# VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

Scheme of Teaching, Examination and Syllabus

M.Tech Chemical Engineering (HCE)

Eligibility: Bachelor's Degree in Engineering or Technology in

a) Chemical Engineering, b) Environmental Engineering, c) Biotechnology, d) AMIE in Appropriate branch e) Petrochemical Engineering f) GATE: CH, BT, ENV ENGG, Petrochemical

**BOARD OF STUDIES IN CHEMICAL ENGINEERING**

**2018-2019**

# VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
## Scheme of Teaching and Examination – 2018-19
## M.Tech: Chemical Engineering (HCE)
## Outcome Based Education(OBE) and Choice Based Credit System (CBCS)

**I SEMESTER**

| Sl. No | Course | Course Code | CourseTitle | Teaching Hours /Week | | Examination | | | | Credits |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Practical/ Field work/ Assignment | Duration in hours | CIE Marks | SEE Marks | Total Marks | |
| 1 | PCC | 18HCE11 | Advanced Engineering Mathematics | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 2 | PCC | 18HCE12 | Advanced Process Control | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 3 | PCC | 18HCE13 | Transport Phenomena | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 4 | PCC | 18HCE14 | Chemical Equipment Design | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 5 | PCC | 18HCE15 | Waste Management Techniques | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 6 | PCC | 18HCEL16 | Process Dynamics and Control Lab | - | 04 | 03 | 40 | 60 | 100 | 2 |
| 7 | PCC | 18RMI17 | Research Methodology and IPR | 02 | -- | 03 | 40 | 60 | 100 | 2 |
| | | | **TOTAL** | **22** | **04** | **21** | **280** | **420** | **700** | **24** |

**Note: PCC: Professional Core Course**

**Internship:** All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination will be conducted during III semester and prescribed credit shall be included in the III semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as failed and have to complete during subsequent University examination after satisfy the internship requirements.

# VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
## Scheme of Teaching and Examination – 2018-19
## M.Tech: Chemical Engineering (HCE)
## Outcome Based Education(OBE) and Choice Based Credit System (CBCS)

**II SEMESTER**

| Sl. No | Course | Course Code | Course Title | Teaching Hours /Week | | Examination | | | | Credits |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Practical/ Field work/ Assignment | Duration in hours | CIE Marks | SEE Marks | Total Marks | |
| 1 | PCC | 18HCE21 | Chemical Process Optimization | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 2 | PCC | 18HCE22 | Catalytic Reaction Engineering | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 3 | PCC | 18HCE23 | Modeling and Simulation | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 4 | PEC | 18HCE24X | Professional Elective - 1 | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 5 | PEC | 18HCE25X | Professional Elective - 2 | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 6 | PCC | 18HCEL26 | Chemical Reaction Engineering Lab | -- | 04 | 03 | 40 | 60 | 100 | 2 |
| 7 | PCC | 18HCE27 | Technical Seminar | -- | 02 | -- | 100 | -- | 100 | 2 |
| **TOTAL** | | | | **20** | **06** | **18** | **340** | **360** | **700** | **24** |

**Note: PCC: Professional Core Course, PEC: Professional Elective Course**

| **Professional Elective - 1** | | **Professional Elective - 2** | |
|---|---|---|---|
| **Course Code under 18HCE23X** | **Course Title** | **Course Code under 18HCE24X** | **Course Title** |
| 18HCE241 | Enzyme Engineering | 18HCE251 | Fermentation Engineering |
| 18HCE242 | Interfacial Engineering | 18HCE252 | Total Quality Management |
| 18HCE243 | Gasification Technology | 18HCE253 | Plantwide Control of Chemical Processes |
| 18HCE244 | Food Processing and Engineering | 18HCE254 | Pharmaceutical Technology |

**Note:**

**1. Technical Seminar:** CIE marks shall be awarded by a committee comprising of HOD as Chairman, Guide/co-guide in any and a senior faculty of the department. Participation in seminar by all postgraduate students of the same and other semesters of the programme shall be mandatory.

The CIE marks awarded for Technical Seminar, shall be based on the evaluation of Seminar Report, Presentation skill and Question and Answer session in the ratio 50:25:25.

**2. Internship:** All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination will be conducted during III semester and prescribed credit shall be included in the III semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as failed and have to complete during subsequent University examination after satisfy the internship requirements.

# VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
## Scheme of Teaching and Examination – 2018-19
## M.Tech: Chemical Engineering (HCE)
## Outcome Based Education(OBE) and Choice Based Credit System (CBCS)

**III SEMESTER**

| Sl. No | Course | Course Code | Course Title | Teaching Hours /Week | | Examination | | | | Credits |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Practical/ Field work/ Assignment | Duration in hours | CIE Marks | SEE Marks | Total Marks | |
| 1 | PCC | 18HCE31 | Advanced Thermodynamics | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 2 | PEC | 18HCE32X | Professional Elective - 3 | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 3 | PEC | 18HCE33X | Professional Elective - 4 | 04 | -- | 03 | 40 | 60 | 100 | 4 |
| 4 | Proj | 18HCE34 | Evaluation of Project Work Phase -1 | -- | 02 | -- | 100 | -- | 100 | 2 |
| 5 | INT | 18HCEI35 | Internship | (Completed during the intervening vacation of I and II semesters and /or II and III semesters.) | | 03 | 40 | 60 | 100 | 6 |
| **TOTAL** | | | | **12** | **02** | **12** | **260** | **240** | **500** | **20** |

**Note: PCC: Professional Core Course, PEC: Professional Elective Course**

| Professional Elective - 3 | | Professional Elective - 4 | |
|---|---|---|---|
| **Course Codee under 18HCE32X** | **Course Title** | **Course Code under 18HCE33X** | **Course Title** |
| 18HCE321 | Risk Analysis and Management | 18HCE331 | Air Pollution Control and Design of Equipment |
| 18HCE322 | Bioinstrumentation and Biosensors | 18HCE332 | Computational Fluid Dynamics |
| 18HCE323 | Solvent Extraction | 18HCE333 | Modern Separation Techniques |
| 18HCE324 | Advanced Oxidation Processes and Technology | 18HCE334 | Fuel Cell Technology |

**Note:**

**1. Project Phase-1:** Students in consultation with the guide/co-guide if any, shall pursue literature survey and complete the preliminary requirements of selected Project work. Each student shall prepare relevant introductory project document, and present a seminar.
CIE marks shall be awarded by a committee comprising of HOD as Chairman, Guide and a Senior Faculty Member of the department. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill and Question and Answer session in the ratio 50:25:25. SEE (University examination) shall be as per the University norms.

**2. Internship:** Those, who have not pursued /completed the internship, shall be declared as failed and have to complete during subsequent University examinations after satisfy the internship requirements. Internship SEE (University examination) shall be as per the University norms.

**VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI**
**Scheme of Teaching and Examination – 2018-19**
**M.Tech: Chemical Engineering (HCE)**
**Outcome Based Education(OBE) and Choice Based Credit System (CBCS)**

**IV SEMESTER**

| Sl. No | Course | Course Code | Course Title | Teaching Hours /Week | | Examination | | | | Credits |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Practical/ Field work/ Assignment | Duration in hours | CIE Marks | SEE Marks Viva voce | Total Marks | |
| 1 | Proj | 18HCE41 | Project Work Phase -2 | -- | 04 | 03 | 40 | 60 | 100 | 20 |
| | | | **TOTAL** | -- | **04** | **03** | **40** | **60** | **100** | **20** |

**Note: Proj: Project.**

**Note:**

**1. Project WorkPhase-2:**

CIE marks shall be awarded by a committee comprising of HOD as Chairman, Guide/co-guide, if any and a Senior Faculty Member of the department. The CIE marks awarded for project work phase -2, shall be based on the evaluation of Project Report subjected to plagiarism check, Project Presentation skill and Question and Answer session in the ratio 50:25:25.

SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

## I SEMESTER

<table>
<tr><th colspan="6">ADVANCED ENGINEERING MATHEMATICS</th></tr>
<tr><td>Subject Code</td><td>:</td><td>18HCE11</td><td>CIE MARKS</td><td>:</td><td>40</td></tr>
<tr><td>No. of Lecture Hrs/Week</td><td>:</td><td>04</td><td>SEE MARKS</td><td>:</td><td>60</td></tr>
<tr><td>Total No. of Lecture Hours</td><td>:</td><td>50</td><td>Exam Marks</td><td>:</td><td>100</td></tr>
<tr><td>Credits</td><td>:</td><td colspan="4">04</td></tr>
<tr><td colspan="6">Course Objectives:<br>Students will<br>1. To learn principles of advanced engineering mathematics through linear algebra and calculus of variations.<br>2. To understand probability theory and random process that serve as an essential tool for applications of electronics and communication engineering sciences.</td></tr>
<tr><td colspan="6">Revised Bloom’s Taxonomy Levels: L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analyzing, L5 – Evaluating, and L6 - Creating</td></tr>
<tr><td colspan="4">Modules</td><td>Teaching Hours</td><td>Blooms Level</td></tr>
<tr><td colspan="4">Module 1</td><td></td><td></td></tr>
<tr><td colspan="4">Linear Algebra-I: Introduction to vector spaces and sub-spaces, definitions, illustrative example. Linearly independent and dependent vectors- Basis-definition and problems. Linear transformationsdefinitions. Matrix form of linear transformations-Illustrative examples. (Text Book: 1)</td><td>10</td><td>L1, L2, L5</td></tr>
<tr><td colspan="4">Module 2</td><td></td><td></td></tr>
<tr><td colspan="4">Linear Algebra-II: Computation of eigen values and eigen vectors of real symmetric matrices-Given’s method. Orthogonal vectors and orthogonal bases. Gram-Schmidt orthogonalization process. (Text Book: 1)</td><td>10</td><td>L1, L3, L4</td></tr>
<tr><td colspan="4">Module 3</td><td></td><td></td></tr>
<tr><td colspan="4">Calculus of Variations: Concept of functional-Eulers equation. Functional dependent on first and higher order derivatives, Functional on several dependent variables. Isoperimetric problems-variation problems with moving boundaries. (Text Book: 2)</td><td>10</td><td>L1, L3, L5</td></tr>
<tr><td colspan="4">Module 4</td><td></td><td></td></tr>
<tr><td colspan="4">Probability Theory: Review of basic probability theory. Definitions of random variables and probability distributions, probability mass and density functions, expectation, moments, central moments, characteristic functions, probability generating and moment generating functions-illustrations. Poisson, Gaussian and Erlang distributionsexamples. (Text Book: 3)</td><td>10</td><td>L1, L3, L5</td></tr>
<tr><td colspan="4">Module 5</td><td></td><td></td></tr>
<tr><td colspan="4">Engineering Applications on Random processes: Classification. Stationary, WSS and ergodic random process. Auto-correlation functionproperties, Gaussian random process. (Text Book: 3)</td><td>10</td><td>L4, L5, L6</td></tr>
<tr><td colspan="6">Course outcomes:<br>After studying this course, students will be able to:<br>1. Understand vector spaces, basis, linear transformations and the process of obtaining matrix of linear transformations arising in magnification and rotation of images.<br>2. Apply the technique of singular value decomposition for data compression, least</td></tr>
</table>

square approximation in solving inconsistent linear systems.
3. Utilize the concepts of functional and their variations in the applications of communication systems, decision theory, synthesis and optimization of digital circuits.
4. Learn the idea of random variables (discrete/continuous) and probability distributions in analyzing the probability models arising in control systems and system communications.
5. Analyze random process through parameter-dependent variables in various random processes.

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.
The question paper will have ten full questions carrying equal marks.
Each full Question consisting of 20 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. David C.Lay, Steven R.Lay and J.J.McDonald: **"Linear Algebra and its Applications",** 5th Edition, Pearson Education Ltd., 2015.
2. Elsgolts, L.: "**Differential Equations and Calculus of Variations**", MIR Publications 3rd Edition, 1977.
3. T.Veerarajan: "**Probability, Statistics and Random Process'',** 3rd Edition, Tata McGraw Hill Co., 2016.

**REFERENCE BOOKS:**

1. 1. Gilbert Strang: "**Introduction to Linear Algebra"**, 5th Edition, Wellesley-Cambridge Press., 2016.
2. Richard Bronson: **"Schaum's Outlines of Theory and Problems of Matrix Operations",** McGraw-Hill, 1988.
3. Scott L. Miller, Donald G.Childers: **"Probability and Random Process with application to Signal Processing",** Elsevier Academic Press, 2nd Edition, 2013.
4. E. Kreyszig, "**Advanced Engineering Mathematics**", 10th edition, Wiley, 2015.

**Web links:**

1.http://nptel.ac.in/courses.php/disciplineId=111
2.http://www.class-central.com/subject/math(MOOCs)
3. http://ocw.mit.edu/courses/mathematics/
4. www.wolfram.com

| ADVANCED PROCESS CONTROL | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE12 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

Course Objectives:
Students will
1. Understand the concepts and origin of the different control systems.
2. Understand various types of controllers.

**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** | | |
| **ADVANCED CONTROL STRATEGIES**<br>Feed forward, cascade, dead time compensation, split range, selective and override control; automatic tuning and gain scheduling. | 10 | L1, L2, L3 |
| **Module 2** | | |
| **INTERNAL MODEL CONTROL**<br>Model based control – IMC structure – development and design; IMC based PID control, MPC. | 10 | L2, L3, L4 |
| **Module 3** | | |
| **MULTIVARIABLE CONTROL**<br>Control loop interaction – general pairing problem, relative gain array and application, sensitivity. Multivariable control – zeros and performance limitations, directional sensitivity and operability, decoupling. | 10 | L3, L4, L5 |
| **Module 4** | | |
| **DISCRETE SYSTEMS**<br>Z – Transform and inverse Z – transform properties, Discrete – Time Response of dynamic system, Pulse Transfer Function, Closed Loop System Stability. | 10 | L3, L4, L5 |
| **Module 5** | | |
| **DIGITAL FEEDBACK CONTROLLERS**<br>Design of digital feedback controllers, digital approximation of classical, effect of sampling, Case study of Industrial Instrumentation and Control system, DCS, PLC, shutdown system. | 10 | L2, L3, L6 |

**Course outcomes:**
After studying this course, students will be able to:
1. Dynamic modeling and system behaviour study
2. Design of controllers
3. Application of control systems in processes

**QUESTION PAPER PATTERN:**
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.
The question paper will have ten full questions carrying equal marks.
Each full Question consisting of 20 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. Bequette, B. W., Process Control: Modeling, Design, and Simulation, Prentice Hall, 2003
2. Stephanopolous, G., "Chemical Process Control", Prentice Hall of India, New Delhi, 1985.

**REFERENCE BOOKS:**

1. Kannan M. Moudgalya, Digital Process Control, John Wiley & Sons Ltd, 2007

| **TRANSPORT PHENOMENA** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE13 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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**:<br>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. | 12 | L1, L2, L6 |
| **Module 4** | | |
| **ENERGY TRANSPORT:**<br>**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.<br>**Radiation:** The spectrum of electromagnetic radiation, absorption and emission at solid surfaces, Planck's distribution law, Wein's displacement law and Stefan- Boltzmann law,<br>Lambart's cosine law, heat exchange by radiation between two black surface elements. | 10 | L1, L2, L4, L5 |
| **Module 5** | | |
| **MASS TRANSPORT:**<br>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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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. Suryavamshi and L. R Dongre, **Transport phenomena**, Nirali Prakashan, 4th edition.

**REFERENCE BOOKS:**

1.Welty, J.R., C.E. Wicks and R.E. Wilson, **Fundamentals of Momentum, Heat and Mass Transfer,** John Wiley and Sons, 4th Edn., John Wiley, 2000.

1. Sissom L.E. and D.R.Pitts, **Elements of Transport Phenomena**, McGraw Hill, New York, 1972.
2. Brodkey R.S. and H.C.Hershey, **Transport Phenomena, A United Approach** McGraw Hill, 1988
3. Warren L. Mccabe, Julian C. Smith, Peter Harriott, Unit **Operations of Chemical Engineering**. Mcgraw-hill, 7th Edition

| **CHEMICAL EQUIPMENT DESIGN** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE14 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

Course Objectives:
Students will

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

**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:<br>1. Double pipe Heat Exchanger.<br>2. Shell and Tube Exchanger.<br>3. Horizontal and Vertical Condensers<br>4. Evaporator Single Effect<br>5. Bubble Cap Distillation Column<br>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 equipment relating to heat and mass transfer.
2. Will be exposed to process integration approach before carrying out design of any

process Equipment.

**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 Engineer's 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,** Nirali Prakashan.

**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, McGraw Hill, 2008.

| **WASTE MANAGEMENT TECHNIQUES** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE15 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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 | 10 | L2, L3, L4 |

| | | |
|---|---|---|
| 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.<br>**ANAEROBIC PROCESS:** Construction and working of UASBR, Rotating biological contactors. Algal ponds, Hyacinth and Duckweed, fish ponds. | | |
| **Module 3** | | |
| **SOLID WASTE:**<br>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:**<br>Thermal conversion techniques, Pyrolysis, Gasification, waste to energy, composting. | 10 | L2, L3, L4 |
| **Module 5** | | |
| **DISPOSAL:**<br>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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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.


| **PROCESS DYNAMICS AND CONTROL LAB** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCEL16 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04(P) | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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 analysed 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 Modeling, **Simulation and Control for Chemical Engineers**, 2nd Edition McGraw Hill, 1990.

| **RESEARCH METHODOLOGY AND IPR** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18RMI17 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 02 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 25 | **Exam Marks** | : | 100 |
| **Credits** | : | 02 | | | |

**Course objectives:**

1. To give an overview of the research methodology and explain the technique of defining a research problem
2. To explain the functions of the literature review in research.
3. To explain carrying out a literature search, its review, developing theoretical and conceptual frameworks and writing a review.
4. To explain various research designs and their characteristics.
5. To explain the details of sampling designs, measurement and scaling techniques and also different methods of data collections.
6. To explain several parametric tests of hypotheses and Chi-square test.
7. To explain the art of interpretation and the art of writing research reports.
8. To explain various forms of the intellectual property, its relevance and business impact in the changing global business environment.
9. To discuss leading International Instruments concerning Intellectual Property Rights.

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** | | |
| Research Methodology: Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India. Defining the Research | 05 | L1, L2, |

| | | |
|---|---|---|
| Problem: Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration | | |
| **Module 2** | | |
| Reviewing the literature: Place of the literature review in research, Bringing clarity and focus to your research problem, Improving research methodology, Broadening knowledge base in research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed. Research Design: Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs. | 05 | L1, L2, |
| **Module 3** | | |
| Design of Sampling: Introduction, Sample Design, Sampling and Non-sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs. Measurement and Scaling: Qualitative and Quantitative Data, Classifications of Measurement Scales, Goodness of Measurement Scales, Sources of Error in Measurement Tools, Scaling, Scale Classification Bases, Scaling Technics, Multidimensional Scaling, Deciding the Scale. Data Collection: Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method. | 05 | L1, L2 |
| **Module 4** | | |
| Testing of Hypotheses: Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Testing of Hypothesis, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure for Hypothesis Testing, Hypothesis Testing for Mean, Proportion, Variance, for Difference of Two Mean, for Difference of Two Proportions, for Difference of Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis. Chi-square Test: Test of Difference of more than Two Proportions, Test of Independence of Attributes, Test of Goodness of Fit, Cautions in Using Chi Square Tests | 05 | L1, L2, L3, L4 |
| **Module 5** | | |
| Interpretation and Report Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports. Intellectual Property: The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) | 05 | L1, L3, L4, L6 |

| | | |
|---|---|---|
| Act1999, Copyright Act,1957,The Protection of Plant Varieties and Farmers' Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992, Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organisation (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT), Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents, Other Use without Authorization of the Right Holder, Layout-Designs of Integrated Circuits, Protection of Undisclosed Information, Enforcement of Intellectual Property Rights, UNSECO. | | |

**Course outcomes:** At the end of the course the student will be able to:

1. Discuss research methodology and the technique of defining a research problem.
2. Explain the functions of the literature review in research, carrying out a literature search, developing theoretical and conceptual frameworks and writing a review.
3. Explain various research designs and their characteristics.
4. Explain the details of sampling designs, measurement and scaling techniques and also different methods of data collections
5. Explain several parametric tests of hypotheses and Chi-square test.
6. Explain the art of interpretation and the art of writing research reports
7. Discuss various forms of the intellectual property, its relevance and business impact in the changing global business environment and leading International Instruments concerning IPR

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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:**

Research Methodology: Methods and Techniques C.R. Kothari, Gaurav Garg New Age International 4th Edition, 2018.

Research Methodology a step-by-step guide for beginners. (For the topic Reviewing the literature under module 2) Ranjit Kumar SAGE Publications Ltd 3rd Edition, 201.

Study Material (For the topic Intellectual Property under module 5) Professional Programme Intellectual Property Rights, Law and Practice, The Institute of Company Secretaries of India, Statutory Body Under an Act of Parliament, September 2013

**REFERENCE BOOKS:**


1. An introduction to Research Methodology Garg B.L et al RBSA Publishers 2002.
2. An Introduction to Multivariate Statistical Analysis Anderson T.W Wiley 3 rd Edition, 2003.
3. Research Methodology Sinha, S.C, Dhiman Ess Ess Publications 2002.
4. Research Methods: the concise knowledge base Trochim Atomic Dog Publishing 2005.
5. How to Write and Publish a Scientific Paper Day R.A Cambridge University Press 1992.
6. Conducting Research Literature Reviews: From the Internet to Paper Fink A Sage Publications 2009.
7. Proposal Writing Coley S.M. Scheinberg, C.A Sage Publications 1990.
8. Intellectual Property Rights in the Global Economy Keith Eugene Maskus Institute for International Economics 2000.


(Common to all branches)

## INTERNSHIP

All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination will be conducted during III semester and prescribed credit shall be included in the III semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as failed and have to complete during subsequent University examination after satisfy the internship requirements.

## II SEMESTER

| CHEMICAL PROCESS OPTIMIZATION | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE21 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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.

| **CATALYTIC REACTION ENGINEERING** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE22 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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, | 10 | L1, L2, L3 |

| | | |
|---|---|---|
| Biocatalysts, Typical industrial catalytic processes, preparation of catalysts- laboratory techniques, Industrial methods, transition models, dual functional catalysts, zeolites, Enzymes, solid supportive materials, catalyst activation. | | |
| **Module 2** | | |
| **CATALYST CHARACTERIZATION:**<br>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):**<br>Catalytic Reactions, Rate controlling steps, Langmuir - Hinshelwood model, Riedel – Eiley Mechanism.<br>**CATALYST DEACTIVATION:**<br>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):**<br>Introduction, non-catalytic fluid-fluid reactions. Non catalytic fluid-solid reactions & models for such reactions to determine time of conversion.<br>**NON IDEAL REACTOR ANALYSIS:**<br>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 HETEROGENEOUS REACTIONS:**<br>Surface kinetics & pore diffusion effects, Evaluation of effectiveness factor,<br>**DESIGN OF REACTORS FOR HETEROGENEOUS CATALYTIC & NON CATALYTIC REACTIONS:**<br>Design of reactors for non-catalytic fluid-fluid and fluid-solid reactions**.** | 10 | L3, L4, L5, L6 |
| **Course outcomes:**<br>After studying this course, students will be able to:<br>1. Explain catalyst physical properties and catalyst characterization.<br>2. Determine kinetics of catalytic and non-catalytic chemical reaction,<br>3. Design catalytic and non-catalytic reactors<br>4. Analyze non catalytic fluid- solid reaction, non-catalytic fluid particle reactions, various models. | | |
| **QUESTION PAPER PATTERN:**<br>The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. | | |

The question paper will have ten full questions carrying equal marks.
Each full Question consisting of 20 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**, Addison 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**, Reinhold Publishing Corporation, NY, 1954
3. Thomas and Thomas, **Introduction to Heterogeneous Catalysts**, Academic Press. London, 1967.

| **MODELING AND SIMULATION** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE23 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

**Course Objectives:**

Students will

1. Understand the principles and applications of modeling and simulation.
2. Impart to the student knowledge on modeling and simulation, classification of mathematical models, steady and unsteady state lumped and distributed systems and other modeling approaches.

**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**<br>Introduction to modeling and simulation, classification of mathematical models, conservation equations and auxiliary relations. | 10 | L1,L2, L3 |
| **Module 2** | | |

| | | |
|---|---|---|
| **STEADY STATE LUMPED SYSTEMS**<br>Degree of freedom analysis, single and network of process units, systems yielding linear and non-linear algebraic equations, flow sheeting – sequential modular and equation oriented approach, tearing, partitioning and precedence ordering, solution of linear and non-linear algebraic equations. | 10 | L2,L3, L4 |
| **Module 3** | | |
| **UNSTEADY STATE LUMPED SYSTEMS**<br>Characteristics for through pipe, analysis of liquid level tank, gravity flow tank, jacketed stirred tank heater, reactors, flash and distillation column, solution of ODE initial value problems, matrix differential equations, simulation of closed loop systems. | 10 | L3,L4, L5 |
| **Module 4** | | |
| **STEADY STATE DISTRIBUTED SYSTEM**<br>Analysis of compressible flow, heat exchanger, packed columns, plug flow reactor, solution of ODE boundary value problems. | 10 | L2,L3, L4 |
| **Module 5** | | |
| **UNSTEADY STATE DISTRIBUTED SYSTEM**<br>Analysis laminar flow in pipe, sedimentation, boundary layer flow, conduction, heat exchanger, heat transfer in packed bed, diffusion, packed bed adsorption, plug flow reactor, hierarchy in model development, classification and solution of partial differential equations. | 10 | L3,L5, L6 |

**Course outcomes:**

After studying this course, students will be able to:

1. Analyze the various types of systems.
2. Classify and apply models for all systems.

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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. Ramirez, W., "Computational Methods in Process Simulation", 2nd Edn., Butterworths, New York, 2000.
2. Luyben, W.L., "Process Modeling Simulation and Control", McGraw-Hill Book Co.,1990.

**REFERENCE BOOKS:**

1. Felder, R. M. and Rousseau, R. W., “Elementary Principles of Chemical

Processes“,John Wiley, 2005.
2. Franks, R. G. E., “Mathematical Modeling in Chemical Engineering“, John Wiley, 1967.

**Professional Elective-1**

| ENZYME ENGINEERING | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE241 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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. | 10 | L1, L2 |
| **Module 2** | | |
| **KINETICS:** Chemical mechanisms of enzyme catalysed reactions, introduction to bioenergetics and kinetics, kinetics of multi-substrate bio reactions, investigations of active sites structures. | 10 | L2, L3, L4 |
| **Module 3** | | |
| **CHEMICAL NATURE OF ENZYME CATALYSIS:** Sigmoidal kinetics and allosteric enzymes, co-enzymes, significance of sigmoidal behaviour. | 10 | L2, L3 |
| **Module 4** | | |
| **APPLICATIONS:** Investigation of enzymes in biological preparation, extraction and purification, enzymes as analytical reagents | 10 | L3, L4 |
| **Module 5** | | |
| **INSTRUMENTAL TECHNIQUES:** Instrumental techniques available for using enzymatic analysis, applications in medicine, industries, and biotechnological applications | 10 | 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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.
The question paper will have ten full questions carrying equal marks.
Each full Question consisting of 20 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, McGraw Hill, 1976.
2. John R. Whitaker, Alphons G J Voragen, and DWS Wong, **Handbook of Food Enzymology,** Marcel Dekker, NewYork, 2003.

| **INTERFACIAL ENGINEERING** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE242 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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 | 10 | L1, L2, L3 |

| | | |
|---|---|---|
| materials; Properties of colloidal systems, Experimental characterization of colloidal dispersions.<br>**SURFACE AND INTERFACIAL TENSION:**<br>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. | | |
| **Module 2** | | |
| **INTRODUCTION TO INTERMOLECULAR AND SURFACE FORCES:**<br>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<br>fluid-solid interfaces in crystallization, development of ceramic materials, catalysts, electronic products and Nano-materials. | 10 | L2, L3, L4 |
| **Module 3** | | |
| **ADSORPTION AT FLUID-FLUID AND FLUID-SOLID INTERFACES:**<br>Adsorption of surfactants, Gibbs and Langmuir monolayers, Gibbs adsorption equation, Surface equation of state, Surface pressure isotherm, Langmuir-Blodgett films and their 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. | 10 | L2, L3, L5 |
| **Module 4** | | |
| **INTERFACIAL RHEOLOGY AND TRANSPORT PROCESSES:**<br>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.<br>**EMULSIONS:**<br>Preparation, characterization and applications, Ostwald ripening, Flocculation and coalescence, Micro-emulsions, characterization and properties, Stability of micro emulsions, Foams, preparation, characterization and stability, Structure of foams. | 10 | L3, L4, L5 |
| **Module 5** | | |
| **INTERFACIAL REACTIONS:**<br>Reactions at fluid-solid interfaces, Langmuir-Hinshelwood | 10 | L4, L5, L6 |

| | | |
|---|---|---|
| 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. | | |

**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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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.

| GASIFICATION TECHNOLOGY | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE243 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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. | 10 | 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. | 10 | 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. | 10 | 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. | 10 | 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. | 10 | 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:**
The SEE question paper will be set for 100 marks and the marks scored will be

proportionately reduced to 60.
The question paper will have ten full questions carrying equal marks.
Each full Question consisting of 20 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

| **FOOD PROCESSING AND ENGINEERING** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE244 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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:**<br>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.<br>**ENERGY ENGINEERING IN FOOD PROCESSING:** | 10 | L1, L2, L5 |

| | | |
|---|---|---|
| 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. | | |
| **Module 2** | | |
| **SEPARATION PROCESSES IN FOOD PROCESSING:** Electrodialysis Systems, Reverse Osmosis Membrane Systems, Membrane Performance, Ultrafiltration Membrane Systems, Concentration Polarization. Types of Reverse-Osmosis and Ultrafiltration Systems, Drying Processes, Dehydration System, Dehydration System Design, Sedimentation, Centrifugation. | 10 | 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. | 10 | 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.<br>**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. | 10 | 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 labelling. Careers in food science and food industries. | 10 | L3, L5, L6 |
| **Course outcomes:**<br>After studying this course, students will be able to:<br>1. Deal with unit operations in food processing, separation and mixing.<br>2. Modify older technologies for storing, packing and avoiding adulteration.<br>3. Purify food items with modern separation technologies. | | |
| **QUESTION PAPER PATTERN:**<br>The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60. | | |

| |
|---|
| The question paper will have ten full questions carrying equal marks.<br>Each full Question consisting of 20 marks<br>There will be 2 full questions (with a maximum of four sub questions) from each module.<br>Each full question will have sub questions covering all the topics under a module.<br>The students will have to answer 5 full questions, selecting one full question from each module. |
| **Graduate Attributes**<br>1. Critical Thinking<br>2. Problem solving<br>3. Use of modern tools<br>4. Life-long learning<br>5. Collaborative and multidisciplinary work |
| **TEXT BOOKS:**<br>1. B. Srilakshmi, **Food Science -** 4th Edn-New Age International-2007.<br>2. N. Shakuntala Manay and M. Shadaksharamurthy, **Foods: Facts and Principles -** New Age Publishers - 2005. |
| **REFERENCE BOOKS:**<br>1. Rick Parker - Thomsan Detmer, **Introduction to Food Science -**2001.<br>2. G. Subbulakshmi and Shobha A. Udupi, **Food Processing and Preservation,** New Age International-2001.<br>3. Norman N. Potter and Joseph H. HotchkinAvi, **Food Science,** Publishing Co-1968.<br>4. John M DeMan, **Principles of Food Chemistry,** 3rd Edition - Springer-1999.<br>5. Heid, J.L. and Joslyn, M.A, **Fundamentals of Food Processing Operation**. The AVI Publishing Co; Westport, 1967.<br>6. Heldman, D.R. **Food Process Engineering**, The AVI Publishing Co; Westport, 1975. |

**Professional Elective -2**

| **FERMENTATION ENGINEERING** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE251 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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**:<br>Fermentation industry growth prospects, general requirements of | 10 | L1, L2, L3 |

| | | |
|---|---|---|
| fermentation processes, basic configurations of fermenter and accessories, parameters to be monitored and controlled in fermentation processes.<br>**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. | | |
| **Module 2** | | |
| **FERMENTATION ENGINEERING**:<br>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.<br>**STERILIZATION:** Media and air-Batch and Continuous In-situ sterilization in fermenter. | 10 | L2, L3 |
| **Module 3** | | |
| **PRODUCT ISOLATION:**<br>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. | 10 | L3, L4, L5 |
| **Module 4** | | |
| **BIO REACTOR CONFIGURATION**:<br>Ideal bioreactors, various configurations, Mechanical construction, various parts and accessories, Mass and Heat transfer: Agitation and aeration, Modes of reactor operations. | 10 | L4, L5, L6 |
| **Module 5** | | |
| **FERMENTATION PRODUCTS**:<br>Details of the process parameters and materials for the industrial manufacture of Antibiotics, solvents, amino acids, organic acids and biopharmaceuticals. | 10 | L4, L5, L6 |
| **Course outcomes:**<br>After studying this course, students will be able to:<br>1. Design and operate fermentation process.<br>2. Isolate fermentation products.<br>3. Design bioreactor and categorize various fermentation products. | | |
| **QUESTION PAPER PATTERN:**<br>The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.<br>The question paper will have ten full questions carrying equal marks.<br>Each full Question consisting of 20 marks<br>There will be 2 full questions (with a maximum of four sub questions) from each module.<br>Each full question will have sub questions covering all the topics under a module.<br>The students will have to answer 5 full questions, selecting one full question from each module. | | |
| **Graduate Attributes**<br>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

| **TOTAL QUALITY MANAGEMENT** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE252 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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. | 10 | L1,L2 |
| **Module 2** | | |
| **TQM PROCESS:** Quality control tools, cost of quality, quality circles, bench marking, strategic quality planning. | 10 | L2,L3 |
| **Module 3** | | |
| **TQM SYSTEMS:** Quality policy deployment, quality function deployment, standardization, designing for quality, manufacturing for quality. | 10 | 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. | 10 | L3,L4, L5 |
| **Module 5** | | |
| **IMPLEMENTATION OF TQM**: KAIZEN, 5s, JIT, POKAYOKE, Taguchi methods, case studies. | 10 | 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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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,

| **PLANTWIDE CONTROL OF CHEMICAL PROCESSES** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE253 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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:** | 10 | L2, L3, L5 |

| | | |
|---|---|---|
| Concept and Criterion, Routh test, Root locus, frequency response analysis. Bode diagrams, Phase margin and gain margin. | | |
| **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 INPUT AND OUTPUT:** 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 equipment.

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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. 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 Modeling, **Simulation and Control for Chemical Engineers**, 2nd Edition McGraw Hill, 1990.

| **PHARMACEUTICAL TECHNOLOGY** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE254 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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. | 10 | 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. | 10 | 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 | 10 | L3, L4, L5 |

| | | |
|---|---|---|
| above listed cosmetics preparation. Mode of packaging, storage conditions.<br>**PARENTERAL TECHNOLOGY:**<br>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. | | |
| **Module 4** | | |
| **MANUFACTURING TECHNIQUES:**<br>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. | 10 | L3, L4, L6 |
| **Module 5** | | |
| **INDUSTRIAL SAFETY:**<br>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.<br>**PATENT INTELLECTUAL PROPERTY RIGHTS AND REGULATORY AFFAIRS:**<br>Definitions, Procedures for applying, Indian Scenario, GATT, TRIPS, TRIMS AND WTO Legal aspects, ISO 9000 series, Total Quality Management, GMP considerations. | 10 | L4, L5, L6 |
| **Course outcomes:**<br>After studying this course, students will be able to:<br>1. Explain various formulations and formulate tablet and capsule.<br>2. Develop manufacturing technologies and apply for various cases.<br>3. Practice industrial safety and involve in patent intellectual property rights and regulatory affairs. | | |
| **QUESTION PAPER PATTERN:**<br>The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.<br>The question paper will have ten full questions carrying equal marks.<br>Each full Question consisting of 20 marks<br>There will be 2 full questions (with a maximum of four sub questions) from each module.<br>Each full question will have sub questions covering all the topics under a module.<br>The students will have to answer 5 full questions, selecting one full question from each module. | | |
| **Graduate Attributes**<br>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.

| **CHEMICAL REACTION ENGINEERING LAB** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCEL26 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04(P) | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 42 | **Exam Marks** | : | 100 |
| **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.<br>4. Change of experiment is allowed only once and 15% Marks allotted to the procedure part to be made zero. |
| **Graduate Attributes**<br>1. Critical Thinking<br>2. Usages of Modern Tools<br>3. Collaborative and Multidisciplinary Work<br>4. Life Long Learning<br>5. Independent and Reflective Learning |
| **TEXT BOOKS:**<br>1. Smith J.M, **Chemical Engineering Kinetics,** 3rd Edition, McGraw- Hill, 1984. |
| **REFERENCE BOOKS:**<br>1. Octave Levenspiel, **Chemical Reaction Engineering** 3rd Edition, John Wiley and sons. |

| **TECHNICAL SEMINAR** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE27 | **CIE Marks** | : | 100 |
| **No. of Lecture Hrs/Week** | : | 02(P) | | | |
| **Credits** | : | 02 | | | |
| Course Objectives:<br>Students will<br>1. Develop skills in searching technical literature, analysing and evaluating it to compare the various approaches and prepare a written report and also presenting it orally. | | | | | |
| CIE marks shall be awarded by a committee comprising of HOD as Chairman, Guide/co-guide if any and a senior faculty of the department. Participation in seminar by all postgraduate students of the same and other semesters of the programme shall be mandatory.<br>The CIE marks awarded for Technical Seminar shall be based on the evaluation of Seminar Report, Presentation skill and Question and Answer session in the ratio 50:25:25. | | | | | |
| **Course outcomes:**<br>After studying this course, students will be able to:<br>1. Prepare reports and compile data.<br>2. Prepare presentation and communicate findings to audience. | | | | | |
| **Graduate Attributes**<br>1. Critical Thinking<br>2. Usages of Modern Tools<br>3. Collaborative and Multidisciplinary Work<br>4. Life Long Learning | | | | | |

**Internship:** All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination will be conducted during III semester and prescribed credit shall be included in the III semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as failed and have to complete during subsequent University examination after satisfying the internship requirements.

## III SEMESTER

| ADVANCED THERMODYNAMICS | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE31 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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:

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

**QUESTION PAPER PATTERN:**
The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

| |
|---|
| The question paper will have ten full questions carrying equal marks.<br>Each full Question consisting of 20 marks<br>There will be 2 full questions (with a maximum of four sub questions) from each module.<br>Each full question will have sub questions covering all the topics under a module.<br>The students will have to answer 5 full questions, selecting one full question from each module. |
| **Graduate Attributes**<br>1. Critical Thinking<br>2. Problem solving |
| **TEXT BOOKS:**<br>1. Jefferson W. Tester, Michael Modell, **Thermodynamics and Its Applications,** 3rd Edition, 1997.<br>2. J.M. Smith and Van Ness H.C, **Introduction to Chemical Engineering, Thermodynamics"-** ,McGraw Hill, 5th edition, 1996. |
| **REFERENCE BOOKS:**<br>1. J.M. Smith and Van Ness H.C, **Introduction to Chemical Engineering Thermodynamics"-** ,McGraw Hill, 5th edition, 1996. |

**Professional Elective-3**

| **RISK ANALYSIS AND MANAGEMENT** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE321 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

**Course Objectives:**
Students will
1. Understand causes and types of risks.
2. Understand risk management.

**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** | | |
| **General:** Risk types, Completion, Permitting, Resource, Operating, Environmental, Manageable, Insurable, Risk Causes, Risk Analysis types and causes. | 10 | L1,L2, L3 |
| **Module 2** | | |
| **Techniques:** General, Risk adjusted discounted rate method, Certainty Equivalent Coefficient method, Quantitative Sensitivity analysis, Probability distribution, Coefficient of variation method, Simulation method, Crude Procedures, Payback period, Expected monetary value method, Refined procedures, Shackle approach, Hiller's model, Hertz model, | 10 | L2,L3, L4 |

| | | |
|---|---|---|
| Goal programming. | | |
| **Module 3** | | |
| **Risk Management:** Emergency relief Systems, Diers program, Bench scale experiments, Design of emergency relief systems, Internal emergency planning, Risk management plan, mandatory technology option analysis, Risk management alternatives, risk management tools, risk management plans, Risk index method, Dowfire and explosion method, Mond index Method. | 10 | L3,L4, L5 |
| **Module 4** | | |
| **Risk Assurance and Assessment:** Property Insurance, Transport insurance, Liability insurance, Pecunious insurance, Risk Assessment, Scope Canvey study, Rijimond pilot study, Low Probability high consequence events. Fault tree analysis, Event tree analysis, Zero Infinity dilemma. | 10 | L2,L3, L4 |
| **Module 5** | | |
| **Risk Analysis in Chemical Industries:** Handling and storage of Chemicals, Process plants, Personnel protection equipments. Environmental risk analysis, International environmental management system, Corporate management system, Environmental risk assessment, Total quality management, Paradigms and its convergence. | 10 | L3,L5, L6 |

**Course outcomes:**

After studying this course, students will be able to:

1. Analyze the various cases of risks in industries
2. Classify and apply remedial actions for risks.

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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. Srivastav, S., “Industrial Maintenance Management”, Sultan Chand & Co., 1998.
2. Rao, P. C. K., “Project Management and Control”, Sultan Chand & Co., Ltd., 1996.

**REFERENCE BOOKS:**

1. Sincero, A. P. and Sincero, G. A., “Environmental Engineering – A Design Approach”, Prentice Hall of India, 1996.
2. Pandya, C. G., “Risks in Chemical Units”, Oxford and IBH Publishers, 1992.
3. Fawcett, H. H., “Safety and Accident Prevention in Chemical Operations by John Wiley & Sons, 1982.
4. Kind, R. W., “Industrial Hazard and Safety Handbook” Butterworth, 1982.

5. Steiner, H. M., “Engineering Economic Principles”, McGraw Hill Book Co., New York, 1996.

| **BIOINSTRUMENTATION AND BIOSENSORS** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE322 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **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. | 10 | 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. | 10 | 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. | 10 | 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. | 10 | L2,L3, L4 |
| **Module 5** | | |
| ELISA, plant cell based biosensors, pesticide biosensors, flow injection analysis based biosensors, stability of biosensors, | 10 | L3,L5, L6 |

| | | |
|---|---|---|
| signal amplification, stabilization and measurement, luminescence based biosensors | | |

**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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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.


| **SOLVENT EXTRACTION** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE323 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

**Course Objectives:**

Students will

1. Acquaint with basics of Solvent extraction.
2. Learn about use of various solvents.
3. Applications of solvent extraction in industries.
4. Develop a sound knowledge on equilibrium in liquid-liquid system, HETS, NETS, HTU, NTU, dispersion and coalescence in extractors and design of extraction

| | | |
|---|---|---|
| column. | | |
| **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** | | |
| **EQUILIBRIUM IN LIQUID-LIQUID SYSTEM**<br>Binary and ternary liquid equilibria, Tie-lines, Critical solution temperature, Tie line correlations, Contour/prism diagrams, Binary / Ternary prediction methods of activity coefficient, Theory and Prediction of diffusivity in liquids, Theory of inter phase mass transport, Estimation and prediction of mass transport coefficients. | 10 | L1,L2, L3 |
| **Module 2** | | |
| **DIFFERENTIAL / STAGE-WISE EQUILIBRIUM CONTACT OPERATIONS**<br>Equilibrium stage-wise contact, Single and multiple contacts with co-current and counter current flow of phases for immiscible and partially miscible solvent phases , Calculation methods, Fractional extraction with reflux of raffinate and extract. Differential contact, HETS, NETS, HTU, NTU concepts and Estimation of these parameters, Mass transfer efficiency, Axial mixing and Residence time distribution in extractors and their estimation. | 10 | L2,L3, L4 |
| **Module 3** | | |
| **DISPERSION AND COALESCENCE IN EXTRACTORS**<br>Characteristics of dispersion involving single and multiple nozzle distributors, Drop size and formation and coalescence, Mean drop size at dispersion and their settling velocities/relative characteristic velocities. Effect of drop oscillation ,wobbling and Internal circulation, Effect of surface active agents, Prediction of drop size and characteristics velocity in spray , packed and mechanically agitated contactors as in RDC, pulsed columns, solute transfer effects on drop dynamics. | 10 | L3,L4, L5 |
| **Module 4** | | |
| **DESIGN OF LIQUID EXTRACTION COLUMNS**<br>Design of extractor height and diameter, Prediction of flow capacities in terms of flooding rates, Regime of operating envelops, hydrodynamic design variables such as hold up, characteristic velocities, pressure drop, Effect of direction of solute transfer on these variables and their prediction methods. | 10 | L2,L3, L4 |
| **Module 5** | | |
| Correction of mass transfer data, Axial mixing correction for column height, Interfacial area estimations, using slow, fast and instantaneous reactions and their application with models for mass transfer coefficients. | 10 | L3,L5, L6 |
| **Course outcomes:**<br>After studying this course, students will be able to: | | |

1. Understand extraction methods.
2. Explain the basics of extraction.

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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. Laddha, G. S. and Degaleesan, T. E., "Transport Phenomena in Liquid Extraction", Tata McGraw Hill, New Delhi, 1976.
2. Hanson, C., Baird, M. H. I. and Lo, T. C., "Hand Book of Solvent Extraction", Wiley International, New York, 1983.

**REFERENCE BOOKS:**

1. Hanson, C., "Recent Advances in Liquid Extraction", Pergamon Press, London, 1972.
2. Treybal, R. E., "Liquid Extraction", McGraw Hill, New York, 1963.

| **ADVANCED OXIDATION PROCESSES AND TECHNOLOGY** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE324 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

**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 AOP, fundamentals of AOPs for water and wastewater treatment. | 10 | L1,L2, L3 |
| **Module 2** | | |
| Photoinduced AOP, UV Photolysis $H_2O_2$, UV/O processes, Ozonation, Fenton processes, Ultrasound processes and principles of sonochemistry. | 10 | L2,L3, L4 |
| **Module 3** | | |

| | | |
|---|---|---|
| Photochemistry, photolysis, fundamentals of semiconductor photocatalysis, photochemical processes for water and wastewater treatment, photooxidation reactions, photocatalytic reactions, photo-initiated oxidations, heterogeneous and homogeneous photocatalysis and kinetic studies. | 10 | L3,L4, L5 |
| **Module 4** | | |
| Fenton processes: homo and heterogeneous process, effect of system composition and process, identification of degradation products. Photoelectrocatalysis process: photooxidation and photomineralization of organic matter in water and air: aqueous systems, substrate oxidation and mineralization, comparative studies of photo-initiated AOPs, biodegradability and toxicological studies. | 10 | L2,L3, L4 |
| **Module 5** | | |
| Application of AOPs for VOC reduction and odour treatment, case studies – textile, pharmaceutical and petroleum and petrochemical industries. | 10 | L3,L5, L6 |

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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. Simon Parsons, Advanced oxidation processes for water and wastewater treatment, IWA Publishing, 2004.
2. Thomas Oppenländer , Photochemical Purification of Water and Air: Advanced Oxidation Processes (AOPs): Principles, Reaction Mechanisms, Reactor Concepts, Wiley-VCH Publishing, 2003.

**REFERENCE BOOKS:**

1. Vincenzo Belgiorno, Vincenzo Naddeo and Luigi Rizzo, Water, wastewater and soil treatment by Advanced Oxidation Processes (AOP), Lulu Enterprises, 2011.
2. Harold J.Ratson, Odor and VOC control handbook, New York, Mcgraw-hill, 1998.

**Professional Elective-4**

| AIR POLLUTION CONTROL AND DESIGN OF EQUIPMENT | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE331 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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. | 10 | 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. | 10 | L1, L2, L4 |
| **Module 3** | | |
| **AIR POLLUTION CONTROL METHODS AND DESIGN OF EQUIPMENT:** Control methods, source correction methods, cleaning of gaseous effluents, design of stacks and industrial ventilation systems. | 10 | 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. | 10 | L1, L2, L5, L6 |
| **Module 5** | | |
| **CONTROL OF GASEOUS EMISSIONS:** Absorption by liquids, adsorption by solids, combustion. Air | 10 | L1, L2, L5 |

| | | |
|---|---|---|
| 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. | | |

**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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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. Cheremisinoff N, **Air Pollution Control,** Design Hand Book, Part I and II, Marcel Dekker, NY, 1977.

| **COMPUTATIONAL FLUID DYNAMICS** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE332 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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 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. | 10 | 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. | 10 | L1, L2, L4 |
| **Module 3** | | |
| One- and two- dimensional, steady; 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. | 10 | 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. | 10 | 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).) | 10 | 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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE333 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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. | 10 | 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 | 10 | L1, L2, L3 |

| | | |
|---|---|---|
| involving dialysis, reverse osmosis, Nanofiltration, ultrafiltration, Microfiltration and Donnan dialysis, Economics of membrane operations, Ceramic membranes. | | |
| **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. | 10 | L3, L4, L6 |
| **Module 4** | | |
| **IONIC SEPARATIONS:** Controlling factors, Applications, Types of equipment employed for electrophoresis, Dielectrophoresis, Ion exchange chromatography and electrodialysis, Commercial Processes. | 10 | 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. | 10 | L3, L4, L5 |

**Course outcomes:**

After studying this course, students will be able to:

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

**QUESTION PAPER PATTERN:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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** | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE334 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 04 | | | |

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. | 10 | L1, L2, L3 |
| **Module 2** | | |
| **FUEL CELL THERMODYNAMICS:** Heat, work potentials, prediction of reversible voltage, fuel cell efficiency. | 10 | 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. | 10 | L2, L3, L4 |
| **Module 4** | | |
| **FUEL CELL CHARACTERIZATION:** In-situ and ex-situ characterization, techniques, i-V curve, Frequency response analyses; Fuel cell. | 10 | 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 | 10 | L4, L5, L6 |

| | | |
|---|---|---|
| cells. | | |

**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:**

The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

The question paper will have ten full questions carrying equal marks.

Each full Question consisting of 20 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.

| EVALUATION OF PROJECT PHASE-1 | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE34 | **CIE MARKS** | : | 100 |
| **No. of Lecture Hrs/Week** | : | 02 (P) | | | |
| **Total No. of Lecture Hours** | : | 32 | | | |
| **Credits** | : | 02 | | | |

**Course Objectives:**

Students will

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

**1. Project Phase-1:** Students in consultation with the guide/co-guide if any shall pursue literature survey and complete the preliminary requirements of selected Project work. Each student shall prepare relevant introductory project document, and present a seminar.
CIE marks shall be awarded by a committee comprising of HOD as Chairman, Guide and a senior faculty of the department. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill and Question and Answer session in the ratio 50:25:25.
SEE (University examination) shall be as per the University norms.

**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.

| INTERNSHIP | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCEI35 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | -- | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | -- | **Exam Marks** | : | 100 |
| **Credits** | : | 06 | | | |

**Internship:** All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination will be conducted during III semester and prescribed credit shall be included in the III semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as failed and have to complete during subsequent University examination after satisfying the internship requirements. A University examination shall be conducted during III semester as per university norms.

## IV SEMESTER

| PROJECT WORK PHASE-2 | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | 18HCE41 | **CIE MARKS** | : | 40 |
| **No. of Lecture Hrs/Week** | : | 04 (P) | **SEE MARKS** | : | 60 |
| **Total No. of Lecture Hours** | : | 50 | **Exam Marks** | : | 100 |
| **Credits** | : | 20 | | | |

**Course Objectives:**

Students will

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

CIE marks shall be awarded by a committee comprising of HOD as Chairman, Guide/co-guide, if any and a Senior faculty of the department. The CIE marks awarded for project work phase-2, shall be based on the evaluation of Project Report subjected to plagiarism check, Project Presentation skill and Question and Answer session in the ratio 50:25:25.
SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

**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.