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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 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)

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
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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**: 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. **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:** **Primary treatment**: pre-treatment, settling tanks and their sizing. **Secondary treatment**: micro-organisms growth kinetics, aerobic biological treatment, activated sludge process, evaluation of bio-kinetic parameters, trickling filters, sludge treatment and disposal. **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:** Source correction methods for air pollution control, Cleaning of gaseous effluents, Particulate emission control, Equipment, system and processes for. ----Particulate pollutants: gravity settler, cyclones, filters, ESP, scrubbers etc. ----Gaseous pollutants: scrubbing, absorption, adsorption, catalytic conversion.	**8**
6	**Solid Waste Management:** Solid waste including plastic, nuclear and hazardous waste management, E waste management	**3**
7	**Noise Pollution:** 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:** Representation of Equilibria, Single stage leaching, Multistage Cross Current Leaching, Multistage Counter Current Leaching, Equipments for Leaching.	06
4	**Adsorption and Ion Exchange:** 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:** 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:** 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. **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. **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. 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 **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. **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: Properties of steam, Use of steam tables, Steam generators, Classification of boilers, Study of high pressure boilers, boiler mountings and accessories. Performance of steam generators. Distribution of steam in plant; Efficient use of steam, steam traps.	**8**
4	Air: 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 Contents: Advantages of Computational Fluid Dynamics Typical Practical Applications Equation Structure Overview of CFD	**02**
2	Module: Preliminary Computational Techniques Contents: Discretisation Approximation to Derivatives Accuracy of the Discretisation Process Wave Representation Finite Difference Method	**04**
3	Module: Theoretical Background Contents: Convergence Consistency Stability Solution Accuracy Computational Efficiency	**06**
4	Module: Weighted Residual Methods Contents: General Formulation Least Squares, Galerkin and Sub domain Formulations. Weak form of Galerkin Method	**08**
5	Module: Finite Element Method Contents: Piece-wise Continuous Trial Functions One Dimensional Linear and Quadratic Elements	**08**

	One Dimensional Heat Transfer Tri-diagonal Matrix Algorithm	
6	Module: Two Dimensional Elements Quadrilateral Elements Steady State Heat Transfer in Two Dimensions Alternating Direction Implicit Method Potential Flow in Two Dimensions	**08**
7	Module: Finite Volume Method One Dimensional Diffusion Two Dimensional Diffusion Diffusion With Convection and The Upwind Scheme	**06**
8	Module: Pressure Velocity Coupling in Steady Flows The Staggered Grid The Momentum Equation 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 Contents: Introduction Graphical Method of Solution Simplex Method Two-Phase Method Duality Dual Simplex Revised Simplex	**10**
2	Module: Transportation Models Contents: Examples of Transportation Models The Transportation Algorithm The Assignment Model The Transshipment Model	**06**
3	Module: Network Models Contents: Scope and Definition of Network Models Minimal Spanning Tree Algorithm Shortest Route Problem Maximal Flow Model	**06**
4	Module: Integer and Dynamic Programming Contents: Branch and Bound Method Travelling Salesman Problem Introduction to Dynamic Programming Forward and Backward Recursion Selected Applications	**06**

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