. Schoem, H.M, **New Chemical Engineering Separation Techniques**, Interscience Publishers, 1972.

REFERENCE BOOKS:

1. Lacey, R.E. and S.Loaeb, **Industrial Processing with Membranes**, Wiley Inter Science, New York, 1972.
2. Ronald W. Roussel, **Handbook of Separation Process Technology**, John Wiley, New York, 1987.
3. Kestory, R.E, **Synthetic polymeric membranes**, Wiley, New York, 1987.
4. M A Mchugh& V J Krukonis (Butterworth Heinmann), **Supercritical Fluid Extraction.**

FUEL CELL TECHNOLOGY

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 1

Subject Code	:	16HCE154	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
Total No. of Lecture Hours	:	50	**Exam Marks**	:	80
Credits	:	03			

Course Objectives:

Students will

1. Understand about fuel cells, their working principle, types, design and performance analysis.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
OVERVIEW OF FUEL CELLS: Low and high temperature fuel cells; Types of fuel cells and applications.	8	L1, L2, L3
Module 2		
FUEL CELL THERMODYNAMICS: Heat, work potentials, prediction of reversible voltage, fuel cell efficiency.	8	L2, L3, L4
Module 3		
FUEL CELL REACTION KINETICS: Electrode kinetics, over voltages, Tafel equation, charge transfer reaction, exchange currents, electro-catalysis - design, activation kinetics, Fuel cell charge and mass transport - flow field, transport in electrode and electrolyte.	8	L2, L3, L4
Module 4		
FUEL CELL CHARACTERIZATION: In-situ and ex-situ characterization, techniques, i-V curve, Frequency response analyses; Fuel cell.	8	L3, L4, L5
Module 5		
BALANCE OF PLANT: Hydrogen production from renewable sources and storage; safety issues, cost expectation and life cycle analysis of fuel cells.	8	L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Explain basics and working principles of the fuel cell technology.
2. Select the suitable materials for electrode, catalyst, membrane for the fuel cells.
3. Determine the mass transfer process, pressure drop and velocity distribution in single cell.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Collaborative and Multidisciplinary Work

TEXT BOOKS:

1. Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, **Fuel Cell Fundamentals**, Wiley, NY (2006).
2. Bard, A. J. , L. R., Faulkner, **Electrochemical Methods**, Wiley, N.Y. (2004)
3. Basu, S. (Ed) **Fuel Cell Science and Technology**, Springer, N.Y. (2007).
4. Liu, H., **Principles of fuel cells**, Taylor & Francis, N.Y. (2006).

REFERENCE BOOKS:

1. M. M. MENCH, **Fuel Cell Engines,** Wiley, 2008.
2. M.T.M. Koper (ed.), **Fuel Cell Catalysis**, Wiley, 2009.
3. J.O'M. Bockris, A.K.N. Reddy, **Modern Electrochemistry**, Springer 1998.

LAB COMPONENT
PROCESS DYNAMICS AND CONTROL LAB
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 1

Subject Code	:	16HCE16	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
Total No. of Lecture Hours	:	50	**Exam Marks**	:	80
Credits	:	02			

Course Objectives:
Students will
1. Experimentally verify the process control concepts studied in theory.
2. Carry out experiment and make observations for various conditions.
3. Study the effect of P, PI and PID control action.
4. Evaluate the inherent characteristic of different valves.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

The following experiments are to be carried out; the data are to be analyzed based on the theoretical aspects, and recorded with comments.	Blooms Level
1. Level control trainer – open and closed loop	L2, L3
2. Flow control trainer – open and closed loop	L2, L3
3. Temperature control trainer – open and closed loop	L2, L3
4. Pressure control trainer – open and closed loop	L2, L3
5. Control valve – Air to close	L3, L4
6. Control valve - air to open	L3, L4
7. Integral to proportional converter & Proportional to integral converter.	L1, L2, L3,L4

Course outcomes:
After studying this course, students will be able to:
1. Apply theoretical knowledge of various control trainers.
2. Acquire practical knowledge of Control valves.
3. Know the use of P, PI and PID controllers.

Conduct of Practical Examination:
1. All laboratory experiments are to be included for practical examination.
2. Students are allowed to pick one experiment from the lot.
3. Strictly follow the instructions as printed on the cover page of answer script for breakup of marks.
4. Change of experiment is allowed only once and 15% Marks allotted to the procedure part to be made zero.

Graduate Attributes
1. Critical Thinking
2. Usages of Modern Tools
3. Collaborative and Multidisciplinary Work
4. Life Long Learning
5. Independent and Reflective Learning

TEXT BOOKS:

1. Coughnour D R, **Process system analysis and control,** 2nd Edition, McGraw Hill, New York, 1991.
2. George Stephanopoules, **Chemical process control**, An Introduction to Theory and Practice, Prentice Hall, New Delhi, 1998

REFERENCE BOOKS:

1. Smith C A and Corripio A B, **Principles and Practice of Automotive Process Control**, John Wiley, New York, 1976.
2. Luyben, Process Modelling, **Simulation and Control for Chemical Engineers**, 2nd Edition McGraw Hill, 1990.

SEMINAR-I

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 1

Subject Code	:	16HCE17	**IA Marks**	:	100
No. of Lecture Hrs/Week	:	03			
Credits	:	01			

Course Objectives:

Students will

1. Develop skills in searching technical literature, analyzing and evaluating it to compare the various approaches and prepare a written report and also presenting it orally.

HOD has to nominate a seminar guide. Candidate has to finalize a seminar topic in consultation with seminar guide. The student has to prepare, submit a seminar report and make a presentation on Seminar topic allotted. The seminar shall be evaluated as internal assessment by a committee constituted by the HOD.

Course outcomes:

After studying this course, students will be able to:

1. Prepare reports and compile data.
2. Prepare presentation and communicate findings to audience.

Graduate Attributes

1. Critical Thinking
2. Usages of Modern Tools
3. Collaborative and Multidisciplinary Work
4. Life Long Learning

PLANT WIDE CONTROL OF CHEMICAL PROCESS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 2

Subject Code	:	16HCE21	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Learn advanced control methods used in industries and research.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
REVIEW OF PROCESS DYNAMICS: First order systems – thermometer, level tank, CSTR, Second order system – U tube manometer, Damped vibrator.	10	L1, L2, L3
Module 2		
FEED BACK CONTROL: Feedback controllers, PID Controller design and tuning, Zeigler –Nichols controller tuning. **STABILITY:** Concept and Criterion, Routh test, Root locus, frequency response analysis. Bode diagrams, Phase margin and gain margin.	12	L2, L3, L5
Module 3		
ADVANCED CONTROL TECHNIQUES: Cascade, feed forward and feed backward, ratio control, selective and adaptive control, smith predictor and internal module controller.	10	L2, L3, L5
Module 4		
MULTI VARIABLE CONTROLLER: Features and examples of multi input and multi output processes, design of cross controller, relative gain array, Niderlinski index. **CONTROL STRUCTURES FOR UNIT OPERATIONS:** Simple distillation column, heat exchanger, evaporator, and reactor.	10	L2, L3, L4, L6
Module 5		
PLANT WIDE CONTROL FOR IMPROVED ECONOMICS: Process operation for a given throughput and for maximum throughput, concept of bottleneck constraint, application of optimizing controllers for throughput maximization on case study processes.	10	L1, L2, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Solve cases related to first and second order system.
2. Use feedback and feed forward controller techniques.

3. Determine stability of control system and carry out controller tuning.
4. Apply controllers to various process equipments.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Collaborative and multidisciplinary work

TEXT BOOKS:

3. Coughnour D R, **Process system analysis and control,** 2nd Edition, McGraw Hill, New York, 1991.
4. George Stephanopoules, **Chemical process control**, An Introduction to Theory and Practice, Prentice Hall, New Delhi, 1998

REFERENCE BOOKS:

3. Smith C A and Corripio A B, **Principles and Practice of Automotive Process Control**, John Wiley, New York, 1976.
4. Luyben, Process Modelling, **Simulation and Control for Chemical Engineers**, 2nd Edition McGraw Hill, 1990.

RESEARCH METHODOLOGY AND INDUSTRIAL SAFETY ANALYSIS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 2

Subject Code	:	16HCE22	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Learn about various types of research, hypothesis, data handling and thesis writing.
2. Learn and get competence in the field of applied statistical methods for work concerning planning and analysis of experiments, regression analysis.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
BASIC CONCEPT: Types of research, Significance of research, Research framework, Case study method, Experimental method, Sources of data, data collection using questionnaire and interviewing.	10	L1, L2
Module 2		
RESEARCH FORMULATION: Components, selection and formulation of a research problem, objectives of formulation and criteria of a good research problem. **RESEARCH HYPOTHESIS:** Criterion for hypothesis construction, nature of hypothesis, need for having a working hypothesis, characteristics and types of hypothesis, procedure for hypothesis testing. **SAMPLING METHODS:** Introduction to various sampling methods and their applications **DATA ANALYSIS:** Sources of data, collection of data, measurement and scaling technique, and different techniques of data analysis.	10	L2, L3, L4
Module 3		
THESIS WRITING AND JOURNAL PUBLICATION: Writing thesis, writing journal and conference papers, IEEE and Harvard styles of referencing. Effective presentation, copy rights and avoiding plagiarism.	10	L4, L5, L6
Module 4		
RISK ANALYSIS: Hazard identification methodologies, risk assessment methods-PHA, HAZOP, MCA, ETA, FTA, Consequence analysis, Probit Analysis.	10	L3, L4, L5

Module 5		
HAZARDS IN WORK PLACES: Nature and type of Work places, Types of hazards, hazards due to improper housekeeping, hazards due to fire in multi floor industries and buildings, guidelines and safe methods in above situations. Workers exposure to hazardous chemicals, TLVs of Chemicals, Physical and Chemical properties of chemicals leading to accidents like fire explosion, ingestion and inhalation, pollution in work places due to hazardous, dust, fumes and vapors, guidelines and safety methods in chemicals handling, storage, entry to confined space.	10	L2, L3, L4

Course outcomes:

After studying this course, students will be able to:

1. Plan experiments according to a proper and correct design plan.
2. Analyze and evaluate experimental results (statistically), according to chosen experimental design.
3. Control and properly use fundamentals such as hypothesis testing, degrees of freedom, ANOVA, fractional design and other design methods/techniques and so on.
4. Be familiar with accident prevention techniques, hazard analysis techniques and legislations pertaining to safety in chemical industries.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Collaborative and multidisciplinary work

TEXT BOOKS:

1. C R Kothari “Research Methodology” New Age International second revised edition
2. Deepak Chawla, Neena Sandhi “Research Methodology Concepts & Cases” Vikas Publications.

REFERENCE BOOKS:

1. Patterson D, **Techniques of safety managements**, McGraw Hill, 1978.
2. Levine S.P and Martin, **Protecting Personnel at Hazardous Wastesites**, Butterworth, 1985, Blake R.P., Industrial Safety, Prentice Hall, 1953.

CATALYTIC REACTION ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 2

Subject Code	:	16HCE23	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Understand basics of heterogeneous catalytic and non-catalytic reactor design.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
INDUSTRIAL CATALYSIS: Classification on catalyst- homogeneous, heterogeneous, Biocatalysts, Typical industrial catalytic processes, preparation of catalysts- laboratory techniques, Industrial methods, transition models, dual functional catalysts, zeolites, Enzymes, solid supportive materials, catalyst activation.	10	L1, L2, L3
Module 2		
CATALYST CHARACTERIZATION: Surface area measurements, BET Theory, pore size distribution, Porosity-Chemisorption techniques, Static and dynamic methods, Crystallography and surface analysis techniques, XRD, XPS, ESCA, ESR, NMR, Raman and Molecular spectroscopy, surface acidity and toxicity, activity, life time, bulk density, thermal stability.	10	L1, L2, L4
Module 3		
KINETICS OF HETEROGENEOUS REACTIONS (CATALYTIC): Catalytic Reactions, Rate controlling steps, Langmuir - Hinshelwood model, Riedel – Eiley Mechanism. **CATALYST DEACTIVATION:** Poisons, Sintering of catalysts, pore mouth plugging and uniform poisoning models, Kinetics of deactivation, Catalyst regeneration.	10	L1, L2, L3, L4
Module 4		
HETEROGENEOUS REACTIONS (NON-CATALYTIC): Introduction, non-catalytic fluid-fluid reactions. Non catalytic fluid-solid reactions & models for such reactions to determine time of conversion. **NON IDEAL REACTOR ANALYSIS:** Mixing concepts, Residence Time Distribution, Response Measurements, segregated flow model, Dispersion model, Series of stirred tanks model, Recycle reactor model, Analysis of non-ideal reactors, two parameter model for CSTR.	10	L2, L3, L4

Module 5		
EXTERNAL DIFFUSION EFFECTS IN ETEROGENEOUS REACTIONS: Surface kinetics & pore diffusion effects, Evaluation of effectiveness factor, **DESIGN OF REACTORS FOR HETEROGENEOUS CATALYTIC & NON CATALYTIC REACTIONS:** Design of reactors for non catalytic fluid-fluid and fluid-solid reactions**.**	10	L3, L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Explain catalyst physical properties and catalyst characterization
2. Determine kinetics of catalytic and non-catalytic chemical reaction,
3. Design catalytic and non-catalytic reactors
4. Analyze non catalytic fluid solid reaction, non-catalytic fluid particle reactions, various models

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life - long Learning

TEXT BOOKS:

1. Smith J.M, **Chemical Engineering Kinetics,** 3rd Edition, McGraw- Hill, 1984.
2. Bischoff and Froment, **Chemical Reactor Design and Analysis**, Addision Wesley, 1982.
3. Fogler H.S, **Elements of Chemical Reaction Engineering**, Prentice Hall, 1986.

REFERENCE BOOKS:

1. Octave Levenspiel, **Chemical Reaction Engineering** 3rd Edition, John Wiley and sons.
2. Emmett, P.H., **Catalysis, Vols. I & II**, Reinfold Publishing Corporation, NY, 1954
3. Thomas and Thomas, **Introduction to Heterogeneous Catalysts**, Academic Press. London, 1967.

WASTE MANAGEMENT TECHNIQUES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 2

Subject Code	:	16HCE24	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
Total No. of Lecture Hours	:	52	**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Learn various types of waste management techniques.
2. Interaction of waste in nature.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
INTRODUCTION TO WASTE WATER: Ecosystem, characteristics, standards, effects of waste water on health, ecosystem, and materials. **TREATMENT PHYSICAL:** Introduction to screening, flow equalization, flocculation, grit removal, sedimentation, flotation. C**HEMICAL:** Introduction to coagulation, precipitation, oxidation, neutralization, chlorination. Detailed study on phosphorous and heavy metals removal.	10	L1, L2, L3
Module 2		
BIOLOGICAL: Introduction to bacterial life cycle, cell culturing, types of biological processes, Aerobic process. Theory of aeration, factor affecting oxygen transfer, Mixing requirements, types of aerators. Nitrification & de-nitrification. Detailed study on Activated sludge process & trickling filter. **ANAEROBIC PROCESS:** Construction and working of UASBR, Rotating biological contactors. Algal ponds, Hyacinth and Duckweed, fish ponds.	10	L2, L3, L4
Module 3		
SOLID WASTE: Sources, characteristics, present techniques of solid waste management, integrated solid waste management, measures and methods to assess solid waste quantities. Functional elements, Generation of solid waste, onsite handling. Collection SCS, HCS, and separation processes, source reduction, 3R's.	10	L2, L3, L4
Module 4		
TRANSFORMATION: Thermal conversion techniques, Pyrolysis, Gasification, waste to energy, composting.	10	L2, L3, L4
Module 5		
DISPOSAL: Site selection, landfill and engineering landfill, leachate and gas collection.	10	L2, L3, L4, L6

Course outcomes:

After studying this course, students will be able to:

1. Differentiate various waste management techniques.
2. Handle waste from various sectors.
3. Suggest Emerging technologies.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Collaborative and multidisciplinary work

TEXT BOOKS:

1. Arecivala S.J. and S.R.Asolekar, **Wastewater Treatment for Pollution Control and Reuse**, 3rd Edition, Tata McGraw Hill Pvt. Ltd., New Delhi, 2009.
2. Metcalf and Eddy, **Wastewater Engineering -Treatment, Disposal & Reuse**, Tata McGraw Hill, 1991
3. H.E. Babbilt and R.Baumann, **Sewage and Sewage Treatment**, 1986.

REFERENCE BOOKS:

1. Martell, **Solid Wastes,** John Wiley, NY, 1975.
2. George Tchobanoglous *et al.*, **Integrated Solid Waste Management**, 2nd Edition, McGraw Hill & Co, 1993.
3. Frank Krieth, **Handbook of Solid waste,** McGraw Hill Inc., NY, 1996.
4. Jagbir Singh, and A.L. Ramanathan (Eds.), **Solid Waste Management Present and Future Challenges,** I.K. International House Pvt. Ltd., New Delhi, 2010.
5. C S Rao, **Environmental Pollution Control and Engineering**, New age international Pvt. Ltd, New Delhi 2009.

ELECTIVE-II
ENZYME ENGINEERING
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 2

Subject Code	:	16HCE251	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will able to:
1. Understand the basics and mechanisms of enzyme catalysis.
2. Impart knowledge on reaction kinetics of free and immobilized enzymes.
3. Study about the industrial applications of enzymes in biological preparation.
4. Study instrumental techniques available for using enzymatic analysis.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
STRUCTURES AND FUNCTIONS OF PROTEINS: Enzyme classification, based on structure classification of amino acids, classifications of proteins, specificities of enzyme action, biosynthesis and properties of proteins.	8	L1, L2
Module 2		
KINETICS: Chemical mechanisms of enzyme catalyzed reactions, introduction to bioenergetics and kinetics, kinetics of multi-substrate bio reactions, investigations of active sites structures.	8	L2, L3, L4
Module 3		
CHEMICAL NATURE OF ENZYME CATALYSIS: Sigmoidal kinetics and allosteric enzymes, co-enzymes, significance of sigmoidal behavior.	8	L2, L3
Module 4		
APPLICATIONS: Investigation of enzymes in biological preparation, extraction and purification, enzymes as analytical reagents	8	L3, L4
Module 5		
INSTRUMENTAL TECHNIQUES: Instrumental techniques available for using enzymatic analysis, applications in medicine, industries, and biotechnological applications	8	L2, L3, L4

Course outcomes:
After studying this course, students will be able to:
1. Explain enzyme and enzyme reactions and various concepts in biochemical engineering
2. Develop ideas on Processing, extraction and Purification of enzymes at an industrial scale

Question Paper Pattern:
This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each

full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Research Skill
4. Use of Modern Tools

TEXT BOOKS:

1. Trevor Palmer, **Understanding Enzymes,** 4th Edition, Prentice Hall, 1991.

REFERENCE BOOKS:

1. Bailey and Ollis, **Biochemical Engineering Fundamentals**, 2nd Edition, McGrawhill, 1976.
2. John R. Whitaker, Alphons G J Voragen, and DWS Wong, **Handbook of Food Enzymology,** Marcel Dekker, NewYork, 2003.

ELECTIVE-II
INTERFACIAL ENGINEERING
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 2

Subject Code	:	16HCE252	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
Total No. of Lecture Hours	:	50	**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will
1. Learn and understand various types of surface and interfacial phenomena.
2. Learn about transport processes and adsorption isotherms.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
INTRODUCTION TO THE ENGINEERING OF INTERFACES: Definitions of fluid-fluid and fluid-solid interfaces, Occurrence of interfaces in science and engineering, Overview of industrial applications of various interfacial phenomena, Colloidal materials; Properties of colloidal systems, Experimental characterization of colloidal dispersions. **SURFACE AND INTERFACIAL TENSION:** Theoretical methods for the calculation of surface and interfacial tension, Experimental techniques for the determination of equilibrium and dynamic tension, Shape of the surfaces, curvature and radius of curvature, Young-Laplace equation, Kelvin equation, Pendant and sessile drops, Adams-Bashforth equation, Characterization of fluid-solid interfaces, Contact angle and wetting phenomena, Young-Dupre equation, Measurement of equilibrium and dynamic contact angles, Deposition of thin films, Mechanism of film nucleation.	8	L1, L2, L3
Module 2		
INTRODUCTION TO INTERMOLECULAR AND SURFACE FORCES: van der Waals forces, Electrostatic double layer force, Disjoining pressure, DLVO theory, Non-DLVO forces. Chemical vapor deposition, molecular beam epitaxy, sputtering and atomic layer deposition techniques, Applications of fluid-solid interfaces in crystallization, development of ceramic materials, catalysts, electronic products and Nano-materials.	8	L2, L3, L4
Module 3		
ADSORPTION AT FLUID-FLUID AND FLUID-SOLID INTERFACES: Adsorption of surfactants, Gibbs and Langmuir monolayers, Gibbs adsorption equation, Surface equation of state, Surface pressure isotherm, Langmuir-Blodgett films and their	8	L2, L3, L5

applications, Radiotracer and neutron reflection techniques for studying adsorption at fluid-fluid interfaces, Henry, Freundlich, Langmuir, Frumkin and Davies adsorption isotherms, Brunauer-Emmett-Teller theory of adsorption, Adsorption hysteresis, Characterization of adsorption at fluid-solid interfaces by vacuum and non-vacuum techniques.		
Module 4		
INTERFACIAL RHEOLOGY AND TRANSPORT PROCESSES: Surface shear viscosity, Surface dilatational viscosity, Boussinesq number, Interfacial tension gradient and Marangoni effect, Gibbs and Marangoni elasticity, Boussinesq-Scriven model; Interfacial turbulence, Motion of drops in a liquid, Thin liquid films, Disjoining pressure and body-force models, Stability of thin liquid film, Black films. **EMULSIONS:** Preparation, characterization and applications, Ostwald ripening, Flocculation and coalescence, Micro-emulsions, characterization and properties, Stability of microemulsions, Foams, preparation, characterization and stability, Structure of foams.	8	L3, L4, L5
Module 5		
INTERFACIAL REACTIONS: Reactions at fluid-solid interfaces, Langmuir-Hinshelwood model, External and internal transport processes, Interfacial poly-condensation reactions, Fast and instantaneous reactions at fluid-fluid interfaces, Reactions at bio-interfaces, Micellar catalysis, Phase transfer catalysis.	8	L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Categorize various interfacial forces, reactions and transport processes.
2. Apply the knowledge of interfacial rheology to various cases.
3. Prepare and conduct studies on emulsions and its applications.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Research Skill
4. Use of Modern Tools

TEXT BOOKS:

1. Adamson, A. W. and Gast, A. P., **Physical Chemistry of Surfaces**, John Wiley, New York, 1997.
2. Ghosh, P., **Colloid and Interface Science**, PHI Learning Pvt. Ltd., New Delhi, 2009.
3. Hiemenz, P. C. and Rajagopalan, R., **Principles of Colloid and Surface Chemistry**, Marcel Dekker, New York, 1997.
4. Stokes, R. J. and Evans, D. F., **Fundamentals of Interfacial Engineering**, Wiley-VCH, New York, 1997.

REFERENCE BOOKS:

1. Baszkin, A. and Norde, W., **Physical Chemistry of Biological Interfaces**, Marcel Dekker, New York, 2000.
2. Edwards, D. A., Brenner, H. and Wasan, D. T., **Interfacial Transport Processes and Rheology**, Butterworth-Heinemann, Boston, 1990.
3. Hunter, R. J., **Foundations of Colloid Science**, Oxford University Press, New York, 2005.
4. Israelachvili, J., **Intermolecular and Surface Forces**, Academic Press, London, 1992.
5. Slattery, J. C., **Interfacial Transport Phenomena**, Springer-Verlag, New York, 1990.

ELECTIVE-II
GASIFICATION TECHNOLOGY
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 2

Subject Code	:	16HCE253	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will
1. Learn about various types of biomass source, properties and gasification.
2. Learn about gasification kinetics, design and gas cleaning technologies.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
BIOMASS AND ITS PROPERTIES: Types and Sources of Biomass, Physical and Thermal Properties of Biomass, Proximate and Ultimate analysis, stoichiometric considerations, Equivalence Ratio, Thermochemical conversion processes, Types of gasifiers, gas yield and its composition.	8	L1, L2, L4
Module 2		
THEORY OF GASIFICATION: Gasification reactions, Gasification processes - Drying, Devolatilization/Pyrolysis, combustion and gasification/reduction, Pyrolysis types and product yield, torrefaction, catalytic gasification.	8	L2, L3, L4
Module 3		
GASIFICATION KINETICS: Kinetic models for gasification-Drying, Devolatilization /Pyrolysis, combustion and gasification/reduction, Chemical equilibrium, char reactivity, Effect of feed properties on gasification, Estimating Equilibrium Gas Composition.	8	L2, L3, L4
Module 4		
DESIGN OF GASIFIERS: Energy and Mass Balance, Heat transfer in gasifiers, Gasifier Efficiency, sizing of downdraft biomass gasifier, design optimization.	8	L3, L4, L5, L6
Module 5		
GAS CLEANING TECHNOLOGIES: Tar formation, composition, reduction of tar by operating conditions, reduction by design, Particulate removal technologies, Environmental emissions.	8	L3, L5, L6

Course outcomes:
After studying this course, students will be able to:
1. Classify biomass and characterize based on source and properties.
2. Determine the rate of gasification for different biomass.
3. Design gasifiers and apply gas cleaning technologies for industries.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Research Skill
4. Use of Modern Tools

TEXT BOOKS:

1. Prabir Basu, **Biomass Gasification and Pyrolysis**, Elsevier Publishing, 2010.

REFERENCE BOOKS:

1. Christoper Higman and Maarenvander Burgt, **Gasification**, Elsevier Publishing, 2003.
2. John Rezaiyan and Nicholas P. Cheremisinoff, **Gasification Technologies - A Primer for Engineers and Scientists,** Taylor and Francis, 2005

ELECTIVE-II
FOOD PROCESSING AND ENGINEERING
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 2

Subject Code	:	16HCE254	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will
1. Learn various methods of food processing.
2. Learn energy related to food, modification of food, packaging, storing and modern technologies.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
INTRODUCTION: General aspects of food industry, world food demand and Indian scenario, constituents of food, quality and nutritive aspects. Food additives, standards, deteriorative factors and their control, preliminary processing methods, conversion and preservation operation. **ENERGY ENGINEERING IN FOOD PROCESSING:** Generation of Steam, Fuel Utilization, Electric Power Utilization, Process Controls in Food Processing, Systems for Heating and Cooling Food Products. Thermal Properties of Foods , Modes of Heat Transfer - Freezing Systems , Frozen-Food Properties, Freezing Time refrigeration system for food products.	8	L1, L2, L5
Module 2		
SEPARATION PROCESSES IN FOOD PROCESSING: Electro-dialysis Systems, Reverse Osmosis Membrane Systems, Membrane Performance, Ultra filtration Membrane Systems, Concentration Polarization. Types of Reverse-Osmosis and Ultra filtration Systems, Drying Processes, Dehydration System, Dehydration System Design, Sedimentation, Centrifugation.	8	L1, L2, L3
Module 3		
FOOD ADDITIVES: Introduction and need for food additives. Types of additives – antioxidants, chelating agents, coloring agents, curing agents, emulsions, flavors and flavor enhancers, flavor improvers, humectants and anti-choking agents, leavening agents, nutrient supplements, nonnutritive sweeteners, pH control agents. Preservatives– types and applications. Stabilizers and thickeners, other additives. Additives and food safety.	8	L2, L3, L4

Module 4		
FOOD CONTAMINATION AND ADULTERATION: Types of adulterants and contaminants. Intentional adulterants. Metallic contamination. Incidental adulterants. Nature and effects. Food laws and standards. **PACKAGING:** Introduction, Food Protection, Product Containment, Product Communication, Product Convenience, Mass Transfer in Packaging Materials. Innovations in Food Packaging, Food Packaging and Product Shelf-life, Food canning technology, fundamentals of food canning technology. Heat sterilization of canned food, containers - metal, glass and flexible packaging. Canning procedures for fruits, vegetables, meats, poultry marine products.	8	L2, L3, L6
Module 5		
MODERN TRENDS IN FOOD SCIENCE: Biotechnology in food. Bio-fortification, Nutraceuticals. Organic foods. Low cost nutrient supplements. Packaging of foods and nutrition labeling. Careers in food science and food industries.	8	L3, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Deal with unit operations in food processing, separation and mixing.
2. Modify older technologies for storing, packing and avoiding adulteration.
3. Purify food items with modern separation technologies.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life-long learning
5. Collaborative and multidisciplinary work

TEXT BOOKS:

1. B. Srilakshmi, **Food Science -** 4th Edn-New Age International-2007.
2. N. Shakuntala Manay and M. Shadaksharamurthy, **Foods: Facts and Principles -** New Age Publishers - 2005.

REFERENCE BOOKS:

1. Rick Parker - Thomsan Detmer, **Introduction to Food Science** -2001.
2. G. Subbulakshmi and Shobha A. Udupi, **Food Processing and Preservation,** New Age International-2001.
3. Norman N. Potter and Joseph H. HotchkinAvi, **Food Science,** Publishing Co-1968.
4. John M DeMan, **Principles of Food Chemistry,** 3rd Edition - Springer-1999.
5. Heid, J.L. and Joslyn, M.A, **Fundamentals of Food Processing Operation**. The AVI Publishing Co; Westport, 1967.
6. Heldman, D.R. **Food Process Engineering**, The AVI Publishing Co; Westport, 1975.

LAB COMPONENT
CHEMICAL REACTION ENGINEERING LAB
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 2

Subject Code	:	16HCE26	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	02			

Course Objectives:
Students will
1. Experimentally verify the reactions in different reactors and determine rate constants studied in theory.
2. Carry out experiment and make observations for various conditions.
3. Study the effect of various parameters involved in reactions.
4. Evaluate the kinetic data.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

At least five of the following experiments are to be carried out; the data are to be analyzed based on the theoretical aspects, and recorded with comments.	Blooms Level
1. Packed bed catalytic reactor	L2, L3, L4
2. Effect of temperature on rate of reaction	L2, L3, L4
3. Enzyme catalyzed reaction in a Batch reactor	L2, L3, L4
4. Fluidized bed reactor	L2, L3, L4
5. Absorption with reaction	L3, L4, L5
6. Integral & differential analysis	L4, L5
7. Study of rusting of iron or burning of coal.	L1, L2, L3,L4

Course outcomes:
After studying this course, students will be able to:
1. Apply theoretical knowledge of various reactors.
2. Acquire practical knowledge of reaction parameters.
3. Determine the conversion and obtain yield for various reactions.

Conduct of Practical Examination:
1. All laboratory experiments are to be included for practical examination.
2. Students are allowed to pick one experiment from the lot.
3. Strictly follow the instructions as printed on the cover page of answer script for breakup of marks.
4. Change of experiment is allowed only once and 15% Marks allotted to the procedure part to be made zero.

Graduate Attributes
1. Critical Thinking
2. Usages of Modern Tools
3. Collaborative and Multidisciplinary Work
4. Life Long Learning
5. Independent and Reflective Learning

TEXT BOOKS:
1. Smith J.M, **Chemical Engineering Kinetics,** 3rd Edition, McGraw- Hill, 1984.

REFERENCE BOOKS:
1. Octave Levenspiel, **Chemical Reaction Engineering** 3rd Edition, John Wiley and sons.

SEMINAR-II

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 2

Subject Code	:	16HCE27	**IA Marks**	:	100
No. of Lecture Hrs/Week	:	03			
Credits	:	01			

Course Objectives:

Students will

1. Develop skills in searching technical literature, analyzing and evaluating it to compare the various approaches and prepare a written report and also presenting it orally.

The student has to prepare, submit a seminar report and make a presentation on Seminar topic allotted. The seminar shall be evaluated as internal assessment by a committee constituted by the HOD.

Course outcomes:

After studying this course, students will be able to:

1. Prepare reports and compile data.
2. Prepare presentation and communicate findings to audience.

Graduate Attributes

1. Critical Thinking
2. Usages of Modern Tools
3. Collaborative and Multidisciplinary Work
4. Life Long Learning

SEMINAR/ PRESENTATION ON INTERNSHIP
(After 8 weeks from the date of commencement)
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 3

Subject Code	:	16HCE31	**IA Marks**	:	25
Credits (16HCE31+16HCE32+16HCE33)	:	20			

Course Objectives:
Students will

1. Know the importance of training.
2. Learn to make presentation.
3. Learn to prepare reports.

The students are required to make a report and make presentation on internship after 8 weeks of their training. A committee to be constituted by HOD to evaluate for 25 marks as Internal Assessment.

Course outcomes:

After studying this course, students will be able to:

1. Classify the industries based on production.
2. Describe the various processes run at industry.
3. Prepare reports and compile data.
4. Prepare presentation and communicate findings to audience.

Graduate Attributes:

1. Understanding processes.
2. Presentation skills.
3. Technical report writing.

REPORT ON INTERNSHIP:
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 3

Subject Code	:	16HCE32	**IA Marks**	:	25
Credits (16HCE31+16HCE32+16HCE33)	:	20			

Course Objectives:

Students will

1. Learn to compile data.
2. Learn to prepare report.

After successful completion of internship, student has to submit a detailed report on the same. Internal guide in consultation with guide of the industry should evaluate for IA marks.

Course outcomes:

After studying this course, students will be able to:

1. Compile data and Prepare reports.

Graduate Attributes:

1. Technical report writing.

EVALUATION AND VIVA VOCE OF INTERNSHIP:
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 3

Subject Code	:	16HCE33	**Exam Marks**	:	50
Credits (16HCE31+16HCE32+16HCE33)	:	20			

Course Objectives:

Students will

1. Learn to make presentation.
2. Learn to prepare reports.

An external examiner has to be called for viva voce and internal guide together with external examiner should evaluate the performance as examination.

Course outcomes:

After studying this course, students will be able to:

1. Prepare presentation and communicate findings to audience.
2. Defend the queries.

Graduate Attributes:

1. Presentation skills.
2. Technical report writing.

PROJECT PHASE-I

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 3

Subject Code	:	16HCE34	**IA Marks**	:	50
Credits	:	01			

Course Objectives:

Students will

1. Learn to collect relevant literature from various journals and published material.
2. Learn various principles used in analyzing of various parameters of study.

Student has to complete literature survey and methodology of the work and submit a report at the end of III Semester which should be evaluated as IA Marks by the departmental committee.

Course outcomes:

After studying this course, students will be able to:

1. Develop skills in searching technical literature, analyzing and evaluating it to compare the various approaches.

Graduate Attributes:

1. Research Skill.
2. Use of Modern Skills.
3. Project Management and Finance.
4. Independent and reflective thinking.

CHEMICAL PROCESS OPTIMIZATION

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 4

Subject Code	:	16HCE41	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:

Students will

1. Understand the concepts and origin of the different optimization methods.
2. Get a broad picture of the various applications of optimization methods used in Chemical Engineering.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
INTRODUCTION: Introduction to optimization, Functions of single and multiple variables-optimality criteria, direct and indirect search methods. Formulation of problems and basic Concepts.	10	L1, L2, L3
Module 2		
OPTIMAL CONTROL PROBLEMS: Euler-Lagrange optimality criteria, Pontryagin's maximum principle, optimal control problems. Numerical methods. **Introduction:** Introduction to optimization, Functions of single and multiple variables - optimality criteria, direct and indirect search methods. Formulation of problems and basic concepts.	10	L2, L3, L4
Module 3		
LINEARIZATION: Fundamental theorem of linear programming, Degenerate solutions, Simplex methods, Cycling, Duality, Complementary slackness conditions. Transformation methods based on linearization. Quadratic and Geometric Programming: problems.	10	L3, L4, L5
Module 4		
OPTIMAL CONTROL PROBLEMS: Introduction to Artificial Intelligence in optimization. Introduction to Genetic algorithm (qualitative treatment only).	10	L3, L4, L5
Module 5		
OPTIMIZATION IN CHEMICAL ENGINEERING: Importance of Engineering economics, various optimization soft wares (qualitative treatment only), use of optimization techniques for process design and integration (take some typical examples)	10	L2, L3, L6

Course outcomes:

After studying this course, students will be able to:

1. Implement the theory and applications of optimization techniques in a comprehensive manner for solving linear and non-linear, geometric, dynamic, integer and stochastic programming techniques.
2. Optimize the different methods in industry for design and production of products, both economically and efficiently.
3. Take optimal decisions in the presence of trade-offs between two or more conflicting objectives.
4. Identify, formulate and solve a practical engineering problem of their interest by applying or modifying an optimization technique.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Life - long Learning

TEXT BOOKS:

1. T.F. Edgar and D.M. Himmelblau," **Optimization Techniques for Chemical Engineers"**, McGraw-Hill, New York, 1985.

REFERENCE BOOKS:

1. K. Deo, "**Optimization Techniques**", Wiley Eastern, 1995.
2. Linn off B, **A User Guide on Process Integration for Efficient Use of Energy,** UMIST.
3. Robin Smith, **Chemical Process Design & Integration**, Wiley, 2005.

ELECTIVE-III
FERMENTATION ENGINEERING
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 4

Subject Code	:	16HCE421	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will
1. Study basics of fermentation processes, microbial kinetics and different strategies for isolation and preservation of industrially important microorganisms.
2. Study all concepts and construction related to Bioreactor.
3. Learn about various types of fermentation products.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
OVERVIEW: Fermentation industry growth prospects, general requirements of fermentation processes, basic configurations of fermenter and accessories, parameters to be monitored and controlled in fermentation processes. **MICROBIAL KINETICS**: Types of reaction, order of reaction, Michealis-Menten constant, effect of temperature on reaction rate, activated complexes, catalyzed reactions, thermal death of microorganisms, enzyme inhibition.	8	L1, L2, L3
Module 2		
FERMENTATION ENGINEERING: Continuous fermentation, advantages and limitations, theory of single and two stage continuous fermentation systems application. Media formulation and preparations-complex and synthetic media, Selection of components, buffers, pH adjustment. **STERILIZATION:** Media and air-Batch and Continuous In-situ sterilization in fermenter.	8	L2, L3
Module 3		
PRODUCT ISOLATION: Selection and improvement of cultures – screening methods, culture preservation, strain improvement. Aseptic culture transfer and incubation, inoculums age/size, studies on growth kinetics in batch, continuous and fed batch cultures. Details of Industrial manufacture of important biotechnological products.	8	L3, L4, L5

Module 4		
BIO REACTOR CONFIGURATION: Ideal bioreactors, various configurations, Mechanical construction, various parts and accessories, Mass and Heat transfer: Agitation and aeration, Modes of reactor operations.	8	L4, L5, L6
Module 5		
FERMENTATION PRODUCTS: Details of the process parameters and materials for the industrial manufacture of Antibiotics, solvents, amino acids, organic acids and biopharmaceuticals.	8	L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Design and operate fermentation process.
2. Isolate fermentation products.
3. Design bioreactor and categorize various fermentation products.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Research Skill
5. Life-long learning

TEXT BOOKS:

1. Stanbury, Whitaker & Hall – **Principles of Fermentation Technology** (1997)
2. Shuler and Kargi **- Bioprocess Engineering**, Prentice Hall of India Pvt. Ltd.(2002)
3. Bailey J.E. and Ollis, D.F. **Biochemical Engineering Fundamentals**, McGraw Hill, (1986).

REFERENCE BOOKS:

1. Pauline M Doran - **Bioprocess Engineering Principles** –, Academic Press, 1995.
2. James M.Lee - **Biochemical Engineering** by, Prentice Hall 1992

ELECTIVE-III
TOTAL QUALITY MANAGEMENT
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 4

Subject Code	:	16HCE422	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will
1. Study the concepts of TQM, process and its implementation for various cases.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
CONCEPTS OF TQM : Basics of total quality, Guru's of TQM, Philosophy of TQM, customer focus, organization, quality philosophies of Deming.	8	L1,L2
Module 2		
TQM PROCESS: Quality control tools, cost of quality, quality circles, bench marking, strategic quality planning.	8	L2,L3
Module 3		
TQM SYSTEMS: Quality policy deployment, quality function deployment, standardization, designing for quality, manufacturing for quality.	8	L3,L4
Module 4		
QUALITY SYSTEM: Need for ISO 9000 system, advantages, clauses of ISO 9000, Implementation of ISO 9000, quality auditing, case studies, introduction to other ISO systems.	8	L3,L4, L5
Module 5		
IMPLEMENTATION OF TQM: KAIZEN, 5s, JIT, POKAYOKE, Taguchi methods, case studies.	8	L4,L5 L6

Course outcomes:
After studying this course, students will be able to:
1. Explain about TQM and highlight the importance of ISO certifications.
2. Can render services for ISO Certification.
3. Implement various TQM methods for various cases.

Question Paper Pattern:
This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Research Skill
5. Life-long learning

TEXT BOOKS:

1. Dale H. Besterfield, **Total Quality Management,** PHI, India.
2. Sharma D.D, **TQM Principles, Practice and Cases**, Chand and Sons, New Delhi.

REFERENCE BOOKS:

1. Rose, J.E, **Total Quality Management,** Kogan Page Ltd. 1993.
2. John Bank., **The Essence of Total Quality Management**, PHI,

ELECTIVE-III
BIOINSTRUMENTATION AND BIOSENSORS
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 4

Subject Code	:	16HCE423	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	04	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	04			

Course Objectives:
Students will
1. Acquaint with basics of analytical chemistry and spectroscopic methods.
2. Learn about use of various equipments/ instruments used for analysis of compounds.
3. Learn about need and types of biosensor.
4. Applications of biosensors in industrial online monitoring.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
BASICS OF ANALYTICAL CHEMISTRY: Chromatography, Electrophoresis - Colloidal solutions of biopolymers and their electrochemical properties. Different methods Hydrodynamic properties: Viscosity, diffusion etc. Molecular weight determination, Osmotic pressure, Reverse osmosis and Donnan effect.	8	L1,L2, L3
Module 2		
SPECTROSCOPIC METHODS: (UV, Vis, IR, Fluorescence, ORD, CD, & PAS), Use of radioactive and stable isotopes and their detection in biological systems. Light and Electron microscopes. Automatic analyzer, protein sequenator, peptide synthesizer and N.A. synthesizer.	8	L2,L3, L4
Module 3		
Lyophilization, Cell sorter. Centrifugation and Rotors angle / vertical, zonal /continuous flow buoyant density centrifugation. Ultra centrifuge - principle and application, GC-MS, HPLC, IC, AAS principles and application.	8	L3,L4, L5
Module 4		
INTRODUCTION TO BIOSENSORS: Biological sensing elements and transducer systems, classification of biosensors, enzyme and whole cell based biosensors, affinity biosensors, amperometric biosensors, immuno sensors.	8	L2,L3, L4
Module 5		
ELISA, plant cell based biosensors, pesticide biosensors, flow injection analysis based biosensors, stability of biosensors, signal amplification, stabilization and measurement, luminescence based biosensors	8	L3,L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Analyze the various compounds using instruments.
2. Explain the basics of sensors.
3. Classify and apply biosensors for various cases.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Research skills
3. Lifelong learning
4. Collaborative and multidisciplinary work

TEXT BOOKS:

1. Yang, V.C. and T.T Ngo, **Biosensors and Their Applications,** Kluwer Academic/ Plenum Publishers, 2000.
2. Ligler, F.S. and Rowe Taitt, C.A, **Optical Biosensors: Present & Future,** Elsevier, Netherlands, 2002.

REFERENCE BOOKS:

1. Turner A.P.F., I. Karube, &G.S.Wilsons, **Biosensors: Fundamentals and Applications,** Oxford Science Publications**,** Oxford, 1987.
2. Ashok Mulchandani and Kim R. Rogers (Eds.), **Enzyme and Microbial Biosensors.**
3. Ashok Mulchandani and Kim R. Rogers, (Eds.), **Affinity Biosensors: Techniques and Protocols,** Humana Press, Totowa, NJ, 1998.
4. Willard and Merit, **Instrumental methods of Analysis,** CSS Publishers, 1986.

ELECTIVE-III
PHARMACEUTICAL TECHNOLOGY
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER 4

Subject Code	:	16HCE424	**IA Marks**	:	20
No. of Lecture Hrs/Week	:	03	**Exam Hours**	:	03
	:		**Exam Marks**	:	80
Credits	:	03			

Course Objectives:
Students will
1. Learn formulations, tablet and capsule making.
2. Learn development, testing of cosmetics.
3. Learn manufacturing technology.
4. Learn patent intellectual property rights and regulatory affairs.

Revised Bloom's Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating

Modules	Teaching Hours	Blooms Level
Module 1		
FORMULATIONS: Introduction, organoleptic properties, purity, particle size, shape and surface area. Solubilization, surfactants and its importance, temperature, pH, co-solvency, solid dispersion, b-cyclodextrin drug-dispersion system, Techniques for the study of crystal properties and polymorphism. Formulation stability studies. A consideration of physicochemical characteristics of new drug molecules with respect to different dosage forms.	8	L1, L2, L3
Module 2		
TABLET MAKING: Compaction of powders with a particular reference to distribution and measurement of forces within the powder mass undergoing compression. Effect of particle size, moisture content, lubrication etc. On Strength of tablets. A brief study on formulation aspects of tablets such as Sublingual, buccal chewable and medicated lozenges. **CAPSULE TECHNOLOGY:** Manufacturing, equipment and machinery used in capsule technology. Formulation and evaluation of hard gelatin capsules and soft gelatin capsules.	8	L2, L3, L4
Module 3		
DEVELOPMENT AND TESTING OF COSMETICS: Cleansing creams, acid creams, bleaching creams, suntan preparations, shampoos nail lacquers, lipsticks, manufacturing equipment used in preparation. The testing measures of the above listed cosmetics preparation. Mode of packaging, storage conditions. **PARENTERAL TECHNOLOGY:** Manufacturing of LVP, SVP, Sterilization and sterility testing of Parenterals, GMP regulations of parenteral technology. Optimization techniques in pharmaceutical formulation and processing: Concept of optimization, optimization parameters, classical optimization, statistical design and optimization methods.	8	L3, L4, L5

Module 4		
MANUFACTURING TECHNIQUES: GMP Significance of pilot scale up phase to effect an orderly set up from the laboratory procedures and formulations to routine production procedures. Pilot study of some important dosage forms such as Tablets, Capsules, Injections and liquid orals and discussions on important parameters such as formula and equipment, product uniformity and stability. Raw materials and process, physical layouts personnel requirements and reporting responsibilities. Input Specifications and in process and finished product specifications.	8	L3, L4, L6
Module 5		
INDUSTRIAL SAFETY: Industrial hazards due to fire accidents, mechanical and electrical equipment, chemical and pharmaceuticals. Monitoring and prevention systems. Industrial effluent treatment. Discussion on Industrial accident case studies, Environment and pollution Acts. **PATENT INTELLECTUAL PROPERTY RIGHTS AND REGULATORY AFFAIRS:** Definitions, Procedures for applying, Indian Scenario, GATT, TRIPS, TRIMS AND WTO Legal aspects, ISO 9000 series, Total Quality Management, GMP considerations.	8	L4, L5, L6

Course outcomes:

After studying this course, students will be able to:

1. Explain various formulations and formulate tablet and capsule.
2. Develop manufacturing technologies and apply for various cases.
3. Practice industrial safety and involve in patent intellectual property rights and regulatory affairs.

Question Paper Pattern:

This question paper will have ten questions. Each full question consists of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module. Each full question will have sub questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.

Graduate Attributes

1. Critical Thinking
2. Problem solving
3. Use of modern tools
4. Research Skill
5. Life-long learning

TEXT BOOKS:

1. Liberman, and Lachman, **The Theory and Practice of Industrial Pharmacy,** 3rd Edition, Lea & Febiger, Philedelphia, 1986.
2. Jain N.K, **Pharmaceutical Product Development,** CBS Publications and Distributions, New Delhi, 2006.

REFERENCE BOOKS:

1. Sidnay H. Willing, Murray M. Tuckerman, and Williams Hitchings, **Good Manufacturing of Pharmaceuticals,** 3rd Edition, Marcell Dekker Inc., NY, 1982.

PROJECT PHASE-II

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 4

Subject Code	:	16HCE43	**IA Marks**	:	50
Credits	:	03			

Course Objectives:

Students will

1. Learn to plan and perform experiments related to project work.
2. Learn to compile data and analyze.
3. Learn to publish data in reputed journals.

Student has to complete project work and submit thesis (Corrected from guide) at the end of IV Semester which should be evaluated as IA Marks by the departmental committee.

Course outcomes:

After studying this course, students will be able to:

1. Perform experiments, obtain results, analyze the results and publish in reputed journals.
2. Complete project thesis as per the standard format by consulting the guides.

Graduate Attributes:

1. Research Skill.
2. Use of Modern Skills.
3. Project Management and Finance.
4. Independent and reflective thinking.

EVALUATION OF PROJECT AND VIVA-VOCE

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER 4

Subject Code	:	16HCE44	**IA Marks**	:	100
Credits	:	10	**Exam Marks**	:	100

Course Objectives:

Students will

1. Learn to compile data and make power point presentation.
2. Learn to prepare reports.

Student has to submit project thesis to the Head of the department through the guide. Evaluation of project report from the VTU by external examiner will be done. The student has to prepare for queries and give a presentation on project work to the External and internal examiners. An external examiner has to be called for viva voce and internal guide together with external examiner should evaluate the performance as examination.

Course outcomes:

After studying this course, students will be able to:

1. Prepare presentation and communicate findings to examiners and audience.
2. Defend the queries.

Graduate Attributes:

1. Presentation skills.
2. Technical report writing.