CHEMICAL ENGINEERING DEPARTMENT

Syllabus
Academic Session 2020-21 onwards
SEMESTER VI

PROCESS EQUIPMENT DESIGN

Lectures: 4 Periods/week — ***Sessional Marks: 30***

University Examination: 3 hours. — ***University Examination Marks: 70***

Pre-requisites: Heat transfer and Mass transfer

Objective: Introduce the basic design concepts for chemical process equipment industrial pressure vessel, storage vessel, heat exchangers, distillation column, absorption column, and reactors used in chemical industries.

Course Outcome:

CO1. Understand the basic design concept of chemical process equipment

CO2. Design the pressure vessel and its closures, distillation column and absorption column

CO3. Design the heat exchanger as per TEMA standards.

CO4. Apply various designs in process plant.

Detailed syllabus

UNIT I — **Lectures 08**
Heat-exchanger
Design of double pipe heat exchanger, Shell and tube type heat exchanger, over all heat transfer Co-efficient.

UNIT II
Evaporators — **Lectures 08**
Design of evaporators (Double and triple effect), Over all heat transfer Co-efficient, heating surface and mechanism of vacuum system etc.

UNIT III — **Lectures 05**
Piping system
Piping: Design of piping system for transfer of fluid covering pipes, valves, fittings, Instrumentation, insulation, Pumps etc.

UNIT IV — **Lectures 08**
Design of distillation column
Design of distillation column-number of plates, stages arrangement of double caps, Dimeter and height of the tower and thickness of the shell.

UNIT V — **Lectures 06**
Design of Absorption column
Design of absorption column, Number of transfer units, Dimeter, Height of the tower and the thickness of the shells

BOOKS RECOMMENDED

Bhattacharyya B.C., “Introduction to Chemical Equipment Design: Mechanical Aspects”, 5th Ed., CBS Publishers, New Delhi, 2008.

Kern D.Q., “Process Heat Transfer”, McGraw-Hill, New York, 1965.

Coulson & Richardson’s Chemical Engineering, Vol. 6, 4th Ed., Elesevier, New Delhi, 2006.

Soares C., “Process Engineering Equipment Handbook”, McGraw-Hill, New York, 2002.

Table 1. Relationship of COs to POs for Process Equipment Design (CL 506):

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	3	-	2	1	-	-	-	-	-	-	-
CO2.	2	2	3	2	2	-	-	-	-	-	-
CO3.	3	2	3	2	2	2	-	-	-	-	-
CO4.	3	2	3	2	-	-	-	-	-	-	-

INSTRUMENTATIION AND PROCESS CONTROL

Lectures: 4 Periods/week ***Sessional Marks: 30***
University Examination: 3 hours. ***University Examination Marks: 70***

Course objective: To provide detail knowledge about various techniques used for the measurement of primary industrial parameters (Flow, level, temperature and pressure) and application of different sensor/transducers, final control element for industrial and control system.

Syllabus:

UNIT I **Lectures 8**

Process variable, Elements of measuring instrument, Static and dynamic response of measuring device; Different types of thermometer and Thermocouples, Absolute pressure, Gauge Pressure, Differential Pressure, Measuring pressure for corrosive fluids, Head flow meters, open channel meters, area flow meters, Flow of dry material.

UNIT II **Lectures 10**

Transmitter, Transducers, Converter, Multiplexer, Pneumatic control valve, Stepper motor, Motorized valve; Data acquisition system and intelligent instruments, Process Instrumentation Diagrams: Representation and symbols, Instrumentation diagram for Distillation Column, Heat exchanger, Petroleum refinery**.**

UNIT III **Lectures 7**

Introductory Concepts: Need for control and automation, Control logic, manipulate variable, Control variable, set point and load; Blending Tank, Stirred Tank, Reactor, Interacting and Non-Interacting Process, Modelling considerations for control purposes.

UNIT IV **Lectures 9**

Linearization of Non-linear function across steady state- Deviation variable, Some Important aspects of Laplace transforms., Forcing functions (Step, Impulse, Ramp) and their Laplace transfer, Transfer functions and the input-output models; Dynamics and analysis of first, second and higher order systems, Transportation Lag, Dead Time.

UNIT V **Lectures 6**

Concept of feedback control, Closed loop and open loop transfer function, Implementation of block diagram, Different type of controllers, Control valve characteristics.

Routh stability criterion, Root locus plot and stability analysis, Bode stability criterion Nyquist stability criterion, Frequency response technique; Phase margin and gain margin;

Text/Reference books

1. Patranabis, D “Principles of Industrial Instrumentation” Tata Mc.Graw Hill Publishing Co.
2. Johnson, C,D,”Process Control Instrumentation Technology” Pearson Education, Inc
3. Coughnaowr, D.D. Process systems Analysis and Control, Mc.Graw –Hill,Inc.
4. SeborgD.E.Edgar, T, and Mellichamp,D.A. “Process Dynamics and Control” John Wiley and Sons, Inc.
5. Stephanopolous, G “Chemical Process Control” Prenticed –Hall.

Course outcome: At the end of the course, the student will be able to

CO1: Understand the various measuring devices in chemical industry.

CO2: Able to explain instrumentation diagram in process flow sheet.

CO3: Sketch the block diagram for various chemical processes.

CO4: Examine the stability concerns of a block diagram.

Course outcome mapping with Programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	1	-	-	-	-	-	-	3
CO2	2	2	3	2	1	-	-	-	-	-	-	2
CO3	2	3	3	3	1	-	-	-	-	-	-	2
CO4	3	3	3	2	2	-	-	-	-	-	-	3

ADVANCE MASS TRANSFER

Lectures: 3 Periods/week — ***Sessional Marks: 30***
University Examination: 3 h — ***University Examination Marks: 70***

Pre-requisite: Mass Transfer and Separation Processes

Syllabus

Unit I

Humidification-phase rule relations and definitions. Humid heat, humid volume, Enthalpy, adiabatic saturation process, wet bulb temp., dew point Lewis relation, humidity Charle's calculation for humidification dehumidification operations.

Adsorption: Adsorption equilibria; Batch, stage-wise and continuous adsorption; Industrial absorbers

Unit II

Evaporator-Evaporation, evaporation with direct heating steam headed evaporators natural circulation units, horizontal tubes, vertical tubes coil evaporators forced circulation evaporators, film type units.

Operation of evaporators- Heat transfer coefficient, operation under vacuum, single and multiple effect evaporators, Economy and capacity of multiple effect system, calculations, forward and backward and mixed feed operation, vapor recompression, integrated evaporators, in tot total plant economy.

Unit III

Vacuum and steam distillation, azeotropic & extractive distillation. Crystallization: Nucleation and crystal growth; Controlled growth of crystals; Industrial crystallizers.

Unit IV

Introduction to advance separation techniques, Mass transfer in membranes Reverse Osmosis, ultra-filtration, Ion exchange,

Text Book / Reference Books:

1. Mass Transfer Operations, Treybal Robert E., 3rd edition, International Edition, McGraw Hill.
2. Unit Operations of Chemical Engineering, Warren, L., McCabe, Julian C.Smith, Peter Harriot, 7th Edition, McGraw Hill.
3. Principles and Modern Applications of Mass Transfer Operations, Benitez Jaime, 2nd Edition, 2009, John Wiley & Sons
4. Separation Process Principles, Seader J D and Henly E J, John Wiley & sons.
5. Principles of Mass Transfer and Separation Process, Dutta Binay K., PHI, New Delhi.

6. Fundamentals of Momentum Heat and Mass Transfer, Welty, J.R., Wicks, C.W., Wilson, R.E. and Rorrer, G., John Wiley & Sons.

Course Outcomes (COs):

After completing this course, you should be able to:

CO1: Understand the mass transfer operations and various methods of conducting mass transfer operations for multi-component system.
CO2: Estimate the diffusivity for the molecular diffusion in gases and liquids.
CO3: Understand various models of inter-phase mass transfer and estimate multi-component mass transfer coefficients.
CO4: Understand and be able to handle the physical and mathematical complexities involved in multi-component mass transfer.

Course outcome mapping with Programme outcomes:

	POs1	**POs2**	**POs3**	**POs4**	**POs5**	**POs6**	**POs7**	**POs8**	**POs9**	**POs10**	**POs11**	**POs12**
CO1	3	3		2		2	2					2
CO2	3	3	3	3			2					2
CO3	3	3	2	2		2	2	1				1
CO4	3	3	3	3		3	2	1				2

Heterogenous Catalysis

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 30***

University Examination: 3 hours. — ***University Examination Marks: 70***

Course objective

This course will provide students understand the kinetics of reaction heterogenous catalytic and non-catalytic reaction.

Unit-I Heterogenous catalysts: Homogeneous processes, global and intrinsic rates, and mechanism of catalytic reactions. Engineering properties of catalysts, surface area measurement theories and techniques. **Lecture 8**

Unit-II. Development of rate equations for solid catalysed fluid phase reactions. Estimation of Kinetic parameters, deactivation of catalyst, rate equation determination for catalytic deactivation **Lecture 8**

Unit-III Effective diffusivity, Thiele modulus, effectiveness factor. Analysis of rate data. Reaction & diffusion within porous catalysts **Lecture 8**

Unit-IV Fluid- solid reactions: Rate expressions for non-catalytic fluid solid system. Kinetics of Fluid Solid Reactions: External transport processes, shrinking core model. **Lecture 8**

Unit-V Fluid-Fluid Reactions: kinetics, design, Straight Mass Transfer, Mass Transfer Plus Not Very Slow Reaction **Lecture 8**

Suggested Reading:

1. Chemical Reaction Kinetics By J.M. Smith (3rd Edition Mc Graw Hill)
2. Chemical Reaction Theory an Introduction By K.G. Denbigh & K.G. Turner (2nd Edition United Press & ELBS 1972)
3. Chemical Kinetic and Reactor Engineering By G. Copper & GVJ jeffery`s (Prentice Hall 1972)
4. Chemical reaction engineering By O.Levenspiel (2nd Edition Willey Eastern, Singapore)
5. Chemical process Principal Part-III By Houghen Watsn & Ragatz [Kinetics & catalysis (2nd Edition asian publication House Bombay)]
6. Element of Chemical Reaction Engineering By Fogler ,H.S. (2nd edition Prentice Hall of India Pvt. Ltd. New Delhi 1999)

Course Outcomes:

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

CO1	**Interpret heterogeneous catalytic and non-catalytic processes.**
CO2	**Evaluate the mass transfer process in reaction system.**
CO3	**Examine kinetics of catalytic and noncatalytic heterogeneous system.**

CO4	**Design reactors for heterogeneous processes.**

Mapping of course outcomes with program outcomes:

Course outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**1**	**1**	**1**	**-**	**-**	**-**	**-**	**1**	**-**	**-**	**-**
CO2	**3**	**3**	**2**	**3**	**-**	**-**	**-**	**-**	**1**	**-**	**-**	**-**
CO3	**3**	**3**	**2**	**3**	**-**	**-**	**1**	**-**	**1**	**-**	**-**	**-**
CO4	**3**	**3**	**3**	**3**	**1**	**-**	**-**	**-**	**1**	**-**	**-**	**-**

CHEMICAL REACTOR ANALYSIS

Lectures: 3 Periods/week ***Sessional Marks: 30***

University Examination: 3 hours. ***University Examination Marks: 70***

Course Objective:

This course will prove advanced knowledge in reactor design and analysis along with providing kinetics of heterogenous catalytic process.

UNIT I

Introduction to ideal reactors, performance equation and reaction mechanism analysis for batch reactor, plug flow reactor, CSTRs, recycle reactor and autocatalytic reactions. Design for multiple reactions: Reactions in parallel, reactions in series, contacting patterns, product distribution **Lectures 8**

UNIT II

Introduction to design for heterogeneous reacting systems: Rate equations for heterogeneous reactions, contacting patterns for two phase systems.

Lectures 8

UNIT III

Design of fixed bed catalytic reactor-isothermal, adiabatic, non-isothermal reactors, design of fluidized bed reactor. **Lectures 8**

UNIT IV

design of slurry reactor, Trickle bed reactor Intra-particle heat and mass transfer-Wheeler's parallel pore model, random pore model. **Lectures 8**

UNIT V

Introduction to biochemical reaction: enzymatic reaction kinematics, Michaelis-Menten Kinetics, Inhibition by a Foreign Substance-Competitive, fermenter reactor design **Lectures 8**

Suggested Reading:

1. Chemical Reaction Kinetics By J.M. Smith (3rd Edition Mc Graw Hill)
2. Chemical Reaction Theory an Introduction By K.G. Denbigh & K.G. Turner (2nd Edition United Press & ELBS 1972)
3. Chemical Kinetic and Reactor Engineering By G. Copper & GVJ jeffery`s (Prentice Hall 1972)

4. Chemical reaction engineering By O.Levenspiel (2^{nd} Edition Willey Eastern, Singapore)
5. Chemical process Principal Part-III By HoughenWatsn&Ragatz [Kinetics & catalysis (2^{nd} Edition asian publication House Bombay)]
6. Element of Chemical Reaction Engineering By Fogler ,H.S. (2^{nd} edition Prentice Hall of India Pvt. Ltd. New Delhi 1999)

Course Outcomes:

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

CO1	**Interpret heterogeneous catalytic and non-catalytic processes.**
CO2	**Evaluate the mass transfer process in reaction system.**
CO3	**Examine kinetics of catalytic and noncatalytic heterogeneous system.**
CO4	**Design reactors for heterogeneous processes.**

Mapping of course outcomes with program specific outcomes:

Course outcomes	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10	PSO11	PSO12
CO1		**1**	**1**	**1**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO2	**3**	**3**	**3**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO3	**3**	**2**	**2**	**1**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO4	**3**	**3**	**2**	**3**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Materials Characterization

Lectures: 3 Periods/week — ***Sessional Marks: 30***
University Examination: 3 hours. — ***University Examination Marks: 70***

Objective: Characterization of materials is essential to the systematic development of new materials and understanding how they behave in practical applications. This course focuses on the principal methods required to characterize broad range of materials such as polymers, ceramics, nanostructures etc. for their applications based on mechanical, optical, thermal properties of materials.

Course outcomes: At the end of the course, student will be able to

CO1	Identifies the various characterization techniques applicable for the material
CO2	Understand the physical and chemical properties of material
CO3	Analyzed the structural properties, thermal properties and morphology of the material.
CO4	Explain the of the properties of material.

Detailed Syllabus:

UNIT I — ***Lectures: 8***

Introduction to materials and Techniques, Production and properties of X-ray, absorption of X-rays and filters, X-ray - diffraction directions, diffraction methods. X-ray - diffraction intensities, factors affecting intensity, 'structure factor' calculations for simple, body centered, face centered, diamond cubic and hexagonal crystal structures. Working principles of diffractometer. Indexing of XRD patterns. Precise lattice parameter determination, Chemical analysis by X-ray diffraction & fluorescence, determination of particle size and micro/macro strains), energy dispersive X-ray microanalysis (EDS).

UNIT II — ***Lectures: 8***

Fundamentals of optics and microscopy techniques, Optical microscope and its instrumental details, Variants in the optical microscopes and image formation. Sample preparation and applications. Introduction to scanning electron microscopy (SEM), sample preparation and applications, Instrumental details and image formation, various imaging techniques and spectroscopy, electron diffraction, and low energy electron diffraction.

UNIT III — ***Lectures: 6***

Introduction to Transmission electron microscopy (TEM), instrumental details and working principles of TEM. Image formation, science of imaging and diffraction, sample preparation procedures and instruments for various materials

UNIT IV — ***Lectures: 6***

Thermal analysis technique: Differential thermal analysis (DTA), Differential Scanning Calorimetry (DSC), Thermogravimetric analysis (TGA), UV-VIS spectroscopy

UNIT V — ***Lectures: 8***

principles of characterization of other materials properties: BET surface area; chemisorption; particle size; zeta potential; rheology; and interfacial tension. Introduction to spectroscopy (UV-vis, IR and Raman)

Texts/References:

1. Y. Leng, Materials Characterization: Introduction to microscopic and spectroscopic methods, 1st Ed., John Wiley & Sons, 2008.
2. A.W. Adamson and A.P. Gast, Physical Chemistry of Surfaces, John Wiley, New York, 1997.
3. D.G. Baird and D.I. Collias, Polymer Processing Principles and Design, Butterworth-Heinemann, Massachusetts, 1995.
4. A.J. Milling, Surface Characterization Methods: Principles, techniques, and applications, Marcel Dekker, 1999.
5. G. Ertl, H. Knozinger and J. Weitkamp, Handbook of Heterogeneous Catalysis, Vol. 2, Wiley-VCH, 1997.
6. W.D. Callister (Jr.), Material Science and Engineering: An introduction, 8th Ed., John Wiley & Sons, 2010.

Chemical Reactor Design

Lectures: 3 Periods/week ***Sessional Marks: 30***

University Examination: 3 hours. ***University Examination Marks: 70***

Course objective : To increase the student's ability to do chemical reactor design by providing the knowledge and tools required to obtain, evaluate, and improve rate equations for use in design, operation and optimization of chemical reactors.

UNIT I **Lectures 6**

Introduction to Reactor design: Single ideal Reactor: Ideal batch reactor, space time and space velocity, steady state mixed flow reactor, steady state plug flow reactor, holding time and space time for flow systems.

UNIT II **Lectures 3**

Introduction to design for heterogeneous reacting systems: Rate equations for heterogeneous reactions, contacting patterns for two phase systems.

UNIT III **Lectures 7**

Thermal characteristics and design of reactors: Batch reactor, PFR, CSTR under adiabatic conditions for first order irreversible reactions

Reactor design: Reactor principles, performance. Reactor and catalyst equipment- Selection of Catalyst, Types of Reactors, Selection of Reactors and Design of Reactor Systems.

UNIT IV **Lectures 8**

Calculation of equilibrium compositions of a set of simultaneous reactions, Performance calculation for batch reactor, plug flow reactor and CSTRs, homogeneous and heterogeneous flow reactors for specific reactions.

UNIT V **Lectures 12**

Design for Single Reactions: Size comparison of single reactors, multiple reactor systems, recycle reactor, autocatalytic reactions.

Design for multiple reactions: Reactions in parallel, reactions in series, contacting patterns, product distribution.

Course Outcomes:

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

CO1	**Analyze the rates of chemical reactions for both homogeneous and heterogeneous reactions**
CO2	**Evaluate the performance calculation for CSTR, PFR , Batch reactors.**
CO3	**Understand catalyst activity, selectivity and stability in reactor design.**
CO4	**Explain Thermal characteristics and design of reactors.**
CO5	**Differentiate single and multiple reactor systems.**

Mapping of course outcomes with program specific outcomes

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12

outcomes												
CO1	**3**	**3**	**-**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO2	**2**	**2**	**1**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO3	**2**	**1**	**1**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO4	**1**	**-**	**1**	**2**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO5	**1**	**2**	**1**	**3**	**2**							

Suggested Reading:

1. Fogler S.H., "Elements of Chemical Reaction Eng.", 3rd Ed., Prentice Hall,1999.

2. Levenspiel, O., "Chemical Reaction Eng." John Wiley & Sons 1972,

3. Froment G.F. and Bischoff K.B., "Chemical Reactor Analysis and Design" John Wiley, 1990.

4. Roberts, G.W., "Chemical Reactions and Chemical Reactors", Wiley, 2009.

Energy option

Lectures: 4 Periods/week ***Sessional Marks: 30***

University Examination: 3 hours. ***University Examination Marks: 70***

Course objective

To impart basic knowledge of current energy sources, scenario, energy conservation, audit and management.

UNIT I **Lectures 8**

Fuels: Solids, liquids and gaseous fuels, Availability and classification. Coal: Theories of formation, Coal composition petrography of Coal calorific value of Coal, Chemical Constitution of Coal, Action of heat and solvent on coal, Coal preparation, handling and storage.

UNIT II **Lectures 8**

Industrial Coal Carbonization low and high temperature carbonization processes Design of Coke ovens with recovery system. Numerical problems based on Combustion, use of grates, combustion of pulverized fuel and fluidized bed combustion, efficient utilization of Indian coals

UNIT III **Lectures 8**

Liquid fuels: Indian cruds & refinery products. Chemical Coal tar distillation Hydrogenation of Coal, FiacherTropse process, other liquefaction process, Synthesis gas from petroleum fractions. Gaseous fuel: Natural gas producer gas reactions and its manufacture, water gas, carbureted water gas

UNIT IV **Lectures 8**

Analysis of flue gases, complete gasification of Coal Lurgi, Kopper'sTotzek, and Winkler process synthesis gas form Coal. Renewable sources of energy and their potential, low Temperature application of solar Energy.

UNIT V **Lectures 8**

Conversion of Bio-mass and their characteristic, physical thermo-chemical and Bio-logical methods of their conversion, Fuel cell

Course Outcomes:

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

CO1	**Understand the basic concepts of coal energy and Indian cruds & refinery products.**
CO2	**Numerical problems based on Combustion and fluidized bed combustion.**
CO3	**Analyse of different different energy sources.**
CO4	**Examine and apply for applications.**

Suggested Reading:

1. Coal Energy system By Bruce Miller, (Published-Academic Press)

2. Fuels and their Combustion By Robert T.HASLAM (5th edition, McGraw Hill)

Fuel and Combustion Technology

Teaching Scheme: ***Sessional Marks: 30***

Lectures: 3 periods/week ***University Examination Marks: 70***

University Examination: 3 hours

Course Objective: This course will provide knowledge regarding solid, liquid and gaseous fuels, their origin, classification, properties, preparation and combustion characteristic of fuel.

Unit 1 **Lectures 8**

Solid fuels: Classification, preparation, cleaning, analysis, ranking and properties - action of heat, oxidation, hydrogenation, carbonization, liquefaction and gasification.

Liquid fuels: Petroleum origin, production, composition, classification, petroleum processing, properties, testing - flow test, smoke points, storage and handling.

Unit 2 **Lectures 8**

Secondary liquid fuels: Gasoline, diesel, kerosene and lubricating oils. Liquid fuels - refining, cracking, fractional distillation, polymerization. Modified and synthetic liquid fuels. ASTM methods of testing the fuels.

Unit 3 **Lectures 10**

Gaseous fuels: Types, natural gas, methane from coal mine, water gas, carrier gas, producer gas, flue gas, blast furnace gas, biomass gas, refinery gas, LPG - manufacture, cleaning, purification and analysis. Fuels for spark ignition engines, knocking and octane number, anti knock additives, fuels for compression, engines, octane number, fuels for jet engines and rockets. Flue gas analysis by chromatography and sensor techniques.

Unit 4 **Lectures 6**

Combustion: Stochiometry, thermodynamics. Nature and types of combustion processes – Mechanism-ignition temperature, explosion range, flash and fire points, calorific value, calorific intensity and theoretical flame temperature.

Unit 5 **Lectures 6**

Combustion calculations, theoretical air requirements, flue gas analysis, combustion kinetics– hydrogen-oxygen reaction and hydrocarbon-oxygen reactions.

Rocket propellants and Explosives - classification, brief methods of preparation, characteristics; storage and handling

Text/Reference Books:

1. Fuels and Combustion, Samir Sarkar, Orient Longman Pvt. Ltd, 3rd edition, 2009
2. Fuels - Solids, liquids and gases - Their analysis and valuation, H. Joshua Philips, Biobliolife Publisher, 2008.
3. An introduction to combustion: Concept and applications - Stephen R Turns, Tata Mc. Graw Hill, 3rd edition, 2012.
4. Fundamentals of Combustion, D P Mishra, 1st edition, University Press, 2010
5. Engineering Chemistry - R. Mukhopadhyay and Sriparna Datta, Newage International Pvt. Ltd, 2007.

Course Outcomes: After completion of this course students will able to

CO1: Classify different kinds of fuels used in process industries.

CO2: Examine the quality of fuel using different test methods.

CO3: Report the flue gas analysis from combustion process.

CO4: Demonstrate the combustion process mechanism of fuel.

Course outcome mapping with Programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	1	1	1	1	1	-	-	-	-	2
CO2	3	3	2	1	2	1	2	-	-	-	-	3
CO3	3	2	3	2	3	2	2	-	-	-	-	3
CO4	3	3	3	2	3	2	2	-	-	-	-	3

Fertilizer technology

Lectures: 4 Periods/week ***Sessional Marks: 30***

University Examination: 3 hours. ***University Examination Marks: 70***

Course objective

To enable the students to learn the fertilizer manufacturing including new or modified fertilizer products and new techniques.

Unit – I **Lectures 10**

Definition of fertilizer, nutrient requirement of different plants paddy, wheat, sugarcane

Natural way of fixing nitrogen, Nitrogen cycle, carbon cycle, different nitrogen fixing plants, bacteria and algae. Role of C/N ratio in the growth of different plants. Organic manure.

Unit-II **Lectures 10**

Production of ammonia-its feed preparation, limitations of using different feed material for hydrogen generation, Reforming process and reformer design. Partial oxidation process and partial oxidation reactor design.

Unit-III **Lectures 10**

Removal of Impurities from synthesis gas CO removal and shift reactor design. CO_2 removal methods, Design of CO_2 absorber, NH_3 synthesis loop design, Design considerations for different types of NH_3 Reactors.

Unit-IV **Lectures 10**

Phosphate fertilizers-different methods of production, NPK, production and drying of NPK fertilizers, Bio-fertilizer.

Unit-V **Lectures 10**

Urea production; special features of urea reactor, prilling tower design.

Course Outcomes:

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

CO1	**Understand the basic concepts of fertilizer for agriculture and manufacturing process.**
CO2	**Design of ammonia reactor and urea pilling tower.**
CO3	**Analyse of different fertilizers.**
CO4	**Examine different fertilizer for different agriculture purpose.**

Suggested Reading:

1. Chemistry and Technology of Fertilizers By V. Sauchelli, (Reinhold Publications)

2. Hand book on Fertilizers By Vasant Gowariler, V.N.Krishnamurthy and Sudha Gowariker (published, Fertilizer Association of India, New Delhi)

3. Dryden's Outlines of Chemical Technology By M. Gopala Rao Sitting Marshal (Affiliated East West Press (Pvt) Ltd, 3 rd Ed., New Delhi).

4. Shreve's Chemical Process Industries, By Austin G.T. (5th edition, McGraw Hill publication, New Delhi)

5. Chemical Technology – By Pandey G.N. and Shukla Vol. I and II, 2nd edition (Vani Books Company – Hyderabad)