Malaviya National Institute of Technology Jaipur

Proposed Curriculum of M. Tech. in Chemical Engineering

Proposed M.Tech. Program Name: Petrochemicals & Polymer Technology

M. Tech. I Semester (Petrochemicals & Polymer Technology)

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHT541	Advanced Polymer Processing	PC	Theory	4	3	0	2
2.	25CHT542	Advanced Reaction Engineering	PC	Theory	4	3	0	2
3.	25CHT543	Petroleum Refining and Petrochemical Production Engineering	PC	Theory	4	3	0	2
4.	25CHP544	Polymer Characterization and Testing	PC	Theory	2	1	0	2
5.	25CHT545	Polymer Technology	PC	Theory	4	3	0	2
				Total Credits	**18**			

M. Tech. II Semester (Petrochemicals & Polymer Technology)

(Any four subjects to be registered)

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHT814	Advanced Polymer Process Modelling	PE	Theory	4	3	0	2
2.	25CHT815	Advanced Process Instrumentation	PE	Theory	4	3	0	2
3.	25CHT816	AI and ML in Process Engineering	PE	Theory	4	3	0	2
4.	25CHT817	Catalysis Science and Technology	PE	Theory	4	3	0	2
5.	25CHT818	Computational Techniques for Engineers	PE	Theory	4	3	0	2
6.	25CHT819	Energy Management in Petrochemical Industries	PE	Theory	4	3	0	2
7.	25CHT820	Hydrogen and Fuel Cell Technologies	PE	Theory	4	3	0	2
8.	25CHT821	Petroleum Industry and Business	PE	Theory	4	3	0	2
9.	25CHT822	Polymer Composites and Blends	PE	Theory	4	3	0	2
10.	25CHT823	Safety and Risk Management in Petrochemical Industries	PE	Theory	4	3	0	2
11.	25CHT824	Statistical Methods	PE	Theory	4	3	0	2
12.	25CHT825	Waste Management in Petrochemical and Polymer Industries	PE	Theory	4	3	0	2
				Total Credits	**16**			

M. Tech. III Semester (Petrochemicals & Polymer Technology)

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHD641	Dissertation-I	PC	-	12	-	-	-

M. Tech. IV Semester (Petrochemicals & Polymer Technology)

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHD642	Dissertation-II	PC	Theory	12	-	-	-

L=Lecture hours/week P=Practical hours/week T=Tutorial hours/week

PC= Program Core PE= Program Elective

Two hours practical in each course may comprise extended industry oriented discussion, hands on practice, field visit, projects to customize and enrich the industry skills, learning experience which inculcate additional opportunities to the students to get experience in emerging trends and technologies.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF CHEMICAL ENGINEERING

Proposed Curriculum of M. Tech. in Chemical Engineering
Proposed M.Tech. Program Name: Petrochemicals & Polymer Technology
M. Tech I Semester (Petrochemicals & Polymer Technology)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT543	Petroleum Refining and Petrochemical Production Engineering	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To impart knowledge of petroleum refining, hydrocarbon processing and petrochemical production.

COURSE OUTCOMES

CO1	Identify the appropriate characterization parameters and specify the properties of petroleum products
CO2	Understand the applications of separation and conversion processes involved in petroleum refining.
CO3	Gain knowledge on production process of various types of petrochemical products.
CO4	Provide a detailed insight of all the chemicals derived from petroleum.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%

b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: World petroleum resources, petroleum industry in India, origin, exploration, drilling and production of petroleum crude, transportation and pre-treatment of crude oil, Composition and classification of petroleum crude.
Quality control of petroleum products: ASTM, TBP and FEV distillation of crude oil, vapour pressure, flash point, fire point etc.

(No. of lectures- 6)

Unit II- Separation and Conversion process: Desalting of crude oil, Atmospheric Distillation, Vacuum Distillation, visbreaking process, coking processes. Thermal and catalytic cracking, hydrocracking, Reforming, hydroprocessing, Alkylation, polymerization and isomerisation.

(No. of lectures- 10)

Unit III- Finishing Process: Sweetening process, Hydrotreating process, Solvent extraction process for lubricating oil base stocks and for aromatics from naphtha and kerosene, Solvent dewaxing process.

(No. of lectures-6)

Unit IV Methane and Synthesis Gas Derivatives: Steam reforming and partial oxidation, gasification. Production of Olefins, Treatment & Up-gradation of C4 and C5 Cuts, Aromatics Production, Manufacturing Ethylene, Propylene and their derivatives.

(No. of lectures- 10)

Unit V- Aromatic Derivatives such as Phenol, aniline etc: Polymers, Elastomers and Synthetic fiber such as nylon, polyester and Styrene butadiene.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Mall I. D., Petrochemical Process Technology, 1st Ed., Macmillan India Ltd., 2007.
2. Rao, B.K.B., Modern Petroleum Refining Processes, Oxford, IBH, 2002.
3. Nelson, W.L., Petroleum Refinery Engineering, McGraw Hill, 1987.
4. Chaval A. and Lefebvre G., Petrochemical Processes, Part-I, 2nd Ed., Technip, 1986.
5. Gary, J.H. and Handwerk, G.E., Petroleum Refining, Technology and economics, Marcel-Dekker, 1984.

Lecture Plan

Lecture No.	Topics to be covered
1.	World petroleum resources, petroleum industry in India
2.	Exploration, drilling and production of petroleum crude
3.	Transportation and pre-treatment of crude oil
4.	Composition and classification of petroleum crude
5.	Quality control of petroleum products: ASTM, TBP and FEV distillation of crude oil
6.	Quality control of petroleum products: vapour pressure, flash point, fire point etc.
7.	Desalting of crude oil
8.	Atmospheric Distillation, Vacuum Distillation
9.	Visbreaking process
10.	Coking processes.
11.	Thermal and catalytic cracking, hydrocracking
12.	Reforming process
13.	Hydroprocessing of crude oil
14.	Alkylation, process
15.	Polymerization process
16.	Isomerization process
17.	Sweetening process
18.	Hydrotreating process
19.	Solvent extraction process for lubricating oil base stocks
20.	Aromatics from naphtha
21.	Aromatics from kerosene
22.	Solvent dewaxing process
23.	Steam reforming process
24.	Gasification process
25.	Partial oxidation process
26.	Production of Olefins
27.	Treatment & Up-gradation of C4 and C5 Cuts
28.	Aromatics Production
29.	Manufacturing of Ethylene
30.	Manufacturing of Propylene
31.	Manufacturing of Ethylene derivatives
32.	Manufacturing of Propylene derivatives
33.	Manufacturing process for Phenol
34.	Manufacturing process for aniline
35.	Manufacturing process for Polymers
36.	Manufacturing process for Elastomers
37.	Manufacturing process for Synthetic fibers
38.	Manufacturing process for polyester
39.	Manufacturing process for nylon
40.	Manufacturing process for Styrene butadiene

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT542	Advanced Reaction Engineering	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide comprehensive knowledge of catalysis, reactor design and their application in the petroleum industry.

COURSE OUTCOMES

CO1	Use the principles of reaction engineering for design and analysis of reactors.
CO2	Analyze and interpret data from catalytic experiments.
CO3	Apply knowledge of catalysis to solve real-world engineering problems.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Introduction of various reactors (BR, CSTR, PFR, MBR), Non-isothermal steady state reactor design, Energy balance, Pressure drop in reactor design (PBR), Multiple steady states.

(No. of lectures- 6)

Unit II- Fundamentals of Catalysis: Homogeneous and Heterogeneous Catalysis, Preparation methods, Steps in catalytic reaction, Analysis of external transport processes in heterogeneous reactions in fixed bed, fluidized bed and slurry reactors. Intrapellet mass transfer, heat transfer, mass transfer with chemical reaction and simultaneous mass and heat transfer with chemical reaction.

(No. of lectures- 8)

Unit III- Catalyst Deactivation: Modes of deactivation – poisoning, fouling and sintering. Determination of deactivation routes, combined effect of deactivation and diffusion on reaction rates, effect of deactivation on selectivity.

(No. of lectures-6)

Unit IV Reactor Design: Design calculation for ideal catalytic reactor operating at isothermal, adiabatic and non-adiabatic conditions. Deviations from ideal reactor performance. Design of industrial fixed-bed, fluidized bed and slurry reactors. Thermal stability of packed bed and fluidized bed reactors.

(No. of lectures- 8)

Unit V- Polymeric Reactions: Introduction to polymeric reactions and their kinetics, rate of polymerization, types of polymerization, and reactors for polymerization reactions.

(No. of lectures- 8)

Unit VI- Case Studies: Industrial reactors and case studies.

(No. of lectures- 4)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Levenspil, O., Chemical Reaction Engineering-An Indian Adaptation, John Wiley & Sons, 2020.
2. Scott Fogler, H., Essentials of Chemical Reaction Engineering, Pearson, 2020.
3. Hill, C. G.; Root, T. W. An Introduction to Chemical Engineering Kinetics & Reactor Design, John Wiley & Sons, 2014.
4. Asua, J. M. Polymer Reaction Engineering, Blackwell Publishing Ltd., 2007.
5. Smith, J. M., Chemical Engineering Kinetics, Mcgraw Hill, 1981.

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction of various reactors (BR, CSTR)
2.	Introduction of various reactors (PFR, MBR)
3.	Non-isothermal steady state reactor design
4.	Energy balance calculations
5.	Pressure drop in reactor design (PBR),
6.	Multiple steady states.
7.	Homogeneous and heterogeneous catalysis
8.	Catalyst preparation methods
9.	Steps in catalytic reaction
10.	External transport processes in heterogeneous reactions in fixed bed reactors

11.	External transport processes in heterogeneous reactions in fluidized bed and slurry reactors
12.	Intrapellet mass transfer and heat transfer
13.	Mass transfer with chemical reaction
14.	Simultaneous mass and heat transfer with chemical reaction.
15.	Modes of deactivation – poisoning, fouling and sintering-I
16.	Modes of deactivation – poisoning, fouling and sintering-II
17.	Determination of deactivation routes
18.	The combined effect of deactivation and diffusion on reaction rates-I
19.	The combined effect of deactivation and diffusion on reaction rates-II
20.	Effect of deactivation on selectivity
21.	Design calculation for ideal catalytic reactor operating at isothermal conditions
22.	Design calculation for ideal catalytic reactor operating at adiabatic conditions
23.	Design calculation for ideal catalytic reactor operating at non-adiabatic conditions
24.	Deviations from ideal reactor performance
25.	Design of industrial fixed-bed reactors
26.	Design of industrial fluidized bed reactors.
27.	Design of industrial slurry reactors.
28.	Thermal stability of packed bed and fluidized bed reactors.
29.	Introduction to polymeric reactions and their kinetics-I
30.	Introduction to polymeric reactions and their kinetics-II
31.	Rate of polymerization reactions
32.	Types of polymerization reactions-I
33.	Types of polymerization reactions-II
34.	Reactors for polymerization reactions
35.	Reactors for polymerization reactions-I
36.	Reactors for polymerization reactions-II
37.	Industrial reactors
38.	Case studies-I
39.	Case studies-II
40.	Case studies-III

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT545	Polymer Technology	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

The Polymer technology course's covers concepts of polymer science and technology, principles, kinetics, types of molecular weights and methodology of polymerization.

COURSE OUTCOMES

CO1	Understand the scientific concepts of polymers technology.
CO2	Understand the knowledge of molecular weights, and its determination method.
CO3	Understand various types of polymerizations, mechanism and its kinetics.
CO4	Understand the industrial polymerization techniques and its applications.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Fundamental concept of Macromolecules, History of polymer science, types of polymers, Classification of polymers, functionality and structure of polymers, property relationship, Molecular forces and chemical bonding in polymer, Glassy to rubber transition in polymer, addition polymers, condensation polymers, copolymers. Effect of structure on properties of polymers

(No. of lectures- 8)

Unit II- Concept of Molecular weight, molecular weight averages, molecular weight distribution, polydispersity, degree of polymerization, and Molecular weight distribution. Determination molecular weight by end group analysis, colligative properties, osmometry, light scattering, and

gas permeation chromatography. Industrial methods of Polymerization such as Bulk, solution, emulsion and suspension polymerization.

(No. of lectures- 8)

Unit III- Types of polymerization such as chain (addition polymerization) and condensation polymerization (step polymerization), types of initiators for free radical polymerization, auto acceleration, chain transfer agents.

(No. of lectures-8)

Unit IV Kinetics and mechanism of free radical polymerization, cationic and ionic polymerization, mayo equation, and methods to determine the chain transfer constants.

(No. of lectures- 8)

Unit V- Principles of Step-reaction (condensation) polymerization, Carothers Equation, Mechanism of stepwise polymerization, Kinetics and statistics of linear stepwise polymerization, Poly-functional step-reaction polymerization

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. George Wypych, Handbook of Polymers, 3rd edition, ChemTec Publishing, 2022.
2. Joel R. Fried, Polymer Science and Technology, Prentice Hall of India, 2014.
3. George Odion, Principles of Polymerization, 4th Edn., Wiley & Sons, 2007.
4. R. O. Ebewele, Polymer Science and Technology, 1st Ed., CRC Press, Boca Raton, 2000.
5. Malcolm P. Stevens, Polymer Chemistry: An Introduction, Oxford University Press; 3rd edition, 1999.
6. F. W. Billmeyer Jr., Textbook of polymer science, John Wiley, New York, 1996.

Lecture Plan

Lecture No.	Topics to be covered
1.	The fundamental concept of Macromolecules
2.	History of polymer science, types of polymers
3.	Classification of polymers, functionality and structure of polymers, property relationship
4.	Molecular forces and chemical bonding in polymer
5.	Glassy to rubber transition in polymer, addition polymers, condensation polymers, and copolymers.
6.	Effect of structure on properties of polymers
7.	Addition polymers, condensation polymers, copolymers
8.	Effect of structure on properties of polymers
9.	Concept of molecular weight, molecular weight averages

10.	Concept of molecular weight distribution, polydispersity-I
11.	Concept of molecular weight distribution, polydispersity-II
12.	Concept of degree of polymerization, and molecular weight distribution
13.	Determination of molecular weight by end group and colligative analysis
14.	Determination of molecular weight by osmometry and light scattering
15.	Determination of molecular weight by gel permeation chromatography
16.	Bulk, solution, emulsion and suspension polymerization
17.	Chain (addition) polymerization -I
18.	Chain (addition) polymerization -II
19.	Condensation (step) polymerization-I
20.	Condensation (step) polymerization-II
21.	Initiators for free radical polymerization
22.	Initiators for auto acceleration reactions
23.	Initiators for chain transfer reactions.
24.	Agents for different reactions
25.	Kinetics and mechanism of free radical polymerization-I
26.	Kinetics and mechanism of free radical polymerization-II
27.	Cationic and ionic polymerization-I
28.	Cationic and ionic polymerization-II
29.	Mayo equation-I
30.	Methods to determine the chain transfer constants-I
31.	Methods to determine the chain transfer constants-II
32.	Methods to determine the chain transfer constants-III
33.	Principles of Step-reaction (condensation) polymerization-I
34.	Principles of Step-reaction (condensation) polymerization-II
35.	Carothers Equation
36.	Mechanism of stepwise polymerization-I
37.	Mechanism of stepwise polymerization-II
38.	Kinetics and statistics of linear stepwise polymerization-I
39.	Kinetics and statistics of linear stepwise polymerization-II
40.	Poly-functional step-reaction polymerization

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT541	Advanced Polymer Processing	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

Course covers the various polymer processing operations such as injection, compression, transfer, extrusion moulding, compounding and mixing, thermoforming and other shaping methods used in polymer industries.

COURSE OUTCOMES

CO1	Analyze the process of injection moulding process for conversion of thermoplastic and analyze processing parameters and variables for modification and improvement of quality of products.
CO2	Analyze the molding process for conversion of thermoset materials like compression, transfer molding.
CO3	Identify appropriate manufacturing techniques for polymer products.
CO4	Analyze the free surface flow in extrusion and post extrusion processes.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- General scenario of the Indian Plastics Processing: Industry Analysis of injection moulding of thermoplastics, Principle and theory of screw plasticization and injection moulding operation; moulding cycle; Process variables; and their importance for machine cycle and quality of product. Moulding defects and their remedies, Gas assist and water assist injection moulding processes. Reaction injection moulding.

(No. of lectures- 8)

Unit II- Analysis of Extrusion process: basic flow pattern; melting mechanism; extruder and die characteristic Diagrams; flow patterns of dies, different types of screw. Plastic product viz. film, pipe, lamination, sheet coating, wire and cable covering. Twin screw extruders and co-extrusion process. Reactive extrusion: principles, equipment and applications.

(No. of lectures- 8)

Unit III- Type of blow Moulding processes: process parameters viz. blow ratio, die shaping, parison control. Blow Moulding faults and their remedies. Stretch blow Moulding process. Rotational Moulding process: analysis of process parameters and utility of the process for variety of products. Thermoforming, types of thermoforming methods, Thermoforming process variables, faults and remedies.

(No. of lectures-8)

Unit IV Analysis of compression and transfer moulding process: process parameters; faults and remedies. Concept of Injection Moulding of thermoset polymers.

(No. of lectures- 8)

Unit V- Processing of fibre reinforced plastics: Calendaring, Fibre Spinning, Pultrusion etc. Types of reinforcement, Compounding and additives for plastics: their utility and effect on properties, Compounding equipment: mixers, blenders, mills, extruders, etc.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. D. V. Rosato & Rosato, Injection Moulding HandBook; Springer, 2012.
2. Tim A. Osswald, Understanding Polymer Processing: Processes and Governing Equations, Carl Hanser Verlag GmbH & Co., 2010.
3. B.R. Gupta, Polymer Processing Technology Asian Books Pvt Ltd., 2008.
4. Polymer Processing Fundamentals, Osswald, A. Tim, Hansar Publishers, 1998.
5. Joel Frados, Plastic Engg. Hand Book of SPI, Wiley, John & Sons, 1st Edition, 1976.

Lecture Plan

Lecture No.	Topics to be covered
1.	General scenario of the Indian plastics processing industry
2.	Analysis of injection moulding of thermoplastics
3.	Principle and theory of screw plasticization
4.	Injection moulding operations
5.	Moulding cycle; Process variables; and their importance for machine cycle and quality of product
6.	Moulding defects and their remedies,

7.	Gas assist and water assist injection moulding processes.
8.	Reaction injection moulding
9.	Basic flow pattern and melting mechanism
10.	Extruder and die characteristic Diagrams
11.	Flow patterns of dies, different types of screw
12.	Plastic product: film, pipe, lamination, sheet coating
13.	Plastic product: wire and cable covering
14.	Twin screw extruders and co-extrusion process
15.	Reactive extrusion: principles
16.	Reactive extrusion: equipment and applications.
17.	Process parameters viz. blow ratio, die shaping, parison control.
18.	Parison control of blow moulding processes
19.	Blow Moulding faults and their remedies.
20.	Stretch blow Moulding process
21.	Rotational Moulding process: analysis of process parameters
22.	Rotational Moulding process: utility of the process for a variety of products
23.	Thermoforming, types of thermoforming methods
24.	Thermoforming process variables, faults and remedies
25.	Process parameters of moulding process-I
26.	Process parameters of moulding process-II
27.	Faults and remedies-I
28.	Faults and remedies-II
29.	Faults and remedies-II
30.	Concept of Injection Moulding of thermoset polymers-I
31.	Concept of Injection Moulding of thermoset polymers-II
32.	Concept of Injection Moulding of thermoset polymers-III
33.	Calendaring
34.	Fibre Spinning, Pultrusion etc.
35.	Types of reinforcement
36.	Compounding and additives for plastics.
37.	Effect of additives on plastics properties
38.	Compounding equipment: mixers,
39.	Compounding equipment: blenders
40.	Compounding equipment: mills, extruders, etc

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHP544	Polymer Characterization and Testing	2	1	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

Course covers various polymeric characterization and testing method of polymeric materials on various testing instruments.

COURSE OUTCOMES

CO1	Evaluate testing of polymeric materials on testing instruments.
CO2	Identify and analyze the chemical structure, molecular weight, morphology, electrical, mechanical and thermal properties of polymers using various analytical techniques.
CO3	Apply appropriate testing methods to ensure polymer products meet specified quality standards.
CO4	Design and execute polymer characterization experiments using appropriate techniques based.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Principles and methods of standardization: preparation of sample, different standards: BS, ASTM, ISI, ISO and their importance. Evaluations of errors in polymer testing, correction of errors.

(No. of lectures- 6)

Unit II- Elemental analysis: CHNSO, ICP-OES and Testing for elastic properties, cure rate, optimum cure time, MFI, density, dimensional measurements, gel time etc and Introduction to

polymer characterization by instrumental techniques such as TGA, DTA, DSC, TMA, XRD, IR, NMR, , GC-MS, GPC, UV-visible spectroscopy. Polymer characterization by SEM, TEM, AFM and optical microscopy.

(No. of lectures- 10)

Unit III- Thermal properties: Specific heat, thermal conductivity, glass transition temperature, thermal diffusivity, heat distortion temperature, vicat softening points etc. Mechanical Properties: Tensile, compressive and flexural, impact, stress strain behavior, creep and fatigue properties etc.

(No. of lectures-8)

Unit IV- Electrical Properties: surface burning characteristics. Insulation resistance –power factor – permittivity - dielectric strength –tracking resistance – arc resistance and antistatic test.

(No. of lectures- 4)

Unit V - Optical properties: refractive index, luminous transmittance, color, haze, water absorption, moisture analysis.

(No. of lectures- 4)

Unit VI- Chemical Properties: Crush and burst strength. Environmental stress cracking resistance, ageing, gas permeability, water vapor permeability and weathering.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. S.K.Nayak, S.N.Yadav, S. Mohanty, Fundamentals of Plastic Testing, Springer, (INDIA) Private Limited, 2020.
2. Grellmann W., Seidler S.,Polymer Testing, Hanser publication, 2013.
3. T. R. Crompton, Physical Testing of Plastics , Rapra Technology Ltd., 2012.
4. Ward I.M., Sweeney J., An Introduction to the Mechanical Properties of Solid Polymers, Wiley, 2004.
5. Vishu Shah, Handbook of Plastics Testing Technology, Wiley-Interscience, 1998.

Lecture Plan

Lecture No.	Topics to be covered
1.	Preparation of sample
2.	Different standards and their importance: BS, ASTM, ISI, ISO-I
3.	Different standards and their importance: BS, ASTM, ISI, ISO-II
4.	Different standards and their importance: BS, ASTM, ISI, ISO-III
5.	Evaluations of errors in polymer testing, correction of errors-I

6.	Evaluations of errors in polymer testing, correction of errors-II
7.	Elemental analysis: CHNSO, ICP-OES
8.	Testing for elastic properties
9.	Cure rate, optimum cure time, MFI,
10.	Density, dimensional measurements, gel time etc.
11.	Introduction to polymer characterization by instrumental techniques
12.	Polymer characterization techniques such as TGA, DTA
13.	Polymer characterization techniques such as DSC, TMA
14.	Polymer characterization techniques such as XRD, IR
15.	Polymer characterization techniques such as NMR, GC-MS
16.	Polymer characterization by GPC, UV-visible spectroscopy
17.	Polymer characterization by AFM and optical microscopy-I
18.	Polymer characterization by AFM and optical microscopy-II
19.	Thermal properties such as specific heat, thermal conductivity
20.	Thermal properties such as glass transition temperature, thermal diffusivity
21.	Thermal properties such as vicat softening points etc.
22.	Mechanical Properties such as tensile, compressive and flexural
23.	Mechanical Properties such as stress strain behavior etc
24.	Mechanical Properties such as fatigue properties etc
25.	Electrical properties such as surface burning characteristics
26.	Electrical properties such as insulation resistance –power factor
27.	Electrical properties such as permittivity - dielectric strength etc.
28.	Electrical properties such as arc resistance and antistatic test
29.	Optical properties such as refractive index, luminous transmittance-I
30.	Optical properties such as refractive index, luminous transmittance-II
31.	Optical properties such as color, haze, water absorption, moisture analysis-I
32.	Optical properties such as color, haze, water absorption, moisture analysis-II
33.	Chemical properties such Crush and burst strength-I
34.	Chemical properties such Crush and burst strength-II
35.	Chemical properties such environmental stress cracking resistance-I
36.	Chemical properties such environmental stress cracking resistance-II
37.	Chemical properties such ageing, gas permeability-I
38.	Chemical properties such ageing, gas permeability-II
39.	Chemical properties such water vapor permeability and weathering-I
40.	Chemical properties such water vapor permeability and weathering-II

M. Tech II Semester (Petrochemicals & Polymer Technology)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT815	Advanced Process Instrumentation	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide knowledge of fundamental principles of process instrumentation, including measurement techniques, sensors, signal conditioning, data acquisition, and process control automation.

COURSE OUTCOMES

CO1	Understand the role, classification, and key measurement principles of industrial instrumentation.
CO2	Identify and select appropriate sensors for measuring temperature, pressure, flow, level, and chemical properties.
CO3	Interpret the process signals using amplification, filtering, and data conversion techniques.
CO4	Understand control loops, PID controllers, tuning methods, and distributed control systems (DCS).

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction to Process Instrumentation: Role of instrumentation in process industries, Classification of instruments, Measurement principles (accuracy, precision, resolution, repeatability).

(No. of lectures- 6)

Unit II- Sensors and Transducers: Temperature measurement (RTDs, thermocouples, infrared sensors), Pressure measurement (strain gauges, piezoelectric, differential pressure transmitters), Flow measurement (orifice plates, ultrasonic, magnetic, Coriolis meters), Level measurement (float, radar, ultrasonic, capacitive sensors), Chemical and gas analyzers (mass spectrometry, non-dispersive Infrared, electrochemical sensors), Measurement of concentration, density, viscosity, and pH, Control valve, Piping and instrumentation diagram.

(No. of lectures- 12)

Unit III- Performance characteristics of instruments and data analysis- Theorems and applications for temperature, pressure, level, and flow.

(No. of lectures-4)

Unit IV Signal Conditioning and Data Acquisition: Signal amplification, filtering, and noise reduction, Analog-to-digital and digital-to-analog conversion, Data logging and processing methods, Industrial data acquisition systems and real-time monitoring.

(No. of lectures- 10)

Unit V- Signal Conditioning and Data Acquisition: Signal amplification, filtering, and noise reduction, Analog-to-digital and digital-to-analog conversion, Data logging and processing methods, Industrial data acquisition systems and real-time monitoring.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Patranabis, D. Principles of Industrial Instrumentation, McGraw-Hill Publishing, New Delhi, 2017.
2. Nakra, B.C. and Chaudhry, K. K. Instrumentation Measurement and Analysis, McGraw-Hill Publishing, New Delhi, 2016.
3. Stephanopoulos, G., Chemical process control: An introduction to theory and practice," Pearson, Chennai, 2015.
4. Eckman, D. P., Industrial Instrumentation, CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2004.

Lecture Plan

Lecture No.	Topics to be covered
1.	Role of instrumentation in process industries-I
2.	Role of instrumentation in process industries-II
3.	Classification of instruments-I
4.	Classification of instruments-II
5.	Measurement principles (accuracy, precision, resolution, repeatability)-I
6.	Measurement principles (accuracy, precision, resolution, repeatability)-II
7.	Temperature measurement (RTDs, thermocouples, infrared sensors)-I
8.	Temperature measurement (RTDs, thermocouples, infrared sensors)-II
9.	Pressure measurement- (strain gauges, piezoelectric etc)-I
10.	Pressure measurement (strain gauges, differential pressure transmitters)-II
11.	Flow measurement (orifice plates, ultrasonic, magnetic, Coriolis meters)-I
12.	Flow measurement (orifice plates, ultrasonic, magnetic, Coriolis meters)-II
13.	Level measurement (float, radar, ultrasonic, capacitive sensors)-I
14.	Level measurement (float, radar, ultrasonic, capacitive sensors)-II
15.	Chemical and gas analyzers (mass spectrometry, non-dispersive Infrared etc.)
16.	Measurement of concentration, density, viscosity, and pH, Control valve-I
17.	Measurement of concentration, density, viscosity, and pH, Control valve-II
18.	Piping and instrumentation diagram
19.	Instruments and data analysis- Theorems and applications for temperature
20.	Instruments and data analysis- Theorems and applications for pressure
21.	Instruments and data analysis- Theorems and applications for level
22.	Instruments and data analysis- Theorems and applications for flow
23.	Signal Conditioning and Data Acquisition: Signal amplification
24.	Signal Conditioning and Data Acquisition: filtering
25.	Signal Conditioning and Data Acquisition: noise reduction
26.	Analog-to-digital and digital-to-analog conversion-I
27.	Analog-to-digital and digital-to-analog conversion-II
28.	Data logging and processing methods-I
29.	Data logging and processing methods-II
30.	Industrial data acquisition systems-I
31.	Industrial data acquisition systems-II
32.	Real-time process monitoring
33.	Fundamentals of process control loops-I
34.	Fundamentals of process control loops-II
35.	Different types of controllers (P, PI, PD, PID) and their working principle-I
36.	Different types of controllers (P, PI, PD, PID) and their working principle-II
37.	Control tuning
38.	Controller stability analysis-I
39.	Controller stability analysis-II
40.	Distributed Control Systems (DCS)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT822	Polymer Composites and Blends	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To understand the principles of polymer composites and blends including thermodynamics, kinetics and phase behaviour.

COURSE OUTCOMES

CO1	Understand the different types of polymer composites and blends.
CO2	Under the effect of blend composition, molecular weight and processing condition on properties of polymer blends and alloys.
CO3	Familiarize with various characterization techniques.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Introduction and overview of composite materials and their need, Enhancement of properties, classification of composites, Matrix-Polymer matrix composites (PMC), Metal matrix composites (MMC), Ceramic matrix composites (CMC), Application of composites**.** Reinforcements Materials.

(No. of lectures- 8)

Unit II- Definition for Blends and Alloys: Reason and advantages of Blending, Selection criteria of blending polymers and designing of blends; Classification of Polymer Blends; Miscible Blends and Immiscible Blends, Methods of blending: Melt blending, solution blending.

(No. of lectures- 6)

Unit III- Concept of immiscibility and miscibility of polymers: Phase Equilibrium Calculation; Huggins – Flory Theory; Factors Affecting Miscibility of Polymer Blends, concept of Compatibility; composition of blends, Solubility Parameter; Interaction Parameter. Determination of miscibility by measurements of Refractive Index, Ultrasonic Velocity.

(No. of lectures-8)

Unit IV- Thermodynamic Principles of blending: Thermodynamics of a Single Component Systems; Polymeric Liquid mixtures; Theory of liquid mixtures; Phase Separation of polymers in blends. Concept of compatibility; Types and Role of Compatibilizer; Methods of Compatibilization; Mechanism of Compatibilization; Properties of Compatibilized Blend.

(No. of lectures- 10)

Unit V- Rheology of Miscible and Immiscible Blends: Rheological models for miscible and immiscible polymer blends and alloys Applications polymer blends and alloys in Automotive, Electrical and Electronics, Medical, Packaging, building and construction, Business machines and communication.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Robeson, L. M., Polymer blends, Hanser publications, USA, 2007.
2. Sharma S.C., Composite materials, Narosa Publications, 2002.
3. Singh, R. P., Polymer Blends and Alloys, Asian Books Private Ltd., 2002.
4. George P. Simon, Polymer Blends and Alloys: 52 (Plastics Engineering) by Routledge Member of the Taylor and Francis, 1999.
5. Daniel Klempner, Kurt C. Frisch, Polymer Alloys II, Blends, Blocks, Grafts, and Interpenetrating Networks, Plenum Press, New York, 1980.

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction and overview of composite materials and their need.
2.	Properties of composite materials
3.	Enhancement of properties of composite materials
4.	Classification of composite materials.
5.	Metal matrix composites (MMC)
6.	Ceramic matrix composites (CMC)
7.	Application of composites
8.	Reinforcements Materials
9.	Reason and advantages of blending
10.	Selection criteria for blending polymers and designing blends

11.	Classification of polymer blends;
12.	Miscible blends and immiscible Blends
13.	Methods of blending
14.	Melt blending, solution blending
15.	Phase Equilibrium Calculation
16.	Huggins – Flory Theory
17.	Factors Affecting Miscibility of Polymer Blends
18.	Concept of Compatibility
19.	Composition of blends
20.	Solubility Parameter
21.	Interaction parameter
22.	Determination of miscibility by measurements of RI, Ultrasonic Velocity
23.	Thermodynamics of a single component systems
24.	Polymeric Liquid mixtures
25.	Theory of liquid mixtures
26.	Phase Separation of polymers in blends
27.	Concept of compatibility
28.	Types and Role of Compatibilizer
29.	Methods of Compatibilization
30.	Mechanism of Compatibilization
31.	Properties of Compatibilized Blend-I
32.	Properties of Compatibilized Blend-II
33.	Rheological models for miscible and immiscible polymer blends and alloys-I
34.	Rheological models for miscible and immiscible polymer blends and alloys-II
35.	Applications of polymer blends and alloys in Automotive
36.	Applications of polymer blends and alloys in Electrical and Electronics
37.	Applications of polymer blends and alloys in Medical
38.	Applications polymer blends and alloys in packaging, building and construction
39.	Applications in Business machines and communication-I
40.	Applications in Business machines and communication-II

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT814	Advanced Polymer Process Modeling	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To learn variety of polymer processes Modeling and advanced transport phenomena.

COURSE OUTCOMES

CO1	Understand the concept of advanced transport phenomena for non-Newtonian fluid.
CO2	Develop and solve complex mathematical model based on fluid mechanics, heat transfer and mass transfer.
CO3	Develop the ability to create analytical solution of polymer processing flow problems.
CO4	Develop the ability of applying shell elemental balances and learn by simplifying the offending complexity of partial differential equation.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Concept of continuum, stress in continuum, equation of continuity, equation of motions, Introduction to vector and Tensor, kinematics and dynamics boundary conditions. Classification of Polymer Processing Operations, Simple Model Flows: Poiseuille flow (pressure flow)

(No. of lectures- 8)

Unit II- Newtonian non-Newtonian isothermal analysis: Newtonian isothermal analysis, Isothermal Analysis, adiabatic analysis, optimal design, non-Newtonian isothermal analysis, non-

Newtonian Adiabatic, analysis. Newtonian model of calendaring, power law model, and calender fed with a finite sheet.

(No. of lectures- 8)

Unit III- Newtonian flow into a cavity: Isothermal Newtonian flow into a cavity, Evaluation of viscous heating in a runner, effect of pressure dependent viscosity, runner and cavity combination, power law into a cavity.

(No. of lectures-8)

Unit IV- Elastic phenomena: die swell and melt fracture, coating, compression molding, transfer molding, thermoforming and vacuum forming.

(No. of lectures- 8)

Unit V- Residence time distribution and mixing: Residence time distribution and mixing extruder as a mixer, mixing in stirred tank, thermal transfer coefficient, diffusion coefficients, viscous dissipation, heat of reaction, convective transfer coefficients.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Bird, R. B., Stewart, W. E. and Lightfoot, E. N., Transport Phenomena, Revised 2^{ed}, An Indian Adaptation, Wiley, 2021.
2. Baird, D. G., Polymer Processing - Principles and Design, Second Edition, John Wiley & Sons Inc., 2014.
3. Morrison, F.A., Understanding Rheology, Oxford University Press, 2001.
4. Slattery, J. C., Momentum, Energy and Mass Transfer in Continua, Robert E. Krieger Publishing Company, New York, 1981.
5. Tadmor, Z. and Gogos C.G., Principles of Polymer Processing, Wiley- Interscience, New York, 1979.
6. Middleman, S., Fundamentals of Polymer Processing, McGraw-Hill Book Company, NY, 1977.

Lecture Plan

Lecture No.	Topics to be covered
1.	Concept of continuum
2.	Stress in continuum
3.	Equation of continuity
4.	Equation of motions
5.	Introduction to vector and tensor, kinematics and dynamics boundary conditions
6.	Classification of polymer processing operations
7.	Simple model flows
8.	Poiseuille flow (pressure flow)

9.	Newtonian isothermal analysis
10.	Isothermal Analysis, adiabatic analysis
11.	Optimal design
12.	Non-Newtonian isothermal analysis
13.	Non-Newtonian adiabatic analysis
14.	Newtonian model of calendaring
15.	Power law model
16.	Calender fed with a finite sheet
17.	Isothermal Newtonian flow into a cavity-I
18.	Isothermal Newtonian flow into a cavity-II
19.	Evaluation of viscous heating in a runner-I
20.	Evaluation of viscous heating in a runner-II
21.	Effect of pressure dependent viscosity
22.	Effect of runner and cavity combination
23.	Effect of power law into a cavity-I
24.	Effect of power law into a cavity-II
25.	Die swell and melt fracture-I
26.	Die swell and melt fracture-II
27.	Coating, compression molding-I
28.	Coating, compression molding-II
29.	Transfer molding-I
30.	Transfer molding-II
31.	Thermoforming and vacuum forming-I
32.	Thermoforming and vacuum forming-II
33.	Residence time distribution and mixing-I
34.	Residence time distribution and mixing-II
35.	Extruder as a mixer
36.	Mixing in stirred tank
37.	Thermal transfer coefficient, diffusion coefficients
38.	Viscous dissipation
39.	Heat of reaction
40.	Convective transfer coefficients

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT823	Safety and Risk Management in Petrochemical Industries	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To develop technical expertise in safety protocols, risk assessment methodologies, and hazard identification techniques in petrochemical industries.

COURSE OUTCOMES

CO1	Understand the fundamental principles underlying safety and risk management.
CO2	Analyze fire hazards, and explosion risks to enhance workplace safety.
CO3	Conduct Hazard and Operability Studies (HAZOP) and apply risk management strategies for petrochemical industries.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Origin of process hazards, Laws codes, Standards, Case histories, Properties of chemicals, Health hazards of industrial substances, Personal protective equipments, Hazard Identification, Hazard evaluation and Control.

(No. of lectures- 8)

Unit II- Fire and Explosion: Fire and explosion hazards, Causes of fire and preventive methods. Flammability characteristics of chemical, fire and explosion hazard, Rating of process plant.

Propagation of fire and effect of environmental factors, Ventilation, Dispersion, Sprinkling and Safety relief valves.

(No. of lectures- 8)

Unit III Designs to Prevent Fires and Explosions: Inerting, Vacuum purging, Pressure purging, Combined pressure-vacuum purging. Static electricity, Fundamentals of static charge, Controlling static electricity.

(No. of lectures-8)

Unit IV- Hazards Identification: Process hazards checklists, Hazards surveys, Hazards and operability studies and Safety reviews.

(No. of lectures- 8)

Unit V- Risk Management Plan and Hazard Assessment: Emergency planning, Onsite and offsite emergency planning, Risk management and First aids. Failure distribution, Failure data analysis, Safety training, Emergency planning and disaster management and Case studies.

(No. of lectures- 8)

TEXTBOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Lees, F. P., Loss Prevention in Process Industries, Vol.1 and 2, 4th Ed., Butterworth, 2022.
2. Crawl D.A. and Louvar J.A., Chemical Process Safety Fundamentals with Applications, 4th Ed., Prentice Hall, 2022.
3. Wentz, C.A., Safety Health and Environmental Protection, McGraw Hill, 1998.

Lecture Plan

Lecture No.	Topics to be covered
1.	Origin of process hazards
2.	Laws codes, Standards
3.	Case histories
4.	Properties of chemicals
5.	Health hazards of industrial substances
6.	Personal protective equipments
7.	Hazard Identification
8.	Hazard evaluation and Control
9.	Fire and explosion hazards
10.	Causes of fire and preventive methods
11.	Flammability characteristics of chemical
12.	Fire and explosion hazard
13.	Rating of process plant
14.	Propagation of fire and effect of environmental factors

15.	Ventilation, Dispersion
16.	Sprinkling and Safety relief valves
17.	Inerting startegies
18.	Vacuum and pressure purging-I
19.	Vacuum and pressure purging-II
20.	Combined pressure-vacuum purging-I
21.	Combined pressure-vacuum purging-II
22.	Static electricity and fundamentals of static charge-I
23.	Static electricity and fundamentals of static charge-II
24.	Controlling static electricity.
25.	Process hazards checklists-I
26.	Process hazards checklists-II
27.	Hazards surveys-I
28.	Hazards surveys-II
29.	Hazards and operability studies-I
30.	Hazards and operability studies-II
31.	Safety reviews-I
32.	Safety reviews-II
33.	Emergency planning
34.	Onsite and offsite emergency planning
35.	Risk management and First aids
36.	Failure distribution, Failure data analysis
37.	Safety trainings
38.	Emergency planning and disaster management
39.	Case studies-I
40.	Case studies-II

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT825	Waste Management in Petrochemical and Polymer Industries	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide comprehensive knowledge and concepts waste management in the petrochemical and polymer industry along with their legislation, regulations and standards for pollution control.

COURSE OUTCOMES

CO1	Assess the waste generated in the petrochemical industry and their effect on the environment.
CO2	Analyze the waste and apply the control and treatment strategies for safe disposal.
CO3	Learn the recycling and waste management methods for polymers and understand the case studies of waste management.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Introduction to the petroleum industry, world distribution of petroleum resources and reserves, utilization, legislation, regulations, standards for pollution and waste management.

(No. of lectures- 4)

Unit II- Pollution and waste from the petroleum industry : Waste from exploration, development & production, waste from hydrocarbon processing, waste from storage, transportation and distribution, oil spills, oil spill responses.

(No. of lectures- 8)

Unit III- Overview of the environmental impact of the petroleum industry: Protection options, legislation, regulations and standards about pollution control.

(No. of lectures- 6)

Unit IV- Treatment of oily wastewater: Characterization of oily wastewater, selection of separation & treatment technologies, oily wastewater treatment plants.

(No. of lectures- 8)

Unit V- Solid waste management: Overview of solid waste from petroleum industry, different treatment methods, management practices, handling of heavy metals.

(No. of lectures- 8)

Unit VI- Polymer recycling: Primary, mechanical, chemical and tertiary recycling Plastic Waste Management Practices –5R and I approach, use of Plastic waste in roads, issues and challenges, Industrial case studies.

(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Jafarinejad, S., Petroleum Waste Treatment and Pollution Control, 1st Edition, Butterworth-Heinemann Publication, UK, 2016.
2. Rao, M. N. Solid and Hazardous Waste Management- Science and Engineering, Butterworth-Heinemann Publication, Abe Books, UK, 2016.
3. Bahadori, A. Waste Management in the Chemical and Petroleum Industries, John Wiley & Sons, 2014.
4. Metcalf & Eddy, Wastewater Engineering-Treatment and Resource Recovery, 5th Edition, McGraw Hill, 2014.
5. Gerald Scatt& Dan Gilad, Degradable Polymers – Principles & Applications, Springer-Science, 2002.

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction to the petroleum industry
2.	World distribution of petroleum resources and reserves
3.	Utilization, legislation and regulations
4.	Standards for pollution and waste management
5.	Overview of Pollution and waste from the petroleum industry
6.	Waste from exploration
7.	Waste during development & production
8.	Waste from hydrocarbon processing
9.	Waste from storage
10.	Waste from transportation and distribution

11.	Waste from oil spills
12.	Oil spill responses
13.	Overview of the environmental impact of the petroleum industry
14.	Fundamental parameters used in environmental impact
15.	Protection options in petroleum industry
16.	Legislation related to petroleum industry
17.	Regulations for petroleum industry
18.	Standards about pollution control in petroleum industry
19.	Sources of wastewater from petroleum industry
20.	Characterization parameters for oily wastewater
21.	Characterization parameters estimation methods for oily wastewater
22.	Selection of separation & treatment technologies-1
23.	Selection of separation & treatment technologies-2
24.	Oily wastewater treatment plants-1
25.	Oily wastewater treatment plants-2
26.	Future perspective of these treatment plants
27.	Overview of solid waste from petroleum industry
28.	Solid waste types and their handling from petroleum industry
29.	Characterization parameters for solid waste
30.	Different treatment methods-1
31.	Different treatment methods-2
32.	Performance evaluation of these methods
33.	Management practices of solid waste
34.	Handling of heavy metals
35.	Introduction of Polymer recycling
36.	Primary, mechanical. chemical and tertiary recycling
37.	Plastic Waste Management Practices –5R and I approach
38.	Use of Plastic waste in roads
39.	Issues and challenges
40.	Industrial case studies

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT821	Petroleum Industry and Business	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide comprehensive knowledge of various aspects of process economics and management principles involved in developing process and plant design.

COURSE OUTCOMES

CO1	Apply the elements of budgeting techniques and cash flows in the petroleum industry.
CO2	Classify and quantify the petroleum engineering uncertainties.
CO3	Assess the oil market and the effect of inflation on international geopolitics.
CO4	Carry out the decision analysis.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

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

(No. of lectures- 4)

Unit II- Petroleum classification: Petroleum classification methods, quantification, assessment of geoscience and reservoir engineering uncertainties – Assessment of reserves, production and demand in the international market.

(No. of lectures- 8)

Unit III- Price of petroleum: Inflation and cost escalation, oil market and OPEC, share of non-OPEC countries in oil production – International oil and gas pricing mechanism – Geopolitics.

(No. of lectures- 6)

Unit IV- Fiscal and accounting: Petroleum Fiscal system, classification and analysis – Reserves Auditing – Accounting systems for oil and gas.

(No. of lectures- 8)

Unit V- Solid waste management: Overview of solid waste from petroleum industry, different treatment methods, management practices, handling of heavy metals.

(No. of lectures- 8)

Unit VI- Model of Economic Growth: without uncertainty, Discovery of Natural Resource, Exchange Rate, Determination of Exchange Rate, Oil Price Shock, Implications of fiscal and trade policies (with special attention to exchange rate policies, BOP crisis and Indian economy), Case studies.

(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Abdel-Aal, H. K. Bakr, A. B. Al-Sahlawi. A: Petroleum Economics and Engineering, Dekrer Publication 1992.
2. Cronquist, C., Estimation and classification of Reserves of Crude oil, Natural Gas, and Condensate, Society of Petroleum Engineers 2001.
3. Johnston, D, International Exploration Economics, Risk, and Contract Analysis, Pennwell Books 2003.
4. Seba R. D., Economics of Worldwide Petroleum Production, 4th Edition, Pennwell Books, OGCL Publications, USA 2016.
5. Thompson R. S. and Wright J. D., "Oil Property Evaluation", 2nd Edition, Thompson- Wright Associates 1985.

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction to upstream economics analysis
2.	Energy overview of India
3.	Time value of money
4.	Cash flow analysis
5.	Capital budgeting techniques
6.	General probability and analysis
7.	Elements of oil cash flows
8.	Gas project cash flow

9.	Petroleum classification methods-1
10.	Petroleum classification methods-2
11.	Petroleum classification methods-3
12.	Quantitative analysis
13.	Assessment of geoscience
14.	Assessment of reservoir engineering uncertainties
15.	Assessment of reserves
16.	Assessment of production and demand in the international market
17.	Assessment of demand in the international market
18.	Fluctuating international market: Effects on economy
19.	Inflation and cost escalation
20.	Oil market analysis
21.	OPEC role in petroleum
22.	Share of non-OPEC countries in oil production
23.	International oil prices mechanism
24.	International gas prices mechanism
25.	Geopolitics-1
26.	Geopolitics-2
27.	Petroleum Fiscal system
28.	Fiscal system classification
29.	Fiscal system analysis
30.	Reserves auditing
31.	Accounting systems for oil
32.	Accounting systems for gas
33.	Model of Economic Growth: without uncertainty
34.	Exchange Rate and determination of Exchange Rate
35.	Oil Price Shock
36.	Implications of fiscal and trade policies
37.	Implications of policies (with special attention to exchange rate policies)
38.	BOP crisis and Indian economy
39.	Case studies-1
40.	Case studies-2

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT819	Energy Management in Petrochemical Industries	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide comprehensive knowledge of energy conservation and management in petrochemical industries.

COURSE OUTCOMES

CO1	Identify the energy conservation opportunities in the plant.
CO2	Conduct an exergy analysis of individual unit operations and their impact on plant economics.
CO3	Apply the concepts of waste heat recovery and heat integration.
CO4	Apply the knowledge of energy audits and regulatory standards.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Typical energy sources, their price and availability, energy and utility cost, energy balance, and energy accounting.

(No. of lectures- 6)

Unit II- Process performance analysis: Basics of exergy, computing exergy values, exergy analysis of unit operations, economic analysis

(No. of lectures- 8)

Unit III- Process conservation opportunities: Energy conservation opportunities in thermal-fluid Systems; combustion systems, steam & condensate systems, energy recovery systems, industrial insulations

(No. of lectures- 8)

Unit IV- Waste heat recovery: Quantification, storage, emerging technologies, impact of heat recovery on utilities, heat exchanger networks.

(No. of lectures- 12)

Unit V- Regulatory framework: Introduction to energy audit, benchmarking and energy performance, standards, codes and regulation

(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Rajalakshmi, S.; Kavitha, G.; Vinoth Kumar, D. Energy and Environment Management Audits, AkiNik Publications, New Delhi 2021.
2. Roosa, S, A.; Doty, S.; Turner, W. Energy Management Handbook, River Publishers 2020.
3. Beggs, C. Energy: Management, Supply and Conservation, Oxford:Butterworth-Heinemann 2002.
4. Kaiser, V. Industrial Energy Management: Refining Petrochemicals and Gas Processing Techniques, Editions Technip 1993.

ONLINE/E-RESOURCES

1. Technical Literature published by Bureau of Energy Efficiency (https://beeindia.gov.in)
2. Technical Literature published by Petroleum Conservation Research Association (https://mopng.gov.in/en)

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction to energy sources
2.	Different types of energy resources
3.	Price and availability
4.	Energy and utility cost
5.	Energy balance
6.	Energy accounting
7.	Basics of exergy
8.	Computing exergy values-1
9.	Computing for exergy values-2
10.	Techniques for analysis
11.	Exergy analysis of unit operations-1

12.	Exergy analysis of unit operations-2
13.	Economic analysis
14.	Cost estimation
15.	Process conservation opportunities
16.	Energy conservation and its opportunities
17.	Conservation in thermal-fluid Systems
18.	Combustion systems
19.	Steam & condensate systems
20.	Energy recovery systems-1
21.	Energy recovery systems-2
22.	Industrial insulations
23.	Waste heat sources
24.	Waste heat quantification
25.	Waste heat storage
26.	Emerging technologies-1
27.	Emerging technologies-2
28.	Emerging technologies-3
29.	Emerging technologies-4
30.	Heat exchanger networks
31.	Pinch analysis
32.	Pinch analysis
33.	Heat integration analysis
34.	Implementation of this analysis
35.	Regulatory framework
36.	Introduction to energy audit
37.	Benchmarking and energy performance
38.	Standards
39.	Standards and codes for energy audit
40.	Regulations for energy audit

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT824	Statistical Methods	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide the fundamentals of experimental designs, analysis tools and techniques, interpretation and applications.

COURSE OUTCOMES

CO1	The fundamentals of experiments and basic statistics, including ANOVA and regression.
CO2	Application of statistical models in analysing experimental data.
CO3	Experimental design and RSM to optimize the response of interest from an experiment.
CO4	Use of statistical software.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction to design and analysis of experiments: Basic concepts and applications, Basic statistics, Analysis of Variance (ANOVA), Regression techniques, Hypothesis testing in multiple regression, Confidence intervals in multiple regression

(No. of lectures- 10)

Unit II- Experimental designs: Randomized complete block design (RCBD), Variants of RCBD such as Latin Square, central composite design, BBD etc.

(No. of lectures- 8)

Unit III- Experimental designs: Full factorial experiments, 2k factorial experiments, Fractional factorial experiments, 2k-p factorial experiments

(No. of lectures- 8)

Unit IV- Response surface methodology: Response surface methodology (RSM), the method of Steepest Ascent, Experimental designs for fitting Response Surfaces, Designs for fitting the First-Order Model, Designs for fitting the Second-Order Model, and Evolutionary operation.

(No. of lectures- 8)

Unit V- Introduction to statistical softwares

(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

5. Montgomery, D. C. Design and Analysis of Experiments, Wiley 2019.
6. Krishnaiah, K.; Shahabudeen, P. Applied Design of Experiments and Taguchi Methods, Prentice Hall of India 2012.
7. Panneerselvam, R. Design and Analysis of Experiments, Prentice Hall of India 2012.
8. Holman, J.P. Experimental Methods for Engineers", McGrawHill, Singapore 2011.
9. Box, G. E. P.; Stuart Hunter, J.; Hunter,W. G. Statistics for Experimenters: Design, Innovation, and Discovery, Wiley 2005.

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction to design and analysis of experiments
2.	Basic concepts and applications
3.	Basic statistics
4.	Several statistical formulas
5.	Analysis of Variance (ANOVA)
6.	Regression techniques
7.	Linear and non-linear model fitting
8.	Hypothesis testing in multiple regression
9.	Confidence intervals in multiple regression
10.	Advanced statistical techniques
11.	Experimental designs-1
12.	Experimental designs for different processes
13.	Randomized complete block design (RCBD)
14.	Variants of RCBD
15.	Latin Square methods
16.	Central composite design
17.	BBD

18.	Other design models
19.	Experimental designs
20.	Full factorial experiments
21.	2k factorial experiments
22.	Fractional factorial experiments
23.	2k-p factorial experiments
24.	Statistical formulas related to factorial design
25.	Comparison with different models
26.	Selection of best models
27.	Response surface methodology (RSM)
28.	The method of Steepest Ascent
29.	Experimental designs for fitting Response Surfaces
30.	Designs for fitting the First-Order Model
31.	Designs for fitting the Second-Order Model
32.	Comparison with different models
33.	Selection of best models
34.	Evolutionary operation
35.	Introduction to statistical softwares
36.	Statistical softwares-1
37.	Statistical softwares-2
38.	Statistical softwares-3
39.	Statistical softwares-4
40.	Comparison and selection of best models with different models

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT818	Computational Techniques for Engineers	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To learn various computational techniques for analyzing and solving chemical engineering problems.

COURSE OUTCOMES

CO1	Understanding of fundamental mathematics and to solve problems of algebraic and differential equations, partial differential equations.
CO2	Ability to convert problem solving strategies to procedural algorithms and to write program structures.
CO3	Ability to solve engineering problems using computational techniques.
CO4	Ability to assess reasonableness of solutions, and select appropriate levels of solution sophistication.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Linear and Non-Linear Algebraic Equations: Introduction, Gauss-Elimination, Gauss-Siedel and LU Decomposition methods, Thomas' algorithm, Single variable and multivariable successive substitution method, single variable and multivariable Newton-Raphson technique, Polynomial root finding methods.

(No. of lectures- 8)

Unit II- Eigen Values and Eigen Vectors of Matrices: Introduction, Fadeev-Leverrier's method, Power method.

(No. of lectures- 4)

Unit III- Function Approximation: Least squares curve fit, Newton's interpolation formulae, Lagrangian interpolation, Pade approximation, Cubic spline approximation. Integration formulae: Trapezoidal rule, Simpson's rule.

(No. of lectures- 6)

Unit IV- Ordinary Differential Equations: Initial Value Problems: Explicit Adams-Bashforth technique, Implicit Adams-Moulton technique, Predictor-corrector technique, Runge-Kutta methods, Stability of algorithms. Boundary Value Problems: Finite difference technique, Orthogonal Collocation (OC), Shooting Techniques.

(No. of lectures- 8)

Unit V- Partial Differential Equations: Classification of PDE, Finite difference technique (Method of lines), Orthogonal collocation.

(No. of lectures- 8)

Unit VI- Case studies: Use of Spreadsheets and MATLAB in Chemical Engineering and Case Studies pertaining to Petroleum and petrochemical processing.

(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Gupta, S. K. Numerical Methods for Engineers, New Age International Ltd., New Delhi 2019.
2. Finlayson, B. A. Introduction to Chemical Engineering Computing, Wiley- Interscience 2006.
3. Curtis, G. and Patrick, W.O., Applied Numerical Analysis, Pearson Education Inc. 2004.
4. Constantinides, A. and Mostoufi, N. Numerical Methods for Chemical Engineers with MATLAB Applications, Prentice Hall 1999.
5. Hanna, O.T. and Sandall, O.C. Computational Methods in Chemical Engineering, Prentice-Hall 1995.

Lecture Plan

Lecture No.	Topics to be covered
1.	Linear and Non-Linear Algebraic Equations
2.	Gauss-Elimination
3.	Gauss-Siedel
4.	LU Decomposition methods
5.	Thomas' algorithm

6.	Single variable and multivariable successive substitution method
7.	Single variable and multivariable Newton-Raphson technique
8.	Polynomial root finding methods
9.	Eigen Values of Matrices
10.	Eigen Vectors of Matrices
11.	Fadeev-Leverrier's method
12.	Power method
13.	Least squares curve fit
14.	Newton's interpolation formulae
15.	Lagrangian interpolation,
16.	Pade approximation
17.	Cubic spline approximation
18.	Integration formulae: Trapezoidal rule, Simpson's rule
19.	Ordinary Differential Equations: Initial Value Problems
20.	Explicit Adams-Bashforth technique
21.	Implicit Adams-Moulton technique
22.	Predictor-corrector technique
23.	Runge-Kutta methods
24.	Stability of algorithms
25.	Boundary Value Problems: Finite difference technique,
26.	Orthogonal Collocation (OC), Shooting Techniques.
27.	Partial Differential Equations
28.	Classification of PDE
29.	Finite difference technique-1
30.	Finite difference technique-2
31.	Finite difference technique-3
32.	Method of lines
33.	Graphical representation of PDE
34.	Orthogonal collocation
35.	Use of Spreadsheets
36.	MATLAB in Chemical Engineering-1
37.	MATLAB in Chemical Engineering-2
38.	MATLAB in Chemical Engineering-3
39.	Case Studies pertaining to Petroleum
40.	Case Studies pertaining to Petrochemical processing

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT816	AI and ML in Process Engineering	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide comprehensive knowledge of various AI and ML techniques and their applications in chemical engineering problems. To implement machine learning models using programming languages and tools such as Python, Tensor Flow, and Scikit-learn.

COURSE OUTCOMES

CO1	Understand the fundamentals of AI and ML.
CO2	Integrate chemical engineering domain knowledge into AI/ML solutions whereby making students equipped for in-demand careers.
CO3	Design and implement ML models such as regression, regularization methods, decision tree, Naïve-Bayes.
CO4	Design and implement ML models such as support vector machine, neural networks, etc.
CO5	Develop problem solving skills in Python, Tensorflow, Keras, sci-kit learn.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction to Artificial Intelligence (AI) and Machine Learning (ML); Types of learning problems: Supervised, Unsupervised, Semisupervised, Overview of optimization techniques: An introduction to Python programming language, list, tuples, set, dictionary. Libraries such as Pandas, NumPy, matplotlib, sklearn.

(No. of lectures- 8)

Unit II- Optimization technique such as Gradient Descent method: Simple linear regression, multiple linear regression, Regularization methods (Ridge, Lasso, ElasticNet regression).

(No. of lectures- 8)

Unit III- Logistic regression, K-Nearest Neighbours algorithm, Decision Trees, Random Forest, Naïve Bayes classifier.

(No. of lectures- 8)

Unit IV- Support Vector Machine, Neural Networks: Single layer neural network, Multilayer neural network, Use of Tensorflow and Keras libraries.

(No. of lectures- 8)

Unit V- Data Preprocessing, Principal Component Analysis, KMeans cluster analysis, ARIMA model.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Géron, A. (2023), Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 3rd edition, O'Reilly Media, Inc. 2023
2. Raschka, S., &Mirjalili, V., Python machine learning: Machine learning and deep learning with Python, scikit-learn, and TensorFlow 2. Packt publishing ltd. 2019
3. Pradhan, M., Kumar, U.D., (2019), Machine Learning using Python, Wiley India Pvt. Ltd. 2019
4. Grus, J. (2019), Data Science from Scratch, 2nd edition, O'Reilly Media, Inc. 2019
5. Müller, A. C., Gudio, Introduction to Machine Learning with Python, O'Reilly Media, Inc., 2018

Lecture Plan

Lecture No.	Topics to be covered
1.	Introduction to Artificial Intelligence (AI) and Machine Learning (ML)
2.	Introduction to Machine Learning (ML)
3.	Types of learning problems: Supervised, Unsupervised, Semi-supervised.
4.	Overview of optimization techniques
5.	An introduction to Python programming language
6.	List, tuples, set and dictionary
7.	Libraries such as Pandas and NumPy
8.	Libraries such as matplotlib and sklearn.

9.	Optimization techniques
10.	Gradient Descent method
11.	Simple linear regression
12.	Multiple linear regression
13.	Regularization methods
14.	Ridge methods
15.	Lasso methods
16.	Elastic-Net regression methods
17.	Logistic regression-1
18.	Logistic regression-2
19.	K-Nearest Neighbours algorithm
20.	Decision Trees
21.	Random Forest
22.	Naïve Bayes classifier
23.	Other models
24.	Sophisticated models
25.	Support Vector Machine
26.	Neural Networks
27.	Single layer neural network
28.	Multilayer neural network
29.	Use of Tensorflow-1
30.	Use of Tensorflow-2
31.	Use of Keras libraries-1
32.	Use of Keras libraries-2
33.	Data Preprocessing-1
34.	Data Preprocessing-2
35.	Principal Component Analysis-1
36.	Principal Component Analysis-2
37.	KMeans cluster analysis-1
38.	KMeans cluster analysis-2
39.	ARIMA model
40.	Others models for AI

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT817	Catalysis Science and Technology	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide a fundamental understanding of homogeneous and heterogeneous catalysis.

COURSE OUTCOMES

CO1	Principles of catalysis and its role in chemical processes, design and evaluate catalysts for specific reactions.
CO2	Analyze and interpret data from catalytic experiments.
CO3	Understand the possible catalytic reaction pathway model and Apply knowledge of catalysis to solve real-world engineering problems.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I-Fundamentals of Catalysis: Homogeneous and Heterogeneous Catalysis, Preparation methods, Steps in catalytic reaction, Analysis of external transport processes in heterogeneous reactions in fixed bed, fluidized bed and slurry reactors. Intrapellet mass transfer, heat transfer, mass transfer with chemical reaction and simultaneous mass and heat transfer with chemical reaction.

(No. of lectures- 12)

Unit II- Catalyst Selectivity: Effect of intra pellet diffusion on selectivities in complex reactions, effect of external mass transfer on selectivities.

(No. of lectures- 6)

Unit III- Catalyst Deactivation: Modes of deactivation – poisoning, fouling and sintering. Determination of deactivation routes, combined effect of deactivation and diffusion on reaction rates, effect of deactivation on selectivity.

No. of lectures- 6)

Unit IV- Reactor Design: Design calculation for ideal catalytic reactor operating at isothermal, adiabatic and non-adiabatic conditions. Deviations from ideal reactor performance. Design of industrial fixed-bed, fluidized bed and slurry reactors. Thermal stability of packed bed and fluidized bed reactors.

(No. of lectures- 8)

Unit V- Industrial Applications: Petrochemicals (cracking, reforming, hydrotreating), Biorefining (biofuel, chemicals synthesis processes), and Environmental Catalysis (CO_2 reduction, NO_x removal, etc.).

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. H. S. Fogler, Elements of Chemical reaction engineering 2022
2. Smith, J. M., "Chemical Engineering Kinetics," 3rd ed., McGraw-Hill 2013
3. Tarhan, M. O., "Catalytic Reactor Design," McGraw-Hill, NY 1983
4. Carberry, J. J.," Chemical and Catalytic Reaction Engineering," McGraw-Hill (Dover Edition) 2001
5. Thomas, J. M. and Thomas, W. J., "Introduction to the Principles of Heterogeneous Catalysis," Academic Press 1967

Lecture Plan

Lecture No.	Topics to be covered
1.	Homogeneous and Heterogeneous Catalysis
2.	Preparation methods
3.	Steps in catalytic reaction,
4.	Analysis of external transport processes in heterogeneous reactions
5.	Fixed bed reactor
6.	Fluidized bed and slurry reactors
7.	Intrapellet mass transfer
8.	Heat transfer with chemical reaction
9.	Mass transfer with chemical reaction-1

10.	Mass transfer with chemical reaction-2
11.	Simultaneous mass and heat transfer with chemical reaction-1
12.	Simultaneous mass and heat transfer with chemical reaction-2
13.	Catalyst selectivity
14.	Effect of intra pellet diffusion
15.	Parameters related to inter pellet diffusion
16.	Diffusion on selectivities of complex reactions
17.	Effect of external mass transfer on selectivities.
18.	Parameters related to external mass transfer
19.	Catalyst Deactivation
20.	Modes of deactivation – poisoning, fouling and sintering.
21.	Determination of deactivation routes
22.	Combined effect of deactivation and diffusion on reaction rates-1
23.	Combined effect of deactivation and diffusion on reaction rates-2
24.	effect of deactivation on selectivity
25.	Reactor Design
26.	Design calculation for ideal catalytic reactor operating at isothermal
27.	Design calculation for ideal catalytic reactor operating at adiabatic and non-adiabatic conditions
28.	Deviations from ideal reactor performance
29.	Design of industrial fixed-bed
30.	Fluidized bed and slurry reactors
31.	Thermal stability of packed bed reactors
32.	Thermal stability of fluidized bed reactors
33.	Petrochemicals processes: cracking
34.	Petrochemicals processes: hydrotreating
35.	Petrochemicals processes: reforming
36.	Biorefining
37.	Biofuel (chemicals synthesis process)
38.	Environmental Catalysis
39.	CO_2 reduction
40.	NO_x removal

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT820	Hydrogen and Fuel Cell Technologies	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To gain insight about hydrogen energy, fuel cells, their working principle, types of fuel cells and performance analysis.

COURSE OUTCOMES

CO1	Gain knowledge on hydrogen production, storage technologies and economic aspects.
CO2	Gain knowledge on fuel cell working principle, types of fuel cell, voltage loss and its reason.
CO3	Understand the role of fluid dynamics, reaction kinetics and mass transfer principles in fuel cell operation. Stacking of fuel cell and fuel processing for fuel cell.

COURSE ASSESSMENT

The course assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I-Introduction to hydrogen energy systems: Current scenario of hydrogen production, Hydrogen production pathways**:** Thermal, Gasification, Electrochemical, and Biological, Infrastructure requirement for hydrogen production, dispensing and utilization

(No. of lectures- 8)

Unit II- Hydrogen Storage and Utilization: General storage methods, compressed storage, Zeolites, Metal hydride storage, chemical hydride storage and cryogenic storage. Utilization in fuel cells, IC engines, Gas turbines, refineries etc.

(No. of lectures- 8)

Unit III- Introduction to Fuel Cell: fuel cell advantages, fuel cell disadvantages, fuel cell performance characterization and modeling, fuel cell technology, Fuel Cell Types**,** Phosphoric acid fuel cell, polymer electrolyte membrane fuel cell, alkaline fuel cell, molten carbonate fuel cell, solid-oxide fuel cell.

(No. of lectures- 8)

Unit IV- Charge and Mass Transport in Fuel Cell: Charges movement, Voltage loss, characteristics of charge transport resistance, conductivity, Mass Transport in electrode versus flow structure, transport in electrode: diffusive and convective transport.

(No. of lectures- 8)

Unit V- Thermodynamics and Reaction Kinetics in Fuel Cell: Heat potential: Work potential: Gibbs free energy, Reversible Voltage, activation energy of charge transfer reactions, rate of reactionatequilibrium: exchange current density, Galvani potential, Butler–Volmer equation, Improving kinetic performance, simplified activation kinetics: Tafel equation.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Fuel Cell Fundamentals (3rd Ed.) by O'Hayre, Ryan/Colella, Whitney/Cha, Suk-Won. Wiley Publications. 2016.
2. James Larminie and Andrew Dicks, Fuel Cell Systems Explained, 2nd Ed., John Wiley & Sons Inc. 2000.
3. Supramaniam Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer. 2010.
4. Frano Barbir, PEM Fuel Cells Theory and Practice, Elsevier Academic Press. 2005.

Lecture Plan

Lecture No.	Topics to be covered
1.	Hydrogen energy systems
2.	Current scenario of hydrogen production
3.	Hydrogen production pathways
4.	Thermal: Gasification routes
5.	Electrochemical, and Biological methods
6.	Infrastructure requirement for hydrogen production
7.	Transportation requirements

8.	Dispensing and utilization
9.	Hydrogen Storage
10.	General storage methods
11.	Compressed storage
12.	Zeolites and Metal hydride storage
13.	Chemical hydride storage and cryogenic storage
14.	Utilization in fuel cells
15.	IC engines, Gas turbines
16.	Refineries
17.	Fuel Cell
18.	Fuel cell advantages and fuel cell disadvantages, fuel cell performance characterization and modeling
19.	Fuel cell technology
20.	Fuel Cell Types
21.	Phosphoric acid fuel cell
22.	Alkaline fuel cell
23.	Polymer electrolyte membrane fuel cell
24.	Molten carbonate fuel cell and solid-oxide fuel cell
25.	Charge and Mass Transport in Fuel Cell
26.	Charges movement and Voltage loss,
27.	Characteristics of charge transport resistance and conductivity
28.	Mass Transport in electrode structure
29.	Mass Transport in electrode versus flow structure
30.	Transport in electrode in diffusive atmosphere
31.	Transport in electrode in convective transport
32.	Several equations for charge and mass transport
33.	Thermodynamics and Reaction Kinetics in Fuel Cell
34.	Heat potential and Work potential
35.	Gibbs Free Energy and reversible Voltage
36.	Activation energy of charge transfer reactions
37.	Rate of reaction at equilibrium :exchange current density, Galvani potential
38.	Butler–Volmer equation
39&40	Improving kinetic performance, simplified activation kinetics: Tafel equation