Savitribai Phule Pune University

Structure and Syllabus

BE (Chemical Engineering)

Course- 2019

W.E.F. 2022-2023

Savitribai Phule Pune University

Final Year of Chemical Engineering (2019 Course)

(With effect from Academic Year 2022-23)

Semester VII

Course Code	Course Name	Teaching Scheme (Hours/week)			Examination Scheme and Marks						Credit Scheme			
		Lecture	Practical	Tutorial	Mid-Sem	End-Sem	Term work	Practical	Oral\Pre	Total	Lecture	Practical	Tutorial	Total
409341	Process Dynamics and Control	03	02	-	30	70	-	50	-	150	3	1	-	4
409342	Chemical Reaction Engineering- II	03	-	-	30	70	-	-	-	100	3	-	-	3
409343	Chemical Engineering Design	03	02	-	30	70	-	-	50	150	3	1	-	4
409344	Elective-III	03	-	-	30	70	-	-	-	100	3	-	-	3
409345	Elective-IV	03	-	-	30	70	-	-	-	100	3	-	-	3
409346	Computer Aided Chemical Engineering- II	-	02	-	-	-	50	-	-	50	-	1	-	1
409347	Project Stage I	-	04	-	-	-	50	-	-	50	-	2	-	2
										Total Credit	**15**	**05**	**-**	**20**
	Total	**15**	**10**	**-**	**150**	**350**	**100**	**50**	**50**	**700**	**15**	**05**	**-**	**20**
409348	Audit Course 7										**Grade**			

Elective-III (409344)	**Elective IV (409345)**
409344(A)Environmental Engineering 409344(B) Membrane Technology 409344(C) Industrial Piping 409344(D) Petroleum Refining	409344 (A) Chemical Process Synthesis 409344(B) Industrial Management & Entrepreneurship 409344 (C) Green Technology 409344 (D) Advance Separation Processes

409348 Audit Course 7(AC7) Options:

AC7- I MOOC/NPTEL- Learn New Skills

Savitribai Phule Pune University

Final Year of Chemical Engineering (2019 Course)

(With effect from Academic Year 2022-23)

Semester VIII

Course Code	Course Name	Teaching Scheme (Hours/week)			Examination Scheme and Marks						Credit Scheme			
		Lecture	Practical	Tutorial	Mid-Sem	End-Sem	Term work	Practical	Oral/Pre	Total	Lecture	Practical	Tutorial	Total
409349	Process Modeling and Simulation	03	02	-	30	70	25	-	50	175	03	1		04
409350	Process Engineering Costing & Plant Design	03	02	-	30	70	25	-	50	175	03	1		04
409351	Elective-V	03	-	-	30	70	-	-	-	100	03			03
409352	Elective-VI	03	-	-	30	70	-	-	-	100	03			03
409353	Project Phase- II	-	12	-	-	-	100	-	50	150		06		06
										Total Credit	**12**	**08**	**-**	**20**
	Total	**12**	**14**	**-**	**120**	**280**	**150**	**-**	**150**	**700**	**12**	**08**	**-**	**20**
409354	Audit Course 8										**Grade**			

Elective V	Elective VI
409351(A) Energy Audit and Conservation	409352(A) Catalysis
409351(B) Chemical Process Safety	409352(B) Nanotechnology
409351(C) Computational Fluid Dynamics	409352(C) Fuel Cell Technology
409351(D) Advanced Materials	409352(D) Petrochemical Engineering
409351 (E) Open Elective	409352 (E) Open Elective

Audit Course 8(AC8) Options:

AC8- I MOOC/NPTEL/- Learn New Skills

SEMESTER I

BE (Chemical Engineering)-2019
Course Code: 409341
Process Dynamics and Control
Credits: 3+1

Teaching Scheme:
Lectures: 3 h / week
Practical: 2 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
PR: 50
Total: 150

Course Outcomes:

CO1	Analyze dynamic behavior of different first order systems for given input.
CO2	Analyze dynamic behavior of different second order systems and select different types of controllers to analyze feedback control systems.
CO3	Determine stability of a feedback control systems by root locus method and set controller parameters by different controller tuning techniques.
CO4	Analyze frequency response of a process by Bode method and predict stability of a feedback control system.
CO5	Design control systems with multiple loops and application of computer in process control.

Unit I: Dynamic behavior of simple processes **(6h)**
Objectives of Chemical Process Control, Mathematical modeling of chemical processes, State variables and state equations, Input-Output model, Linearization of nonlinear systems, Types of Forcing functions, dead-time systems, First order systems/processes – Thermometer, Liquid level tank, Liquid level tank with constant outlet (pure capacitive), isothermal and non-isothermal CSTR, Dynamic response of first order system to impulse and step inputs, basic concepts of MIMO systems.

Unit II: Design of single-loop feedback control systems **(7h)**
Second order systems/processes – Damped vibrator, Interacting and Non-interacting systems, Step response of second order system, Characteristics of under-damped system. Classical controllers – P, PI, PD, PID and ON- OFF controllers. Concept of feed-back control system, Servo & Regulatory problem, Block diagram reduction of complicated control systems, and Dynamic behavior of feed-back control processes.

Unit III: Stability Analysis of feed-back systems **(7h)**
Notion of stability, Characteristic equation, stability analysis of feedback control system using Routh-Hurwitz criteria, Root locus. Simple performance criteria – controller tuning with one-quarter decay ratio criteria, Time Integral performance criteria by ISE, IAE, ITAE, etc., selection of feed-back controller, Controller tuning using process reaction curve by Cohen-coon technique.

Unit IV: Frequency response analysis of linear processes **(7h)**

Response of first order system to sinusoidal input, Frequency response characteristics of general linear system, Bode diagrams - First order system, Second order system, Pure capacitive process, dead time system, P, PI, PD & PID, Bode stability criteria, Gain margin, Phase Margin, Nyquist Stability criteria, Ziegler Nicholes Tuning technique

Unit V: Design of complex control system **(7h)**

Design of controllers with difficult dynamics such as large time-delay systems, inverse-response systems. Analysis and design of control systems with multiple loops (cascade, selective, split range control systems) Analysis and design of advanced control systems (feed forward, ratio, adaptive and inferential control systems)

Unit VI: Digital and Computer- based Control Systems: **(6h)**

Sampling of continuous signals to discrete- time signals, reconstruction of continuous- time signals from discrete- time signals using hold elements, Digital approximation of classical controllers, Role of digital computer in process control as process interface for data acquisition and control, Centralized control systems, supervisory control systems (SCADA), microcomputer- based control systems (PLC, DCS), Plant wide control for plants involving compressor, Heat Exchanger, Adiabatic Plug Flow Reactor.

List of Experiments (minimum 8):

1. Dynamic response of liquid tank level system
2. Dynamic response of thermometer in oil bath thermo well system
3. Dynamic response of two interacting systems
4. Dynamic response of two non-interacting systems
5. Dynamic response of an On-off controller
6. Dynamic response of P, PI and PID controllers
7. Root locus analysis
8. Root locus analysis on software (Ex. MATLAB)
9. Bode plot on software (Ex. MATLAB)
10. PID control loop simulation for a first order process (Ex. SIMULINK)
11. Cascade control system
12. Heat exchanger control system

Reference Books:

1. Chemical Process Control, George Stephanopoulos, PHI publication,
2. Process System Analysis & Control, Donald R. Coughanour, Mc Graw Hill
3. Process Control – Modelling, Design & Control, B. Wayne Bequette, PHI Publication
4. Process Dynamics & Control, Dale E. Seaborg, Thomal F. Edgar, Dancan A. Mellichamp
5. Process Dynamics, Modeling & Control – Babatunde A. Ogunnaike, W. Harmon Ray, Oxford University Press Inc.
6. Computer Control of Processes – M. Chidambaram, Alpha Science International Ltd.
   Instrument Engineers Handbook (Process Control) –Bella G. Liptak, Elsevier

BE (Chemical Engineering)-2019
Course Code: 409342
Chemical Reaction Engineering II
Credits: 3

Teaching Scheme:	**Examination Scheme:**
Lectures: 3h / week	In Semester: 30
	End Semester: 70
	Total: 100

Unit I: Heterogeneous Reactions (6 h)

Types, rates, contacting patterns. Fluid-Particle reactions: Selection of model unreacted core model, progressive conversion model, Rate of reaction for shrinking spherical particles. Determination of rate controlling step, application to design, application to fluidized bed with entrainment.

Unit II: Fluid – Fluid Reaction (7 h)

Rate equation for reaction, kinetic regimes (case A to H), film conversion parameter, slurry reaction kinetics, aerobic fermentation, application to design (fast and slow reactions), mixer settler, Semi batch contacting pattern, reactive distillation and extractive reactions

Unit III: Catalysis and Adsorption (7 h)

Surface chemistry and adsorption, adsorption isotherms and rates of adsorption. Catalysis: Determination of surface area by BET method, void volume and solid density, pore-volume distribution, catalyst selection, preparation of catalyst and its deactivation, poisoning and regeneration, nature and mechanism of catalytic reactions.

Unit IV: Reaction and Diffusion in porous catalyst (7 h)

Gaseous diffusion in single cylindrical pore, diffusion in liquids, in porous catalyst, surface diffusion, mass transfer with reaction: effectiveness factor, experimental and calculated effectiveness factor, selectivity's for porous catalysts, rates for poisoned porous catalysts.

Unit V: Solid- catalyzed Reaction (7 h)

Rate equation (Film resistance, surface phenomenon, pore diffusion) experimental methods for finding rates, determining controlling resistances and rate equation, product distribution in multiple reactions.

Unit VI: Design of Heterogeneous Catalytic Reactors and Biochemical Reaction Systems (6h)

Fluidized bed reactor, isothermal and adiabatic fixed bed reactor, fluidized bed reactor, slurry reactor, enzyme fermentation: Michaelis–Menten (M-M) kinetics, inhibition by foreign substance.

Reference Books:

1) Chemical Reaction Engineering: Octave Levenspiel (2nd & 3rd Edition)
2) Chemical Engineering Kinetics: J. M. Smith (3rd Edition)
3) Elements of Chemical Reaction Engineering: H. Scott Fogler (4th Edition)
4) Heterogeneous Reactions: Analysis Examples and reactor Design. Vol.1 & 2- Doraiswamy L. K. and Sharma M. M.
5) An Introduction to Chemical Reaction Kinetics & Reactor Design - C.G.Hill.

BE (Chemical Engineering)-2019 Course
Code: 409343
Chemical Engineering Design
Credits: 3 + 1

Teaching Scheme:
Lectures: 3 h / week
Drawing: 2 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
OR: 50
Total: 150

Course Outcomes:

CO1	Develop the mechanical and process design of the plate distillation column.
CO2	Design the process and mechanical aspects of the packed bed distillation column.
CO3	Apply basic concepts, design calculations and materials of construction of the piping system
CO4	Differentiate the types and applications of the plant utilities required in the process industries
CO5	Identify the types of the maintenance and the process safety measures to be taken in the design and operation of the project

Unit 1: Agitators and Reaction vessels **6Hrs**

Study of various types of agitators, their selection, applications, baffling, agitator shaft diameter calculations which includes twisting moment, equivalent bending moment, power requirement calculations for agitation systems.

Reaction vessels: introduction, classification, heating systems, design of vessels, study and design of various types of jackets like plain, half coil, channel, limpet oil, study and design of internal coil reaction vessels, heat transfer coefficients in coils.

Unit 2: Storage Vessels **7 Hrs**

Study of various types of storage vessels and applications, Atmospheric vessels, vessels for storing volatile and non-volatile liquids, storage of gases, Losses in storage vessels, Various types of roofs used for storage vessels, Design of cylindrical storage vessels as per IS: 803- design of base plates, shell plates, roof plates, wind girders, curb angles for self-supporting and column supported roofs. Design of rectangular tanks as per IS: 804.Stresses in the shell of a tall vertical vessel, and period of vibration.

Vessel supports- introduction and classification of supports, design of skirt supports considering stresses due to dead weight, wind load, seismic load, design of base plate, skirt bearing plate, anchor bolts, bolting chairs and skirt shell plates Design of saddle supports, ring stiffeners.

Unit 3: Heat Exchangers **7 Hrs**

Shell and tube heat exchanger- General design considerations- LMTD correction factor, fluid allocation, fluid velocities, stream temperatures, pressure drop, shell side and tube side heat transfer coefficients, overall heat transfer coefficient, mechanical design of shell and tube heat exchanger thickness of shell and shell cover, channel cover, tube sheet, size and number of tie rods and spacers.

Design of double pipe heat exchanger. Plate heat exchanger: advantages, disadvantages, design procedure, temperature correction factor, heat transfer coefficients, pressure drop.

Evaporators: classification, criteria for selection, design of calendria type evaporator.

Unit 4: **Design of distillation column** **7 Hrs**

Design variables in distillation, design methods for binary systems, plate efficiency, approximate column sizing, plate contactors, and plate hydraulic design.

Unit 5: Design of Packed column **6Hrs**

Choices of plates or packing, packed column design procedure, packed bed height (distillation and absorption), HTU, Cornell's method, Onda's method, column diameter, column internals, wetting rates, column auxiliaries.

Unit 6: Piping Design **7 Hrs**

A brief revision covering friction factor, pressure drop for flow of non-compressible and compressible fluids, (Newtonian Fluids), pipe sizing, economic velocity. Pipe line networks and their analysis for flow in branches, restriction orifice sizing. Pipe supports, non-Newtonian fluids – types with examples, pressure drop calculations for non-Newtonian fluids. Pipe line design on fluid dynamic parameter. Design of pipeline for natural gas, Pipeline design for transportation of crude oil.

Term work: Process and Mechanical design and drawing of any five equipments from unit 1 to 6 which should include at least two sheets based on AUTOCAD/Autodesk or design software.

Reference Books:

1. "Process equipment design" by L.E. Brownell and E. Young, John Wiley, New York, 1963.
2. "Introduction to Chemical Equipment Design" by B.C. Bhattacharya C.B.S. Publications.
3. "Process Equipment Design" by M.V. Joshi, Mcmillan India.
4. "Chemical Engineering Vol. 6" by J.M. Coulson, J.F. Richardson and R.K. Sinott, PergamonPress.

5. “Chemical Engineering volume 2” by J. M. Coulson, J. F. Richardson, and R. K. SinottPergamon Press.
6. “Applied Process Design for Chemical and Petrochemical Plants” vol 1 and 2, Ludwig E.E., GulfPublishing Company, Texas.
7. “Indian standards Institution” code for unfired pressure vessels, IS - 2825
8. “Chemical Process Equipment-Selection and design” Walas S.M. Butterworth Heinamen, McGraw Hill book company, New York
9. “Mass Transfer Operations” by Treyball R.E., McGraw Hill, New York.
10. Pipe Drafting and Design by Roy A Parisher& Robert A. Rhea, Gulf Professional Publishing, 2012.
11. Hydraulics and Fluid Mechanics by Modi and Seth, Standard Publishers Distributors.
12. “Process Design of Equipments” by S. D. Dawande, Central Techno Publication

BE (Chemical Engineering)-2019 Course
Code: 409344
Elective III
Credits: 3

409344: (A) Environmental Engineering

Teaching Scheme
Lectures: 3 h / week

Examination Scheme
In Semester: 30
End Semester: 70
Total: 100

Course Outcomes:

CO1	Classify types of pollutions and illustrate pollution laws and standards
CO2	Identify air Pollution-Sources, Effects and Measurement and apply Controlling Methods
CO3	Differentiate types, sources and effects of water pollutants in wastewater and determine Wastewater characteristics
CO4	Select and design the wastewater treatments to minimize water pollution
CO5	Apply tertiary wastewater Treatment and Solid Waste Management for its disposal

Unit I: Introduction (6 h)

An overview of environmental engineering, pollution of air, water and soil, impact of population growth on environment, environmental impact of thermal, hydro and nuclear energy, chemical pollution, solid wastes, prevention and control of environmental pollution, water and air pollution laws and standards, clean development mechanisms (CDM), Kyoto protocol.

Unit II: Air Pollution- Sources, Effects and Measurement (7 h)

Definition of air pollution, sources scales of concentration and classification of air pollutants. Effects of air pollutants on human health, plants, animals, materials, Economic effects of air pollution, sampling and measurement of air pollutants, air pollution control standards: WHO, BIS, MPCB, CPCB.

Unit III: Air Pollution Control Methods and Equipment (7 h)

Particulate pollution: cleaning methods, collection efficiency, particulate collection systems, Basic design and operating principles of settling chamber, cyclone separator, fabric filter, electrostatic precipitator. Operating principles of spray tower, centrifugal scrubber, venturi scrubber, selection of particulate collector. Gaseous pollution: Principles of control by absorption, adsorption, combustion or catalytic oxidation, removal of SOx, NOx. Numerical problems based on the theory.

Unit IV: Water Pollution (7 h)

Domestic and industrial wastewater, types, sources and effects of water pollutants. Waste water characteristics–DO, BOD, COD, TOC, total suspended solids, colour and odour, bacteriological quality, oxygen deficit, determination of BOD constants. Water quality standards: ICMR, WHO, MPCB and CPCB.

Unit V: Wastewater Treatment **(7 h)**

Principles of primary treatment and secondary treatment, process design and basic operating principles of activated sludge (suspended growth) process, sludge treatment and disposal, trickling filter, Moving Bed Bio film Reactor (MBBR). Advanced methods of waste water treatment: UASB, photo catalytic reactors, wet-air oxidation, Membrane Bioreactor (MBR) and biosorption.

Unit VI: Tertiary Water Treatment and Solid Waste Management **(6 h)**

Tertiary treatment: disinfection by chlorine, ozone and hydrogen peroxide, UV rays, recovery of materials from process effluents, micro-screening, biological nitrification and denitrification, granular medium filtration. Land Pollution: Sources and classification of solid wastes, disposal methods, incineration, composting, recovery and recycling.

Reference Books:

1. Rao C. S. "Environmental Pollution Control Engineering", Wiley Eastern Publications.
2. Metcalf and Eddy "Wastewater Engineering", Tata McGraw Hill Publishers.
3. Mahajan S.P. "Pollution Control in Process Industry", Tata McGraw Hill Publishers
4. J.C. Mycock, John D. McKenna, Louis Theodore "Handbook of Air Pollution Control Engineering and Technology".
5. Flagan R.C. and Seinfield J.H. "Fundamentals of Air Pollution Engineering" Prentice-Hall, Inc. , Englewood Cliffs, New Jersey.
6. Peavy H.S. and Rowe D.R. and Tchobanoglous G. "Environmental Engineering" McGraw-Hil International Ed., 1985,
7. Martin Crowford "Air Pollution Control theory" McGraw-Hill Inc.,US.
8. Stern "Air Pollution", Vol.-I and Vol.-II, 2nd Edition, Academic Press, New York.
9. G. Kiely, Environmental Engineering, McGraw Hill 1997.

BE (Chemical Engineering)-2019 Course
Code: 409344
Elective III
Credits: 3
409344: (B) Membrane Technology

Teaching Scheme:	**Examination Scheme:**
Lectures: 3 h / week	In Semester: 30
	End Semester: 70
	Total: 100

Unit I: Introduction to membrane processes, membrane materials and their properties **(6h)**

Introduction: Objectives, classification, and selection criteria for industrial separation processes, historical background and introduction to membranes and membrane processes. Benefits and drawbacks of membrane processes over conventional separation processes. Definitions of membrane, types of membranes (isotropic, anisotropic) volume flux, retention, separation factor. Membrane materials and their properties: Types of polymeric materials used for membrane preparation, Factors affecting properties of polymers, membrane polymers (porous, nonporous, and inorganic membranes), thermal, mechanical and chemical stability of polymers, membrane characterization.

Unit II: Membranes and membrane modules **(7h)**

Introduction, preparation of isotropic (nonporous and microporous) and anisotropic membranes, choice of polymer, casting solution solvent, precipitation medium and casting solution modifiers, interfacial polymerization membranes, solution-coated composite membranes, repairing membrane defects, metal and ceramic membranes, carbon membranes, glass membranes, liquid membranes, hollow fiber membranes. Membrane modules: Introduction, plate and frame model, spiral wound module, tubular module, capillary module, hollow fiber model, vibrating and rotating modules, comparison and selection of module configurations.

Unit III: Transport theories in Membranes **(7h)**

Introduction, driving forces, transport through microporous and dense membranes, solution diffusion theory (for dialysis, RO, hyper filtration, gas separation, pervaporation membranes), structure-permeability relationships, diffusion coefficients, sorption coefficients, pore flow theory (for UF, MF membranes), Ferry-Rankin equation, surface and depth filters, Knudsen diffusion and surface diffusion through microporous membranes.

Unit IV: Concentration polarization and fouling of membranes **(7h)**

Introduction, boundary layer film model, concentration polymerization in liquid separation and gas separation processes, effect of cross-, co- and counter-flow arrangements, gel layer model, osmotic pressure model, methods of reducing concentration polarization (turbulence promoters), temperature polarization, membrane fouling, methods to reduce fouling, membrane cleaning.

Unit V: Applications of UF, MF, RO processes (6h)

Describe basic transport theory, membranes and materials used, membrane selectivity, concentration polarization and fouling, membrane modules, system designs (batch, continuous, multistep, and multistage) and applications for each process. Applications: RO-Desalination of brackish and sea water, getting ultrapure water, waste water treatment, NF, organic solvent separation. UF- Food industry (cheese production, clarification of fruit juice), separation of oil-water emulsions, process water and product recycling. MF-Sterile filtration of pharmaceuticals, sterilization of wine and beer, drinking water treatment,

Unit VI: Applications of GS, PV, and other membrane processes (7h)

Describe basic transport theory, membranes and materials, membrane selectivity, concentration polarization and fouling, membrane modules, system designs (batch, continuous, multistep, and multistage) and applications for each process. Applications of: GS- Hydrogen separations, oxygen/nitrogen separation, natural gas separations, CO_2 separations, vapor/gas separations, vapor/vapor separations, dehydration of air. PV- Solvent dehydration, water purifications, organic/organic separations. Electro dialysis: Brackish water desalination, salt recovery from seawater, electrode ionization, Carrier facilitated transport (coupled transport membranes, ELM) - Removal and recovery of metals from dilute solutions, CO_2/H_2S separation, olefin separation, oxygen/nitrogen separations. Thermally-driven membrane processes (membrane distillation), membrane contactors, electrically driven membrane processes (electrodialysis, membrane electrolysis), membrane reactors and bioreactors.

Reference Books:

1. Marcel Mulder, Basic Principles of Membrane Technology, Kluwer Academic Publications.
2. Coulson and Richardson's Chemical Engineering, Volume 2, Elsevier.
3. S.P. Nunes, and K.V. Peinemann, membrane Technology in the chemical industry, Wiley-VCH.
4. R. Rautanbach and R. Albrecht, Membrane Process, John Wiley & Sons.
5. R.Y.M. Huang, Perevoparation Membrane Separation Processes, Elsevier.
6. J.G. Crespo, K.W. Boddekes, Membrane Processes in Separation and Purification, Kluwer Academic Publications.
7. Larry Ricci and the staff of chemical engineering separation techniques, McGraw Hill publications.
8. Richard W. Baker, Membrane Technology and Applications, John Wiley & Sons, Ltd

BE (Chemical Engineering)-2019 Course
Code: 409344
Elective III
Credits: 3
409344: (C) Industrial Piping

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit 1: Introduction: (6 Hrs)

Importance of piping in chemical industry, Pipes & Tubing, Classification of pipes, Pipe codes and specification. Pipe sizing, Schedule numbers, BWG, NPS. Desirable properties of piping materials, materials for low, normal & high temperature services, materials for corrosion resistance. Basic energy equation for flow, calculation of frictional losses, pressure drop for Newtonian & Non-Newtonian fluids. Calculation of pipe diameter, thickness, equivalent lengths, etc, single liquid lines, single gas &vapor lines, NPSH.

Unit 2: Pipe fittings: (7 Hrs)

Pipe fittings their advantages & disadvantages. Criteria for selection of pipe joints, pipe joints for similar and dissimilar material, valves expansion effects and methods for reducing them. Safety valves & other pressure relieving devices. Calculation of frictional losses, pressure drop for Newtonian & Non-Newtonian fluids.

Unit 3: Piping layout: (7 Hrs)

Piping layout piping diagrams, standard symbols & notations, types & design of pipe support, erection and maintenance of supporting, restraining and bracing systems. Fundamental considerations in pipe vibrations, types of vibrations, their prevention and control. Protection of pipe system such as cathode protection, painting, etc.

Unit 4: Piping design-1: (7 Hrs)

Pipeline design on fluid dynamics. Complex pipelines in series and parallel. Pipeline storage capacity. Piping design for two phase flow, dispersed flow. Slurry pipeline – design parameters, slurry rheology for homogeneous & heterogeneous slurries. Piping & components as gas expands – isothermal flow, adiabatic flow.

Unit 5: Piping design-2: (6 Hrs)

Design of pipeline for transportation of crude oil & for natural gas. Design of pipes in sea water. Empirical correlations for flow of oil, gasoline, hydrocarbons. Piping for cryogenic materials. Piping arrangements and factors considered in heat exchanger piping, reactor piping, process & storage vessel piping, reboiler piping, piping for compressor & pumps, utility piping.

Unit :6 Piping insulation: **(7 Hrs)**

Insulation for piping systems. Purpose of insulation. Insulation materials, their selection criteria, their important properties. Principles of heat transfer to the extent of application to heat loss/gain through bare pipe surfaces. Critical thickness of insulation, estimating thickness of insulation, optimum thickness of insulation.

Text Books:

1. Piping Design for process plants by H. F. Rase, John Wiley.
2. Process piping systems, ed" D. J.Deutsch, Chemical Engineering Magazine. McGraw Hill
3. Industrial Piping by Littleton C.T., McGraw Hill.
4. Process Design of Equipments, Dr.S.D.Dawande, Central Techno Publications.
5. Handbook of Piping Design, G.K. Sahu, New Age International Publisher.
6. Process Piping Design Vol. 1 and 2, R. Weaver, Gulf Publishing.

References Books:

1. Handbook of Piping Design, G.K. Sahu, New Age International Publisher.

BE (Chemical Engineering)-2019 Course
Code: 409344
Elective III
Credits: 3
409344: (D) Petroleum Refining

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
TW: 25
Total: 100

Unit I: Petroleum Composition and Products (6h)
Origin, formation, composition & Exploration of petroleum, crude assay, overall refinery Flow, specifications of petroleum products such as LPG, Gasoline, Kerosene, Diesel, lube oil, etc. as per standards like ASTM, ISO, etc.

Unit II: Crude Oil Distillation (7h)
Pre-refining operations such as Settling, Moisture removal, Desalting, Storage, Heating through exchangers and pipe still heaters, Atmospheric distillation, Vacuum distillation

Unit III: Conversion Processes (7 h)
Significant conversion processes such as catalytic & thermal cracking, hydro-cracking, reforming and coking.

Unit IV: Lube oil and Bitumen (7h)
Lube oil production, Properties of lube oil, deasphalting, Solvent extraction, dewaxing, Finishing operations, Lube oil additives, Manufacture of Bitumen.

Unit V: Supporting Processes (7h)
Hydrogen Management: Production and recovery, Sulphur Recovery, Environmental Pollution aspects in refinery

Unit VI: Finishing Processes and Logistics (6h)
Blending, Additives, Storage of products, Transportation, Safety norms, Housekeeping, Marketing of petroleum and petroleum products

Seminar (TW): The term-work shall be based on technical report prepared by individual or small group (2-3) of students on studies in industrial applications (case studies) of petroleum refining processes. Students are expected to deliver seminar presentation using audio-visual techniques on the topic.

Reference Books:

1. Gary J H, Handwerk G E, 'Petroleum refining technology and economics', Marcel Dekker, Inc.
2. Speight J G, 'The Chemistry and technology of petroleum', CRC Press.
3. Myers, 'Handbook of Petroleum Processing', McGraw-Hill Education.

BE (Chemical Engineering)-2019 Course
Code: 409345
Elective IV
Credits: 3
409345: (A) Chemical Process Synthesis

Teaching Scheme:	**Examination Scheme:**
Lectures: 3 hr / week	In Semester : 30
	End Semester : 70
	Total: 100

Unit I: Introduction to Chemical Process Design **(6h)**
Introduction, approach to process development, development of new process, different considerations, development of particular process, overall process design, hierarchy of process design, onion model, approach to process design.

Unit II: Choice of Reactor **(7h)**
Reaction path, types of reaction systems, reactor performance, idealized reactor models, reactor concentration, temperature, pressure, phase, catalyst.

Unit III: Choice of Separator **(7 h)**
Separation of heterogeneous mixtures, separations of homogeneous mixtures, distillation, azeotropic distillation, absorption, evaporation, drying etc

Unit IV: Distillation Sequencing **(7h)**
Distillation sequencing using simple columns, heat integration of sequences of simple distillation columns, distillation sequencing using thermal coupling, optimization of reducible structure.

Unit V: Heat Exchanger Network And Utilities **(7h)**
Energy targets, composite curves, heat recovery pinch, threshold problems, problem table algorithm, process constraints, utility selection, furnaces, combined heat and power, integration of heat pump, integration of refrigeration cycles, overall heat exchanger network and utilities.

Unit VI: Safety And Health Considerations: **(6 h)**
Fire, explosion, toxic release, intensification of hazardous materials, attenuation of hazardous materials, quantitative measures of inherent safety, overall safety and health considerations.

Reference Books:

1. Chemical process design- Robin Smith, Wiley.
2. Conceptual design of chemical process-James Douglas, McGraw Hill Book Company.
3. Unit process in organic synthesis – P.H. Groggins, Tata McGraw Hill Publishing Company Ltd.
4. Dryden's Outline of Chemical Engineering, Rao and M Gopala, East-West Press.

BE (Chemical Engineering)-2019 Course
Code: 409345
Elective IV
Credits: 3
409345: (B) Industrial Management and Entrepreneurship

Teaching Scheme:
Lectures : 3 hr / week

Examination Scheme:
In Semester : 30
End Semesters: 70
Total: 100

Unit I: The Entrepreneurial Development Perspective (6 h)
Concepts of Entrepreneurship Development, Evolution of the concept of Entrepreneur, Entrepreneur Vs. Entrepreneur, Entrepreneur Vs. Entrepreneurship, Entrepreneur Vs. Manager, Attributes and Characteristics of a successful Entrepreneur, Role of Entrepreneur in Indian economy and developing economies with reference to Self-Employment Development, Entrepreneurial Culture.

Unit II: Creating Entrepreneurial Venture and Project Management (7 h)
Business Planning Process, Environmental Analysis - Search and Scanning, Identifying problems and opportunities, Defining Business Idea, Basic Government Procedures to be complied with, Technical, Financial, Marketing, Personnel and Management Feasibility, Estimating and Financing funds requirement - Schemes offered by various commercial banks and financial institutions like IDBI, ICICI, SIDBI, SFCs, Venture Capital Funding.

Unit III: Entrepreneurship Development and Government (7 h)
Role of Central Government and State Government in promoting Entrepreneurship - Introduction to various incentives, subsidies and grants, Fiscal and Tax concessions available, Role of following agencies in the Entrepreneurship Development - District Industries Centers (DIC), Small Industries Service Institute (SISI), Entrepreneurship Development Institute of India (EDII), National Institute of Entrepreneurship & Small Business Development (NIESBUD), National Entrepreneurship Development Board (NEDB), Why do Entrepreneurs fail - The FOUR Entrepreneurial Pitfalls (Peter Drucker), Women Entrepreneurs: Reasons for Low / No Women Entrepreneurs, Role, Problems and Prospects. Case studies of Successful Entrepreneurial Ventures, Failed Entrepreneurial Ventures and Turnaround Ventures.

Unit IV: Management Theories and Managerial Work (7 h)
Stages of team development (Tuckman), Team role theory (Belbin), Management roles (Henry Mintzberg), Situational leadership (Blanchard), Hierarchy of needs (Maslow), Five competitive forces (Porter), Interview of mid / large cap industry professional (preferably MBA) to understand practical usage of any of these theories. Business communication**,** communication process, communication styles, and communication forms in organizations, fundamentals of business writing, patterns of business messages, report writing, public speaking and oral reporting, verbal and nonverbal communication, use of visual and presentation aides, and cultural and international dimensions of communication, Organization behavior.

Unit V: Project Management based on Microsoft Project (6 h)

Introduction, Project management concepts, Using Microsoft project, Start your plan, Adding resources to the model, Resource management & crashing, Resource rates & using calendars, Handling multiple projects, uncertain activity times, Tracking, Baseline & reports, Assignment – case study of a project involving various resources, timeline & costs, Business excellence through six sigma and kaizen.

Unit VI: Marketing Management (7 h)

Introduction to the basic concepts and principles of marketing, Consumer Behavior, Marketing Research, Product & Brand Management, Integrated Marketing Communications, Marketing Channels, International Marketing, Internet Marketing, Business-to-Business Marketing, Understanding the role of marketing in society and the firm, marketing concept, market segmentation, target marketing, demand estimation, product management, channels of distribution, promotion and pricing. Introduction to the concepts, principles, and techniques used in gathering, analyzing and interpreting the data for marketing decisions. The role of information in marketing decisions, research problem, formulation, research design methods, measurement and design of research instruments, sampling design, data collection methods, data analysis and presentation of research results.

Reference Books:

1. Entrepreneurship: New Venture Creation - David H. Holt, Prentice Hall PTR, 1992.
2. Entrepreneurship - Robert D. Hisrich, Michael P. Peters, Dean A. Shepherd, McGraw-Hill Education, 2013.
3. The Culture of Entrepreneurship - Brigitte Berger, Ics Press, 1991.
4. Project Management - K. Nagarajan, New Age International, 2004.
5. Dynamics of Entrepreneurship Development - Vasant Desai, Himalaya Publishing House, 2001.
6. Entrepreneurship Development**:** An Interdisciplinary Approach, S. G. Bhanushali, Himalaya Publishing House, 1987
7. Thought Leaders –ShrinivasPandit, Tata McGraw-Hill Education, 2002.
8. Entrepreneuring: The Ten Commandments for Building a Growth Company, Steven C. Brandt, Archipelago Pub., 1997.
9. Business Gurus Speak - S.N. Chary, 2002.
10. The Entrepreneurial Connection –Gurmit Narula, Tata Mc-Graw Hill.
11. Business Marketing Management: B2B, Michael Hutt, Thomas Speh, Cengage Learning, 2012.

BE (Chemical Engineering)-2019 Course
Code: 409345
Elective IV
Credits: 3

409345: (C) Green Technology

Teaching Scheme:
Lectures : 3 hr / week

Examination Scheme:
In Semester : 30
End Semesters : 70
Total: 100

Unit 1: Principles and concepts of Green Chemistry: (6 Hrs)
Introduction, Sustainable Development and Green Chemistry, Atom Economy, Atom Economic Reactions, Rearrangement Reactions, Addition Reactions, Atom Un-economic Reactions, Substitution Reactions, Elimination Reactions, Wittig Reactions, Reducing Toxicity, Measuring Toxicity

Unit 2: Production, Problems and Prevention: (7 Hrs)
Introduction, Some Problems Caused by Waste, Sources of Waste from the Chemical Industry, The Cost of Waste, Waste Minimization Techniques, The Team Approach to Waste Minimization, Process Design for Waste Minimization, Minimizing Waste from Existing Processes, On-site Waste Treatment, Physical Treatment, Chemical Treatment, Bio-treatment Plants, Design for Degradation, Degradation and Surfactants, DDT, Polymers, Some Rules for Degradation, Polymer Recycling, Separation and Sorting, Incineration, Mechanical Recycling, Chemical Recycling to Monomers

Unit 3: Measuring and controlling environmental performance: (7 Hrs)
The Importance of Measurement, Lactic Acid Production, Safer Gasoline, Introduction to Life Cycle Assessment, Green Process Metrics, Environmental Management Systems, The European Eco-management and Audit Scheme, Eco-labels, Legislation, Integrated Pollution Prevention and Control. Catalysis and green chemistry: Introduction to Catalysis, Comparison of Catalyst Types, Heterogeneous Catalysts, Basics of Heterogeneous Catalysis, Zeolites and the Bulk Chemical Industry, Heterogeneous Catalysis in the Fine Chemical and Pharmaceutical Industries, Catalytic Converters, Homogeneous Catalysis, Transition Metal Catalysts with Phosphine Ligands, Greener Lewis Acids, Asymmetric Catalysis, Phase Transfer Catalysis, Hazard Reduction, C–C Bond Formation, Oxidation Using Hydrogen Peroxide, Bio-catalysis, Photocatalysis.

Unit 4: Organic solvents, Environmentally benign solutions: (7 Hrs)
Organic Solvents and Volatile Organic Compounds, Solvent-free Systems, Supercritical Fluids, Supercritical Carbon Dioxide, Supercritical Water, Water as a Reaction Solvent, Water-based Coatings, Ionic Liquids, Ionic Liquids as Catalysts, Ionic Liquids as Solvents, Fluorous Biphase Solvents. Renewable resources: Biomass as a Renewable Resource, Energy, Fossil Fuels, Energy from Biomass, Solar Power, Other Forms of Renewable Energy, Fuel Cells, Chemicals from Renewable Feedstock's, Chemicals from Fatty Acids, Polymers from Renewable Resources, Some Other Chemicals from Natural Resources, Alternative Economies, The Syngas Economy, The Biorefinery, Chemicals from renewable feed stocks.

Unit 5: Emerging Greener technologies and Alternative energy solutions: (6 Hrs)
Design for Energy Efficiency, Photochemical Reactions, Advantages of and Challenges Faced by Photochemical, Processes, Examples of Photochemical Reactions, Chemistry Using Microwaves, Microwave Heating, Microwave-assisted Reactions, Sonochemistry, Sonochemistry and Green

Chemistry, Electrochemical Synthesis, Examples of Electrochemical Synthesis. Designing greener processes: Conventional Reactors, Batch Reactors, Continuous Reactors, Inherently Safer Design, Minimization, Simplification, Substitution, Moderation, Limitation, Process Intensification, Some PI Equipment, Examples of Intensified Processes, In-process Monitoring, Near-infrared Spectroscopy

Unit 6: Industrial case studies: **(7 Hrs)**
A Brighter Shade of Green, Greening of Acetic Acid Manufacture, EPDM Rubbers, Vitamin C, Leather Manufacture, Tanning, Fatliquoring, Dyeing to be Green, Some Manufacturing and Products Improvements, Dye Application, Polyethene, Radical Process, Ziegler–Natta Catalysis, Metallocene Catalysis, Eco-friendly Pesticides, Insecticides. An integrated approach to a greener chemical industry: Society and Sustainability, Barriers and Drivers, The Role of Legislation, EU White Paper on Chemicals Policy, Green Chemical Supply Strategies

Text Books:

1. Mike Lancaster, Green Chemistry, Royal Society of Chemistry, 2010.
2. Paul T. Anastas John C. Warner, Green Chemistry: Theory and Practice, Oxford University Press, 2000.
3. Jay Warmke, Annie Warmke, Green Technology, Educational Technologies Group, 2009.

E-Resources: NPTEL/SWAYAM

BE (Chemical Engineering)-2019 Course
Code: 409345
Elective IV
Credits: 3
409345: (D) Advanced Separation Processes

Teaching Scheme:
Lectures : 3 hr / week

Examination Scheme:
In Semester: 30
End Semesters: 70
Total: 100

Course Outcomes:

CO1	To built advanced concepts of separation techniques used in chemical industries.
CO2	To investigate the principles and functioning advanced separation techniques.
CO3	To utilize the advanced separation technique in problem solving where conventional techniques are not fruitful and require replacement.
CO4	To Identify the applications of advanced separation techniques as per industrial requirement.
CO5	To recognize the selection criteria between advanced separation techniques and conventional separation techniques
CO6	To Identify the suitable technique for the Separation of specific component in various industrial application.

Unit I: Multicomponent Distillation **(6 h)**

Multicomponent distillation - basic principles, low key high key components, concept of K value and its application in design, tray to tray calculations, Thiele-Geddes and Maddox methods, case studies, Azeotropic and extractive distillation, choice of entrainer.

Unit II: Azeotropic & Extractive Distillation **(7 h)**

Azeotropic & extractive distillation – working principles, residue curve maps, homogeneous azeotropic distillation, pressure swing distillation, column sequences, heterogeneous Azeotropic distillation.

Unit III: Reactive Separations **(7 h)**

Separation based on reversible chemical complexation, reactive distillation, reactive extraction, reactive crystallization, working principles and process design aspects for all, applications of all.

Unit IV: Membrane Separation Techniques **(7 h)**

Mechanisms of separation in MF,UF,RO, dialysis, electro dialysis, pervaporation, gas permeation and their mass transfer aspects in detail, design parameters for all processes, fouling, liquid emulsion membranes, industrial applications.

Unit V: Adsorption **(6 h)**

General principles, detailed study of temperature swing adsorption (TSA) and pressure swing adsorption (PSA) with study of cycles, liquid chromatography as a separation processes- basic concepts, phenomena and their characterization, chromatography options, separation systems, characteristics of solids and their selection for various applications, column design and filling, applications of chromatography in separation of enzymes and proteins, industrial examples.

Unit VI: Non Conventional Separation Techniques **(7 h)**

Introduction and working principles - zone electrophoresis, zone refining, molecular sieves, ultra centrifugation, foam formation, collapse and drainage phenomena, and equipments, adsorption properties of foams, modes of operation of foam fractionation equipments, principle of froth flotation, properties of foam related to flotation operation, design and development of flotation equipment, applications of the above.

Reference Books:

1) "Basic Principles of Membrane Technology", Mulder M., Luksvar Academic.
2) "Chemical Engineering Vol- 2 ", Richardson – Coulson, Pargamon.
3) "Mass transfer Operations", Treybal, Mc GRaw Hill Publication.
4) "Handbook of Separation Process Technology", Rousseau, Wiley –Interscience.
5) "Separation Techniques for chemical engineers", Schweitzer, Mc Graw – Hill Publications
6) Separation processes, King C. J., Mc GRaw Hill Publication.

BE (Chemical Engineering)-2019 Course
Code: 409347
Computer Aided Chemical Engineering II

Credits: 1

Teaching Scheme:	**Examination Scheme:**
Practical: 2 Hrs/ Week	TW: 50 Marks Total: 50 Marks

Minimum 10 Practical Assignments must be completed using computational as well as simulation softwares. **Aspen plus**, ***Hysys, ChemCAD, EnviroPro, ANSYS, Mathcad, Matlab, Unisim, DWSim etc***. can be used for solving practical assignments.

1. Computer program for solving basic linear algebra involving matrix operations
2. Computer program for solving non-linear algebraic equation/s
3. Computer program for solving steady state staged operation (distillation, gas absorption, L-L extraction, etc.)
4. Computer program for solving un-steady state staged operation (distillation, gas absorption, L-L extraction, etc.)
5. Computer program for plotting P-x-y and T-x-y diagram
6. Computer program for design of reactor/ heat exchangers. distillation column/or any chemical equipment
7. Computer program for solving ODE or PDE using finite difference method
8. Simulation of mass transfer equipment using simple and rigorous methods
9. Simulation of product synthesis using different reactors
10. Simulation of steady state flow sheet synthesis
11. Simulation of dynamic flow sheet synthesis
12. Simulation of fluid flow problems with or without heat/mass transport

BE (Chemical Engineering)-2019 Course
Code: 409348
Project Phase I Credits: 1

Teaching Scheme:	**Examination Scheme:**
Practical: 4 h / week	**TW: 50**
	Total: 50

The department should display the list of approved teachers (guides) along with the project titles proposed by them. The students should be given liberty to choose the project area and project guide of their own choice. The student can also choose a state-of-the-art problem of their own interest based on the recent trends in Chemical Engineering / Science in consultation with the guide. They shall work on the designated problem either individually or in groups (maximum **two** students per group).

During the first term the students are required to:

1. Define the research problem.
2. Write a *research proposal*, which should contain –
   a. Project title
   b. Introduction
   c. Origin of the problem
   d. Literature review of research and development at national & international level
   e. Significance of the problem
   f. Objective
   g. Methodology
   h. Details of collaboration (if any)
3. Carry out *preliminary* experimental investigations or product design or process design etc.
4. Summarize the results (if any).

The student is required to prepare a month wise work plan (for both semesters) immediately after the allotment of the project and the department is required to maintain a progress report of every student/project. The progress report should reflect monthly progress done by the student as per the work plan. The progress report is to be duly signed by the respective project guide by giving the remarks/marks/grades etc. on the periodic progress done by the student at the mid of the term and should be **submitted along with project report** at the end of respective terms to the examiners as a supporting document for evaluation. Every student will be examined orally based on the topic of his/her project and relevant area to evaluate his understanding of the problem and the progress made by the student during the term. Students should submit a neatly typed and spiral bound *research proposal* at the end of the first term in the following format.

Font: Times New Roman, Font size: 12, Headings: 14, Spacing: 1.5, typed on one side of the A4 size paper with proportionate diagrams, figures, graphs, photographs, tables etc.

Referencing style:

1. Guo J. X. and Gray D. G., Chiroptical behavior of (acetyl)(ethyl)cellulose liquid-crystalline solutions in chloroform, *Macromolecules, 22*, (1989), 2086.

(Reference numbers should be mentioned in the main text as a superscript)

The proposal should contain:

Page 1: The cover page - should mention: Project title, Name of the student, Name of the guide, Exam seat number and Year.

Page 2: Certificate

Page 3: Index

Page 4 onwards: Research proposal (as above), experimental investigation details and result if any. Last page: References

The department should prepare a template of the format of the project report and supply it to the students so as to maintain the uniformity in the project reports.

Students are encouraged to participate and present their project work in various events, competitions, conferences and seminars etc. in consultation with their guide.

Note: The project guides are required to educate the students about antiplagiarism policy of SPPU and apply the same while doing the project.

SEMESTER II

BE (Chemical Engineering)-2019 Course
Code: 409349
Process Modeling & Simulation
Credits: 3 + 1

Teaching Scheme:
Lecture: 3 hrs/week
Practical: 2 hrs/week

Examination Scheme:
In Semester: 30
End Semesters: 70
Oral: 50 Marks
TW: 25
Total: 175

Course Outcomes:

CO1	Understand different types of models and fundamental laws governing models.
CO2	Apply modeling laws to Fluid flow system& simulation.
CO3	Develop mathematical models for heat transfer systems.
CO4	Formulate modeling equations for mass transfer systems.
CO5	Apply modeling laws to different types of chemical reactors & simulation.
CO6	Simulate mathematical models using various numerical methods.

Unit I: Introduction to Modeling **(6 h)**

Introduction, definition of modeling and simulation, different types of models, application of mathematical modeling, scope of coverage. Fundamental Laws: Continuity equation, energy equation, and equation of motion, transport equation, equation of state, phase and chemical equilibrium, chemical kinetics.

Unit II: Models in Fluid Flow Operations: **(7 h)**

The continuity equation, Flow through Packed bed column, Laminar Flow in narrow Slit, Flow of Film on the outside of circular tube, Momentum fluxes for creeping flow in to slot.

Unit III: Heat Transfer and other Equipments **(7 h)**

Two heated tanks, double pipe heat exchanger, shell and tube heat exchanger, cooling towers Single effect and multi effect evaporators, agitated vessels, pressure change equipments, mixing process, fluid – solid operations.

Unit IV: Mass Transfer Equipments **(7 h)**

Flash distillation, differential distillation, and continuous binary distillation in tray and packed column, vaporizers, single phase and multiphase separation, multi-component separation, drying equipments, adsorption, absorbers and strippers. Batch liquid- liquid extraction, continuous extraction, multistage counter current extraction, Mixer-Settler Extraction Cascades, Staged Extraction Columns.

Unit V: Reaction Equipments **(7 h)**

Batch reactor, Semi batch reactor, Continuous stirred tank reactor, Plug flow reactor, Slurry reactor, Trickle bed reactor, Bubble column reactor, Packed column reactor, Bioreactors, Reactors used in effluent treatments, Fluidized bed reactor.

Unit VI: Applications of modeling and simulation **(6 h)**

Applications of modeling and simulation in distillation, Transient analysis of staged absorbers, unsteady state analysis in reactor system, Modeling and simulation of effluent treatment plant, Use of numerical methods to solve different models.

Practical:
Ten practical will be conducted with the use of mathematical and chemical engineering CAD software's such as ***Hysys,*** **Aspen plus,** ***ChemCAD, EnviroPro, Mathcad, Matlab, Unisim, DWSim*** etc. development

of programs for numerical methods and process simulation.

Reference Books:

1. Luyben W. L., "Process Modeling Simulation and Control for Chemical Engineers", McGraw Hill, 1988.
2. Davis M. E., "Numerical Methods and Modeling for Chemical Engineers", Wiley, New York, 1984.
3. Finlayson B. A., "Nonlinear analysis in Chemical Engineering", McGraw Hill, New York, 1980.
4. Chapra S.C., R.P. Canale, "Numerical Methods for Engineers", Tata-McGraw Hill Publications
5. Franks R.E.G., "Modeling and Simulation in Chemical Engineering", Wiley Intrscience, NY
6. John Ingam, Irving J. Dunn., "Chemical Engineering Dynamic Modeling with PC Simulation", VCH Publishers.
7. Kayode Coker A., "Chemical Process Design, Analysis and Simulation", Gulf Publishing Company.
8. Himmelblau D., K.B. Bischoff, "Process Analysis and Simulation", John wiley & Sons.
9. Wayne Blackwell, "Chemical Process Design on a Programmable Calculator", McGraw Hill.
10. R. W. Gaikwad, "Process Modeling and Simulation", Dennett & Co.

BE (Chemical Engineering)-2019 Course
Code: 409350
Process Engineering Costing & Plant Design
Credits: 3 + 1

Teaching Scheme:
Lecture: 3 hrs/week
Practical: 2 hrs/week

Examination Scheme:
In Semester: 30
End Semesters: 70
Oral: 50
TW: 25
Total: 175

Course Outcomes:

CO1	Apply the knowledge of overall aspects of the Chemical Engineering Plant Design.
CO2	Implement basic concepts and various terms of cost Engineering and make cost estimation and cost-profit analysis of chemical manufacturing process.
CO3	Apply Techniques for economic optimization and optimum design.
CO4	Understand the optimization of different process equipment.
CO5	Apply network Techniques such as CPM and PERT for the Chemical Engineering Project management.

Unit I: Process Development **(6 h)**

Process selection, study of alternative processes, pilot plant, scale up methods, flow sheet preparation, sketching techniques, equipment numbering, stream designation, material and energy balances. Plant Design: Design basis, process selection - selection of equipment, specification and design of equipment's, material of construction, plant location, plant layout and installation, safety, start up, shutdown and operating guidelines, loss prevention and Hazop study.

Unit II: Cost Engineering **(7 h)**

Time value of money and equivalence, interest-simple, compound and continuous, present worth and discount, annuities, perpetuities and capitalized cost methods, depreciation, nature of depreciation, methods of determining depreciation, taxes and insurances, types of taxes and insurances, procedure for cost comparison after taxes.

Unit III: Cost Estimation **(7 h)**

Cash flow for industrial operations, cumulative cash position of cash flow for an industrial operations, capital investments, fixed capital cost, working capital cost, start-up costs, process equipment cost estimation, cost index, cost factors in capital investment, methods of estimating capital investment, estimation of plant cost, estimation of total product cost, manufacturing cost, general expenses. Profitability: Criteria of profitability, payout period, return on investment, present value, cash flow analysis, alternative investment analysis.

Unit IV: Economic Optimization and Optimum Design **(7 h)**

Nature of optimization, uni-variable and multivariable systems, analytical, graphical and incremental methods of solution, Lagrange multiplier method, linear programming, other techniques and strategies establishing optimum conditions, break even chart for production schedule, optimum production rates in plant operation, optimum conditions in batch and cyclic operation.

Unit V: Optimization of Different Process Equipment **(6 h)**

Transportation systems, heat exchangers, evaporators, mass transfer equipments and reactors. determination of height and diameter of different process equipments at conditions of optimum cost. Pinch technology analysis. Preparation of techno-economic feasibility report.

Unit VI: Scheduling and Networking of Project **(7 h)**

Role of project engineering in project organization, start up and shut downs of project; preliminary data for construction projects; process engineering; plot plans, scheduling the project; engineering design and drafting, the design report, organization of design report. Critical path method (CPM): events and activities; network diagramming; earliest start time and earliest finish time ;latest start time and latest finish time; float, advantage of CPM; cost to finish t h e projects earlier than normal cost; precedence diagramming. programme evaluation and review technique (PERT): pert network and time estimates.

Practical:

1. Minimum six drawings of following preferably on Auto CAD/Autodesk.
   Standard symbols as per IS code
   Process flow diagram.
   Piping and instrumentation diagram.
   Utility diagram.
   Plant layouts and elevations.
   Piping GA drawing.
   Piping isometrics.
2. Minimum two assignments based on theory to be solved on computer.

Reference Books:

1. M. S. Peters & K. D. Timmerhaus, "Plant Design and economics for chemical engineers." Mc Graw Hill (2002).
2. Richard Turton, R.C. Bailie, W.B. Whiting, J.A. Shaeiwitz, "Analysis, Synthesis and Design of Chemical Processes", Prentice Hall
3. R.K Sinnot," Coulson & Richardson's Chemical Engineering- Chemical Engineering Design", Vol. 6, Butterworth-Heinemann
4. Kalyanmoy Deb, "Optimization For Engineering Design-Algorithms and Examples", PHI Learning Private Limited
5. S.S. Rao, "Engineering Optimization- Theory and Practice", New Age International
6. T.F.Edgar, D.M. Himmelblau,"Optimization of Chemical Processes", McGraw Hill
7. Srinath L. S., “PERT AND CPM.” affiliated East Press Pvt. Ltd., New York (1973)
8. Perry J. H.,”Chemical engineering handbook” 7^{TH} ed. Mc Graw Hill (1997)

BE (Chemical Engineering)-2019Course

Code: 409351

Elective V

Credits: 3

409351: (A): Energy Audit and Conservation

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit 1: Energy Scenario: **(7 Hrs)**

Classification of energy sources, commercial and noncommercial energy, energy resources, commercial energy production, final energy consumption, energy needs of growing economy, long term energy scenario. energy and environment, air pollution, climate change, energy security, energy conservation and its importance, energy strategy for the future, energy conservation act-2001 and its features. Applications of renewable energy sources.

Unit 2: Energy Management and Audit: **(6 Hrs)**

Definition, energy audit – need, types of energy audit, energy management (audit) approach understanding energy costs, bench marking, energy performance, matching energy use requirement maximizing system efficiencies, optimizing the input requirements, fuel and energy substitution, energy audit instruments, role, responsibilities and duties of energy management

Unit 3: Guidelines for writing energy audit report: **(7 Hrs)**

Report-writing, preparations and presentations of energy audit reports, Post monitoring of energy conservation projects, MIS, Case-studies / Report studies of Energy Audits, data presentation in report, findings recommendations, impact of renewable energy on energy audit recommendations. Instruments for Audit and Monitoring Energy and Energy Savings, Types and Accuracy. Case studies of implemented energy cost optimization projects in electrical utilities as well as thermal utilities.

Unit 4: Energy Available for Industrial Use: **(7 Hrs)**

Introduction, methodology for forecasting industrial energy supply and demand. New energy technologies and conservation, motivation of implementing conservation measures, evaluating costs and benefits of conservation measures.

Unit 5: Management and Organization of Energy Conservation Programs: **(6 Hrs)**

Human aspect of energy conservation, involvement tree, elements of energy management program, promoting energy conservation, program planning, setting goals, setting priorities, allocation of resources, and scheduling, measuring, monitoring and reporting, organization of energy conservation programs, plant level organization, division level organization, corporate level organization.

Unit 6: Guidelines for Improving Process Operations for Energy Conservation: **(7 Hrs)**

Energy conservation checklist, potential energy conservation in boilers, chilled water plants and central air –conditioning system, compressors and fans, heat pumps and cooling systems, water heaters and coolers, lighting systems, motors and transformers, mixing vessels, heat exchangers, evaporators, distillations, housekeeping

Textbooks:

1. Industrial Energy Management and Utilization, Larry C. Witte, Philip S. Schmidt, Davis R. Brown. 1988
2. Energy Engineering and Management- Amlan Chakrabarti, PHI Learning-2011.
3. Energy Conservation in the Chemical and Process Industries, Colin D. Grant, The Institution of Chemical Engineers. 1979

References Books:

1. Handbook of Industrial Energy Conservation, S. David HU.
2. Guidebook for National Certification Examination for Energy Managers and Energy Auditors- Book 1, 2,3 and 4. Bureau of Energy Efficiency (BEE)
3. Energy Conservation in the Process Industries- W. F. Kenny, Academic Press Inc., 1984
4. Solar Engineering of Thermal Processes, John A. Duffie and William A. Beckman, 3rd edition-2006

E-Resources: NPTEL/SWAYAM Courses

BE (Chemical Engineering)-2019 Course
Code: 409351
Elective V
Credits: 3
409351: (B) Chemical Process Safety

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Course Outcomes:

CO1: Able to estimate incident rates and toxicity level in process industries

CO2: Able to evaluate the work space environment related to noise, dust and toxicants

CO3: Able to study fire and explosion in Chemical and Allied industries

CO4: Able to understand the methods to prevent fire and explosion

CO5: Able to conduct HAZOP studies in chemical industries

CO6: Able to implement various techniques for safe work environment

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Unit I: **(6 h)**

Concepts and definition, safety culture, storage of dangerous materials, plant layout safety systems, OSHA incidence rate, FAR, FR, The accident process: Initiation, propagation, and termination, toxicology: ingestion, inhalation, injection, dermal absorption, dose versus response curves, relative toxicity, threshold limit values.

Unit II: **(7 h)**

Industrial hygiene: government regulations, identification, evaluation: evaluating exposures to volatile toxicants by monitoring, evaluating worker exposures to dusts, evaluating worker exposures to noise, estimating worker exposures to toxic vapors.

Unit III: **(7 h)**

Technology and process selection, scale of disaster, fire triangle, distinction between fires and explosion, definitions of ignition, auto-ignition temperature, fire point, flammability limits, mechanical explosion deflagration and detonation, confined explosion, unconfined explosion, vapour cloud explosions, boiling liquid expanding vapour explosion (BLEVE), dust explosion, shock wave, flammability characteristics of liquids and vapours, minimum oxygen concentration (MOC) and inerting.

Unit IV: **(7 h)**

Control of toxic chemicals, Storage and handling of flammable and toxic chemical, Runway reactions, Relief system risk and hazards management, Design to prevent Fires and Explosions: Inerting, static Electricity, Explosion proof equipment and Instrument, Ventilation, sprinkler systems and Miscellaneous Design for preventing Fires and Explosion.

Unit V: **(6h)**

Hazards identification: process hazards checklists, hazard surveys, hazard and operability studies (HAZOP), safety reviews. Risk assessment: review of probability theory, interaction between process units, revealed and unrevealed failure, and probability of coincidence, event trees and fault trees.

Unit VI: **(7h)**

Safety versus production, Hazard models and risk data. Tackling disasters, plan for emergency. Risk management routines, Emergency shutdown systems, Role of computers in safety, Prevention of hazard human element, Technology and process selection.

References:

1. Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety: Fundamentals with applications, Prentice Hall, Inc, 1990.
2. P. P. Leos, Loss prevention in process Industries, Vol 1 and 2 Butterworth, 1983
3. R. W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982
4. Khulman, Introduction of Safety Science, TUV Rheinland, 1986
5. W. E. Baker, Explosion, hazards and Evaluation, Elsevier, Amsterdam, 1983
6. O. P. Kharbanda and E. A. Stallworthy, Management of Disasters and How to Prevent Them. Grower 1986

BE (Chemical Engineering)-2019 Course
Code: 409351
Elective V
Credits: 3
409351: (C) Computational Fluid Dynamics

Teaching Scheme:	**Examination Scheme:**
Lectures: 3 h / week	In Semester: 30
	End Semester: 70
	Total: 100

Unit I: Governing Equations **(7 h)**

Fluid flow phenomena, flow terminologies, conservation principles, Reynolds Transport Theorem, Stokes Theorem, Integral and Differential approaches, Equation of continuity, Navier stokes equations, Energy Equation, equations in vector forms, Mathematical classification of governing equations, Boundary conditions, conservative and non-conservative forms.

Unit II: Solution Techniques for Governing Equations: FDM **(7h)**

Discretization of governing equations using FDM, FDM grid, forward differencing, backward differencing, FTCS, Explicit methods, Implicit Methods, Semi-implicit methods, solving of governing equations using Euler's, Jacobi, Crank Nicholson and ADI Methods, error analysis, stability criterion, Courant-Friedrichs-Levi condition, convergence and consistency

Unit III: Solution Techniques for Governing Equations: FVM **(7h)**

Finite volume concept, FVM mesh, discretization using FVM, solution of 1-D diffusion equation with and without sources, solution of 2-D diffusion steady and unsteady state, solution of convection-diffusion equation, Conservation, Accuracy, Convergence, Consistency, Stability, Transportive-ness, boundedness, upwind schemes, pressure-velocity coupling, SIMPLE, SIMPLEC and SIMPLER algorithms.

Unit IV: CFD modeling of Turbulence Flows **(7h)**

Introduction to turbulent flows, characteristics, time averaging techniques, mean velocity, turbulent eddies and scales, RANS, Reynolds stresses, turbulent flow models, mixing length, energy dissipation, algebraic models, one equation models, Spalart-Allmaras Model, two equation models, **k-** ε and k- ω models, problem closure, Direct Numerical Solution, Large Eddy Simulation,

Unit V:CFD modeling of Multiphase Flows **(6h)**

Basic Physics of Multiphase flow, applications, classification of multiphase flows, flow patterns, dispersed phases, separated phases, bubbly, slug, annular, stratified, wavy flows for horizontal and vertical geometries, governing equations, Multiphase flow modeling, discrete phase modeling, continuous phase modeling, VOF, Euler-Euler, Euler-Lagrangean Models.

Unit VI: CFD Simulation **(6 h)**

Applications and Scope of CFD, advantages and limitations, stages of CFD simulations, introduction to CFD Software (Ansys/Open Foam),preprocessing, grid types, geometry and mesh generation, solvers, different models for CFD simulation, boundary conditions, post processing, graphics and animations, plots, contours, streamlines, velocity profiles

Reference Books:

1) Anderson J. D. 1992.Computational Fluid Dynamics: The Basics with Applications, McGraw-Hill
2) Ferziger J. H. 2002. Computational Methods for Fluid Dynamics,3rd Edition, springer
3) Patankar S.V. 1981.Numerical Heat Transfer and Fluid Flow, McGraw-Hill
4) Moukalled F., Mangani L.,Darwish M.2015.The Finite Volume Method in Computational Fluid Dynamics: An Advanced Introduction with OpenFOAM® and Matlab, springer
5) Brennen C. E.2005. Fundamentals of Multiphase Flows, Cambridge University Press
6) Versteeg H. K., Malalasekera W. 1995. An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Pearson

BE (Chemical Engineering)-2015 Course
Code: 409351
Elective V
Credits: 3

409351: (D) Advanced Materials

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit I: **(6h)**

Advanced metallic systems, steels for special applications, austempered ductile iron.

Unit II: **(7h)**

Advanced polymeric materials, new polymeric materials such as Kevlar, Nomex, UHMWPE and fiber technology.

Unit III: **(7h)**

Advanced ceramic materials, advanced powder synthesis techniques, advanced processing methods, micro structural design and grain boundary engineering, case studies.

Unit IV: **(7h)**

Introduction to composite materials, factors influencing the properties of composite materials like fiber parameter, matrix, interface & molding methods. Phase selection criteria. reinforcing mechanisms. interfaces, advantages and disadvantages. Polymer composites. Reinforcing and matrix materials, prepregs, fiber winding techniques, fabrication techniques, laminates, mechanical behavior, etc

Unit V: **(6h)**

Metal composites, types of reinforcement, chemical compatibility, fabrication processes, mechanical behaviour and properties, ceramic composites. Matrices and reinforcement. Why to reinforce ceramics, fabrication methods, crack propagation and mechanical behaviour.

Unit VI: **(7h)**

Carbon composites, their properties, fabrication methods and their applications, ablative polymers, their applications, air craft materials, introduction to nonmaterial, synthesis & characterization of nonmaterial, application of nonmaterial with special reference to chemical engineering.

Reference Books:

1. Modern Ceramic Engineering, Richorson R.W., Marcel Dekker.
2. Composite Materials, Chawala K.K., Springer Science & Business Media.
3. FRP Technology, Weather head R., Applied Science Publishers.
4. Engineering Polymers, Dyson R.W., Springer Science & Business Media
5. Polymers of high technology, electronics and photonics, Bowden M.J & Turner S.R., ACS Symp. Ser. 346, 1987.

BE (Chemical Engineering)-2019 Course
Code: 409352
Elective VI
Credits: 3
409352: (A) Catalysis

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit I: **(6h)**

Introduction to catalysis, application to industrial processes – one example each from inorganic, fine organic chemical, petroleum refining, petrochemical and biochemical industries. Types of catalysis: homogeneous catalysis.

Unit II: **(7h)**
Heterogeneous catalysis: introduction, phase transfer and tri-phase catalysis, liquid – liquid and solid – liquid catalysis, mechanism, engineering problems, mass transfer considerations and reactor types.

Unit III: **(7h)**
Gas – solid catalytic reactions: adsorption theories and concept of active site. Adsorption isotherm and Langmuir – Hinshelwood approach, diffusion effects in the catalyst.

Unit IV: **(7h)**
Preparation of catalysts – supported metal and metal oxide catalyst. major steps involved in catalysts preparation and formation, physical methods of catalyst characterization for determination of surface area by bet method, pore volume and average pore size distribution, effectiveness of the catalyst, selectivity of the catalyst, deactivation of catalyst, mechanism of catalyst poisoning.

Unit V: **(6h)**
Zeolites – structural chemistry of Zeolites, templated molecular sieves, size and shape selectivity, a few industrial applications of Zeolites, modification of Zeolites.

Unit VI: **(7h)**
Biocatalysts – enzymes, lipases and microbes as catalysts, mechanism of participation of enzymes in a few typical reactions, Michaelis – Menten kinetics, inhibition of enzyme reaction and kinetics.

Reference Books:

1. Smith J.M.: “Chemical Engineering Kinetics”, 3rd Edition, McGraw Hill
2. Satterfield Charles N.: Heterogeneous Catalysis in Industrial Practices, McGraw- Hill International Editions, 2nd Edition 1993.
3. Bailey James, Davis Ollis: “Biochemical Engineering”, McGraw Hill
4. Wingard L.B.: Enzyme Engineering, Fr. Inter Science, N.Y. 1972.
5. Carberry J. J.: Chemical and Catalytic Reaction Engineering, McGraw Hill, New York, 1976.

BE (Chemical Engineering)-2019 Course
Code: 409352
Elective VI
Credits: 3
409352: (B) Nanotechnology

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Course Outcomes:

CO1	To understand the concept of Nano scale and Nanotechnology, and classify various types of Nano material.
CO2	Learn the synthesis procedure of Nano material and its method of synthesis according to application.
CO3	Identify the suitable type of Characterization technique for Nano material.
CO4	distinguished the fundamental concept of Nano colloids and its chemistry and learn about aspects of quantum dots
CO5	Identify the concept of semiconductor and its types and differentiate between intrinsic and extrinsic semiconductors and P-n junction.
CO6	Identify the application of Nanotechnology in chemical Engineering and evaluate the impact of Nanotechnology on Environment and its safety aspects.

Unit I: Introduction (6h)

Introduction to nanotechnology and nanomaterials, how it all began: synthesis of carbon buck balls, list of stable carbon allotropes extended, fullerenes, metallofullerenes, solid C60, bucky onions, nanotubes, nanocones, properties of individual nanoparticles, methods of synthesis for carbon nanostructures

Unit II: Synthesis Procedures of Nanomaterials (7h)
Bottom-up vs. top-down, epitaxial growth, self-assembly, modelling and applications production techniques of nano-tubes carbon arc bulk synthesis in presence and absence of catalysts high-purity material (bucky paper) production using pulsed laser vaporization (PLV) of pure and doped graphite high-pressure CO conversion (HIPCO) nano-tube synthesis based on boudoir reaction chemical vapor deposition (CVD)

Unit III: Characterizations of Nanomaterials (7h)
Optical microscopy, electron microscopy, secondary electron scattering, back scattering, scanning probe microscopes, focussed ion beam technique, X-ray diffraction, SPM-AFM,

STM, optical, electronic and vibrational spectroscopic tools.

Unit IV: Semiconductors and Quantum Dots **(7h)**

Intrinsic semiconductors, band gaps, law of mass action, mobility of charge carriers extrinsic semiconductors the p-n junction, ferromagnetism energy gaps the nearly free electron model the number of orbitals in a band electrons and holes, effective masses review of classical mechanics, de Broglie's hypothesis, Heisenberg uncertainty principle Pauli exclusion principle, Schrödinger's equation, properties of the wave function, application: quantum well, wire, dot, quantum cryptography

Unit V: Nano Colloids and Chemistry **(6h)**

Surface tension and interfacial tension surfaces at equilibrium surface tension measurement, contact angles, colloidal stability, electrical phenomena at interfaces Van der Waals forces between colloidal particles, Photocatalysis nanostructured materials. Self-assembly and catalysis.

Unit VI: Unit Applications, Safety and Environment **(7h)**

Waste water treatment, nanobiotechnology: drug delivery, nanoclay, nanocomposites, surface coatings. self cleaning materials, hydrophobic nanoparticles. biological nanomaterials. Nanoelectronics,. nanomachines & nanodevices societal, health and environmental impacts.

Commercial processes for nanotechnology and chemical engineering applications: nanohydrogel, photocatalytic reactors, nanoclay synthesis, polymer nanocomposite, introduction to industries which produces commercial nanomaterials

Reference Books:

1. Introduction to Nano Science, (CRC Press of Taylor and Francis Group LLC), G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, May 2008, 856pp, ISBN-13: 978142004805
2. Ashby, Michael F., Ferreira, *Paulo* J., Schodek, Daniel L. 2009. *Nanomaterials and nanotechnologies*: An overview. In: Nanomaterials, Nanotechnologies and Design, Linacre Haus, Jordan Hill, Oxford, 2009.
3. Introduction to Nanoscience and Nanotechnology, K. K. Chattopadhyay, A.N. Banerjee, PHI Learning Private Limited.
4. Applied Colloid and Surface Chemistry, Richard M. Pashley and Marilyn E. Karaman, John Wiley & Sons Ltd, 2004.
5. Nanostructuring Operations in Nanoscale Science and Engineering, Kal Renganathan Sharma, The McGraw-Hill Companies, Inc. ISBN: 978-0-07-162609-5, 2010.

BE (Chemical Engineering)-2019 Course

Code: 409352

Elective V

Credits: 3

409352: (C) Fuel Cell Technology

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit I: Fundamentals **(6 h)**

Electrochemical cells, electrolytic cell, galvanic cell, construction and working, Faraday's law of electrolysis, problems on displacements, classification of electrodes, Nernst's theory, single electrode potential , EMF of cell, EMF series, common types of cells.

Unit II: Introduction **(7 h)**

Potential convention, current conventions, equilibrium constants, mass transfer limited current, Cottrell equation, factors affecting reaction rate and current, mechanism involving electrode reactions, reversibility kinetics, Butler-Volmer Equations, Tafel plots , Tafel equation, equations governing modes of mass transfer – Nernst-Planck Equation, Ficks law of diffusion, concept of Helmholtz plane.

Unit III: Hydrogen fuel cell **(7 h)**

Introduction to hydrocarbon based fuel cells, general issues, fossil fuels and other fuels used, H_2 production from renewable sources and storage, working of H_2 fuel cell, safety issues, steam reforming, internal reforming, cost estimation.

Unit IV: Proton Exchange Membrane Fuel Cell **(6 h)**

Introduction, working of PEMFC, electro chemistry modeling, exchange current density, local surface over potential (activation loss), current & mass conversion, gas phase species diffusivity, membrane phase electronic conductivity, osmotic drag coefficient, back diffusion flux, fuel crossover.

Unit V: Solid Oxide Fuel Cells **(7 h)**

Introduction, working of SOFC, modeling SOFC (Nernst voltage, current distribution, & over potential of electrolytes, electric potential field) modeling current transport & potential field, activation over potential, cell potential, treatment of electrolyte interface, Ohmic over potential, Activation over potential, Modeling electrochemical potential.

Unit V: Fuel Cell Systems **(7 h)**

System processes – fuel processing, rejected heat utilization, system optimization – pressurization, temperature utilization, heat recovery, fuel cell networking, life cycle analysis of fuel cells, hybrid systems – introduction to microbial and enzymatic fuel cell.

Reference Books:

1. Bokris John O'm, Srinivasan S., "Fuel cells-their electrochemistry", McGraw Hill 1969.
2. Appleby A.J. Fralkes F. R., "Fuel cell handbook", Van Nostrand Reinhold 1989.
3. Kordesch Karl, Simader G., "Fuel cells and their applications", VCH publications 1996.
4. U S Department of energy, "Fuel cell: a handbook",
5. Leo J.M.J., Blomen, Mugerwa M. N., "Fuel cell systems", Plenum Press.

BE (Chemical Engineering)-2019 Course
Code: 409352
Elective VI
Credits: 3
409352: (D) Petrochemical Engineering

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Course Outcomes:

CO1	Analyze status of petrochemical industries and its necessity in India
CO2	Get acquainted and interpret the first generation petrochemicals and its basic raw materials
CO3	Evaluate and recognize process and methodology for separation and purification techniques in petrochemical complexes
CO4	Analyze and Differentiate between First generation and second generation petrochemicals and its feedstock and different types of polymers and its preparation methodologies along with its use in industries.
CO5	Evaluate the different safety norms and aspects in petrochemical industry and pollution control norms and methods of elimination.

Unit I: (6h)

Introduction to petrochemical, petrochemical industry in India, basic raw material for petrochemical synthesis and their sources, preparation of feedstock for petrochemical production, main building blocks of petrochemical industry

Unit II: (7h)
First generation raw material like olefins, aromatics, naphthenes. Production of aromatics, naphthenes and other hydrocarbon feedstock, aromatic separation into B, T, X.

Unit III: (7h)
Production of low molecular weight olefins by hydrocarbon cracking, furnaces, separation techniques and purification.

Unit IV: (7h)
Combining olefins and aromatics to produce second generation intermediates such as glycols, amines, acids, ketones that can be used also as solvents and formulating agents.

Unit V: (7h)
Polymers: bulk, engineering and specialty, types of polymerization such as bulk, emulsion and suspension etc, at least two polymeric products and manufacture from each class, few examples (flow sheet, applications) of polymers like polyester, nylon, etc

Unit VI: **(6h)**

Integration of refinery and petrochemical plants with power generation, pollution control – norms and methods of elimination, brief description on safety considerations

Reference Books:

1. Modern Petroleum Technology, Hobson and Pohl, Vol. I & II, John Wiley and Sons, New York.
2. Introduction to petrochemical industry and refinery by Speight, Encyclopedia of Life Support systems.
3. Dryden's Outline of chemical industry, M Gopal Rao, M Sittig, East –West press.
4. Petrochemical Process Technology, ID Mall, Macmillan India Ltd., New Delhi
5. Modern Pertoleum Refinery Engineering, Bhaskar Rao, published by Aman Dhanani.

BE (Chemical Engineering)-2019 Course
Code: 409353
Phase II
Credits: 6

Teaching Scheme:
Practical: 12 h / week

Examination Scheme:
TW: 100
OR: 50
Total: 150

During the second term the students are required to:

1. Carry out detailed experimental work on previously defined (Phase I) research problem.
2. Write a *Project Report,* which should be broadly divided into the following sections –
    a. Abstract
    b. Introduction
    c. Experimental
    d. Results and Discussion
    e. Conclusion
    f. Plant layout and costing
    g. References

Students should submit a neatly typed and spiral bound *Project Report* at the end of the term in the following format.

Font: Times New Roman, Font size: 12, Headings: 14, Spacing: 1.5, typed on one side of the A4 size paper with proportionate diagrams, figures, graphs, photographs, tables etc.

Referencing style:

2. Guo J. X. and Gray D. G., Chiroptical behavior of (acetyl) (ethyl) cellulose liquid-crystalline solutions in chloroform, *Macromolecules*, *22*, (1989), 2086.

(Reference numbers should be mentioned in the main text as a

superscript) The *Project Report* should contain:

1. The cover page –must mention: Project title, Name of the student(s), Name of the guide, Exam seat number and Year.
2. Certificate from guide
3. Certificate from industry (if any)
4. Index
5. Detailed *Project Report* having sections 'a' to 'g' from above.

The student is required to prepare a month wise work plan (for both semesters) immediately after the allotment of the project and the department is required to maintain a progress report of every student/project. The progress report should reflect monthly progress done by the student as per the work plan. The progress report is to be duly signed by the respective project guide by giving the remarks/marks/grades etc. on the periodic progress done by the student at the mid of the term and should be **submitted along with project report** at the end of respective terms to the examiners as a supporting document for evaluation.

Each student is required give **presentation** of his work for 10 minutes using 10-12 slides. The presentation will be followed by question answer session of 5 min. Every student will be examined orally for 50 marks based on the topic of his/her project and relevant area to evaluate his understanding of the problem. Term work assessment for 100 marks will be based on student's workup, performance and progress (depth and quality of work) during the term.

The department should prepare a template of the format of the project report and supply it to the students so as to maintain the uniformity in the project reports.

Students are encouraged to participate and present their project work in various events, competitions, conferences and seminars etc. in consultation with their guide.

Note: The project guides are required to educate the students about antiplagiarism policy of SPPU and apply the same while doing the project.