SCHEME & SYLLABUS OF

VII & VIII SEMESTERS

[for 2020 admitted batch, 175 credit course]

B.E. CHEMICAL ENGINEERING

2023 - 2024

About Institute:

Siddaganga Institute of Technology (SIT) was established in the year 1963 by Siddaganga Education Society, as a private self-financing institution with the following vision and mission.

Vision of the Institute:

To develop thoughtful and creative young minds in a learning environment of high academic ambience by synergizing spiritual values and technological competence.

Mission of the Institute:

- To continuously strive for the total development of students by educating them in state-of-the art technologies and managerial competencies providing best in class learning experience with emphasis on skills, values and learning outcomes and helping them imbibe professional ethics and societal commitment.
- To create research ambience that promotes interdisciplinary research catering to the needs of industry and society.
- To collaborate with premier academic and research institutions and industries to strengthen multidisciplinary education, applied research, innovation, entrepreneurship and consulting ecosystems.

Quality Policy:

Siddaganga Institute of Technology is committed to:

- Impart quality education by establishing effective learning-teaching – learning processes to produce competent engineers with high professional ethics and social responsibility.
- Create congenial environment and provide state-of-the-art infrastructure.
- Continually improve the effectiveness of the quality management system.
- Satisfy all applicable requirements.

Vision of the Department:

To be an internationally renowned department for chemical engineering education and research meeting the aspirations of society.

Mission of the Department:

M1. To impart quality education in chemical engineering at all levels.

M2. To foster cutting edge research and development in chemical engineering. M3. To produce responsible and ethical engineers to serve society.

Program Educational Objectives (PEOs)

The Program Educational Objectives of the program are:

The graduates shall possess

1. a sound knowledge of chemical engineering to pursue

a successful professional career.

2. a spirit of inquiry and urge to pursue research in chemical engineering and thrust areas.
3. high ethical values and be socially responsible in discharging their duties.
4. knowledge of the latest developments in their field of activity and commit themselves to life-long learning.

Program Specific Outcomes (PSOs):

The following are the PSOs defined by the Chemical Engineering department: PSO-1: Graduates will be able to apply the knowledge of science and transport process for production and separation of chemicals in chemical and allied industries

PSO-2: Graduates will be able to analyze processes/equipment taking into consideration, process safety, project engineering, economics and environmental aspects.

PSO-3: Graduates will be able to analyze processes using process control, process optimization and integration using modelling/simulation tools for process development

PSO-4: Graduates will be able to design chemical equipment for a given process.

Program Outcomes:

The following are the Program Outcomes:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

The above POs are achieved through curriculum that offers courses under mathematics and basic sciences, basic engineering courses, professional core, professional electives, laboratory courses, open electives, humanity courses, projects, technical seminar and the industrial training and mandatory courses. Each course under these course components have COs that are mapped to the POs. The attainment of POs is achieved through attaining the COs.

SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU

(An autonomous institute affiliated to Visvesvaraya Technological University, Belagavi, Approved by AICTE, New Delhi)

SCHEME OF TEACHING AND EXAMINATION [for 2020 batch, A. Y. 2023-2024]

7th Semester

SL No.	Course	Course Code	Course Title	Teaching Department	Teaching hrs/week			Examination				Credits
					Theory lecture	Tutorial	Practical/ Drawing	Duration in hrs.	SEE Marks	CIE Marks	Total Marks	
1	PC	7RCH01	Transport Phenomena	Chemical	4	1	--	3	50	50	100	**4.5**
2	PC	7RCH02	Computer Applications & Modelling in Chemical Engineering	Chemical	4	--	--	3	50	50	100	**4.0**
3	PE	7RCHE3	Professional Elective – 3	Chemical	3	--	--	3	50	50	100	**3.0**
4	OE		Open Elective – 3	OD	3	--	--	3	50	50	100	**3.0**
5	PCL	7RCHL1	Computer Applications & Simulations Lab	Chemical	--	--	3	3	50	50	100	**1.5**
6	Project	7RCHMP1	Project Work Phase – 1	Chemical	--	--	4	--	--	100	100	**2.0**
7	INT	7RCHIT1	Internship	Chemical				--	--	100	100	**2.0**
8	Seminar	7RCHTS1	Technical seminar	Chemical	--	--	2	--	---	100	100	**1.0**
9	Research	7RCHRW	Research work (optional)	Chemical	--	--	24	--	---	50	50	**6.0**
				Total	**14**	**01**	**33**	**15**	**250**	**550**	**800**	**21.0**

Student has to complete Internship for minimum 4 weeks in intervening vacation of either 4th to 5th Semester or 6th to 7th Semester.

Examination of Internship will be conducted at the end of 7th Semester.

Technical Seminar has to be carried out under the Supervision and Guidance of Major Project Work Guide.

No SEE for Project Work Phase – 1, Internship, Technical Seminar

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SCHEME OF TEACHING AND EXAMINATION [for 2020 batch, A. Y. 2023-2024]

8th Semester

SL No.	Course	Course Code	Course Title	Teaching Department	Teaching hrs/week			Examination				Credits
					Theory lecture	Tutorial	Practical/ Drawing	Duration in hrs.	SEE Marks	CIE Marks	Total Marks	
1	PE	8RCHE4	Professional Elective – 4	Chemical	3	--	--	3	50	50	100	**3.0**
2	PE	8RCHE5	Professional Elective – 5	Chemical	3	--	--	3	50	50	100	**3.0**
3	PE	8RCHE6	Professional Elective – 6	Chemical	3	--	--	3	50	50	100	**3.0**
4	Project	8RCHMP1	Project Work Phase – 2	Chemical	--	2	16	3	50	50	100	**9.0**
				Total	**09**	**02**	**16**	**12**	**200**	**200**	**400**	**18.0**

SUMMARY OF CREDITS DISTRIBUTION		CIE EVALUATION SCHEME	
SEMESTER	**CREDITS**	**Evaluation**	**Marks Distribution**
I	21.00	Test 1/ Test 2 (50 Marks Each)	16x2= 32
II	19.00	Assignment 1/ Assignment 2 (15 Marks each)	03x2=06
III	24.00	Quiz 1 (20 Marks)	02x1=02
IV	24.00	**Total**	**40**
V	24.00	**Assignments:** Should be group assignments **(Max10 Students)** on Complex Engineering Problems addressing minimum 3 Graduate Attributes.	
VI	24.00	**Quiz:** After the Test 2. MCQ Type	
VII	21.00		
VIII	18.00		
Total	**175.00**		

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DEPARTMENT OF CHEMICAL ENGINEERING

7th & 8th Semester , B.E. - Chemical Engineering

Professional Electives

Elective - 3 [2020 batch - VII sem]		**Elective - 5 [2020 batch - VIII SEM]**	
7RCHE31	Biochemical Engineering	8RCHE51	Pilot plant and Scale up Methods
7RCHE32	Project Engineering and Financial Management	8RCHE52	Nanomaterials
7RCHE33	Design of Process Equipment	8RCHE53	Waste Water Treatment Methods
Elective - 4 [2020 batch - VIII sem]		**Elective - 6 [2020 batch - VIII SEM]**	
8RCHE41	Optimization of Chemical Processes	8RCHE61	Petrochemicals
8RCHE42	Surface and Interfacial Engineering	8RCHE62	Green Chemical Engineering
8RCHE43	Polymer Technology	8RCHE63	Solid Waste Management

2020 batch	
SEM	CREDIT
I	21.0
II	19.0
III	24.0
IV	24.0
V	24.0
VI	24.0
VII	21.0
VIII	18.0
Total	**175.0**

VII SEMESTER

TRANSPORT PHENOMENA

Contact Hours/ Week	: 4+1+0 (L+T+P)	Credits :	4.5
Total Lecture Hours	: 52	CIE Marks :	50
Total Tutorial Hours	: 13	SEE Marks :	50
Sub. Code	: 7RCH01		

Course Objectives:

This course will enable students to:

1. Introduce the concept & steps in model building for transport processes
2. Learn about first principles, empirical models and build models for engineering processes
3. Acquaint with analogies between heat, momentum and mass transfer.
4. Develop equation of continuity and equation of motion, heat and mass transfer expression for various processes and equipment
5. Educate students about application of modeling techniques to latest and emerging processes and equipment.

Unit - I

Viscosity and the mechanism of Momentum Transport: Newton's law of viscosity (NLV), newtonian and non - newtonian fluids, effect of temperature and pressure on viscosity of fluids. Numerical problems on the application of Newton's law of viscosity.

Velocity distribution in Laminar Flow: Steady state shell momentum balance, general boundary conditions applicable to momentum transport problems of Chemical Engineering. The flow situations for a) flow over a flat inclined plate, b) flow through a circular tube, c) flow through annulus, d) flow between parallel plate and through a slit for laminar flow are required. Simple numerical problems using the equations derived in the above fluid flow situations.

12 + 2 Hrs

Unit - II

Thermal Conductivity and mechanism of Energy Transport: Fourier law of heat conduction. Temperature and pressure dependence on thermal conductivity of solids and fluids. Numerical problems on the application of fourier's law of heat conduction.

Temperature Distribution in solids and in Laminar Flow: Steady state shell energy balances. General boundary conditions applicable to the heat conduction problems of Chemical Engineering for, a) heat conduction with internal generation by electrical, nuclear, viscous b) heat conduction through compound walls, overall heat transfer coefficient, c) heat conduction in a cooling fin : Forced and Free conduction heat transfer problems (only derivations)

12 + 3 Hrs

Unit - III

Diffusivity and mechanism of Mass Transport: Fick's law of diffusion, Effect of temperature and pressure on diffusivity in liquid and gases.

Concentration Distributions in solids and in Laminar Flow: Steady state shell mass balance, General boundary conditions applicable to the mass transport problems of chemical engineering, on a) Diffusion through stagnant gas and liquid film b) Equimolar counter diffusion c) Diffusion with homogeneous and heterogeneous reaction d) Diffusion into falling film-forced convection mass transfer. **Note:** In all above one-dimensional problems only to be considered)

12 + 3 Hrs

Unit - IV

Analogies between Momentum, Heat and Mass Transport: Numerical problems using analogies. a) Reynolds analogy b) Prandtl's analogy c) Chilton and Colburn analogy & d) Martinnelli's analogy.

8 + 3 Hrs

Unit - V

Equations of Change: Equation of continuity, equation of motion and Navier-Stokes equation, Application of this equation in solving simple steady problems previously solved.

8 + 2 Hrs

TEXTBOOKS:

Bird, Stewart and Lightfoot	"Transport Phenomena",. John Wiley, 2e , 2006, ISBN: 978-8126508082.
Wilke, Wikcs and Watson	"Fundamentals of Momentum, Heat and Mass Transfer", John Wiley, 5e , 2010, ISBN: 978-8126528387

REFERENCE BOOKS:

Robert S. Brodkey and Harry C. Hershey	"Transport Phenomena Unified Approach", Brodkey Publishing 2003, ISBN: 978-0070079632
Raj B	"Introduction to Transport Phenomena: Momentum, Heat and Mass", Prentice Hall India Learning Private Limited, 1e, 2012, ISBN: 978-8120345188

Course Outcomes:

After the completion of the course, the student will be able to:

1. Apply the fundamental knowledge of science and engineering to formulate transport process expressions and solve those equation

using first principles.
2. Derive the solutions of steady and unsteady-state transport processes and analyse the obtained mathematical solutions.
3. Apply the analogies of momentum, heat and mass transfer and interpret the results.
4. Formulate continuity, motion, heat and mass transfer equations, for real life transport problems related to chemical and biological systems.
5. Demonstrate life long learning by application of transport process principles for emerging and novel processes

COMPUTER APPLICATIONS AND MODELLING IN CHEMICAL ENGINEERING

Contact Hours/ Week	: 4 +0+0(L+T+P)	Credits :	4.0
Total Lecture Hours	: 52	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 7RCH02		

Course Objectives:

This course will enable students to:
1. Adopt appropriate numerical methods to solve non-linear algebraic and transcendental equations, ordinary differential equation and calculate a definite integral; develop C-program to perform the numerical solution to a chemical engineering problem.
2. Apply C program principles to determine the bubble point and dew point temperature using Antoine equations; calculate the volume of reactors and time required for given conversion; and to evaluate adiabatic flame temperature using Newton Raphson method.
3. Use C program to design heat exchangers and distillation column.
4. Formulate and solve process design problems, apply appropriate mathematical model, and select an appropriate solution method to obtain required result.
5. Formulate and solve process design problems, based on fundamental analysis and using mathematical models of chemical processes.

Unit-I

Numerical Techniques: (Algorithm and C program)

Simultaneous linear algebraic equation- Gauss Jordan (material balance for distillation and mixing), Non-linear algebraic equation- Newton Raphson (Specific volume of binary mixture using real gas equations) Ordinary Differential Equation- R-K Method ($dC_A/dt = K\ Ca^2$) Numerical Integration-Simpson's 1/3rd Rule (Batch Reactor to find time) Curve Fitting- Least Square (Arrhenius).

8 Hrs

Unit - II

Applications: (Algorithm and C program) P – X,Y and T – X, Y evaluation Calculation of Bubble Point and Dew Point for Ideal multi-component system. Flash Vaporization for multi-component system Design of Adiabatic Batch Reactor, PFR, CSTR Adiabatic Flame Temperature. **14 Hrs**

Unit - III

Design: (Algorithm and C Program) Double pipe Heat Exchanger (Area, Length and Pressure drop) Shell Tube Heat Exchanger (Area, Number of tubes, Pressure drop) Distillation Column (Bubble cap-Stage wise calculation for binary mixture).

8 Hrs

Unit - IV

Modelling: Models and model building, principles of model formulations, precautions in model building, Fundamental laws: Review of shell balance approach, continuity equation, energy equation, equation of motion, transport equation of state equilibrium and Kinetics, classification ofmathematical models.

8 Hrs

Unit - V

Mathematical modeling and solution to Process Engineering Operations: Basic tank model -level v/s time, multi component flash drum, Batch distillation - Vapor composition with time, Batch reactor, Heat exchanger (co-current and counter current) - Steady state energy balance. **14 Hrs**

TEXTBOOKS:

1	Pradeep Ahuja	Introduction to Numerical Methods in Chemical Engineering, PHI Learning, 2010, 1e, ISBN: 9788120340183
2	Raul Raymond	Programming for Chemical Engineers Using C,C++ and MATLAB, 2010, 1e, ISBN:978-9380298207
3	William. L. Luyben	Process Modeling Simulation and Control forChemical Engineers, McGraw Hill, 2e, 1990 ISBN: 9780071007931
4	Kotur P. B.	Computer Concepts & C Programming, 23rd edition, 2013, ISBN: 9788128001109

REFERENCE BOOKS:

1	H. Scott Fogler	Elements of Chemical Reaction Engineering, Prentice Hall, 5e, 2015, ISBN: 9780133887518.
2	Smith J.M and H. C. Vanness	Introduction to Chemical Engg. Thermodynamics,McGraw Hill, 8e, 2017, ISBN: 9781259696527.
3	Amiya K. Jana	Chemical Process Modelling and Computer Simulation, PHI Learning Private Limited, 1e, 2017,ISBN-13: 978-9387472075

Course Outcomes:

After the completion of the course, the student will be able to:

1. Apply appropriate numerical methods and C programming skills to solving chemical engineering problems.
2. Develop an algorithm and program to evaluate bubble and dew point values for a given multicomponent mixture.
3. Develop an algorithm and C program to design heat exchanger, distillation column and reactor
4. Apply the principles of modelling and build models for process operations.
5. Develop mathematical models for process systems using modelling concept and physical laws.

PROFESSIONAL ELECTIVE-3 : BIOCHEMICAL ENGINEERING

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 7RCHE31		

Course Objectives: The objectives of the course are to:

1. Disseminate knowledge of microbiology, biochemistry, and chemical engineering concepts for industrial biotechnology applications.
2. Introduce the concepts of enzyme kinetics and cell growth kinetics in the context of Bioprocessing.
3. Describe the various downstream Bioprocessing methods and be able to choose the appropriate product recovery techniques.
4. Educate students about the latest and emerging bioprocess technologies relative to healthcare, agriculture, food, and energy.

Unit - I

Introduction to Biochemical Engineering: Role of chemical engineering in Bioprocessing.

Microbiology: Introduction to Prokaryotic and Eukaryotic cells, cellular machinery, nutritional requirements, microbial taxonomy. Industrially important organisms - Bacteria, Yeasts, Molds, Algae and Protozoa.

6 Hrs

Unit– II

Biochemistry: Chemicals of life – Lipids, sugars and polysaccharides; amino acids, proteins and enzymes; vitamins, biopolymers, nucleic acids (RNA, DNA) and their derivatives.

7 Hrs

Unit - III

Enzyme Catalyzed Reactions: Enzyme nomenclature, mechanism and kinetics using various models, evaluation of kinetic parameters, factors affecting enzyme activity: Effect of inhibitors, temperature, pH etc. Determination of kinetic parameters for various types of inhibitions. Batch and continuous enzyme reactor kinetics. Multi-substrate enzyme kinetics. Enzyme immobilization: Types, reaction kinetics and applications. **9 Hrs**

Unit - IV

Microbial Biomass and Product Formation: Cellular metabolism, quantification of cell concentration, growth cycle, cell growth kinetics in batch cultures, product formation, death kinetics, effect of pH, dissolved oxygen and temperature. Monod cell growth kinetics, substrate inhibition, kinetic models with growth inhibitors. Cell growth in continuous reactors - Chemostat for measurement of cell growth & product formation kinetics.

8 Hrs

Unit - V

Fermentation Technology: Ideal fermenters, medium formulation, operation and maintenance of typical aseptic aerobic fermentation processes, alternate bioreactor configurations, design of sterilization Equipment, introduction to Single-use technology for upstream Bioprocessing.

Downstream Processing: Steps involved in product recovery operations, typical operations involved – filtration, centrifugation, sedimentation, chromatography and emerging technologies including single-use systems, tangential-flow filtration, membrane chromatography. **9 Hrs**

TEXTBOOK:

Shuler, M.L., Kargi, F., and DeLisa M.P	"Bioprocess Engineering – Basic Concepts", Prentice-Hall Inc., Upper Saddle River, NJ, 3e,2017, ISBN: 978-0-13-706270-6

REFERENCE BOOKS:

Wei-Shou Hu	"Engineering Principles in Biotechnology", John Wiley & Sons, Inc., Hoboken, NJ, USA,1e, 2018, ISBN: 978-1-11-915904-9
Rao, D.G	"Introduction to Biochemical Engineering", Tata McGraw-Hill Education Pvt Ltd, New Delhi., 2e, 2010, ISBN: 0-07-015138-5
RegineEibl, DieterEibl	Eds. "Single-Use Technology in Biopharmaceutical Manufacture", John Wiley & Sons, Inc., Hoboken, NJ, USA, 2e, 2019, ISBN: 9781119477839

Course Outcomes:

After the completion of the course, the student will be able to:

1. Demonstrate the knowledge of biology, biochemistry, and chemical

engineering to formulate appropriate criteria for selecting bioprocess technologies.
2. Apply the concepts of enzyme and cell growth kinetics to analyze and derive rate equations for enzyme-based bioprocesses, fermentation and sterilization.
3. Analyze data including enzyme and cell growth kinetics and solve problems of upstream bio processing.
4. Demonstrate the knowledge of animal and plant cell biology to formulate appropriate criteria for selecting relevant bioprocess technologies and identify applications.
5. Demonstrate life-long learning of bioprocess technologies as emerging tools in the context of healthcare, agriculture, food and energy.

PROFESSIONAL ELECTIVE – 3: PROJECT ENGINEERING AND FINANCIAL MANAGEMENT

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 7RCHE32		

Course objectives:

This course will enable students to:

1. Acquire the knowledge about principles of project management and factors affecting site selection of a process plant.
2. Introduce to the concepts of cost estimation, cost index and different methods of cost estimation.
3. Acquire knowledge about the Project risk analysis and their types
4. Describe the time value of money, types of taxes, methods adopted for evaluation of profitability and replacement.
5. Educate students about application of the above principles of project management, risk analysis, financial analysis with respect to process or organization.

Unit – I

Projects and Project Management: The function of project management, Projects – management, initiation, risks, objectives, and success.

Project Site Considerations: Plant location and site selection, Site layout, Plant layout, Utilities, Environmental considerations.

7 Hrs

Unit – II

Analysis of Cost Estimation: Cash flow for industrial operations, Factors affecting investment and production costs, Capital investment, Estimation of capital investment, Cost indexes, Cost components in capital investment, Methods for estimating capital investment, Estimation of revenue, Estimation of total production cost, Gross profit, Net profit, and Cash flow, Contingencies.

8 Hrs

Unit – III

Project risk analysis: Sources, majors and prospective on risk, sensitivity analysis, scenario analysis, break-even analysis, simulation analysis, decision tree analysis, managing risk, project selection under risk, risk analysis in practice.

8 Hrs

Unit – IV

Interest, Time Value of Money, Taxes, and Fixed Charges: Interest, Cost of capital, Time value of money, Cash flow patterns, Compounding and discounting factors, Income taxes, Fixed charges.

Analysis of Financial Statements: Financial ratios, DuPont analysis, standardized financial statements, Applications of financial statement analysis. **8 Hrs**

Unit – V

Profitability, Alternative Investments, and Replacements: Profitability standards, Methods for calculating profitability, Alternative investments, Replacements, Practical factors in alternative investment and replacement analysis.

8 Hrs

TEXTBOOKS:

1	Ghattas, R.G.& Mc Kee, S.L.	"Practical Project Management",Pearson Education Asia, 1e, 2008, ISBN: 978-8131707418
2	Pinto, P.K.	"Project Management", Pearson Education,3e, 2012 ISBN: 9780273767428

REFERENCE BOOKS:

1	Prasanna Chandra.	Project Planning: Analysis, Selection, Implementation and Review, MC- Graw Hill Education, 8e, 2017, ISBN: 9789332902572.

Course outcomes:

After the completion of course, student will be able to :

1. Identify the principles governing a project and good factors influencing a plant location for a given process.
2. Apply the capital investment, cost index and cash flow principles to obtain a solution for a given conditions.
3. Identify the appropriate risk analysis criteria for a given project

4. Apply the knowledge of financial ratios, financial statement analysis, profitability standards and methods, alternative investments and replacement for a project under given constraints.
5. Understand the profitability standards and methods of calculating the profitability and alternative investments and replacements

PROFESSIONAL ELECTIVE-3 : DESIGN OF PROCESS EQUIPMENT

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Practice Hours	: 0	SEE Marks :	50
Sub. Code	: 7RCHE33		

Course Objectives:

This course will enable students to:

1. Application of standard design principles and method for the design of storage vessel and its accessories
2. Application of standard design principles and method for design of agitated reaction vessel
3. Application of standard design principles and methods for design of cooling tower and adsorption columns
4. Application of standard design principles for design of tall vertical vessel.
5. Acquire knowledge to design process equipment and components adopting design standards, rules of thumb, safety, environmental standards and local regulations for a given process

General Guidelines for the course:

1. Detailed Chemical Engineering Process Design of the following equipment needs to taught in the class.
2. Necessary aspects studied in "Chemical Equipment Design" is to be applied for mechanical design of system components.
3. Use of standard code books to be taught.

Unit -I

Design of Storage vessel. **8 Hrs**

Unit –II

Design of agitated reaction vessel. **8 Hrs**

Unit –III

Design of cooling tower. **7 Hrs**

Unit –IV

Design of adsorption column. **8 Hrs**

Unit – V

Design of tall vertical vessel. **8 Hrs**

Note for Semester End Examination: The question paper to contain **Two** full design problems (100 Marks each) for the equipment from the above list and student to answer anyone.

Perry's Chemical Engineer's Handbook shall be allowed in the examination as reference.
IS Code books shall be permitted in the examination hall.

The answer shall include detailed process design steps using the data given in the problem, mechanical design for components

TEXTBOOKS:

1	Prudich EM. et. al.,	Perry's Chemical Engineers Handbook, McGraw Hill, 8e, 2007, ISBN: 978-0071511438
2	Thakore S. B. &Bhatt B. I	Introduction to Process Engineering And Design, McGraw Hill Education, 2e, 2017, ISBN: 978-9351341789.

REFERENCE BOOKS:

1	Robert. E. Treybal	*Mass Transfer Operation"*, Mc Graw Hill, NY, 3e, 2012, ISBN: 9781259029158
2	Sinnott GavinTowler R.K	*Chemical Engineering*-Vol 6, Elsevier, 5e, 2005, ISBN-13: 978-9380501161
3	V.V. Mahajani & S.B. Umarji	Joshi's Process Equipment Design, LaxmiPublications, 5e, 2016, ISBN: 978-9351380191
4	S. D. Dawande	Process Design of Equipment–Vol 2, Central TechnoPublications, 2012, ISBN-13: 978-8189904425
5	Bhattacharyya	Introduction to Chemical Equipment Design: Mechanical Aspects, CBS Publishers, 1e, 2017, ISBN-13: 978-8123909455

Course Outcomes:

After the completion of the course, the student will be able to:

1. Demonstrate skill to design storage vessel and agitated vessel using Standard code for the prescribed condition
2. Demonstrate skill to design cooling tower depending on the psychometric condition and operational requirement
3. Design adsorption tower along with appropriate adsorbent for the

given operating conditions following design procedure.

4. Design of appropriate tall vertical tower depending on the local wind velocities and geographic location for given design restrictions.
5. Demonstrate reasonable skill to design process equipment and its components adopting design standards, rules of thumb, safety, environmental standards and local regulations for a given process

COMPUTER APPLICATIONS AND SIMULATION LAB

Lab Hours/ Week	: 0+0+3 (L+T+P)	Credits :	1.5
Sub. Code	: 7RCHL1	CIE Marks :	50
		SEE Marks :	50

Course Objectives:
This course will enable students to:

1. Identify applications of numerical techniques in solving chemical engineering problems.
2. Introduce to acquire skills required to write algorithm and execute program for estimation of Bubble point, Dew point, Flash vaporization point for a mixture and Adiabatic flame temperature of a burning flame.
3. Develop skill to write algorithm and write and execute program for elementary design of heat exchangers and distillation column.
4. Acquaint with usage of MATLAB for estimation of thermodynamic properties, rate constants of reactions and solve linear equations.
5. Familiarize in usage of simulation software for determination of thermo-physical properties of pure components, generation of VLE data of binary component system, heat exchanger and distillation column and flash drum
6. Develop skills in application of modern tools, ethics and team work by applying appropriate methodology to obtain best solution to a given operating conditions of a process or equipment.

PART A: C Program 30 marks

1. Application of Newton Raphson method for determining Specific volume of binary mixture.
2. Application of Runge-Kutta Method to find the concentration profile in a reactor.
3. Application of Simpson's 1/3rd for determining the time required for the given reaction in a Batch Reactor.
4. Estimation of Curve fitting by least square method (Re Vs. f).
5. Application of Newton Raphson method to find Bubble Point and Dew Point for Ideal multi-component system.
6. Application of Newton Raphson method to determine Flash Vaporization for multi-component system.
7. Application of Newton Raphson method to Design of Adiabatic Batch Reactor, PFR.

8. Application of Newton Raphson method to evaluate the Adiabatic Flame Temperature.
9. Design of Double pipe Heat Exchanger (Area, Length and Pressure drop).
10. Design of Distillation Column (Bubble cap).

Part B: MATLAB **20 Marks**

1. Determination of specific volume using Equation of state.
2. Estimation of the rate constants in a series reaction, each of first order kinetics.
3. Determination of heat to be removed in a crystallizer.
4. Solution to the system of linear equations using matrix inversion and matrix left division.

Simulation software

5. Introduction to suggested software available (flow sheeting)
6. Simulation Studies of flash drum, Distillation Column, CSTR, PFR
7. Process simulation study involving mixing, reactor, Distillation, Heat Exchanger for any of the following process:
   a. Ethylene Glycol from Ethylene oxide
   b. Atmospheric distillation of crude oil

NOTE:

- One question from PART – A Excluding Numerical Techniques – 30 marks
- One question from PART – B (Simulation of any above process) – 20 marks

SOFTWARE'S SUGGESTED:

1) C Program
2) DESIGN-II
3) MATLAB

TEXTBOOKS:

1	Pradeep Ahuja	Introduction to Numerical Methods in Chemical Engineering, PHI Learning, 2010, ISBN: 9788120340183
2	Myers, A.L and Seider. W.D	Introduction to Chemical Engineering and Computer Calculations", 1976, ISBN: 9780134792385

3	William. L. Luyben	Process Modeling Simulation and Control For Chemical Engineers, McGraw Hill, 2e, 1990 ISBN: 9780071007931.

REFERENCE BOOKS:

1	H. Scott Fogler	Elements of Chemical Reaction Engineering, Prentice Hall, 5e, 2015, ISBN: 9780133887518.
2	Smith J.M and H. C. Vanness	Introduction to Chemical Engg. Thermodynamics, McGraw Hill, 8e, 2017, ISBN: 9781259696527.
3	Amiya K. Jana	Chemical Process Modelling and Computer Simulation, PHI Learning Private Limited, 1e, 2017, ISBN-13: 978-9387472075
4	Kamal I. M. Al-Malah	MATLAB Numerical Methods with Chemical Engineering Applications, McGraw-Hill Education, 2013, ISBN: 9780071831291

Course Outcomes:

After the completion of the course, the student will be able to:

1: Apply appropriate numerical methods, C programming and MATLAB for solving chemical engineering problems.

2: Develop an algorithm, write and execute C program to design double pipe heat exchanger, distillation column.

3: Demonstrate skills in application of Design II simulation software to develop flow sheet for distillation column, PFR, CSTR and analyse the performance of the equipment

4. Develop flow sheet for production of ethylene glycol and atmospheric distillation column and evaluate its performance and validate the results

5. Demonstrate skills in application of modern tools, ethics and team work along with application of appropriate methodology to obtain best solution to a given operating conditions of a process or equipment

PROJECT WORK PHASE-I

Lab Hours/ Week:4	Credits	:	2.0
Subject Code: 7RCHMP1	CIE Marks	:	100
	SEE Marks	:	0

Course Objectives:

This course will enable students to:

1. Train the students to identify societal and industrial unmet needs needing chemical engineering solutions.
2. Introduce research methods including design of experiments and data analysis to provide valid conclusions after conducting investigations.

3. Guide students to develop process engineering solutions or design process equipment to the selected problem/unmet need.
4. Acquaint students to societal, health, safety, finance and legal issues in addition to responsibility to the professional engineering practice.
5. Teach modern engineering tools including process modelling, simulation and optimization to solve the selected problem.
6. Exemplify ethical behavior in the context of conduction of experiments, data analysis and reporting.
7. Train to function effectively as an individual, and as a member or leader in a team, and in multidisciplinary settings to solve problems within the area of expertise.
8. Give directions to students to evaluate and critically assess results and be able to document and present one's own work.
9. Illustrate the need for life-long learning including innovation and entrepreneurship.

Course Outline:

Students must identify an industrially or societally relevant problem and solve using chemical engineering principles and economics. This must be done in consultation with faculty of the department or a practicing chemical engineer from the industry. The students are advised to take up projects that can be performed using the facilities and infrastructure of the department and the institute. However, students are encouraged to think "out of the box" and take up challenging projects. If the projects are innovative and potentially has high impact, then the department would consider approving on a case by case basis. The department also encourages students to take up projects towards developing a "technology" or a "product". SIT's technology incubation centre will facilitate any subsequent commercialization. The major project can be performed by a team of 3 to 4 students. One or more faculty of the department can advise the project and can be performed within the department or in an Industry or a Research Institute. A co-guide from the Industry or Research Institute is also allowed.

The major project is evaluated over two semesters (VII and VIII). It carries 2 credits in the VII semester and is evaluated for 100 marks (100% CIE only). In the VIII semester, it carries 13 credits and evaluated for 100 marks [50% CIE & 50% SEE].

The project can be taken by group of 4 students and major project can be carried out in the dept. under a guide or out side the department in institute/ company with a guide from the dept. and co guide from the institute/ company.

Relevance of topic	10 marks
Report	20 marks
Evaluation by guide	25 marks
Presentation	30 marks
Viva	15 marks
TOTAL	100 marks

Evaluation Procedure:

Continuous Internal Examination (CIE) marks breakup

Project presentation (seminar) highlighting literature review, problem statement, hypothesis, objectives and feasibility ofthe project (Phase 1)	10 Marks
Project report (hard copy of the presentation slides)	20 Marks
Assessment of the project by the guide and co-guide (if any)	25 Marks
Project presentation (seminar) highlighting objectives and progress of the project (Phase 2)	30 Marks
Viva Voce – by Internal Examiners	15 Marks
Grand Total	**100 Marks**

REFERENCE BOOKS:

1	Lazic, Z.R	"Design of Experiments in Chemical Engineering; A Practical Guide", WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2004, ISBN: 3-527-31142-4
2	Piemonte, V., De Falco, M., Basile, A	"Sustainable Development in Chemical Engineering: Innovative Technologies", Wiley, West Sussex, United Kingdom, 2013, ISBN: 978-1-119-95352-4
3	Kakava, N.	"Technopreneurship: Conceptualized", Lap Lambert Academic Publishing GmbH KG, Germany, 2012, ISBN: 978-3-659-24027-0
4	Leong, E.C., Heah, C.L-H., Ong, K.K.W.	Guide to Research Projects for Engineering Students: Planning, Writing and Presenting. CRC Press, 2015, ISBN: 9781482238778

Course Outcomes:

On successful completion of the course, the student will be able to

1. Identify the issues prevailing in areas where chemical engineering is applied.
2. Demonstrate sound technical knowledge of the selected project topic and apply the knowledge of basic sciences and chemical

engineering to meet the unmet needs.

3. Identify appropriate research methods including design of experiments and data analysis to provide valid conclusions after conducting investigations.
4. Develop process engineering solutions and/or design process equipment to the selected problem.
5. Demonstrate knowledge about implications of the proposed solution with respect to finance, environment and sustainability and society.
6. Demonstrate the ability to apply modern engineering tools including process modelling, simulation and optimization to the selected topic with an understanding of the constraints.
7. Display ethical behavior in the context of conduction of experiments, data analysis and reporting.
8. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings to solve problems within the area of expertise.
9. Evaluate and critically assess one's own and others' results and be able to document and present one's own work for a given target group, with requirements on structure, format, and language usage.
10. Demonstrate the need for further knowledge and continuously develop competencies including innovation and entrepreneurship.

INTERNSHIP

Lab Hours/ Week	: --	Credits :	2.0
Sub. Code	: 7RCHIT1	CIE Marks :	0
		SEE Marks :	0

Course Objectives:

This course will enable students to:

1. Introduce the process and the technical details about process adopted and organizational structure in the industry.
2. Acquaint students to the process flow diagram, its interpretation with respect to of unit operations, unit processes and utilities in the industry
3. Apply the acquired knowledge of material and energy balances to the given process.
4. Analyze the design and conduct investigation of complex problem encountered in the industry
5. Acquaint students to Ethics, safety, environment and society, quality aspects, project management and finance, individual team work required for smooth functioning of the organization.
6. Acquaint with the major engineering challenges faced in the industry and need for lifelong learning to trouble shoot the challenges in industry.
7. Prepare a technical report and presentation about the given industrial process.

Guidelines:
Students have to undergo for a period of 4 weeks minimum during the vacation between even and odd semesters of II or III year. Those students who are unable to complete during these period will have to undergo training after VIII semester and the VIII semester results will be announced only after the successful completion of Industrial Training.

Scheme of Evaluation:
Evaluation by DSEC is for 100 marks. This is a mandatory subject and carries ZERO credit. Student has to get a minimum of 40 % marks for a pass. If a student fails, then the training has to be repeated in its entirety.

Evaluation by the supervisor of the industry	**25 marks**
Evaluation by DSEC	
1.Relevance of training programme	10 marks
2.Report	25 marks
Evaluation of training by DSEC	40 marks
TOTAL	100 marks

Course Outcomes:
After the completion of the course, the student will be able to:
1. Demonstrate knowledge about the process and the technical details about process adopted and organizational structure in theindustry.
2. Identify the role of various unit operations, unit processes and utilities in the industry with the help of a process flow diagram
3. Verify the material and energy balances adopted in the process and validate them.
4. Verify the design of unit operation or unit process equipment adopted in the industry by under its standard operating conditions.
5. Demonstrate knowledge and skills acquired in terms of Ethics, safety, environment and society, quality aspects, project management and finance, individual team work required for smooth functioning of the organization.
6. Illustrate the major engineering challenges faced in the industry and troubleshooting practices adopted in industry.
7. Develop a good technical report and participate in oral presentation about the internship undertaken covering various above aspects

TECHNICAL SEMINAR

Lab Hours/ Week	: 0+0+2 (L+T+P)	Credits :	1.0
Sub. Code	: 7RCHTS1	CIE Marks:	50
		SEE Marks :	0

Course Objectives:
This course will enable students to:

1. Acquaint with skills required for searching technical literature, analyzing and evaluating its content in terms of introduction, current status, experimental methodology, results and discussion with other literatures available in open domain
2. Acquire knowledge about essential components to be adopted for a good written report, and incorporate the same based on the literature review and analysis carried out.
3. Educate on oral presentation skills, power point presentation techniques, oral communication techniques for a good presentation based on the written report.

Seminar marks break-up	
Relevance of the topic	5 marks
Report	10 marks
presentation	25 marks
Viva	10 marks
TOTAL	**50 marks**

Course Outcomes:
After the completion of the course, the student will be able to:
1. Demonstrate knowledge and skills required for searching technical literature, analyzing and evaluating its content and its comparison with other literatures reported in open domain for a topic of interest
2. Exhibit the knowledge about essential components to be adopted for a good written report, and incorporate the same based on the literature review and analysis carried out.
3. Illustrate the oral presentation skills, power point presentation techniques, oral communication techniques for a good presentation based on the written report.

RESEARCH WORK (OPTIONAL)

Lab Hours/ Week	: 0+0+2 (L+T+P)	Credits :	6.0
Sub. Code	: 7RCHRW	CIE Marks:	50
		SEE Marks :	0

Course Objectives:
This course will enable students to:
1. Identify societal and industrial unmet needs requiring chemical engineering solutions.
2. Demonstrate research techniques such as literature reviews and the evaluation of previous work in the area.
3. Learn research methods including design of experiments and

data analysis to provide valid conclusions after conducting investigations.

4. Understand process engineering solutions or design process equipment to the selected problem/unmet need.
5. Acquaint to the societal, health, safety, finance and legal issues in addition to responsibility to the professional engineering practice.
6. Use modern engineering tools including process modelling, simulation and optimization to solve the selected problem.
7. Exemplify ethical behavior in the context of conduction of experiments, data analysis and reporting.
8. Demonstrate the ability to work individually, and as a member or leader in a team and in multidisciplinary settings, on a significant open ended problem.
9. Illustrate the need for life-long learning including innovation and entrepreneurship.

Course Outline:

Totally six credits are prescribed for UG research. Research work can be taken up individually or a group of two students from the same or different departments. Students who pursue UG research and complete successfully are exempted from studying professional elective I (PE-1) in V semester and professional elective II (PE-2) in VI semester.

Students are required to develop a research proposal after discussions with the supervisor and consulting relevant literature on the topic of the research. They must identify an industrially or societally relevant problem and solve using chemical engineering principles and economics. This must be done in consultation with faculty of the department or a practicing chemical engineer from the industry. If the projects are innovative and potentially has high impact, then the department would consider approving on a case by case basis. The department also encourages students to take up projects towards developing a “technology” or a “product”. SIT’s technology incubation centre will facilitate any subsequent commercialization. The UG research can be performed individually or a group of two students from the same or different departments. One or more faculty of same or different departments can advise the project.

The students are required to identify the guide, propose the research topic and submit the application in the format available in the department, to the HoD at the beginning of V semester. If the work is interdisciplinary, one guide will be allotted from each of the participating departments. Students who have opted UG research shall carry out an extensive literature survey to decide abstract, introduction, motivation, objectives and methodology. Further, they shall work on the research to complete the project with a publication of paper in refereed journal/conference of repute.

CIE shall be from the start to completion of the UG Research. The final CIE marks shall be the average of all the CIEs marks reduced to maximum 50 marks. In case, the students complete the UG research before the end of VI semester, they can appear for VI semester SEE viva-voce examination. The prescribed 06 credits shall be included with the credits of the VI semester. In case, UG research is incomplete, students are permitted to continue with the same during the subsequent year/s of the programme. SEE shall be conducted at VII or VIII semester examinations depending on the semester during which the students complete the research. The credits of UG research shall be added to the corresponding semester to the students appear for the SEE.

The students can opt to discontinue the UG research at any time of the programme. However, they have to complete professional electives I (PE-1) and II (PE-2) to become eligible for the award of degree. In case, UG research is incomplete even after the completion of VIII semester and students wish to continue the UG research, they shall be permitted to do so till they complete it within the maximum period of the programme. However, the appearance to SEE shall be considered as first attempt and credits shall be included with VIII semester grade card, indicating the year in which the students have appeared for the SEE.

Break-up of CIE marks for Research Component

Sl. No.	**Evaluation Component**	**Marks**
1	Evaluation by the Supervisor of the research work (Guide)	15
2	Evaluation by a panel of 3 faculty members, including Guide as one of the member, constituted by BoS.	
	i) Report writing (Report should consist of Abstract, Introduction, Literature review, Research Objectives, Methodology (Experiments), Data Collection Analysis, Results, Conclusions and Scope for future work.)	10
	ii) Presentation and Demonstration	15
	iii) Publication of work in National/International Journals/ Conferences	10
	Total	**50**

Break-up of SEE marks for Research Component

Examiners panel consists of One internal examiner (Guide) + One external examiner (to be selected by Controller from the panel of three examiners suggested by guide and recommended by BoS)

Sl. No.	**Evaluation Component**	**Marks**
1	Project presentation and demonstration	30
2	Viva-voce	20
	Total	**50**

Such of the UG students who have opted for Research Work have to submit their research findings in the form of a report in line with Major Project report. Two copies of the report are to be prepared (one for the department and one for the student)

REFERENCE BOOKS:

1	Lazic, Z.R	"Design of Experiments in Chemical Engineering; A Practical Guide", WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2004, ISBN: 3-527-31142-4
2	Piemonte, V., De Falco, M., Basile, A	"Sustainable Development in Chemical Engineering: Innovative Technologies", Wiley, West Sussex, United Kingdom, 2013, ISBN: 978-1-119-95352-4
3	Kakava, N.	"Technopreneurship Conceptualized", Lap Lambert Academic Publishing GmbH KG, Germany, 2012, ISBN: 978-3-659-24027-0
4	Leong, E.C., Heah, C.L-H., Ong, K.K.W.	Guide to Research Projects for Engineering Students: Planning, Writing and Presenting. CRC Press, 2015, ISBN: 9781482238778

Course Outcomes:
On successful completion of the course, the student will be able to

1. Identify a research problem or design related to chemical engineering or allied areas.
2. Apply basic principles and knowledge found in the literature related to the selected research topic
3. Identify appropriate innovative research methodology including design of experiments and data analysis to provide valid conclusions after conducting investigations.
4. Develop process engineering solutions and/or design process equipment to the selected problem.
5. Demonstrate knowledge about implications of the proposed solution with respect to finance, environment, sustainability and society.
6. Demonstrate the ability to apply modern engineering tools including process modelling, simulation and optimization to the selected topic with an understanding of the constraints.
7. Collaborate effectively and ethically, while conducting experiments, data analysis and reporting.
8. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings to solve problems within the area of expertise.
9. Collect, interpret, and critique data to resolve a research

question or evaluate a design and communicate research findings.

10. Develop and satisfy intellectual curiosity, the need for further knowledge and continuously develop competencies including innovation and entrepreneurship.

VIII SEMESTER

PROFESSIONAL ELECTIVE-4 : OPTIMIZATION OF CHEMICAL PROCESS

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE41		

Course Objectives:

This course will enable students to:

1. Acquaint with the different types of optimization techniques problems encountered inchemical engineering.
2. Introduce to different optimization techniques for single variable problems.
3. Develop skills to obtain optimized solution methods for linear programming problems.

Unit – I

Introduction to Optimization – Definition, Benefits, Scope for optimization, Statement of an optimization problem, Classification of optimization problems, applications of optimization in engineering. (Review of linear algebra) **Optimization Problem Formulation** – Process models for optimization, classification of process models, degree of freedom analysis, and Optimization problem formulation. **8 Hrs**

Unit – II

Basic Concepts of Optimization: Continuity of functions, Unimodal and multimodal functions, and multivariate functions. (Review of Matrix, Gradient Vector, and Hessian Matrix). Convex and concave functions, Monotonic functions, Global and local minimum (or maximum), Saddle point – Necessary and sufficient conditions. **8 Hrs**

Unit – III

Concepts of Optimization: Unconstrained and constrained problems, Optimality criteria for unconstrained single variable functions, Optimality criteria for unconstrained multivariable functions, Equality constrained problems – Variable elimination method and method of Lagrange Multipliers. Inequality constrained problems – method of Lagrange Multipliers and Karush-Kuhn-Tucker (KKT) conditions. **8 Hrs**

Unit – IV

Unconstrained Single Variable Optimization: Numerical precision, Scaling, Error and Convergence criteria, Direct Search method [Bracketing methods (Exhaustive search method and Bounding phase method) and Region elimination methods (Dichotomous search method, Interval Halving method, Fibonacci search method, Golden Section search method)], Methods requiring derivatives (Gradient based methods): Newton-Raphson method, Bisection method, Secant method. **8 Hrs**

Unit – V

Linear Programming Problem (LPP) – Introduction, applications, Formulation of linear programming models, Graphical solution of LPP, Linear programs in standard form. Solving system of linear equations. The Simplex Method – Simplex method, Use of artificial variables, Two phase method.

7 Hrs

TEXTBOOKS:

1	T. F. Edgar, D. M.Himmelblau and L. S. Lasdon	Optimization of Chemical Processes, 2nd Edition, McGraw Hill, 2001. ISBN: 9780070393592
2	A. Ravindran, K. M. Ragsdell, G. V. Reklaitis	Engineering Optimization: Methods and Applications, 2nd Edition, Wiley India, 2006. ISBN: 9780471558149

REFERENCE BOOKS:

1	S. S. Rao	Engineering Optimization: Theory and Practice, 4th Edition, John Wiley & Sons, Inc, 2009. ISBN: 9780470183526
2	Ranjan Ganguli	Engineering Optimization – A modern approach, Universities Press, 2011. ISBN: 9788173717390

Course Outcomes:

On successful completion of the course, the student will be able to

1. Apply concepts of optimization for problem formulation.
2. Apply and analyze different optimization techniques.
3. Develop solutions for single variable optimization problems.
4. Develop solutions for Linear optimization problems.

PROFESSIONAL ELECTIVE – 4: SURFACE AND INTERFACIAL ENGINEERING

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE42		

Course Objectives:

This course will enable students to:

1. Acquaint with the significant forces involved in colloidal systems, formation of emulsions and foams
2. Introduce to fluid-solid interfaces and biological interfaces
3. Acquaint with adsorption at fluid-fluid and fluid solid interfaces in behavior of surfactants
4. Elaborate the properties of surfactants and choose the right type of surfactant for an application.

Unit – I

Introduction to engineering of interfaces: Definition and examples of interfaces, industrial applications of interfacial phenomena. Colloidal materials: Properties and characterization of colloidal systems Surface and interfacial tension: Theoretical methods for the calculation of surface and interfacial tension; Experimental techniques for the determination of equilibrium and dynamic tension; Shape of the surfaces: curvature and radius of curvature; Young-Laplace equation; Kelvin equation; Pendant and sessile drops; Adams-Bashforth equation. **8 Hrs**

Unit – II

Characterization of fluid-solid interfaces: Contact angle and wetting phenomena, Young-Dupré equation; Measurement of equilibrium and dynamic contact angles. Deposition of thin films: Mechanism of film nucleation-Chemical vapor deposition, molecular beam epitaxy, sputtering and atomic layer deposition techniques; Applications of interfaces in crystallization, ceramics, catalysts, electronic products and nanomaterials. Introduction to intermolecular and surface forces: van der Waals forces, Electrostatic double layer force, Disjoining pressure, DLVO theory, Non- DLVO forces. **8 Hrs**

Unit – III

Adsorption at fluid-fluid and fluid-solid interfaces: Adsorption of surfactants; Gibbs and Langmuir monolayers, Gibbs adsorption equation, Surface equation of state, Surface pressure isotherm. Langmuir-Blodgett films and their applications, radiotracer and neutron reflection techniques for studying adsorption at fluid-fluid interfaces. Adsorption isotherms, Adsorption hysteresis, Characterization of adsorption at fluid-solid interfaces by vacuum and non-vacuum techniques. Interfacial rheology and transport processes: Surface shear viscosity, Surface dilatational viscosity, Boussinesq number, Interfacial tension gradient and Marangoni effect, Gibbs and Marangoni elasticity, Boussinesq-Scriven model, Interfacial turbulence, Motion of drops in a liquid. Thin liquid films: Disjoining pressure and body-force models, Stability of thin liquid film, Black films. **8 Hrs**

Unit – IV

Emulsions: Preparation, characterization and applications, Ostwald ripening, Flocculation and coalescence, Microemulsions: characterization and properties, Stability of microemulsions. Foams: preparation, characterization and stability, Structure of foams. Interfacial reactions: Reactions at fluid-solid interfaces, Langmuir-Hinshelwood model. External and internal transport processes: Interfacial polycondensation reactions, Fast and instantaneous reactions at fluid-fluid interfaces, Reactions at biointerfaces, Micellar catalysis, Phase transfer catalysis.

9 Hrs

Unit – V

Biological interfaces: Adsorption of proteins at interfaces, Biomembranes, Interfacial forces at biointerfaces, Adhesion and fusion phenomena, Biomaterials. Nanomaterials: Classification and preparation, Self-assembly, Nanoparticles, Nanowires, nanorods and nanotubes. Microporous and mesoporous materials: Lithographic techniques, Toxic effects of nanomaterials.

6 Hrs

TEXTBOOKS:

1	Hiemenz, P. C. and Rajagopalan, R.	"Principles of Colloid and Surface Chemistry", 3ed , CRC Press, Boca Raton, FL, 1997. ISBN-13: 978-0-82-479397-5.
2	Ghosh P.	"Colloid and Interface Science", PHI Learning Private Limited, Delhi, 2009. ISBN-13: 978-8-12-033857-9.

REFERENCE BOOKS:

1	Stokes, R. J. and Evans, D. F	"Fundamentals of Interfacial Engineering", Wiley-VCH, Weinheim, Germany, 1996. ISBN-13: 978-0-47-118647-2.
2	Hunter R. J	**"**Foundations of Colloid Science", 2e, OUP Oxford, 2000, ISBN-13: 978-0198505020

Course Outcomes:

On successful completion of the course, the student will be able to

1. Outline the significant forces between colloidal systems, how they can be calculated approximately and exactly, and how they can be measured.
2. Demonstrate the knowledge about factors influencing formation of

emulsions and foams and stabilization of emulsions.
3. Manipulate the wettability of surfaces.
4. Apply the principles and properties for modification of active at interfaces and selection of right surfactant for a given application.
5. Outline the interfacial forces at biointerfaces.

PROFESSIONAL ELECTIVE – 4: POLYMER TECHNOLOGY

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE43		

Course Objectives:
This course will enable students to:
1. Acquaint with the structure and classification of polymers.
2. Familiarize with polymer different synthesis methods and conformation of polymer synthesized by various characterization techniques adopted for polymers.
3. Acquaint with advanced methods of polymer synthesis for applications such as membrane separation, biomedical and new process applications.
4. Acquaint with various methods available for polymer degradation to protect the environment.

Unit-I

Introduction and classification: Classification of polymers: Thermoplastics and thermosets, classification based on mechanism of polymerization and polymer structure. Polymer structure: Copolymers, Tacticity, Geometric Isomerism, and Nomenclature. Molecular weight: Molecular weight distribution and molecular weight averages. Application of polymers. **8 Hrs**

Unit-II

Synthesis of polymers: Step growth polymerization**:** Molecular-weight in step-growth polymerization, Step growth polymerization kinetics. Chain-Growth polymerization: Free-Radical Polymerization and Copolymerization, Ionic Polymerization and Copolymerization, Coordination Polymerization, Controlled Radical Polymerizations. Chemical structure determination: Vibrational Spectroscopy, Nuclear Magnetic Resonance Spectroscopy.

8 Hrs

Unit-III

Conformation, Solution, and Molecular Weight: Polymer Conformation and Chain Dimensions. Polymer solutions: The Flory–Huggins Theory, Equation-of-State Theories, Phase equilibria, Determination of interaction parameter, and prediction of solubilities. Measurement of Molecular Weight: Osmometry, Light-

Scattering Methods, Intrinsic Viscosity Measurements, and Gel-Permeation Chromatography. **8 Hrs**

Unit-IV

Polymer for advanced technologies: Membrane Science and Technology: Barrier Polymers, Membrane Separations, Mechanisms of Transport, Membrane Preparation. Biomedical Engineering and Drug Delivery: Controlled Drug Delivery, Gene therapy, and Antimicrobial Polymers. Applications in Electronics and Energy: Electrically Conductive Polymers, Polymeric Batteries, and Organic Photovoltaic Polymers. Photonic Polymers: Nonlinear Optical Polymers and Light-Emitting Diodes. Sensor applications.
8 Hrs

Unit-V

Polymer degradation and environment: Polymer Degradation and Stability: Thermal Degradation, Mechanodegradation, Oxidative and UV Stability, Chemical and Hydrolytic Stability**.** Management of Plastics in the Environment: Recycling, Incineration, and Biodegradation.
7 Hrs

TEXTBOOKS:

1	Fried, Joel	Polymer Science and Technology, (3rd edition), Prentice Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, 2000. ISBN-13: 978-0-13-703955-5
2	Premamoy Ghosh	Polymer Science and Technology: Plastics, rubbers, blends, and composites, 3e, Tata Mc. Graw-Hill Publishing Company, New Delhi, 2010. ISBN: 9780070707047
3	R. Sinha	Outlines of Polymer Technology: Manufacture of Polymers ,1e, Prentice Hall of India Pvt. Ltd., New Delhi, 2002. ISBN: 8120317289

REFERENCE BOOKS:

1	F.W.Bill Meyer	Text book of polymer science, (3rd ed.) John Wiley &sons 1984. ISBN: 9788126511105
2	John Scheirs	Polymer Recycling Science Technology and Applications, 1e, Wiley 2001, ISBN:9780471970545.

Course Outcomes: On successful completion of the course, the student will be able to

1. Demonstrate knowledge about the types of polymers, their characteristics and applications.
2. Illustrate types of synthesis of polymers for depending on the

nature of polymers.
3. Identify the appropriate polymeric material for new and advanced applications.
4. Demonstrate knowledge about methods available to degrade the Polymers to benefit in saving the environment.

PROFESSIONAL ELECTIVE – 5: PILOT PLANT AND SCALE UP METHODS

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE51		

Course Objectives:
This course will enable students to:

1. Acquaint with the knowledge about pilot plant, model, prototype and similarity.
2. Introduce to dimensional analysis and differential equations in scaling up of processes.
3. Describe the application of the similarity criterion for the principal types of regimes in chemical engineering.
4. Acquire with skills for scaling up of distillation, evaporation, extraction and absorption processes.
5. Acquire with the skills for scaling up of mixing systems and chemical reactors.

Unit – I

Introduction: pilot plant, prototypes and models.
Principles of Similarity: static, dynamics, kinematics, thermal, and chemical similarities criteria and examples.
8 Hrs

Unit – II

Dimensional Analysis: differential equation, Regime concept.
8 Hrs

Unit – III

Scale (up / down) equation, extrapolation, boundary effects.
8 Hrs

Unit - IV

Scale up problem on transfer operation, momentum, heat and mass transfer. **8 Hrs**

Unit – V

Scale up problems on mixing, agitated vessels and chemical reactors. **7 Hrs**

TEXTBOOKS:

1	Johnstone and Thring.	"Pilot plants Models and scale up method in Chemical Engineering", McGraw-Hill Inc., US, 1957, ISBN- 978-0070326934

REFERENCE BOOKS:

1	Horker and Backhurst	"Process plant design", Elsevier, 1973, ISBN-9781483162386

Course Outcome:

By the end of this course student will be able to:

1. Differentiate pilot plant, model and prototype
2. Apply the principles of dimensional analysis or differential equations for a given process under considerations
3. Illustrte the various similarity criterion for static and dynamic regimes ofchemical engineering processes.
4. Apply the Scale up principles to mass transfer equipment.
5. Apply the Scale up principles to mixing and chemical reactors.

PROFESSIONAL ELECTIVE – 5: NANO MATERIALS

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE52		

Course Objectives:

This course will enable students to:

1. Introduce to the fundamentals of Nanomaterials and its impact onenvironment.
2. Acquaint with methods for synthesis and fabrication of desired Nanomaterials by physical and chemical methods
3. Acquaint with Synthesis of fullerene, Graphene oxide and carbon Nano tubes.
4. Introduce to large scale synthesis and characterization of Nanomaterials.
5. Familiarize with synthesis of Nano-composites and its applications.

Unit-I

General introduction, basic idea of nanomaterials, types of Nanomaterials: 0D, 1D, 2D and special Nanomaterials. Nano-scale size effect, surface area to volume ratio, properties of

Nanomaterials (magnetic, electrical, mechanical and optical). Applications of Nanomaterials.

Nanotechnology – Health, environment and society: Health impact: Medical applications to cure diseases and the health hazards. ***Environmental impact:*** Nanopollution, Environmental benefits of nanotechnology, e.g. energy water filtration and remediation. *Societal impact:* Implications of nanotechnology on society, issues with nanotechnology, nanopolicies and institutions, nanotech and war, public perception and public involvement in the nano discourse. **8 Hrs**

Unit-II

Synthesis of Nanomaterials: Top down and bottom up approaches with the examples. **Physical methods:** Ball milling, Inert gas condensation Arc discharge, Ion sputtering, Laser ablation, spray pyrolysis, flame pyrolysis, thermal evaporation, pulsed laser deposition, molecular beam epitaxy.

Chemical methods: Metal nano-crystals by reduction, solvo-thermal synthesis, photochemical synthesis, electrochemical synthesis, micelles and micro-emulsions, chemical vapor deposition (CVD), sol-gel process.

Lithographic techniques: Photolithography, electron beam and focused ion beam lithography. **8 Hrs**

Unit-III

Carbon nanomaterials: Introduction: Allotropes of carbon and their structures. Fullerenes: synthesis (combustion flame synthesis, arc discharge) and applications (super-capacitors, adsorbents, catalysts, synthetic diamonds). Graphene and Graphene oxide (Synthesis and applications).

Carbon Nanotubes (CNT): Types of carbon Nanotubes and their structure, production of CNT by arc discharge method, laser ablation method and chemical vapor deposition (CVD) method (principle, raw material, mechanism, yield, and quality in each method).

Properties of CNTs (electrical, magnetic, mechanical and vibrational properties); Applications of CNTs (field emission, hydrogen storage, fuel cells, sensors, super capacitor).

8 Hrs

Unit-IV

Manufacturing nanomaterials: from research to industry (sol-gel, solvo- thermal, milling, CNT, metals).

Characterization methods: General classification of characterization methods, Microscopy techniques, atomic force microscopy (AFM), BET surface area, Diffusion Reflectance Spectroscopy (DRS) and X-ray Photoelectron Spectroscopy (XPS).

8 Hrs

Unit-V

Nanocomposites: An Introduction: Metal - Metal Nanocomposites, Polymer-Metal Nanocomposites.

Ceramic Nanocomposites: Core - Shell structured Nanocomposites, **Superhard Nanocomposite:** applications.

Nano Semiconductors: Nanocomposites for biomedical devices, sensors, energy storage and automobiles. **7 Hrs**

TEXTBOOK:

1	Frank J. Owens and Charles P. Poole Jr	The Physics and Chemistry of NanoSolids, Wiley-Inter science, 2008, ISBN: 978-0-470-06740-6.

REFERENCE BOOKS:

1	G. Ozin and A. Arsenault	Nanochemistry: A Chemical Approach to Nanomaterials, RSC Publishing, 2005, 1e, ISBN-978-1-84755-895-4,
2	Edward L. Wolf	Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Wiley-VCH, 2005,1e, ISBN: 978-3-527-61898-9.
3	P.M. Ajayan, L.S. Schadler, P.V. Braun	Nanocomposite science and technology, Wiley, New York, 2015, 1e, ISBN: 9783527303595

Course outcomes:

At the end of this course students will be able to

1. Illustrate the fundamentals of Nanomaterials and its environmental impact
2. Demonstrate knowledge about synthesis of Nanomaterials by different methods
3. Elaboratre on fabrication of Fullerenes, Graphene oxide and carbon Nano tubes
4. Illustrate synthesis of nanomaterials in large scale and identify the appropriate characterization methods.
5. Apply appropriate method for synthesis of Nano-composites.

PROFESSIONAL ELECTIVE – 5: WASTE WATER TREATMENT METHODS

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE53		

Course Objectives:

This course will enable students to:

1. Introduce to the characteristics of water and wastewater, water standards and regulations.
2. Acquaint with the physical, chemical and biological methods to treat wastewater.
3. Understand the various sludge treatment and disposal methods.
4. Introduce to the complete waste water treatment methods in specific process industries.

Unit-I

Wastewater management: Introduction, legislation, regulations, and government agencies.
Wastewater Characteristics: Physical characteristics: colour, odour, temperature, turbidity, total solids.
Chemical characteristics: inorganic and organic characteristics and their determination.
Biological Characteristics: Classification of microorganisms, pathogenic organisms, Toxicity, Estimation of BOD, COD.

8 Hrs

Unit-II

Pretreatment: Equalization, Neutralization, Grease and Oil Removal, Toxic Substances.
Primary Treatment: Screens, Grit Chambers, Comminutors, Gravity Sedimentation, coagulation and flocculation: types of coagulants, coagulant aids, coagulation theory, optimum dose of coagulant. **8 Hrs**

Unit-III

Secondary Treatment: Biological process for wastewater treatment. Suspended and attached growth processes - Aerobic and Anaerobic. Activated Sludge Process, Trickling filters, Rotating Biological Contactors; Lagoons.
Physical-Chemical Treatment: Adsorption, Ion Exchange, Advanced Oxidation Processes, Membrane Bioreactors (MBRs).

8 Hrs

Unit-IV

Sludge Processing: Objectives, Concentration: Thickening and Flotation, Stabilization (Anaerobic Digestion, Aerobic Digestion, High Lime Treatment), Sludge Dewatering: Centrifugation, Vacuum Filtration, Pressure Filtration, Belt-Press Filters, Sand Beds.
Sludge Disposal: Incineration, Sanitary Landfills, Beneficial Reuse of Biosolids. **8 Hrs**

Unit-V

Wastewater Treatment in specific industries: Sugar, Dairy, Distillery, Textile, Pharmaceutical and Petrochemical industries.

7 Hrs

TEXTBOOKS:

1	Mark J. Hammer, Mark J. Hammer, Jr.,	"Water and Wastewater Technology", 7th Edition, PHI Learning Private Ltd., New Delhi, 2012. ISBN: 9780135114049
2	Patwardhan, A.D	"Industrial Waste Water Treatment", 2nd Edition, PHI learning, 2017, ISBN: 978-81-203-3350-5

REFERENCE BOOKS:

1	Metcalf & Eddy	"Wastewater Engineering Treatment and Reuse", McGraw Hill Education Private Ltd. New York, 2014, 5e, ISBN: 7-302-05857-1.
2	Eckenfelder, W.W	"Industrial Water Pollution Control", McGraw-Hill, 2001, 1e, ISBN: 9780070393646.
3	Don W. Green; Robert H. Perry	Perry's Chemical Engineers' Handbook, McGraw-Hill education, New York, 2008, 8e, ISBN: 9780071422949.

Course Outcomes:
After the completion of the course, the student will be able to:

1. Illustrate knowledge about the water quality, water standards and basic characteristics of wastewater, water standards and regulations
2. Apply the physical, chemical and biological principles to treat wastewater.
3. Demonstrate the working principle of various sludge treatment and disposal methods.
4. Illustrate in detail the wastewater treatment methods in industries such sugar, distillery, textile, pharmaceutical and petrochemical industries.

PROFESSIONAL ELECTIVE 6: PETROCHEMICALS

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE61		

Course Objectives:
This course will enable students to:
1. Acquaint with the history, developments and importance of petrochemical industries along with major unit processes involved
2. Introduce to the manufacturing process and applications of certain Important petrochemicals produced from C1, C2, C3, C4 compounds and BTX compounds (Benzene, Toluene and Xylene)
3. Acquaint with the merits and demerits of manufacturing process of few petrochemicals
4. Acquaint with the major engineering problems encountered during the production of petrochemicals

Unit – I

Overview of petrochemical industries: Definition of petrochemicals, overall view of petrochemicals, History of petrochemical industries, Feed stocks for petrochemical industries (Natural gas, Crude oil, Coal, oil shale, Tar sand and gas hydrates, synthesis gas),Production of hydrocarbon intermediates: Fluidized bed catalytic cracking, catalytic reforming, steam cracking, hydrocracking, hydrodealkylation. **8 Hrs**

Unit – II

Petrochemicals from Methane, Synthesis gas and Ethylene: Chemicals based on direct reactions of methane: Carbon Disulfide, Hydrogen Cyanide , Chloromethanes (reactions involved and uses), Chemicals based on reaction of synthesis gas: Ammonia , Methyl alcohol (The ICI low-pressure process), Formaldehyde (The HaldorTopsoe and Nippon Kasei process), Oxo Aldehydes and Alcohols , Ethylene Glycols (reactions involved, and uses)

Chemicals based on Ethylene : Oxidation of Ethylene (The Scientific Design Co. Ethylene Oxide process), Derivatives of Ethylene Oxide (Ethylene glycols and Ethanol amines -reactions and uses) , Chlorination of Ethylene , Vinyl Chloride(The European Vinyls Corporation process), Perchloro- and Trichloroethylene , Acetaldehyde, Hydration of Ethylene , Oligomerization of Ethylene, Alpha Olefins Production , Linear Alcohols , Butene-I (reactions and uses). **8 Hrs**

Unit – III

Petrochemicals from Propane and Propylene: Chemicals based on propane: Oxidation of Propane, Chlorination of Propane, Dehydrogenation of Propane, Nitration of Propane (reactions and uses)
Chemicals based on propylene: Ammoxidation of Propylene (Montedison-UOP acrylonitrile process), Propylene oxide, Hydroformylation of Propylene: The Oxo Reaction (process description with flowsheet), Oxidation of Propylene (Acrolein , Acrylic Acid) , Propylene Oxide,Oxyacylation of Propylene, Chlorination of Propylene ,Hydration of Propylene,Addition of Organic Acids to Propene, Disproportionation of Propylene (Metathesis) (Reactions and uses).

8 Hrs

Unit – IV

Petrochemicals from C4 Olefins: Chemicals from n-butane: Oxidation and isomerization of butane, The Monsanto process for producing maleic anhydride from butane, Isomerization, naphtha-based chemicals.

Chemicals from n-Butenes: Oxidation of Butenes,hydration of Butenes, Oligomerization of Butenes (reactions and uses)
Chemicals from Isobutylene: Oxidation of Isobutylene, Epoxidation of Isobutylene , Addition of Alcohols to Isobutylene , Hydration of Isobutylene, Carbonylation of Isobutylene, Dimerization of Isobutylene (reactions and uses)
Chemicals from Butadiene: Adiponitrile , Hexamethylenediamine, Adipic Acid , Butanediol , Chloroprene , Cyclic Oligomers of Butadiene(reactions and uses). **7 Hrs**

Unit – V

Chemicals Based on Benzene, Toluene, and Xylenes: Review of technologies available for production of Benzene, Toluene, Xylene and Cumene UOP's EB*one* process manufacturing of Ethylbenzene, UOP QMax™ process for Cumene production, Production of Linear Alkyl Benzene Sulfonate for Detergents.
Reactions and Chemicals of Benzene : Alkylation of Benzene, Chlorination of Benzene , Nitration of Benzene , Oxidation of Benzene, Hydrogenation of Benzene.
Reactions and Chemicals of Toluene: Dealkylation of Toluene, Disproportionation of Toluene, Oxidation of Toluene , Chlorination of Toluene , Nitration of Toluene, Carbonylation of Toluene (reactions and uses) Chemicals from Xylenes, Terephthalic Acid , Phthalic Anhydride , Isophthalic Acid. **8 Hrs**

TEXTBOOKS:

1	B. K. Bhaskararao	"A Text on Petrochemicals", 2004, Khanna Publishers, 5e,ISBN: 9788174090444.
2	Frank (Xin X.) Zhu, James A. Johnson, David W. Ablin, and Gregory A. Ernst	"Efficient petrochemical processes", 2020, John Wiley & Sons, Inc.,1e, ISBN – 9781119487869.
3	Sami Pattar	"Chemistry of petrochemical processes",2000, Gulf Publishing Company, Houston, Texas,2e, ISBN : 9780080501086.
4	Dryden and Gopal Rao	"Outlines of chemical technology",1997, East-West Press (Pvt.) Ltd., 3e, ISBN: 9788185938790.

REFERENCE BOOKS:

1	Sarkar G. N	"Advanced Petrochemicals", 2002, Khanna Publishers, 1e, ISBN-13: 978-8174090966.
2	Donald L.Burdick and William L .Leffler	"Petrochemicals, in nontechnical language", 2010,4e, Pennwell corporation, ISBN : 9781593702168

3	Uttam Ray Chaudhurai	"Fundamentals of petroleum and petrochemical engineering", 2011, CRC Press, 1e, ISBN : 9781439851609.

Course Outcomes:

After the completion of the course, the student will be able to:

1. Demonstrate the knowledge of history of petrochemical industries, sources for petrochemical production and unit processes for petrochemical production.
2. Describe the production process and applications of various chemicals produced from Methane, synthesis gas and ethylene.
3. Illustrate the production process and applications of various chemicals produced from propane and propylene.
4. Describe the production process and applications of various chemicals produced from butane, isobutylene and butadiene.
5. Identify the right production process for synthesis from BTX along with different applications of products synthesized using BTX.

PROFESSIONAL ELECTIVE 6:
GREEN CHEMICAL ENGINEERING

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE62		

Course Objectives:

This course will enable students to:

1. Introduce to the fundamental understanding of basic chemistry/technology principles with the frame work of Green Chemistry.
2. Acquaint with the development of latest technologies and methodologies for reduction of waste and its prevention.
3. Acquaint with the tools of green technology involved in process synthesis and unit operations and assessment of environmental implications of a process.
4. Introduce to the principles of Life Cycle Assessment tools and methods.

Unit – I

Principles of Green Chemistry and Green Engineering: Introduction to Green Chemistry: Definition, Principles of Green Chemistry and Examples; Green Engineering, Definition and Principles of Green Engineering, Sustainability - Atom Economy, Atom Un-economic Reactions, Reducing toxicity.

8 Hrs

Unit – II

Waste: Production, Problems and Prevention: Introduction, Some problems caused by Waste, Sources of Waste from the Chemical Industry, Cost of Waste, Waste minimization techniques, On-site treatment- Physical, Chemical and Bio treatment Plant, Design for Degradation – Surfactants, DDT, Polymers and rules for degradation; Polymer Recycling: Separation and Sorting, Incineration, Mechanical Recycling, Chemical Recycling to Monomers. **8 Hrs**

Unit – III

Evaluating Environmental Performance during process synthesis: Introduction: Tier 1 Environmental performance tools- Economic Criteria, Environmental Criteria, TLV, PEL, and REL, Toxicity Weighing, Evaluating, Alternative Synthetic pathway, Tier2-Environmental Performance Tools, Environmental Release Assessment – Release Quantification Methods, Modeled Release Estimate: Storage Tan Working and Breathing Losses.
8 Hrs

Unit – IV

Unit Operations and Pollution Prevention: Introduction, Pollution Prevention in material selection for Unit Operations, Prevention for Chemical Reactors - Material use and selection for reactors, reaction type and reactor choice, Reactor Operation, Pollution prevention for separation devices – Choice of Mass separating agent, process design and operation Heuristics for separation technologies,, Pollution prevention examples for separations, Pollution prevention in storage tank and fugitive sources. **8 Hrs**

Unit – V

Life Cycle Assessment: Introduction to Product Life Cycle concepts, Life Cycle Assessment Terminologies, Methodology, Inventories, Life Cycle Impact assessment- Classification, Characterization, Valuation, Interpretation of Life cycle data and practical limits of Life cycle assessments, Uses of Life cycle studies. **8 Hrs**

TEXTBOOKS:

1	M. Lancaster	" Green Chemistry – An Introductory Text, 2nd Ed., RSC Publishing, Cambridge, UK, 2010, ISBN: 978-1847558732
2	David Allen, D and Shonnard, D	"Green Engineering: Environmentally Conscious Design of Chemical Processes", 1st Ed., Pearson, New Jersey, 2001, ISBN: 978-0130619082

REFERENCE BOOKS:

1	Anastas, P., Warner, J	Green Chemistry: Theory and Practice, 1st Ed., Oxford University Press, London, 2005, ISBN:978-0198506980

2	Martin A. Abhrama, Ed.	Sustainability in Science and Engineering- Defining Principles, Vol.1, Elsevier Science and Technology , 2006, ISBN: 978-0444517128
3	Ann. E. Marteel – Parish., Martin A. Abhram, Ed.	Green Chemistry and Engineering- A path way to sustainability,1st Ed., Wiley-AIChE, 2014, ISBN: 978-0470413265

Course Outcomes:

After the completion of the course, the student will be able to:

1. Illustrate the principles of green chemistry and engineering.
2. Identify nature of waste, its treatment and prevention and application ofright tools to minimize the hazard.
3. Apply right evaluation tools in process synthesis stage from environment point of view.
4. Design products that are safe and hazard free.
5. Demonstrate skill to apply Life cycle assessment as a tool for a product

PROFESSIONAL ELECTIVE 6: SOLID WASTE MANAGEMENT

Contact Hours/ Week	: 3+0+0 (L+T+P)	Credits :	3.0
Total Lecture Hours	: 39	CIE Marks :	50
Total Tutorial Hours	: 0	SEE Marks :	50
Sub. Code	: 8RCHE63		

Course Objectives:

This course will enable students to:

1. Introduce to the concept of solid waste, its characteristics, classification, laws governing solid waste, waste functional elements of solid waste management, sources and handling of biomedical waste, e-waste and hazardous waste.
2. Acquaint with the types of municipal solid waste collection systems, their characteristics, merits and demerits,
3. Acquaint with the processing of solid waste for reduction of solid waste by aerobic and anaerobic composting, systems, operation and maintenance of the same and handling of organic waste. and its recycling, and incineration as alternative methods and its benefits and limitations
4. Introduce to the principles of landfilling, types of landfilling, design, construction, and operations of landfill facilities, methodologies for energy recovery and management of leachate systems.
5. Introduce the concept of reduce, recycle and reuse concept to minimize solid waste and protect the environment and enhance resource efficiency. Biomedical waste, industrial waste and e-waste management guidelines and regulations.

Unit – I

Introduction: Functional Elements Municipal Solid Waste *(Management & Handling)* Rules, 2000 and *e-waste (Management) Rules, 2016.*

Generation of Solid Wastes: Types of Solid Waste, Hazardous Wastes, Sources of Industrial Wastes, Properties of Solid Wastes, Quantities of Solid Wastes. **8 Hrs**

Unit – II

On-Site Handling, Storage, and Processing: On-Site Handling, On-Site Storage, On-Site Processing of Solid Wastes, Processing Techniques for Solid Waste, Processing of Hazardous Wastes.

8 Hrs

Unit – III

Biological and Thermal Processes: Recovery of Biological Conversion Products – Composting, Anaerobic Digestion, Thermal Processes - Incineration with Heat Recovery, Combustion, Gasification, Waste-to-Energy Systems, Efficiency Factors, Incineration process, factors affecting incineration process, and air pollution prevention in incinerators.

8 Hrs

Unit – IV

Ultimate Disposal: Landfilling of Solid Waste, Landfilling Methods and Operations, Important Factors in Preliminary Selection of Landfill Sites, Occurrence of Gases and Leachate in Landfills, Gas and Leachate Movement and Control.

8 Hrs

Unit – V

Reuse, Recycling, and Recovery, Short- and Long-Term Actions for Effective Industrial Solid-Waste management, *e-waste* management, Biomedical Waste, Biomedical Waste Handling Rules and its Impact on Human Health.

7 Hrs

TEXTBOOKS:

1	George Tchobanuglour	"Intergrated Solid Waste Management", 1e, McGraw-Hill Education, 1993, ISBN:9780071128650
2	Iqbal Khan &Naved Ahsan	Textbook of Solid Wastes Management PB", 1e,CBS, 2007, ISBN: 9788123909448.
3	Sasikumar K & Sanoop Gopi Krishana P	Solid Waste Management", 3e, PHI learning Pvt.Ltd, 2009, ISBN: 9788120338692.

REFERENCE BOOKS:

1	Frank Krieth	"Handbook of Solid waste" , Tata McGraw-Education, 1994, ISBN: 9780070358768.

2	Cherry	"Solid and Hazardous Waste Management" 1e, CBS, 2016, ISBN: 9788123928302.
3	Frank Kreith & George Tchobanoglous	"Handbook of Solid Waste Management", 2e, McGraw-Hill Education, 2002, ISBN: 978-0071356237.

Course Outcomes: On successful completion of the course, the student will be able to

1. Illustrate the nature of the solid waste, properties of solid waste, types of solid waste, steps in functional elements of municipal solid management and legislations available and its significance.
2. Elaborate on the solid waste collection systems, types, merits and demerits of them.
3. Demonstrate knowledge about the processing of solid waste for reduction of solid waste by aerobic and anaerobic composting, systems, operation and maintenance of the same and handling of organic waste. and its recycling, and incineration as alternative methods and its benefits and limitations
4. Describe to the principles of Landfilling, types of Landfilling, design, construction, and operations of landfill facilities, methodologies for energy recovery and management of Leachate systems.
5. Identify the appropriate Reuse, Recycling, and Recovery methods for municipal solid waste, Industrial Solid-Waste management, *e-waste* management, Biomedical Waste management and regulations.

PROJECT PHASE-II

Lab Hours/ Week:16	Credits :	9.0
Subject Code: 8RCHMP1	CIE Marks :	50
	SEE Marks :	50

Course Objectives:
This course will enable students to:

1. Train the students to identify societal and industrial unmet needs needing chemical engineering solutions.
2. Introduce research methods including design of experiments and data analysis to provide valid conclusions after conducting investigations.
3. Guide students to develop process engineering solutions or design process equipment to the selected problem/unmet need.
4. Acquaint students to societal, health, safety, finance and legal issues in addition to responsibility to the professional engineering practice.

5. Teach modern engineering tools including process modelling, simulation and optimization to solve the selected problem.
6. Exemplify ethical behavior in the context of conduction of experiments, data analysis and reporting.
7. Train to function effectively as an individual, and as a member or leader in a team, and in multidisciplinary settings to solve problems within the area of expertise.
8. Give directions to students to evaluate and critically asses results and be able to document and present one's own work.
9. Illustrate the need for life-long learning including innovation and entrepreneurship.

Course Outline:
Students must identify an industrially or societally relevant problem and solve using chemical engineering principles and economics. This must be done in consultation with faculty of the department or a practising chemical engineer from the industry. The students are advised to take up projects that can be performed using the facilities and infrastructure of the department and the institute. However, students are encouraged to think "out of the box" and take up challenging projects. If the projects are innovative and potentially has high impact, then the department would consider approving on a case by case basis. The department also encourages students to take up projects towards developing a "technology" or a "product". SIT's technology incubation centre will facilitate any subsequent commercialization. The major project can be performed by a team of 3 to 4 students. One or more faculty of the department can advise the project and can be performed within the department or in an Industry or a Research Institute. A co-guide from the Industry or Research Institute is also allowed.

The project can be taken by group of 4 students and major project can be carried out in the dept. under a guide or outside the department in institute/ company with a guide from the dept. and co guide from the institute/ company.

The major project is evaluated over two semesters (VII and VIII). It carries 2 credits in the VII semester and is evaluated for 100 marks (100% CIE only). In the VIII semester, it carries 13 credits and evaluated for 100 marks [50% CIE & 50% SEE].

CIE marks breakup

Seminar on project and demonstration	20 marks
Report	10 marks
Evaluation by guide	15 marks
Co-curricular activities	5 marks
TOTAL	50 marks

Semester End Examination (SEE) marks breakup

Presentation (seminar) and demonstration (Final Phase)	30 Marks

Viva Voce Examination	20 Marks
Grand Total	**50 Marks**

REFERENCE BOOKS:

1	Lazic, Z.R	"Design of Experiments in Chemical Engineering: A Practical Guide", WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2004, ISBN: 3-527-31142-4
2	Piemonte, V., De Falco, M., Basile,A.,	Sustainable Development in Chemical Engineering: Innovative Technologies, Wiley, West Sussex, United Kingdom, 2013, ISBN: 978-1-119-95352-4
3	Kakava, N.,	Technopreneurship: Conceptualized. Lap Lambert Academic Publishing GmbH KG,Germany, 2012, ISBN: 978-3-659-24027-0

Course Outcomes:

On successful completion of the course, the student will be able to

1. Identify the issues prevailing in areas where chemical engineering is applied.
2. Demonstrate sound technical knowledge of the selected project topic and apply the knowledge of basic sciences and chemical engineering to meet the unmet needs.
3. Use of research methods including design of experiments and data analysis to provide valid conclusions after conducting investigations.
4. Develop process engineering solutions and/or design process equipment to the selected problem.
5. Demonstrate knowledge about implications of the proposed solution with respect to finance, environment and sustainability and society.
6. Demonstrate the ability to apply modern engineering tools including process modelling, simulation and optimization to the selected topic with an understanding of the constraints.
7. Display ethical behavior in the context of conduction of experiments, data analysis and reporting.
8. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings to solve problems within the area of expertise.
9. Evaluate and critically assess one's own and others' results and be able to document and present one's own work for a given target group, with requirements on structure, format, and language usage.
10. Demonstrate the need for further knowledge and continuously develop competencies including innovation and entrepreneurship.