**AC: 11-05-2017**
**Item No. 4.189**

# UNIVERSITY OF MUMBAI

Revised syllabus (Rev- 2016) from Academic Year 2016 -17

# Chemical Engineering

**Second Year** with Effect from **AY 2017-18**
**Third Year** with Effect from **AY 2018-19**
**Final Year** with Effect from **AY 2019-20**
Under

## FACULTY OF TECHNOLOGY

As per **Choice Based Credit and Grading System**
With effect from the AY 2016–17

# From Coordinator's Desk

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Technology of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty of Technology, University of Mumbai, in one of its meeting unanimously resolved that, each Board of Studies shall prepare some Program Educational Objectives (PEO's) give freedom to affiliated Institutes to add few (PEO's) course objectives course outcomes to be clearly defined for each course, so that all faculty members in affiliated institutes understand the depth approach of course to be taught, which will enhance learner's learning process. It was also resolved that, maximum senior faculty from colleges experts from industry to be involved while revising the curriculum.  I am happy to state that, each Board of studies has adhered to the resolutions passed by Faculty of Technology, developed curriculum accordingly. In addition to outcome based education, **Choice Based Credit and Grading System** is also introduced to ensure quality of engineering education.

Choice Based Credit and Grading System enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. University of Mumbai has taken a lead in implementing the system through its affiliated Institutes  Faculty of Technology has devised a transparent credit assignment policy adopted ten points scale to grade learner's performance. Credit grading based system was implemented for Second Year of B.E. in Chemical Engineering from the academic year 2017-2018. This system is carried forward for Third Year of B.E. in Chemical Engineering in the academic year 2018-2019 and will be implemented for Fourth Year B.E. in the year 2019-2020 respectively.

**Dr. S. K. Ukarande**

**Co-ordinator,**

**Faculty of Technology,**

**Member - Academic Council**

**University of Mumbai, Mumbai**

## Preamble to the Revision of Syllabus in Chemical Engineering

To match the increasing pace of development in all fields including Chemical Engineering and Biotechnology along with use of softwares for process plant and process engineering, there is demand on academician to upgrade the curriculum in Education. The availability of free software such as Scilab, DW SIM expand the boundaries of learning. Hence, the Undergraduate Curriculum in Chemical Engineering must provide the necessary foundation for a Chemical Engineer to be able to specialize in any area as and when the need and opportunity arise. The Curriculum must integrate knowledge of the basic and advanced sciences with problem solving abilities and inclusion of technological development. The Curriculum must be broad enough to cover all areas from design to operation of Process plants. It should be deep enough to enable the learners to carry out research and develop products to meet rapidly changing needs and demands. The major challenge in the current scenario is to ensure quality to the stakeholders along with expansion. Accreditation is the principal means of quality assurance in higher education and reflects the fact that in achieving recognition, the institution or program of study is committed and open to external review to meet certain minimum specified standards. The major emphasis of this accreditation process is to measure the outcomes of the program that is being accredited. Program outcomes are essentially a range of skills and knowledge that a student will have at the time of graduation from the program.

With these objectives, a meeting was organized at Thadomal Shahani Engineering College Bandra on 17th November 2016 which was attended by Industries experts, heads of the departments and subject faculty of affiliating Institutes. The program objectives and outcomes were thoroughly discussed in this meeting and the core structure of the syllabus was formulated keeping in mind choice based credit and grading system curriculum to be introduced in this revised syllabus for B.E. (Chemical Engineering) for all semesters. Views from experts and UG teachers were taken into consideration and final Academic and Exam scheme was prepared with the consent of all the members involved. Subject wise meetings were held to finalize the detail syllabus in Bharati Vidyapeeth College of Engineering on 13th Jan 2017, SS Jondhale College of Engineering on 27th Jan 2017, Datta Meghe College of Engineering Airoli on 20th February 2017 and 13th April 2017 and in D. J. Sanghavi College of Engineering on 17th April 2017.

The Program Educational Objectives finalized for the undergraduate program in Chemical Engineering are:

1. To prepare the student for mathematical, scientific and engineering fundamentals
2. To motivate the student to use modern tools for solving real life problems
3. To inculcate a professional and ethical attitude, good leadership qualities and commitment to social responsibilities.
4. To prepare the student in achieving excellence in their career in Indian and Global Market.

**Dr. Kalpana S. Deshmukh,**
**Chairman, Board of Studies in Chemical Engineering (Adhoc),**
**University of Mumbai**

# General Guidelines

**Tutorials**

- The number of tutorial batches can be decided based on facilities available in the institution.
- Tutorials can be creative assignments in the form of models, charts, projects, etc.

**Term Work**

- Term work will be an evaluation of the tutorial/practical done over the entire semester.
- It is suggested that each tutorial/practical be graded immediately and an average be taken at the end.
- A minimum of eight tutorials/ten practical will form the basis for final evaluation.
- The total 25 marks for term work (except project and seminar) will be awarded as follows:

  Tutorial / Practical Journal – 20 marks

  Overall Attendance – 05

    Further, while calculating marks for attendance, the following guidelines shall be adhered to:

    75 % to 80%. – 03 marks

    81% to 90% - 04 marks

    91% onwards – 05 marks

**Theory Examination**

- In general all theory examinations will be of 3 hours duration.
- Question paper will comprise of total six questions, each of 20 Marks.
- Only four questions need to be solved.
- Question one will be compulsory and based on maximum part of the syllabus.

**Note:**

In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus as far as possible.

**Practical Examination:**

- Duration for practical examination would be the same as assigned to the respective Lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments.

# Project and Seminar Guidelines

- Project Groups: Students can form groups with minimum 2 (Two) and not more than 3 (Three)

- The load for projects may be calculated proportional to the number of groups, not exceeding two hours per week.

- The load for projects may be calculated as:
  Sem VII: ½ hr for teacher per group.
  Sem VIII: 1 hr for teacher per group.

- Each teacher should have ideally a maximum of three groups and only in exceptional cases four groups can be allotted to the faculty.

- Seminar topics will be the consensus of the project guide and the students. Each student will work on a unique topic.

- The load for seminar will be calculated as one hour per week irrespective of the number of students

- Students should spend considerable time in applying all the concepts studied, into the project. Hence, eight hours each were allotted in Project A, B and three hours for Seminar to the students.

## University of Mumbai
## Program Structure for B.E. Chemical Engineering (Revised 2016)
## T.E. Semester V (w.e.f 2018-2019)

| Course code | Course Name | Teaching Scheme (Contact Hours) | | | Credits Assigned | | | |
|---|---|---|---|---|---|---|---|---|
| | | Theory | Practical | Tutorial | Theory | Practical | Tutorial | Total |
| CHC501 | Computer programming and Numerical Methods | 4 | - | - | 4 | - | - | 4 |
| CHC502 | Mass transfer Operations-I (MTO- I) | 4 | - | - | 4 | - | - | 4 |
| CHC503 | Heat transfer Operations (HTO) | 4 | - | - | 4 | - | - | 4 |
| CHC504 | Chemical Reaction Engineering-I (CRE I) | 4 | - | - | 4 | - | - | 4 |
| CHC505 | Business Communication & Ethics | 2 | - | 2 | - | - | 2 | 2 |
| CHDE501X | Department Elective I | 4 | - | - | 4 | - | - | 4 |
| CHL501 | Computer programming and Numerical Methods lab | - | 2 | - | - | 1 | - | 1 |
| CHL502 | Chemical Engineering Lab IV (MTO-I) | - | 3 | - | - | 1.5 | - | 1.5 |
| CHL503 | Chemical Engineering Lab V (HTO) | - | 3 | - | - | 1.5 | - | 1.5 |
| CHL504 | Chemical Engineering Lab VI (CRE-I) | - | 2 | - | - | 1 | - | 1 |
| | Total | 20 | 14 | - | 20 | 5 | 2 | 27 |

| Course code | Course Name | Examination Scheme | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Theory | | | | | Term Work | Pract /Oral | Oral | Total |
| | | Internal Assessment | | | End Sem Exam | Exam Duration (in hrs) | | | | |
| | | Test 1 | Test 2 | Avg | | | | | | |
| CHC501 | Computer programming and Numerical Methods | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHC502 | Mass transfer Operations-I (MTO- I) | 20 | 20 | 20 | 80 | 3 | | - | - | 100 |
| CHC503 | Heat transfer Operations (HTO) | 20 | 20 | 20 | 80 | 3 | | - | - | 100 |
| CHC504 | Chemical Reaction Engineering-I (CRE I) | 20 | 20 | 20 | 80 | 3 | | - | - | 100 |
| CHC505 | Business Communication & Ethics | - | - | - | - | - | 50 | - | - | 50 |
| CHDE501X | Department Elective I | 20 | 20 | 20 | 80 | 3 | | - | - | 100 |
| CHL501 | Computer programming and Numerical Methods Lab | - | - | - | - | 2 | 25 | 25 | - | 50 |
| CHL502 | Chemical Engineering Lab IV (MTO-I) | - | - | - | - | 3 | 25 | 25 | - | 50 |
| CHL503 | Chemical Engineering Lab V (HTO) | - | - | - | - | 3 | 25 | 25 | - | 50 |
| CHL504 | Chemical Engineering Lab VI (CRE-I) | - | - | - | - | 2 | 25 | 25 | - | 50 |
| | Total | | | 100 | 400 | - | 150 | 100 | - | 750 |

| Department Elective I (Sem V) | | |
|---|---|---|
| Engineering Stream (Elective Code) | Advanced Sciences Stream (Elective code) | Technology Stream (Elective Code) |
| 1. Piping Engineering (CHDE5011)<br>2. Instrumentation (CHDE5014) | 1. Colloids and Interfaces (CHDE5012) | 1. Advanced Material Sciences (CHDE5013) |

**University of Mumbai**
**Program Structure for B.E. Chemical Engineering (Revised 2016)**
**T.E. Semester VI (w.e.f 2018-2019)**

| Course code | Course Name | Teaching Scheme (Contact Hours) | | | Credits Assigned | | | |
|---|---|---|---|---|---|---|---|---|
| | | Theory | Practical | Tutorial | Theory | Practical | Tutorial | Total |
| CHC601 | Environmental Engineering (EE) | 4 | - | - | 4 | - | - | 4 |
| CHC602 | Mass transfer Operations –II (MTO-II) | 4 | - | - | 4 | - | - | 4 |
| CHC603 | Transport Phenomenon | 3 | - | 1 | 3 | - | 1 | 4 |
| CHC604 | Chemical Reaction Engineering –II (CRE- II) | 4 | - | - | 4 | - | - | 4 |
| CHC605 | Plant Engineering & Industrial Safety | 3 | - | 1 | 3 | - | 1 | 4 |
| CHDE602X | Department Elective II | 4 | - | - | 4 | - | - | 4 |
| CHL601 | Chemical Engineering Lab VII (EE) | - | 3 | - | - | 1.5 | - | 1.5 |
| CHL602 | Chemical Engineering Lab VIII (MTO-II) | - | 3 | - | - | 1.5 | - | 1.5 |
| CHL603 | Chemical Engineering LabIX CRE-II) | - | 2 | - | - | 1 | - | 1 |
| | Total | 22 | 8 | 2 | 22 | 4 | 2 | 28 |

| Course code | Course Name | Examination Scheme | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Theory | | | | | Term Work | Pract /Oral | Oral | Total |
| | | Internal Assessment | | | End Sem Exam | Exam Duration (in hrs) | | | | |
| | | Test 1 | Test 2 | Avg | | | | | | |
| CHC601 | Environmental Engineering (EE) | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHC602 | Mass transfer Operations –II (MTO-II) | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHC603 | Transport Phenomenon | 20 | 20 | 20 | 80 | 3 | 25 | - | - | 125 |
| CHC604 | Chemical Reaction Engineering –II (CRE- II) | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHC605 | Plant Engineering & Industrial Safety | 20 | 20 | 20 | 80 | 3 | 25 | - | - | 125 |
| CHDE602X | Department Elective II | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHL601 | Chemical Engineering Lab VII (EE) | - | - | - | - | 3 | 25 | 25 | | 50 |
| CHL602 | Chemical Engineering Lab VIII (MTO-II) | - | - | - | - | 3 | 25 | 25 | - | 50 |
| CHL603 | Chemical Engineering Lab IX CRE-II) | - | - | - | - | 2 | 25 | 25 | - | 50 |
| | Total | | | 120 | 480 | - | 125 | 75 | -- | 800 |

| Department Elective II (Sem VI) | | |
|---|---|---|
| Engineering Stream (Elective Code) | Management Stream (Elective Code) | Technology Stream (Elective Code) |
| 1. Computational Fluid Dynamics (CHDE6021) | 1. Operation Research (CHDE6022) | 1. Biotechnology (CHDE6023) |

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHC501** | **Computer Programming & Numerical Methods** | **4** |

**Prerequisites:**

- Differential Calculus.
- Integral Calculus.
- Differential Equations.
- Linear Algebraic Equations.

**Course Objectives:**

- To familiarize students with the use of software in solving numerical problems.
- To develop analytical thinking in designing programs.
- To learn to interpret results of computer programs and debug the same.
- To learn to present results in graphical form.

**Course Outcomes:**

- The students will be able to solve linear algebraic equations.
- The students will be able to solve non-linear algebraic equations.
- The students will be able to solve differential equations.
- The students will be able to solve partial differential equations.

| Module | Contents | Contact Hours |
|---|---|---|
| **1** | • Fundamentals of Python<br>• Variables<br>• Expressions and Arithmetic<br>• Conditional Execution<br>• Functions<br>• Lists and Objects | **8** |
| **2** | • Solution of algebraic and transcendental equations.<br>• Bisection Method<br>• RegulaFalsi Method.<br>• Successive substitution.<br>• Secant Method.<br>• Newtons Method for one and two simultaneous equations<br>• Applications in Chemical Engineering | **8** |
| **3** | • Systems of linear equations.<br>• Gaussian Elimination<br>• Gauss Jordan Method<br>• LU Decomposition<br>• Jacobi Iteration Method<br>• Gauss-Seidel Method.<br>• Applications in Chemical Engineering | **8** |

| | | |
|---|---|---|
| **4** | • Ordinary differential equations.<br>• Euler's explicit and implicit methods.<br>• Runge-Kutta second and fourth order methods.<br>• Adams-Bashforth formulas.<br>Predictor and Corrector Formulas<br>• Gear's Method<br>• Applications in Chemical Engineering | **10** |
| **5** | • Difference Equations<br>• Linear and Non-linear equations<br>• Applications to Absorption, Adsorption , Extraction etc. | **6** |
| **6** | • Partial differential equations.<br>• One-dimensional diffusion equation: Transient and Steady-state problems using explicit and implicit methods.<br>• Two-dimensional diffusion: steady-state problems. | **8** |

**Assessment**

**Internal**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**Text Books**


1. Numerical Methods for Engineers. By Santosh K. Gupta New Age Publishers, Second Edition, 2010
2. Introduction to Chemical Engineering Computing by Bruce A. Finlayson Wiley-International, 2005.
3. Numerical Methods by Chapra and Canale, $4^{th}$ Ed.


**References**


1. Learning Python
   Mark Lutz and David Ascher
2. Numerical Methods
   John Mathews

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHC502** | **Mass Transfer Operation I** | **4** |

**Prerequisites:**

- Knowledge of chemistry, physics, physical chemistry, mathematics, process calculations and unit operations.

**Course Objectives:**

- To give insight of mass transfer basic principle and mass transfer mechanisms.

**Course Outcomes:**

At the end of the course students will be able to:

- Demonstrate the knowledge of mass transfer by applying principles of diffusion, mass transfer coefficients, and interphase mass transfer.
- Understand the concept and operation of various types of gas-liquid contacts equipments.
- Determine NTU, HTU, HETP and height of packed bed used for Absorption and Humidification operations.
- Find time required for drying and design of drying equipments.

| Module | Contents | Contact Hours |
|---|---|---|
| 1 | **Molecular Diffusion in Gases and Liquid:** Basics of Molecular Diffusion, Fick's First Law of Molecular Diffusion, Various fluxes and relations between them, Molecular Diffusion in binary gas mixtures- Steady state diffusion of one component innon-diffusing second component, Equimolal counter diffusion of two components. Molecular Diffusion in binary liquid solutions- Steady state diffusion of one component in non-diffusing second component, Steady State Equimolal counter diffusion of two components.<br>Diffusivity of gases. Theoretical and experimental determination of diffusivities, Diffusivities of liquids - Theoretical Determination. Diffusion in Solids: Ficks law of diffusion in solids, Types of Solid Diffusion, Diffusion through Polymers, Diffusion through Crystalline Solids, Diffusion in Porous Solids | 10 |
| 2 | **Mass Transfer Coefficients:** Definition of Mass Transfer Coefficient, F-Type and K-Type Mass Transfer Coefficients and relations between them, Mass Transfer Coefficients in Laminar and Turbulent Flow. Heat, Mass and Momentum Transfer Analogies and dimensionless numbers, Interphase Mass Transfer- Individual and Overall Mass Transfer Coefficients and relation between them. Methods of contacting two insoluble phases- Continuous Contact, Stage-wise Contact. Cocurrent, counter current and cross current operations, Equillibrium stage definition and concepts, equilibrium stage | 12 |

| | | |
|---|---|---|
| | operations: material balance, concepts of operating line and equilibrium line, theoretical stage, point and stage efficiency, overall efficiency. Continuous contacting, concepts of HTU,NTU,HETP etc. | |
| 3 | **Equipments for Gas-Liquid Contacting:**<br>Classification of equipments for gas-liquid contacting<br>• Gas dispersed and liquid continuous phase-Sparged Vessels (Bubble Columns), Mechanically Agitated Vessels, Tray Towers.<br>• Liquid dispersed phase and gas continuous phase -Venturi Scrubbers, Wetted Wall Towers, Spray Towers and Spray Chambers, Packed Towers.<br>Comparison of Packed Towers with Tray Towers. | 06 |
| 4 | **Gas Absorption:**<br>Solubility of gases in liquids, Effect of temperature and pressure on solubility, Ideal and Non-ideal solutions, Choice of solvent for gas absorption, Single component gas absorption- Cross Current, Co-current, Countercurrent, Multistage Counter current Operation. Absorption with Chemical Reactions. | 07 |
| 5 | **Drying:**<br>Introduction to drying, Equilibrium, Different types of moisture contents, Rate of Drying and drying curve, Batch Drying and calculation of time of drying, Continuous drying. Equipments for drying. | 06 |
| 6 | **Humidification and Dehumidification:**<br>Introduction, Vapor Pressure Curve, Properties of Vapor-Gas mixtures [Understanding various terms], Theory of wet bulb temperature, Adiabatic Saturation Curves, Humidity Charts, Adiabatic operation : (Air water systems) water coolers, cooling towers | 07 |

**Assessment**

**Internal**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**Text Book**


1. Treybal R.E. , Mass transfer operation, 3 Ed., McGraw Hill New York, 1980.
2. McCabe W.L. and Smith J.C., Unit operation in chemical engineering, 5 Ed., McGraw Hill, NewYork,1993.

3. Geankoplis C.J., Transport processes and unit operations, Prentice Hall, New Delhi 1997.

**References**

1. Coulson J.M. Richardson J.F., Backhurst J.R. and Harker J.H., Coulson and Richardson chemical Engineering, vol 1 & 2, Butterworth Heinman, New Delhi, 2000.
2. Dutta B.K., Mass Transfer and separation processes, Eastern economy edition, PHI learning private ltd, New Delhi, 2009.

| Course Code | Course/ Subject Name | Credits |
| --- | --- | --- |

| CHC 503 | Heat Transfer Operations | 4 |
|---|---|---|

**Prerequisites:**

- Units and Dimensions, Fluid Flow Principles, Laws of Thermodynamics, Solution Technique of ODEs and PDEs.

**Course Objectives:**

- Students should be able to calculate heat transfer rates by various modes of heat transfer, for various geometry of equipment and should get introduced to Unsteady Heat Transfer.
- Students should be able to design Double Pipe Heat Exchanger and also be able to do preliminary design of Shell and Tube Heat Exchanger. Should be familiar with Extended Surfaces, Evaporators, and Agitated Vessels etc.

**Course Outcomes:**

Upon Completion of this course students would be able to

- Analyze Steady and Unsteady State Conduction systems.
- Analyze Convective Heat transfer Systems.
- Analyze Radiative Heat Transfer Systems.
- Analyze Extended Surfaces, Evaporators and Agitated Vessels.
- Basic design of DPHE and STHE.

| Module | Contents | Contact Hours |
|---|---|---|
| 1 | **Introduction to Heat Transfer Operations and Heat Transfer by Conduction** Fundamentals of heat transfer, basic modes of heat transfer. Concept of driving force and heat transfer coefficients, rate expressions for three modes i. e. conduction, convection, radiation. **Steady State Conduction:-**Fourier's Law, thermal conductivity, conduction through a flat slab, composite slab, conduction through a cylinder wall, composite cylinder, Conduction through hollow sphere, composite sphere. Thermal resistance network. Critical radius of insulation. **Unsteady state conduction: -**Lumped Parameter Analysis - systems with negligible internal resistance (Heat transfer by convection and radiation). Biot number, Fourier number, Heating a body under conditions of negligible surface resistance, heating a body with finite surface and internal resistance. | 10 |
| 2 | **Heat Transfer by Convection** **Forced and Natural Convection:-**Fundamental considerations in convective heat transfer, significant parameters in convective heat transfer such as momentum diffusivity, thermal diffusivity, Prandtl number, Nusselt number, dimensional analysis of convective heat transfer-Natural and Forced convection, convective heat transfer correlations for internal and external flows, equivalent diameter | 8 |

| | | |
|---|---|---|
| | for heat transfer, estimation of wall temperature, Reynold's Analogy, Prandtl' Analogy, Coulburn's Analogy. Correlations for heat transfer by natural convection from hot surfaces of different geometries and inclination. | |
| **3** | **Boiling and Condensation: -**Introduction, types of condensation, Nusselt's theory of condensation, correlations for vertical and horizontal tube, plate, for stack of tubes etc. Heat transfer to boiling liquids, regimes of pool boiling of saturated liquid, correlations for estimating the boiling heat transfer coefficients. | **6** |
| **4** | **Heat Transfer by Radiation**<br>Emissivity, absorptivity, black body, grey body, opaque body, Stephan Boltzmann law, Kirchhoff's law. Calculations for rate of heat transfer by radiation (Steady State) for various cases. Construction and working of various types of Box and Cylindrical types of Furnaces. | **8** |
| **5** | **Heat Exchangers**<br>**Extended Surfaces: -**longitudinal, transverse and radial fins, calculations with different boundary conditions, efficiency and effectiveness of fin, calculation of rate of heat transfer. | **5** |
| **6** | **DPHE and STHE**: -Overall Heat Transfer Coefficients (U), Resistance form of U, LMTD, and Wilson plot; fouling factors. Process design of Double Pipe Heat Exchanger. Preliminary process design and Kern's method of Design for Shell and Tube Heat Exchanger. Effectiveness-NTU method. | **5** |
| **7** | **Heat Transfer to Vessels: -** Jacketed Vessels, Internal Coils and Agitated Vessels- heat transfer correlations and calculations.<br>**Evaporators:-**Types of Tubular Evaporators, Performance Capacity and Economy, Boiling Point Elevation, Mass and Enthalpy Balances For Single Effect Evaporators, Multieffect Evaporators:- Methods of Feeding; Mass and Energy balance. | **6** |

**Assessment**

**Internal**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**Text Books**

1. B. K. Datta, Heat Transfer: Principles and applications, PHI learning.
2. Yunus A. Cengel and A. J. Ghajar, Heat and Mass Transfer.
3. Welty, Wicks, Wilson and Rorrer, Fundamentals of Momentum, Heat and Mass Transfer,5th Edition, Wiley India.
4. D. Q. Kern, Process Heat Transfer, McGraw hill, 1997.

**References**

1. MaCabe W. L., Smith J. C., Harriot P., Unit Operations of Chemical Engineering, 5th edition, McGraw Hill,1993.
2. Holman J. P., Heat Transfer, 9th Edition, McGraw Hill, 2008.
3. R. K. Sinnot, Coulson & Richardsons Chemical Engineering Design, Vol 1 & 6, Elsevier Science & Technology Books.

| Course Code | Course Name | Credits |
|---|---|---|
| **CHC504** | **Chemical Reaction Engineering-I** | **4** |

**Prerequisites:**

- Students should know basic chemistry pertaining to chemical reactions, chemical formula etc. They are required to be aware of chemical process and unit operations used for the manufacturing of chemical products. Simple to complex numerical methods of solving one and two dimensional Mathematical equations.

**Course Objectives:**

- To understand the different types of reactions and formulation of their reaction rate.
- Development of Kinetic model for homogeneous reactions giving emphasis on various types of reactions.
- Development of design strategy for homogeneous reactions considering different types of reactors.
- To understand the effect of temperature on reactor performance for adiabatic and non adiabatic operation

**Course Outcomes:**

- Students will be able to identify and analyze different types of homogeneous reactions.
- Students will be able to apply the knowledge they have gained to develop kinetic models for different types of Homogeneous reactions
- Students will be able to find the model equation and use this model to design the reactors used for Homogeneous reactions.
- Students will be able to understand the effect of temperature on reactor performance for adiabatic and non adiabatic operation and develop kinetic model to design the reactors for adiabatic and non-isothermal operations.

| Module | Topics | Contact Hours |
|---|---|---|
| **1** | Introduction to Reaction Engineering: Classification of reactions, definitions of reactions rate, variables affecting reaction rate, speed of chemical reactions.<br>Kinetics of homogenous reactions: Simple reactor types, the rate equation, concentration dependent term of rate equation. Molecularity and order of reaction. Rate constant k, representation of an elementary and nonelementary reaction. Kinetic models for non elementary reactions. Testing kinetic models. Temperature dependant term of rate equations from Arrhenius theory and comparison with collision and transition state theory. Activation energy and temperature dependency. Predictability of reaction rate from theory. | **10** |
| **2** | Methods of analysis of experimental data | **12** |

| | | |
|---|---|---|
| | For constant volume and Variable Volume Batch Reactor-Integral Method of analysis of experimental data. Differential Method of analysis of experimental data. Concept of Half Life/Fractional Life. Overall order of irreversible reaction. Analysis of total pressure data. Reversible and irreversible reaction in parallel and in series. Homogeneous catalyzed reactions, Auto catalytic reactions, Shifting Order reactions. | |
| **3** | Design of Reactors:<br>Ideal batch reactor and concept of batch time. Flow reactor and concept of space time / space velocity and holding time/residence time. Ideal Mixed Flow reactor(MFR) and Plug Flow Reactor (PFR). Design for single reactions: Single reactor performance of reversible and irreversible first order, pseudo first order, second order reactions for MFR, PFR. Graphical and analytical techniques.<br>Combination of reactors: PFR in series/ parallel, unequal size MFR in series, performance of the above for the first order and second order reactions. Semi batch reactor and Recycle Reactor.<br>Design for complex reactions: Irreversible and Reversible reactions in series and parallel with same or different order in various combinations. | **12** |
| **4** | Heat and pressure effects:<br>Single Reactions: Calculations of heats of reaction and equilibrium constants from thermodynamics, equilibrium conversion, general graphical design procedure. Optimum temperature progression, Energy balances equations in adiabatic and non-adiabatic case. Exothermic reaction in mixed flow, Rules for choice of reactors and optimum operation of reactors. | **10** |

**Assessment**

**Internal:**

- Assessment consists of average of two tests which should be conducted at proper interval.

**End Semester Theory Examination:**

- Question paper will comprise of 6 questions, each carrying 20 marks.
- Total 4 questions need to be solved.
- Question No.1 will be compulsory and based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules.
- Weightage of marks should be proportional to number of hours assigned to each Module.

## References


1. LevenspielO., Chemical Reaction Engineering, John Wiley&Sons,3ed.,1999.
2. Smith J.M., Chemical Reaction Engineering, 3ed.,TataMcGrawHill,1980.
3. Fogler, H.S. Elements of Chemical Reaction Engineering, 4ed.,PHI, 2008

4. Hill C.G., Chemical Reaction Engineering.
5. Walas, Reaction Kinetics for Chemical Engineers, McGraw Hill, 1959.

| Course Code | Course/Subject Name | Credits |
| --- | --- | --- |

| CHC505 | Business Communication and Ethics | 2 |
|---|---|---|

**Prerequisites:**

- Students should have basic knowledge of English and general engineering.

**Course Objectives**

- To inculcate in students professional and ethical attitude, effective communication skills, teamwork, multidisciplinary approach, and an ability to understand Engineers' social responsibilities
- To provide students with an academic environment where they will be aware of the excellence, leadership and lifelong learning needed for a successful professional career
- To inculcate professional ethics and codes of professional practice
- To prepare students for successful careers that meets the global Industrial and Corporate requirement

**Course Outcomes:**

Students will be able to

- Communicate effectively in both oral and written form and equip to demonstrate knowledge of professional and ethical responsibilities.
- participate and succeed in campus placements and competitive examinations like GATE, TOFEL
- Possess entrepreneurial approach and ability for life-long learning
- Have education necessary for understanding the impact of Engineering solutions on Society, and demonstrate awareness of contemporary issues Detailed Syllabus.
- Design a technical document using precise language, suitable vocabulary and apt style.
- Develop the life skills/ interpersonal skills to progress professionally by building stronger relationships.
- Demonstrate awareness of contemporary issues knowledge of professional and ethical responsibilities.
- Apply the traits of a suitable candidate for a job/higher education, upon being trained in the techniques of holding a group discussion, facing interviews and writing resume/SOP.
- Deliver formal presentations effectively implementing the verbal and non-verbal skills.

| Module | Contents | Contact Hours |
|---|---|---|
| 1 | **Report Writing**<br>Objectives of Report Writing<br>Language and Style in a report<br>Types : Informative and Interpretative (Analytical, Survey and Feasibility) and Formats of reports (Memo, Letter, Short and Long Report) | **05** |

| | | |
|---|---|---|
| **2** | **Technical Writing**<br>Technical PaperWriting (IEEE Format)<br>Proposal Writing | **03** |
| **3** | **Introduction to Interpersonal Skills**<br>Emotional Intelligence<br>Leadership and Motivation<br>Team Building<br>Assertiveness<br>Conflict Resolution and Negotiation Skills<br>Time Management<br>Decision Making | **09** |
| **4** | **Meetings and Documentation**<br>Strategies for conducting effective meetings<br>Notice, Agenda and Minutes of a meeting<br>Business meeting etiquettes | **02** |
| **5** | **Introduction to Corporate Ethics**<br>Professional and work ethics (responsible use of social media - Facebook, WA, Twitter etc.)<br>Introduction to Intellectual Property Rights<br>Ethical codes of conduct in business and corporate activities(Personal ethics, conflicting values, choosing a moral response and<br>making ethical decisions) | **02** |
| **6** | **Employment Skills**<br>Group Discussion<br>Resume Writing<br>Interview Skills<br>Presentation Skills<br>Statement of Purpose | **07** |

**Term Work**

The term work shall be comprised of the neatly written Journal comprising below mentioned assignments.

Assignment 1- Interpersonal Skills (Group activity Role play)
Assignment 2- Interpersonal Skills (Documentation in the form of soft copy or hard copy)
Assignment 3- Cover Letter Resume
Assignment 4- Report Writing
Assignment 5- Technical Proposal (document of the proposal)
Assignment 6- Technical Paper Writing
Assignment7 -Meetings Documentation (Notice, Agenda, Minutes of Mock Meetings)
Assignment 6- Corporate Ethics (Case study, Role play)
Assignment 8- Printout of the PowerPoint presentation

**Term-work Marks: 50 Marks**

The marks of term-work shall be judiciously awarded depending upon the quality of the term work including that of the report on experiments assignments. The final certification acceptance of Term work warrants the satisfactory the appropriate completion of the assignments, presentation, book report, group discussion and internal oral the minimum passing marks to be obtained by the students. The following weightage of marks shall be given for different components of the term work.

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- Attendance : 05 Marks
- Assignments : 20 Marks
- Internal Oral: 25 Marks. Comprising of:
  Presentation of the Project Report: 10 Marks
  Book Report (one copy per group): 05 Marks
  Group discussion: 10 Marks

**References**


1. Fred Luthans, *"Organizational Behavior",* McGraw Hill, edition
2. Lesiker and Petit, *"Report Writing for Business",* McGraw Hill, edition
3. Huckin and Olsen, *"Technical Writing and Professional Communication",* McGraw Hill
4. Wallace and Masters, *"Personal Development for Life and Work",* Thomson Learning, 12th edition
5. Heta Murphy*, "Effective Business Communication",* McGraw Hill, edition
6. Sharma R.C. and Krishna Mohan, *"Business Correspondence and Report Writing",*Tata McGraw-Hill Education
7. Ghosh,B. N.,*"Managing Soft Skills for Personality Development",* Tata McGraw Hill. Lehman,
8. Dufrene, Sinha, "BCOM", Cengage Learning, 2nd edition
9. Bell, Smith, "Management Communication" Wiley India Edition,3rd edition.
10. Dr. Alex, K.,"Soft Skills", S Chand and Company
11Subramaniam,R., "Professional Ethics" Oxford University Press.
12. Robbins Stephens P., "Organizational Behavior", Pearson Education
13. https://grad.ucla.edu/asis/agep/advsopstem.pdf

| Course Code | Course Name | Credits |
|---|---|---|
| **CHDE5011** | **Department Elective I-Piping Engineering** | **4.0** |

**Prerequisites:**

- Basics of various Chemical Process.

**Course Objectives:**

- To introduce students to the crucial role of piping engineer in turn key projects
- To make students understand the approval drawings and execute the work adhering to procedures and standards
- To understand the layout and manage the work with adequate safety and reliability

**Course Outcomes:**

By the end of the course students should be able

- understand the piping fundamentals, codes and standards
- understand pipe fittings, selections, drawings and dimensioning
- understand Pipe Material specifications
- understand pressure design of pipe systems

| Module | Content | Contact Hours |
|---|---|---|
| **1** | **Introduction to Piping**<br>1.1 Introduction to piping<br>1.2 Piping<br>1.3 Pipe classification<br>1.4 General definitions<br>1.5 Length, area, surface & volume acronyms and abbreviation. Color coding of piping as per types fluid passing through piping (IS 2379:1990)<br>1.6 Concept of high point vent and low point drain.<br>1.7 Duties & responsibilities of piping field engineer | **06** |
| **2** | **Materials of Piping**<br>2.1Selection of material for piping,<br>2.2 Desirable properties of piping materials<br>2.3Iron Carbide Diagram<br>2.4 Materials for various temperature and pressure conditions,<br>2.5 Materials for corrosion resistance.<br>2.6 Pipe coating and insulation | **08** |

| | | |
|---|---|---|
| **3** | **Piping Components**<br>3.1 Pipe & tube product<br>3.2 Pipe sizes & materials, Mitre Joint.<br>3.3 Pipes joints & bending (Cold & Hot Bending), Welding defect (NDT)<br>3.4 Valves: Types of valves and selection<br>3.5 Strainers & traps<br>3.6 Expansion joints<br>3.7 Threaded joints<br>3.8 Types of piping support | **10** |
| **4** | **Piping Codes and Standards**<br>4.1Introduction of ASME codes<br>4.2 Code cases interpretation<br>4.3 Introduction of ASME B 31.1, 31.2, 31.3<br>4.4 Introduction of ANSI<br>4.5 Introduction of ASTM<br>4.6 Introduction of API<br>4.7 Introduction of AWS | **06** |
| **5** | **Piping System Design**<br>5.1 Flows through Pipes.<br>5.2 Loss of energy / head in pipes Loss of head due to friction.<br>5.3Minor energy losses,<br>5.4Water hammer in pipes Unit.<br>5.5Design Principles and Line Sizing<br>5.6. Mitre Joint Calculation.<br>5.7 Various stresses in piping<br>5.8 Bending stress calculation | **10** |
| **6** | **Piping Drawing**<br>6.1 Piping drawing symbols and abbreviations<br>6.2 Classification/Types of drawing<br>6.3 Introduction to simple piping drawings<br>6.3.1 Plot Plan<br>6.3.2 G.A.Drawing<br>6.3.3 Process flow diagram (P.F.D)<br>6.3.4 Piping and instrumentation diagram (P&ID)<br>/ Engineering flow diagram. | **08** |

**Assessment**

**Internal**

- Assessment consists of average of two tests which should be conducted at proper interval

**End Semester Theory Examination:**

- Question paper will comprise of 6 questions, each carrying 20 marks.
- Total 4 questions to be solved
- Question no.1 will be compulsory and based on entire syllabus where in sub questions can be asked.

- Remaining questions will be randomly selected from all the modules.
- Weightage of marks should be proportional to number of hours assigned to each module.

**References**


1. Handbook of piping design- S.K. Sahu Elsevier Publishers
2. Piping/mechanical hand book- Mohinder L. Nayyar. Peter H. O. Fischer, Manager, Pipeline Operations, Bechtel
3. Piping Design Handbook by John J. Mcketta, by Marcel Dekker, Inc, New York.


**Recommended:**

i. Arrange visit to a process industry and discuss different features of process piping in use.

ii. Arrange expert lecture by some experienced process piping engineer.

| Course Code | Course/Subject Name | Credits |
|---|---|---|
| CHDE5012 | Department Elective I- Colloids and Interfaces | 4 |

**Prerequisites:**

- Basic knowledge of Chemical Engineering, basic concept of electron, atom, ions, molecules & molecular rearrangements, Basic knowledge of fluid flow, thermodynamics and heat transfer, Various types of material and metals, Basic knowledge of particle size measurement.

**Course Objectives:**

- To understand the fundamental knowledge of the Colloids, interfaces and explain their applications
- To understanding of basic nomenclature, concepts and tools of colloid and interface science and engineering; multi-phase nano-systems; mechanics and thermodynamics on small scales.
- To impart the interdisciplinary subject in which chemical engineers, chemists and biotechnologists are involved
- Understand the engineering aspects of fluid-fluid and fluid-solid interfaces and Surface energy.

**Course Outcomes:**

Upon completion of the course, the student should be able to

- Describe the colloidal state, including colloids and their preparation and properties as well as fundamental concepts in colloid and interface engineering.
- Discuss factors that affect colloidal systems and important factors on solid/liquid interactions as well as apply knowledge in colloid and surface science and analyze and solve problems calculations concerning the practical problems
- Explain experimental techniques used to determine colloidal properties; interfacial phenomena
- To facilitate skills transfer from another relevant area of engineering or science and technology to the study of Interfacial engineering.
- Students should understand, know how to interpret and apply the following topics in colloid and interface engineering to wettability, solubility, surface tension, diffusion, sedimentation, colloid stability and aggregation, adsorption, electrical interfacial layer and surface equilibrium and experimental methods for surface characterization
- Gain knowledge of fabrication methods in nanotechnology and characterization methods in nanotechnology.

| Module | Contents | Contact hrs |
|---|---|---|
| 01 | Introduction of Colloids, The colloidal state and classification, Importance of colloids, Properties and application of colloid systems, interaction between particles, colloid stability and aggregation | 06 |
| 02 | Surface tension and interfacial tension surfaces, Experimental | 08 |

| | | |
|---|---|---|
| | method for measurement of Surface Tension, dynamic surface tension & Contact Angle, Vander Waals forces between colloidal particles | |
| **03** | Surfactants: classification, properties, applications<br>Surfactants in solution: micelles, vesicles, Micro emulsions<br>Electrical phenomena at interfaces: Electric double layer, zeta potential, DLVO theory | **08** |
| **04** | Surface free energy, films on liquid substrates (mono-molecular films, Langmuir-Blodgett layers),<br>Adsorption-Langmuir and Gibbs adsorption isotherm,<br>Types of Interface (Solid-Gas, Solid-liquid, liquid –gas, liquid-liquid) and its features | **08** |
| **05** | Top-down and bottom-up approach for nanostructure Methods: Vacuum Synthesis, Gas Evaporation Tech, Condensed Phase, Synthesis, Sol Gel Processing, Polymer Thin Film | **07** |
| **06** | Interaction between Biomolecules & Nanoparticle Surface,<br>Influence of Electrostatic Interactions in the binding of Proteins with Nanoparticles, The Electronic effects of bimolecule - Nanoparticle Interaction, Different Types of Inorganic materials used for the synthesis of Hybrid Nano-bio assemblies,<br>Application. | **07** |
| **07** | Particle Size, Surface area, Volume, Equivalent Diameter and Aerodynamic Diameter<br>Measurement Methods – Microscopy, Optical Counter, Electrical Aerosol Analyzer, Bacho Microparticle classifier, Particle Size analyzer<br>Particle mass, Volumetric flow rate and average particle concentration calculation | **08** |

**Assessment**

**Internal:**

- Assessment consists of an average of two tests which should be conducted at proper interval.

**End Semester Theory Examination:**

- Question paper will comprise of 6 questions, each carrying 20 marks.
- Total 4 questions need to be solved.
- Question No.1 will be compulsory and based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules.

**Textbook/References Book**


1. J. C. Berg, An Introduction to Interfaces and Colloids: The Bridge to Nanoscience, World Scientific, Singapore
2. P. Ghosh, Colloid and Interface Science, PHI Learning, New Delhi
3. R. J. Hunter, Foundations of Colloid Science, Oxford University Press, New York

4. D.J. Shaw, Colloid and Surface Chemistry, 4th Edition, Butterworth-Heinemann, Oxford
5. Myers, D. Surfaces, Interfaces, and Colloids: Principles and Applications. New York
6. Robert J. Stokes, D Fennell Evans, “Fundamentals of Interfacial Engineering”, Wiley-VCH
7. P. C. Hiemenz and R. Rajagopalan, Principles of Colloid and Surface Chemistry, Marcel Dekker, New York
8. Louis Theodore, A John, Nanotechnology: Basic Calculations for Engineers and Scientists - Willy & Sons
9. T. Pradeep, Nano-The Essentials, Understanding Nanoscience and Nanotechnology,
10. Kal Ranganathan Sharma, Nanostructuring Operations in NanoScale Science and Engineering, McGraw-Hill

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHDE5013** | **Department Elective I- Advanced Material Science** | **4** |

**Prerequisites**

- Mechanical, Electrical, Magnetic and Optical Properties of Materials, Commonly used Materials of Construction and their Selection, Corrosion in Materials.

**Course Objectives**

- To understand various advanced materials such as conducting polymers, high temperature polymers, stainless steels, composites, ceramics, etc.
- To understand the properties and engineering applications of the above materials.
- To understand the fabrication methods of the above materials.

**Course Outcomes**

At the end of the course the student will:

- Identify various types of advanced materials such as polymers, ceramics and composites.
- Understand the properties of various advanced polymeric, ceramic and metallic materials and their applications in various fields.
- Have knowledge of different types of composite materials and their properties and applications.
- Understand the fabrication of various composite materials.
- Have knowledge of types of nanotubes and nanosensors and their applications.
- Understand the different thin film coating methods and their applications in various fields.

| Module | Contents | Contact Hours |
|---|---|---|
| **1** | **Advanced Metallic Materials:**<br>Stainless Steels: Types, properties of stainless steels, corrosion resistance and selection of stainless steels, failure of stainless steels.<br>High Temperature Alloys: Properties and types.<br>Titanium Alloys and Cobalt-Chromium Alloys: Composition, properties and applications.<br>Nitinol as Shape Memory Alloy and its applications. | **08** |
| **2** | **Advanced Polymeric Materials:**<br>Structure, preparation, and application of various conducting polymers, high temperature polymers and liquid crystal polymers.<br>Biomedical applications of polymers such as hydrogels, polyethylene, polyurethanes, polyamides and silicone rubber. | **06** |
| **3** | **Ceramic Materials:**<br>Properties of ceramic materials, classification of ceramic materials, ceramic crystal structures.<br>Behaviour of ceramic materials: dielectric, semiconductor, | **08** |

| | | |
|---|---|---|
| | ferroelectric, magnetic, and mechanical behaviour.<br>Preparation and application of ceramic materials: Alumina, Partially Stabilized Zirconia, Sialon, Silicon Nitride, Silicon Carbide.<br>Processing of Ceramics. | |
| **4** | **Composite Materials:**<br>Necessity of composite materials, classification of composite materials, types of matrix materials and reinforcements, reinforcement mechanism, choosing material for matrix and reinforcement.<br>**Fiber Reinforced Plastic Processing:**<br>Open Moulding Processes : Filament Winding Process<br>Closed Moulding Processes : Pultrusion and Pulforming, Sheet Moulding Compound Process<br>**Carbon-Carbon Composites :** Fabrication and Properties | **08** |
| **5** | **Metal Composites:**<br>Advantage of metal composite over metal, types of reinforcement and matrix fabrication types, various fabrication processes: diffusion bonding process, in-situ process, mechanical behaviour and properties.<br>**Ceramic Composites:**<br>Matrices and reinforcements, mechanical properties, fabrication methods: Slurry infiltration processes, chemical vapour infiltration process. | **08** |
| **6** | **Carbon Nanotubes:** Synthesis, properties and applications.<br>**Nanoshells:** Types, properties and applications.<br>**Nanosensors:** Assembly methods, nanosensors based on optical, quantum size, electrochemical and physical properties.<br>**Thin Film Coatings:** Physical and chemical vapour deposition coatings, hard facing, thermal spraying, diffusion process, useful material for appearance, corrosion and wear. | **07** |

**Assessment**

**Internal:**

- Assessment consists of average of two tests which should be conducted at proper interval.

**End Semester Theory Examination:**

- Question paper will comprise of 6 questions, each carrying 20 marks.
- Total 4 questions need to be solved.
- Question No. 1 will be compulsory and based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules.
- Weightage of marks should be proportional to number of hours assigned to each module.

**Text Books and Reference Books**

1. B.K. Agrawal, Introduction to Engineering Materials, Tata McGraw Hill Education Pvt. Ltd., 2012.
2. A.K. Bhargava, Engineering Material: Polymers, Ceramics and Composites, PHI Learning Pvt. Ltd., Second Edition 2012.
3. Dr. H.K. Shivanand and B.V. Babu Kiran, Composite Material, Asian Books Private Limited, 2010.
4. T. Pradeep, Nano: The Essentials, Tata McGraw-Hill Education Pvt. Ltd., 2010.
5. William Smith, Structure and Properties of Engineering Alloys, Second Edition, McGraw Hill International Book Co.
6. William Smith, Javed Hasemi, Ravi Prakash, Material Science and Engineering, Tata McGraw Hill Education Company Ltd., 2006.
7. Kenneth G. Budinski, Michael K. Budinski, Engineering Materials Properties and Selection, 8th Edition, Prentice Hall.
8. Bowden M.J. and Tumber S.R., Polymer of High Technology, Electronics and Photonics, ACS Symposium Series, ACS, 1987.
9. Dyson, R.W., Engineering Polymers, Chapman and Hall, First Edition, 1990.
10. Chawala K.K., Composite Materials, Science and Engineering, 3rd Edition.
11. Sujata V. Bhat, Biomaterials, Narosa Publication Pvt. Ltd., Second Edition, 2005.
12. V. Raghavan, PHI Learning Private Ltd, Sixth Edition.

| Course Code | Course/ Subject Name | Credits |
|---|---|---|

| CHDE5014 | Department Elective I- Instrumentation | 4 |
|---|---|---|

**Prerequisites**

- Process Calculations

**Course Objectives**

- To understand the primary mechanisms of sensors
- To understand how measured quantities are processed for transmission and control
- To understand how alarms and interlocks are incorporated into over-all instrumentation and control
- To understand basic control configurations of typical process units

**Course Outcomes**

- The student will be able to calculate the output of various measuring schemes
- The student will be able to select a DAQ card for any given application
- The student will be able to select the appropriate type of instrument for any application
- The student will be able to prepare a basic control scheme for process units
- The student will be able to write programs for a PLC.

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| Module | Contents | Contact Hours |
|---|---|---|
| 1 | Fundamentals of Measuring Instruments:<br>Introduction Standards and Calibration, Elements of Measuring Systems, Classification of Instruments, Performance Characteristics, Errors in Measurement. | 04 |
| 2 | Primary Sensing Mechanisms:<br>Introduction, Resistive Sensing Elements, Capacitive Sensing Elements, Inductive Sensing Elements, Thermo-electric Sensing Elements, Piezo-electric Sensing Elements, Elastic Sensing Elements, Pneumatic Sensing Elements, Deferential Pressure Sensing Elements, Expansion Sensing Elements.. | 04 |
| 3 | Signal Conversion:<br>Signal Conditioning , Wheatstone Bridge, Potentiometer Measurement System, Signal Processing, Mechanical Amplifier, Electronic Amplifier, A/D and D/A conversion, Signal Transmission, Selection of DAQ cards. | 04 |
| 4 | Measuring Instruments:<br>Flow Measurement, Temperature Measurement, Level Measurement, Pressure Measurement. | 10 |
| 5 | Valves and Drives:<br>Introduction, Control Valve Characteristics, Sizing and Selection of Valves, Variable Drives. | 04 |
| 6 | Programmable Logic Controllers: | 04 |

| | | |
|---|---|---|
| | Introduction, Ladder Logic, Applications of PLCs to typical processes. | |
| **7** | Introduction to Safety Relief Systems:<br>Introduction, Types of Relieving Devices, Relief Valves, Rupture Discs, Over-pressurization, Emergency Depressurization, Introduction to SIL Classification, LOPA Methods, Basic Process Control<br>Schemes. | **10** |

**Assessment**

**Internal:**

- Assessment consists of average of two tests which should be conducted at proper interval.

**End Semester Theory Examination:**

- Question paper will comprise of 6 questions, each carrying 20 marks.
- Total 4 questions need to be solved.
- Question No. 1 will be compulsory and based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules.
- Weightage of marks should be proportional to number of hours assigned to each module.

**Refrences**


1. K. Krishnaswamy and S. Vijayachitra, Industrial Instrumentation, second Edition, New Age International.
2. B. E. Noltingk, Jones Instrument Technology, Vol. 4 and 5, Fourth Edition, Butterworth-Heinemann.
3. W. Bolton, Instrumentation and Control Systems, First Edition, Newnes, Elsevier, 2004.
4. Stephanopoulos, Chemical Process Control, Prentice Hall of India.
5. John P. Bentley, Principles of Measurement Systems, Third edition, Addison Wesley Longman Ltd., UK, 2000.
6. Doebelin E.O, Measurement Systems - Application and Design, Fourth edition, McGraw-Hill International Edition, New York, 1992.
7. Noltingk B.E., Instrumentation Reference Book, 2nd Edition, Butterworth Heinemann, 1995


| Course Code | Course/ Subject Name | Credits |
|---|---|---|

| CHL501 | Computer Programming and Numerical Methods Lab | 1 |
|---|---|---|

Minimum Ten practicals should be performed from the modules of Theory course of Computer Programming and Numerical Methods (CHC501)

**Term work**

Term work shall be evaluated based on performance in practical.

| | |
|---|---|
| Practical Journal: | 20 marks |
| Attendance: | 05 marks |
| **Total:** | **25 marks** |

**Practical Examination**

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments

| Course Code | Course/ Subject Name | Credits |
|---|---|---|

| CHL502 | Chemical Engineering Lab IV (MTO–I) | 1.5 |
|---|---|---|

**Concept for Experiments**

Minimum of ten experiments are to be conducted.

- To determine the diffusivity of given liquid sample.
- To study diffusion through porous solids and determine effective diffusivity.
- To determine Mass Transfer Coefficient in a packed extraction column
- To determine Mass Transfer Coefficient in a packed extraction column
- To determine Mass Transfer Coefficient in a spray extraction column
- To estimate the mass transfer coefficient in flow process system (eg. benzoic acid + water).
- To determine mass transfer co-efficient in gas liquid system by evaporation.
- To study absorption in packed tower.
- To determine the efficiency of cooling and tower study of Humidification and water cooling operations.
- To study the operation of a fluidized bed drier and analyze drying curve.
- To determine rate of absorption and study absorption in spray tower.
- To study batch drying and plot drying curve.
- To study hydrodynamics of packed bed and study variation in pressure drop with velocity.
- Experiments demonstrating determination of mass transfer coefficient/diffusivity/ number of transfer units, HTU, HETP are envisaged.

**Term work**

Term work shall be evaluated based on performance in practical.

Practical Journal: 20 marks

Attendance: 05 marks

**Total: 25 marks**

**Practical Examination**

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHL503** | **Chemical Engineering Lab IV (HTO)** | **1.5** |

**Concept for Experiments**

Minimum of ten experiments are to be conducted.

1. Thermal conductivity of a metal rod.
2. Heat transfer through composite wall.
3. Newtonian heating/cooling.
4. Heat transfer by forced convection.
5. Heat transfer by natural convection.
6. Heat transfer by condensation.
7. Stefan Boltzmann's apparatus
8. Kirchoff's law
9. Double pipe heat exchanger
10. Shell & Tube heat exchanger
11. Finned tube heat exchanger
12. Heat transfer in agitated vessel.

**Term work**

Term work shall be evaluated based on performance in practical.

Practical Journal: 20 marks
Attendance: 05 marks
**Total: 25 marks**

**Practical Examination**

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments.

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHL504** | **Chemical Engineering Lab VI (CRE–I)** | **1** |

**Concept for Experiments**

Minimum 10 experiments need to be performed by the students on following concepts

1. Differential and Integral Analysis (Order of Reaction at Room Temperature)
2. Arrhenius Constants (Verification of Laws)
3. Order and rate constant using Half Life Method
4. Study of Pseudo Order Reaction
5. Acidic Hydrolysis
6. Batch Reactor
7. Plug Flow Reactor (PFR)
8. Continuous Stirred Tank Reactor (CSTR)
9. Continuous Stirred Tank Reactors Series (Three CSTRs In Series)
10. PFR – CSTR In Series Combination

**Term work**

Term work shall be evaluated based on performance in practical.

Practical Journal: 20 marks

Attendance: 05 marks

**Total: 25 marks**

**Practical Examination**

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight experiments out of ten experiments.

**University of Mumbai**
**Program Structure for B.E. Chemical Engineering (Revised 2016)**
**T.E. Semester VI (w.e.f 2018-2019)**

| Course code | Course Name | Teaching Scheme (Contact Hours) | | | Credits Assigned | | | |
|---|---|---|---|---|---|---|---|---|
| | | Theory | Practical | Tutorial | Theory | Practical | Tutorial | Total |
| CHC601 | Environmental Engineering (EE) | 4 | - | - | 4 | - | - | 4 |
| CHC602 | Mass transfer Operations –II (MTO-II) | 4 | - | - | 4 | - | - | 4 |
| CHC603 | Transport Phenomenon | 3 | - | 1 | 3 | - | 1 | 4 |
| CHC604 | Chemical Reaction Engineering –II (CRE- II) | 4 | - | - | 4 | - | - | 4 |
| CHC605 | Plant Engineering & Industrial Safety | 3 | - | 1 | 3 | - | 1 | 4 |
| CHDE602X | Department Elective II | 4 | - | - | 4 | - | - | 4 |
| CHL601 | Chemical Engineering Lab VII (EE) | - | 3 | - | - | 1.5 | - | 1.5 |
| CHL602 | Chemical Engineering Lab VIII (MTO-II) | - | 3 | - | - | 1.5 | - | 1.5 |
| CHL603 | Chemical Engineering Lab IX CRE-II) | - | 2 | - | - | 1 | - | 1 |
| | Total | 22 | 8 | 2 | 22 | 4 | 2 | 28 |

| Course code | Course Name | Examination Scheme | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Theory | | | | | Term Work | Pract /Oral | Oral | Total |
| | | Internal Assessment | | | End Sem Exam | Exam Duration (in hrs) | | | | |
| | | Test 1 | Test 2 | Avg | | | | | | |
| CHC601 | Environmental Engineering (EE) | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHC602 | Mass transfer Operations –II (MTO-II) | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHC603 | Transport Phenomenon | 20 | 20 | 20 | 80 | 3 | 25 | - | - | 125 |
| CHC604 | Chemical Reaction Engineering –II (CRE- II) | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHC605 | Plant Engineering & Industrial Safety | 20 | 20 | 20 | 80 | 3 | 25 | - | - | 125 |
| CHDE602X | Department Elective II | 20 | 20 | 20 | 80 | 3 | - | - | - | 100 |
| CHL601 | Chemical Engineering Lab VII (EE) | - | - | - | - | 3 | 25 | 25 | | 50 |
| CHL602 | Chemical Engineering Lab VIII (MTO-II) | - | - | - | - | 3 | 25 | 25 | - | 50 |
| CHL603 | Chemical Engineering Lab IX CRE-II) | - | - | - | - | 2 | 25 | 25 | - | 50 |
| | Total | | | 120 | 480 | - | 125 | 75 | -- | 800 |

| Department Elective II (Sem VI) | | |
|---|---|---|
| Engineering Stream (Elective Code) | Management Stream (Elective Code) | Technology Stream (Elective Code) |
| 1. Computational Fluid Dynamics (CHDE6021) | 1. Operation Research (CHDE6022) | 1. Biotechnology (CHDE6023) |

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHC601** | **Environmental Engineering** | **4** |

**Prerequisites:**

- Basic concepts of Fluid Flow Operations, Solid Fluid Mechanical Operations, Mass Transfer Operations and Chemical Reaction Engineering.

**Course Objectives:**

- Students should be able to understand the scope of subjects in Chemical Industry.
- Students should learn to apply the Environmental Engineering concepts to control management of various types of pollutants.

**Course Outcomes:**

- To understand Importance of environmental pollution, such as air, water, solid, noise. Various pollutants sources, adverse effects, Environmental Legislation
- To understand meteorological aspects air pollutant dispersion. Sampling and measurement, Control Methods and Equipment:
- To understand Sampling, measurement of various water pollutants.
- To understand and design various Waste Water Treatments,

| Module | Contents | Contact Hours |
|---|---|---|
| **1** | Environmental pollution, Importance of environmental pollution control, Concept of ecological balance, Role of environ-mental engineer, Environmental Legislation & Regulations, Industrial pollution emissions &Indian standards, Water (prevention & control of pollution) act, Air (prevention & control of pollution) act. | **2** |
| **2** | **Water Pollution**:<br>Classification of sources and effect of water pollutant on human being and ecology, Sampling, measurement and standards of water quality, Determination of organic matters: DO, BOD, COD, and TOC.<br>**Determination of inorganic substances**: nitrogen, phosphorus, trace elements, alkalinity. **Physical characteristics**: suspended solids, dissolved solids, colour and odour, Bacteriological measurements. | **8** |
| **3** | **Waste Water Treatment:**<br>**Primary treatment**: pre-treatment, settling tanks and their sizing.<br>**Secondary treatment**: micro-organisms growth kinetics, aerobic biological treatment, activated sludge process, evaluation of bio-kinetic parameters, trickling filters, sludge treatment and disposal.<br>**Tertiary treatment**: advanced methods for removal of nutrients, suspended and dissolved solids, Advanced biological systems, Chemical oxidation, Recovery of materials from process effluents. | **12** |
| **4** | **Air Pollution:** | **14** |

| | | |
|---|---|---|
| | Air pollutants, sources and effect on man and environment, behaviour and fate of air pollutants, photochemical smog, Meteorological aspects of Air pollutants: Temperature lapse rate and stability, inversion, wind velocity and turbulence, Plume behaviour, Dispersion of air pollutants, Gaussian plume model, Estimation of plume rise, Air pollution sampling and measurement, Analysis of air pollutants | |
| **5** | **Air Pollution Control Methods and Equipment:**<br>Source correction methods for air pollution control, Cleaning of gaseous effluents, Particulate emission control, Equipment, system and processes for.<br>----Particulate pollutants: gravity settler, cyclones, filters, ESP, scrubbers etc.<br>----Gaseous pollutants: scrubbing, absorption, adsorption, catalytic conversion. | **8** |
| **6** | **Solid Waste Management:**<br>Solid waste including plastic, nuclear and hazardous waste management, E waste management | **3** |
| **7** | **Noise Pollution:**<br>Noise pollution: measurement and control, effect on man and environment. | **1** |

**Assessment**

**Internal**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**Text Books**

1. Rao, C.S., Environmental Pollution Control Engineering, New Age International (P) Ltd.
2. Peavy, H. S., Rowe, D.R., Tchobanoglous, G., Environmental Engineering, McGraw-Hill Book Company Limited
3. Metcalf et al., Waste Water Treatment, Disposal & Reuse, Tata McGraw Hill Publishing Company Limited.
4. Mahajan, S.P., Pollution Control in Process Industries, Tata McGraw Hill Publishing Company Limited.

**References**

1. Industrial and Pollution Engineering, Cavaseno, VinCene N.T.

2. Sewage Disposal and Air Pollution Engineering, S.K. Garg
3. Chemistry for Environmental Engineering, C.N. Sawyer
4. Wastewater Engineering, B.C Punmia

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHC602** | **Mass Transfer Operations II** | **4** |

**Prerequisites:**

- Knowledge of chemistry, physics, physical chemistry and mathematics.
- Knowledge of process calculations.
- Knowledge of diffusion, mass transfer coefficients, modes of contact of two immiscible phases.

**Course Objectives:**

- To understand design methods for distillation columns.
- To understand design of extractor and leaching equipments.
- To understand membrane separation.
- To understand crystallisation process and to design crystallization equipments

**Course Outcomes**

At the end of the course student will be able to:

- understand equilibrium in all separation process
- design the mass transfer equipments for extraction, leaching and crystallization processes
- design distillation column
- choose the separation operation which will be economical for the process
- optimize the process parameters
- understand membrane separation processes principle and working

| Module | Contents | Contact Hours |
|---|---|---|
| **1** | **Distillation:** Introduction to Distillation, Vapor-liquid Equilibrium-At constant Pressure and At constant temperature, Minimum and maximum boiling Azeotropes. Methods of distillation [binary mixtures] – Flash Distillation, Differential distillation, Rectification. Calculations of number of ideal stages in multistage countercurrent rectification. McCabe Thiele Method. Ponchon-Savarit Method, Lewis-Sorel Method, Concepts of [Brief Discussion], Steam Distillation, Azeotropic Distillation, Extractive Distillation, Reactive Distillation, Molecular Distillation, Introduction to Multicomponent Distillation. | 12 |
| **2** | **Liquid-Liquid Extraction:** Introduction to Liquid-Liquid Extraction, Choice of Solvent for Liquid-Liquid Extraction, Triangular coordinate system, Ternary Equilibria [Binodal Solubility Curve with effect of temperature and pressure on it], Single Stage Operation, Multistage Cross Current Operation, Multistage Counter Current Operation[with | 10 |

| | | |
|---|---|---|
| | and without reflux, Equipments for liquid-liquid extraction. | |
| **3** | **Leaching:**<br>Representation of Equilibria, Single stage leaching, Multistage Cross Current Leaching, Multistage Counter Current Leaching, Equipments for Leaching. | 06 |
| **4** | **Adsorption and Ion Exchange:**<br>Introduction to Adsorption, Types of Adsorption, Adsorption Isotherms, Single Stage Adsorption, Multistage Cross Current Adsorption, Multistage Counter Current adsorption, Equipments for Adsorption, Break through curve, Ion Exchange Equilibria, Ion Exchange Equipments | 12 |
| **5** | **Crystallization:**<br>Solubility curve, Super saturation, Method of obtaining super saturation, Effect of heat of size and growth of crystal, Rate of Crystal growth and ΔL law of crystal growth, Material and energy balance for crystallizers, Crystallization equipment-description. | 4 |
| **6** | **Membrane separation Technique:**<br>Need of membrane separation, and its advantages, classification of membrane separation process, Various membrane configurations. Various membrane and their applications, Ultrafiltration, Nanofiltration. Reverse osmosis, Pervaporation, Membrane distillation. | 4 |

**Assessment**

**Internal**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**References**


1. Treybal R.E. , Mass transfer operation, 3 Ed., McGraw Hill New York, 1980.
2. McCabe W.L. and Smith J.C., Unit operation in chemical engineering, 5 Ed., McGraw Hill New York 1993.
3. Geankoplis C.J., Transport processed and unit operations, Prentice Hall, New Delhi 1997.
4. Coulson J.M. Richardson J.F., Backhurst J.R. and Harker J.H., Coulson and Richardson chemical engineering, vol 1 & 2, Butterworth Heinman, New Delhi, 2000.
5. R.K. Sinnot (Ed) Coulson and Richardson chemical engineering, vol 6, Butterworth Heinman, NewDelhi, 2000.

6. Kiran D. Patil, Principals and Fundamentals of mass transfer operation II, Nirali Prakashan Pune.
7. Dutta B.K., Mass Transfer and separation processes, Eastern economy edition, PHI learning private ltd, New Delhi, 2009.

| Course Code | Course/Subject Name | Credits |
|---|---|---|
| **CHC603** | **Transport Phenomena** | **4.0** |

**Prerequisites:**

- Continuity equation, equation motion covered in Fluid Mechanics, Diffusion and absorption from Mass Transfer and Conduction, convection and radiation from Heat Transfer.
- Numerical methods to solve ordinary differential equations.

**Course Objectives:**

- Students will be able to get depth knowledge of momentum, energy and mass transport.
- Applications of fundamental subjects learned, towards chemical engineering problems.
- Ability to analyze industry oriented problems.

**Course Outcomes:**

- Understanding of transport processes.
- Student will learn to establish and simplify appropriate conservation statements for momentum, energy and mass transfer processes.
- Ability to do momentum, energy and mass transfer analysis.
- To apply conservation principles, along with appropriate boundary conditions for any chemical engineering problem.

| Module | Contents | Contact Hours |
|---|---|---|
| 1 | **Introduction:** Importance of transport phenomena, Introduction to analogies between momentum, heat and mass transfer and defining of dimensionless number, Eulerian and Lagrangian approach, introduction of molecular and convective flux, equation of continuity, motion and energy. | **06** |
| 2 | **Momentum Transport:** Introduction of viscosity and mechanism of momentum transport: Newton's law of viscosity, Newtonian & Non-Newtonian fluids, Pressure and temperature dependence of viscosity, theory of viscosity of gases and liquids. Velocity distribution in laminar flow: Shell momentum balances and boundary conditions a) Flow of falling film b) Flow through the circular tube c) Flow through an annulus d) Flow in a narrow slit e) Adjacent flow of two immiscible fluids | **10** |
| 3 | **Energy Transport:** The introduction of thermal conductivity and mechanism of energy transport: Fourier's law of heat conduction, temperature and pressure dependence of thermal conductivity in gases and liquids. Temperature distribution in solids and in laminar flow, shell energy balance and boundary conditions a) Heat conduction with electrical heat source b) Heat conduction with a nuclear heat source c) Heat conduction with a viscous heat | **10** |

| | | |
|---|---|---|
| | source d) Heat conduction with a chemical heat source e) Heat conduction with variable thermal conductivity f) Heat conduction in composite wall and cylinder g) Heat conduction in a cooling fin | |
| **4** | **Mass Transport:** Introduction of diffusivity and mechanism of mass transport: Definitions of concentrations, velocities and mass fluxes, Fick's law of diffusion, temperature and pressure dependence of mass diffusivity. Concentration distribution in solids and in laminar flow, Shell mass balances and boundary conditions a) Diffusion through stagnant gas film b) Diffusion with heterogeneous chemical reaction c) Diffusion with homogeneous chemical reaction d) Diffusion into a falling liquid film (Gas absorption) | **10** |

**Term Work**

Term work shall consist of minimum eight tutorials from entire syllabus which are to be given at regular intervals Batch wise.

Tutorials: 20 Marks
Attendance: 05 Marks
Total: **25 Marks**

**Assessment**

**Internal**

- Assessment consists of average of two tests which should be conducted at proper interval

**End Semester Theory Examination**:

- Question paper will be comprises of six questions, each carrying 20 Marks.
- Total 4 questions need to be solved.
- Question no. 1 will be compulsory and based on entire syllabus wherein sub-questions can be asked.
- Remaining questions will be randomly selected from all the modules.
- Weightage of marks should be proportional to number of hours assigned to each module.

**References**


1. Bird, R.B., W.E. Stewart and E.N. Lightfoot, Transport Phenomena, Wiley, New York, 2nd ed., 2002.
2. Christie J. Geankoplis, Transport Processes and Separation Process Principles, $4^{th}$ Edition, 2004
3. Slattery, J.C., Advanced Transport Phenomena, Cambridge University Press, Cambridge, 1999.
4. Brodkey, R.S. and H.C. Hershey, 1988, Transport Phenomena: A Unied Approach, McGraw-Hill, New York.
5. Bodh Raj, Introduction to Transport Phenomena (Momentum, Heat and Mas), PHI Learning Pvt. Ltd, Eastern Economy Edition.


| Course Code | Course/Subject Name | Credits |
|---|---|---|

| CHC604 | Chemical Reaction Engineering II | 4.0 |
|---|---|---|

**Prerequisites:**

- Students should know basic chemistry pertaining to chemical reactions, chemical formula etc. They are required to be aware of chemical process and unit operations used for the manufacturing of chemical products. Simple to complex numerical methods of solving one and two dimensional Mathematical equations.

**Course Objectives:**

- To understand the concept of Residence Time Distribution (RTD) in various reactors and obtain the actual design parameters to design Real Reactor.
- To find the model equation and use this model to design the reactors used for heterogeneous non catalytic reactions.
- To apply the knowledge they have gained to develop kinetic model and Design strategy for heterogeneous catalytic reactions.
- To apply the knowledge they have gained to develop kinetic model and use this model to design the reactors used for Fluid-Fluid reactions.

**Course Outcomes:**

- Students will be able to understand the concept of Residence Time Distribution (RTD) in various reactors and obtain the actual design parameters to design Real Reactor.
- Students will be able to find the model equation and use this model to design the reactors used for heterogeneous non catalytic reactions.
- Students will be able to apply the knowledge they have gained to develop kinetic model and Design strategy for heterogeneous catalytic reactions.
- Students will be able to apply the knowledge they have gained to develop kinetic model and use this model to design the reactors used for Fluid-Fluid reactions.

| Module | Content | Contact Hours |
|---|---|---|
| 1 | **Non Ideal flow reactors:** Concept of residence time distribution (RTD), Measurement and characteristics of RTD, RTD in Ideal batch reactors, Plug Flow Reactor and CSTR. Zero Parameter Model – Segregation and Maximum mixedness model. One parameter model–Tanks in series model and Dispersion Model. Effect of dispersion on conversion for general irreversible reaction case, Diagnostic methods of analysis of flow patterns in reactors, Role of micro and macro mixing and segregation in ideal (MFR, PFR) and non ideal reaction cases. | 12 |
| 2 | **Non Catalytic heterogeneous Reactions:** **Kinetics:** General mechanism of reaction. Various models. Specific cases with respect: (a) Film diffusion controlling. | 10 |

| | | |
|---|---|---|
| | (b) Ash diffusion controlling. (c) Chemical reaction controlling.<br>**Design of reactors for non-catalytic reactions**: Experimental reactors for heterogeneous Reactions, Non-Catalytic Fluid Solid Reactions in Flow Reactor. Application to design of continuous solid flow reactors; various design considerations, Application of fluid bed reactors and their design consideration. | |
| **3** | **Kinetics and mechanism** of various Heterogeneous reactions and design consideration of reactors used during different operating conditions.<br>**Catalytic heterogeneous reactions**: Properties of solid catalysts, Physical adsorption and Chemisorption, Surface area and pore size distribution, Langmuir-Hinshelwood model, and General mechanism of solid catalyzed fluid phase reactions. Special cases when (a) Film resistance controls. (b) Surface phenomenon controls. (c) Surface reaction controls (d) Pore diffusion controls.<br>Concept of effectiveness factor of catalyst and its dependence on catalyst properties and kinetic parameters. Numericals based on physical properties of catalyst, Derivations for LHHW model mechanism-various cases, Effectiveness factor. Numericals based on kinetics<br>**Introduction to Catalytic Reactors**: Packed Bed Reactor Fluidized Bed, Trickle Bed and Slurry Reactor. Numericals based on Design of Packed Bed Reactor (Calculation of weight/volume of catalyst). | **12** |
| **4** | **Kinetics of fluid-fluid reactions**: Reaction with mass transfer, the rate equation pertaining to fast to very slow reactions.<br>**Applications to design:** Design of gas-liquid, liquid-liquid and gas liquid-solid reactors- Heterogeneous reactors, Bubble heterogeneous reactors, co-current and counter-current flow packed bed reactors. | **10** |

**Assessment**

**Internal**

- Assessment consists of average of two tests which should be conducted at proper interval

**End Semester Theory Examination**:

- Question paper will be comprises of six questions, each carrying 20 Marks.
- Total 4 questions need to be solved.
- Question no. 1 will be compulsory and based on entire syllabus wherein sub-questions can be asked.
- Remaining questions will be randomly selected from all the modules.

- Weightage of marks should be proportional to number of hours assigned to each module.

**References**

1. Levenspiel O., Chemical Reaction Engineering, John Wiley&Sons,3rd ed.,1999.
2. Smith J.M., Chemical Reaction Engineering, 3rd ed., TataMcGrawHill,1980.
3. Fogler, H.S. Elements of Chemical Reaction Engineering, 4th ed.,PHI, 2008
4. HillC. G., Chemical Reaction Engineering.
5. Walas, Reaction Kinetics for Chemical Engineers, McGraw Hill, 1959.

| Course Code | Course/Subject Name | Credits |
| --- | --- | --- |

| CHC605 | Plant Engineering and Industrial Safety | 4 |
|---|---|---|

**Prerequisites:**

- Knowledge of Process Calculations, Thermodynamics and Fluidflow.

**Course Objectives:**

- At the end of the course the students should understand the knowledge of industrial safety, plant utilities.
- They should able to understand industrial accidents and hygiene, hazards and risk analysis.
- They should able to understand various types of steam generators, its performance.
- They should be able to understand various properties of compressed air, air drying methods, study different types of compressors and calculate the power required by compressors.
- They should understand how to select vacuum system.

**Course Outcomes**

- Students should be able to identify the causative and initiating factors of accidents. They should be able to make quantitative assessment of vapour release and noise impact.
- Students should be able to understand and evaluate situations causing industrial fire and evaluate risk. .
- Students should learn and understand type of boilers and be able to calculate its efficiency.
- Students should be able to calculate work requirements for compressors and draw schematic of instrument air, plant air and venting system.

| Module | Contents | Contact Hours |
|---|---|---|
| 1 | Industrial Accidents: Causative and initiating factors of accidents. Identifying the causative and initiating factors of Industrial accidents, case studies. | 3 |
| | Industrial Hygiene. Definition and evaluation of toxicity and noise | 5 |
| | Ventilation. Local Ventilation, Dilution Ventilation. Problems on Ventilation airflow. | 1 |
| 2 | Fire. Fire triangle, Flammability characteristics of liquids and gases, Limiting oxygen concentration, ignition energy, auto ignition, auto oxidation, adiabatic compression. Ignition sources, spray and mist. | 2 |
| | Explosion: Detonation, Deflagration, Confined explosion, unconfined explosion, VCE, BLEVE, Problems on energy of chemical explosion. | 5 |
| | Types of relief systems | 2 |
| | HAZOP, How to do a HAZOP. HAZOP Checklist. | 2 |
| | Risk assessment: Event tree analysis, Fault tree analysis. | 2 |

| | | |
|---|---|---|
| **3** | Steam generators:<br>Properties of steam, Use of steam tables, Steam generators, Classification of boilers, Study of high pressure boilers, boiler mountings and accessories.<br>Performance of steam generators. Distribution of steam in plant; Efficient use of steam, steam traps. | **8** |
| **4** | Air:<br>Reciprocating compressors, work calculations, PV Diagrams, Two stage compression system with intercooler, problems of work and volumetric efficiency. Instrument Air System, Process Air System, Vacuum producing devices | **6** |

**Term Work**

Term work shall consist of minimum eight tutorials (two from each module) from entire syllabus which are to be given at regular intervals Batch wise.

Tutorials: 20 Marks

Attendance: 05 Marks

Total: **25 Marks**

**Assessment**

**Internal:**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**References**


1. Crowl, D. A. and Louvar, J. P.; Chemical Process Safety: Fundamentals with Applications; Prentice Hall, Englewood
2. Khurmi, R. S. and Gupta, J. K. A textbook of thermal Engineering, S. Chand.
3. Rajput, R.K .A textbook of Power Plant Engineering. Laxmi Publications (P) Ltd., Navi Mumbai.
4. K. S. N. Raju, Chemical Process Industry Safety, McGraw Hill Education.

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHDE6021** | **Department Elective II -Computational Fluid Dynamics** | **04** |

**Prerequisites:**

- Linear Algebra
- Partial Differential Equations
- Scilab or Python

**Course Objectives:**

- To understand the formulation of CFD problems
- To discretize the problems
- To solve the set of equations in simple cases using Scilab routines.
- To understand and use software in CFD

**Course Outcomes:**

- The student will be able to obtain flow profiles for some simple applications using Scilab.
- The student will be able to use appropriate software for solving realistic problems.

| Module | Contents | Contact Hours |
|---|---|---|
| **1** | Module: Introduction<br>Contents: Advantages of Computational Fluid Dynamics<br>Typical Practical Applications<br>Equation Structure<br>Overview of CFD | **02** |
| **2** | Module: Preliminary Computational Techniques<br>Contents: Discretisation<br>Approximation to Derivatives<br>Accuracy of the Discretisation Process<br>Wave Representation<br>Finite Difference Method | **04** |
| **3** | Module: Theoretical Background<br>Contents: Convergence<br>Consistency<br>Stability<br>Solution Accuracy<br>Computational Efficiency | **06** |
| **4** | Module: Weighted Residual Methods<br>Contents: General Formulation<br>Least Squares, Galerkin and Sub domain Formulations.<br>Weak form of Galerkin Method | **08** |
| **5** | Module: Finite Element Method<br>Contents: Piece-wise Continuous Trial Functions<br>One Dimensional Linear and Quadratic Elements | **08** |

| | | |
|---|---|---|
| | One Dimensional Heat Transfer<br>Tri-diagonal Matrix Algorithm | |
| **6** | Module: Two Dimensional Elements<br>Quadrilateral Elements<br>Steady State Heat Transfer in Two Dimensions<br>Alternating Direction Implicit Method<br>Potential Flow in Two Dimensions | **08** |
| **7** | Module: Finite Volume Method<br>One Dimensional Diffusion<br>Two Dimensional Diffusion<br>Diffusion With Convection and The Upwind Scheme | **06** |
| **8** | Module: Pressure Velocity Coupling in Steady Flows<br>The Staggered Grid<br>The Momentum Equation<br>The Simple Algorithm | **06** |

**Assessment**

**Internal**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**Text Books**

1. C.A.J. Fletcher; Computational Techniques for Fluid Dynamics 1; Springer-Verlag Berlin Heidelberg GmbH
2. P. Seshu; Textbook of Finite Element Analysis; PHI Learning Private Limited, New Delhi
3. H.K. Versteeg and W. Malalasekera; An Introduction To Computational Fluid Dynamics; Longman Scientific & Technical

**References**

1. John D. Anderson; Computational Fluid Dynamics; McGraw Hill Education Private Limited

| Course Code | Course/ Subject Name | Credits |
|---|---|---|
| **CHDE6022** | **Department Elective II -Operations Research** | **4** |

**Prerequisites:**

- Linear Algebra
- Computer Programming

**Course Objectives:**

- To understand Linear Programming and its applications to OR models.
- To understand and solve network models in OR.
- To understand Game theory and its applications.
- To study and design Queuing systems.

**Course Outcomes:**

- The student will be able to solve typical OR models using linear integer and dynamic programming techniques.
- The student will be able to model and solve network flow problems in OR.
- The student will be able to make decisions under various scenarios.
- The student will be able to design Queuing Systems.

| Module | Contents | Contact Hours |
|---|---|---|
| **1** | Module: Linear Programming<br>Contents: Introduction<br>Graphical Method of Solution<br>Simplex Method<br>Two-Phase Method<br>Duality<br>Dual Simplex<br>Revised Simplex | **10** |
| **2** | Module: Transportation Models<br>Contents: Examples of Transportation Models<br>The Transportation Algorithm<br>The Assignment Model<br>The Transshipment Model | **06** |
| **3** | Module: Network Models<br>Contents: Scope and Definition of Network Models<br>Minimal Spanning Tree Algorithm<br>Shortest Route Problem<br>Maximal Flow Model | **06** |
| **4** | Module: Integer and Dynamic Programming<br>Contents: Branch and Bound Method<br>Travelling Salesman Problem<br>Introduction to Dynamic Programming<br>Forward and Backward Recursion<br>Selected Applications | **06** |

| | | |
|---|---|---|
| **5** | Module: Deterministic Inventory Models<br>Contents: Classic EOQ Model<br>EOQ with Price Breaks<br>Dynamic EOQ Models<br>No-Setup Model<br>Setup Model | **06** |
| **6** | Module: Decision Analysis and Game Theory<br>Contents: Decision Making under Certainty<br>Decision Making under Risk<br>Decision Under Uncertainty<br>Game Theory | **06** |
| **7** | Module: Queuing Systems<br>Contents: Elements of a Queuing Model<br>Role of Exponential Distribution<br>Pure Birth and Death Models<br>Generalized Poisson Queuing Model<br>Measures of Performance | **08** |

**Assessment**

**Internal**

- Assessment consists of two tests which should be conducted at proper intervals.

**End Semester theory examination**

- Question paper will comprise of 6 questions each carrying 20 questions.
- Total 4 questions need to be solved
- Question no.1 will be compulsory based on entire syllabus wherein sub questions can be asked.
- Remaining questions will be randomly selected from all the modules
- Weightage of marks should be proportional to number of hours assigned to each module

**Text Books**

1. Operations Research; Hamdy A. Taha; Eighth Edition; Prentice Hall India

**References**


1. Hillier and Lieberman; Introduction to Operations Research


| Course Code | Course/ Subject Name | Credits |
|---|---|---|

| CHDE6023 | Department Elective II -Biotechnology | 04 |
|---|---|---|

## Prerequisites

- Knowledge of biology, chemistry, chemical engineering

## Course Objectives

- At the end of the course the students should understand the basic concept of biotechnology. They should be able to classify micro-organisms, understand cell structure and basic metabolism.
- They should be able to understand basic knowledge about biological polymers.
- They should be able to understand basic knowledge about enzyme technology.
- They should understand role of biotechnology in medical field and industrial genetics.
- They should know importance of biotechnology in agricultural, food and beverage industries, environment, energy and chemical industries.
- They should understand to how to recover biological products.

## Course Outcomes

- Students will demonstrate the knowledge of biotechnology in various fields.
- Students will know cell and metabolism.
- Students will have deep knowledge of biological polymers.
- Students will have deep knowledge of enzymes.
- Students will able to know about other uses of biotechnology in medical/pharmaceutical field and industrial genetics.
- Students will be able to understand how biotechnology helps in agricultural, food and beverage industry, chemical industries, environment and energy sectors.
- Students will be able to understand how biological products are recovered.

| Module | Contents | Contact Hours |
|---|---|---|
| 1 | **Introduction:** Traditional and modern applications of biotechnology. Classification of micro-organisms. Structure of cells, types of cells. Basic metabolism of cells. Growth media. Microbial growth kinetics. | 7 |
| 2 | **Biological polymers:** Lipids, Proteins, Amino acids, Nucleic acids, Carbohydrates, Macronutrients and micronutrients. | 6 |
| 3 | **Enzyme Technology:** Nomenclature and classification of enzymes. Enzyme kinetics. Michaels Menten Kinetics, Immobilized enzyme kinetics, Immobilization of enzymes. Industrial applications of enzymes. The technology of enzyme production | 7 |
| 4 | **Biotechnology in health care and genetics:** Pharmaceuticals and bio-pharmaceuticals, antibiotics, vaccines and monoclonal antibodies, gene therapy. Industrial genetics, protoplast and cell fusion technologies, genetic engineering& protein engineering, Introduction to Bio-informatics. Potential lab biohazards of genetic engineering. Bioethics. | 10 |
| 5 | **Applications of biotechnology:** Biotechnology in agriculture, food and beverage industries, chemical industries, environment and energy sectors. | 8 |
| 6 | **Product recovery operations:** Dialysis, Reverse osmosis, ultrafiltration, microfiltration, chromatography, electrophoresis, | 10 |

| | | |
|---|---|---|
| | elecrodialysis, crystallization and drying. | |

**Assessment**

**Internal**

- Assessment consists of average of two tests which should be conducted at proper interval

**End Semester Theory Examination:**

- Question paper will comprise of 6 questions, each carrying 20 marks.
- Total 4 questions to be solved
- Question no.1 will be compulsory and based on entire syllabus where in sub questions can be asked.
- Remaining questions will be randomly selected from all the modules.
- Weightage of marks should be proportional to number of hours assigned to each module.

**Reference Books**


1. Shuller M.L. and F. Kargi. 1992. Bioprocess Engineering, Prentice-Hall, Englewood Cliffs,NJ.
2. Bailey. J.E. and Ollis D.F. 1986, Biochemical Engineering Fundamentals, 2 nd Edition, McGraw Hill, New York.
3. Kumar H.D., Modern Concepts of Biotechnology, Vikas Publishing House Pvt. Ltd.
4. Gupta P.K., Elements of Biotechnology, Rastogi Publications
5. Inamdar, Biochemical Engineering, Prentice Hall of India.


| Course Code | Course/ Subject Name | Credits |
|---|---|---|

| CHL601 | Chemical Engineering Lab VII (EE) | 1.5 |
|---|---|---|

**Concept for Experiments**

Students should be able to apply the Environmental Engineering concepts to control and management of various types of pollutants. A minimum of TEN experiments must be performed on following concepts:

- Physical characterization (TDS /turbidity measurement) of waste water.
- Chemical characterization (chloride ion, sulphate ion etc.) of waste water.
- Determination of organic matters (dissolved oxygen) in waste water.
- Sampling measurement and standard of water quality (determination of BOD).
- Sampling measurement and standard of water quality (determination of COD).
- Determination of toxic matters (phenol, chromium etc.) in waste water.
- Determination of inorganic matters (heavy metal) in waste water.
- Measurement of particulate matter in air.
- Measurement of gaseous pollutant (any one) in air.
- Measurement of various types of residues or solids in the given sample.
- Measurement of sound level.

**Term work**

Term work shall be evaluated based on performance in practical.

Practical Journal: 20 marks
Attendance: 05 marks
**Total: 25 marks**

**Practical Examination**

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight out of ten experiments.

| **Course Code** | **Course/ Subject Name** | **Credits** |
|---|---|---|

| CHL602 | Chemical Engineering Lab VIII (MTO II) | 1.5 |
|---|---|---|

**Concept for Experiments**

A minimum of TEN experiments must be performed on following concepts:

- Verification of Rayleigh Equation.
- To determine the percentage recovery of solute by solid liquid leaching operation (multistage crosscurrent).
- To determine the vapour-liquid equilibrium curve.
- To find out distribution coefficient. [eg. acetic acid between water and toluene]
- To verify Freundlich adsorption isotherm
- To find the yield of crystals in batch crystallizer.
- To prepare the ternary phase diagram of Binodal solubility curve and tie line relationship for ternary system
- To study distillation at total reflux in a packed column.
- To determine the efficiency of steam distillation
- To study the performance of Swenson Walker crystallizer and also to determine the yield.
- To carry out multistage cross current operation in liquid liquid extraction and compare with single stage operation
- To carry out multistage cross current adsorption and compare with single stage operation.

**Term work**

Term work shall be evaluated based on performance in practical.

| | |
|---|---|
| Practical Journal: | 20 marks |
| Attendance: | 05 marks |
| **Total:** | **25 marks** |

**Practical Examination**

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight out of ten experiments.

| Course Code | Course/ Subject Name | Credits |
|---|---|---|

| CHL603 | Chemical Engineering Lab IX (CRE II) | 1 |
|---|---|---|

**Concept for Experiments**

Minimum 10 experiments need to be performed by the students on following concepts:

1. Residence Time Distribution (RTD) In Continuous Stirred Tank Reactor (CSTR)- Pulse Input
2. Residence Time Distribution (RTD) In Plug Flow Reactor (PFR) – Pulse Input
3. Residence Time Distribution (RTD) In Packed Bed Reactor (PBR) – Pulse Input
4. Residence Time Distribution (RTD) In Continuous Stirred Tank Reactor (CSTR) – Step Input
5. Residence Time Distribution (RTD) In Plug Flow Reactor (PFR) – Step Input
6. Void volume, Porosity and solid density of catalyst
7. Semibatch reactor
8. Solid fluid heterogeneous non – catalytic reaction
9. Soli fluid Heterogeneous catalytic reaction.
10. Study of adsorption isotherm
11. Adiabatic batch reactor

**Term work**

Term work shall be evaluated based on performance in practical.

Practical Journal: 20 marks
Attendance: 05 marks
**Total: 25 marks**

**Practical Examination**

- Duration for practical examination would be the same as assigned to the respective lab per week.
- A student becomes eligible for practical examination after completing a minimum of eight out of ten experiments.