CURRICULUM

Academic Year 2018– 2019

DEPARTMENT OF CHEMICAL ENGINEERING

V &VI Semester B. E.

RAMAIAH INSTITUTE OF TECHNOLOGY

(Autonomous Institute, Affiliated to VTU)

BANGALORE – 54

About the Institute:

Ramaiah Institute of Technology (RIT) (formerly known as M. S. Ramaiah Institute of Technology) is a self-financing institution established in Bangalore in the year 1962 by the industrialist and philanthropist, Late Dr. M S Ramaiah. The Institute is accredited with A grade by NAAC in 2016 and all engineering departments offering bachelor degree programs have been accredited by NBA. RIT is one of the few institutes with faculty student ratio of 1:15 and achieves excellent academic results. The institute is a participant of the Technical Education Quality Improvement Program (TEQIP), an initiative of the Government of India. All the departments are full with competent faculty, with 100% of them being postgraduates or doctorates. Some of the distinguished features of RIT are: State of the art laboratories, individual computing facility to all faculty members. All research departments are active with sponsored projects and more than 130 scholars are pursuing PhD. The Centre for Advanced Training and Continuing Education (CATCE), and Entrepreneurship Development Cell (EDC) have been set up on campus. RIT has a strong Placement and Training department with a committed team, a fully equipped Sports department, large air-conditioned library with over 80,000 books with subscription to more than 300 International and National Journals. The Digital Library subscribes to several online e-journals like IEEE, JET etc. RIT is a member of DELNET, and AICTE INDEST Consortium. RIT has a modern auditorium, several hi-tech conference halls, all air-conditioned with video conferencing facilities. It has excellent hostel facilities for boys and girls. RIT Alumni have distinguished themselves by occupying high positions in India and abroad and are in touch with the institute through an active Alumni Association. RIT obtained Academic Autonomy for all its UG and PG programs in the year 2007. As per the National Institutional Ranking Framework, MHRD, Government of India, Ramaiah Institute of Technology has achieved 60th rank in 2018 among the top 100 engineering colleges across India.

About the Department:

Instituted in 1978, the Department was the first to offer a course in Chemical Engineering by a self-financing engineering institution in Bangalore and the fifth in RIT. Since its inception the department has moved steadily towards the fulfilment of its mission and is emerging as a significant player in the academic landscape of Chemical Engineering education in our country. The Department is certified four times in succession by the National Board for Accreditation. Over 2000 students have graduated in 33 batches. The Department offers excellent infrastructure and students have won various prestigious awards, international internships and high accolades for innovative projects. The Department has secured majority of the university ranks. The expertise of the faculty covers a wide range of disciplines and they are engaged in cutting edge technological research. The average experience of faculty in the department is more than twenty years and they are alumni of IISc, IIT and NITs. Enriching insights by eminent dignitaries from the practicing world are arranged under the activities of Society of Chemical Engineers & IIChE Student Chapter at the Institute. The Department is approved as Research Center by VTU for higher qualifications like M.Sc. Engg. (By Research) and Ph.D. degrees. Research Projects from DRDO, AICTE and DST have been successfully completed. The Annual Technical Symposium organized by the department for students – RASAYAN encompasses a plethora of events such as Paper presentations, Poster presentations, M.S. Ramaiah Memorial Technical Quiz etc to challenge the young minds. The Bangalore Regional Centre of the Indian Institute of Chemical Engineers is functioning from this department for more than a decade. The country's most prestigious event in Chemical Engineering - Indian Chemical Engineering Congress - CHEMCON-2011 was organized here. The event invited the top chemical engineers of the nation to our Institute. A joint session with Canadian Universities in the area of Energy and Environment was also a part of this event

VISION OF THE INSTITUTE

To evolve into an autonomous institution of international standing for imparting quality technical education

MISSION OF THE INSTITUTE

MSRIT shall deliver global quality technical education by nurturing a conducive learning environment for a better tomorrow through continuous improvement and customization

QUALITY POLICY

We at MS Ramaiah Institute of Technology strive to deliver comprehensive, continually enhanced, global quality technical and management education through an established Quality Management System complemented by the synergistic interaction of the stake holders concerned

VISION OF THE DEPARTMENT

To be a leading chemical engineering department for imparting quality technical education and progressive research at global level.

MISSION OF THE DEPARTMENT

1. To provide a state of art environment and a rigorous academic program that train students to excel in fundamental sciences, chemical and allied engineering fields.
2. To offer a programme that inculcates creative thinking and lifelong learning contributing to the advancements in chemical sciences and its application.
3. To foster principles of sustainability and promote environmentally benign technologies for the benefit of society.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs):

The B.E. Chemical Engineering Program at Ramaiah Institute of Technology aims to provide a strong foundation of scientific and technical knowledge in a state of art learning ambience. It equips the graduates with problem solving abilities, teamwork, and communication skills necessary throughout their careers. They are consistent with the following Educational Objectives:

1. To produce graduates with a strong foundation and understanding of the fundamental principles of mathematics, science and engineering enabling graduates to pursue their careers as practicing chemical engineers in Chemical and Allied Engineering fields.
2. To produce graduates who are prepared to pursue their post-graduation and Research in the emerging and allied areas of Chemical Engineering and Business.
3. To produce graduates who possess skills with professional integrity and ethics to assume professional leadership roles and administrative positions.
4. To provide students with opportunities to integrate with multidisciplinary teams to develop and practice written and oral communication skills.

PROGRAM OUTCOMES (POs):

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs):

The Chemical Engineering graduate will be able to

PSO1: Acquire in-depth knowledge of chemical engineering, process economics, management, safety and environmental aspects required to pursue their career in chemical industry and allied engineering areas.

PSO2: Apply computational and simulation tools to solve, design and optimize chemical engineering problems/ processes.

PSO3: Design processes, perform experiments, prepare technical and management modules, economic evaluation and demonstrate professional engineering competence.

Curriculum Course Credits Distribution
Batch 2016-17

Semester	Humanities & Social Sciences (HSS)	Basic Sciences / Lab (BS)	Engineering Sciences/ Lab (ES)	Professional Courses- Core (Hard core, soft core, Lab) (PC-C)	Professional Courses - Electives (PC-E)	Other Electives (OE)	Project Work (PW)	Internship/ other activities (IS/ECA)	Total semester load
First	2	9	14						25
Second	4	9	12						25
Third		9		16					25
Fourth		4		21					25
Fifth	2			19	4				25
Sixth				15	4		6		25
Seventh				14	8	4			26
Eighth					4		14	6	24
Total	8	31	26	85	20	4	20	6	200

SCHEME OF TEACHING
V SEMESTER

Sl. No.	Course Code	Course Name	Category	Credits					Contact Hours
				L	T	P	S	Total	
1.	CH51	Chemical Reaction Engineering-II	PC-C	3	1	0	0	4	5
2.	CH52	Industrial Pollution Control and Safety	PC-C	3	0	0	1	4	4
3.	CH53	Economics and Entrepreneurship	PC-C	3	0	0	1	4	4
4.	CH54	Introduction to Transport Phenomenon	PC-C	3	0	0	0	3	3
5.	CH55	Intellectual Property Rights	HSS	2	0	0	0	2	2
6.	CHE5X	*Elective- Group A	PE	4	0	0	0	4	4
7.	CHL56	Chemical Reaction Engineering Lab	PC-C	0	0	1	0	1	2
8.	CHL57	Computational Methods Laboratory	PC-C	0	1	1	0	2	4
9.	CHL58	Pollution Control Laboratory	PC-C	0	0	1	0	1	2
			Total	**18**	**2**	**3**	**2**	**25**	**30**

CHE51	Petroleum Technology
CHE52	Green Technology
CHP53	Cheminformatics
CHE54	Hazard Analysis and Risk Management
CHE55	Process Instrumentation and Data Analysis

SCHEME OF TEACHING
VI SEMESTER

Sl. No.	Course Code	Course Name	Category	Credits					Contact Hours
				L	T	P	S	Total	
1.	CH61	Chemical Process Industries	PC-C	3	0	0	0	3	3
2.	CH62	Biochemical Engineering	PC-C	2	0	0	1	3	3
3.	CH63	Mass Transfer-II	PC-C	2	1	0	1	4	5
4.	CH64	Design Project/ Interdisciplinary Project Work	PW	0	0	6	0	6	12
5.	CHE6x	*Elective- Group B	PE	4	0	0	0	4	4
6.	CH65	Process Equipment Design and Drawing	PC-C	1	1	1	0	3	5
7.	CHL66	Mass Transfer Laboratory	PC -C	0	0	1	0	1	2
8.	CHL67	Simulation Laboratory	PC-C	0	0	1	0	1	2
			Total	**12**	**2**	**9**	**2**	**25**	**36**

CHE61	Natural Gas Engineering and Transportation
CHE62	Non-Conventional Energy Sources and Technology
CHE63	Composite Materials
CHE64	Advance Thermodynamics
CHE65	Operations Research

V Semester

CHEMICAL REACTION ENGINEERING-II	
Course Code: CH 51	Credits: 3:1:0:0
Prerequisites: Chemical Reaction Engineering-I	Contact Hours:70
Course Coordinator/s: Chemical Engineering Department	

Unit I

Fluid-particle reactions: kinetics- selection of a model, shrinking core model for spherical particles of unchanging size, rate of reaction for shrinking spherical particles, extensions, determination of rate controlling .Fluid –particle reactor design for non-catalytic heterogeneous reactions

Unit II

Fluid-fluid reactions: kinetics- the rate equation. Introduction to catalysis. Steps in a catalytic reactions, Adsorption on solid surfaces, Physical properties of catalysts, Classification and Preparation of catalyst, Estimation methods for catalytic properties. Promoters, inhibitors and accelerators.

Unit III

Mechanism of catalysis, Rate controlling steps and their derivation for finding rates. Deactivating catalysts- mechanisms of catalyst deactivation, the rate and performance equations.

Unit IV

Solid catalyzed reactions: Spectrum of kinetic regimes. Rate equation for surface kinetics. Pore diffusion resistance combined with surface kinetics. Porous catalyst particles. Heat effects during reaction. Performance equations for reactors containing porous catalyst particles. Experimental methods for finding rates.

Unit V

Packed bed catalytic reactor and reactors with suspended solid catalyst. Fluidized reactors of various type. Qualitative design of fluidized bed reactor. Kinetics of trickle bed and slurry reactors.

Text Books:

1. Levenspiel, O., Chemical Reaction Engineering, 3rd Edition, John Wiley &Sons.
2. Smith, J.M., Chemical Engineering Kinetics, 3rd Edition, McGraw Hill.

Reference Books:

1. Fogler, H.S., Elements of Chemical Reaction Engineering, 3rd Edition, Prentice Hall.
2. Carberry, J.J., Chemical & Catalytic Reaction Engineering, McGraw Hill.

Course Outcomes: On successful completion of this course students will be able to

1. Explain the kinetics of heterogeneous reaction system and design a reactor for non-catalytic reaction.(PO-1,2,3,4,PSO-1,2)
2. Prepare the catalysts of required properties and can evaluate its performance.(PO-1,2,3,4,PSO-1,2)
3. Develop the mechanism and determine the deactivation rate of catalytic reactions.(PO-1,2,3,4,PSO-1,2)
4. Determine the effectiveness of catalyst and calculate rate experimentally.(PO-1,2,3,4,PSO-1,2)
5. Explain and design various types of reactors. (PO-1,2,3,4,PSO-1,2)

INDUSTRIAL POLLUTION CONTROL AND SAFETY
Course Code: CH 52 Credits: 3:0:0:1 Prerequisites: Engineering Chemistry, Environmental Studies Contact Hours: 56 Course Coordinator/s:Chemical Engineering Department

Unit I

Introduction: Importance of environment for mankind. Biosphere and layers of atmosphere. Hydrological cycle and nutrient cycles. Types of pollution. Damages from environmental pollution. Need of environmental legislations and environmental Acts in India. Functions of central and state pollution control boards. Global warming, Kyoto protocol, Role of environmental groups like Green Peace.

Sources, sampling and analysis of wastewater: Water resources. Origin of wastewater. Evaluation, classification and characterization of wastewater. Physical and chemical characteristics.BOD, COD and their importance. Types of water pollutants and their effects. Sampling, and methods of analysis.

Unit II

Wastewater treatment: Preliminary, primary, secondary and tertiary treatments of wastewater. Sludge treatment and disposal. Modern treatment methods. Recovery of materials from process effluents.

Applications to Industries: Norms and standards of treated water. Origin, characters, and treatment methods of typical industries – petroleum refinery, pulp and paper, fertilizer, distillery, and textile processing.

Unit III

Air pollution aspects: Nature of air pollution. Classification of air pollutants. Sources of air pollutants. Air quality criteria and standards. Plume behavior and dispersion of air pollutants. Effects of air pollution on health, vegetation, and materials.

Air pollution treatment: Sampling of pollutants. Methods of estimation of air pollutants. Automobile pollution. Control methods for particulates and gaseous pollutants. Pollution from chemical industries. Origin, control methods, and equipment used in typical industries – Thermal power plants, metallurgical industries, and cement industries. Carbon credits.

Unit IV

Solid waste treatment: Origin. Classification and microbiology. Properties and their variation. Engineered systems for solid waste management – generation, onsite handling, storage, collection, transfer and transport, composting, sanitary land filling.

Unit V

Noise control: Sources and definitions. Determination of noise levels. Noise control criteria and noise exposure index. Administrative and engineering controls. Acoustic absorptive materials.

Safety: Introduction to Process Safety- Intrinsic & Extrinsic Safety. The Hazards- Toxicity, Flammability, Fire, Explosions. Sources of ignition, Pressure.

Safety devices: Pressure relief valves. Ruptures discs. Blow down systems. Flare systems. Flame arrestors. Deflagration arrestors and explosion suppression. Personal safety devices.

Process safety analysis: HAZAN and HAZOP comparison. Sequence of operability study. Risk analysis and estimation. Safety check list. Computer based quantitative risk analysis. ISO and OSHAS.

Self-study:
Biosphere and layers of atmosphere. Hydrological cycle and nutrient cycles.
Origin, characters, and treatment methods of typical industries – petroleum refinery, pulp and paper, fertilizer, distillery, and textile processing.
Origin, control methods, and equipment used in typical industries – Thermal power plants, metallurgical industries, and cement industries.
Noise control criteria and noise exposure index
Personal safety devices.

Text Books:

1. Rao, C.S., Environmental Pollution Control Engineering, New Age International, Reprint 2002.
2. Mahajan, S.P., Pollution Control in Process Industries, Tata McGraw Hill, 1999.

Reference Books:

1. Perkins, H.C., Air Pollution, McGraw Hill, 1974.
2. Hagerty. D.J., Solid Waste Management, Van Nostrand Reinhold, 1973.
3. Metcalf and Eddy, Waste Water Engineering, Treatment, Disposal & Reuse, Tata McGraw Hill, 4th Edition, 2003.

Course Outcomes: On successful completion of the coursestudents will be able to
1. Explain the types of pollutions and their sources and analyze effects of pollutants in water. (PO-1, 2, 3, 4, 6, 7, PSO-1)
2. Design waste water treatment plants depending on the type of industrial waste waters. (PO-1, 2, 3, 4, 6, 7, PSO-1)

3. Identify the sources of air pollution by carrying out air sample analysis and suggest schemes for its prevention. (PO-1, 2, 3, 4, 6, 7, PSO-1)
4. Suggest schemes for processing municipal and industrial solid-wastes.(PO-1, 2, 3, 4, 6, 7, PSO-1)
5. Determine noise levels and suggest suitable technique for abatement of noise levels. Explain industrial process safety needs based on the history and operation methods of a process industry. (PO-1, 2, 3, 4, 6, 7, PSO-1)

ECONOMICS AND ENTREPRENEURSHIP	
Course Code: CH 53	Credits: 3:0:0:1
Prerequisites: Nil	Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department	

Unit I

Cost Analysis: Factors involved in project cost estimation, methods employed for the estimation of the capital investment. Estimation of working capital. Time value of money and equivalence.

Unit II

Depreciation And Taxes: Depreciation calculation methods. Equivalence after Taxes. Cost comparison after taxes.

Unit III

Profitability: Methods for the evaluation of profitability. Break-even analysis.

Unit IV

Entrepreneur: Meaning of Entrepreneur; Evolution of the Concept, Functions of an Entrepreneur, types of Entrepreneur, Entrepreneurship qualities, entrepreneurship development.

Small Scale Industry: Definition; Characteristics; Need and rationale: Scope; role of SSI in Economic Development. Advantages of SSI. Steps to Start and SSI – Government policy towards SSI; Different Policies of S.S.I., Impact of Liberalization, Privatization, Globalization on S.S.I., IPR for entrepreneurs.

Unit V

Institutional Support: Different Schemes; TECKSOK; KIADB; KSSICE; KSIMC; DIC Single Window Agency: SISI; NSIC; SIDBI; KSFC.

Preparation of Project: Meaning of Project; Project Identification; Project Selection; Project Report; Need and Significance of Report; Contents; formulation; Guidelines by Planning Commission, Identification & evaluation of Business Opportunities: Market Feasibility Study; Technical Feasibility Study; Financial Feasibility Study & Social Feasibility Study.

Self-Study Topics:

Estimation of capital investment for a specific plant.
Depreciation calculation for a specific equipment by various methods.
Selection of a process/equipment based on profitability analysis.

Writing the detailed process for starting an enterprise
Preparation of project report for applying financial support for starting an enterprise.

Text Books:

1. Peters and Timmerhaus, Plant Design and Economics for Chemical Engineers, McGraw Hill, 5th edition, 2003.
2. Charantimath, P.M., Entrepreneurship Development – Small Business Enterprises, Pearson Education, 2006.

Reference Books:

1. Desai, V., Dynamics of Entrepreneurial Development & Management, Himalaya Publishing House.
2. Schweyer, H. E., Process Engineering Economics, McGraw Hill, NY.
3. Gupta, C.B., Kanka, S.S., Entrepreneurship & Small Business Management, S Chand & Sons, 2007.
4. Donald E Garrett, Chemical engineering economics, 1989.

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

1. Estimate various costs involved in a process industry. (PO-1, 6, 7, 9, 10, 12, PSO-3)
2. Calculate and analyze the costs of depreciation and taxes. (PO-1, 6, 7, 9, 10, 12, PSO-3)
3. Apply different tools to estimate profitability of a company.(PO-1, 6, 7, 9, 10, 12, PSO-3)
4. Demonstrate the ability to find an attractive market that can be reached economically. (PO- 6, 7, 8, 9, 10, 12, PSO-3)
5. Prepare project reports to obtain funding from different agencies. (PO- 6, 7, 8, 9, 10, 12, PSO-3)

INTRODUCTION TO TRANSPORT PHENOMENON	
Course Code: CH 54	Credits: 3:0:0:0
Prerequisites: Momentum Transfer, Process Heat Transfer	Contact Hours: 42
Course Coordinator/s: Chemical Engineering Department	

Unit I

Introduction: Fundamental laws of Transport phenomena – Newton's law of viscosity, Fourier's law of heat conduction and Fick's law of diffusion. Molecular theory of viscosity, thermal conductivity and diffusivity of gases at low density. Molecular mechanisms for transport of momentum in liquids, and heat and mass in liquids and solids. Analogy between the laws. Types of fluids; Types of flow. Numerical problems on the application and use of NLV, FLHC and FLD.

Unit II

Dimensional Analysis: Dimensional homogeneity, Rayleigh and Buckingham-π method. Significance of different dimensionless numbers. Elementary treatment of similitude between model and prototype.

Analogies: Analogies between Momentum, Heat and Mass Transport: Application of Reynold's, Prandtl's and Chilton & Colburn analogies.

Unit III

Shell Balances for Momentum transfer: Steady state Shell momentum balances, Pressure driven fully developed laminar flow in a pipe and annulus, Gravity driven flow in a thin film on an inclined plane, Flow between parallel plates. Analytically solvable problems.

Non Newtonian flow in a tube and over flat plate (Power law and Bingham fluids).

Unit IV

Shell balances for energy transfer: Steady State Shell Energy Balances, Temperature profile in a single and composite slab. Steady state one dimensional heat conduction with temperature dependent thermal conductivity. Heat conduction with internal generation by electrical, nuclear, viscous energy sources. Heat conduction in a cooling fin of variable cross-section and geometry. Analytically solvable problems.

Unit V

Equations of Change: Equation of continuity. Equation of motion; Navier – Stokes equation. Application of these equations in solving simple steady state momentum transfer problems previously discussed.

Text Book:

1. Bird, Stewart and Lightfoot, Transport Phenomena, I &II Edition, John Wiley, 1994& 2002.

Reference Books:

1. Welty, Wicks and Wilson**,** Fundamentals of Momentum, Heat and Mass Transport, 3rd Edition, John Wiley, 1983.

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

1. Explain different fundamental laws of transport and understand the behavior of transport properties with changes in operating conditions.(PO-1, 2, 3, PSO-1)
2. Apply different analogies to common chemical engineering problems. (PO-1, 2, 3, PSO-1)
3. Derive mathematical equations by shell balance technique for different practical flow situations.(PO-1, 2, 3, PSO-1, 2)
4. Derive mathematical equations by shell balance technique for different practical heat transfer problems.(PO-1, 2, 3, PSO-1, 2)
5. Apply transport equations to any kind of physical problem and develop mathematical equations representing the process.(PO-1, 2, 3, PSO-1, 2)

INTELLECTUAL PROPERTY RIGHTS

Course Code: CH 55	Credits: 2:0:0:0
Prerequisites: Nil	Contact Hours: 28
Course Coordinator/s: Chemical Engineering Department	

Unit I

Introduction to IPR: Globalization, Knowledge era, History of IPR.

Different forms of IPR – Copy Rights, Trade Marks, Industrial designs, Patents and Trade secrets; Role of IPR in Research and Development.

Design: Designs that can be registered, Procedures of registration.

Unit II

Patents: patent as an intellectual property, Brief history of patents-Indian and global scenario, Principles underlying Patent law.

Ideas: Generation and review of ideas, process and Product Patents.

Unit III

Procedure for Obtaining Patent: Patent Contents – Patent Drafting: Filing requirements.

Case Studies on Patents: Related to chemical and allied industries

Unit IV

Trademarks: Nature, Essentials, Protection, Trademarks **(**contd.) Service marks and Laws.

Case Studies on Trademarks: Related to chemical and allied industries.

Unit V

Copy Right: Characteristics and Requirements; Neighbouring rights, Ownership; Infringement of Copy right.

Case Studies on Copy Rights: Related to chemical and allied industries.

Text Book:

1. Wadehra, B.L., Law relating to Patents, Trademarks, Copyright, Designs and Geographical Indications, 2^{nd} Edition, Universal Law publishing Co. Pvt. Ltd., 2002.

Reference Books:

1. PrabudhaGanguli, Intellectual Property Rights, Tata McGraw Hill Publishing Co. Ltd., 2001.
2. Manish Arora, Guide to Patents Law, 4^{th} Edition, Universal Law publishing Co. Pvt. Ltd., 2007.

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

1. Understand the role of IPR and its importance. (PO-8, 10, 12 PSO-3)
2. Understand Indian and global scenario of patents. (PO-8, 10, 12 PSO-3)
3. Search for patents and apply for the same. (PO-8, 10, 12 PSO-3)
4. Understand the nature and protection of trade marks. (PO-8, 10, 12 PSO-3)
5. Understand the requirements and infringement of Copyright.
   (PO-8, 10, 12 PSO-3)

PETROLEUM TECHNOLOGY
Course Code: CHE51 Credits: 4:0:0:0 Prerequisites: Nil Contact Hours: 56 Course Coordinator/s: Chemical Engineering Department

Unit I

Indian Petroleum industry: Prospects & Future. Major companies. World production, Markets, Offshore and onshore, Oil well technology.

Composition of crude: Classification. Evaluation of petroleum. UOP-k factor, TBP analysis, EFV analysis. Average boiling point. ASTM curves. Thermal properties of petroleum fractions.
Product properties and test methods: Gas. Various types of gas and LPG. Reid vapor pressure analysis. Gasoline and naptha. Octane No. Oxidation stability.
Additives for gasoline. Kerosene. Characterization for flash point or fire point, volatility, burning qualities etc, Diesel, octane testing, viscosity etc. Grades of diesels e.g. HSD, LDO. Diesel additives. Lube oils: Types, tests-carbon residue and viscosity index

Unit II

Crude pre-treatment: Pumping of crude oils. Dehydration of crude by chemical, gravity, centrifugal, electrical de-salter and comparison of each. Heating of crude-heater, different types of pipe still heaters including box type, cylindrical etc. Crude distillation, arrangement of towers for various types of reflux. Design aspects for atmospheric and vacuum column. Atmospheric distillation distillation unit: internals and operational.

Unit III

Treatment techniques: Types of impurities present and various desulphurisation processes. Production and treatment of LPG.LNG technology. Sweetening operations for gases including merox, ethanolamine, copper chloride, stertford etc. Catalytic de sulphonisation. Treatment of kerosene, De-aromatisation and merox. Treatment of diesel, naptha: desulpurisation by hydrogen and catalysts. Treatment of lubes: sulphuric acid, clay treatment, solvent treatment-phenol, furfural.

Unit IV

Thermal Processes: Thermal cracking reactions- theory of thermal cracking. Properties of cracked materials and factors influencing the properties of cracked materials. Visbreaking, dubbs two coil cracking process.

Catalytic cracking: Comparison of thermal and catalytic cracking. Carbonium ion chemistry. Feedback requirements. Cracking conditions. Commercial cracking analysis. Various catalytic cracking processes. Fixed bed crackers. Moving bed crackers. Fluid catalytic cracking-flexi cracking-ortho-flow reactor. Theory of coking: various types of coking processes. Delayed coking, fluid coking, contact coking, flexi coking. Naptha cracking, naptha cracking for ethylene as feed selection and gas yield. Hydro cracking. Theory of hydro cracking. Catalysts for hydro cracking.

Unit V

Catalytic reforming: Theory of reforming. Factors influencing, reforming, reforming catalysts, feedstock requirements. Platforming, isoplushondriforming, refining forming, power forming and flexiforming.

Text Books:

1. Nelson, Petroleum Refinery Engineering, 4th Edition, McGraw Hill, 1964.
2. BhaskaraRao, Modern Petroleum Refining Processes, 3rd Edition, Oxford and IBH, 1997.

Reference Books:

1. Desikan and Sivakumar,Unit Processes in Organic Chemical Industries (Eds.), CEDC, IITM, 1982.

Course Outcomes: On successful completion of the coursestudents will be able to

1. Classify the crude and understand the composition. (PO-1, 2, 3, PSO-1, 2)
2. Explain crude pretreatment methods and operations involved in it.
   (PO-1,3, PSO- 2)
3. Explain various impurities present in the crude and methods for their treatment to produce useful products like LPG, LNG, Gasoline, lube etc.
   (PO-2, 3, 4 PSO-1, 2)
4. Explain various petroleum cracking processes. (PO-2, PSO- 2)
5. Explain crude processing methods. (PO-1, 3, PSO- 1)

GREEN TECHNOLOGY

Course Code: CHE52 — Credits: 4:0:0:0
Prerequisites: Engineering Chemistry — Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department

Unit I

Introduction: Green chemistry and technology for sustainable development, Environmental laws, carbon credits, environmental management system standards-ISO 14000 series.

Unit II

Green Chemistry: Principles of Green Chemistry, Atom efficiency, Energy conservation, Waste minimization, Substitution.

Unit III

Life-Cycle Assessment: History, Process, Methodology, Streamlining and Application.

Unit IV

Pollution prevention planning: Structure of the pollution prevention process, Environmental Audits.

Unit V

Design for the environment and improvement in manufacturing operations, case studies.

Text Books:

1. Anastas P.T., Warner J.C., Green Chemistry: Theory and Practice. Oxford Science Publications, Oxford, 1998.
2. Paul L. Bishop, Pollution Prevention: Fundamentals and Practice, McGraw Hill, 2000.

Reference Books:

1. Mike Lancaster, Green Chemistry- An Introductory Text, Royal Society of Chemistry Publishing, 2010
2. Boyle, Godfrey, Bob Everett, Janet Ramage, Energy Systems and Sustainability: Power for a Sustainable Future, Oxford University Press, 2004.

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

1. Understand environment laws, carbon credits, ISO 14000 series. (PO-3, 4, 9, PSO-1)
2. Apply principles of green chemistry. (PO-3, 4, 9, PSO-1)
3. Understand the importance of green technology in sustainable development.(PO-3, 4, 9, PSO-1)
4. Utilize tools of green technology and life cycle assessment.(PO-3, 4, 9, PSO-1)
5. Conduct pollution prevention planning and environment friendly design. (PO-3, 4, 9, PSO-1)

CHEMINFORMATICS	
Course Code: CHE53	Credits: 4:0:0:0
Prerequisites: Nil	Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department	

Unit I

Introduction: Cheminformatics, History and Evolution of cheminformatics, Use of cheminformatics, Prospects of cheminformatics, Molecular Modelling and Structure Elucidation.

Unit II

Representation of Molecules and Chemical Reactions, Nomenclature; Different types of Notations; SMILES Coding; Matrix Representations; Structure of Molfiles and Sdfiles; Libraries and toolkits; Different electronic effects; Reaction classification, Properties estimation using ASPEN v8 suite.

Unit III

Database Design & their Management, Database Concepts. Structured Query Language. Design of Chemical Databases, Data Abstraction; Data Models; Instances & Schemes; E-R Model - Entity and entity sets; Relations and relationship sets; E-R diagrams; Reducing E-R Diagrams to tables; Network Data Model: Basic concepts; Hierarchical Data Model: Basic Concepts; Metadatabases; Indexing and Hashing; Basic concepts; Text Databases; Introduction to Distributed Database Processing, Data Security. Intefacing programs with databases; Structure databases; Reaction Databases; Literature Databases; Medline; GenBank; PIR; CAS Registry; National Cancer Institute (NCI) Database.

Unit IV

Searching Chemical Structure, Full structure search; sub structure search; basic ideas; similarity search; Three dimensional search methods; Basics of Computation of Physical and Chemical Data and structure descriptors; Data visualization and Non-linear Mapping.

Unit V

Chemo-informatics Applications, Prediction of Properties of Compounds; Linear Free Energy Relations; Quantitative Structure-Property Relations; Descriptor Analysis; Model Building; Modelling Toxicity; Structure-Spectra correlations; Prediction of NMR, IR and Mass spectra; Computer Assisted Structure elucidations; Computer Assisted Synthesis Design, Introduction to drug design; Target Identification and Validation; Lead Finding and Optimization; Analysis of HTS data; Virtual Screening; Design of Combinatorial Libraries; Ligand-Based and

Structure Based Drug design; Application of Cheminformatics in Drug Design, Applications of chemoinformatics in chemical engineering.

Text Books:

1. Johann Gasteiger and Thomas Engel (2003), Chemoinformatics, Wiley VCH Verlag GmbH & Co, USA.
2. Andrew R Leach and Valerie J Gillet (2007), Introduction to Chemoinformatics, Springer

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

1. Explain the prospects of cheminformatics. (PO-1, 4, 5, 9, PSO-1)
2. Formulate the molecules and chemical reactions in precise language and notation. (PO- 1, 2, 4, 5, 9,PSO-1)
3. Implement algorithms and data structures.(PO- 1, 2, 3, 4, 5, 9,PSO-1)
4. Determine the chemical structure.(PO- 1, 4, 5, 9,PSO-1)
5. Apply tools of Cheminformatics for predicting properties of compounds and drug design. (PO- 1, 2, 3, 4, 5, 9,PSO-1)

HAZARD ANALYSIS AND RISK MANAGEMENT

Course Code: CHE54 Credits: 4:0:0:0
Prerequisites: Nil Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department

Unit I

Plant Hazards:Fire hazards. Chemical hazards, Toxic hazards, Explosion hazards, Electrical hazards, Mechanical hazards, Radiation hazards, Noise hazards.Control, precautions & prevention, Safety measures in plant.

Unit II

Fire hazards, Chemical hazards, Toxic hazards, Explosion hazards, Electrical hazards, Mechanical hazards, Radiation hazards, Noise hazards, Control, precautions & prevention, Safety measures in plant.

Unit III

Storage & Transportation of chemicals: Characteristics of chemical with special reference to safe storage & handling of chemicals, Layout of storage, various modes of transport and Safety precautions in transportation of different types of chemicals.

Unit IV

Risk Analysis Techniques: Hazard & Operability (HAZOP) studies, Hazard Analysis (HAZAN), Fault Tree Analysis, and Consequence Analysis.

Unit V

Onsite and Offsite emergency management plans. Human Error Analysis. Accident Error Analysis. Economics of Risk Management.

Text Book:

1. K. V. Raghavan and AA. Khan, Methodologies in Hazard Identification and Risk Assessment, Manual by CLRI, 1990.
2. V. C. Marshal, Major Chemical Hazards, Ellis Horwood Ltd., Chichester, 1987.
3. Sam Mannan, Lees, Loss Prevention in the Process Industries, Hazard Identification, Assessment and Control, 4th Edition, Butterworth Heineman, 2012.

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

1. Classify and identify hazards in chemical industries.
   (PO-1, 2, 3, 7, PSO, 1)
2. Explain various types of hazards in process industry.
   (PO-1, 2, 3, 7, PSO, 1)
3. Apply precautions in chemical storage and handling.
   (PO-1, 2, 3, 7, PSO, 1)
4. Perform fault tree and event tree risk analysis and quantify them.
   (PO-1, 2, 3, 7, PSO, 1)
5. Train plant personnel and prepare emergency management plans.
   (PO-1, 2, 3, 7, PSO, 1)

PROCESS INSTRUMENTATION AND DATA ANALYSIS	
Course Code: CHE55	Credits: 4:0:0:0
Prerequisites: Nil	Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department	

Unit I

Measurement quality. Characteristics of instruments. Measurement methods for temperature, thermal conductivity, and viscosity.

Unit II

Measurement methods for pressure, flow rate, and liquid level.

Unit III

Measurement methods for vapour pressure, density, and electrical conductivity.

Unit IV

Role of experiments in engineering and technology. Data collection and interpretation requirements Graphical and numerical data processing; Variable-screening techniques.

Unit V

Introduction to design of experiments, Factorial method.

Text Books:

1. Ray, M.S., Engineering Experimentation: Ideas, Techniques, Presentation, McGraw Hill Book Co. Inc., New York, 1988.
2. Eckmen, D. P., Process Instrumentation, CBS Publishers and Distributors, 2006.

Reference Books:

1. Gibbings, J.C., the Systematic Experiment, Cambridge University Press, Cambridge, U.K, 1986.
2. Austin E. Frisbane, Industrial Instrumentation Fundamentals, McGraw Hill Co. Inc, NY, 1983.
3. H.S. Mickely, T.K. Sherwood & C.E. Reed, Applied Mathematics in Chemical Engineering, 3rd Edition, Tata McGraw Hill, 1999.

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

1. Decide which instrument to be used for measuring a particular physical property. (PO- 1, 2, PSO-1)
2. Understand principle and working of temperature, thermal conductivity, pressure, flow rate, liquid level measuring instruments. (PO- 1, 2, 3, PSO-1)
3. Understanding principle of density and electrical conductivity measurement methods. (PO- 1, 2, 3, PSO-1)
4. Analyze the data obtained graphically and numerically and perform regression analysis. (PO- 1, 2, 3, 4, PSO-1)
5. Optimize the data using factorial method.(PO- 1, 2, 3, 4, PSO-1)

CHEMICAL REACTION ENGINEERING LABORATORY

Course Code:CHL56 **Credits:** 0:0:1:0
Prerequisites: Chemical Reaction Engineering Contact Hours: 28
Course Coordinator/s: Chemical Engineering Department

List of experiments suggested:

1. Batch Reactor
2. Isothermal plug flow reactor
3. Mixed flow reactor
4. Semi batch reactor
5. Heterogeneous catalytic Reactor
6. Segregated flow reactor
7. Adiabatic Reactor
8. Packed bed Reactor
9. RTD Studies in Tubular Reactor
10. Effect of temperature on Rate of reaction
11. Bio Chemical Reaction (Batch)
12. Enzyme catalyzed reactions in batch reactor
13. RTD Studies in mixed flow reactor
14. Sono-chemical reactor
15. Photochemical reactor

Course Outcome: The student will be able to

1. Understand the kinetics of the reaction. (PO- 1, 2, 4, 9, 11, PSO- 1, 3)
2. Evaluate the activation energy of the reactions. (PO- 1, 2, 4, 9, 11, PSO- 1, 3)
3. Evaluate the non-ideality in the reactors. (PO- 1, 2, 4, 9, 11, PSO- 1, 3)

COMPUTATIONAL METHODS LABORATORY

Course Code:CHL57 **Credits**: 0:1:1:0
Prerequisites: Engineering Mathematics IV, Fundamentals of Computing
Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department

List of programmes:

1. MATLAB – Matrices/ Polynomials/ Integral/ Differential/ Plots
2. Data handling and regression using MS-Excel
3. Non-linear algebraic equation
4. Problems on general material balance
5. Numerical Integration- Simpson's 1/3 Rule
6. Ordinary Differential Equation- R-K Method
7. Curve Fitting-Least Square
8. Calculation of Bubble Point and Dew Point for Ideal multi-component system
9. P-xy and T-x,y data generation from the given vapor pressure data
10. Flash Vaporization for multi-component system
11. Design of Batch Reactor/ PFR/ CSTR
12. Double pipe heat exchanger (Area, Length and Pressure drop)

Course Outcome: On successful completion of the course students will be able to
1. Analyze chemical engineering problems by using numerical methods. (PO- 1, 2, 3, 4, 5, PSO-2)
2. Write programs in C for solving problems using computational techniques and execute them in laboratory. (PO- 1, 2, 3, 4, 5, PSO-2)
3. Write programs in MATLAB for solving problems using computational techniques and execute them in laboratory. (PO- 1, 2, 3, 4, 5, PSO-2)

POLLUTION CONTROL LABORATORY

Course Code:CHL58 **Credits:** 0:0:1:0
Prerequisites: Nil Contact Hours: 28
Course Coordinator/s: Chemical Engineering Department

List of experiments:

1. Determination of pH, alkalinity of samples.
2. Determination of turbidity of sample using Nepheloturbidometer.
3. Determination of dissolved, suspended and volatile solids.
4. Optimum coagulant dosage using Jar test.
5. Settle able and suspended particulate matter in air using high volume sampler.
6. Determine of chloride, iodide, nitrate ions in water samples using Ion selective electrode.
7. Determination of BOD.
8. Determination of COD.
9. Dissolved oxygen determination using DO meter.
10. Estimation of Copper in mining leachate using photo-colorimeter
11. MPN count.
12. Determination concentration of Sodium, Potassium, Calcium using flame photometer.
13. Determination of concentration of COx, SOx, NOx in air sample.
14. Analysis using FTIR
15. Estimation of Chromium using UV Vis Spectrophotometer.

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

1. Characterize water in terms of the pollutants present in it and determine its quality. (PO- 2, 3, 4, 6, 7, 8, 12, PSO-1, 3)
2. Determine pollutants in air. (PO- 2, 3, 4, 6, 7, 8, 12, PSO-1, 3)
3. Use instruments to determine pollutant compositions. (PO- 2, 3, 4, 6, 7, 8, 12, PSO-1, 3)

VI Semester

CHEMICAL PROCESS INDUSTRIES	
Course Code:CH61	**Credits**: 3:0:0:0
Prerequisites: Nil	Contact Hours: 42
Course Coordinator/s: Chemical Engineering Department	

Unit I

Sulfur: Elemental Sulfur mining, Sulfur from ores, Oxides of Sulfur (SO_2, SO_3).
Industrial Gases: CO_2, H_2, O_2, N_2, Water gas and Shift gas.
Acids: Sulfuric, Nitric, Hydrochloric, phosphoric acid.

Unit II

Chlor-Alkali Industries: Sodium chloride, Soda ash, Caustic soda, Chlorine, Bleaching powder.
Fertilizers: Ammonia, Urea, Ammonium chloride, Ammonium nitrate, Ammonium phosphate, Ammonium sulfate, DAP, Biofertilizers.

Unit III

Phosphorous Industries: Manufacture of white and Red Phosphorus, Pentoxide, Phosphatic Fertilizers, Super Phosphate and Triple Super Phosphate.
Fermentation Industries: Production of alcohol, acetic acid and citric, penicillin.

Unit IV

Petroleum Industries: Constituents of crude petroleum refining and processing. Production of Ethylene, Propylene.

Unit V

Polymers and Rubber: Polymerization, PVC, LDPE, Polyproylene, cross linked polymers, natural rubber, synthetic rubber and rubber compounding.
Miscellaneous Industries: Paints, Pigments, Vanishes, Enamel, Lacquers - White Lead and Zinc oxide, Hydrogen peroxide (H_2O_2), Silicon carbide (SiC), Glass, Cement (Types, manufacture of portland cement, slag cement).

Text Books:

1. Shreve's, Chemical Process Industries, McGraw Hill, 4th Edition.
2. RaoGopal&Sittig Marshall, Dryden – Outlines of Chemical Technology for 21st Century, 3rd Edition, and EWP.

Reference Book:

1. Bose, P.K., Chemical Engineering Technology, Vol. 1,2, Books and Allied (Pvt) Ltd, 2011.
2. Desikan and Sivakumar ,Unit Processes in Organic Chemical Industries (Eds.), CEDC, IITM, 1982.

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

1. Develop flow chart which includes various unit processes and unit operations for sulfur based chemicals, industrial gases and acids. (PO- 1, 2, 3, 4, 7, 12, PSO- 1)
2. Write manufacturing process based on reactions, operations involved in the production of chlor-alkali chemicals and fertilizer industries. (PO- 1, 2, 3, 4, 7, 12, PSO- 1)
3. Explain and develop the material requirements, flow diagrams in the manufacturing of phosphorous based chemicals and fermentation industries.(PO- 1, 2, 3, 4, 7, 12, PSO- 1)
4. Design based on the knowledge of processing of crude petroleum and petro chemicals. (PO- 1, 2, 3, 4, 7, 12, PSO- 1)
5. Develop flow chart and explain the production of polymer based chemicals, rubber and miscellaneous industries. (PO- 1, 2, 3, 4, 7, 12, PSO- 1)

BIOCHEMICAL ENGINEERING	
Course Code: CH62	**Credits:**2:0:0:1
Prerequisites: Nil	Contact Hours: 42
Course Coordinator/s: Chemical Engineering Department	

Unit I

Introduction: Bioprocess engineering and technology. Role of a Chemical engineer in bioprocess industry. An introduction to basic biological sciences. Microbiology: Structure of cells: Prokaryotes and Eukaryotes. Classification of micro-organisms. Characteristics and control of microorganisms. Environmental and Industrial microbiology.

Biochemistry: Chemicals of Life: Lipids, Sugars, Polysaccharides, Amino acids and proteins, Vitamins, Biopolymers, Nucleic Acids: RNA, DNA and their derivatives (Structure, Biological function and Importance for life only to be studied).

Unit II

Enzymes and Proteins: Detailed structure of proteins and enzymes: Primary, Secondary, Tertiary and quaternary. Functions. Production and purification of Enzymes (Methods only).Nomenclature and Classification of enzymes. Mechanism and Kinetics using various models. Kinetics of Enzyme action: Michaelis–Menten rate equation. Derivation with Equilibrium and Pseudo- (quasi-) steady state approximations. Experimental determination of rate parameters: Batch and continuous flow experiments.

Unit III

Enzyme Inhibition: Effect of Inhibitors (Competitive, noncompetitive, uncompetitive, substrate and product inhibitions), Temperature and pH on the rates enzyme catalyzed reactions.

Unit IV

Fermentation Technology: Ideal reactors: A review of Batch and Continuous flow reactors for bio kinetic measurements. Microbiological reactors: Operation and maintenance of typical aseptic aerobic fermentation processes. Formulation of medium: Sources of nutrients. Alternate bioreactor configurations. Introduction to sterilization of bioprocess equipment. Design of batch & continuous sterilization equipment.

Unit V

Growth Kinetics of Microorganisms: Transient growth kinetics (Different phases of batch cultivation). Quantification of growth kinetics: Substrate limited growth, Models with growth inhibitors, Logistic equation, and Filamentous cell growth model. Continuous culture: Optimum Dilution rate, Critical Dilution rate in Ideal Chemostat. Introduction to Fed-batch reactors. Strategies and Steps involved in product purification.

Self-Study Topics:
Structure, biological function and importance of various biomolecules
Protein structures
Demonstration of enzyme inhibition using practical problem
Batch and continuous sterilization
Downstream processes.

Text Book:
1. Bailey and Ollis, Biochemical Engineering Fundamentals, 2ndEdition, McGraw Hill, 1976.
2. Shuler, M. L. and Kargi, F.**,** Bioprocess Engineering, 2nd Edition, Prentice Hall, 2002.

Reference Books:
1. Pelczer, Microbiology Concept and Application, 5th Edition, McGraw Hill, 2001 Reprint.
2. Stanbury and Whittaker, Principles of Fermentation Technology, II Edition.

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

1. Explain the basics of microbiology and role of Chemical Engineers in bioprocess industries. (PO-1, 2, 3, 9, 11, 12, PSO-1)
2. Perform kinetic studies of enzymatic reactions to have control over these processes and design such systems. (PO-1, 2, 3, 12, PSO-1)
3. Perform kinetic studies of enzymatic reactions in presence of inhibitors to design such systems to handle them. (PO-1, 2, 3, 12, PSO-1)
4. Explain in details about the fermentation technology, operation and maintenance of equipment in these industries. (PO-1, 2, 3, 12, PSO-1)
5. Explain the kinetics of microbial growth and control of bioreactors. (PO-1, 3, 6, 7, 9, 12, PSO-1)

MASS TRANSFER-II

Course Code:CH63 **Credits:** 2:1:0:1
Prerequisites : Mass Transfer-I, **Contact Hours:**70
Course Coordinator/s: Chemical Engineering Department

Unit I

Absorption: Absorption. Solvent selection for absorption. Material balance and concept of driving force and minimum solvent rates. Multistage absorption columns. Design of Plate columns. Absorption and desorption factors. Construction details. HETP and HTU concepts. Liquid phase hold up and pressure drop in absorption towers. Operating line and minimum solvent flow rates. Design of packed towers (height and diameter).Multi-component absorption. Absorption with chemical reaction.

Unit II

Distillation: Introduction. Vapour liquid equilibria (T-x,y, P-x,y. H-x,y and x-y diagrams for binary mixtures). Relative volatility. Prediction of VLE from vapour pressure data using Raoult's law. VLE for multi-component systems. Non-ideal systems. Azeotropes. Immiscible systems. Steam distillation. Flash and simple distillation.

Multistage distillation. Multi-stage rectification column. Design using McCabe Thiele method for binary mixtures. Ponchon-Savarit method. Efficiencies–overall, local, and Murphree plate efficiencies. Multicomponent distillation. Vacuum, molecular, extractive and azeotropic distillations.

Unit III

Liquid-liquid extraction: Ternary equilibrium. Solvent selection. Single stage. Multistage-cross-current, counter-current extraction. Equipment for liquid-liquid extraction.

Unit IV

Leaching operation: Equipment for leaching. Preparation of solids for leaching. Equilibrium diagrams. Calculation of single stage and multi-stage leaching operation.

Unit V

Membrane Separations: Membranes. Membrane modules. Concentration Polarisation and Fouling. Classification of Membrane Separation Processes. Microfiltration. Ultrafiltration. Nanofiltration. Reverse Osmosis. Dialysis.. Gas Permeation.

Self-Study Topics:

Vapour liquid equilibria (T-x,y, P-x,y. H-x,y and x-y diagrams for binary mixtures).Azeotropes,Vacuum, molecular, extractive and azeotropic distillations.

Equipment for liquid-liquid extraction., Equipment for leaching. Electrodialysis. Pervaporation.

Text Books:

1. Dutta, B.K., Mass Transfer Principles and Separation Processes, 1st Edition, PHI, 2006.
2. Narayanan, K.V., Laksmikutty, B., Mass Transfer - Theory and Practice, 1st Edition, CBS, 2014.

Reference Books:

1. Treybal, R.E., Mass Transfer Operations, 3rd Edition, McGraw Hill, 1981.
2. Wankat P.C., Rate Controlled Separations, Elsevier, 1990.
3. Foust, A., Principals of Unit Operation, 2nd Edition, John Wiley, 1994.
4. Geankoplis, C. J, Transport Processes and Unit Operation, Prentice Hall (I), 2000.

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

1. Understand absorption process and design such equipment's.

(PO- 1, 2, 3, 12, PSO-1)

1. Understand vapor-liquid equilibrium and single state and batch operation.
2. (PO- 1, 2, 3, PSO-1)
3. Design equipment for continuous rectification. (PO- 1, 2, 3, 12, PSO-1)
4. Explain liquid-liquid extraction and select/design for the same. (PO- 1, 2, 3, 12, PSO-1)
5. Explain leaching and design equipment's for it. (PO- 1, 2, 3, 12, PSO-1)

DESIGN PROJECT

Course Code:CH64 **Credits:** 0:0:6:0
Prerequisites: Chemical Process Calculations, Process Equipment Design and Drawing **Contact Hours:** 84
Course Coordinator/s: Chemical Engineering Department

A group of students will be assigned a case study, or an analytical problem to be carried out under the supervision of a guide. The group shall not contain more than four students. Guides will be allocated in the beginning of the sixth semester and the problem on design of a process is identified. The project group should complete design project and use software ASPEN PLUS or HYSYS for process simulation studies and submit the report at the end of the semester. The project will be evaluated by the guide and a project co-ordination committee to award the CIE marks.

Course Outcomes: The student should be able to

1. Carry out literature review on selected product and process.(PO- 2, PSO-1)
2. Write material balance, energy balance and thermodynamics for selected process. (PO- 1,2,3, PSO-1)
3. Design and select various equipment's for the process. (PO- 1,2,3,7 PSO-1, 2)
4. Carry out computational and economic analysis. (PO- 1, 2, 3, 11, 12, PSO-1, 2, 3)
5. Contribute as team member and prepare precise project report with appropriate reference. (PO-8, 9, 10, 11, 12, PSO-3)

NATURAL GAS ENGINEERING AND TRANSPORTATION	
Course Code: CHE61	**Credits:** 4:0:0:0
Prerequisites: Petroleum Technology, Chemical Engineering Thermodynamics	**Contact Hours:** 56
Course Coordinator/s: Chemical Engineering Department	

Unit I

Introduction: Overview of the gas industry and gas processing, Field operations and inlet receiving.
Gas Compression: Methods of gas compression, thermodynamic considerations.

Unit II

Fundamentals of vapor-liquid equilibria and distillation, Gas hydrates, Gas dehydration.

Unit III

Cryogenic extraction of natural gas liquids (NGL).Minor component (nitrogen, helium, mercury, and BTEX) recovery or removal. Acid Gas (hydrogen sulfide and carbon dioxide) removal.

Unit IV

Sweetening and dehydration of condensate and natural gas liquids (NGL).
Sulfur recovers with the Claus process, Tail gas cleanup.

Unit V

Acid gas injection. Liquefied natural gas (LNG), production, storage, transportation, and regasification.

Text Books:

1. Katz, D. L. and Lee, R.L., Natural Gas Engineering, McGraw Hill, 1990.

Reference Books:

1. Kidnay, A.J., Parnish, W.R., Dekker, Fundamentals of Natural Gas Processing, McGraw Hill.
2. Mokhatab, S., Handbook of Natural Gas Transmission and Processing.

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

1. Explain the basic principles of gas compression.(PO-1, 2, 3, 7, PSO-1)
2. Understand various methods of gas dehydration. (PO-1, 2, 3, 7, PSO-1)
3. Explain gas treatment processes and impurity removal methods. (PO-1, 2, 3, 7, PSO-1)
4. Design to the gas processing and transportation system. (PO-1, 2, 3, 7, PSO-1)
5. Understand LNG production and processing. (PO-1, 2, 3, 7, PSO-1)

NON-CONVENTIONAL ENERGY SOURCES AND TECHNOLOGY

Course Code: CHE62	**Credits: 4**:0:0:0
Prerequisites: Nil	Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department	

Unit I

Introduction to conventional & non-conventional energy sources: Conventional energy sources; non-conventional energy sources; advantages; limitations. Classification of fuels. Calorific value. Characteristics of good fuels. Comparison between solid, liquid and gaseous fuels.

Solar Energy: Solar radiation and its measurement – solar constant, solar radiation at earth's surface, solar radiation geometry, solar radiation measurement. Introduction to solar energy. Applications – solar water heating, space heating, space cooling, solar thermal electric conversion. Agriculture and industrial process heating, solar distillation, solar pumping, solar cooking.

Unit II

Energy from biomass (bio – energy): Introduction. Biomass conversion Technologies. Wet processes. Dry processes. Biogas generation. Factors affecting biodigestion or generation of gas. Classification of biogas plants. Advantages and disadvantages of floating drum plant. Advantages and disadvantages of fixed dome type plant. Types of biogas plants (KVIC model &Janata model).Selection of site for biogas plant.

Unit III

Bio – Energy (Thermal Conversion): Methods of obtaining energy from biomass. Thermal gasification of biomass. Classification of biomass gasifiers. Chemistry of gasification process. Applications of the gasifiers.

Unit IV

Wind Energy: Introduction. Basic components of WECS (wind energy conversion system). Classification of WECS. Types of wind machines- horizontal axis machines, vertical axis machines. Applications of wind energy.

Energy from the oceans: Introduction. Ocean thermal electric conversion (OTEC).Methods of ocean thermal electric power generation. Open cycle OTEC system. Closed or Anderson OTEC cycle, hybrid cycle. Application of energy from oceans.

Unit V

Fuel Cells Basics: Fuel Cells, Difference between batteries and fuel cells. Components of fuel cells. Principle of working of fuel cells. Performance characteristics and efficiency of fuel cells, Fuel cell stack, Fuel cell power plant.

Fuel cell types: Alkaline fuel cells. Polymer electrolyte fuel cells. Phosphoric acid fuel cells. Molten carbonate fuel cells. Solid oxide fuel cells. Types of solid acid fuel acid fuel cells. Applications. Problems with fuel cells.

Text Books:

1. Rai, G.D., Non-Conventional Energy Sources, Khanna Publications, 1st Edition, Second Reprint, 2010.
2. Sukhatme, S.P., Solar Energy, Third Edition, 1st Reprint, Tata McGraw Hill, New Delhi, 2008.

Reference Books:

1. Jain, P.C., Jain, M., Engineering Chemistry, DhanpatRai& Sons, 10th Edition, 3rd Reprint, 1995.
2. Rai, G.D., Solar Energy Utilization, 4th Edition, Khanna Publications.

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

1. Compare different types of fuels and elucidate the application of solar energy.(PO-1, 7, PSO-1)
2. Understand biomass conversion technologies and types of biogas plants. (PO-1, 3, 7, PSO-1)
3. Understand thermal gasification of biomass and chemistry of gasification. (PO-1, 7, PSO-1)
4. Explain technologies of Wind energy and ocean. (PO-1, 7, PSO-1)
5. Apply latest technology like fuel cell. (PO-1, 3, 7, PSO-1)

COMPOSITE MATERIALS

Course Code: CHE63 **Credits:**4:0:0:0
Prerequisites: Material Science **Contact Hours:** 56
Course Coordinator/s: Chemical Engineering Department

Unit I

Synthesis And Fabrication: Advanced and future materials with emphasis on Ceramic, Semi-conducting and Super-conducting materials with superior structural, optical and electrical properties.

Techniques for preparation of ultra-pure, ultra-fine powders: of oxides, nitrides, carbides etc., with very well defined characteristics and superior properties.

Unit II

Processing Techniques: such as sintering, hot pressing, hot isostaticpressing, tape-casting, sol-gel processing for the formation of monolithic ceramics. Composites (ceramic, ceramic metal, as well as metal matrix). SiO2. Glasses from above powders**.**

Unit III

Processing Techniques based on reaction methods: such as Chemical vapour deposition (CVD), vapour phase epitaxy, plasma-enhanced chemical vapour deposition (PECVD), chemical vapour infiltration (CVI). Self-propagating high temperature synthesis (SHS) for the preparation of monolithic ceramics, composites, coating, thin films, whiskers and fibres and semi conducting materials such as Si and Gallium Arsenide**.**

Unit IV

Synthesis and processing of mixed ceramic oxides with high temperature super conducting properties
Reinforcement, additives, fillers for polymer composite, master batch& compounding**.**

Unit V

Polymer composite. Fibre reinforced composites. Stress – Strain modulus relationship Nano composites.

Characteristics & applications in marine, aerospace, building & computer industry. Manufacturing methods, hand layouts, filament winding, pultrusion, SMC, DMC.

Text Books:

1. Kingrey,W.D., Introduction to Ceramics, 2^{nd} Edition, John Wiley & Sons, 1976.
2. Chawla, K.K., Advanced Composites, 2^{nd} Edition, John Wiley & Sons, 1993.

Reference Books:

1. James T. Schockel Ford, Introduction to Material Science for Engineering, McMillan Publications.
2. Van Vlack, L.H., Material Science and Engineering, Dorling Kindersley Pvt Ltd, 2006.
3. Nicholas, P., Paul N., Chermisinoff, A.,Fibre Reinforced Plastic Deskbook, Arbor science publishing Inc, 1978.

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

1. Understand the various types of composites and important properties sought for definite application. (PO- 1, 2, PSO-1)
2. Explain preparation techniques of carbides, nitrides etc. and characterization. (PO- 1, 2, PSO-1)
3. Explain mechanical / physical techniques of sintering monolithic, ceramics, metals etc. (PO- 1, 2, PSO-1)
4. Understand techniques of CVD, PECVD, CVI, SHS for composite preparation including nano materials. (PO- 1, 2, 5, PSO-1)
5. Fabricateand design of reinforced polymer composites. (PO- 1, 2, 3, 5, 12, PSO-1)

ADVANCED THERMODYNAMICS

Course Code:CHE64 **Credits:** 4:0:0:0
Prerequisites: Chemical Engineering Thermodynamics **Contact Hours:** 56
Course Coordinator/s: Chemical Engineering Department

Unit 1

Classical Thermodynamics: Fundamental concepts & terminologies related to thermodynamics. Laws of thermodynamics: Conventional & Postulatory approaches. Analysis of different thermodynamic processes: Adiabatic, Isothermal, Isobaric, Isochoric, Polytropic. Concepts of Internal Energy, Enthalpy, Entropy, Free Energies (Gibbs & Helmholtz). Exact differentials and Maxwell's Relations. Concept of molecular degrees of freedom, relations for Cp and Cv, Clausius Clapeyron Equation.

Unit II

Kelvin and Clausius statements for Second Law and their equivalence. Analysis of ideal heat cycle (Carnot cycle) and its applications to Heat Engines, Heat Pumps and Refrigerators. Different Equations of State: Ideal Gas Equation, Virial Equations, Van der Waals Equations, Peng Robinson & Soave Redlich Kwong Equations.

Unit III

Fugacity, Compressibility, fugacity coefficient. Real gas mixtures, Ideal solution of real gases and liquids, Equilibrium in multi phase systems, Gibbs phase rule for non-reactive components. Fundamental property relations for systems of variable composition, partial molar prosperities. Concept of chemical potential, chemical equilibrium and phase equilibrium.

Unit IV

Macroscopic and microscopic descriptions of the state of a system. Comparative study of classical & statistical thermodynamics: Newtonian mechanics, Hamiltonian approach, Lagrangian approach. Concept of statistical ensembles, partition functions and thermodynamic properties

Unit V

Thermodynamic probability and thermodynamic entropy. Microscopic interpretation of heat and work, evaluation of thermodynamic properties using partition functions. Introduction to molecular simulations.

Text Books:

1. Jefferson Tester & Michael Modell, Thermodynamics & Its Applications.
2. McQuarrie, Statistical Mechanics

3. Kenneth Wark Jr., Advanced Thermodynamics for Engineers, McGraw-Hill Inc., 2001.

References

1. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Sons, 1998.
2. Holman, J.P., Thermodynamics, Fourth Edition, McGraw-Hill Inc., 1998.
3. Smith, J.M and Van Ness., H.C., Introduction to chemical Engineering Thermodynamics, Fourth Edition, McGraw-Hill Inc., 1987.
4. Sears, F.W. and Salinger G.I., Thermodynamics, Kinetic Theory and Statistical Thermodynamics, third Edition, Narosa Publishing House, New Delhi, 1993.
5. Thipse, S.S., Advanced Thermodynamics, Narosa Publishing, 2013.
6. Rao, Y.V.C., Postulational and Statistical thermodynamics, Allied Publisher Limited, New Delhi, 1994.
7. Sonntag, R.E., and Vann Wylen, G., Introduction to Thermodynamics, Classical and Statistical, third Edition, John Wiley and Sons, 1991.

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

1. Understand second law, Maxwell relations and relation for entropy changes. (PO- 1, 2, PSO-1)
2. Comprehend the philosophical and mathematical interpretations of Second law and apply it to real life problems, and use the models for non ideal gases for practical problems in chemical engineering. (PO- 1, 2, PSO-1)
3. Explain concept of fugacity, fugacity coefficient, and partial molar properties. (PO- 1, 2, PSO-1)
4. Explain and use the concepts of ensembles and statistical mechanics to develop the thermodynamic equations for a system of particles. (PO- 1, 2, PSO-1)
5. Analyze thermodynamic probability, degeneracy of energy levels and partition functions. (PO- 1, 2, PSO-1)

OPERATIONS RESEARCH

Course Code: CHE65 **Credits:** 4:0:0:0
Prerequisites: Engineering Mathematics I and II Contact Hours: 56
Course Coordinator/s: Chemical Engineering Department

Unit I

Introduction: Definition. Scope of Operations Research (OR).Approach and limitations of O.R. Models. Characteristics and phases of O.R.

Linear Programming Problems: Mathematical formulation of L.P. Problems. Graphical solution method.

The Simplex Method: 1 & 2 – slack, surplus and artificial variables. Dual simplex method. Degeneracy and procedure for resolving degenerate cases.

Unit II

Assignment problems: Balanced and Unbalanced assignment problems. Maximization assignment problems. Travelling salesman problems.

Transportation Problem: Basic feasible solutions by different methods. Finding optimal solution. MODI method. Degeneracy. Unbalanced transportation problems. Maximization Problems.

Unit III

Sequencing: Johnson's algorithm. n jobs - 2 machines, n jobs -3 machines, and n jobs-n machines without passing sequence. 2 jobs-n machines. Graphical solutions.

Deterministic Models: Inventory, EOQ Models. With and without shortages. Ordering cost. Carrying cost.

Unit IV

PERT-CPM Techniques: Network construction. Determining critical path. Variance and probability of completing the project. Calculation of different floats. Project duration. Crashing of simple networks.

Unit V

Replacement model: Replacement of items which fails completely-individual replacement, group replacement. Replacement of items where maintenance cost increases with time and the value of money changes with time.

Text Books:

1. Srinath, L. S., Introduction to Pert and CPM, 3rd Edition, East West, 1998.
2. Kantiswaroop, Gupta,P. K. and Manmohan, Operation Research, 9th Edition, S Chand & Co., 1999.

Reference books:

1. Sharma, S. D., Operation Research, 8th Edition, Kedarnath& Co, 2003.

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

1. Develop the linear mathematical models for and solve them for their maximization and minimization using graphical and analytical methods. (PO-1, 2, 11, PSO-3)
2. Solve Balanced and Unbalanced Assignment problems and Transportation problems for Maximization and Minimization. (PO-2, 11, PSO-3)
3. Solve problems on Sequencing of jobs in n machines and Inventory for cost analysis. (PO-2, 11, PSO-3)
4. Develop Network construction and determining critical path, Variance and probability of completing the project by PERT-CPM method. (PO-2, 11, PSO-3)
5. Develop model for replacement of individual items, group replacement and maintenance cost analysis. (PO-2, 11, PSO-3)

PROCESS EQUIPMENT DESIGN AND DRAWING

Course Code: CH65 **Credits:** 1:1:1:0
Prerequisites: Chemical Process Calculations, **Contact Hours:** 70
Process Equipment Drawing, Process Heat Transfer, Mass Transfer-I and II
Course Coordinator/s: Chemical Engineering Department

Detailed chemical engineering process and mechanical design of the equipment: Pressure vessel - Jacketed vessel, Double pipe Heat exchanger, Shell & Tube Heat exchanger, Condensers – Horizontal and vertical, Evaporator – Single effect, Distillation Column, Packed Bed Absorption Column, Rotary Dryer.
Standard Code books to be used. The detailed dimensional drawings shall include sectional front view, Full Top/side view depending on equipment and major component drawing with dimensioning and Part Template.

Reference Books:

1. Joshi, M.V., Process Equipment Design, Macmillan India, 1991.
2. Brownell, L.E. and Young, E.H., Process Equipment Design - Vessel Design, John Wiley and Sons, Inc.1959.
3. Ludwig, E.E., Applied Process Design for Chemical and Petrochemical Plants, Vol. 1 and 2, 3rd Ed., Gulf Publishing Co. 1997.
4. Indian Standards Institution, Code for Unfired Pressure Vessels, IS – 2825.
5. Bhattacharya, B.C, Introduction to Chemical Equipment Design, CBS Publications, 1985.
6. Perry's Chemical Engineers Handbook.

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

1. Design Heat Transfer Equipment's as per standard procedure. (PO- 2, 3, PSO-1, 2)
2. Design Mass Transfer Equipment's. (PO- 2, 3, PSO-1, 2)
3. Design pressure vessels and other equipment's with reference to IS Standards. (PO- 2, 3, PSO-1, 2)

MASS TRANSFER LABORATORY

Course Code: CHL66 **Credits:** 0:0:1:0
Prerequisites: Mass Transfer **Contact Hours:** 28
Course Coordinator/s: Chemical Engineering Department

List of experiments suggested:

1. Diffusion of organic vapour in air
2. Simple Distillation
3. Packed column/ plate column distillation
4. Steam distillation
5. Solid – liquid leaching
6. Surface evaporation
7. Tray dryer
8. Adsorption studies
9. Liquid-Liquid/Vapour –Liquidequilibrium
10. Liquid extraction – (cross current: 1 and 2 or 3 stage)
11. Hold up studies in packed columns
12. Rotary/ vacuum dryers
13. Wetted wall column
14. Cooling tower
15. Solid dissolution

Course Outcome: The student will be able to

1. Understand the working principles of mass transfer equipment's. (PO-1, 2, 3, PSO-1, 3)
2. Evaluate the performance of mass transfer equipment's. (PO-1, 2, 3, PSO-1, 3)
3. Select and design mass transfer equipment's. (PO-1, 2, 3, PSO-1, 3)

SIMULATION LABORATORY	
Course Code: CHL67	**Credits:** 0:0:1:0
Prerequisites: Nil	Contact Hours: 28
Course Coordinator/s: Chemical Engineering Department	

List of simulations suggested:

1. Introduction to suggested software available (flow sheeting)
2. Simulations Studies of flash drum, Distillation Column, CSTR, PFR, Heat Exchanger.
3. Simulation Studies of pump, compressor, cyclone, heater.
4. Process simulation study involving mixing, reactor, distillation, heat exchanger for any of the following;
    a. Ethylene Glycol from Ethylene oxide
    b. Propylene Glycol from Propylene oxide
    c. Aromatic stripper with recycle stream (Benzene, Toluene, Xylene)
    d. Cyclohexane
    e. Ethanol Amine

Software Suggested: ASPEN ONE, HYSYS, CHEMCAD, DESIGN-II, UNISIM

Course Outcome: On successful completion of the course students will be able to

1. Apply process simulation software. (PO-2, 3, 5, 12, PSO-2)
2. Simulate a chemical engineering process. . (PO-2, 3, 5, 12, PSO-2)
3. Optimize the parameters in a process using simulation software.
   (PO-2, 3, 5, 12, PSO-2)