ANNA UNIVERSITY:: CHENNAI 600 025
AFFILIATED INSTITUTIONS
M. TECH. PETROLEUM REFINING AND PETROCHEMICALS
REGULATIONS – 2017
CHOICE BASED CREDIT SYSTEM

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

1. To create mastery of the basic principles of engineering science that underlies modern chemical process principles used in petroleum industries.
2. To make employable process engineers in refinery fields and to work towards the development of sustainable technologies in petroleum and allied industries.
3. To address to meet the world's ever increasing demand for hydrocarbon fuel, thermal energy and waste management.
4. To exhibit professional, ethical codes of conduct, team work and continuous learning for catering the ever changing needs of the society.

PROGRAMME OUTCOMES (POs)

On successful completion of this programme, the graduates will have the

1. Ability to apply knowledge of mathematics, Science and Engineering.
2. Ability to design a system, component, or process to meet desired needs with realistic constraints such as economical, environmental, social, ethical, health, safety, manufacturability and sustainability
3. Ability to conduct experiments, analyze and interpret data.
4. Capacity to formulate and solve complex problems associated with refinery fields based on the realistic situation.
5. Ability to identify the impact of engineering solutions in a global, economic, and social context.
6. Ability to communicate effectively by conveying technical material through both formal written medium and also through oral presentations.
7. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practices especially in petroleum and allied industries.
8. The competency in utilizing the available resources effectively and optimally.
9. Knowledge on the importance of professional and ethical responsibilities in an organization.
10. Inclination towards acquiring knowledge on the latest developments in the field of petroleum refining and petrochemicals.

Programme Educational Objectives	**Programme Outcomes**									
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
I	✓	✓	✓	✓	✓	✓	✓			
II		✓	✓	✓		✓				✓
III		✓	✓	✓	✓	✓		✓		
IV		✓			✓	✓			✓	✓

Year	SEM	Subjects	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
Year I	SEM I	Advanced Numerical Methods	✓		✓							
		Catalytic Reaction engineering		✓			✓			✓		✓
		Petroleum Refinery Engineering	✓	✓	✓	✓			✓			
		Petroleum Thermodynamics	✓	✓	✓	✓			✓			
		Professional Elective I										
		Professional Elective II										
		Petroleum testing Laboratory	✓	✓	✓	✓			✓			
	SEM II	Natural Gas Engineering	✓	✓	✓	✓			✓	✓		
		Petrochemicals	✓	✓	✓	✓			✓	✓		
		Advanced Process Control	✓	✓	✓	✓			✓			
		Multicomponent Distillation	✓	✓	✓	✓						
		Professional Elective III										
		Professional Elective IV										
		Seminar										
Year II	SEM IV	Corrosion Engineering	✓	✓	✓	✓			✓			
		Professional Elective V										
		Professional Elective VI										
		Internship	✓	✓			✓	✓			✓	✓
		Project Work (Phase I)	✓	✓			✓	✓			✓	✓
	SEM V	Project Work (Phase II)	✓	✓			✓	✓			✓	✓

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CHOICE BASED CREDIT SYSTEM
I TO IV SEMESTERS CURRICULUM AND SYLLABUS

SEMESTER I

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA5153	Advanced Numerical Methods	FC	5	3	2	0	4
2.	PP5101	Petroleum Refinery Engineering	PC	3	3	0	0	3
3.	PP5102	Petroleum Thermodynamics	PC	5	3	0	2	4
4.	CX5151	Catalytic Reaction Engineering	FC	5	3	2	0	4
5.		Professional Elective I	PE	3	3	0	0	3
6.		Professional Elective II	PE	3	3	0	0	3
PRACTICALS								
7.	PP5111	Petroleum Testing Laboratory	EEC	4	0	0	4	2
			TOTAL	**28**	**18**	**4**	**6**	**23**

SEMESTER II

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PP5201	Natural Gas Engineering	PC	3	3	0	0	3
2.	PP5202	Petrochemicals	PC	3	3	0	0	3
3.	CX5251	Advanced Process Control	PC	3	3	0	0	3
4.	CX5252	Multicomponent Distillation	PC	3	3	0	0	3
5.		Professional Elective III	PE	3	3	0	0	3
6.		Professional Elective IV	PE	3	3	0	0	3
PRACTICALS								
7.	PP5211	Seminar	EEC	4	0	0	4	2
			TOTAL	**22**	**18**	**0**	**4**	**20**

SEMESTER - III

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PP5391	Corrosion Engineering	PC	3	3	0	0	3
2.		Professional Elective V	PE	3	3	0	0	3
3.		Professional Elective VI	PE	3	3	0	0	3
PRACTICALS								
4.	PP5311	Internship	EEC	2	0	0	2	1
5.	PP5312	Project Work (Phase I)	EEC	12	0	0	12	6
			TOTAL	**23**	**9**	**0**	**14**	**16**

SEMESTER – IV

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	PP5411	Project Work (Phase II)	EEC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

TOTAL CREDITS: 71

List of Professional Electives (PE)

SEMESTER - I, PROFESSIONAL ELECTIVES I

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	CX5071	Multiphase Flow	PE	3	3	0	0	3
2.	CX5072	Fluidization Engineering	PE	3	3	0	0	3
3.	CX5073	Piping and Instrumentation	PE	3	3	0	0	3
4.	PP5001	Separation Process Techniques	PE	3	3	0	0	3

SEMESTER - I , PROFESSIONAL ELECTIVES II

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	CX5074	Computational Fluid Dynamics	PE	3	3	0	0	3
2.	CX5075	Solvent Extraction	PE	3	3	0	0	3
3.	CX5391	Process Modeling and Simulation	PE	5	3	2	0	4
4.	CX5076	Industrial Instrumentation	PE	3	3	0	0	3

SEMESTER - II, PROFESSIONAL ELECTIVES III

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	ES5092	Design of Experiments	PE	3	3	0	0	3
2.	CX5091	Safety and Hazard Control	PE	3	3	0	0	3
3.	CX5092	Energy Management	PE	3	3	0	0	3
4.	PP5002	Reservoir Engineering	PE	3	3	0	0	3

SEMESTER - II, PROFESSIONAL ELECTIVES -IV

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	CX5077	Project Engineering of Process Plants	PE	3	3	0	0	3
2.	CX5078	Process Optimization	PE	3	3	0	0	3
3.	PP5003	Petroleum Economics	PE	3	3	0	0	3
4.	PP5004	Non- Conventional Petroleum Resource	PE	3	3	0	0	3

SEMESTER - III, PROFESSIONAL ELECTIVES -V

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	CX5081	Intellectual Property Rights	PE	3	3	0	0	3
2.	CX5095	Environment, Health and Safety in industries	PE	3	3	0	0	3
3.	CX5080	Operations Research	PE	3	3	0	0	3
4.	CX5093	Pilot Plant and Scale up methods	PE	3	3	0	0	3

SEMESTER - III, PROFESSIONAL ELECTIVES -VI

S.No	COURSE CODE	COURSE TITLE	CATEG ORY	CONTACT PERIODS	L	T	P	C
1.	PP5005	Enhanced Oil Recovery	PE	3	3	0	0	3
2.	CX5082	Gas Transportation	PE	3	3	0	0	3
3.	CX5083	Green Chemistry and Engineering	PE	3	3	0	0	3
4.	CX5084	Fuel Cell Technology	PE	3	3	0	0	3

Foundation Courses (FC)

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA5153	Advanced Numerical Methods	FC	5	3	2	0	4
2.	CX5151	Catalytic Reaction Engineering	FC	5	3	2	0	4

Professional Core (PC)

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PP5101	Petroleum Refinery Engineering	PC	3	3	0	0	3
2.	PP5102	Petroleum Thermodynamics	PC	5	3	0	2	4
3.	PP5201	Natural Gas Engineering	PC	3	3	0	0	3
4.	PP5202	Petrochemicals	PC	3	3	0	0	3
5.	CX5251	Advanced Process Control	PC	5	3	2	0	4
6.	CX5252	Multicomponent Distillation	PC	3	3	0	0	3
7.	PP5391	Corrosion Engineering	PC	3	3	0	0	3
8.	PP5111	Petroleum Testing Laboratory	PC	4	0	0	4	2

Employability Enhancement Courses (EEC)

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PP5211	Seminar	EEC	4	0	0	4	2
2.	PP5311	Internship	EEC	2	0	0	2	1
3.	PP5312	Project Work (Phase I)	EEC	12	0	0	12	6
4.	PP5411	Project Work (Phase II)	EEC	24	0	0	24	12

MA5153 **ADVANCED NUMERICAL METHODS**

(Common to Environmental Science and Technology, Chemical Engineering and PRPC) **L T P C 3 2 0 4**

OBJECTIVES :

- The course will develop numerical methods aided by technology to solve algebraic, transcendental and differential equations and to apply finite element methods for solving the boundary value problems in differential equations. The course will further develop problem solving skills and understanding of the application of various methods in solving engineering problems. This will also serve as a precursor for future research.

UNIT I ALGEBRAIC EQUATIONS **12+3**

Systems of linear equations : Gauss elimination method – Pivoting techniques – Thomas algorithm for tri diagonal system – Jacobi, Gauss Seidel, SOR iteration methods – Conditions for convergence - Systems of nonlinear equations : Fixed point iterations, Newton's method, Eigenvalue problems : Power method and Given's method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS **12+3**

Runge - Kutta methods for system of IVPs – Numerical stability of Runge - Kutta method – Adams - Bashforth multistep method, Shooting method, BVP : Finite difference method, Collocation method and orthogonal collocation method.

UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATIONS **12+3**

Parabolic equations : Explicit and implicit finite difference methods – Weighted average approximation - Dirichlet's and Neumann conditions – Two dimensional parabolic equations – ADI method : First order hyperbolic equations – Method of numerical integration along characteristics – Wave equation : Explicit scheme – Stability.

UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS **12 +3**

Laplace and Poisson's equations in a rectangular region : Five point finite difference schemes, Leibmann's iterative methods, Dirichlet's and Neumann conditions – Laplace equation in polar coordinates : Finite difference schemes – Approximation of derivatives near a curved boundary while using a square mesh.

UNIT V FINITE ELEMENT METHOD **12+3**

Basics of finite element method : Weak formulation, Weighted residual method – Shape functions for linear and triangular element – Finite element method for two point boundary value problems, Laplace and Poisson equations.

TOTAL : 60+15=75 PERIODS

OUTCOMES :

After completing this course, students should demonstrate competency in the following skills:

- Solve an algebraic or transcendental equation, linear system of equations and differential equations using an appropriate numerical method.
- Solving the initial boundary value problems and boundary value problems using finite difference and finite element methods.

- Selection of appropriate numerical methods to solve various types of problems in engineering and science in consideration with the minimum number of mathematical operations involved, accuracy requirements and available computational resources.

REFERENCES :

1. Burden, R.L., and Faires, J.D., "Numerical Analysis – Theory and Applications", 9th Edition, Cengage Learning, New Delhi, 2016.
2. Gupta S.K., "Numerical Methods for Engineers", New Age Publishers, 1995.
3. Jain M. K., Iyengar S. R., Kanchi M. B., Jain, "Computational Methods for Partial Differential Equations", New Age Publishers ,1993.
4. Sastry, S.S., "Introductory Methods of Numerical Analysis", 5th Edition, PHI Learning, 2015.
5. Saumyen Guha and Rajesh Srivastava, "Numerical methods for Engineering and Science", Oxford Higher Education, New Delhi, 2010.
6. Smith, G. D., "Numerical Solutions of Partial Differential Equations: Finite Difference Methods", Clarendon Press, 1985.

PP5101 PETROLEUM REFINERY ENGINEERING L T P C
3 0 0 3

OBJECTIVES

- To impart detailed knowledge on petroleum refining operations, this course being the last part in a three parts series.

UNIT I **9**

Origin, Exploration and production of petroleum, Types of crudes, Composition, characteristics, products pattern and characteristics, indigenous and imported crudes, Availability Vs Demands, Future outlook.

UNIT II **9**

Engineering aspects of refining, Reaction stoichiometry; Chemical kinetics; Thermochemistry and chemical equilibrium; Mixing in flow systems; Reactor design. Crude heating, Primary distillation, principles, Separation of cuts, Gaps/ overlaps, Stripping, Desalting, heat balance in distillation, Energy input and recovery, Vacuum distillation, Types of trays, Draw offs, intermediate product quality control.

UNIT III **9**

Lube oil and wax processing, solvent extraction, Dewaxing, Deciling, Deasphalting, Clay contacting, principles, technologies, operating parameters, Feed and product qualities and yields. Asphalt Manufacture, product qualities, Air blowing technology, Tankage operations, Storage and handling of crude products.

UNIT IV **9**

Fluid catalytic cracking, principles, recent developments, Feed stocks and product yields and qualities, Catalysts and operating parameters. Hydrocracking, principles, process requirements, product yields and qualities, Residcracking – implications and technology.

UNIT V **9**

Catalytic reforming and Isomerisation, Reforming, Principles, developments in technology, Catalyst types and their performance, Effects of operating parameters, Feed quality, Product improvement; Sulphur removal, Aromatics removal, Hydrofinishing, Catalyst regeneration, Catalytic dewaxing. Environmental aspects of refining.

TOTAL: 45 PERIODS

OUTCOMES

- Students learn about the petroleum additives, support systems, and safety measures, environmental, quality and economic aspects.

REFERENCES

1. Donald L.Katz and Robert L.Lee, Natural Gas Engineering, Mc Graw – Hill Publishing Company, NY, 1990.
2. Hobson, G.D. – Modern petroleum Refining Technology, 4th Edition, Institute of Petroleum U.K. 1973.
3. Nelson, W.L "Petroleum Refinery Engineering" McGraw Hill Publishing Company Limited, 1985.
4. Smalheer, C.V and R.Kennedy Smith Lubricant Additives. The Lezius – Hill Company, Cleveland, Ohio. USA, 1987
5. Watkins, R.N "Petroleum Refinery Distillation", 2nd Edition, Gulf Publishing Company, Texas, 1981.

PP5102 **PETROLEUM THERMODYNAMICS** **L T P C**
3 0 2 4

OBJECTIVES

- To present the application of thermodynamic principles in petroleum and allied processes from chemical engineering viewpoint.

UNIT I INTRODUCTION **9+6**

Behaviour of Gases and Liquids – Gas laws, Density, Mole percent, Weight percent, Volume percent, Specific gravity, Heat, Work Closed and Open Systems, First and Second Laws of thermodynamics, specific heats, Compressibility factor, PVT relationships, Vapour pressure, Claussius – Clayperson equation, heat of vaporization.

UNIT II CHEMICAL THERMODYNAMICS OF PETROLEUM HYDROCARBONS **9+6**

Free energy change, Heat of reaction, Entropy change, Heat capacity, Heat of formation, Fugacity, Pressure – Temperature diagram, Pressure – Volume diagram, Density – Temperature diagram for one and two component system. Pressure – Composition diagram, Temperature – Composition diagram, Temperature – Composition diagram, for multi component system Gibbs phase rule

UNIT III QUALITATIVE PHASE BEHAVIOUR OF HYDROCARBON SYSTEMS **9+6**

Calculation of liquid and vapour composition of Bubble point and Dew point pressure for multi component system. Equilibrium constant

UNIT IV HYDROCARBON FLUID CHARACTERISTICS **9+6**

Gas formation volume factor, Gas solubility, Oil formation volume factor, Viscosity

UNIT V PROPERTIES OF MIXTURES 9+6

Dalton Law Volumetric analysis of a gas mixture – apparent weight and gas constant – specific heats of a gas mixture – determination of calorific values of fuels – oil and fuel vapour mixtures – steam condenser.

TOTAL: 75 PERIODS

OUTCOME

- The Students will be well versed with the behavior of fluids under PVT conditions and also apply them for practical purpose. The study further provides a comprehensive exposition to theory and application of solution thermodynamics.

REFERENCES

1. Jean vidal, Thermodynamics Application in chemical Engineering and the petroleum industry, Institute Francais bu petrole publications,France 2003
2. John J.McKetta Jr. ""Advances in Petroleum Chemistry and Refining"" – Volume 9 (Inter-science Publications), NY, 1983.
3. Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular thermodynamics of fluid-phase Equilibria, 3rd Edn, Prentice Hall Inc., New Jersey, 1999
4. Rao., Y.V.C., Chemical Engineering Thermodynamics, University Press, Hyderabad, 2005
5. Smith J.M., H.C. Van Ness, M.M. Abbott .Introduction to Chemical Engineering Thermodynamics. VI Edition, Tata M.Graw-Hill publishing Company Limited, New Delhi
6. Stanley.I.sandler,' Chemical and Engineering Thermodynamics' Wiley, 1988.
7. Tester, J. W. and M. Modell, Thermodynamics and Its Applications. 3rd Edn.Prentice Hall, New Jersey, 1997.

CX5151 CATALYTIC REACTION ENGINEERING L T P C
3 2 0 4

OBJECTIVE:

- To impart knowledge on different types of chemical reactors, the design of chemical reactors under isothermal and non-isothermal conditions

UNIT I CATALYST AND ITS CHARACTERIZATION 15

General definition of catalysts, Design for catalysts – Primary constitutents, secondary constituents; Catalyst supports. Methods of determining catalysts activity – static methods, Study of structure pore radii; Mercury porosimetry, determination of true and apparent densities of catalysts; Structural study of electron microscopy, determination of mechanical strength of catalysts-static methods, dynamic methods; Methods of thermal analysis.

UNIT II KINETICS OF HETEROGENEOUS CATALYTIC REACTIONS 12

Adsorption on Solid Catalysts. Rate Equations. Complex Catalytic Reactions. Experimental Reactors. Model Discrimination and Parameter Estimation. Sequential Design of Experiments. Physicochemicafl tests

UNIT III TRANSPORT PROCESSES WITH REACTIONS CATALYZED BY SOLIDS 16

Reaction of a component of a fluid at the surface of a solid. Mass and heat transfer resistances. Molecular-, Knudsen-, and surface diffusion in pores. Diffusion and reaction in a catalyst particle. Influence of diffusion limitations on the selectivities of coupled reactions. Criteria for the importance of intraparticle diffusion limitations. Multiplicity of steady states in catalyst particles.

Diagnostic experimental criteria for the absence of internal and external mass transfer limitations. Nonisothermal particles.

UNIT IV CATALYST DEACTIVATION 11

Types of Catalyst Deactivation. Kinetics of Catalyst Poisoning. Kinetics of Catalyst Deactivation by Coke Formation.

UNIT V THE MODELING OF CHEMICAL REACTORS. 21

Approach. Aspects of Mass-, Heat- and Momentum Balances. Fixed bed catalytic reactors. Design and Modeling of Fixed Bed Reactors. Pseudohomogeneous Models-The Basic One- Dimensional Model. One-Dimensional Model with Axial Mixing. Two-Dimensional Pseudohomogeneous Models. One-Dimensional Model Accounting for Interfacial and Intraparticle Gradients. Two-Dimensional Heterogeneous Models. Fluidized bed and transport reactors -Introduction. Technological Aspects of Fluidized Bed and Riser Reactors. Some Features of the Fluidization and Transport of Solids. Heat Transfert in Fluidized Beds. Modeling of Fluidized Bed Reactors. Modeling of a Transport of Riser Reactor. Catalytic Cracking of Vacuum Gas Oil.

TOTAL : 75 PERIODS

OUTCOME:

- Students would have gained knowledge on the selection of the reactor for the reaction and its design

REFERENCES

1. An Introduction to Chemical Engineering Kinetics & Reactor Design, Charles G. Hill, Jr., JohnWiley & Sons, 1977.
2. Chemical Reaction Engineering, Octave Levenspiel, John Wiley & Sons, 3rd Edition, 1999.
3. Chemical Reactor Analysis and Design, Gilbert F. Froment and Kenneth B. Bischoff, John Wiley & Sons, 2nd Edition, 1990.
4. Elements of Chemical Reaction Engineering, H. Scott Fogler, Prentice Hall International Series, 3rd Edition, 2000.
5. Fundamentals of Chemical Reaction Engineering, Mark E. Davis and Robert J.Davis, McGrawHill, 2003.

PP5111 PETROLEUM TESTING LABORATORY L T P C

0 0 4 2

OBJECTIVES

- To impart practical knowledge on different petroleum testing methods.

LIST OF PETROLEUM TESTING EXPERIMENTS

1. Determination of flash point, fire point and Smoke point estimation
2. Viscosity, Aniline point and API gravity Determination
3. Hydrogen sulphide content determination
4. Determination of calorific value, Carbon residue determination (Conradson apparatus)
5. Bitumen testing
6. Cloud point and pour point estimation
7. Congealing point of wax
8. Foaming characteristics of lube oil and Corrosion testing of petroleum oil
9. Distillation characteristics
10. Moisture content determination

TOTAL: 60 PERIODS

LIST OF EQUIPMENTS

One equipment in each of the following

1. Flash and fire point apparatus
2. Brookfield Viscometer
3. Aniline point apparatus
4. Specific gravity apparatus
5. Antek elemental sulphur and nitrogen analyzer
6. Bomb calorimeter
7. Ductility meter
8. Conradson apparatus
9. Cloud and pour point apparatus
10. Lubricity tester
11. Smoke point apparatus
12. Copper strip corrosion test apparatus
13. Distillation apparatus
14. Dean & Stark apparatus

OUTCOMES

- Students learn petroleum testing, determination of aniline point, softening point, carbon residue, foaming characteristics, Sulphur content etc.

PP5201 NATURAL GAS ENGINEERING L T P C

3 0 0 3

OBJECTIVES

- To know the stages of production and processing of natural gas.

UNIT I INTRODUCTION 12

Availability of natural gas, Properties and composition, Exploration and control of gas, output, Estimation of availability quantity. Natural gas application in Chemical Process and transportation industry LNG technology, Natural gas storage and transport, Economics of natural gas utilization.

UNIT II GAS TREATMENT AND PROCESSING 12

General Hydrodynamic equations for flow of fluids through porous media, two dimensional flow problems and potential theory methods, gravity flow systems, systems of non uniform permeability, multiple well systems using computerized streamline tracking methods.

UNIT III MULTIPHASE SYSTEMS 11

Use of multiphase flow correlations to determine flow ratio and pressure traverse in flowing oil wells, gas condensate wells, gathering systems and pipe lines, application of correlations to the design of gas system

UNIT IV GAS TREATMENT 10

Reservoir fluid properties – PVT properties for oil gas systems, phase Behavior of complex hydrocarbon mixtures at high temperature and pressure – thermodynamic property evaluation, packages used in petroleum industry.

TOTAL : 45 PERIODS

OUTCOMES

- To learn origin, properties, treatment, transportation, storage and liquefaction of natural gas.

REFERENCES

1. Dermott, M.C. Liquified Natural Gas Technology, Neysos Park Ridge, N.J. 1973.
2. Donald L.Katz and Robert L.Lee, Natural Gas Engineering, Mc Graw – Hill Publishing Company, NY, 1990.
3. Dring, M.M – The Natural Gas Industry – A review of World Resources and Industrial Applications, Butterworth, London, 1974.
4. Guide to Natural Gas Utilization Technologies, Fairmount Press Inc. 1987.
5. Lom. W.L and A.F. Williams, Substitute Natural Gas, Kalstod Willey, New York, 1976.
6. M.J. Econonides A.Daniel "Petroleum Production Systems", Prentice Hall Petroleum Engineering series 2012.
7. Michael J.Economides, A.Daniel Hill and Christine Ehlig – Economides, Petroleum Production Systems, PTR Prontice Hall, NJ, 2012.
8. Speight, J.G Fuel Science and Technology Handbook, Marcel Decker Inc. 2007.

PP5202 PETROCHEMICALS L T P C

3 0 0 3

OBJECTIVES

- To impart knowledge on petrochemicals used in refinery industries.

UNIT I **5**

Petrochemical industries and their feed stocks survey of petrochemical industry. Resources and generation of different feed stocks-their purification, separation of individual components by adsorption, low temperature fractionation and crystallization.

UNIT II **6**

Production and utilization of synthesis gas: generation of synthesis gas by steam reforming of naptha and natural gas, fuel oil partial oxidation. chemicals from synthesis gas, methanol via synthesis gas route, formaldehyde from methanol, chloromethane by direct chlorination of methane, trichloroethylene, perchloroethylene by pyrolysis of carbon tetra chloride. Fischer-Tropsch process

UNIT III **10**

Petrochemical based on methane, ethylene, acetylene, propylene and butane: acetylene and methanol from methane , VCM, VAM, ethylene oxide and ethylene glycol, ethanol amides from ethylene. VCM, VAM, acrylonitrile etc. from acetylene. Isopropanol, Propylene oxide, Glycerine, acrylonitrile, Acrylic acid, etc. From propylene. Production of butadiene by dehydrogenation of butane, nitrogen.

UNIT IV **12**

Separation and utilization of aromatics: catalytic reforming operation-seperation of BTX from Reformate .isolation of benzene, toluene, xylene. aromatics derived from thermal cracking of naptha, pyrolysis gasoline hydrogenation process. Alkylation of benzene. production of pthalic anhydride etc. synthetic detergents: classification of detergents production of KERYL Benzene Sulphonate etc., filter, binders, dyes, perfumes, etc. for detergents. Hard and soft detergents.

UNIT V **12**

Synthetic fibres, rubbers, plastics, resins: method, mechanism and types of polymerization , production of HDPE,LDPE, PP,PVC, polystyrene, poly butadiene, etc., manufacture of polyesters, nylons, acrylic fibres,etc. production of phenol formaldehyde resin, epoxy resin, production principle of ABS plastic, polycarbonates, etc.manufacturing techniques of butyl rubber, SBR, isoprene rubber, etc .

TOTAL : 45 PERIODS

OUTCOMES

- To learn about resources, separation techniques in refining and concerned materials obtained from refining.

REFERENCES

1. B.K.B.Rao, A Text on Petrochemicals, Khanna publishers.
2. Brownstein A.M. Trends in Petrochemical Technology, Petroleum Publishing Company, 1976.
3. I D Mall, Petrochemical process technology, Macmillan, 2006.
4. Robert Meyers, Handbook of Petrochemicals production Processes(McGraw Hill Handbooks), 2004

CX5251 ADVANCED PROCESS CONTROL L T P C
3 0 0 3

OBJECTIVES

- To introduce dynamic response of open and closed loop systems, control loop components and stability of control systems along with instrumentation.

UNIT I ADVANCED CONTROL STRATEGIES 9

Feed forward, cascade, dead time compensation, split range, selective and override control; automatic tuning and gain scheduling

UNIT II INTERNAL MODEL CONTROL 9

Model based control – IMC structure – development and design; IMC based PID control, MPC

UNIT III MULTIVARIABLE CONTROL 9

Control loop interaction – general pairing problem, relative gain array and application, sensitivity. Multivariable control – zeros and performance limitations, directional sensitivity and operability, decoupling

UNIT IV DISCRETE SYSTEMS 9

Z – Transform and inverse Z – transform properties, Discrete – Time Response of dynamic system, Pulse Transfer Function, Closed Loop System Stability.

UNIT V DIGITAL FEEDBACK CONTROLLERS 9

Design of digital feedback controllers, digital approximation of classical, effect of sampling, Case study of Industrial Instrumentation and Control system, DCS, PLC, shutdown system.

TOTAL: 45 PERIODS

OUTCOMES

- Students get knowledge on control strategies of process variables and digital feedback controllers for automatic process control.

REFERENCES

1. Bequette, B. W., Process Control: Modeling, Design, and Simulation, Prentice Hall,2003
2. Kannan M. Moudgalya, Digital Process Control, John Wiley & Sons Ltd,2007
3. Stephanopolous, G., "Chemical Process Control", Prentice Hall of India, New Delhi,1985.

CX5252 MULTICOMPONENT DISTILLATION L T P C
3 0 0 3

OBJECTIVE:

- To provide comprehensive knowledge on multicomponent distillation principle, thermodynamic property evaluation and design.

UNIT I THERMODYNAMIC PRINCIPLES 9

Fundamental Thermodynamic principles involved in the calculation of vapor – liquid equilibria and enthalpies of multi component mixtures – Use of multiple equation of state for the calculation of K values – Estimation of the fugacity coefficients for the vapor phase of polar gas mixtures – calculation of liquid – phase activity coefficients.

UNIT II THERMODYNAMIC PROPERTY EVALUATION 9

Fundamental principles involved in the separation of multi component mixtures – Determination of bubble-point and Dew Point Temperatures for multi component mixtures – equilibrium flash distillation calculations for multi component mixtures – separation of multi component mixtures at total reflux.

UNIT III MINIMUM REFLUX RATIO FOR MCD SYSTEM 9

General considerations in the design of columns – Column sequencing – Heuristics for column sequencing – Key components – Distributed components – Non-Distributed components – Adjacent keys. Definition of minimum reflux ratio – calculation of Rm for multi component distillation – Underwood method – Colburn method.

UNIT IV VARIOUS METHODS OF MCD COLUMN DESIGN 9

Theta method of convergence – Kb method and the constant composition method -Application of the Theta method to complex columns and to system of columns – Lewis Matheson method – Stage and reflux requirements – Short cut methods and Simplified graphical procedures.

UNIT V VARIOUS TYPES OF MCD COLUMNS 9

Design of sieve, bubble cap, valve trays and structured packing columns for multi component distillation – computation of plate efficiencies.

TOTAL : 45 PERIODS

OUTCOME:

- The students will understand the importance of mulitcomponent distillation, fundamental concepts and its applications.

REFERENCES

1. Holland, C.D., "Fundamentals of Multi Component Distillation", McGraw Hill Book Company,1981
2. Van Winkle, "Distillation Operations", McGraw Hill Publications, 1987.

PP5211 **SEMINAR** **L T P C**
0 0 4 2

OBJECTIVE:

- To provide exposure to the recent developments.
- To improve the students presentation skills.

OUTCOME:

- The students will get better employability and communication skills. Students are expected to present two seminars along with report on any recent topic in Environmental Science and Technology

PP5391 **CORROSION ENGINEERING** **L T P C**
3 0 0 3

OBJECTIVES

- To impart knowledge on corrosion in petroleum refining.

UNIT I TYPES OF CORROSION AND TESTING METHODS 9

Basic principles of corrosion and its control – Forms of corrosion, uniform, Galvanic, Crevis, pitting, selective leaching, erosion, stress-corrosion, cracking – Cavitation phenomena & their effects – Corrosion testing – Field testing – Electrochemical techniques for measurement of corrosion rates, corrosion detection and components examination – Accelerated salt-spray testing.

UNIT II CORROSION PROTECTION METHODS 9

Corrosion inhibitors, electroplated coatings, conversion coatings, anodizing, hot dipping, spray metal coatings, zinc coating by alloying, electrophoteric coatings and electro painting, powder coating, electrical methods of corrosion protection, composite materials in corrosion minimization – Cathodic and Anodic protections.

UNIT III CORROSION IN SPECIFIC ENVIRONMENTS 9

Corrosion damage to concrete in industrial and marine environments and its protection; biological corrosion, halogen corrosion of metals, environmental degradation of materials, corrosion and inspection managements in chemical processing and petrochemical industries.

UNIT IV CORROSION IN SPECIFIC CASES AND CONTROL 12

Corrosion in structure – corrosion of stainless steels – corrosion in power equipments, corrosion in electrical and electronic industry – corrosion and selection of materials of pulp and paper plants – corrosion aspects in nuclear power plants – corrosion of surgical implants and prosthetic devices.

UNIT V CORROSION AND COUNTRY'S ECONOMY 6

Corrosion protection management–process maintenance procedures under corrosion Environments

TOTAL : 45 PERIODS

OUTCOMES

- Students learn about the types of corrosion, protection methods, corrosion in specific environments, corrosion in specific cases and control.

REFERENCE

1. Fontana, M.G., "Corrosion Engineering", Edn 3, McGraw Hill, 1989
2. Roberge, P.R., Handbook of Corrosion Engineering, McGraw-Hill,2000

PP5312 **PROJECT WORK PHASE I** **L T P C**
0 0 12 6

OBJECTIVE:

- To apply the principles learned from variorius courses to solve real time problem.

Students have to do a research-based project in the department or in an industry andsubmit a report at the end of Phase I

PP5411 **PROJECT WORK PHASE II** **L T P C**
0 0 24 12

OBJECTIVE:

- To apply the principles learned from variorius courses to solve real time problem.

OUTCOME:

The students will get confidence to solve challenging problems.

Phase II of Project Work is a continuation of Phase I of Project. Students submit a report at the end of Phase II.

CX5071 **MULTIPHASE FLOW** **L T P C**
3 0 0 3

OBJECTIVE:

- To understand the concepts of multiphase flow and particle interation.

UNIT I CHARACTERISTICS OF MULTIPHASE FLOWS 9

Significance of multiphase flows, important non-dimensional numbers, parameters of characterization, particle size measurement, size distribution and moments, size distribution models

UNIT II PARTICLE FLUID INTERACTION 9

Equation of motion for a single particle, calculation of drag, motion of a particle in two dimensions, effects of unsteady and non-uniform flow fields, effect of acceleration, effect of coupling; Interaction between particles, mechanism of interaction, interparticle forces, hard sphere model, soft sphere model, discrete element modeling, semi-empirical methods, kinetic theory, force chains.

UNIT III MODELING OF MULTIPHASE FLOWS 9

Flow patterns - identification and classification - flow pattern maps and transition - momentum and energy balance - homogeneous and separated flow models - correlations for use with homogeneous and separated flow models - void fraction and slip ratio correlations - influence of pressure gradient - empirical treatment of two phase flow - drift flux model - correlations for bubble, slug and annular flows

UNIT IV CONSERVATION EQUATIONS 9

Averaging procedures - time, volume, and ensemble averaging, quasi-one-dimensional flow, two-fluid volume-averaged equations of motion, turbulence and two-way coupling.

UNIT V MULTIPHASE SYSTEMS 9

Flow regime and hydrodynamic characteristics of packed bed, fluidized bed, pneumatic conveying, bubble column, trickle beds; Conventional and novel measurement techniques for multiphase systems including CARPT, Laser Doppler anemometry, Particle Image Velocimetry.

TOTAL: 45 PERIODS

OUTCOME:

- The students will understand the importance and analysis of multiphase flow.

REFERENCES

1. Clift, R., Weber, M.E. and Grace, J.R., Bubbles, Drops, and Particles, Academic Press, New York, 2005.
2. Crowe, C. T., Sommerfeld, M. and Tsuji, Y., Multiphase Flows with Droplets and Particles, CRC Press, 2011
3. Fan, L. S. and Zhu, C., Principles of Gas-solid Flows, Cambridge University Press, 2005
4. Govier, G. W. and Aziz. K., "The Flow of Complex Mixture in Pipes", Van Nostrand Reinhold, New York, 1972.
5. Kleinstreuer, C., Two-phase Flow: Theory and Applications, Taylor & Francis, 2003
6. Rhodes, M., Introduction to Particle Technology, John Wiley & Sons, New York.2008.
7. Wallis, G.B., "One Dimensional Two Phase Flow", McGraw Hill Book Co., New York,

CX5072 FLUIDIZATION ENGINEERING L T P C

3 0 0 3

OBJECTIVE:

- Students gain knowledge on fundamentals of fluidization engineering, hydrodynamics, heat and mass transfer effects.

.UNIT I INTRODUCTION 5

The Fluidized state, Nature of hydrodynamic suspension, particle forces, species of Fluidization, Regimization of the fluidized state, operating models for fluidization systems, Applications of fluidization systems.

UNIT II HYDRODYNAMICS OF FLUIDIZATION SYSTEMS 12

General bed behaviour, pressure drop, Flow regimes, Incipient Fluidization, Pressure fluctuations, Phase Holdups, Measurements Techniques, Empirical Correlations for Solids holdup, liquid holdup and gas holdup. Flow models – generalized wake model, structural wake model and other important models.

UNIT III SOLID MIXING AND SEGREGATION 8

Phase juxtapositions operation shifts, Reversal points, Degree of segregation, Mixing Segregation equilibrium, Generalised fluidization of poly disperse systems, liquid phase Mixing and gas phase mixing.

UNIT IV HEAT AND MASS TRANSFER IN FLUIDIZATION SYSTEMS 12

Mass transfer – Gas Liquid mass transfer, Liquid Solid mass transfer and wall to bed mass transfer, Heat transfer – column wall – to – bed heat transfer, Immersed vertical cylinder to bed heat transfer, Immersed horizontal cylinder to bed heat transfer.

UNIT V MISCELLANEOUS SYSTEMS 8

Conical Fluidized bed, Moving bed, Slurry bubble columns, Turbulent bed contactor,Two phase and Three phase inverse fluidized bed, Draft tube systems, Semifluidized bed systems, Annular systems, Typical applications, Geldart's classification for power assessment, Powder characterization and modeling by bed collapsing.

TOTAL : 45 PERIODS

OUTCOME:

- The students will understand the importance of fluidization engineering, solid mixing and its applications.

REFERENCES

1. Fan, L. S., "Gas- liquid Solid Fluidization Engineering", Butterworths, 1989,
2. Kunii, D. and Levenspiel, O., "Fluidization Engineering", 2nd Edn., Butterworth-Heinemann, London, 1991.
3. Kwauk, M., "Fluidization - Idealized and Bubbleless, with applications", Science Press, 2009.

CX5073 PIPING AND INSTRUMENTATION L T P C

3 0 0 3

OBJECTIVES

- Students gain knowledge on fundamentals of piping engineering, pipe hydraulics, piping supports and instrumentation.

UNIT I FUNDAMENTALS OF PIPING ENGINEERING 9

Definitions, Piping Components their introduction, applications. Piping MOC, Budget Codes and Standards, Fabrication and Installations of piping.

UNIT II PIPE HYDRAULICS AND SIZING 9

Pipe sizing based on velocity and pressure drop consideration cost, least annual cost approach, pipe drawing basics, development of piping general arrangement drawing, dimensions and drawing of piping.

UNIT III PLOT PLAN 9

Development of plot plan for different types of fluid storage, equipment layout, process piping layout, utility piping layout. Stress analysis -Different types of stresses and its impact on piping, methods of calculation, dynamic analysis, flexibility analysis.

UNIT IV PIPING SUPPORT 9

Different types of support based on requirement and its calculation.

UNIT V INSTRUMENTATION 9

Final Control Elements; measuring devices, instrumentation symbols introduction to process flow diagram (PFD) and piping & instrumentation diagram (P&ID)

TOTAL : 45 PERIODS

OUTCOME:

- Be familiar with standards, selection, support and instrumentation.

REFERENCES

1. Luyben, W. L.," Process Modeling Simulation and Control for Chemical Engineers,McGraw Hill, 1990.
2. Piping Design Handbook edited by Johan J McKetta, CRC Press, 1992.
3. Piping Handbook, 6 th edition, M.L. Nayyar, P.E., Mc Graw-Hill, Inc

PP5001 SEPARATION PROCESS TECHNIQUES L T P C
3 0 0 3

OBJECTIVE

- To present recent advances in separation techniques from a chemical engineering view point

UNIT I GENERAL 12

Review of conventional processes, recent advances in separation techniques based on size, surface properties, ionic properties and other special characteristics of substances. Process concept, theory and equipment used in cross flow filtration, cross flow electrofiltration, dual functional filter, surface based solid-liquid separations involving a second liquid, sirofloc filter.

UNIT II MEMBRANE SEPARATIONS 8

Types and choice of membranes, plate and frame, tubular, spiral wound and hollow fibre membrane reactors and their relative merits, commercial, pilot plant and laboratory membrane pemeators involving dialysis, reverse osmosis, nanofiltration, ultrafiltration, microfiltration and Donnan dialysis, economics of membrane operations, ceramic membranes.

UNIT III SEPARATION BY ADSORPTION TECHNIQUES 8

Mechanism, types and choice of adsorbents, normal adsorption techniques, affinity chromatography and immuno chromatography, types of equipment and commercial processes, recent advances and process economics

UNIT IV IONIC SEPARATIONS 8

Controlling factors, Types of equipment employed for electrophoresis, dielectrophoresis, Ion Exchange chromatography and electrodialysis, Commercial processes and applications

UNIT V OTHER SEPARATION TECHNIQUES 9

Separations involving lyophilization, pervaporation and permeation techniques for solids, liquids and gases, industrial viability and examples, zone melting, addiuctive crystallization, other separation processes, supercritical fluid extraction, oil spill management, industrial effluent treatment by modern techniques.

TOTAL : 45 PERIODS

OUTCOMES

- To learn Liquid-solid, Gas-Solid, Liquid-Gas separation process, membrane modules, separation techniques and membrane materials.

REFERENCES

1. Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
2. King, C. J., “Separation Processes”, Tata McGraw Hill Co., Ltd., 1982.
3. Nakagawal, O. V., “Membrane Science and Technology”, Marcel Dekker, 1992.

4. Phillip C. Wankat , Separation Process Engineering (2nd Edition),Printice Hall,2007
5. Rousseau, R. W., “Handbook of Separation Process Technology”, John Wiley, New York, 2009.

CX5074 COMPUTATIONAL FLUID DYNAMICS L T P C
3 0 0 3

OBJECTIVE

- Be able to demonstrate competence in setting up computational fluid dynamics models for some industrially important applications. This technical competence in building and conducting CFD simulations is a skill which enhances employability.

UNIT I CONSERVATION LAWS AND TURBULENCE MODELS 9

Governing equations of fluid flow and heat transfer –mass conservation, momentum and energy equation, differential and integral forms, conservation and non-conservation form. Characteristics of turbulent flows, time averaged Navier Strokes equations, turbulence models-one and two equation, Reynolds stress, LES and DNS

UNIT II FINITE DIFFERNCE APPROXIMATION 9

Mathematical behaviour of PDE, finite difference operators, basic aspects of discretization by FDM, explicit and implicit methods, error and stability analysis

UNIT III FINITE VOLUME METHOD 15

Diffusion problems – explicit and implicit time integration; Convection-diffusion problems– properties of discretisation schemes, central, upwind, hybrid, QUICK schemes; Solution of discretised equations.

UNIT IV FLOW FIELD COMPUTATION 6

Pressure velocity coupling, staggered grid, SIMPLE algorithm, PISO algorithm for steady and unsteady flows

UNIT V GRID GENERATION 6

Physical aspects, simple and multiple connected regions, grid generation by PDE solution, grid generation by algebraic mapping.

TOTAL: 45 PERIODS

OUTCOME:

- Students will be in a position to analyse the flow behavior in various systems.

REFERENCES

1. Anderson, J. D., “Computational Fluid Dynamics: The Basics with Applications”, McGraw-Hill, 1995.
2. Chung T.J Computational Fluid Dynamics Cambridge University Press 2003.
3. Fletcher, C. A. J., “Computational Techniques for Fluid Dynamics”, Springer Verlag, 1997.
4. Ghoshdastidar, P.S., “Computer Simulation of flow and heat transfer” Tata McGraw –Hill Publishing Company Ltd. 1998.
5. Muralidhar, K., and Sundararajan, T., “Computational Fluid Flow and Heat Transfer”, NarosaPublishing House, New Delhi, 2001.
6. Subas, V. Patankar “Numerical heat transfer fluid flow”, Hemisphere Publishing Corporation, 1980.

7. Taylor, C and Hughes, J.B. “Finite Element Programming of the Navier Stock Equation”, Pineridge Press Limited, U.K., 1981.
8. Versteeg, H.K. and Malalasekera, W., “An Introduction to Computational Fluid Dynamics: The Finite Volume Method”, Pearson Education Ltd., 2007.

CX5075 SOLVENT EXTRACTION L T P C
3 0 0 3

OBJECTIVES

- Student develop a sound knowledge on equilibrium in liquid-liquid system, HETS, NETS, HTU, NTU, dispersion and coalescence in extractors and design of extraction column.

UNIT I EQUILIBRIUM IN LIQUID-LIQUID SYSTEM 9

Binary and ternary liquid equilibria, Tie-lines, Critical solution temperature, Tie line correlations ,Contour/prism diagrams, Binary / Ternary prediction methods of activity coefficient, Theory and Prediction of diffusivity in liquids, Theory of inter phase mass transport, Estimation and prediction of mass transport coefficient

UNIT II DIFFERENTIAL / STAGE-WISE EQUILIBRIUM CONTACT OPERATIONS 9

Equilibrium stage-wise contact, Single and multiple contacts with co-current and counter current flow of phases for immiscible and partially miscible solvent phases , Calculation methods, Fractional extraction with reflux of raffinate and extract. Differential contact, HETS, NETS, HTU, NTU concepts and Estimation of these parameters, Mass transfer efficiency, Axial mixing and Residence time distribution in extractors and their estimation.

UNIT III DISPERSION AND COALESCENCE IN EXTRACTORS 13

Characteristics of dispersion involving single and multiple nozzle distributors, Drop size and formation and coalescence, Mean drop size at dispersion and their settling velocities/relative characteristics velocities. Effect of drop oscillation ,wobbling and Internal circulation, Effect of surface active agents, Prediction of drop size and characteristics velocity in spray , packed and mechanically agitated contactors as in RDC, pulsed columns, solute transfer effects on drop dynamics.

UNIT IV DESIGN OF LIQUID EXTRACTION COLUMNS 14

Design of extractor height and diameter, Prediction of flow capacities in terms of flooding rates, Regime of operating envelops, Hydrodynamic design variables such as hold up, characteristic velocities, pressure drop, Effect of direction of solute transfer on these variables and their prediction methods, Correction of mass transfer data, Axial mixing correction for column height, Interfacial area estimations, using slow, fast and instantaneous reactions and their application with models for mass transfer coefficients.

TOTAL: 45 PERIODS

OUTCOME:

- The students will understand the fundamentals and importance of extraction processes in process industries.

REFERENCES

1. Hanson, C., “Recent Advances in Liquid Extraction”, Pergamon Press, London, 1972.
2. Hanson, C., Baird, M. H. I. and Lo, T. C., “Hand Book of Solvent Extraction”, Wiley – International, New York, 1983.

3. Laddha, G. S. and Degaleesan, T. E., ”Transport Phenomena in Liquid Extraction”, Tata McGraw Hill, New Delhi, 1976.
4. Treybal, R. E., “Liquid Extraction”, McGraw Hill, New York, 1963.

CX5391 PROCESS MODELING AND SIMULATION L T P C
3 2 0 4

OBJECTIVE:

- To understand the basics of model construction.
- To learn about solving model equations and validation of the models.

UNIT I INTRODUCTION 9+6

Introduction to modeling and simulation, classification of mathematical models, conservation equations and auxiliary relations.

UNIT II STEADY STATE LUMPED SYSTEMS 9+6

Degree of freedom analysis, single and network of process units, systems yielding linear and non-linear algebraic equations, flowsheeting – sequential modular and equation oriented approach, tearing, partitioning and precedence ordering, solution of linear and non-linear algebraic equations.

UNIT III UNSTEADY STATE LUMPED SYSTEMS 9+6

Analysis of liquid level tank, gravity flow tank, jacketed stirred tank heater, reactors, flash and distillation column, solution of ODE initial value problems, matrix differential equations, simulation of closed loop systems.

UNIT IV STEADY STATE DISTRIBUTED SYSTEM 9+6

Analysis of compressible flow, heat exchanger, packed columns, plug flow reactor, solution of ODE boundary value problems.

UNIT V UNSTEADY STATE DISTRIBUTED SYSTEM 9+6

Analysis laminar flow in pipe, sedimentation, boundary layer flow, conduction, heat exchanger, heat transfer in packed bed, diffusion, packed bed adsorption, plug flow reactor, hierarchy in model development, classification and solution of partial differential equations - Empirical modeling, parameter estimation, population balance and stochastic modeling.

TOTAL : 75 PERIODS

OUTCOME:

- Understanding the fundamental of modeling and simulation, system analysis and evaluation.

REFERENCES

1. Felder, R. M. and Rousseau, R. W., “Elementary Principles of Chemical Processes“,John Wiley, 2000.
2. Franks, R. G. E., “Mathematical Modelling in Chemical Engineering“, John Wiley, 1967.
3. Luyben, W.L., "Process Modelling Simulation and Control", McGraw-Hill Book Co.,1973.
4. Ramirez, W., "Computational Methods in Process Simulation", 2nd Edn.,Butterworths, New York, 2000.

CX5076 **INDUSTRIAL INSTRUMENTATION** **L T P C**
3 0 0 3

OBJECTIVES

- Students get the knowledge on how to measure process variables, analytical instrumentation, automatic process controls.

UNIT I **5**

Introduction – Variables, Units & standards of measurement, Measurement terms – characteristic. Data Analysis.

UNIT II **12**

Process Variables Measurement–Temperature systems– Thermocouples, Thermo resistive system, Filled-system thermometers, Radiation thermometry, Location of temperature measuring devices in equipments, Pressure system – Mechanical pressure elements Pressure Transducers and Transmitters, Vacuum measurement, Resonant wire pressure Transducer, Flow system – Differential producers, Variable area flow meters, Velocity, vortex, mass, ultrasonic & other flow meters, positive displacement flow meters, Open – channel flow measurements, Force systems, Strain gauges Humidity Moisture system, Humidity Measurement, Moisture measurement system, Rheological system, Viscosity measurement, Radiation system, Nuclear radiation instrumentation.

UNIT III **12**

Analytical instrumentation – Analysis instruments, Sample conditioning for process analyzers, X-ray Analytical methods, Quadrupole mass spectrometry, Ultra violet Absorption Analysis, Infra red process analyzers, Photometric reaction product analysers Oxygen analyzers, Oxidation – reduction potential measurements, pH measuring systems, Electrical conductivity and Resistivity measurements, Thermal conductivity, gas analysis, Combustible, Total hydro carbon, and CO analyzer, Chromatography.

UNIT IV **9**

Fundamentals of Automatic process control – Control algorithms-Automatic controllers – Electronic controllers -Electric controllers (Traditional) - Hydraulic controllers – Fluidics -Programmable controllers.

UNIT V **7**

Sensors, Transmitters and control valves - Pressure, Flow, Level, Temperature and Composition sensors, Transmitters, Pneumatic and electronic control valves, Types, Actuator, accessories, Instrumentation symbols and Labels.

TOTAL: 45 PERIODS

OUTCOMES

- Students get the knowledge on how to measure process variables, analytical instrumentation, automatic process controls.

REFERENCES

1. Astrom K.J., Bjon wittenmark, Computer controlled systems, Prentice- Hall of India, New Delhi1994.
2. Cartis Johnson, Process Control Instrumentation Technology, Prentice-Hall of India, New Delhi 1993.
3. Considine D M and Considine G D “Process Instruments Controls” Handbook 3rd Edition, McGraw – Hill Book Co., NY, 1990.

4. Eckman D.P. “Industrial Instrumentation”, Wiley Eastern Ltd., 1989.
5. Ernest Doebelin, Measurement systems, McGraw – Hill Book, Co., NY, 1975.
6. Fribance, “Industrial Instrumentation Fundamentals” ,Mc Graw Hill Co. Inc. New York 1985
7. Scborg D E,.Edgar T.F and Mellichamp D.A, “Process Dynamics and Control” John Wiley 1989.

ES5092 DESIGN OF EXPERIMENTS L T P C
3 0 0 3

OBJECTIVE:

- To impart basic knowledge on statistical design of experiments.
- To learn about various methods employed for the design of experiments.

UNIT I CONCEPTS AND TERMINOLOGY 5

Review of hypothesis testing – P Value, “t” Vs paired “t” test, simple comparative experiment, planning of experiment – steps. Terminology - factors, levels, variables, Design principles – replication, randomization, blocking, confounding, Analysis of variance, sum of squares, degrees of freedom.

UNIT II SINGLE FACTOR EXPERIMENTS 10

Completely randomized design, Randomized block design, effect of coding the observations, Latin Square design, orthogonal contrasts, comparison of treatment means – Duncan’s multiple range test, Newman- Keuel’s test, Fisher’s LSD test, Tukey’s test.

UNIT III FACTORIAL EXPERIMENTS 10

Main and interaction effects, Rules for sum of squares and expected mean square, two and three factor full factorial design, 2k designs with two and three factors, Yate’s algorithm, practical applications.

UNIT IV SPECIAL EXPERIMENTAL DESIGNS 10

Blocking and confounding in 2k design, nested design, split – plot design, two level fractional factorial design, fitting regression models, introduction to response surface methods- Central composite design.

UNIT V TAGUCHI TECHNIQUES 10

Introduction, Orthogonal designs, data analysis using ANOVA and response graph, parameter design – noise factors, objective functions (S/N ratios), multi-level factor OA designs, applications.

TOTAL : 45 PERIODS

OUTCOME:

- The students will be in a position to solve problems involving many factors.
- Be familiar with statistical tools for environmental applications

REFERENCES

1. Angela M.Dean and Daniel Voss, Design and Analysis of Experiments, Springer texts in Statistics, 2000.
2. Douglus C.Montgomery, Design and Analysis of Experiments, John Wiley & Sons,2005
3. Philip J.Ross, Taguchi Techniques for Quality Engineering, Prentice Hall, 1989.

CX5091 **SAFETY AND HAZARD CONTROL** **L T P C**
3 0 0 3

OBJECTIVES

- Become a skilled person in HAZOP and hazard analysis and able to find out the root cause of an accident. Gain knowledge in devising safety policy and procedures to be adopted to implement total safety in a plant.

UNIT I **9**

Conventional and modern concepts of safety, Basic Principles and concepts in hazard identification, Chemical hazards, Process and operation hazard, Hazards from utilities like air, water, steam etc., Occupational health hazards, Hazard and operability Studies, Safety Audits.

UNIT II **9**

Past Accident Analysis, Consequence Analysis of fire, gas/vapour, Dispersions and explosion, Vulnerability models, Fault and Event Tree Analysis.

UNIT III **9**

Safety in plant design and layout. Risk Assessment.

UNIT IV **9**

Safety measures in handling and storage of chemicals, Process plant, personnel Protection, First Aid.

UNIT V **9**

Disaster mitigation, Emergency Preparedness plans.

TOTAL: 45 PERIODS

OUTCOME:

- Students understand that behind each fatality or serious injury there are thousands of at - risk behaviours and unidentified hazards that contributed to the incident
- State the definition of a hazard and explain how to identify hazards in the industries/workplace.
- Determine methods for controlling hazards in the workplace.
- Complete a Job Hazard Analysis for a typical worker task.

REFERENCES

1. Coulson J.M and Richardson J.F., Chemical Engineering, Vol. 1 (Chaper 4) Asian Book House Pvt. Ltd., New Delhi. 1998.
2. Frank P.Less, Loss Prevention in Process Industries, Vol. I and Vol II Butterworth, London, 1980.
3. Guidelines for Chemical Process Quantitative Risk Analysis, Published by Centre for Chemical Process Safety of the AICh.E., New York, USA. 1989.
4. Major Hazard Control, Manual by International Labour Organization, Geneva, 1990.
5. Marshal, V.C Major Chemical Hazards, Ellis Harwood Ltd. Chichester, U.K. 1987.
6. R.K.Sinnott, Coulson & Richardson's Chemical Engineering, Vol.6 Butlerworth – Heinmann. Oxford, 1996.
7. Raghavan, K.V and A.A Khan, Methodologies in Hazard Identification and Risk Assessment, Manual by CLRI., Dec, 1990.
8. Safety in Chemical and Petrochemical Industries, Report of the Inter Ministry Group, Dept. of Chemicals and Petrochemicals, Govt.of India, ICMA Publications. 1986.

9. Well, G.S Safety Process Plants Design, George Godwin Ltd., London, John Wilelys and Sons, New York, 1980.

CX5092 ENERGY MANAGEMENT L T P C
3 0 0 3

OBJECTIVES

- Students gain the knowledge on energy sources, various forms, demand, power requirements, conservation and optimization techniques and the sources of continuous power.

UNIT I **9**

Energy sources; coal oil, natural gas; nuclear energy; hydro electricity, other fossil fuels; geothermal; supply and demand; depletion of resources; need for conservation; uncertainties; national and international issues.

UNIT II **9**

Forecasting techniques, energy demand, magnitude and pattern, input and output analysis, energy modeling and optimal mix of energy sources. Energy - various forms, energy storage, structural properties of environment.

UNIT III **9**

Bio-geo-chemical cycles; society and environment population and technology. Energy and evolution, growth and change, patterns of consumption in developing and advances countries, commercial generation of power requirements and benefit.

UNIT IV **9**

Chemical industries, classification, conservation in unit operation such as separation, cooling tower,drying, conservation applied to refineries, petrochemical, fertilizers, cement, pulp and paper, food industries, chloro alkali industries, conservation using optimization techniques.

UNIT V **9**

Sources of continuous power, wind and water, geothermal, tidal and solar power, MHD, fuel cells, hydrogen as fuel. Cost analysis, capacity; production rate, system rate, system cost analysis, corporate models, production analysis and production using fuel inventories, input-output analysis, economics, tariffs.

TOTAL: 45 PERIODS

OUTCOME

- The students will be in a position to develop energy efficient process
- Students will focus on the conservation of energy while developing industrial processes

REFERENCES

1. Gramlay, G. M., Energy , Macmillan Publishing Co., New York, 1975.
2. Krentz, J. H., Energy Conservation and Utilisation , Allyn and Bacur Inc., 1976.
3. Loftiness, R.L. – Energy Hand Book, Van Nostrand Reinhold Company, New York, 1978.
4. Rused, C. K., Elements of Energy Conservation , McGraw-Hill Book Co., 1985.

PP5002 **RESERVOIR ENGINEERING** **L T P C**
3 0 0 3

OBJECTIVES

- To provide a general idea about Reservoir Drive Mechanisms and also to understand the effects of production/ injection on recovery of reserves.

UNIT I **12**

Fluid Flow Through Porous Media. Single Phase and Multiphase Flow Equations, Linear and Radial flow in Reservoir: Derivation of Diffusivity Equation, PVT Analysis for Oil: Hydrocarbon Phase Behavior, Determination of the PVT Parameters.

UNIT II **12**

Gas Reservoir Engineering, Condensate Reservoirs, Reserve estimation Methods: Volumetric and Material Balance Equation. Reservoir Simulation.

UNIT III **12**

Reservoir Drive Mechanisms, Natural Water Influx Reservoir, Pressure Maintenance water Flooding Performance Calculations for Stratified Reservoirs.

UNIT IV **9**

Productivity Index, IPR. Water and Gas Coning, Decline Curve Analysis

TOTAL : 45 PERIODS

OUTCOMES

- To enable the student to interpret cross plots, flow through porous media, PVT analysis for oil, simulation and gas condensate reservoirs.

REFERENCES

1. Applied Petroleum Reservoir Engineering B.C Craft, M. Hawkins, and Ronald E. Terry.
2. Dake, L.P; Fundamentals of reservoir Engineering
3. Gas Reservoir Engineering: John W. Lee and R.A. Wattenbarger.
4. Integrated Petroleum Reservoir Management: A. satter, G. Thakur.
5. Oil Reservoir Engineering S.J. Pirson
6. Petroleum Reservoir Engineering Physical Properties James W. Amyx, Daniel M. Bass and Robert L. Whiting
7. Towler, B. Fundamental Principles of Reservoir Engineering

CX5077 **PROJECT ENGINEERING OF PROCESS PLANTS** **L T P C**
3 0 0 3

OBJECTIVE

- Students should be able to design a project at the end of the course by themselves.

UNIT I **9**

Project definition, Project Profile and standards, Feed back information (MIS), Evaluation and Modification, Selection, Criteria.

UNIT II **9**

Planning the process, Strategic and Managerial Planning, Organising the process planning, cost and costing, Cost Control systems, Economic Balancing, Network Planning, Methods (PERT/CPM), Engineering Flow Diagrams, Cost requirements, Analysis and Estimation of Process Feasibilities (Technical/Economical) Analysis, Cost – Benefit Ratio Analysis, Project Budgeting, Capital Requirements, capital Market, Cash Flow Analysis, Break even strategies.

UNIT III **9**

Plant Engineering Management, Objectives, Programme, Control, Plant Location and Site Selection, Layout diagrams, Selection and procurement of equipment and machineries, Installation, Recommission, Commissioning and performance appraisal, Strategies choice and Influence, Product planning and development, Provision and maintenance of service facilities.

UNIT IV **9**

Process safety, Materials safety and Handling regulations, Safety in equipment and machinery operations, Design considerations of safety organization and control, Pollution, Pollution control and Abatement, Industrial Safety Standard Analysis.

UNIT V **9**

Government regulations on procurement of raw materials and its allocation. Export – Import regulations, Pricing policy, Industrial licensing procedure, Excise and other commercial taxes, Policies on depreciation and corporate tax, Labour laws, Social welfare legal measurements, Factory act, Regulations of Pollution Control Board.

TOTAL: 45 PERIODS

OUTCOME:

- Students will understand the significance of management information system, planning, budgeting, proess plant safety and government regulations for process industries.

REFERENCES

1. Cheremisinoff, N. P., Practical Guide to Industrial Safety: Methods for Process Safety Professionals, CRC Press, 2001
2. Couper, J. R., Process Engineering Economics, CRC Press, 2003.
3. Perry, J. H. “Chemical Engineer’s Hand Book”, 8th Ed., McGraw Hill, New York, 2007.
4. Peters, M. S., Timmerhaus, C. D. and West, R. E., “Plant Design and Economics for Chemical Engineers”, 5th Edn., McGraw Hill, 2003.
5. Silla, H., Chemical Process Engineering: Design and Economics, CRC Press, 2003
6. Vinoski, W., Plant Management Handbook, Pearson Education, Limited, 1998
7. Watermeyer, P., Handbook for Process Plant Project Engineers, John Wiley and Sons, 2002

CX5078 **PROCESS OPTIMIZATION** **L T P C**
3 0 0 3

OBJECTIVE

- Students should be able to optimize the process for a given chemical industry at the end of the course.

UNIT I INTRODUCTION 5

Problem formulation, degree of freedom analysis, objective functions, constraints and feasible region, Types of optimization problem.

UNIT II LINEAR PROGRAMMING 10

Simplex method, Barrier method, sensitivity analysis, Examples.

UNIT III NONLINEAR UNCONSTRAINED OPTIMIZATION 10

Convex and concave functions unconstrained NLP, Newton's method Quasi-Newton's method, Examples.

UNIT IV CONSTRAINED OPTIMIZATION 10

Direct substitution, Quadratic programming, Penalty Barrier Augmented Lagrangian Methods.

UNIT V MULTI OBJECTIVE OPTIMIZATION 10

Weighted Sum of Squares method, Epsilon constrain method, Goal attainment, Examples. Introduction to optimal control and dynamic optimization.

TOTAL: 45 PERIODS

OUTCOME:

- Understanding of different objective functions and analytical methods.
- Ability to solve various multivariable optimization problems.

REFERENCES

1. Diwaker, U. W. "Introduction to Applied Optimization", Kluwer, 2003.
2. Edgar, T. F., Himmelblau, D. M. and Ladson, L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill, New York, 2003.
3. Joshi, M. C. and Moudgalya, K. M., "Optimization, Theory and Practice", Narosa, New Delhi, 2004.
4. Rao, S. S., Engineering Optimization: Theory and Practice, New Age Publishers, 2000

PP5003 PETROLEUM ECONOMICS L T P C

3 0 0 3

OBJECTIVES

- To introduce process economics and industrial management principles.

UNIT I 9

Introduction to upstream economics analysis, energy overview of India – Time value of money, cash flow analysis, capital budgeting techniques, general probability, elements of oil and gas project cash flows.

UNIT II 9

Reserves classification methods, quantification, assessment of geoscience and reservoir engineering uncertainties – Assessment of reserves, production and demand in international market.

UNIT III 9

Inflation and cost escalation, oil market and OPEC, share of non OPEC countries in oil production – International oil and gas pricing mechanism – Geopolitics.

UNIT IV **9**

Petroleum Fiscal system, classification and analysis – Reserves Auditing – Accounting systems for oil and gas.

UNIT V **9**

Project Economic Evaluation and petroleum economic models – Decision analysis – Valuation of petroleum properties.

TOTAL : 45 PERIODS

OUTCOMES

- Students will be able to make cost estimation, feasibility analysis, management, organization and quality control that will enable the students to perform as efficient managers.

REFERENCES

1. Abdel-Aal, H. K. Bakr, A. B. Al-Sahlawi. A : Petroleum Economics and Engineering, Dekrer Publication, 1992
2. Cronquist, C., Estimation and classification of Reserves of Crude oil, Natural Gas, and Condensate, SPE (2001)
3. Johnston, D, “International Exploration Economics, Risk, and Contract Analysis”, Pennwell Books, 2003.
4. Seba R. D., “Economics of Worldwide Petroleum Production”, OGCL Publications, USA, 1998.
5. Thompson R. S. and Wright J. D., “Oil Property Evaluation”, 2nd Edition, Thompson Wright Associates, 1985.

PP5004 NON-CONVENTIONAL PETROLEUM RESOURCES **L T P C**

3 0 0 3

OBJECTIVES

- Students gain knowledge on synthesizing various products from non-conventional petroleum resources.

UNIT I **10**

Introduction and present status of coal bed methane. Formation and properties of coal bed methane. Thermodynamics of coal bed methane. Drilling, completion and logging of coal bed methane wells.

UNIT II **10**

Hydro-fracturing of coal bed methane seam. Production, installation and surface facilities. Well operation and production equipments. Treating and disposing produced water. Testing of coal bed methane wells.

UNIT III **10**

Introduction and present status of gas hydrates. Formation and properties of gashydrates. Thermodynamics of gas hydrates. Phase behavior of gas hydrates.Kinetics of gas hydrates. Drilling and completion of gas hydrates wells. Preventionand control of gas hydrates.

UNIT IV **6**

Gas hydrates accumulation in porous media. Gas extraction from gas hydrates.Uses and applications of gas hydrates.

UNIT V **9**

Introduction and present status of shale gas. Formation and properties of shalegas. Drilling and completion of shale gas. Uses and application of shale gas,Prevention of shale gas. Environmental issues in shale gas exploration. Futureprospects of shale gas.

TOTAL: 45 PERIODS

OUTCOMES:

- Students will understand the recovery of various value added products from non-conventional petroleum resources.

REFERENCES

1. Carrol John, Natural Gas Hydrates: A guide for engineers, Gulf Publications, 2003
2. Farooqi Ali, S M, Jones S A and Meldau R F, Practical Heavy Oil Recovery, SPE, 1997
3. James T. Bartis, Frank Camm, David S. Ortiz, Producing Liquid Fuels from Coal, Prospects and Policy Issues. NETL, DOE, USA, 2008,
4. Pramod Thakur, Steve Schatzel and Kashy Aminian, (Editors), Coal Bed Methane: From Prospects to Pipeline, Elsevier, 2014
5. Rafiqul Islam, M, Unconventional Gas Reservoirs: Evaluation, Appraisal, and Development, Gulf Professional Publishing, 2014
6. Warner, H.R., Emerging and Peripheral Technologies, Society of Petroleum Engineers, Handbook, Volume VI, 2009

CX5081 **INTELLECTUAL PROPERTY RIGHTS** **L T P C**
3 0 0 3

OBJECTIVES

- After completing the course, the students will have capacity to solve, on their own hand, minor juridical questions within “Intellectual Property Rights”. They will also be able to follow and understand more complex juridical discussions.

UNIT I **5**

Introduction – Invention and Creativity – Intellectual Property (IP) – Importance – Protection of IPR – Basic types of property (i). Movable Property ii. Immovable Property and iii. Intellectual Property.

UNIT II **10**

IP – Patents – Copyrights and related rights – Trade Marks and rights arising from Trademark registration – Definitions – Industrial Designs and Integrated circuits – Protection of Geographical Indications at national and International levels – Application Procedures..

UNIT III **10**

International convention relating to Intellectual Property – Establishment of WIPO – Mission and Activities – History – General Agreement on Trade and Tariff (GATT).

UNIT IV **10**

Indian Position Vs WTO and Strategies – Indian IPR legislations – commitments to WTO-Patent Ordinance and the Bill – Draft of a national Intellectual Property Policy – Present against unfair competition.

UNIT V **10**

Case Studies on – Patents (Basumati rice, turmeric, Neem, etc.) – Copyright and related rights – Trade Marks – Industrial design and Integrated circuits – Geographic indications – Protection against unfair competition.

TOTAL: 45 PERIDOS

OUTCOMES:

- After completing the course, the students will have capacity to solve, on their own hand, minor juridical questions within "Intellectual Property Rights". They will also be able to follow and understand more complex juridical discussions.

REFERENCES

1. Eli Whitney, United States Patent Number: 72X, Cotton Gin, March 14, 1794.
2. Intellectual Property Today: Volume 8, No. 5, May 2001, [www.iptoday.com].
3. Subbaram N.R. "Handbook of Indian Patent Law and Practice ", S. Viswanathan, Printers and Publishers Pvt. Ltd., 1998.
4. Using the Internet for non-patent prior art searches, Derwent IP Matters, July 2000.

CX5095 ENVIRONMENT, HEALTH AND SAFETY IN INDUSTRIES L T P C

3 0 0 3

OBJECTIVE

- To make students to get a clear picture of environment, health and safety systems, their features and techniques used and the principles and methods of effective training.

UNIT I INTRODUCTION **9**

Need for developing Environment, Health and Safety systems in work places. Status and relationship of Acts, Regulations and Codes of Practice .Role of trade union safety representatives. International initiatives. Ergonomics and work place.

UNIT II OCCUPATIONAL HEALTH AND HYGIENE **9**

Definition of the term occupational health and hygiene. Categories of health hazards. Exposure pathways and human responses to hazardous and toxic substances. Advantages and limitations of environmental monitoring and occupational exposure limits. Hierarchy of control measures for occupational health risks. Role of personal protective equipment and the selection criteria. Effects on humans, control methods and reduction strategies for noise, radiation and excessive stress.

UNIT III WORKPLACE SAFETY AND SAFETY SYSTEMS **9**

Features of the satisfactory design of work premises HVAC, ventilation. Safe installation and use of electrical supplies. Fire safety and first aid provision. Significance of human factors in the establishment and effectiveness of safe systems. Safe systems of work for manual handling operations. Control methods to eliminate or reduce the risks arising from the use of work equipment. Requirements for the safe use of display screen equipment. Procedures and precautionary measures necessary when handling hazardous substances. Contingency arrangements for events of serious and imminent danger.

UNIT IV TECHNIQUES OF ENVIRONMENTAL SAFETY **9**

Elements of a health and safety policy and methods of its effective implementation and review. Functions and techniques of risk assessment, inspections and audits. Investigation of accidents- Principles of quality management systems in health and safety management. Relationship

between quality manuals, safety policies and written risk assessments. Records and other documentation required by an organisation for health and safety. Industry specific EHS issues.

UNIT V EDUCATION AND TRAINING 9

Requirements for and benefits of the provision of information, instruction, training and supervision. Factors to be considered in the development of effective training programmes. Principles and methods of effective training. Feedback and evaluation mechanism.

TOTAL: 45 PERIODS

OUTCOME

- On completion of the course, the students are expected to be familiar with accident prevention techniques, hazard analysis techniques and legislations pertaining to safety in chemical industries.

REFERENCES

1. Effective Environmental, Health, and Safety Management Using the Team Approach by Bill Taylor, Culinary and Hospitality Industry Publications Services2005
2. Environmental and Health and Safety Management by Nicholas P. Cheremisinoff and Madelyn L. Graffia, William Andrew Inc. NY, 1995
3. The Facility Manager's Guide to Environmental Health and Safety by Brian Gallant, Government Inst Publ., 2007.

CX5080 OPERATIONS RESEARCH L T P C

3 0 0 3

OBJECTIVE

- To learn various methods of solving engineering problems using mathematical tools.

UNIT I MATHEMATICAL PROGRAMMING 12

Introduction, Linear Programming, Solution by simplex method, Duality, Sensitivity analysis, Dual simplex method, Integer Programming, Branch and bound method, Geometric programming and its application.

UNIT II DYNAMIC PROGRAMMING 10

Elements of DP models, Bellman’s optimality criteria, Recursion formula, Solution of multistage decision problem by DP method. Application is Heat Exchange Extraction systems.

UNIT III PERT, CPM and GERT 9

Network representation of projects, Critical path calculation, construction of the timechart and resource leveling, Probability and cost consideration in project scheduling, Project control. Graphical Evaluation and Review Techniques.

UNIT IV ELEMENTS OF QUEUING THEORY 7

Basic elements of the Queuing model, M/M/1 and M/M/C Queues.

UNIT V ELEMENTS OF RELIABILITY THEORY 7

General failure distribution, for components, Exponential failure distributions, General model, Maintained and Non-maintained systems, Safety Analysis.

TOTAL: 45 PERIODS

OUTCOMES:

- Understand the mathematical tools that are needed to solve optimization problems.
- Understand to use mathematical softwares to solve the proposed models.
- Understand to identify and develop operation research models for the real systems and to solve it.

REFERENCES

1. Carter, M. W. and Price, C. C., Operations Research: A Practical Introduction Contributor, CRC Press, 2001.
2. Edgar, T. F., Himmelblau, D. M. and Ladson, L. S., “Optimization of Chemical Processes”, 2nd Ed., McGraw Hill, New York, 2003.
3. Hillier, F. S., and Lieberman, G. J., Introduction to Operations Research, McGraw- Hill, 2005
4. Taha, H. A., “Operations Research, An introduction”, 6th Ed., Prentice Hall of India, New Delhi, 2006.

CX5093 PILOT PLANT AND SCALE UP METHODS L T P C
3 0 0 3

OBJECTIVE

- To impart knowledge on scale up techniques
- To understand the application of scale up of Chemical equipments

UNIT I PRINCIPALS OF SIMILARITY, PILOT PLANTS & MODELS 9

Introduction to scale-up methods, pilot plants and models and principles of similarity.

UNIT II DIMENSIONAL ANALYSIS AND SCALE-UP CRITERION 9

Dimensional analysis, regime concept, similarity criterion and scale up methods used in chemical engineering.

UNIT III SCALE-UP OF HEAT TRANSFER EQUIPMENT 9

Typical problems in scale-up of mixing equipment and heat transfer equipment

UNIT IV SCALE-UP OF MASS TRANSFER EQUIPMENT 9

Scale-up of distillation columns and packed towers for continuous and batch processes

UNIT V SCALE-UP OF CHEMICAL REACTORS 9

Kinetics, reactor development & scale-up techniques for chemical reactors.

TOTAL : 45 PERIODS

OUTCOME:

- Students will be in a position to design large scale plant based on pilot plant studies and scale-up methods.

REFERENCES

1. Donald G. Jordan,"Chemical Process Development" (Part 1 and 2), Interscience Publishers,1988.
2. Johnstone and Thring ," Pilot Plants Models and Scale-up methods in Chemical Engg.", McGraw Hill, New York, 1962.

3. Marko Zlokarnik, “Dimensional Analysis and Scale-up in Chemical Engg.", Springer Verlag, Berlin, Germany, 1986.

PP5005 ENHANCED OIL RECOVERY L T P C
3 0 0 3

OBJECTIVES

- To impart knowledge on how residual oil is recovered and the problems associated with Enhanced Oil Recovery.

UNIT I FUNDAMENTALS OF ENHANCED OIL RECOVERY 9

Pore Geometry, Microscopic aspects of displacement. Residual oil magnitude and mobilization. Buoyancy forces and prevention of trapping, Wettability, Residual oil and Oil recovery. Macroscopic aspect of displacement.

UNIT II WATER FLOODING 9

Properties, sampling and analysis of oil field water; Injection waters; Water flooding - Sweep efficiency, Predictive techniques, Improved water flood processes, Performance of some important water floods.

UNIT III ENHANCED OIL RECOVERY OPERATIONS-1 10

Flooding – miscible, CO2, polymer, alkaline, surfactants, steam;

UNIT IV ENHANCED OIL RECOVERY OPERATIONS-2 10

Gas injection, in-situ combustion technology, microbial method.

UNIT V PROBLEMS IN ENHANCED OIL RECOVERY 7

Precipitation and deposition of Asphaltenes and Paraffins, Scaling problems, Formation of damage due to migration of fines, Environmental factors.

TOTAL: 45 PERIODS

OUTCOMES

- Students would gain knowledge on residual oil recovery, operations and problems of Enhanced Oil Recovery.

REFERENCES

1. Donaldson, E.C. and G. V. Chilingarian, T. F. Yen, “Enhanced oil Recovery – I & II”, Fundamentals and Analysis, Elsevier Science Publishers, New York, 1985.
2. Lake, L.W., “Enhanced oil recovery”, Prentice Hall, 1989.
3. Schumacher, M.M., “Enhanced oil recovery: Secondary and tertiary methods”, Noyes Data Corp., 1978.
4. Van Poollen, H.K. “Fundamentals of enhanced oil recovery”, PennWell Books, 1980.

CX5082 GAS TRANSPORTATION L T P C
3 0 0 3

OBJECTIVES

- Students gain knowledge on selection of right type of transport and various types of pipes, pipeline protection techniques and design of pipeline.

UNIT I **9**

Introduction, widespread use, the various types, the advantages and the special features of pipelines.

UNIT II **9**

The fluid mechanics of various types of pipe flow including incompressible and compressible flows of Newtonian fluids, non-Newtonian fluids, flow of solid/liquid mixture (slurry), flow of solid/air mixture (pneumatic transport), and flow of capsules (capsule pipelines).

UNIT III **9**

Various types of pipes (steel, concrete, PE, PVC, etc.), valves (gate, globe, ball, butterfly, etc.) and pressure regulators in pipelines. Blowers and compressors (for gases). Various kinds of flowmeters, sensors, pigs (scrapers) and automatic control systems used in pipelines.

UNIT IV **9**

Various means to protect pipelines against freezing, abrasion and corrosion, such as cathodic protection, Planning, construction and operation of pipelines, including modern use of advanced technologies such as global positioning systems (GPS), directional drillings, automatic control using computers, and pipeline integrity monitoring such as leak detection.

UNIT V **9**

Structural design of pipelines —load considerations and pipe deformation and failure. Economics of pipelines including life-cycle, Cost analysis and comparison of the costeffectiveness of pipelines with alternative modes of transport such as truck or railroad. Legal, safety and environmental issues about pipelines.

TOTAL: 45 PERIODS

OUTCOME:

- Students will be able to select right type of transport, pipeline protection techniques and design of pipeline.

REFERENCES

1. Liu, H., R. L. Gandhi, M. R. Carstens and G. Klinzing, "Freight pipelines: current status and anticipated use,"(Report of American Society of Civil Engineers (ASCE) Task Committee on freight Pipelines), ASCE J. of Transportation Engr., vol. 124, no. 4, pp.300-310, Jul/Aug 1998.
2. Liu, H and T. Marrero, "Pipeline engineering research and education at universitie in the United States," C.D. Proc. of Intl. Conf. on Engr. Education (ICEE-98), Rio de Janeiro Brazil, 15 pages, August 17-20, 1998.

CX5083 **GREEN CHEMISTRY AND ENGINEERING** **L T P C**

3 0 0 3

OBJECTIVE

- To make students aware of global environmental issues, concepts behind pollution prevention, environmental risks, green chemistry, methods to evaluate environmental costs and life cycle assessments.

UNIT I **9**

Overview of Major Environmental Issues, Global Environmental Issues. Air Quality Issues. Water Quality Issues, Ecology, Natural Resources, Description of Risk. Value of Risk Assessment in the

Engineering Profession. Risk-Based Environmental Law. Risk Assessment Concepts. Hazard Assessment. Dose-Response. Risk Characterization.

UNIT II **9**

Pollution Prevention- Pollution Prevention Concepts and Terminology. Chemical Process Safety. Responsibilities for Environmental Protection. Environmental Persistence. Classifying Environmental Risks Based on Chemical Structure. Exposure Assessment for Chemicals in the Ambient Environment.

UNIT III **9**

Green Chemistry. Green Chemistry Methodologies. Quantitative/Optimization-Based Frameworks for the Design of Green Chemical Synthesis Pathways. Green Chemistry Pollution Prevention in Material Selection for Unit Operations. Pollution Prevention for Chemical Reactors. Pollution Prevention for Separation Devices. Pollution Prevention Applications for Separative Reactors. Pollution Prevention in Storage Tanks and Fugitive Sources.

UNIT IV **9**

Process Energy Integration. Process Mass Integration. Case Study of a Process Flow sheet-Estimation of Environmental Fates of Emissions and Wastes.

UNIT V **9**

Magnitudes of Environmental Costs. A Framework for Evaluating Environmental Costs. Hidden Environmental Costs. Liability Costs. Internal Intangible Costs. External Intangible Costs. Introduction to Product Life Cycle Concepts. Life-Cycle Assessment. Life-Cycle Impact Assessments. Streamlined Life-Cycle Assessments. Uses of Life- Cycle Studies.

TOTAL: 45 PERIODS

OUTCOMES

- Upon completion of this course, the students would understand the fundamentals of green chemistry and engineering
- Application of these principles during the design, retrofit and management of chemical processes for a more sustainable chemical manufacturing

REFERENCES

1. Allen, D.T., Shonnard, D.R, Green Engineering: Environmentally Conscious Design of Chemical Processes. Prentice Hall PTR 2002.
2. MukeshDoble and Anil Kumar Kruthiventi, Green Chemistry and Engineering, Elsevier, Burlington, USA, 2007.

CX5084 **FUEL CELL TECHNOLOGY** **L T P C**

3 0 0 3

OBJECTIVES

- Students gain knowledge on fuel cell principles, kinetics, in-situ and ex-situ characterization, fuel cell power plant and applications.

UNIT I **9**

Overview of fuel cells: Low and high temperature fuel cells; Fuel cell thermodynamics - heat, work potentials, prediction of reversible voltage, fuel cell efficiency.

UNIT II **9**

Fuel cell reaction kinetics - electrode kinetics, overvoltage, Tafel equation, charge transfer reaction, exchange currents, electro catalysis - design, activation kinetics, Fuel cell charge and mass transport - flow field, transport in electrode and electrolyte.

UNIT III **9**

Fuel cell characterization - in-situ and ex-situ characterization techniques, i-V curve, frequency response analysis; Fuel cell modelling and system integration: - 1D model – analytical solution and CFD models.

UNIT IV **9**

Balance of plant; Hydrogen production from renewable sources and storage; safety issues, cost expectation and life cycle analysis of fuel cells.

UNIT V **9**

Fuel cell power plants: fuel processor, fuel cell power section (fuel cell stack), power conditioner; automotive applications, portable applications

TOTAL : 45 PERIODS

OUTCOME:

After completing the course, student should have learnt

- Basics and working principles of the Fuel cell, reaction kinetics, characterization. .
- Design and stack making process for real field applications

REFERENCES

1. Bard,A. J. , L. R., Faulkner,Electrochemical Methods, Wiley, N.Y.(2004) Ref Book.
2. Basu,S.(Ed) Fuel Cell Science and Technology,Springer, N.Y.(2007).
3. Fuel cell tech nology handbook, edited by Gregor Hoogers, CRC Press 2003.
4. Liu, H.,Principles of fuel cells, Taylor & Francis, N.Y. (2006).
5. O'Hayre, R.P.,S. Cha,W. Colella, F.B.Prinz, Fuel Cell Fundamentals,Wiley, NY (2006).